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

# Multifamily Restructuring

Measure Number 2022-MF-RESTRUC-D

DRAFT CASE REPORT

Multifamily Envelope, HVAC, Water Heating, Lighting, and Covered Processes

Prepared by TRC | September 2020

**Please submit comments to info@title24stakeholders.com by October 30, 2020.**

CALIFORNIA ENERGY CODES & STANDARDS

A STATEWIDE UTILITY PROGRAM

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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 is a draft report. The Statewide CASE Team encourages readers to provide comments on the proposed code changes and the analyses presented in this draft report. When possible, provide supporting data and justifications in addition to comments. Suggested revisions will be considered when refining proposals and analyses. The Final CASE Report will be submitted to the California Energy Commission in December 2020.*

*Email comments and suggestions to* info@title24stakeholders.com *by* ***October 30, 2020****. 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 Draft 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 commercial 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 that it is time 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 proposed 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 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 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, the more stringent of the residential or nonresidential requirements for roofs, walls, floors, and fenestration will apply to multifamily building envelopes by assembly type. In some cases, the Statewide CASE Team grouped submeasures to create cost-effective prescriptive packages.
- Residential HVAC requirements of Sections 150.0, 150.1, and 150.2 apply to HVAC systems serving individual dwelling units. Nonresidential requirements of

Sections 120.2 through 120.5, 140.4, and 141.0 apply to HVAC systems serving common areas and central systems serving multiple dwelling units.

- 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 Draft 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, some multifamily chapters 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 Draft CASE 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 Products** Apply the more stringent prescriptive requirements by slope type (low or steep) and climate zone, as cost effective. This change would increase aged solar reflectance (ASR) and thermal emittance for low-slope roofs in buildings taller than three habitable stories in Climate Zones 13 and 15 from 0.55 to 0.63. It would add 0.55 solar reflectance and 0.75 thermal emittance requirements in Climate Zones 9 through 11 and 14 for low-slope roofs in buildings under four habitable stories.

  For steep-sloped roofs, the proposed code requirement would align with the current requirement for multifamily buildings under four habitable stories, due to low likelihood of steep-sloped roofs in taller multifamily buildings. Multifamily buildings in Climate Zones 1 through 9 and 16 would not have an ASR requirement.

- **Submeasure B: Envelope – Roof/Ceiling Insulation**

  **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 both Option B (below deck insulation high-performance attic) and Option C (ducts in conditioned space) pathways. Apply high-rise residential prescriptive U-factor requirements using both the metal building and wood-framed or other roof categories.

- **Submeasure C1: 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)

  This submeasure was packaged with fenestration properties and all-electric HVAC submeasures for cost-effectiveness.

- **Submeasure C2: 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 D1: Envelope – Fenestration Properties New Construction**

  **Mandatory Measures**: Applies the low-rise residential mandatory maximum U-factor requirement to multifamily buildings greater than three habitable stories that use non-curtain wall fenestration types.

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

  The current nonresidential code table includes four window categories (fixed, operable, curtainwall/storefront and glazed doors) while the residential code bundles all window types into a single area-weighted average requirement (with some variation by climate zone). The proposed code creates two window categories, with climate-zone differentiation only for RSHGC in Climate Zone 1 – curtainwall/storefront and all-other windows

  - Curtainwall and storefront windows: Applies a more stringent requirement than current code.
  - All-other windows: Applies the current residential window requirements for all other windows. Allows for an area-weighted average across all fenestration to fulfill the prescriptive requirement. This removes the operable/fixed/glazed door distinctions currently defined in the nonresidential code.

  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 residential code refers to this as adjusted solar heat gain coefficient (SHGC) and the nonresidential code as Relative SHGC (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.

  This measure was packaged with wall u-factor and the all-electric HVAC submeasures for cost-effectiveness.

- **Submeasure D2: Envelope – Fenestration Properties Alterations and Additions:**

  **Alterations:** The proposed code has different requirements by window type; fixed, operable, glazed door, and curtain wall. The requirements are the same for all climate zones, except Climate Zone 1 which has a less stringent SHGC requirement.

**Additions:** The proposed code requirements are based on an area-weighted average of thermal properties for all fenestration.

For both alterations and addition, the proposal calls for less restrictive requirements when a small volume of fenestration is being added or altered. This proposal constitutes thermal property levels that fall between the current nonresidential and residential requirements.

- **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 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.

  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 5 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 indirectly 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 verification of duct sealing for multifamily buildings three habitable stories and less 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 six percent leakage to outside. Diagnostic field verification and test protocols are described in Residential Reference Appendix RA3.1.

- **Submeasure H: Space Conditioning – Space Cooling Airflow Rate and Fan Efficacy** Apply mandatory verification of airflow and fan efficacy for multifamily buildings three habitable stories and less 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.
- **Submeasure I: Space Conditioning – Refrigerant Charge Verification** Apply prescriptive verification of refrigerant charge for multifamily buildings three habitable stories and less 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.
- **Combination G-I: Space Conditioning – HERS Verification Package** All three verification measures (duct sealing, airflow rate and fan efficacy, and refrigerant charge) will apply to many 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 proposed as a prescriptive requirement. Based on cost effectiveness results duct sealing was not justified in Climate Zones 1, 3, and 5 and is not included in the package in these climates.

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 Products | 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, and CF2R-ENV-04 |
| Roof/Ceiling Insulation | Mandatory | 150.0(a) and 120.7(a) | N/A | N/A |
| Roof/Ceiling Insulation | Prescriptive | 150.1 and 140 | Residential 2.6.6 and Nonresidential 5.5.3 | CF1R-NCB-01-E, NRCC-ENV-E, and CF2R-ENV-03 |

| Measure Name | Type of Requirement | Sections of Code Unified | Sections of ACM Reference Manual Unified | Compliance Document(s) Unified |
|---|---|---|---|---|
| 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 |
| 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. 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. 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 Draft 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 Products | CZ 9-11, 13-15 | 5.21 and greater |
| Roof/Ceiling Insulation | All | N/A |
| Wall U-Factor | CZ 1-5, 8-10, 13 | 0.58-1.28 |
| QII | CZ 1-6, 8-16 | 1.11-2.91 |
| Fenestration Properties | All | 0.02-5.32 |
| Fenestration Area | All | N/A |
| Wall U-Factor, Fenestration Property, All-Electric Combination | All | >1 |
| Duct Insulation | All | N/A |
| HVAC Verification Package | All (refrigerant charge CZ 2, 8-15; duct sealing CZ 2, 4, 6-16) | 1.53-3.79 |

## 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 Properties (Total)** | **0.93** | **0.62** | **(0.01)** | **34.9** |
| New Construction | 0.19 | 0.11 | (0.00) | 7.0 |
| Additions and Alterations | 0.74 | 0.51 | (0.01) | 28.0 |
| **Roof/Ceiling Insulation (Total)** | **0.01** | **(0.01)** | **(0.01)** | **(1.6)** |
| New Construction | 0.01 | (0.01) | (0.01) | (1.6) |
| Additions and Alterations | N/A | N/A | N/A | N/A |
| **Wall U-Factor (Total)** | **0.08** | **(0.02)** | **0.0** | **5.3** |
| New Construction | 0.08 | (0.02) | 0.0 | 5.3 |
| 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)** | **6.5** | **1.5** | **0.6** | **335** |
| New Construction | (0.4) | (0.1) | 0.2 | 50 |
| Additions and Alterations | 7.0 | 1.7 | 0.4 | 284 |
| **Duct Insulation (Total)** | **(0.04)** | **(0.00)** | **(0.01)** | **(5.6)** |
| New Construction | (0.01) | (0.00) | (0.00) | (0.8) |
| Additions and Alterations | (0.04) | (0.00) | (0.01) | (4.7) |
| **HVAC Verification Package (Total)** | **8.66** | **2.82** | **(0.02)** | **297** |
| New Construction | 2.49 | 0.83 | (0.01) | 86.3 |
| Additions and Alterations | 6.18 | 1.99 | (0.02) | 211 |

Energy modeling of envelope measures consistently revealed minimal energy savings potential across all four multifamily prototypes. Savings were on the order of 15 kWh and 3 therms per-dwelling unit, as shown in Section 4.3 Per-Unit Energy Impacts Results. This indicates that improvements upon the current prescriptive requirements have reached a point of diminishing returns. In some cases, especially regarding windows, reducing the thermal conductivity (u-factor) of the envelope leads to increased energy use as the building's mechanical cooling is needed to purge internal gains unable to dissipate through the envelope. These low savings in turn result in persistent difficulty showing cost effectiveness of potential proposed code changes; savings are not high enough to cover even minimal cost variations. Additionally, variances between CBECC-Res and CBECC-Com modeling algorithms resulted in minimal, or even negative savings in one software (and therefore building sector) where the other software calculated sufficient savings to become code in prior years. In pursuit of a unified multifamily code that follows all cost-effectiveness requirements, the Statewide CASE Team grouped submeasures into prescriptive packages to achieve cost-effectiveness and in some cases reverted to relaxing some standards in either the residential or nonresidential chapters. This necessity leads to per-unit energy losses in certain building subsectors. The statewide energy losses from such measures are typically low because the population of affected buildings is low. In aggregate, the proposed changes result in net statewide energy savings from envelope measures.

Since there is no duct model currently in the software, the HVAC verification package savings were estimated using a workaround to modeling duct leakage in CBECC-Com. This is described in Section 4.2.1.2. This approach accounts for the reduced airflow to the space and resulting heating and cooling system increases to deliver the same capacity to the space. However, it does not fully account for the energy losses associated with conditioning air that is subsequently lost to outside the thermal envelope. Therefore, it is anticipated that this approach is a conservative estimate of the energy savings associated with duct sealing measures. The increase in energy use from the duct insulation measures is minimal.

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 Products | 157 | $16,712 |
| Roof/Ceiling Insulation | (47) | ($4,941) |
| Wall U-Factor | 101 | $10,769 |
| Quality Insulation Installation | 51.08 | 8,183 |
| Fenestration Properties | 4,704 | $499,514 |
| Fenestration Area | N/A | N/A |
| Duct Insulation | (48) | ($5,098) |
| HVAC Verification Package | 1,953 | $207,409 |
| Total | 6,871 | $729,789 |

## 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 low-rise and high-rise buildings 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 is a draft report. The Statewide CASE Team encourages readers to provide comments on the proposed code changes and the analyses presented in this draft report. When possible, provide supporting data and justifications in addition to comments. Suggested revisions will be considered when refining proposals and analyses. The Final CASE Report will be submitted to the California Energy Commission in December 2020.*

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The overall goal of this Draft 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 Draft 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, 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 (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, application to dwelling units or common 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, the more stringent of the residential or nonresidential 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 individual dwelling units. Nonresidential requirements of Sections 120.2 through 120.5, 140.4, and 141.0 apply to HVAC systems serving common areas and central systems serving multiple dwelling units.
- 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 Draft CASE Report. For more information on the proposed 2022 multifamily measures, view draft CASE Reports posted at https://title24stakeholders.com/measures/building-types/multifamily/2022/.

This Draft 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, flat non-attic roofs for low-rise multifamily.

### 2.1.1 Building Envelope

For multifamily envelope requirements, the Statewide CASE Team proposes to apply the more stringent requirement between the current nonresidential and 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 will have different levels of impact relative to the current code based on the same low-rise/high-rise designation. The proposed changes and impacts are summarized as follows:

#### *2.1.1.1 Submeasure A Envelope: Roof Products*

This submeasure applies the more stringent prescriptive requirements by slope type (low or steep) and climate zone, as cost effective. This change would increase aged solar reflectance (ASR) and thermal emittance for low slope roofs in buildings taller than three habitable stories in Climate Zones 13 and 15 from 0.55 to 0.63. It would add 0.55 solar reflectance and 0.75 thermal emittance requirements in Climate Zones 9 through 11 and 14 for low slope roofs in buildings under four habitable stories.

For steep sloped roofs, the proposed code would remove the ASR requirement for buildings four habitable stories or greater in Climate Zones 2 through 9 to align with the current requirements for buildings under four habitable stories.

This measure impacts all 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 – Roof/Ceiling Insulation*

This submeasure applies 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.

Apply prescriptive low-rise residential requirements from Table 150.1-B to high rise buildings with attics, including both Option B (below-deck insulation high-performance attic) and Option C (ducts in conditioned space) pathways. For buildings less than four habitable stories without attics, apply high-rise residential prescriptive U-factor requirements using both the metal building and wood-framed or other roof categories.

### 2.1.1.3 Submeasure C1: Envelope – Wall U-Factor

This 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 was modeled in the Proposed.
2. Use the current residential modeling method that uses the same wall assembly type(s) in the Standard as was modeling in the Proposed 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<br>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<br>2x6 framing = 0.071<br>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 |

| Wall Type | Climate Zones | Mandatory Assembly U-factor | Prescriptive Assembly U-factor |
|---|---|---|---|
| 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 |

#### *Submeasure C2: Envelope – Quality Insulation Installation (QII)*

This measure 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.

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 bundles all window types into a single requirement (with some variation by climate zone) and allows compliance based on an area-weighted average. The proposed code creates two window categories each with a climate-zone differential only for Climate Zone 1, as shown in Table 6.

This proposal removes the distinct requirements between operable, fixed, and glazed doors currently defined in the nonresidential requirements and applies the residential requirement structure based on an area-weighted average.

- Curtainwall and storefront windows: Lower the U-factor down to the residential U-factor of 0.38, and lowers the SHGC to 0.25, except in Climate Zone 1 where it is proposed to be 0.35.
- All-other windows: Apply the current residential window requirements of 0.30 U-factor and 0.23 SHGC to all windows, except in Climate Zone 1 where it is proposed to be 0.35.

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.

**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 2-16 | 0.38 | 0.25 | 0.46 |
| All Other | CZ 1 | 0.30 | 0.35 | NR* |
| | CZ 2-16 | 0.30 | 0.23 | NR* |

*NR = No requirement

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 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.

For window alterations, the proposed code has different requirements by window type; fixed, operable, glazed door, and curtain wall. The proposed requirements result in increased stringency for buildings four habitable stories and greater and reduced stringency for buildings three habitable stories and less. Increasing stringency for alignment with residential requirements did not prove cost effective. For window additions, the proposed code requirements are based on an area-weighted average of thermal properties for all fenestration. 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 | CZ 1 | 0.38 | 0.35 | 0.46 |
| | CZ 2-16 | 0.38 | 0.25 | 0.46 |
| Fixed Windows | CZ 1 | 0.30 | 0.35 | NR |
| | CZ 2-16 | 0.30 | 0.24 | NR |
| Operable Windows | CZ 1 | 0.40 | 0.35 | NR |
| | CZ 2-16 | 0.40 | 0.21 | NR |
| Glazed Doors | CZ 1 | 0.45 | 0.35 | 0.17 |
| | CZ 2-16 | 0.45 | 0.23 | 0.17 |
| Additions: Area-Weighted Average | CZ 1 | 0.34 | 0.35 | NR |
| | CZ 2-16 | 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 |

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 measures in most cases apply current low-rise residential requirements to all individual systems serving dwelling units and apply nonresidential requirements to systems serving common 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.

#### *2.1.2.1 Submeasure F: Space Conditioning – Duct Insulation:*

The Statewide CASE Team evaluated duct insulation requirements for ducts in conditioned space and ducts in unconditioned space. The initial 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 indirectly conditioned space, R-6 insulation for all other ducts within indirectly 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 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 indirectly conditioned space, unless verified as low leakage. For return ducts in indirectly 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 proposed changes described above; therefore, the recommendation presented in this Draft CASE Report is that existing high-rise requirements for R-4.2 mandatory duct insulation on supply ducts in indirectly conditioned space (regardless of whether they are verified low leakage ducts or not) apply to all multifamily buildings. The existing allowance in both low-rise and high-rise buildings for uninsulated ducts exposed to directly conditioned space remains. For ducts in all other locations including unconditioned space the proposal is that 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. This proposal does not result in increased stringency but does result in reduced stringency in certain situations. 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 verification of duct sealing for multifamily buildings three habitable stories and less 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. For multifamily buildings four habitable stories and greater there is currently a prescriptive requirement that duct leakage be tested to not exceed 6 percent total leakage for single zone systems serving less than 5,000 $ft^2$ with greater than 25 percent of duct surface area in unconditioned space. Multifamily apartments predominantly have ductwork located within indirectly conditioned, typically within a soffit or interior walls, and therefore this proposal would impact most multifamily buildings four habitable stories and greater. This requirement applies to new construction and entirely new or complete replacement duct systems in alterations and additions.

Altered duct systems and space-conditioning systems in alterations and additions require 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. This scenario is not directly evaluated in this draft report and will be included in the final report.

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

This proposal applies mandatory verification of airflow and fan efficacy for multifamily buildings three habitable stories and less 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. There is currently no comparable requirements under the nonresidential code and therefore this proposal would impact multifamily buildings four habitable stories and greater by imposing new mandatory testing requirements. This requirement applies to new construction and entirely new or complete replacement space-conditioning systems in alterations and additions.

Altered space-conditioning systems with mechanical cooling in alterations and additions require cooling coil airflow testing to meet 300 cfm per ton of nominal cooling capacity or greater. This scenario is not directly evaluated in this draft report and will be included in the final report.

#### *2.1.2.4 Submeasure I: Space Conditioning – Refrigerant Charge Verification:*

This proposal applies prescriptive verification of refrigerant charge for multifamily buildings three habitable stories and less 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. There is currently no comparable requirements under the non-residential code and therefore this proposal would impact multifamily buildings four habitable stories and greater by imposing new prescriptive testing requirements. This requirement applies to new construction and both entirely new or complete replacement space-conditioning systems and altered space-conditioning systems with mechanical cooling in alterations and additions.

#### *2.1.2.5 Combination G-I: Space Conditioning – HVAC Verification Package:*

All three verification measures (duct sealing, airflow rate and fan efficacy, and refrigerant charge) will apply to many 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.

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, 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 within indirectly conditioned space. 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 the other. 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. While this may have made sense as the codes were nascent and focused on the most prevalent building types at the time, the logic of this split has become increasingly questionable. Codes developed with analyses focused on single family homes miss the fact that neither the equipment nor the enclosure of apartments are adequately represented in a single family context. Likewise, analyses of commercial buildings cannot adequately capture the realities of 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. It is difficult to explain to architects, mechanical professionals, builders, and building departments why two buildings in the same project, one three habitable stories and the other four habitable stories, have completely different requirements for fenestration, ventilation, space conditioning equipment, envelope performance, and air tightness. Both 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 code does not include a prescriptive compliance path for flat roofs, and it forces comparison to an attic roof assembly when the performance modeling approach is used. The performance-equivalent flat roof cannot be constructed cost effectively, but because prior residential codes were developed without a flat-roof prototype, that cost effectiveness was never considered.

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 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 Products*

Prescriptive requirements are largely similar between low-rise and high-rise multifamily buildings following the same steep-sloped and low-sloped categorization. Divergences are minor and climate zone dependent. Steep sloped roof requirements in the nonresidential code are derived primarily based on energy modeling in shorter commercial buildings rather than high-rise residential buildings that rarely have steep roof slopes.

#### *2.2.1.2 Submeasure B: Envelope – Roof/Ceiling Insulation*

The prescriptive options for low-rise multifamily buildings do not include an option for flat 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 flat 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.

#### *2.2.1.3 Submeasure C1: 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. 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. 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.

#### *2.2.1.4 Submeasure C2: 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.

#### *2.2.1.5 Submeasure D: Envelope – Fenestration Properties*

Energy modeling of window thermal properties' variance between the code's nonresidential and residential software platforms reveals results 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. But 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—but the residential software shows relatively significant savings from the same modeling test.

#### *2.2.1.6 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 the one 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, ductwork is used to distribute conditioned air throughout the apartment. Thermal and air leakage losses can be significant, particularly when ducts are in unconditioned spaces. When ducts are in indirectly 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 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 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 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 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 apartment. Thermal and air leakage losses can be significant, particularly when ducts are in unconditioned spaces. When ducts are in indirectly 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 are not 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 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 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 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 home 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 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 adds liquid line filter drier verification to the standard installation process and adds verification requirements to HERS procedures. Additionally, the 2014 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 B) |
| (b) Wall Insulation | 150.0(c), 120.7(b) | Single list of U-factor requirements by assembly type and fire rating (submeasure C) |
| (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(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 |
| (b) Systems Serving Individual dwelling units | 150.0(h) | Residential requirements applied to systems serving individual dwelling units in high-rise buildings (space conditioning submeasures) |
| (c) Central Systems and Systems Serving Common Use Areas | 120.2 through 120.5 | Nonresidential requirements applied to systems serving multiple dwelling units in low-rise buildings |
| 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 | |

| New Section | Content From | Change in Application of Requirements |
|---|---|---|
| (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 (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 individual dwelling units in high-rise buildings (space conditioning submeasures) |
| | Common Area | 140.4(c) through (o) | Nonresidential requirements applied to systems serving multiple dwelling units in low-rise buildings |
| (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) between residential and nonresidential 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. This Draft CASE Report does not address additional changes to the Reference Appendices that may result from creation of the multifamily chapters and consequential revisions to the low-rise residential and nonresidential chapters. The Compliance Improvement Team has conducted a preliminary analysis, identifying the areas that need closer reviewer in response to the proposed multifamily chapters. The Statewide CASE Team may have the opportunity to address these changes to the Reference Appendices in the Final CASE Report for this topic.

#### *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 and further detail about Proposed and Standard Design conditions associated with the entire multifamily restructuring measure in Section 7.4.

#### *2.3.1.4 Summary of Changes to the Compliance Manuals*

The Statewide CASE Team recommends creation of a Multifamily Compliance Manual. 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 7.5 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 7.6 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 Products:** The multifamily restructuring proposal aligns roof product requirements from Code Sections 150.1(c)11 for residential and 140.3(a)1A for nonresidential to create a set of unified prescriptive roof assembly U-factor, solar reflectance, and thermal emittance thresholds. This results in two product categories, low-sloped roofs and steep-sloped roofs, and the requirements are further grouped by climate zones.

**Roof/Ceiling Insulation**: The proposal aligns the roof/ceiling insulation requirements from Code Sections 150.1(c)1A for residential and 140.3(a)1B for nonresidential to create a set of unified prescriptive roof and ceiling insulation assembly U-factor requirements. This results in two assembly categories, attic roofs and non-attic roofs. Within the attic roofs category, Option B (with insulation between roof rafters and an additional ceiling insulation) and Option C (with ceiling insulation only between the attic and conditioned space) from residential code remain. Within the non-attic roofs category, the two current nonresidential roof-type categories of metal building and wood-framed and others remain with the same requirements.

**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 two window categories differentiated by the window type.

- Curtainwall and storefront 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.

**Fenestration Properties in alterations and additions:** The proposal creates a new alterations and additions table with different requirements by window type and situation.

- Curtainwall and storefront windows
- Fixed windows
- Operable windows
- Glazed doors

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 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:

- Solar reflectance by roof slope and climate zone
- Roof insulation 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 5 percent west-facing window to floor area liming currently in the residential ACM

See Section 7.4 of this report for the details.

#### 2.3.2.4 Summary of Changes to Compliance Manuals

The Statewide CASE Team strongly recommends creation of a Multifamily Compliance Manual. A separate section within the Residential Compliance Manual or Nonresidential Compliance Manual is the next best option. 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 individual dwelling units and nonresidential requirements from Sections 120.2 through 120.5 and 140.4(c) through (o) to systems serving multiple dwelling units and/or 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, with the exception of minor language changes, to provide additional clarity on when specific HVAC system are subject to or exempt from fan efficacy and refrigerant verification test protocols. Application of the residential code language to all multifamily buildings with HVAC systems serving individual dwelling units would result in new reference to the residential appendices for buildings more than three habitable stories (previously subject to nonresidential requirements). This will include applicable HERS verification protocols for duct testing, airflow and fan watt draw, and refrigerant charge verification in Sections RA3.1, RA3.2, and RA3.3.

#### 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. A separate section within the Residential Compliance Manual or Nonresidential Compliance Manual is the next best option. 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 installation and verification forms would be converted to nonresidential certificates of installation (NRCI) and nonresidential certificates of verification (NRCV) forms for use with all multifamily buildings regardless of number of stories.

- 2019-CF2R-MCH-20a-DuctLeakageTest-NewConst
- 2019-CF2R-MCH-20b-DuctLeakage-LLDCS
- 2019-CF3R-MCH-20a-DuctLeakageTest-NewConst
- 2019-CF3R-MCH-20b-DuctLeakage-LLDCS
- 2019-CF2R-MCH-23a-AirflowRate-AllZonesCallingOnly

- 2019-CF2R-MCH-23b-AirflowRate-EveryZonalControlMode
- 2019-CF2R-MCH-23d-AirflowRate-MeasurementOnly-AllZonesCallingOnly
- 2019-CF2R-MCH-23e-AirflowRate-AllZonesCallingOnly-WithCFVCS
- 2019-CF2R-MCH-23f-AirflowRate-EveryZonalControlMode-WithCFVCS
- 2019-CF3R-MCH-23a-AirflowRate-AllZonesCallingOnly
- 2019-CF3R-MCH-23b-AirflowRate-EveryZonalControlMode
- 2019-CF3R-MCH-23d-AirflowRate-MeasurementOnly-AllZonesCallingOnly
- 2019-CF3R-MCH-23e-AirflowRate-AllZonesCallingOnly-WithCFVCS
- 2019-CF3R-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-CF3R-MCH-22a-FanEfficacy-AllZonesCallingOnly
- 2019-CF3R-MCH-22b-FanEfficacy-EveryZonalControlMode
- 2019-CF3R-MCH-22c-FanEfficacy-AllZonesCallingOnly-WithCFVCS
- 2019-CF3R-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-CF3R-MCH-25a-RefrigerantCharge-Superheat
- 2019-CF3R-MCH-25b-RefrigerantCharge-Subcooling
- 2019-CF3R-MCH-25c-RefrigerantCharge-WeighinObservation
- 2019-CF3R-MCH-25d-RefrigerantCharge-FID
- 2019-CF3R-MCH-25e-RefrigerantCharge-WinterSetUp

## 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 \|<br>4+ habitable stories | **Low-rise** residential prescriptive requirements \|<br>3 habitable stories or fewer |
|---|---|---|
| Roofing Product | 0.20-0.75 ASR by roof slope and climate zone<br>0.75 thermal emittance | 0.20-0.63 ASR by roof slope and climate zone<br>0.75 thermal emittance |
| Roof/Attic Insulation | Metal building; U-factor of 0.041. Wood framed and others: U-factors of 0.028, 0.034 or 0.039 by climate zone.<br>No prescriptive measure for buildings with attics | 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.<br>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<br>SHGC: 0.22-0.26<br>VT: 0.17-0.46 | U-factor: 0.30<br>SHGC: 0.23 or NR<br>VT: no requirement |
| Fenestration Area Metric | Window to wall area – maximum 40% overall | 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 |
| Cooling Coil Airflow | No requirement, is modeled within the compliance software | Mandatory ≥ 350 cfm/ton |
| 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 |
| 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.

There are no relevant requirements in other parts of the California Building Code for the space conditioning submeasures.

### 2.4.3 Relationship to Local, State, or Federal Laws

There are no relevant new requirements in relation to local, state, or federal laws in this proposal.

### 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 Products

- **Design Phase:** Designers specify roof assembly and roofing products and provide necessary information to populate the CF1R/NRCC forms. Pertinent details include 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 products and specifications are listed on the CF2R-ENV-04-E/NRCI-ENV-01-E installation forms. Building inspectors will confirm that the installed roofing products match the indicated performance details.

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 – Roof/Ceiling Insulation

- **Design Phase:** Designers specify roof assembly, including roof and ceiling insulation, and provide necessary information to populate the CF1R/NRCC forms. Pertinent details include the presence of an attic and accompanying insulation locations, types, and levels.
- **Permit Application Phase:** The design professional is responsible for the completion and submission of the Certificate of Compliance documents with roof and ceiling insulation information.
- **Construction Phase:** Once a roof's structural components are in place, roofing contractor or sometimes a dedicated insulation contractor will install the roof and ceiling insulation as specified in the construction documents. Minimal

coordination between trades is involved in comparison to construction of other building assemblies.

- **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 installed roof and ceiling insulations match the indicated location, insulation type, and level details.

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

#### *2.5.1.3 Submeasure C1: 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.

#### *2.5.1.4 Submeasure C2: 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.

#### *2.5.1.5 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].

- **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 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.

#### *2.5.1.6 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 distribution system is sealed, and the ductwork is tested to determine the leakage percentage. The mechanical installer completes the certificates of installation.
- **Inspection Phase:** Duct insulation is not verified by a HERS Rater or ATT, but if

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

duct testing is required, a HERS Rater conducts verification testing and completes the certificate of verification forms. 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 verification currently required or proposed.

#### *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 certificates of installation.
- **Inspection phase:** a HERS Rater conducts verification testing of duct leakage and completes the certificate of verification forms. A building inspector conducts a final inspection.

The compliance and enforcement process for this Submeasure G is entirely new for multifamily buildings four habitable stories and greater; however, it is identical to that which currently exists for low-rise residential buildings. The existing field verification and diagnostic test requirements will not be modified. The new requirements mostly impact installers, verifiers, and inspectors. The mechanical installer will need to accommodate time for duct leakage testing during installation, and coordination will be required between the installer and the HERS Rater. Mechanical installers that work on multifamily buildings both fewer than and greater than or equal to four habitable stories will be familiar with this process and likely already have relationships with HERS Rater. Those that exclusively work on multifamily buildings four habitable stories and greater will need to familiarize themselves with this process and contract directly with a HERS Rater or have the builder do so. 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. The distribution system is sealed, and the ductwork is tested to determine the leakage percentage. 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:** A HERS Rater conducts verification testing of airflow and fan efficacy and completes the certificate of verification forms. A building inspector conducts a final inspection.

The compliance and enforcement process for this Submeasure G is entirely new for multifamily buildings four habitable stories and greater; however, the process is identical to what currently exists for low-rise residential buildings. The existing field verification and diagnostic test requirements will not be modified. The new requirements mostly impact installers, verifiers, and inspectors. The mechanical installer will need to accommodate time for airflow and fan power testing during installation, and coordination will be required between the installer and the HERS Rater. Mechanical installers that work on multifamily buildings both fewer than and greater than or equal to four habitable stories will be familiar with this process and likely already have relationships with the HERS Rater. Those that exclusively work on multifamily buildings four habitable stories and greater will need to familiarize themselves with this process and contract directly with a HERS Rater or have the builder do so. 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.
- **Inspection Phase:** A HERS Rater conducts verification testing of refrigerant charge and completes the certificate of verification forms. A building inspector conducts a final inspection.

The compliance and enforcement process for this Submeasure G is entirely new for multifamily buildings four habitable stories and greater; however, it is identical to that which currently exists for low-rise residential buildings. The existing field verification and diagnostic test requirements will not be modified. The new requirements mostly impact installers, verifiers, and inspectors. Mechanical installers that work on multifamily buildings both fewer than and greater than or equal to four habitable stories will be familiar with this process and likely already have relationships with HERS Rater. Those that exclusively work on multifamily buildings four habitable stories and greater will need to familiarize themselves with this process and contract directly with a HERS Rater or have the builder do so. 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.

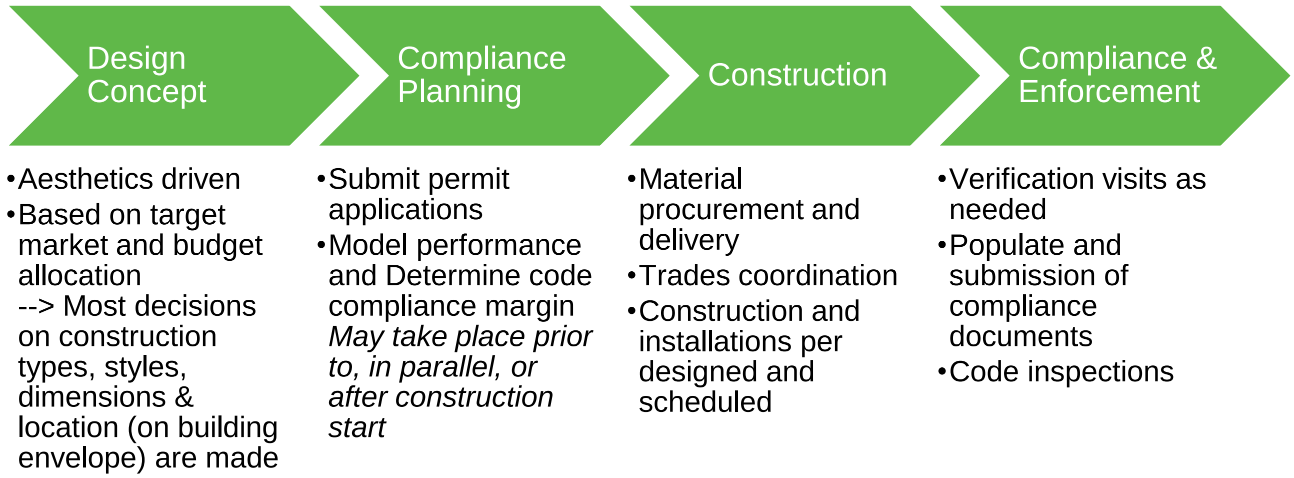


**Figure 1: Thermal envelope construction process.**

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 & Enforcement |
|---|---|---|---|---|
| Designer | ● | | | |
| Developer/Owner | ● | | | |
| Architect/Engineer | ● | ● | ● | |
| Plan Examiner | | ● | | |
| Energy Consultant | | ● | | ● |
| Contractor/Installer | | | ● | ● |
| HERS Rater | | | | ● |
| Building Inspector | | | | ● |

### *Submeasure A: Envelope – Roofing Products*

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 – Roof/Ceiling Insulation*

Roof and ceiling insulation location, type, and performance are a function of roof assemblies. Depending on the presence of an attic versus flat roof and roof deck construction, a combination of insulations at the roof deck and ceiling may be specified. Regardless, contractors execute the installations per design.

### *Submeasure C1: 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 C2: 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.

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 Products*

This proposed submeasure aligns roof product solar reflectance and thermal emittance requirements across multifamily buildings in climate zones groups, primarily based on the roof slope. The proposal does not introduce additional product performance stringency nor selection limitations beyond existing roof requirements.

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.

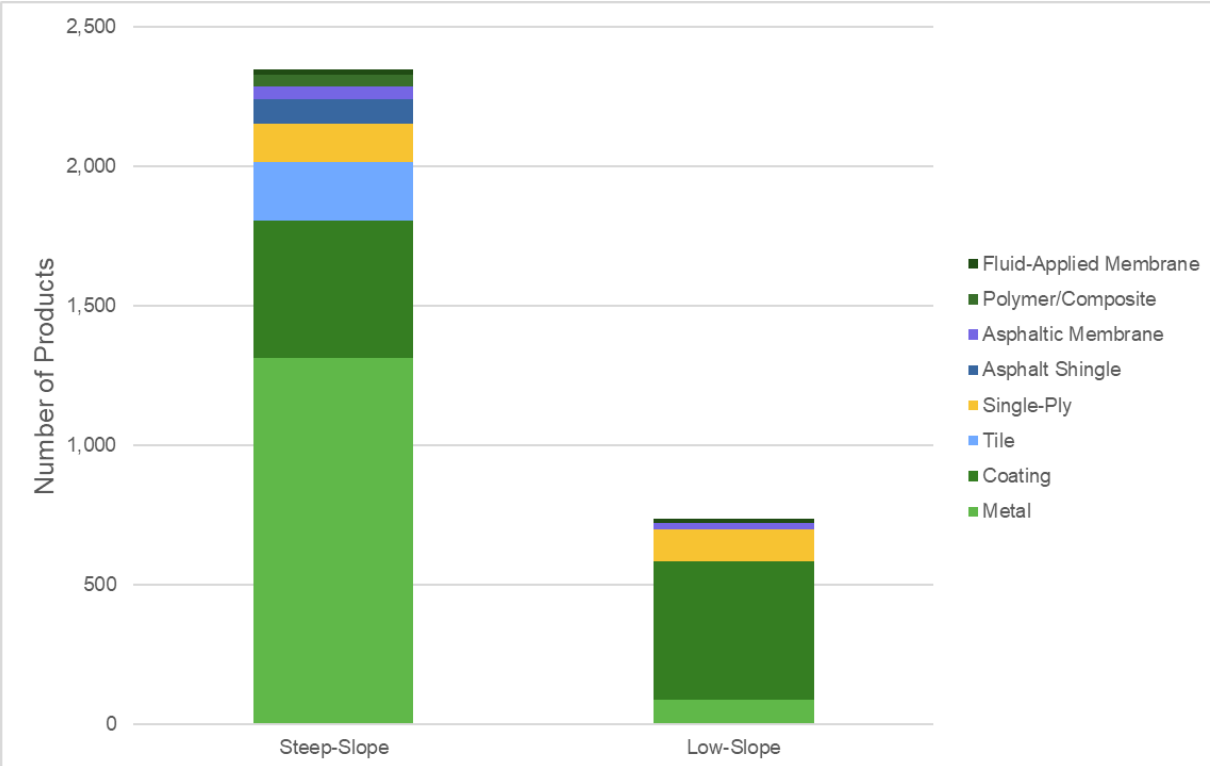


**Figure 2: Number of CRRC-registered products that meet current Title 24, Part 6 minimum criteria for ASR and thermal emittance.**

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 – Roof/Ceiling Insulation*

The proposed submeasure combines roof and ceiling insulation requirements across high-rise and low-rise multifamily buildings in climate zones groups, primarily based on the presence of an attic. Adjustments are made to subject multifamily buildings with flat 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.

#### 3.1.2.3 Submeasure C1: 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 |

| Wall type | Current U-factor | Proposed U-factor | Change | Analysis |
|---|---|---|---|---|
| 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.

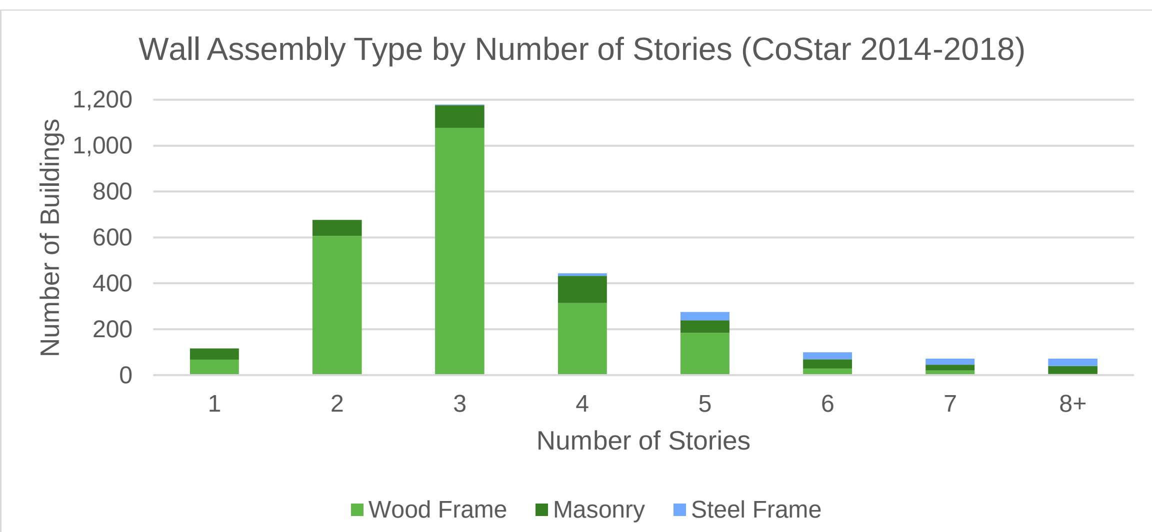


**Figure 3: Wall construction type by number of habitable stories.**

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.

#### *3.1.2.4 Submeasure C2: 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.

### 3.1.2.5 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 proposed fenestration thermal properties constitute the most efficient and technically-possible level when using metal-framed dual-pane window construction. To achieve the proposed levels, window manufactures must apply a blend of thermal improvement strategies including warm edge spacers, wider thermal breaks, argon fill, and additional or improved low-e coatings. The Statewide CASE Team's proposal assumes builders that can't achieve the proposed efficiency levels from available dual-pane products would prioritize their design aesthetics and make other energy improvement elsewhere via the performance route, or they may choose to use triple pane window products at higher cost, or use multiple, smaller site-built windows that allow for non-metal framing options like vinyl framing or wood.

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 researched if it would be appropriate to apply a less rigid energy efficiency standard for NAFS 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 clearly warranted for structural purposes. However, ultimately the proposal found that cost effectiveness can be achieved even with Class AW windows when combined with the proposed all-electric requirements in a different CASE Report. The same requirements are therefore proposed for all non-curtain wall windows, independent of Performance Class.

The biggest challenge to meet the proposed values will be for large site-built windows and other cases 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 all 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 have an easier time meeting these requirements, they would have a difficult time 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 U.S. designers, as a move to clear and unobstructed window design is 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 for a luxury apartment would make this window type undesirable to builders and architects.

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. 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 5 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 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.

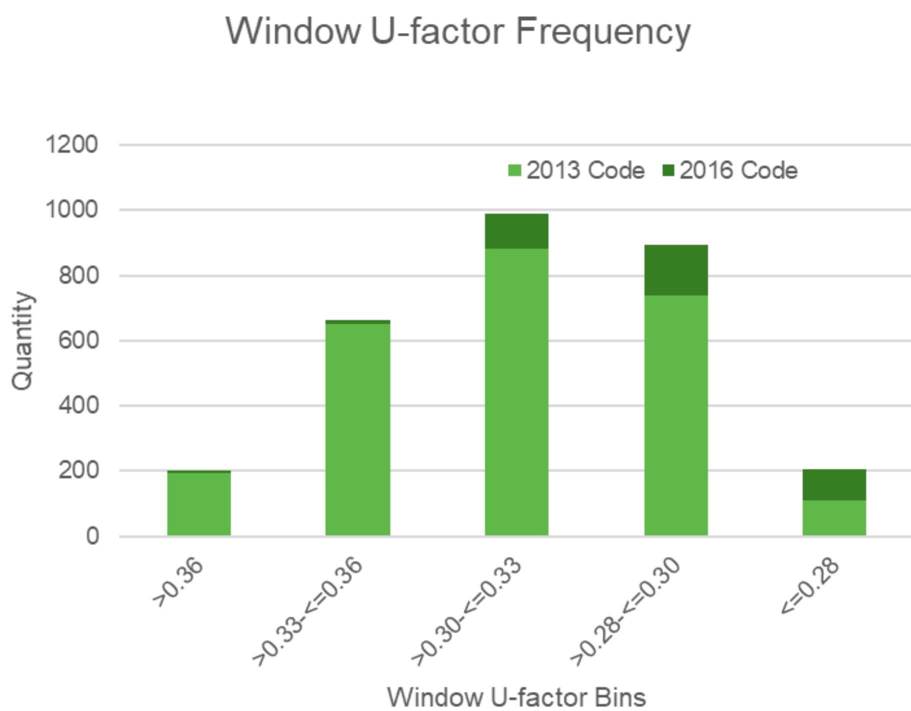


**Figure 4: Window U-factor frequency – CalCERTS data.**

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.

### *3.1.2.6 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.

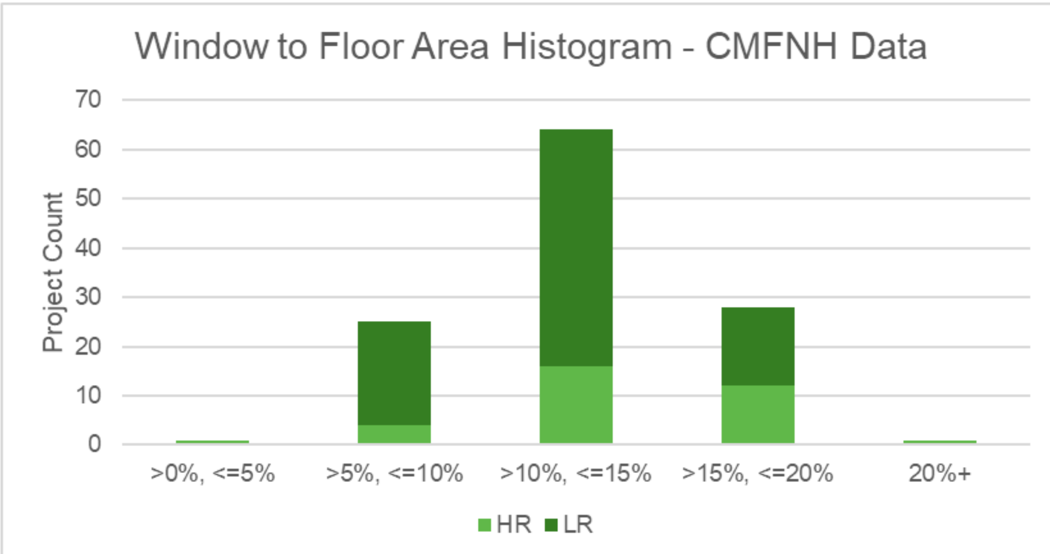


**Figure 5: Window-to-floor area histogram – CMFNH data.**

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

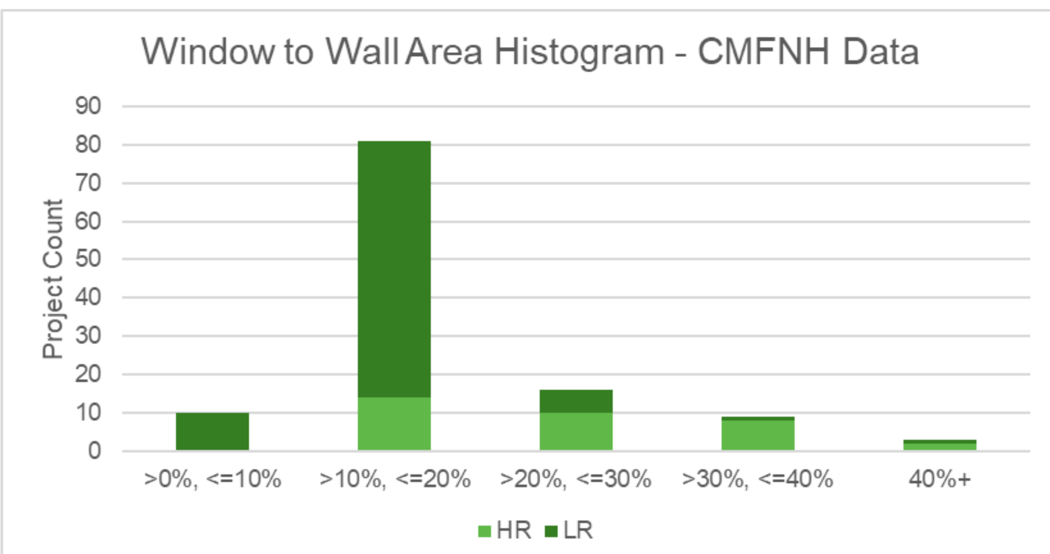


**Figure 6: Window to wall area histogram - CMFNH Data.**

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.

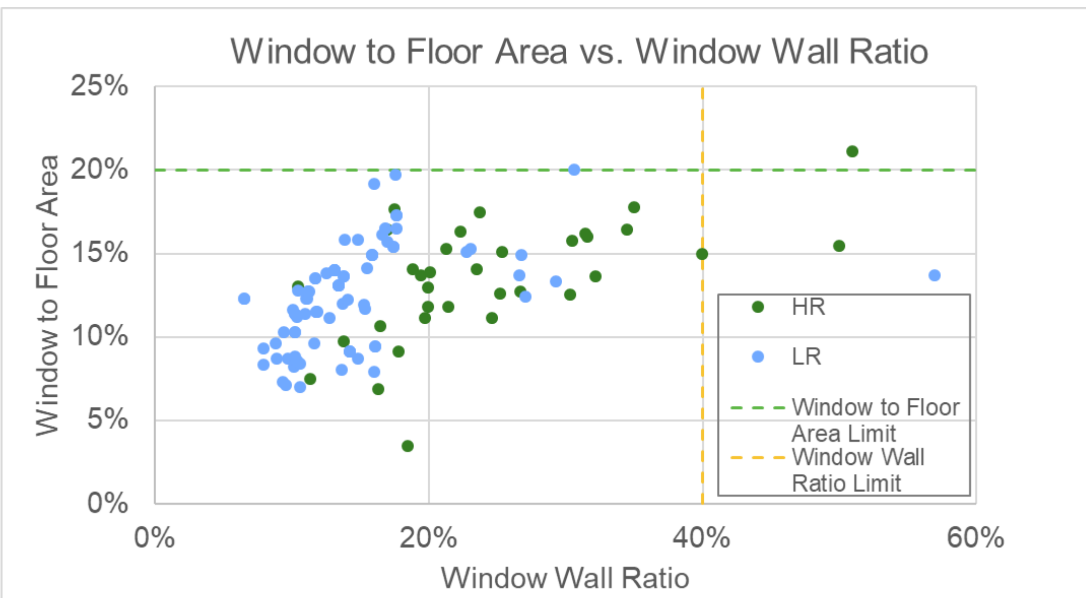


**Figure 7: Window area ratios in CMFNH high-rise buildings.**

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 5 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, contractors, and HERS Raters. 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 right sizing the mechanical equipment, so ductwork and fan systems are also properly sized and not oversized for the application. 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 space cooling systems, and refrigerant charge verification applies to all individual 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.

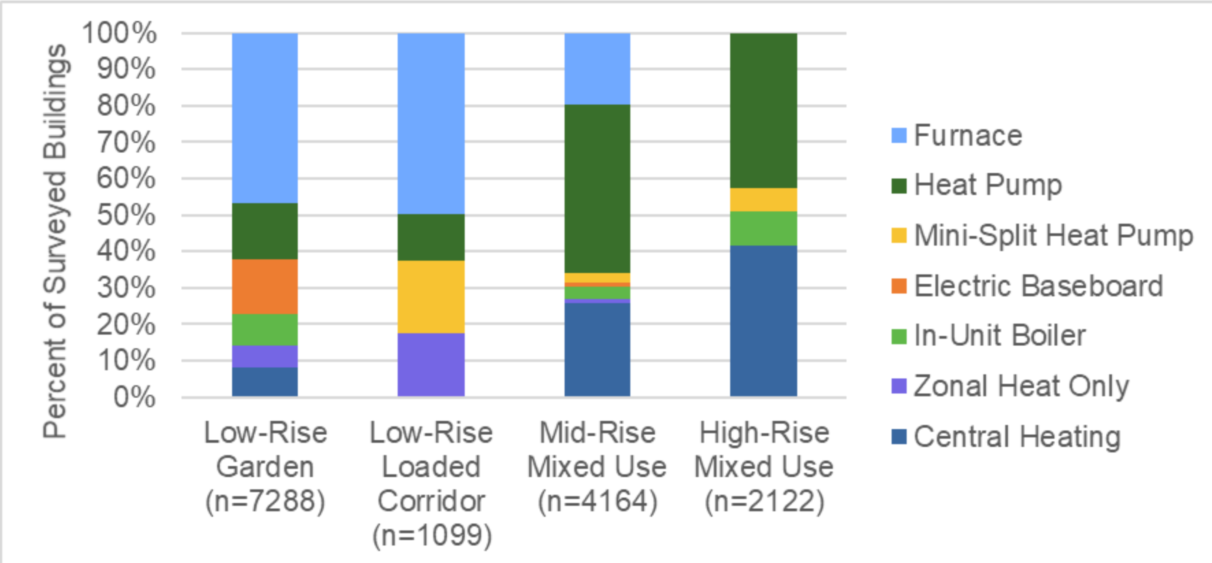


**Figure 8: Distribution of HVAC heating system type for sample of California multifamily projects.**

Source: Evergreen Economics

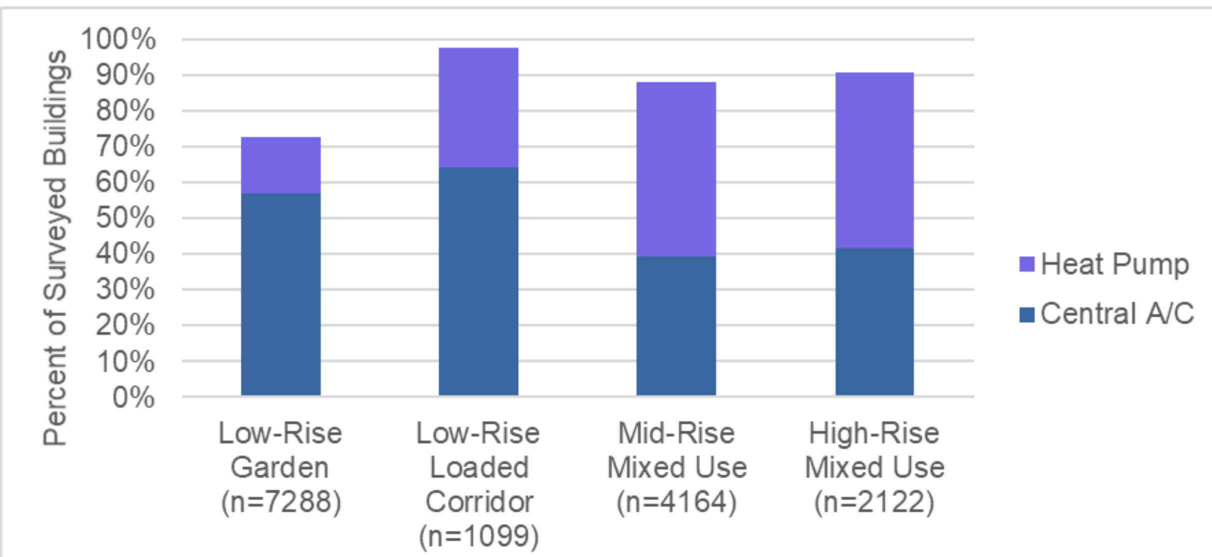


**Figure 9: Percent of projects with mechanical cooling for sample of California multifamily projects.**

Source: Evergreen Economics.

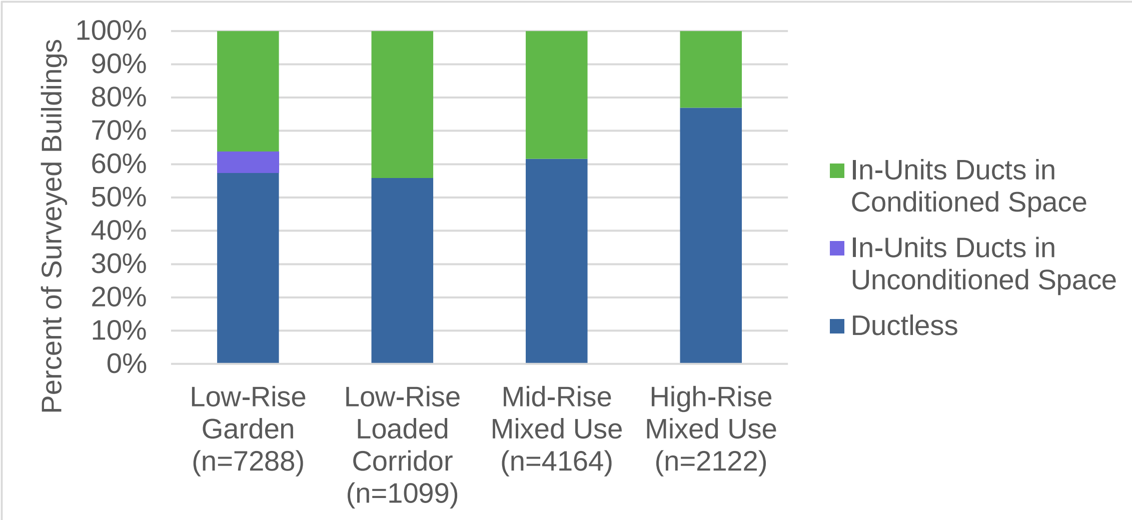


**Figure 10: Distribution of duct type and location for sample of California multifamily projects.**

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
- One HVAC contractor

Most of the stakeholders welcomed the proposed alignment, and many were supportive of the idea of one code especially considering some projects they have worked on 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.

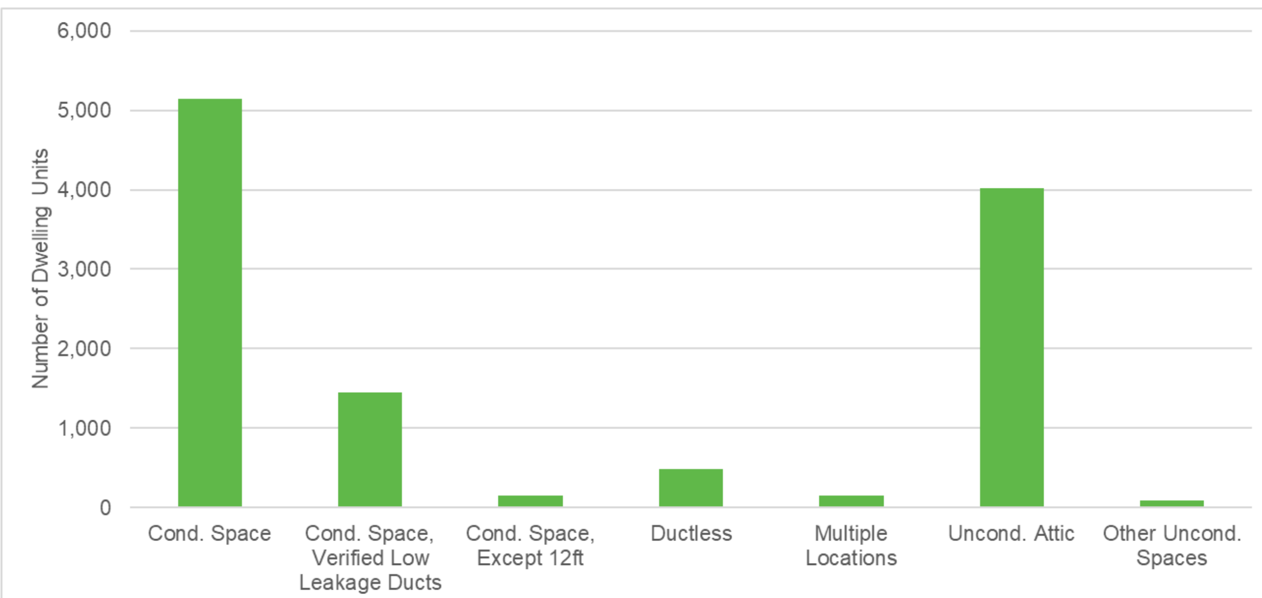


**Figure 11: Distribution of HVAC system duct location for multifamily projects up to three habitable stories.**

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.

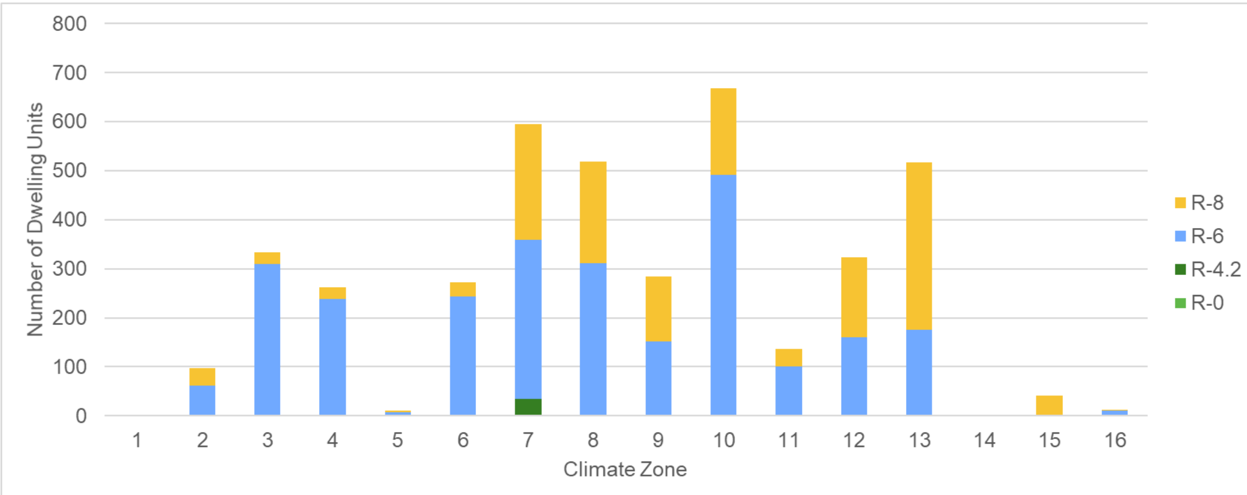


**Figure 12: Distribution of duct insulation R-value by climate zone for ducts in unconditioned space in multifamily projects up to three habitable stories.**

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.

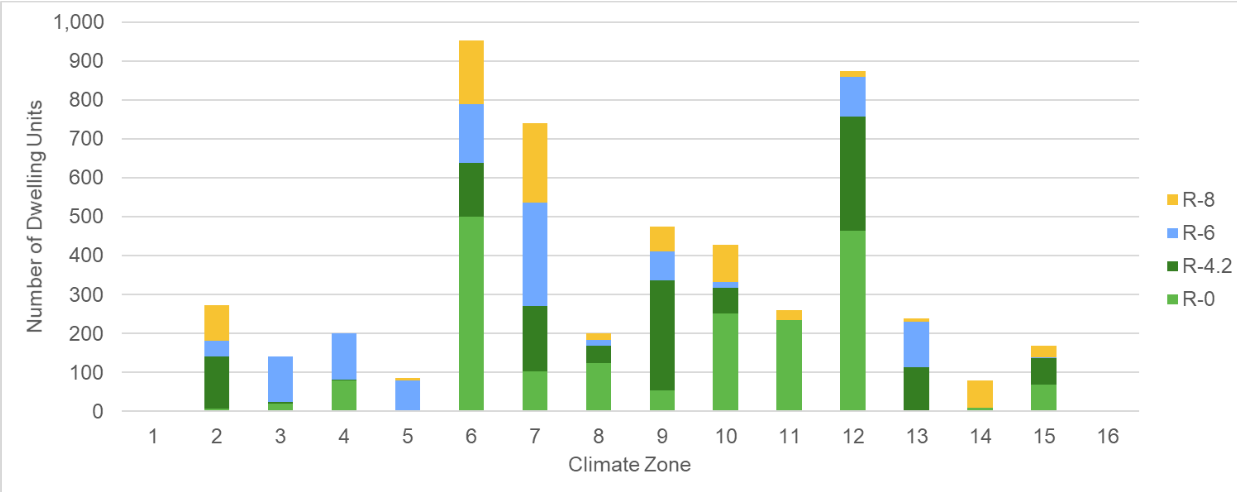


**Figure 13: Distribution of duct insulation R-value by climate zone for ducts in conditioned space in multifamily projects up to three habitable stories.**

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 indirectly 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.

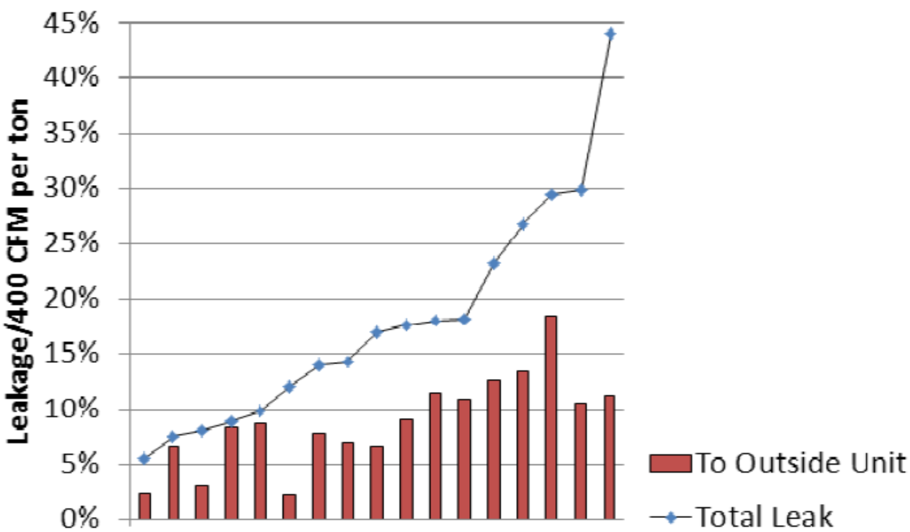


**Figure 14: Duct leakage for a sample of multifamily projects one to three habitable stories built under the 2005 Title 24, Part 6 code.**

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.

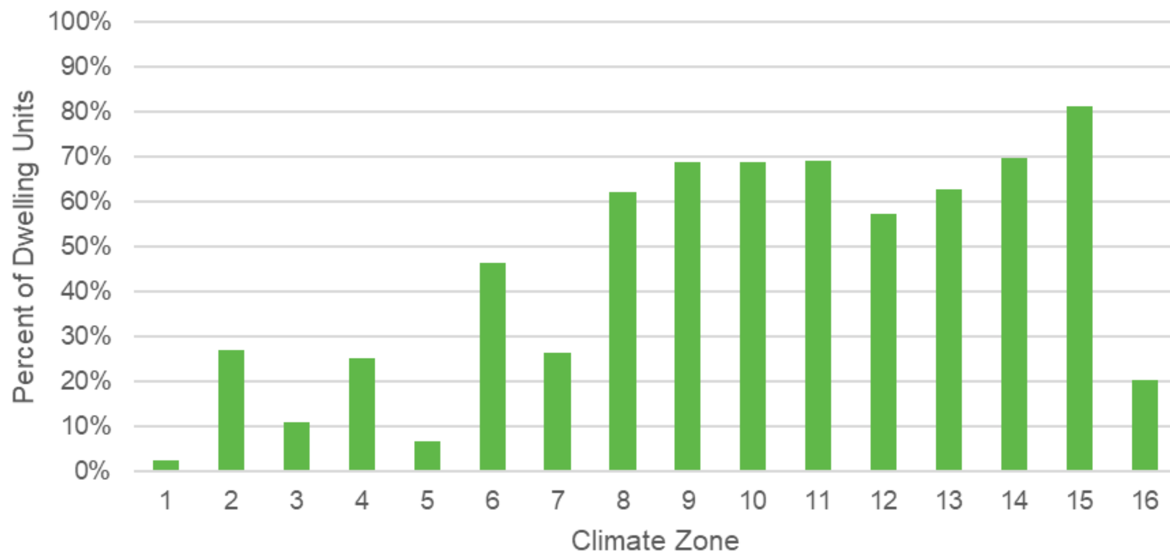


**Figure 15: Percent of new construction multifamily projects up to three habitable stories with refrigerant charge verification.**

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.

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[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 29 present the estimated impact of the adoption of proposed measures. Submeasures not listed are assumed to have no economic impact.

[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.

#### 3.4.1.1 Building Envelope

**Submeasure A: Envelope – Roof Products**

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

| Impact Type | Employment (jobs) | Labor Income | Value Added | Output |
|---|---|---|---|---|
| Direct Effects (Additional spending by Residential Builders) | 34 | $2,164,087 | $3,647,272 | $5,922,579 |
| Indirect Effect (Additional spending by firms supporting Residential Builders) | 13 | $835,226 | $1,301,866 | $2,311,897 |
| Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects) | 16 | $891,585 | $1,595,478 | $2,604,460 |
| Total Economic Impacts | 63 | $3,890,898 | $6,544,616 | $10,838,936 |

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

**Submeasure C1: Envelope – Wall U-Factor**

**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) | 303 | $19,386,255 | $32,672,883 | $53,055,467 |
| Indirect Effect (Additional spending by firms supporting Residential Builders) | 117 | $7,482,094 | $11,662,334 | $20,710,361 |
| Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects) | 144 | $7,986,970 | $14,292,559 | $23,331,195 |
| Total Economic Impacts | 564 | $34,855,320 | $58,627,777 | $97,097,022 |

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

### Submeasure C2: Envelope – Quality Insulation Installation

#### 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) | 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 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) | 5,068 | $324,880,172 | $547,541,111 | $889,118,030 |
| Indirect Effect (Additional spending by firms supporting Residential Builders) | 1,956 | $125,386,981 | $195,440,591 | $347,069,890 |
| Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects) | 2,401 | $133,847,828 | $239,518,617 | $390,990,543 |
| Total Economic Impacts | 9,425 | $584,114,981 | $982,500,318 | $1,627,178,463 |

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 26: 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) | 86 | $5,514,637 | $9,294,166 | $15,092,220 |
| Indirect Effect (Additional spending by firms supporting Residential Builders) | 33 | $2,128,365 | $3,317,481 | $5,891,293 |
| Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects) | 41 | $2,271,983 | $4,065,678 | $6,636,819 |
| Total Economic Impacts | 161 | $9,914,985 | $16,677,326 | $27,620,332 |

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

**Table 27: 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) | 28 | $2,923,751 | $2,888,732 | $5,138,502 |
| Indirect Effect (Additional spending by firms supporting Bldg. Designers & Energy Consult.) | 18 | $1,204,259 | $1,627,014 | $2,586,414 |
| Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects) | 22 | $1,233,431 | $2,206,930 | $3,603,108 |
| Total Economic Impacts | 68 | $5,361,442 | $6,722,677 | $11,328,024 |

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 28: 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) | 19 | $1,949,168 | $1,925,822 | $3,425,668 |
| Indirect Effect (Additional spending by firms supporting Residential Builders) | 12 | $802,840 | $1,084,676 | $1,724,276 |
| Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects) | 15 | $822,287 | $1,471,287 | $2,402,072 |
| Total Economic Impacts | 47 | $3,574,294 | $4,481,785 | $7,552,016 |

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

### Submeasure I: Space Conditioning – Refrigerant Charge Verification

**Table 29: 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) | 19 | $1,949,168 | $1,925,822 | $3,425,668 |
| Indirect Effect (Additional spending by firms supporting Bldg. Designers & Energy Consult.) | 12 | $802,840 | $1,084,676 | $1,724,276 |
| Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects) | 15 | $822,287 | $1,471,287 | $2,402,072 |
| Total Economic Impacts | 47 | $3,574,294 | $4,481,785 | $7,552,016 |

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, 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

[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.

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.

## 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 30 and Table 31.

**Table 30: 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 31: 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 that 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 do 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.

[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.

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 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 Products**

There are existing Title 24, Part 6 requirements that cover roofing product 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 in the 2020 research version. For Climate Zones 13 and 15, the baseline Standard Design assumes a prescriptive ASR level of 0.63 and thermal emittance of 0.75 for low rise multifamily buildings (with three habitable stories and fewer). The climate zones other than 13 and 15 do not have prescriptive requirement in energy code and are defaulted to the mandatory 0.1 ASR instead and the same 0.75 thermal emittance by the software.

While the 5-story and 10-story simulation runs would result in increased energy use, the resulting statewide energy savings remain positive for the restructuring topic overall.

**Table 32: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change - Roof Products**

| Prototype ID | Climate Zone | Parameter Name | Standard Design Parameter Value | Proposed Design Parameter Value |
|---|---|---|---|---|
| 2-Story Garden Style, 3-Story Loaded Corridor | (low-sloped roofs) CZ 9-11, 14 | Roofing Aged Solar Reflectance/ Thermal Emittance | 0.10 / 0.75 | 0.55 / 0.75 |
| 5-Story Mixed Use, 10-Story Mixed Use | (low-sloped roofs) CZ 13, 15 | Roofing Aged Solar Reflectance/ Thermal Emittance | 0.55 / 0.75 | 0.63 / 0.75 |

**Submeasure B: Envelope – Roof/Ceiling Insulation**

There is an existing Title 24, Part 6 requirement that covers 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.

Table 36 presents precisely which parameters were modified and what values were used in the Standard Design and Proposed Design. Specifically, the proposed conditions align the prescriptive requirements for *flat roof* of low-rise multifamily buildings with the *wood-framed roof* requirements of high-rise multifamily building, as specified in Table 140.3-C in 2019 Title 24, Part 6. The proposed flat roof for low-rise prototypes is modeled using wood framed assemblies to match the required U-factor levels from Table 140.3-C. The proposed measure is compared against a baseline of current code compliant attic roof for low-rise multifamily buildings per Option C in Table 150.1-B.

This is a restructuring submeasure to align the requirements across low-rise and high-rise multifamily buildings for flat roofs by setting equivalent requirement levels specifically for low-rise buildings without attics. This submeasure will result in increased TDV energy use in Climate Zones 1-7 and 12-16 and energy savings in Climate Zones 8-11, aggregating in negative savings for this submeasure.

**Table 33: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change - Roof/Ceiling Insulation**

| Prototype ID | Climate Zone | Parameter Name | Standard Design Parameter Value | Proposed Design Parameter Value |
|---|---|---|---|---|
| 2-Story Garden Style, 3-Story Loaded Corridor | CZ 1,11-16 | Roof Assembly | R-38 ceiling cavity insulation, no attic insulation | 0.028 U- factor |
| | CZ 2,4,8-10 | Roof Assembly | R-30 ceiling cavity insulation, no attic insulation | 0.028 U- factor |
| | CZ 3,5,6 | Roof Assembly | R-30 ceiling cavity insulation, no attic insulation | 0.034 U- factor |
| | CZ 7 | Roof Assembly | R-30 ceiling cavity insulation, no attic insulation | 0.039 U- factor |

### Submeasure C1: 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 34 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 assess the energy impact for high fire rating walls in a three-story prototype switching from adhering to existing residential to the proposed high fire rating U-factor requirements, and the reverse scenario of a five-story prototype switching from adhering to existing nonresidential to the proposed low fire rating U-factor requirements. The bottom row assesses the energy impacts for the five-story and ten-story prototype buildings unifying into a high fire-rating requirement by changing from adhering to existing nonresidential to the proposed high fire rating U-factor requirements.

**Table 34: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change - Wall U-Factor**

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

### Submeasure C2: 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 but Climate Zone 7 where there are 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 35 presents precisely which parameters were modified 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 two rows (by Prototype ID) represent energy savings from buildings four habitable stories or more for the two proposed new construction window categories; curtainwalls and storefronts, and all-other windows.

For the second 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 2 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. As per the nonresidential ACM, the presence of operable windows in a zone triggers a change in infiltration rates to reflect natural ventilation from the windows in certain conditions. Therefore, the Statewide CASE Team modeled the area-weighted blend entirely as operable, as it has the same energy impact as modeling each window type individually.

The bottom three rows (by Prototype ID) simulate energy impacts for the alteration cases. These prototypes are based on 1990 era vintage energy measures for the envelope and mechanical equipment. This better represents the energy use profile and therefore estimated savings 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, either curtainwall windows or with a blend of fixed windows, operable windows, and glazed doors. The blend is modeled as 59 percent fixed windows, 39 percent operable windows, and 2 percent glazed doors. The "Prototype D Existing" row isolates the energy loss effects of changing the U-factor requirement from 0.30 to 0.37. The proposed SHGC requirement maintains the "NR" for no requirement for buildings three habitable stories or fewer in Climate Zones 1, 3, 5, and 16 as is the current residential requirement. This is modeled as an SHGC of 0.35 as per the residential ACM. The last two rows (by Prototype ID) assess the energy impact for lowering both the U-factor and SHGC requirements for existing high-rise buildings adhering to the proposed alterations requirements.

**Table 35: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change – Fenestration Properties**

| Prototype ID<br><br>Proposed category: Application scenario | Climate Zone | Parameter Name | Standard Design Parameter Value | Proposed Design Parameter Value |
|---|---|---|---|---|
| 5-Story Mixed Use, 10-Story Mixed Use<br><br>Curtainwall/Store Fronts | 1 | U-Factor/SHGC* | 0.41/0.26 | 0.38/0.35 |
| | 2-16 | | | 0.38/0.25 |
| 5-Story Mixed Use, 10-Story Mixed Use<br><br>All Others: Blended Nonresidential to “All Others” | 1 | U-Factor/SHGC (a combined category for Fixed, Operable fenestrations, and Glazed Doors) * | 0.40/0.24 | 0.30/0.35 |
| | 2-16 | | | 0.30/0.23 |
| Low Rise Prototype D Existing | 1, 3, 5, 16 | U-Factor/SHGC | 0.30/NR** | 0.34/NR** |
| | 2, 4, 6-15 | | 0.30/0.23 | 0.34/0.23 |
| High-Rise Existing<br><br>Curtainwall/Store Fronts | 1 | U-Factor/SHGC* | 0.47/0.41 | 0.38/0.35 |
| | 2, 4, 6-15 | | 0.47/0.31 | 0.38/0.25 |
| | 3, 5 | | 0.58/0.41 | 0.38/0.25 |
| | 16 | | 0.47/0.41 | 0.38/0.25 |
| High-Rise Existing<br><br>All Others: Blended NR to “All Others” | 1 | U-Factor/SHGC (a combined category for Fixed, Operable fenestrations, and Glazed Doors) * | 0.47/0.41 | 0.34/0.35 |
| | 2, 4, 6-15 | | 0.47/0.31 | 0.34/0.23 |
| | 3, 5 | | 0.58/0.41 | 0.34/0.23 |
| | 16 | | 0.47/0.41 | 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.

### 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 are 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 ductwork in indirectly 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. If the current requirements for multifamily building 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 36 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-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 3-story loaded corridor prototype.

For the component of this submeasure that impacts ducts in indirectly 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 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. 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 same insulation value was applied on both the supply and return side.

The impacts of the proposed submeasures are climate-specific; therefore, energy savings are evaluated in each climate zone where the proposal applies.

**Table 36: 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 | 3, 5-7 | 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 within directly or indirectly conditioned space. The Statewide CASE Team modified the Standard Design so that it calculated 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). 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 6 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 37 presents precisely which parameters were modified and what values were used in the Standard Design and Proposed Design. Specifically, the proposed conditions assume six 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 impacts of leakage to outside were evaluated by reducing the supply airflow to the zone corresponding in magnitude to estimated leakage to outside values. In both cases the design airflow rate was set to 300 cfm per ton (see Table 38 and associated description for justification). The Standard Design airflow was reduced to account for 12 percent leakage to outside resulting in a final airflow rate of 264 cfm per ton. The Proposed Design airflow was reduced to account for six percent leakage to outside resulting in a final airflow rate of 282 cfm per ton. Fan power and heating and cooling capacity was fixed across the Standard Design and Proposed Design.

This approach accounts for the reduced airflow to the space, and as a result, increased operation of the heating and cooling system to deliver the same capacity to the space. However, it does not fully account for the energy losses associated with conditioning air that is subsequently lost to outside the thermal envelope. Therefore, it is anticipated that this approach underestimates the energy savings associated with duct sealing, particular during heating operation.

**Table 37: 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 | All | CBECC-Com | Residential - Zone System - Fan – Flow Capacity | 300 cfm/ton * (1-12%) = 264 cfm/ton | 300 cfm/ton * (1-6%) = 282 cfm/ton |

### 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 so that it calculated 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 38 presents precisely which parameters 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.

The impacts of the proposed submeasures are climate-specific; therefore, energy savings are evaluated in each climate zone where the proposal applies. The impacts of cooling coil airflow and fan efficacy were evaluated independently.

**Table 38: 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 so that it calculated 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 39 presents precisely which parameters 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 impacts of the proposed submeasures are climate-specific; therefore, energy savings are evaluated in each climate zone where the proposal applies.

**Table 39: 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 | 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 40 presents the prototypical buildings and weighting factors that the Energy Commission requested the Statewide CASE Team use for each Building Type ID in the Statewide Construction Forecast.

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

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

**Table 40: 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.

### 4.3.1 Building Envelope

#### *4.3.1.1 Submeasure A: Envelope – Roof Products*

Energy savings and peak demand reductions per unit are presented in Table 41 through Table 44 from new construction buildings. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. Per-unit electricity savings for the first year are expected to range from 3.66 to 49.50 kWh/yr, and natural gas use is expected to increase between 0.04 to 1.87 therms/yr depending upon prototype building and climate zone. Demand reductions are expected to range between 0 to 0.03 kW depending upon prototype building and climate zone.

The results tables are presented in the following order:

- Low-sloped roofs, new requirement of 0.55 ASR, for two-story and three-story prototypes
- Low-sloped roofs, increase to 0.63 ASR, for five-story and ten-story prototypes

**Table 41: First-Year Energy Impacts Per Dwelling Unit– Low-Slope New Requirement of 0.55 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 | 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 | 42.08 | 0.03 | (0.75) | 1651 |
| 10 | 49.01 | 0.03 | (0.95) | 1574 |
| 11 | 49.50 | 0.03 | (1.21) | 1795 |
| 12 | N/A | N/A | N/A | N/A |
| 13 | N/A | N/A | N/A | N/A |
| 14 | 40.33 | 0.03 | (1.87) | 1296 |
| 15 | N/A | N/A | N/A | N/A |
| 16 | N/A | N/A | N/A | N/A |

**Table 42: First-Year Energy Impacts Per Dwelling Unit– Low-Slope New Requirement of 0.55 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 | 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 | 36.09 | 0.02 | (0.18) | 1433 |
| 10 | 42.13 | 0.03 | (0.28) | 1500 |
| 11 | 39.54 | 0.02 | (0.41) | 1567 |
| 12 | N/A | N/A | N/A | N/A |
| 13 | N/A | N/A | N/A | N/A |
| 14 | 30.16 | 0.03 | (0.65) | 1211 |
| 15 | N/A | N/A | N/A | N/A |
| 16 | N/A | N/A | N/A | N/A |

**Table 43: 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 | 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 | 8.82 | 0.00 | (0.26) | 192 |
| 14 | N/A | N/A | N/A | N/A |
| 15 | 11.35 | 0.00 | (0.10) | 299 |
| 16 | N/A | N/A | N/A | N/A |

**Table 44: 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 | 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 | 3.66 | 0.00 | (0.10) | 82 |
| 14 | N/A | N/A | N/A | N/A |
| 15 | 4.60 | 0.00 | (0.04) | 119 |
| 16 | N/A | N/A | N/A | N/A |

#### *4.3.1.2 Submeasure B: Envelope – Roof/Ceiling Insulation*

Energy savings and peak demand reductions per unit are presented in Table 45 and Table 46 for new construction buildings. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. Per-unit electricity use for the first year are expected to range between an increase of 149 to a decrease of 18 kWh/yr and natural gas use to range between an increase of 3.71 to a decrease of 0.84 therms/yr depending upon prototype building and climate zone. Demand changes are expected to range between an increase of 0.07 kW and decrease of 0.04 kW depending prototype building and climate zone.

Increased energy used are expected in some climate zones due to the proposed U-factors equivalent to high-rise wood-framed roofs being applied to low-rise flat roofs for unification purposes.

### Table 45: First-Year Energy Impacts Per Dwelling Unit– Roof/Ceiling Insulation, 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 | (0.42) | 0.04 | (0.62) | (250) |
| 2 | 1.48 | 0.04 | 0.09 | (29) |
| 3 | (1.20) | 0.04 | (0.21) | (422) |
| 4 | (1.12) | 0.03 | 0.51 | (317) |
| 5 | (0.83) | 0.03 | (0.37) | (230) |
| 6 | (8.73) | 0.02 | (0.07) | (557) |
| 7 | (10.27) | 0.02 | (0.23) | (730) |
| 8 | 5.84 | 0.04 | 0.06 | 461 |
| 9 | 3.42 | 0.03 | 0.25 | 221 |
| 10 | 5.03 | 0.03 | 0.27 | 125 |
| 11 | 4.47 | 0.04 | (0.68) | 250 |
| 12 | 3.02 | 0.04 | (0.76) | (86) |
| 13 | (88.83) | (0.02) | 0.84 | (3,379) |
| 14 | (11.30) | 0.03 | (0.19) | (374) |
| 15 | (149.13) | (0.03) | 0.18 | (5,366) |
| 16 | 0.72 | 0.04 | (0.73) | (240) |

### Table 46: First-Year Energy Impacts Per Dwelling Unit– Roof/Ceiling Insulation, 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 | (6.11) | 0.00 | (3.06) | (1,256) |
| 2 | 5.17 | 0.00 | (1.78) | (133) |
| 3 | (3.34) | (0.00) | (0.89) | (489) |
| 4 | 2.32 | (0.00) | (0.60) | (389) |
| 5 | (4.47) | (0.00) | (0.99) | (544) |
| 6 | (9.02) | (0.01) | (0.19) | (367) |
| 7 | (11.79) | (0.02) | (0.08) | (589) |
| 8 | 16.33 | 0.00 | (0.11) | 1111 |
| 9 | 11.92 | 0.00 | (0.21) | 533 |
| 10 | 18.04 | 0.01 | (0.44) | 489 |
| 11 | 13.37 | (0.01) | (1.96) | 300 |
| 12 | 13.25 | 0.00 | (2.05) | 11 |
| 13 | (76.93) | (0.05) | (1.12) | (3,489) |
| 14 | (6.37) | (0.00) | (1.64) | (500) |
| 15 | (138.90) | (0.07) | (0.03) | (4,778) |
| 16 | (2.51) | (0.00) | (3.71) | (1,411) |

#### 4.3.1.3 Submeasure C1: Envelope – Wall U-Factor

Energy savings and peak demand reductions per unit are presented in Table 47 through Table 50 from new construction 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 high-rise wood-framed requirements, 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 residential requirements, five-story prototype
- Framed, high fire rating (two- and three-hr) in high-rise: from adhering to residential to high-rise wood-framed requirements, five-story and ten-story prototype (increased energy use)

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

In Table 47, 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 reductions are expected.

**Table 47: 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 |

In Table 48, per-unit savings for the first year are expected to range from 8.61 to 16.19 kWh/yr and 1.42 to 4.57 therms/yr depending upon climate zone. There are no demand reductions expected.

**Table 48: 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 | 8.80 | (0.00) | 4.57 | 1,366 |
| 2 | 15.17 | 0.00 | 3.67 | 1,340 |
| 3 | 8.61 | (0.00) | 2.91 | 892 |
| 4 | 9.86 | (0.00) | 2.37 | 900 |
| 5 | 10.67 | (0.00) | 3.14 | 935 |
| 6 | N/A | N/A | N/A | N/A |
| 7 | N/A | N/A | N/A | N/A |
| 8 | 9.24 | (0.00) | 1.42 | 629 |
| 9 | 10.22 | 0.00 | 1.62 | 704 |
| 10 | 12.77 | 0.00 | 1.89 | 798 |
| 11 | N/A | N/A | N/A | N/A |
| 12 | 15.42 | 0.00 | 3.21 | 1,353 |
| 13 | 16.19 | 0.00 | 2.22 | 1,056 |
| 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 |

In Table 49 and Table 50, per-unit electricity use for the first year are expected to range from an increase of 39.86 to a decrease of 0.52 kWh/yr and natural gas use to increase between 0.4 to 8.39 therms/yr depending upon prototype building and climate zone. Demand increases are expected to range between 0 kW and 0.02 kW depending on prototype building and climate zone. Increased energy used are expected for results in Table 49 and Table 50 due to the proposed U-factors equivalent to high-rise wood-framed roofs being applied to low-rise flat roofs for unification purposes.

**Table 49: First-Year Energy Impacts Per Dwelling Unit– Framed, High and Low 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 | 0.00 | (0.00) | (0.55) | (188) |
| 7 | 0.47 | (0.00) | (0.47) | (144) |
| 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 | (16.77) | (0.01) | (3.02) | (1,596) |
| 12 | N/A | N/A | N/A | N/A |
| 13 | N/A | N/A | N/A | N/A |
| 14 | (15.72) | (0.01) | (3.07) | (1,543) |
| 15 | (24.80) | (0.01) | (0.94) | (1,276) |
| 16 | (11.89) | (0.01) | (5.05) | (1,663) |

**Table 50: First-Year Energy Impacts Per Dwelling Unit– Framed, High and Low 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 | (0.03) | (0.00) | (0.50) | (171) |
| 7 | 0.52 | (0.00) | (0.40) | (123) |
| 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 | (29.48) | (0.02) | (5.38) | (2,661) |
| 12 | N/A | N/A | N/A | N/A |
| 13 | N/A | N/A | N/A | N/A |
| 14 | (30.07) | (0.01) | (5.79) | (2,740) |
| 15 | (39.86) | (0.02) | (1.96) | (2,055) |
| 16 | (21.32) | (0.01) | (8.39) | (2,732) |

#### *4.3.1.4 Submeasure C2: Envelope – Quality Insulation Installation*

Energy use and peak demand changes per unit for the 5-story and 3-story prototypes are presented in Table 51 and Table 52. As shown, the scenario, per-unit savings for the first year are expected to range from an increase of 45.43 kWh/yr to a decrease of 30.85 kWh/yr and natural gas use to increase from 4.92 to decrease of 6.47 therms/yr depending upon climate zone. Demand reduction impacts are negligible. Energy Savings levels vary by climate zones. 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 51: 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 52: 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) |

#### 4.3.1.5 Submeasure D: Envelope – Fenestration Properties

Energy savings and peak demand reductions per unit are presented Table 53 through Table 59 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
  - A combined category *All Others* for Fixed, Operable Fenestrations, and Glazed Doors: 5-story and 10-story prototypes
- Alterations:
  - Curtainwall/storefronts: high rise existing prototype
  - Combined fixed, operable, and glazed doors: high rise existing prototype

In Table 53 and Table 54 for curtainwall windows in new construction, per-unit electricity use for the first year are expected to range between an increase of 62.92 kWh/yr to a savings of 0.65 kWh/yr and natural gas savings from 0.74 to 17.05 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 53: 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 | (25.23) | (0.02) | 12.13 | 2,437 |
| 2 | (2.92) | (0.00) | 3.11 | 827 |
| 3 | (4.65) | (0.00) | 2.78 | 640 |
| 4 | (6.01) | (0.00) | 2.00 | 492 |
| 5 | (5.91) | (0.00) | 2.59 | 528 |
| 6 | (10.75) | (0.00) | 1.16 | 88 |
| 7 | (11.27) | (0.00) | 0.97 | 4 |
| 8 | (9.18) | 0.00 | 1.10 | 134 |
| 9 | (7.84) | 0.00 | 1.33 | 263 |
| 10 | (6.10) | 0.00 | 1.51 | 354 |
| 11 | (0.72) | 0.00 | 2.70 | 893 |
| 12 | (3.49) | 0.00 | 2.53 | 724 |
| 13 | (1.52) | 0.00 | 2.04 | 692 |
| 14 | (1.77) | 0.00 | 2.61 | 806 |
| 15 | 0.65 | 0.00 | 0.74 | 421 |
| 16 | (1.16) | (0.00) | 4.80 | 1,287 |

**Table 54: 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 | (62.92) | (0.02) | 17.05 | 2,763.62 |
| 2 | (9.96) | (0.00) | 5.14 | 1,195.59 |
| 3 | (12.29) | (0.00) | 4.57 | 910.49 |
| 4 | (14.82) | (0.00) | 3.30 | 649.83 |
| 5 | (13.09) | (0.00) | 4.32 | 780.70 |
| 6 | (20.59) | (0.00) | 1.93 | 61.20 |
| 7 | (19.50) | (0.00) | 1.69 | (5.36) |
| 8 | (18.52) | (0.00) | 1.84 | 92.07 |
| 9 | (16.56) | (0.00) | 2.23 | 324.11 |
| 10 | (13.89) | 0.00 | 2.51 | 475.88 |
| 11 | (7.73) | 0.00 | 4.42 | 1,251.11 |
| 12 | (12.21) | (0.00) | 4.15 | 990.77 |
| 13 | (9.21) | 0.00 | 3.31 | 927.75 |
| 14 | (8.47) | 0.00 | 4.30 | 1,166.54 |
| 15 | (3.65) | 0.01 | 1.23 | 569.34 |
| 16 | (9.94) | (0.00) | 7.73 | 1836.52 |

In Table 55 and Table 56 for the combined all-others window category in new construction, per-unit electricity use for the first year are expected to range from an increase of 106.26 to a decrease of 48.88 kWh/yr and natural gas use savings from 2.37 to 35.85 therms/yr depending upon prototype building and climate zone. Demand charges are expected to range between an increase of 0.04 kW to a decrease of 0.02 kW depending on prototype building and climate zone.

**Table 55: 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 | (22.52) | (0.02) | 25.05 | 5,781 |
| 2 | 11.31 | (0.00) | 9.93 | 3,044 |
| 3 | (92.68) | (0.03) | 13.51 | 974 |
| 4 | 2.57 | (0.00) | 6.41 | 2029 |
| 5 | (106.26) | (0.03) | 12.57 | 613 |
| 6 | (10.98) | (0.00) | 3.74 | 774 |
| 7 | (15.33) | (0.00) | 3.14 | 430 |
| 8 | (3.89) | (0.00) | 3.56 | 1,059 |
| 9 | (0.27) | 0.00 | 4.27 | 1,390 |
| 10 | 6.43 | 0.00 | 4.85 | 1,699 |
| 11 | 22.08 | 0.01 | 8.66 | 3,327 |
| 12 | 12.19 | 0.00 | 8.13 | 2,780 |
| 13 | 21.13 | 0.01 | 6.52 | 2,735 |
| 14 | 18.49 | 0.01 | 8.24 | 3,081 |
| 15 | 34.66 | 0.01 | 2.37 | 2,068 |
| 16 | 13.45 | (0.00) | 15.25 | 4,460 |

**Table 56: 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 | (80.99) | (0.04) | 35.85 | 7,065 |
| 2 | 8.26 | (0.00) | 16.01 | 4,672 |
| 3 | (7.11) | (0.01) | 14.04 | 3,502 |
| 4 | (5.03) | (0.00) | 10.25 | 3,028 |
| 5 | (8.48) | (0.01) | 13.26 | 3,058 |
| 6 | (25.41) | (0.00) | 5.98 | 1,074 |
| 7 | (29.01) | (0.01) | 5.16 | 632 |
| 8 | (13.83) | 0.00 | 5.70 | 1,525 |
| 9 | (8.21) | 0.00 | 6.85 | 2,062 |
| 10 | 1.99 | 0.01 | 7.77 | 2,552 |
| 11 | 26.79 | 0.01 | 14.13 | 5,164 |
| 12 | 8.99 | 0.00 | 13.12 | 4,229 |
| 13 | 24.09 | 0.01 | 10.46 | 4,150 |
| 14 | 19.97 | 0.01 | 13.38 | 4,730 |
| 15 | 48.88 | 0.02 | 3.80 | 3,159 |
| 16 | 5.21 | (0.01) | 24.23 | 6,575 |

For window alterations, the proposed measure achieves energy savings in high rise buildings for either curtainwall/storefront, or other windows (manufactured or site built). In low-rise buildings, the proposed unified multifamily requirements are less stringent than current code leading to energy losses.

In Table 57, representing curtain wall window replacements in high rise buildings, per-unit electricity savings for the first year are expected to range from 19.91 to 327.31 kWh/yr and natural gas use savings from 3.71 to 16.46 therms/yr depending upon prototype building and climate zone. Demand changes are expected to range between a decrease of 0 kW and 0.06 kW depending on prototype building and climate zone.

**Table 57: 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 | 94.69 | 0.01 | 10.73 | 4,863 |
| 2 | 39.40 | 0.01 | 11.82 | 4,687 |
| 3 | 281.67 | 0.04 | 16.46 | 11,431 |
| 4 | 35.39 | 0.01 | 8.38 | 3,875 |
| 5 | 314.56 | 0.03 | 15.90 | 11,060 |
| 6 | 26.24 | 0.00 | 5.51 | 2,306 |
| 7 | 19.91 | 0.00 | 4.76 | 1,767 |
| 8 | 32.97 | 0.01 | 5.36 | 2,711 |
| 9 | 42.11 | 0.01 | 6.14 | 3,395 |
| 10 | 52.77 | 0.02 | 6.55 | 3,725 |
| 11 | 60.00 | 0.03 | 9.65 | 5,295 |
| 12 | 42.91 | 0.02 | 9.78 | 4,585 |
| 13 | 57.28 | 0.03 | 7.56 | 4,721 |
| 14 | 71.79 | 0.02 | 9.10 | 5,294 |
| 15 | 110.19 | 0.04 | 3.71 | 5,208 |
| 16 | 327.31 | 0.06 | 4.12 | 8,455 |

Table 58, representing window replacements of manufactured or site built glazing in high rise buildings, per-unit electricity savings for the first year are expected to range from 69.01 to 379.81 kWh/yr and natural gas use savings from 5.16 to 20.51 therms/yr depending upon prototype building and climate zone. Demand changes are expected to range between a decrease of 0.01 kW and 0.07 kW depending on prototype building and climate zone.

**Table 58: First-Year Energy Impacts Per Dwelling Unit – Combined Fixed, Operable, and Glazed Doors, 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 | 94.10 | 0.01 | 19.48 | 7,081 |
| 2 | 96.51 | 0.02 | 16.39 | 7,557 |
| 3 | 328.04 | 0.04 | 20.51 | 13,651 |
| 4 | 93.56 | 0.02 | 11.57 | 6,505 |
| 5 | 366.21 | 0.04 | 19.81 | 13,183 |
| 6 | 83.23 | 0.01 | 7.63 | 4,311 |
| 7 | 69.01 | 0.01 | 6.52 | 3,352 |
| 8 | 97.14 | 0.02 | 7.45 | 5,169 |
| 9 | 109.54 | 0.02 | 8.46 | 6,006 |
| 10 | 126.27 | 0.03 | 9.04 | 6,463 |
| 11 | 135.05 | 0.05 | 13.48 | 8,659 |
| 12 | 107.93 | 0.03 | 13.60 | 7,560 |
| 13 | 133.90 | 0.05 | 10.43 | 7,885 |
| 14 | 152.05 | 0.04 | 12.47 | 8,638 |
| 15 | 222.32 | 0.06 | 5.16 | 8,952 |
| 16 | 379.81 | 0.07 | 9.61 | 11,117 |

In Table 59, representing window replacements of manufactured or site built glazing in low rise buildings, per-unit electricity use for the first year are expected to range from an increase of 6.56 to a decrease in 13.91 kWh/yr and natural gas use from an increase of 0.64 to 8.41 therms/yr depending upon prototype building and climate zone. Demand changes are expected to range between an increase of 0.01 kW to a decrease of 0.01 kW depending on prototype building and climate zone.

**Table 59: First-Year Energy Impacts Per Dwelling Unit – Combined Fixed, Operable, and Glazed Doors, 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 | (5.31) | 0.00 | (8.04) | (3,130) |
| 2 | 0.17 | 0.00 | (4.59) | (1,651) |
| 3 | (0.87) | 0.00 | (3.16) | (1,171) |
| 4 | 4.51 | 0.01 | (2.88) | (931) |
| 5 | (0.84) | 0.00 | (3.22) | (1,181) |
| 6 | 6.16 | 0.01 | (1.27) | (182) |
| 7 | 6.88 | 0.01 | (0.80) | 67.20 |
| 8 | 13.91 | 0.01 | (1.09) | (77) |
| 9 | 10.91 | 0.01 | (1.66) | (442) |
| 10 | 8.79 | 0.00 | (2.13) | (739) |
| 11 | 0.97 | 0.00 | (4.10) | (1,910) |
| 12 | 4.89 | 0.01 | (3.75) | (1,440) |
| 13 | 0.40 | (0.00) | (2.92) | (1,277) |
| 14 | 1.20 | (0.00) | (4.64) | (1,891) |
| 15 | (6.56) | (0.01) | (0.64) | (758) |
| 16 | 2.83 | 0.01 | (8.41) | (3,110) |

#### *4.3.1.6 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*

These two submeasures are not increasing stringency but do result in reduced stringency in certain situations. The energy and peak demand impacts per unit are presented in Table 60 through Table 61.

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 were evaluated using the three-story loaded corridor prototype in CBECC-Res and presented per dwelling unit in Table 60. The energy impacts will be similar for both the five-story and ten-story mixed use prototypes as the average dwelling unit size across all three prototypes is very similar. Per-unit increase in energy use for the first year are expected to range from 2 to 16 kWh/yr and 0 to 1 therms/yr depending upon climate zone. Demand increases are expected to range between 0 kW and 0.015 kW depending on climate zone.

Table 61 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 1.5 therms/yr depending upon climate zone. Demand increases are expected to range between 0 kW and 0.007 kW depending on climate zone.

**Table 60: First-Year Energy Impacts Per Dwelling Unit – Three-Story Loaded Corridor Prototype Building – 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 | (12) | (0.011) | (0.3) | (636) |
| 12 | (8) | (0.007) | (0.2) | (515) |
| 13 | (11) | (0.009) | (0.2) | (575) |
| 14 | (13) | (0.011) | (0.2) | (649) |
| 15 | (16) | (0.011) | 0.0 | (612) |
| 16 | (12) | (0.007) | (0.8) | (610) |

**Table 61: 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 reductions per unit are presented in Table 62 through Table 63 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 2 to 30 kWh/yr depending upon climate zone. Demand reductions/increases are expected to range between 0.001 kW and 0.009 kW depending on climate zone.

Impacts on natural gas use are estimated to be negligible. This is a result of the limitation of the energy modeling approach (see Section 4.2.1.2) which does not accurately account for the losses of conditioning air that is never delivered to the dwelling unit. It is expected that actual savings will be higher than what is presented here.

**Table 62: First-Year Energy Impacts Per Dwelling Unit – Five-Story Mixed-Use Prototype Building – 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 | 2 | 0.002 | 0.001 | 57 |
| 2 | 13 | 0.005 | (0.003) | 492 |
| 3 | 9 | 0.003 | (0.003) | 348 |
| 4 | 17 | 0.006 | 0.002 | 660 |
| 5 | 10 | 0.003 | (0.002) | 280 |
| 6 | 17 | 0.005 | (0.002) | 539 |
| 7 | 16 | 0.005 | 0.001 | 481 |
| 8 | 21 | 0.006 | (0.003) | 712 |
| 9 | 20 | 0.007 | 0.001 | 698 |
| 10 | 22 | 0.008 | 0.006 | 761 |
| 11 | 20 | 0.007 | (0.014) | 632 |
| 12 | 19 | 0.007 | 0.007 | 723 |
| 13 | 27 | 0.009 | (0.002) | 960 |
| 14 | 16 | 0.006 | (0.006) | 528 |
| 15 | 30 | 0.008 | 0.000 | 906 |
| 16 | 10 | 0.004 | 0.000 | 273 |

**Table 63: First-Year Energy Impacts Per Dwelling Unit – 10-Story Mixed-Use Prototype Building – 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 | 3 | 0.001 | (0.004) | 68 |
| 2 | 12 | 0.005 | (0.006) | 442 |
| 3 | 9 | 0.003 | (0.002) | 345 |
| 4 | 16 | 0.006 | 0.001 | 599 |
| 5 | 10 | 0.003 | (0.002) | 284 |
| 6 | 17 | 0.005 | 0.000 | 522 |
| 7 | 16 | 0.005 | (0.001) | 479 |
| 8 | 20 | 0.006 | (0.001) | 652 |
| 9 | 18 | 0.006 | (0.001) | 620 |
| 10 | 20 | 0.007 | (0.002) | 674 |
| 11 | 18 | 0.006 | (0.004) | 555 |
| 12 | 17 | 0.006 | (0.003) | 635 |
| 13 | 24 | 0.007 | (0.003) | 847 |
| 14 | 14 | 0.005 | 0.000 | 451 |
| 15 | 25 | 0.006 | 0.000 | 745 |
| 16 | 9 | 0.004 | (0.003) | 241 |

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

Energy savings and peak demand reductions per unit are presented in Table 64 through Table 65 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 74 to 274 kWh/yr depending on climate zone. Per-unit gas use is expected to increase from one to five therms/yr depending upon climate zone. Demand reductions/increases are expected to range between 0.009 kW and 0.071 kW depending on climate zone.

There are 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 energy use which subsequently increases heating energy use.

**Table 64: First-Year Energy Impacts Per Dwelling Unit – Five-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 | 74 | 0.009 | (3.4) | 1,336 |
| 2 | 134 | 0.034 | (2.9) | 4,115 |
| 3 | 95 | 0.020 | (2.3) | 2,774 |
| 4 | 141 | 0.041 | (1.9) | 4,760 |
| 5 | 98 | 0.019 | (2.0) | 2,333 |
| 6 | 138 | 0.035 | (1.1) | 4,039 |
| 7 | 124 | 0.032 | (0.8) | 3,511 |
| 8 | 165 | 0.045 | (1.0) | 5,253 |
| 9 | 164 | 0.048 | (1.2) | 5,285 |
| 10 | 185 | 0.055 | (1.5) | 5,701 |
| 11 | 199 | 0.060 | (2.8) | 6,030 |
| 12 | 173 | 0.050 | (2.8) | 5,496 |
| 13 | 224 | 0.065 | (2.3) | 7,134 |
| 14 | 187 | 0.051 | (2.4) | 5,666 |
| 15 | 274 | 0.071 | (0.7) | 8,471 |
| 16 | 159 | 0.032 | (4.7) | 3,616 |

Table 65: 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 | 75 | 0.009 | (3.3) | 1,340 |
| 2 | 127 | 0.031 | (2.8) | 3,709 |
| 3 | 95 | 0.019 | (2.1) | 2,709 |
| 4 | 134 | 0.038 | (1.8) | 4,298 |
| 5 | 96 | 0.018 | (1.9) | 2,348 |
| 6 | 135 | 0.033 | (1.0) | 3,893 |
| 7 | 126 | 0.032 | (0.8) | 3,541 |
| 8 | 155 | 0.040 | (0.9) | 4,784 |
| 9 | 153 | 0.041 | (1.1) | 4,738 |
| 10 | 169 | 0.047 | (1.4) | 5,085 |
| 11 | 186 | 0.051 | (2.9) | 5,339 |
| 12 | 158 | 0.043 | (2.6) | 4,796 |
| 13 | 199 | 0.053 | (2.2) | 6,127 |
| 14 | 174 | 0.044 | (2.4) | 5,041 |
| 15 | 232 | 0.055 | (0.7) | 6,958 |
| 16 | 149 | 0.029 | (4.2) | 3,285 |

#### *4.3.2.4 Submeasure I: Space Conditioning – Refrigerant Charge Verification*

Energy savings and peak demand reductions per unit are presented in Table 66 through Table 67 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 1 to 99 kWh/yr depending upon climate zone. There are no natural gas savings for this submeasure. Demand reductions/increases are expected to range between 0 kW and 0.028 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.

**Table 66: First-Year Energy Impacts Per Dwelling Unit – 5-Story Mixed-Use Prototype Building – 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 | 4 | 0.003 | 0.0 | 102 |
| 2 | 26 | 0.011 | 0.0 | 1,149 |
| 3 | 17 | 0.006 | 0.0 | 682 |
| 4 | 34 | 0.013 | 0.0 | 1,375 |
| 5 | 19 | 0.006 | 0.0 | 559 |
| 6 | 38 | 0.011 | 0.0 | 1,207 |
| 7 | 35 | 0.010 | 0.0 | 1,068 |
| 8 | 47 | 0.015 | 0.0 | 1,618 |
| 9 | 47 | 0.016 | 0.0 | 1,659 |
| 10 | 52 | 0.017 | 0.0 | 1,752 |
| 11 | 52 | 0.022 | 0.0 | 2,076 |
| 12 | 40 | 0.017 | 0.0 | 1,627 |
| 13 | 60 | 0.023 | 0.0 | 2,290 |
| 14 | 53 | 0.019 | 0.0 | 1,996 |
| 15 | 99 | 0.028 | 0.0 | 3,327 |
| 16 | 25 | 0.011 | 0.0 | 675 |

**Table 67: First-Year Energy Impacts Per Dwelling Unit – 10-Story Mixed-Use Prototype Building – 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 | 0.003 | 0.0 | 137 |
| 2 | 25 | 0.010 | 0.0 | 1,029 |
| 3 | 18 | 0.006 | 0.0 | 688 |
| 4 | 33 | 0.012 | 0.0 | 1,242 |
| 5 | 20 | 0.006 | 0.0 | 600 |
| 6 | 38 | 0.011 | 0.0 | 1,185 |
| 7 | 36 | 0.010 | 0.0 | 1,102 |
| 8 | 45 | 0.013 | 0.0 | 1,487 |
| 9 | 44 | 0.013 | 0.0 | 1,492 |
| 10 | 48 | 0.015 | 0.0 | 1,565 |
| 11 | 47 | 0.018 | 0.0 | 1,792 |
| 12 | 36 | 0.014 | 0.0 | 1,401 |
| 13 | 53 | 0.018 | 0.0 | 1,936 |
| 14 | 49 | 0.016 | 0.0 | 1,766 |
| 15 | 83 | 0.021 | 0.0 | 2,711 |
| 16 | 1 | 0.000 | 0.0 | 17 |

# 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.

Two of the submeasures, Roof Products and Fenestration Properties, are applicable to additions and alterations. For roof products, the per-unit energy cost savings for new construction apply to additions and alterations as well. For Fenestration Properties, the alterations proposal differs from new construction requirements, and 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 68 through Table 81. Per-unit energy cost savings results in nominal collars are presented in Appendix H.

#### 5.1.2.1 Submeasure A: Envelope – Roof Products

**Table 68: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction – Low-Slope Increase to 0.55 ASR, 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 | 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 | $332.16 | ($46.50) | $285.66 |
| 10 | $332.16 | ($59.79) | $272.37 |
| 11 | $386.97 | ($76.40) | $310.57 |
| 12 | N/A | N/A | N/A |
| 13 | N/A | N/A | N/A |
| 14 | $343.79 | ($119.58) | $224.21 |
| 15 | N/A | N/A | N/A |
| 16 | N/A | N/A | N/A |

### Table 69: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction – Low-Slope Increase to 0.55 ASR, 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$) |
|---|---|---|---|
| 4 | 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 | $259.50 | ($11.53) | $247.97 |
| 10 | $276.80 | ($17.30) | $259.50 |
| 11 | $296.02 | ($24.99) | $271.03 |
| 12 | N/A | N/A | N/A |
| 13 | N/A | N/A | N/A |
| 14 | $249.89 | ($40.37) | $209.52 |
| 15 | N/A | N/A | N/A |
| 16 | N/A | N/A | N/A |

### Table 70: 2023 PV 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 (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 | 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 | $44.91 | ($11.76) | $33.15 |
| 14 | N/A | N/A | N/A |
| 15 | $56.48 | ($4.74) | $51.74 |
| 16 | N/A | N/A | N/A |

**Table 71: 2023 PV 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 (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 | 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 | $18.54 | ($4.39) | $14.15 |
| 14 | N/A | N/A | N/A |
| 15 | $22.44 | ($1.93) | $20.51 |
| 16 | N/A | N/A | N/A |

### 5.1.2.2 Submeasure B: Envelope – Roof/Ceiling Insulation

**Table 72: 2023 PV 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 (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 1 | ($3.32) | ($39.86) | ($43.18) |
| 2 | ($9.96) | $4.98 | ($4.98) |
| 3 | ($58.13) | ($14.95) | ($73.08) |
| 4 | ($86.36) | $31.56 | ($54.81) |
| 5 | ($14.95) | ($24.91) | ($39.86) |
| 6 | ($93.00) | ($3.32) | ($96.33) |
| 7 | ($111.27) | ($14.95) | ($126.22) |
| 8 | $76.40 | $3.32 | $79.72 |
| 9 | $21.59 | $16.61 | $38.20 |
| 10 | $4.98 | $16.61 | $21.59 |
| 11 | $86.36 | ($43.18) | $43.18 |
| 12 | $34.88 | ($49.82) | ($14.95) |
| 13 | ($637.75) | $53.15 | ($584.60) |
| 14 | ($53.15) | ($11.63) | ($64.77) |
| 15 | ($940.01) | $11.63 | ($928.39) |
| 16 | $3.32 | ($44.84) | ($41.52) |

**Table 73: 2023 PV 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 (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 1 | ($32.68) | ($184.53) | ($217.21) |
| 2 | $86.50 | ($109.57) | ($23.07) |
| 3 | ($28.83) | ($55.74) | ($84.58) |
| 4 | ($30.76) | ($36.52) | ($67.28) |
| 5 | ($32.68) | ($61.51) | ($94.19) |
| 6 | ($51.90) | ($11.53) | ($63.43) |
| 7 | ($98.03) | ($3.84) | ($101.88) |
| 8 | $197.99 | ($5.77) | $192.22 |
| 9 | $105.72 | ($13.46) | $92.27 |
| 10 | $113.41 | ($28.83) | $84.58 |
| 11 | $173.00 | ($121.10) | $51.90 |
| 12 | $128.79 | ($126.87) | $1.92 |
| 13 | ($534.38) | ($69.20) | ($603.58) |
| 14 | $15.38 | ($101.88) | ($86.50) |
| 15 | ($824.63) | ($1.92) | ($826.56) |
| 16 | ($32.68) | ($184.53) | ($217.21) |

#### 5.1.2.3 Submeasure C1: Envelope – Wall U-Factor

**Table 74: 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 | $42.25 | $194.13 | $236.37 |
| 2 | $73.15 | $158.60 | $231.75 |
| 3 | $27.79 | $126.45 | $154.24 |
| 4 | $50.47 | $105.28 | $155.75 |
| 5 | $26.01 | $135.72 | $161.73 |
| 6 | N/A | N/A | N/A |
| 7 | N/A | N/A | N/A |
| 8 | $43.13 | $65.72 | $108.86 |
| 9 | $47.58 | $74.26 | $121.84 |
| 10 | $51.58 | $86.54 | $138.12 |
| 11 | N/A | N/A | N/A |
| 12 | $91.16 | $142.97 | $234.13 |
| 13 | $82.05 | $100.70 | $182.74 |
| 14 | N/A | N/A | N/A |
| 15 | N/A | N/A | N/A |
| 16 | N/A | N/A | N/A |

### 5.1.2.4 Submeasure C2: Envelope – Quality Insulation Installation

**Table 75: 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 |

### 5.1.2.5 Submeasure D: Envelope – Fenestration Properties

**Table 76: 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 | ($88.05) | $509.61 | $421.56 |
| 2 | $6.45 | $136.59 | $143.03 |
| 3 | ($10.67) | $121.31 | $110.64 |
| 4 | ($4.45) | $89.54 | $85.09 |
| 5 | ($21.35) | $112.71 | $91.36 |
| 6 | ($37.80) | $52.94 | $15.14 |
| 7 | ($44.25) | $44.96 | $0.71 |
| 8 | ($27.79) | $50.94 | $23.15 |
| 9 | ($15.56) | $61.06 | $45.49 |
| 10 | ($8.23) | $69.39 | $61.17 |
| 11 | $31.35 | $123.20 | $154.55 |
| 12 | $11.56 | $113.77 | $125.34 |
| 13 | $26.46 | $93.32 | $119.78 |
| 14 | $20.01 | $119.38 | $139.39 |
| 15 | $38.02 | $34.82 | $72.84 |
| 16 | $8.67 | $213.92 | $222.59 |

**Table 77: 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 | ($237.52) | $715.63 | $478.11 |
| 2 | ($17.61) | $224.45 | $206.84 |
| 3 | ($40.98) | $198.49 | $157.51 |
| 4 | ($34.30) | $146.72 | $112.42 |
| 5 | ($51.73) | $186.79 | $135.06 |
| 6 | ($77.88) | $88.46 | $10.59 |
| 7 | ($78.99) | $78.06 | ($0.93) |
| 8 | ($68.98) | $84.90 | $15.93 |
| 9 | ($46.17) | $102.24 | $56.07 |
| 10 | ($33.38) | $115.70 | $82.33 |
| 11 | $15.76 | $200.68 | $216.44 |
| 12 | ($14.46) | $185.87 | $171.40 |
| 13 | $9.64 | $150.86 | $160.50 |
| 14 | $6.12 | $195.69 | $201.81 |
| 15 | $40.61 | $57.89 | $98.50 |
| 16 | ($24.66) | $342.38 | $317.72 |

**Table 78: 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 | ($59.37) | $1,059.43 | $1,000.06 |
| 2 | $90.72 | $435.95 | $526.67 |
| 3 | ($422.45) | $590.97 | $168.51 |
| 4 | $64.26 | $286.80 | $351.06 |
| 5 | ($441.58) | $547.66 | $106.08 |
| 6 | ($37.35) | $171.27 | $133.92 |
| 7 | ($70.93) | $145.37 | $74.44 |
| 8 | $18.45 | $164.71 | $183.17 |
| 9 | $44.69 | $195.84 | $240.53 |
| 10 | $70.26 | $223.61 | $293.87 |
| 11 | $180.54 | $394.97 | $575.52 |
| 12 | $116.06 | $364.96 | $481.02 |
| 13 | $174.98 | $298.16 | $473.15 |
| 14 | $155.20 | $377.74 | $532.94 |
| 15 | $246.14 | $111.55 | $357.69 |
| 16 | $90.05 | $681.46 | $771.51 |

**Table 79: 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 | ($297.60) | $1,519.76 | $1,222.16 |
| 2 | $106.06 | $702.22 | $808.29 |
| 3 | ($7.60) | $613.43 | $605.82 |
| 4 | $65.82 | $458.10 | $523.92 |
| 5 | ($47.10) | $576.12 | $529.02 |
| 6 | ($88.82) | $274.61 | $185.79 |
| 7 | ($129.98) | $239.32 | $109.34 |
| 8 | ($0.37) | $264.24 | $263.87 |
| 9 | $42.09 | $314.71 | $356.80 |
| 10 | $82.70 | $358.71 | $441.41 |
| 11 | $249.95 | $643.39 | $893.34 |
| 12 | $142.59 | $588.99 | $731.58 |
| 13 | $240.12 | $477.85 | $717.97 |
| 14 | $207.49 | $610.81 | $818.30 |
| 15 | $367.13 | $179.34 | $546.47 |
| 16 | $58.78 | $1,078.74 | $1,137.52 |

**Table 80: 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 | $380.11 | $461.16 | $841.27 |
| 2 | $304.46 | $506.36 | $810.83 |
| 3 | $1,275.14 | $702.45 | $1,977.58 |
| 4 | $305.57 | $364.87 | $670.44 |
| 5 | $1,237.68 | $675.67 | $1,913.35 |
| 6 | $152.97 | $245.96 | $398.93 |
| 7 | $90.30 | $215.38 | $305.68 |
| 8 | $227.14 | $241.92 | $469.06 |
| 9 | $312.43 | $274.83 | $587.26 |
| 10 | $350.44 | $294.02 | $644.47 |
| 11 | $485.43 | $430.60 | $916.03 |
| 12 | $365.28 | $427.88 | $793.15 |
| 13 | $477.27 | $339.50 | $816.78 |
| 14 | $508.79 | $407.00 | $915.79 |
| 15 | $727.78 | $173.24 | $901.01 |
| 16 | $1,277.18 | $185.55 | $1,462.73 |

**Table 81: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– Alterations - Combined Fixed, Operable, Glazed Doors Category, 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 | $394.20 | $830.76 | $1,224.96 |
| 2 | $604.66 | $702.78 | $1,307.44 |
| 3 | $1,485.40 | $876.17 | $2,361.57 |
| 4 | $621.16 | $504.14 | $1,125.30 |
| 5 | $1,438.31 | $842.33 | $2,280.64 |
| 6 | $405.14 | $340.65 | $745.80 |
| 7 | $284.44 | $295.54 | $579.98 |
| 8 | $557.74 | $336.56 | $894.30 |
| 9 | $660.10 | $378.91 | $1,039.00 |
| 10 | $712.57 | $405.59 | $1,118.16 |
| 11 | $895.95 | $602.06 | $1,498.01 |
| 12 | $712.76 | $595.20 | $1,307.96 |
| 13 | $895.58 | $468.50 | $1,364.08 |
| 14 | $936.56 | $557.80 | $1,494.36 |
| 15 | $1,307.40 | $241.29 | $1,548.69 |
| 16 | $1,495.05 | $428.19 | $1,923.24 |

#### *5.1.2.6 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 Products*

The Statewide CASE Team assessed the roof product proposal's incremental costs 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 (California Codes and Standards Enhancement (CASE) initiative 2020)proposal indicate that installation costs of the same type of roofing were the same regardless of the reflective level of the products. Interviews with the Metal Buildings Manufacturers Association and CWI Commercial Roofing & Waterproofing further confirmed that installation costs do not vary between cases of new construction and alterations.

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. The Statewide CASE Team collected and compared installed costs, material and labor cost, for *asphalt roll one-ply* installation (0.10 ASR) to be \$2.52 per ft$^2$ and *TPO single-ply Tan* installation (0.61 ASR) to be \$1.90. Because the installed costs for the higher performing and market-prevalent roof products also has low costs, there are no incremental costs for raising the ASR from 0.10 to 0.55. Nonetheless the Statewide CASE Team introduced a conservative \$.10 per ft$^2$ for the cost-effectiveness analyses.

Raising the ASR level from 0.55 to 0.63 involves choosing TPO roof 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.

#### *5.1.3.2 Submeasure B: Envelope – Roof/Ceiling Insulation*

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

#### *5.1.3.3 Submeasure C1: 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 Statewide CASE Team derived cost estimates for baseline and proposed wall assemblies using cost data from RS Means Online (Means 2020). Specific baseline and proposed assembly details relied upon previous CASE wall assemblies, technical limits for exterior continuous insulation, compatible Underwriters' Laboratories (UL)-published fire-rated assemblies and similar construction techniques in terms of constructability and market readiness. The resulting prototype assemblies are created using readily available components and materials, they meet the U-factor requirements, and adhere to UL-published specifications to meet the required minimum fire-resistance rating for each given scenario.

The Statewide CASE Team used the assembly details to determine the appropriate component and costs per ft$^2$ of wall construction. All assembly component costs included materials, labor, and industry standard overhead and profit. The resulting costs were used to calculate cost per ft$^2$ for each prototype assembly. Table 122 displays the incremental cost data. For the purpose of cost-effectiveness calculations, the Statewide CASE Team converted the per $ft^2$ wall assembly incremental measure costs to a per dwelling unit cost based on each prototype's features.

**Table 82: Component and Incremental Measure Costs for Proposed Wall U-Factor, 5-Story Mixed Use Prototype, Low Fire Rating**

| 5-Story Mixed Use<br>Framed construction; Low 0- or 1-hr fire rating | | | |
|---|---|---|---|
| **Prototype ID Proposed Category: Application Scenario** | **Component** | **Product & Technique** | **Cost per $ft^2$** |
| U-factor: 0.059 | Continuous Insulation | R1.45 (EPS ½") | $1.23 |
| | Number of Gypsum Board | 1 | $1.46 |
| | Frame Type | Wood Frame 2x6 16" OC | $2.41 |
| | Cavity Insulation | 16" OC R-21 unfaced | $1.41 |
| | Number of Gypsum Board (interior facing) | 1 | $1.46 |
| | Assembly Cost | | $7.97 |
| U-factor: 0.051 | Continuous Insulation | R4.5 | $2.16 |
| | Number of Gypsum Board | 1 | $1.46 |
| | Frame Type | Wood Frame 2x4 16" OC | $2.41 |
| | Cavity Insulation | 16" OC R-19 unfaced | $1.14 |
| | Number of Gypsum Board (interior facing) | 1 | $1.46 |
| | Assembly Cost | | $8.63 |
| Incremental Cost | | | $0.66 |

#### *5.1.3.4 Submeasure C2: Envelope – Quality Insulation Installation*

The incremental first cost of 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). 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 is 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 83: 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 |

#### 5.1.3.5 Submeasure D: Envelope – Fenestration Properties

Overall window costs are derived 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. Further, the technology improvements that impact thermal properties have intertwined and inconsistent impact window-to-window. The proposed use of an area-weighted blend across fixed and operable window types 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 therefore inherently a blend of fixed and operable window cost. All the aspects combined results in the fact that no one product is appropriately representative of the current baseline or proposed case. Instead, costs must be considered at top-down aggregate level across a range of window products employing various blends of technology improvements.

In order to arrive at incremental cost changes, the Statewide CASE Team leveraged cost data compiled by the ASHRAE 90.1 committee for their 2016 and 2019 updates. This data evaluated the incremental technical improvement cost for 27 specific 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 including the 2011 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.

From the available data, the Statewide CASE Team assessed incremental measures costs following four different methodologies. Because the data was from window-walls only, which have minimal thermal bridging, the Statewide CASE Team shifted ranges of u-factor performance to represent the all-others proposed measure. For example, for the all-others window category the proposal is for a U-factor change from 0.40 to 0.30. The Statewide CASE Team's cost analysis was between a 0.34 U-factor and a 0.24 U-factor window. This represents the same reduction in overall U-factor as for the proposed code change, assuming use of the costliest u-factor impactful aluminum framing but adjusts for the impact of additional framing inherent in the operable and fixed window categories. The same glazing components that achieve 0.34 and 0.24 u-factors in a window-wall, would achieve the respective 0.40 and 0.30 u-factor in an area-weighted blend of fixed, operable, and glazed door fenestration, using Performance Class AW windows, for multifamily properties. The proposed code change in SHGC, from 0.24 to 0.23, will occur as a secondary impact from the same technical measures (principally various low-e coating variations) that produced the u-factor reduction, and therefore add no additional cost. For curtain wall windows in this proposal, the data represents curtainwall window costs directly and therefore the Statewide CASE Team did not need to shift the assessed u-factors.

The four methods were:

- Power function: The Statewide CASE Team plotted each window's u-factor and associated cost in a scatter plot. Using Excel's curve-fit function, the highest correlation matching curve is a power function. Applying the u-factor analysis points of 0.34 and 0.24 along this function yields an incremental cost of $8.68 per $ft^2$ of glazing.
- Market-Minimum: Using the same scatter plot, the Statewide Case team compared the lowest cost product available at each of the assessed data points. This method yields an incremental measure cost of $12.60 per $ft^2$ of glazing for the same u-factor improvement as above.
- Aggregated technical measure costs: This method looked at two specific windows within the dataset, closest related to the targeted analysis points. A 0.36 U-factor, 0.25 SHGC window represents the baseline. A 0.26 U-factor, 0.24 SHGC window represents the improved case. Adding together the costs of each

specific technical features used by the improved window in relation to the baseline yields an incremental measure cost of $6.91 per ft$^2$ of glazing.

In order to calculate a conservative cost-effectiveness for the new construction proposal's all-others window category, the Statewide CASE Team applied the highest incremental cost result from these four methods. The proposed windows requirements are at the lowest end of the spectrum of available data, and near the technical limit for a dual-pane window. There are fewer cost data points from windows that meet the proposed requirements, and no capacity to interpolate costs much beyond the u-factors proposed. Taking the highest incremental cost from the available methods mitigates against the potential for data analysis error.

The Statewide CASE Team separately accounted for cost savings in Climate Zone 1 for moving from a 0.24 SHGC requirement to 0.35 SHGC. The Statewide CASE Team isolated the cost saving associated with the SHGC reduction on products that still meet or exceed the 0.30 u-factor requirement. This showed a $5.07 per ft$^2$ of glazing savings for going from 0.24 to 0.35 SHGC. Combining the $13.38 increase to achieve the improved U-factor and the $5.07 savings from the SHGC requirement relaxation yields a net incremental cost of $7.53 per ft$^2$ of glazing.

For curtain walls, the power function method yielded a cost of $1.25, the market-minimum method yielded a cost of $0.24, and the aggregated technical measure cost yielded a total of $1.00. To be consistent with the nonresidential Statewide CASE Team, the Statewide CASE Team applied a cost of $1.00. For Climate Zone 1, statewide CASE Team did not assess a cost savings relative to the shift from 0.26 to 0.35 for Climate Zone 1.

Due to the uncertainties of this cost-collection method, the Statewide CASE Team also reviewed a data set of 65 different double pane windows from the 2013 Title 24, Part 6 Statewide CASE Team's fenestration research. It was not possible to apply the same formal analysis methodologies due to data limitations (range and quantity of data points). However, review of a similar scatter plot of the available data indicated that the costs represented in the ASHRAE data set were similar to those in the 2013 CASE research set.

Table 84 presents the resultant incremental measure cost for the two proposed area-weighted average windows thermal property reductions.

**Table 84: Incremental Measure Costs for Proposed Fenestration Thermal Properties – New Construction**

| | | Baseline | | Proposed | | |
|---|---|---|---|---|---|---|
| **Window Type** | **Climate Zones** | **U-Factor (maximum)** | **SHGC (maximum)** | **U-Factor (maximum)** | **SHGC (maximum)** | **IMC** |
| Curtainwall | CZ 1 | 0.41 | 0.26 | 0.38 | 0.35 | $1.00 |
| | CZ 2-15 | 0.41 | 0.26 | 0.38 | 0.25 | $1.00 |
| All Other | CZ 1 | 0.40 | 0.24 | 0.30 | 0.35 | $7.53 |
| | CZ 2-15 | 0.40 | 0.24 | 0.30 | 0.23 | $12.60 |

For alterations, the Statewide CASE Team applied a similar method, but assessed incremental costs specific for fixed, and operable windows distinctly, and then used an area-weighted incremental cost average to represent the whole-building fenestration replacement. The u-factor data shift was more pronounced for operable windows than for fixed windows, representing the extra window framing materials used for operable windows. For alterations, 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 due to aesthetic or other functional purposes, and not energy code compliance.

For alterations, the proposed change in SHGC goes beyond what would occur a second order impact from the same u-factor reduction technologies. The Statewide CASE Team create 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 in order to accentuate costs specific to the SHGC change itself, rather than secondary from u-factor improvements. This power function became the basis for the concurrent SHGC shift. It is likely that this method is still double counting costs to some degree, as the same technologies that yield lower u-factors result in lower SHGC. By summing them, the incremental cost estimates are conservative in nature.

Table 85 presents the resultant incremental measure cost for window alterations. The data is separated by curtain wall vs. an area-weighted cost for all-other windows.

**Table 85: 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 | CZ 1 | 0.47 | 0.41 | 0.38 | 0.35 | $3.97 |
| | CZ 2, 4, 6-15 | 0.47 | 0.31 | 0.38 | 0.25 | $5.53 |
| | CZ 3 &5 | 0.58 | 0.41 | 0.38 | 0.25 | $7.55 |
| | CZ 16 | 0.47 | 0.41 | 0.38 | 0.25 | $6.31 |
| All Other | CZ 1 | 0.47 | 0.41 | 0.34 | 0.35 | $4.23 |
| | CZ 2, 4, 6-15 | 0.47 | 0.31 | 0.34 | 0.23 | $5.79 |
| | CZ 3 &5 | 0.58 | 0.41 | 0.34 | 0.23 | $9.31 |
| | CZ 16 | 0.47 | 0.41 | 0.34 | 0.23 | $6.57 |

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 $ft^2$ of window area incremental measure costs to a per dwelling unit cost based on each prototype's features.

#### *5.1.3.6 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 Products

Research and interview results 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 – Roof/Ceiling Insulation

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

#### 5.1.4.3 Submeasure C1: 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.

#### 5.1.4.4 Submeasure C2: 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.

#### 5.1.4.5 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.

#### 5.1.4.6 Submeasure E: Envelope – Fenestration Area

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

### 5.1.5 Cost Effectiveness

#### 5.1.5.1 Submeasure A: Envelope – Roof Products

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.

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.

Results of the per-unit cost-effectiveness analyses are presented in Table 86 through Table 89 for new construction and for additions and alterations for the two-story and three-story prototype buildings respectively.

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. The submeasure applies to additions and alterations and the same B/C ratios for new construction apply to additions and alternations.

**Table 86: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction, Additions & Alterations – Low-Slope New Requirement of 0.55 ASR, 2-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 | $285.66 | $44.08 | 6.48 |
| 10 | $272.37 | $44.75 | 6.09 |
| 11 | $310.57 | $48.49 | 6.40 |
| 12 | N/A | N/A | N/A |
| 13 | N/A | N/A | N/A |
| 14 | $224.21 | $43.00 | 5.21 |
| 15 | N/A | N/A | N/A |
| 16 | N/A | N/A | N/A |

**Table 87: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction, Additions & Alterations – Low-Slope New Requirement of 0.55 ASR, 3-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 | $247.97 | $30.87 | 8.03 |
| 10 | $259.50 | $31.35 | 8.28 |
| 11 | $271.03 | $33.97 | 7.98 |
| 12 | N/A | N/A | N/A |
| 13 | N/A | N/A | N/A |
| 14 | $209.52 | $30.12 | 6.96 |
| 15 | N/A | N/A | N/A |
| 16 | N/A | N/A | N/A |

**Table 88: 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 | 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 | $33.15 | $0.00 | Infinite |
| 14 | N/A | N/A | N/A |
| 15 | $51.74 | $0.00 | Infinite |
| 16 | N/A | N/A | N/A |

**Table 89: 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 | 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 | $14.15 | $0.00 | Infinite |
| 14 | N/A | N/A | N/A |
| 15 | $20.51 | $0.00 | Infinite |
| 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 – Roof/Ceiling Insulation*

The Statewide CASE Team did not perform cost-effectiveness analyses because the submeasure includes a reduction in stringency, rather than an increase. The result is an energy increase and cost reduction.

#### *5.1.5.3 Submeasure C1: 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.

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.

Results of the per-unit cost-effectiveness analyses are presented in Table 90 for new construction. The submeasure is not applicable to additions or alterations.

The proposed code change is not cost-effective on its own and is cost-effective when packaged with the all-electric HVAC submeasure in every climate zone for which the change is proposed. Combined results are shown in Section 5.1.5.7

**Table 90: 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 | $236.37 | $183.43 | 1.29 |
| 2 | $231.75 | $183.43 | 1.26 |
| 3 | $154.24 | $183.43 | 0.84 |
| 4 | $155.75 | $183.43 | 0.85 |
| 5 | $161.73 | $183.43 | 0.88 |
| 6 | N/A | N/A | N/A |
| 7 | N/A | N/A | N/A |
| 8 | $108.86 | $183.43 | 0.59 |
| 9 | $121.84 | $183.43 | 0.66 |
| 10 | $138.12 | $183.43 | 0.75 |
| 11 | N/A | N/A | N/A |
| 12 | $234.13 | $183.43 | 1.28 |
| 13 | $182.74 | $183.43 | 1.00 |
| 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.

#### *5.1.5.4 Submeasure C2: 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.

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.

There is no change in design costs. Neither costs associated with scheduling and managing the verification process nor potential costs to achieve necessary insulation installation quality are included.

According to the Energy Commission's definitions, a measure is cost-effective if the benefit-to-cost (B/C) ratio is greater than 1.0. 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.

Results of the per-unit cost-effectiveness analyses are presented in Table 91.

**Table 91: 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.

#### 5.1.5.5 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.

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 nominal PV costs and cost savings.

Results of the per-unit cost-effectiveness analyses are presented in Table 92 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 proposed code change for new construction is not cost effective on its own and is cost-effective when packaged with the all-electric HVAC submeasure in every climate zone for which the change is proposed. Combined results are shown in Section 5.1.5.7.

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 92: 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 | $421.56 | $105.80 | 3.98 |
| 2 | $143.03 | $105.80 | 1.35 |
| 3 | $110.64 | $105.80 | 1.05 |
| 4 | $85.09 | $105.80 | 0.80 |
| 5 | $91.36 | $105.80 | 0.86 |
| 6 | $15.14 | $105.80 | 0.14 |
| 7 | $0.71 | $105.80 | 0.01 |
| 8 | $23.15 | $105.80 | 0.22 |
| 9 | $45.49 | $105.80 | 0.43 |
| 10 | $61.17 | $105.80 | 0.58 |
| 11 | $154.55 | $105.80 | 1.46 |
| 12 | $125.34 | $105.80 | 1.18 |
| 13 | $119.78 | $105.80 | 1.13 |
| 14 | $139.39 | $105.80 | 1.32 |
| 15 | $72.84 | $105.80 | 0.69 |
| 16 | $222.59 | $105.80 | 2.10 |

**Table 93: 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 | $478.11 | $161.92 | 2.95 |
| 2 | $206.84 | $161.92 | 1.28 |
| 3 | $157.51 | $161.92 | 0.97 |
| 4 | $112.42 | $161.92 | 0.69 |
| 5 | $135.06 | $161.92 | 0.83 |
| 6 | $10.59 | $161.92 | 0.07 |
| 7 | ($0.93) | $161.92 | (0.01) |
| 8 | $15.93 | $161.92 | 0.10 |
| 9 | $56.07 | $161.92 | 0.35 |
| 10 | $82.33 | $161.92 | 0.51 |
| 11 | $216.44 | $161.92 | 1.34 |
| 12 | $171.40 | $161.92 | 1.06 |
| 13 | $160.50 | $161.92 | 0.99 |
| 14 | $201.81 | $161.92 | 1.25 |
| 15 | $98.50 | $161.92 | 0.61 |
| 16 | $317.72 | $161.92 | 1.96 |

**Table 94: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – Combined Category *All Others*, 5-Story Prototype Building**

| Climate Zone | Benefits<br>TDV Energy Cost Savings + Other PV Savings[a]<br>(2023 PV$) | Costs<br>Total Incremental PV Costs[b]<br>(2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $1,000.06 | $796.64 | 1.26 |
| 2 | $526.67 | $1,333.02 | 0.40 |
| 3 | $168.51 | $1,333.02 | 0.13 |
| 4 | $351.06 | $1,333.02 | 0.26 |
| 5 | $106.08 | $1,333.02 | 0.08 |
| 6 | $133.92 | $1,333.02 | 0.10 |
| 7 | $74.44 | $1,333.02 | 0.06 |
| 8 | $183.17 | $1,333.02 | 0.14 |
| 9 | $240.53 | $1,333.02 | 0.18 |
| 10 | $293.87 | $1,333.02 | 0.22 |
| 11 | $575.52 | $1,333.02 | 0.43 |
| 12 | $481.02 | $1,333.02 | 0.36 |
| 13 | $473.15 | $1,333.02 | 0.35 |
| 14 | $532.94 | $1,333.02 | 0.40 |
| 15 | $357.69 | $1,333.02 | 0.27 |
| 16 | $771.51 | $1,333.02 | 0.58 |

**Table 95: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – Combined Category *All Others*, 10-Story Prototype Building**

| Climate Zone | Benefits<br>TDV Energy Cost Savings + Other PV Savings[a]<br>(2023 PV$) | Costs<br>Total Incremental PV Costs[b]<br>(2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $1,222.16 | $1,219.25 | 1.00 |
| 2 | $808.29 | $2,040.18 | 0.40 |
| 3 | $605.82 | $2,040.18 | 0.30 |
| 4 | $523.92 | $2,040.18 | 0.26 |
| 5 | $529.02 | $2,040.18 | 0.26 |
| 6 | $185.79 | $2,040.18 | 0.09 |
| 7 | $109.34 | $2,040.18 | 0.05 |
| 8 | $263.87 | $2,040.18 | 0.13 |
| 9 | $356.80 | $2,040.18 | 0.17 |
| 10 | $441.41 | $2,040.18 | 0.22 |
| 11 | $893.34 | $2,040.18 | 0.44 |
| 12 | $731.58 | $2,040.18 | 0.36 |
| 13 | $717.97 | $2,040.18 | 0.35 |
| 14 | $818.30 | $2,040.18 | 0.40 |
| 15 | $546.47 | $2,040.18 | 0.27 |
| 16 | $1,137.52 | $2,040.18 | 0.56 |

The proposed code change for additions and alterations is cost-effective in Climate Zones 1-5 and 9-16. Stakeholders expressed a strong desire for consistent requirements across climate zones to facilitate manufacturing norms and consistent product stocking practices. Because the submeasure is cost effective statewide when weighted by existing multifamily building stock, as shown in Table 96 and Table 97, the Statewide CASE Team recommends the measure apply across all climate zones. The weighted benefit-to-cost ratio average is 1.26 for the curtainwall/storefront category and of 1.19 for the combined fixed, operable, glazed door category. The code change only results in increased stringency for buildings four habitable stories and greater. Therefore, cost-effectiveness results are included only for the high-rise existing prototype.

**Table 96: 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 | Percent of Existing Multifamily Building Stock |
|---|---|---|---|---|
| 1 | $841.27 | $349.74 | 2.41 | 0.40% |
| 2 | $810.83 | $539.19 | 1.50 | 2.36% |
| 3 | $1,977.58 | $866.27 | 2.28 | 12.30% |
| 4 | $670.44 | $539.19 | 1.24 | 6.46% |
| 5 | $1,913.35 | $866.27 | 2.21 | 1.04% |
| 6 | $398.93 | $539.19 | 0.74 | 7.33% |
| 7 | $305.68 | $539.19 | 0.57 | 6.77% |
| 8 | $469.06 | $539.19 | 0.87 | 11.35% |
| 9 | $587.26 | $539.19 | 1.09 | 25.21% |
| 10 | $644.47 | $539.19 | 1.20 | 7.34% |
| 11 | $916.03 | $539.19 | 1.70 | 1.90% |
| 12 | $793.15 | $539.19 | 1.47 | 10.56% |
| 13 | $816.78 | $539.19 | 1.51 | 3.57% |
| 14 | $915.79 | $539.19 | 1.70 | 1.84% |
| 15 | $901.01 | $539.19 | 1.67 | 0.93% |
| 16 | $1,462.73 | $665.49 | 2.20 | 0.64% |

**Table 97: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – Additions and Alterations – Combined Fixed, Operable, and Glazed Door Category 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 | Percent of Existing Multifamily Building Stock |
|---|---|---|---|---|
| 1 | $1,224.96 | $684.92 | 1.79 | 0.40% |
| 2 | $1,307.44 | $937.51 | 1.39 | 2.36% |
| 3 | $2,361.57 | $1,507.46 | 1.57 | 12.30% |
| 4 | $1,125.30 | $937.51 | 1.20 | 6.46% |
| 5 | $2,280.64 | $1,507.46 | 1.51 | 1.04% |
| 6 | $745.80 | $937.51 | 0.80 | 7.33% |
| 7 | $579.98 | $937.51 | 0.62 | 6.77% |
| 8 | $894.30 | $937.51 | 0.95 | 11.35% |
| 9 | $1,039.00 | $937.51 | 1.11 | 25.21% |
| 10 | $1,118.16 | $937.51 | 1.19 | 7.34% |
| 11 | $1,498.01 | $937.51 | 1.60 | 1.90% |
| 12 | $1,307.96 | $937.51 | 1.40 | 10.56% |
| 13 | $1,364.08 | $937.51 | 1.46 | 3.57% |
| 14 | $1,494.36 | $937.51 | 1.59 | 1.84% |
| 15 | $1,548.69 | $937.51 | 1.65 | 0.93% |
| 16 | $1,923.24 | $1,063.81 | 1.81 | 0.64% |

#### 5.1.5.6 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.

#### 5.1.5.7 Combination Submeasure C (Wall U-factor), Submeasure D (Fenestration Properties) All-Electric HVAC, and Photovoltaics (CZ 16 only)

Submeasures C and D are not cost-effective as standalone measures. When packaged with the all-electric HVAC measure from the Multifamily All-Electric Package CASE Report, the submeasure package is cost-effective in all but Climate Zone 16. In Climate Zone 16, the Statewide CASE Team proposes an additional photovoltaic requirement scaled in size to the building. This constitutes a 35 kW system for the high-rise prototype and a 30 kW system for the mid-rise prototype. Details of the Multifamily All-Electric Package proposal are included in the CASE Report posted at https://title24stakeholders.com/2022-cycle-case-reports/. Table 98 through Table 101 show the combined results of submeasure C: Wall U-factor, submeasure D: fenestration properties, and all-electric HVAC.

**Table 98: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – Curtainwall/Storefronts + Electric HVAC + 30 kW PV (CZ 16 only), 5-Story Prototype Building**

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Benefits Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $1,319 | $9,613 | >1 |
| 2 | $938 | $12,366 | >1 |
| 3 | $1,141 | $11,798 | >1 |
| 4 | $775 | $11,845 | >1 |
| 5 | $732 | $9,654 | >1 |
| 6 | $495 | $9,643 | >1 |
| 7 | $397 | $9,675 | >1 |
| 8 | $455 | $9,751 | >1 |
| 9 | $565 | $9,654 | >1 |
| 10 | $501 | $9,896 | >1 |
| 11 | $973 | $9,981 | >1 |
| 12 | $854 | $9,848 | >1 |
| 13 | $741 | $9,862 | >1 |
| 14 | $435 | $9,791 | >1 |
| 15 | $358 | $9,910 | >1 |
| 16 | $101 | $8,832 | >1 |

**Table 99: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – Combined Category Curtainwall/Storefront+ Electric HVAC + 35 kW PV (CZ 16 only), 10-Story Prototype Building**

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Benefits Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $1,717 | $9,604 | >1 |
| 2 | $1,104 | $12,405 | >1 |
| 3 | $1,279 | $11,817 | >1 |
| 4 | $867 | $11,872 | >1 |
| 5 | $851 | $9,672 | >1 |
| 6 | $517 | $9,661 | >1 |
| 7 | $490 | $9,698 | >1 |
| 8 | $480 | $9,770 | >1 |
| 9 | $621 | $9,680 | >1 |
| 10 | $562 | $9,917 | >1 |
| 11 | $1,203 | $10,008 | >1 |
| 12 | $985 | $9,892 | >1 |
| 13 | $836 | $9,890 | >1 |
| 14 | $624 | $9,817 | >1 |
| 15 | $412 | $9,960 | >1 |
| 16 | $89 | $8,940 | >1 |

### Table 100: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – Combined Category All Other Windows + Framed (Wood or Metal) + Electric HVAC + 35 kW PV (CZ 16 only), 5-Story Prototype Building

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Benefits Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $2,469 | $8,723 | >1 |
| 2 | $1,730 | $10,873 | >1 |
| 3 | $1,802 | $10,305 | >1 |
| 4 | $1,343 | $10,351 | >1 |
| 5 | $1,348 | $8,161 | >1 |
| 6 | $754 | $8,333 | >1 |
| 7 | $571 | $8,366 | >1 |
| 8 | $821 | $8,258 | >1 |
| 9 | $989 | $8,161 | >1 |
| 10 | $965 | $8,402 | >1 |
| 11 | $1,294 | $8,671 | >1 |
| 12 | $1,544 | $8,355 | >1 |
| 13 | $1,368 | $8,368 | >1 |
| 14 | $718 | $8,481 | >1 |
| 15 | $539 | $8,600 | >1 |
| 16 | $399 | $7,698 | >1 |

### Table 101: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – Combined Category All Other Windows + Electric HVAC + 10 kW PV (CZ 16 only), 10-Story Prototype Building

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Benefits Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $2,540 | $8,522 | >1 |
| 2 | $1,686 | $10,400 | >1 |
| 3 | $1,671 | $9,813 | >1 |
| 4 | $1,245 | $9,867 | >1 |
| 5 | $1,243 | $7,667 | >1 |
| 6 | $658 | $7,657 | >1 |
| 7 | $570 | $7,693 | >1 |
| 8 | $698 | $7,765 | >1 |
| 9 | $889 | $7,676 | >1 |
| 10 | $905 | $7,912 | >1 |
| 11 | $1,836 | $8,004 | >1 |
| 12 | $1,515 | $7,888 | >1 |
| 13 | $1,370 | $7,886 | >1 |
| 14 | $1,269 | $7,812 | >1 |
| 15 | $830 | $7,955 | >1 |
| 16 | $117 | $7,599 | >1 |

## 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.

The proposed requirements impact alterations when an entirely new or complete replacement duct system or space-conditioning systems is installed. Conservatively, the per-unit energy savings for an alteration are assumed to be the same as for new construction. Existing homes, with less insulation and poorer performance systems, typically will experience higher savings from these measures than a new construction home.

### 5.2.2 Energy Cost Savings Results

#### *5.2.2.1 Submeasure F: Space Conditioning – Duct Insulation*

These two submeasures are 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 102 and Table 103. Per-unit energy are presented in nominal dollars in Appendix H in Table 188 and Table 189.

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

**Table 102: 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 | $9 | $0 | $9 |
| 2 | $76 | ($0) | $76 |
| 3 | $54 | ($0) | $54 |
| 4 | $102 | $0 | $102 |
| 5 | $43 | ($0) | $43 |
| 6 | $83 | ($0) | $83 |
| 7 | $74 | $0 | $74 |
| 8 | $110 | ($0) | $110 |
| 9 | $107 | $0 | $108 |
| 10 | $117 | $0 | $117 |
| 11 | $98 | ($1) | $97 |
| 12 | $111 | $0 | $111 |
| 13 | $148 | ($0) | $148 |
| 14 | $82 | ($0) | $81 |
| 15 | $140 | $0 | $140 |
| 16 | $42 | $0 | $42 |

**Table 103: 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 | $11 | ($0) | $10 |
| 2 | $68 | ($0) | $68 |
| 3 | $53 | ($0) | $53 |
| 4 | $92 | $0 | $92 |
| 5 | $44 | ($0) | $44 |
| 6 | $80 | ($0) | $80 |
| 7 | $74 | $0 | $74 |
| 8 | $101 | ($0) | $100 |
| 9 | $96 | ($0) | $96 |
| 10 | $104 | ($0) | $104 |
| 11 | $86 | ($0) | $85 |
| 12 | $98 | ($0) | $98 |
| 13 | $131 | ($0) | $130 |
| 14 | $69 | ($0) | $69 |
| 15 | $115 | ($0) | $115 |
| 16 | $37 | ($0) | $37 |

#### 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 104 and Table 105. Per-unit energy are presented in nominal dollars in Appendix H in Table 190 and Table 191.

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

**Table 104: 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 | $338 | ($133) | $206 |
| 2 | $749 | ($115) | $634 |
| 3 | $518 | ($91) | $427 |
| 4 | $808 | ($75) | $733 |
| 5 | $440 | ($80) | $359 |
| 6 | $667 | ($45) | $622 |
| 7 | $574 | ($33) | $541 |
| 8 | $851 | ($42) | $809 |
| 9 | $865 | ($51) | $814 |
| 10 | $942 | ($64) | $878 |
| 11 | $1,046 | ($117) | $929 |
| 12 | $959 | ($112) | $846 |
| 13 | $1,194 | ($95) | $1,099 |
| 14 | $972 | ($100) | $873 |
| 15 | $1,333 | ($29) | $1,305 |
| 16 | $745 | ($188) | $557 |

**Table 105: 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 | $334 | ($128) | $206 |
| 2 | $682 | ($111) | $571 |
| 3 | $501 | ($84) | $417 |
| 4 | $733 | ($72) | $662 |
| 5 | $435 | ($74) | $362 |
| 6 | $642 | ($42) | $600 |
| 7 | $581 | ($35) | $545 |
| 8 | $775 | ($38) | $737 |
| 9 | $777 | ($47) | $730 |
| 10 | $843 | ($60) | $783 |
| 11 | $941 | ($119) | $822 |
| 12 | $845 | ($107) | $739 |
| 13 | $1,034 | ($90) | $944 |
| 14 | $874 | ($98) | $776 |
| 15 | $1,099 | ($27) | $1,072 |
| 16 | $675 | ($170) | $506 |

#### *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 106 and Table 107. Per-unit energy are presented in nominal dollars in Appendix H in Table 192 and Table 193.

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 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$) |
|---:|---:|---:|---:|
| \ | $16 | $0 | $16 |
| 2 | $177 | $0 | $177 |
| 3 | $105 | $0 | $105 |
| 4 | $212 | $0 | $212 |
| 5 | $86 | $0 | $86 |
| 6 | $186 | $0 | $186 |
| 7 | $164 | $0 | $164 |
| 8 | $249 | $0 | $249 |
| 9 | $256 | $0 | $256 |
| 10 | $270 | $0 | $270 |
| 11 | $320 | $0 | $320 |
| 12 | $251 | $0 | $251 |
| 13 | $353 | $0 | $353 |
| 14 | $307 | $0 | $307 |
| 15 | $512 | $0 | $512 |
| 16 | $104 | $0 | $104 |

**Table 107: 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 | $21 | $0 | $21 |
| 2 | $158 | $0 | $158 |
| 3 | $106 | $0 | $106 |
| 4 | $191 | $0 | $191 |
| 5 | $92 | $0 | $92 |
| 6 | $183 | $0 | $183 |
| 7 | $170 | $0 | $170 |
| 8 | $229 | $0 | $229 |
| 9 | $230 | $0 | $230 |
| 10 | $241 | $0 | $241 |
| 11 | $276 | $0 | $276 |
| 12 | $216 | $0 | $216 |
| 13 | $298 | $0 | $298 |
| 14 | $272 | $0 | $272 |
| 15 | $417 | $0 | $417 |
| 16 | $3 | $0 | $3 |

### 5.2.3 Incremental First Cost

#### *5.2.3.1 Submeasure F: Space Conditioning – Duct Insulation*

These two submeasures are 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 the cost for a HERS Rater to conduct onsite verification of duct leakage as well as costs for the mechanical contractor to conduct additional sealing on the system. Costs are presented in Table 108. 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 some additional sealing will be required by the mechanical contractor. For a typical dwelling unit, the Statewide CASE Team estimated that a half-hour of additional labor may be required at an hourly rate of $120 per hour for a total incremental labor cost of $60. $10 for material is also included in the total cost.

HERS Rater costs were collected from research studies (Statewide Reach Code Team 2017), prior project experience, and stakeholder feedback. Reviewed costs ranged from $25 per dwelling unit on the low-end assuming sampling to $250 per dwelling unit not assuming any sampling. Assuming most projects will take advantage of sampling protocols the Statewide CASE Team arrived at a typical cost of $125 per dwelling unit, which includes sampling of at least one-in-five.

**Table 108: First Cost Summary for Duct Leakage Testing**

| Cost component | Cost per Dwelling Unit |
|---|---:|
| Material | $10 |
| Labor | $60 |
| HERS Rater | $125 |
| Total Incremental First Cost | $195 |

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

Incremental costs for this measure reflect the cost for a HERS Rater to conduct onsite verification of system airflow rate and fan watt draw. Costs are presented in Table 109. Based on feedback from stakeholders most cooling systems should already 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.

HERS Rater costs were collected from research studies (Statewide Reach Code Team 2017), prior project experience, and stakeholder feedback. Reviewed costs ranged from $20 to $100 per dwelling unit for both of the tests combined. The Statewide CASE Team arrived at a typical cost of $100 per dwelling unit which includes sampling of at least one-in-five.

**Table 109: First Cost Summary for Cooling Coil Airflow and Fan Efficacy**

| Cost component | Cost per Dwelling Unit |
|---|---:|
| Material | $0 |
| Labor | $0 |
| HERS Rater | $100 |
| Total Incremental First Cost | $100 |

#### *5.2.3.4 Submeasure I: Space Conditioning – Refrigerant Charge Verification*

Incremental costs for this measure reflect the cost for a HERS Rater to conduct onsite verification of proper refrigerant charge. Costs are presented in Table 110. 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.

HERS Rater costs were collected from research studies (Statewide Reach Code Team 2017), prior project experience, and stakeholder feedback. Reviewed costs ranged from $28 to $150 per dwelling unit. The Statewide CASE Team arrived at a typical cost of $100 per dwelling unit, which includes sampling of at least one-in-five.

**Table 110: First Cost Summary for Refrigerant Charge Verification**

| Cost component | Cost per Dwelling Unit |
|---|---:|
| Material | $0 |
| Labor | $0 |
| HERS Rater | $100 |
| Total Incremental First Cost | $100 |

### 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:

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

### 5.2.4.1 Submeasure F: Space Conditioning – Duct Insulation

These two submeasures are not increasing stringency; therefore, costs and cost-effectiveness analysis are not presented.

### 5.2.4.2 Submeasure G: Space Conditioning – Duct Leakage Testing

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 of the HERS verification only. It is expected that over the next two decades building practices will improve and sealing will become standard place for all multifamily buildings. 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 111. There is no difference in regular maintenance between the two system types.

**Table 111: Duct Leakage Testing Summary of Replacement Cost**

| | Cost per Dwelling Unit |
|---|---:|
| Incremental First Cost | $195 |
| Present Value of Replacement Cost at Year 20 | $108 |
| Present Value of Remaining Useful Life at Year 30 | ($40) |
| Total Present Value of Incremental Cost | $263 |

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

It is expected that the HVAC 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 of the HERS verification only. It is expected that over the next two decades building practices will improve, and sealing will become standard place for all multifamily buildings. 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 112. There is no difference in regular maintenance between the two system types.

**Table 112: Cooling Coil Airflow and Fan Efficacy Summary of Replacement Cost**

| | Cost per Dwelling Unit |
|---|---|
| Incremental First Cost | $100 |
| Present Value of Replacement Cost at Year 20 | $55 |
| Present Value of Remaining Useful Life at Year 30 | ($21) |
| Total Present Value of Incremental Cost | $135 |

#### 5.2.4.4 Submeasure I: Space Conditioning – Refrigerant Charge Verification

It is expected that the HVAC 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 of the HERS verification only. It is expected that over the next two decades building practices will improve, and sealing will become standard place for all multifamily buildings. 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 112. There is no difference in regular maintenance between the two system types.

**Table 113: Refrigerant Charge Verification Summary of Replacement Cost**

| | Cost per Dwelling Unit |
|---|---|
| Incremental First Cost | $100 |
| Present Value of Replacement Cost at Year 20 | $55 |
| Present Value of Remaining Useful Life at Year 30 | ($21) |
| Total Present Value of Incremental Cost | $135 |

### 5.2.5 Cost Effectiveness

The space conditioning submeasures proposes 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

These two submeasures are 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 114 through Table 115 for new construction. The proposed submeasure is not cost effective on its own over the 30-year period of analysis relative to the existing conditions in any climate zone. 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 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.

There are also existing duct leakage testing requirements triggered by an altered space-conditioning or duct system in multifamily building three stories and fewer. The requirements are for a maximum of 15 percent total leakage and 10 percent leakage to outside tested by a HERS Rater. This scenario is not directly evaluated in this draft report and will be included in the final report.

**Table 114: 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 | $9 | $263 | 0.03 |
| 2 | $76 | $263 | 0.29 |
| 3 | $54 | $263 | 0.20 |
| 4 | $102 | $263 | 0.39 |
| 5 | $43 | $263 | 0.16 |
| 6 | $83 | $263 | 0.32 |
| 7 | $74 | $263 | 0.28 |
| 8 | $110 | $263 | 0.42 |
| 9 | $108 | $263 | 0.41 |
| 10 | $117 | $263 | 0.45 |
| 11 | $97 | $263 | 0.37 |
| 12 | $111 | $263 | 0.42 |
| 13 | $148 | $263 | 0.56 |
| 14 | $81 | $263 | 0.31 |
| 15 | $140 | $263 | 0.53 |
| 16 | $42 | $263 | 0.16 |

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 115: 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 | $10 | $263 | 0.04 |
| 2 | $68 | $263 | 0.26 |
| 3 | $53 | $263 | 0.20 |
| 4 | $92 | $263 | 0.35 |
| 5 | $44 | $263 | 0.17 |
| 6 | $80 | $263 | 0.31 |
| 7 | $74 | $263 | 0.28 |
| 8 | $100 | $263 | 0.38 |
| 9 | $96 | $263 | 0.36 |
| 10 | $104 | $263 | 0.39 |
| 11 | $85 | $263 | 0.33 |
| 12 | $98 | $263 | 0.37 |
| 13 | $130 | $263 | 0.50 |
| 14 | $69 | $263 | 0.26 |
| 15 | $115 | $263 | 0.44 |
| 16 | $37 | $263 | 0.14 |

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 116 through Table 117 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.

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.

There are also existing cooling coil airflow testing requirements triggered by an altered refrigerant-containing system component in multifamily building three stories and fewer. The requirements are for a minimum of 300 cfm per ton of nominal cooling capacity tested by a HERS Rater. This scenario is not directly evaluated in this draft report and will be included in the final report.

**Table 116: 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 | $206 | $135 | 1.53 |
| 2 | $634 | $135 | 4.70 |
| 3 | $427 | $135 | 3.17 |
| 4 | $733 | $135 | 5.44 |
| 5 | $359 | $135 | 2.67 |
| 6 | $622 | $135 | 4.62 |
| 7 | $541 | $135 | 4.01 |
| 8 | $809 | $135 | 6.00 |
| 9 | $814 | $135 | 6.04 |
| 10 | $878 | $135 | 6.51 |
| 11 | $929 | $135 | 6.89 |
| 12 | $846 | $135 | 6.28 |
| 13 | $1,099 | $135 | 8.15 |
| 14 | $873 | $135 | 6.47 |
| 15 | $1,305 | $135 | 9.68 |
| 16 | $557 | $135 | 4.13 |

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 117: 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 | $206 | $135 | 1.53 |
| 2 | $571 | $135 | 4.24 |
| 3 | $417 | $135 | 3.10 |
| 4 | $662 | $135 | 4.91 |
| 5 | $362 | $135 | 2.68 |
| 6 | $600 | $135 | 4.45 |
| 7 | $545 | $135 | 4.05 |
| 8 | $737 | $135 | 5.47 |
| 9 | $730 | $135 | 5.41 |
| 10 | $783 | $135 | 5.81 |
| 11 | $822 | $135 | 6.10 |
| 12 | $739 | $135 | 5.48 |
| 13 | $944 | $135 | 7.00 |
| 14 | $776 | $135 | 5.76 |
| 15 | $1,072 | $135 | 7.95 |
| 16 | $506 | $135 | 3.75 |

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 118 through Table 119 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 1, 3, 5 and 16. 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.

**Table 118: 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 | $16 | $135 | 0.12 |
| 2 | $177 | $135 | 1.31 |
| 3 | $105 | $135 | 0.78 |
| 4 | $212 | $135 | 1.57 |
| 5 | $86 | $135 | 0.64 |
| 6 | $186 | $135 | 1.38 |
| 7 | $164 | $135 | 1.22 |
| 8 | $249 | $135 | 1.85 |
| 9 | $256 | $135 | 1.90 |
| 10 | $270 | $135 | 2.00 |
| 11 | $320 | $135 | 2.37 |
| 12 | $251 | $135 | 1.86 |
| 13 | $353 | $135 | 2.62 |
| 14 | $307 | $135 | 2.28 |
| 15 | $512 | $135 | 3.80 |
| 16 | $104 | $135 | 0.77 |

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 119: 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 | $21 | $135 | 0.16 |
| 2 | $158 | $135 | 1.18 |
| 3 | $106 | $135 | 0.79 |
| 4 | $191 | $135 | 1.42 |
| 5 | $92 | $135 | 0.69 |
| 6 | $183 | $135 | 1.35 |
| 7 | $170 | $135 | 1.26 |
| 8 | $229 | $135 | 1.70 |
| 9 | $230 | $135 | 1.70 |
| 10 | $241 | $135 | 1.79 |
| 11 | $276 | $135 | 2.05 |
| 12 | $216 | $135 | 1.60 |
| 13 | $298 | $135 | 2.21 |
| 14 | $272 | $135 | 2.02 |
| 15 | $417 | $135 | 3.10 |
| 16 | $3 | $135 | 0.02 |

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 – HERS Verification Package*

The three HERS 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 120 through Table 121 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, 3 and 5.

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 and heating loads and will experience higher energy savings and improved cost effectiveness.

**Table 120: 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 | $106 | $398 | 0.27 |
| 2 | $832 | $532 | 1.56 |
| 3 | $414 | $398 | 1.04 |
| 4 | $799 | $398 | 2.01 |
| 5 | $328 | $398 | 0.83 |
| 6 | $677 | $398 | 1.70 |
| 7 | $597 | $398 | 1.50 |
| 8 | $1,166 | $532 | 2.19 |
| 9 | $1,175 | $532 | 2.21 |
| 10 | $1,259 | $532 | 2.36 |
| 11 | $1,350 | $532 | 2.54 |
| 12 | $1,182 | $532 | 2.22 |
| 13 | $1,611 | $532 | 3.03 |
| 14 | $1,250 | $532 | 2.35 |
| 15 | $2,019 | $532 | 3.79 |
| 16 | $527 | $398 | 1.33 |

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 – New Construction Refrigerant Charge**

| Climate Zone | Benefits<br>TDV Energy Cost Savings + Other PV Savings[a]<br>(2023 PV$) | Costs<br>Total Incremental PV Costs[b]<br>(2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $100 | $398 | 0.25 |
| 2 | $724 | $532 | 1.36 |
| 3 | $397 | $398 | 1.00 |
| 4 | $710 | $398 | 1.79 |
| 5 | $330 | $398 | 0.83 |
| 6 | $650 | $398 | 1.64 |
| 7 | $595 | $398 | 1.50 |
| 8 | $1,055 | $532 | 1.98 |
| 9 | $1,044 | $532 | 1.96 |
| 10 | $1,110 | $532 | 2.09 |
| 11 | $1,161 | $532 | 2.18 |
| 12 | $1,006 | $532 | 1.89 |
| 13 | $1,365 | $532 | 2.56 |
| 14 | $1,087 | $532 | 2.04 |
| 15 | $1,648 | $532 | 3.10 |
| 16 | $479 | $398 | 1.21 |

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 Products*

Table 122 presents the first-year statewide energy and energy cost savings from newly constructed buildings by climate zone. Table 123 presents first-year statewide savings from new construction, additions, and alterations.

**Table 122: Statewide Energy and Energy Cost Impacts – New Construction – Low-Slope, 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 | N/A | N/A | N/A | N/A | N/A |
| 2 | N/A | N/A | N/A | N/A | N/A |
| 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 | N/A | N/A | N/A | N/A | N/A |
| 9 | 2,996 | 0.11 | 0.07 | 0 | $0.75 |
| 10 | 1,058 | 0.05 | 0.03 | 0 | $0.28 |
| 11 | 302 | 0.01 | 0.01 | 0 | $0.08 |
| 12 | N/A | N/A | N/A | N/A | N/A |
| 13 | 1,143 | 0.01 | 0.00 | 0 | $0.04 |
| 14 | 226 | 0.01 | 0.01 | 0 | $0.05 |
| 15 | 338 | 0.00 | 0.00 | 0 | $0.02 |
| 16 | N/A | N/A | N/A | N/A | N/A |
| TOTAL | 6,064 | 0.19 | 0.11 | 0 | $1.21 |

a. First-year savings from all buildings completed statewide in 2023.

**Table 123: Statewide Energy and Energy Cost Impacts – New Construction, Alterations, and Additions – Low-Slope, 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 | 0.19 | 0.11 | (0.00) | 6.98 |
| Additions and Alterations | 0.74 | 0.51 | (0.01) | 27.96 |
| TOTAL | 0.9 | 0.62 | (0.01) | 34.9 |

a. First-year savings from all alterations completed statewide in 2023.

### *6.1.1.2 Submeasure B: Envelope – Roof/Ceiling Insulation*

Table 124 presents the first-year statewide energy and energy cost savings from newly constructed buildings by climate zone. Table 125 presents first-year statewide savings from new construction.

**Table 124: Statewide Energy and Energy Cost Impacts – New Construction – 2-Story, 3-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) | $(0.01) |
| 2 | 389 | 0.00 | 0.00 | (0.00) | $(0.01) |
| 3 | 1,888 | (0.01) | 0.00 | (0.00) | $(0.16) |
| 4 | 984 | 0.00 | (0.00) | (0.00) | $(0.07) |
| 5 | 175 | (0.00) | 0.00 | (0.00) | $(0.02) |
| 6 | 834 | (0.01) | (0.01) | (0.00) | $(0.05) |
| 7 | 897 | (0.01) | (0.01) | (0.00) | $(0.09) |
| 8 | 1,173 | 0.02 | 0.01 | (0.00) | $0.22 |
| 9 | 2,753 | 0.03 | 0.01 | (0.00) | $0.25 |
| 10 | 973 | 0.02 | 0.01 | (0.00) | $0.08 |
| 11 | 278 | 0.00 | (0.00) | (0.00) | $0.01 |
| 12 | 1,568 | 0.02 | 0.01 | (0.00) | $0.00 |
| 13 | 458 | (0.04) | (0.02) | (0.00) | $(0.28) |
| 14 | 208 | (0.00) | (0.00) | (0.00) | $(0.02) |
| 15 | 135 | (0.02) | (0.01) | (0.00) | $(0.11) |
| 16 | 84 | (0.00) | (0.00) | (0.00) | $(0.02) |
| TOTAL | **12,862** | **0.01** | **(0.01)** | **(0.01)** | **$(0.28)** |

a. First-year savings from all buildings completed statewide in 2023.

**Table 125: Statewide Energy and Energy Cost Impacts – New Construction, Alterations, and Additions – 2-Story, 3-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 | 0.01 | (0.01) | (0.01) | (1.59) |
| Additions and Alterations | N/A | N/A | N/A | N/A |
| TOTAL | 0.01 | (0.01) | (0.01) | (1.59) |

#### 6.1.1.3 Submeasure C1: Envelope – Wall U-Factor

Table 126 and Table 127 present the first-year statewide energy and energy cost savings from newly constructed buildings by climate zone.

Table 128 presents first-year statewide savings from new construction.

**Table 126: Statewide Energy and Energy Cost Impacts – New Construction – Framed, High Fire Rating (2- and 3-hr), 3-Story; 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 | 63 | 0.00 | (0.00) | 0.00 | $0.01 |
| 2 | 371 | 0.01 | 0.00 | 0.00 | $0.08 |
| 3 | 1,800 | 0.01 | (0.00) | 0.00 | $0.26 |
| 4 | 938 | 0.01 | (0.00) | 0.00 | $0.14 |
| 5 | 167 | 0.00 | (0.00) | 0.00 | $0.03 |
| 6 | N/A | N/A | N/A | N/A | N/A |
| 7 | N/A | N/A | N/A | N/A | N/A |
| 8 | 1,118 | 0.01 | (0.00) | 0.00 | $0.12 |
| 9 | 2,624 | 0.03 | 0.00 | 0.00 | $0.30 |
| 10 | 927 | 0.01 | 0.00 | 0.00 | $0.12 |
| 11 | N/A | N/A | N/A | N/A | N/A |
| 12 | 1,495 | 0.02 | 0.00 | 0.00 | $0.33 |
| 13 | 436 | 0.01 | 0.00 | 0.00 | $0.07 |
| 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 | **9,939** | **0.11** | **0.00** | **0.02** | **$1.46** |

a. First-year savings from all buildings completed statewide in 2023.

**Table 127: 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 | N/A |
| 2 | N/A | N/A | N/A | N/A | N/A |
| 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 | 1,868 | (0.00) | (0.00) | (0.00) | ($0.06) |
| 7 | 2,009 | 0.00 | (0.00) | (0.00) | ($0.05) |
| 8 | N/A | N/A | N/A | N/A | N/A |
| 9 | N/A | N/A | N/A | N/A | N/A |
| 10 | N/A | N/A | N/A | N/A | N/A |
| 11 | 622 | (0.01) | (0.01) | (0.00) | $(0.17) |
| 12 | N/A | N/A | N/A | N/A | N/A |
| 13 | N/A | N/A | N/A | N/A | N/A |
| 14 | 466 | (0.01) | (0.00) | (0.00) | ($0.13) |
| 15 | 303 | (0.01) | (0.00) | (0.00) | ($0.07) |
| 16 | 188 | (0.00) | (0.00) | (0.00) | ($0.05) |
| TOTAL | **5,456** | **(0.03)** | **(0.02)** | **(0.01)** | **($0.54)** |

a. First-year savings from all buildings completed statewide in 2023.

**Table 128: 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 | 0.08 | (0.02) | 0.0 | 5.3 |
| Additions and Alterations | N/A | N/A | N/A | N/A |
| TOTAL | 0.08 | (0.02) | 0.0 | 5.3 |

#### *6.1.1.4 Submeasure C2: Envelope – Quality Insulation Installation*

Table 129 present the first-year statewide energy and energy cost savings from newly constructed buildings by climate zone.

**Table 129: 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 (million 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 | NA | 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.

#### *6.1.1.5 Submeasure D: Envelope – Fenestration Properties*

Table 130 presents the first-year statewide energy and energy cost savings from newly constructed buildings by climate zone. Table 131 presents first-year statewide savings from new construction.

**Table 130: 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 | (0.00) | (0.00) | 0.00 | $0.16 |
| 2 | 991 | 0.01 | (0.00) | 0.01 | $0.49 |
| 3 | 4,807 | (0.39) | (0.14) | 0.06 | $0.84 |
| 4 | 2,504 | 0.00 | (0.00) | 0.02 | $0.81 |
| 5 | 445 | (0.04) | (0.01) | 0.01 | $0.05 |
| 6 | 2,123 | (0.03) | (0.01) | 0.01 | $0.26 |
| 7 | 2,282 | (0.04) | (0.01) | 0.01 | $0.15 |
| 8 | 2,985 | (0.02) | (0.00) | 0.01 | $0.49 |
| 9 | 7,008 | (0.01) | 0.01 | 0.03 | $1.55 |
| 10 | 2,476 | 0.01 | 0.01 | 0.01 | $0.67 |
| 11 | 707 | 0.01 | 0.01 | 0.01 | $0.38 |
| 12 | 3,991 | 0.04 | 0.01 | 0.03 | $1.78 |
| 13 | 1,165 | 0.02 | 0.01 | 0.01 | $0.51 |
| 14 | 529 | 0.01 | 0.00 | 0.00 | $0.26 |
| 15 | 345 | 0.01 | 0.00 | 0.00 | $0.11 |
| 16 | 214 | 0.00 | (0.00) | 0.00 | $0.15 |
| TOTAL | 32,739 | **(0.41)** | **(0.14)** | **0.21** | **$8.67** |

a. First-year savings from all buildings completed statewide in 2023.

**Table 131: 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 | (0.4) | (0.1) | 0.2 | 50 |
| Additions and Alterations | 7.0 | 1.7 | 0.4 | 284 |
| TOTAL | 6.5 | 1.5 | 0.6 | 335 |

#### 6.1.1.6 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 132 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 3,936 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 132: 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 Products | 0.93 | 222 | (0.01) | (65) | 157 |
| Roof/Ceiling Insulation | 0.01 | 3 | (0.01) | (50) | (47) |
| Wall U-Factor | 0.08 | 19 | 0.02 | 82 | 101 |
| QII | 0.03 | 0.00 | 0.01 | 0.00 | 0.00 |
| Fenestration Properties | 7.00 | 1,573 | 1.00 | 3,130 | 4,704 |
| TOTAL | 8.05 | 1,817 | 1.01 | 3,097 | 4,915 |

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 an entirely new or complete replacement duct system or space-conditioning systems 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.

#### *6.2.1.1 Submeasure F: Space Conditioning – Duct Insulation*

These two submeasures are not increasing stringency but do 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.

The 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 133 presents the first-year statewide energy and energy cost impact from newly constructed buildings by climate zone.

Table 134 presents first-year statewide impact from new construction, additions, and alterations.

### Table 133: 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 134: 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 | (0.04) | (0.00) | (0.01) | ($0.82) |
| TOTAL | (0.04) | (0.00) | (0.01) | ($0.96) |

a. First-year savings from all new construction and alterations completed statewide in 2023.

#### *6.2.1.2 Combination G-I: Space Conditioning – HERS Verification Package*

Statewide results for the three HERS 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 Statewide CASE Team recommends that the three HERS measure be required for multifamily building four habitable stories and greater in all climate zones except Climate Zone 1, even though the duct leakage testing alone is not cost effective. In most multifamily buildings, the HERS measures will be applied as a package. 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 HERS package was not found to be cost effective in Climate Zones 1, 3 and 5. These climate zones are heating dominated with very minimal cooling savings. The limitations of the duct leakage modeling approach in CBECC-Com applied in this analysis (see Section 4.2.1.2) resulted in negligible heating savings in all climate zones and does not accurately account for the losses of conditioning air that is never delivered to the dwelling unit. It is expected that actual savings will be higher than what is presented here particularly for heating dominated climates. As a result, the Statewide CASE Team recommends that only airflow rate and fan efficacy requirements apply to Climate Zones 1, 3 and 5 and this is reflected in the statewide savings presented here.

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. This savings for this portion of the building stock in Climate Zones 2 and 8 through 15 are accounted for in the results.

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.

Table 135 presents the first-year statewide energy and energy cost savings from newly constructed buildings by climate zone.

Table 136 presents first-year statewide savings from new construction, additions, and alterations.

**Table 135: Statewide Energy and Energy Cost Impacts – New Construction – HERS 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 | 55 | 0.00 | 0.00 | (0.00) | $0.01 |
| 2 | 875 | 0.06 | 0.02 | (0.00) | $0.37 |
| 3 | 1,585 | 0.15 | 0.03 | (0.00) | $0.68 |
| 4 | 826 | 0.11 | 0.04 | (0.00) | $0.66 |
| 5 | 147 | 0.01 | 0.00 | (0.00) | $0.05 |
| 6 | 700 | 0.10 | 0.03 | (0.00) | $0.47 |
| 7 | 753 | 0.10 | 0.03 | (0.00) | $0.45 |
| 8 | 2,634 | 0.30 | 0.09 | (0.00) | $1.55 |
| 9 | 6,185 | 0.68 | 0.23 | (0.00) | $3.68 |
| 10 | 2,185 | 0.27 | 0.09 | (0.00) | $1.39 |
| 11 | 624 | 0.08 | 0.03 | (0.00) | $0.44 |
| 12 | 3,522 | 0.35 | 0.14 | (0.00) | $2.09 |
| 13 | 1,028 | 0.15 | 0.05 | (0.00) | $0.84 |
| 14 | 467 | 0.06 | 0.02 | (0.00) | $0.31 |
| 15 | 304 | 0.06 | 0.02 | (0.00) | $0.32 |
| 16 | 70 | 0.01 | 0.00 | (0.00) | $0.04 |
| TOTAL | **21,961** | **2.49** | **0.83** | **(0.01)** | **$13.33** |

a. First-year savings from all new buildings completed statewide in 2023.

**Table 136: Statewide Energy and Energy Cost Impacts – New Construction, Alterations, and Additions – HERS Package**

| 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 | 2.49 | 0.83 | (0.01) | $13.33 |
| Additions and Alterations | 6.18 | 1.99 | (0.02) | $32.57 |
| TOTAL | 8.66 | 2.82 | (0.02) | $45.90 |

a. First-year savings from all new construction and alterations 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 of Air Pollutant Emissions Factors (AP-42). See Appendix C for additional details on the methodology used to calculate GHG emissions.

Table 137 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 4,870 metric tons of carbon dioxide equivalents (metric tons CO2e) would be avoided.

**Table 137: 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 | (0.04) | (11) | (0.01) | (38) | (48) |
| HVAC Verification Package | 8.66 | 2,083 | (0.02) | (130) | 1,953 |
| TOTAL | **8.62** | **2,072** | (0.03) | (168) | **1,905** |

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.

[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.

### 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 HERS 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 that may result from creation of the multifamily chapters and consequential revisions to the low-rise residential and nonresidential chapters. The Statewide CASE Team may have the opportunity to address additional changes to the Reference Appendices in the Final CASE Report for this topic.

## 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. 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 of the Draft CASE Report in the Final CASE Report, pending discussion with the Energy Commission about the best solution.

## 7.6 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 138 through Table 141 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 Products

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 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
- The Statewide CASE Team assigned low slope versus steep slope based on the number of habitable stories and the roof type. For example, one- and two-story buildings with attics were assigned as 80 percent steep slope, and 20 percent low slope.

Table 138 presents the culmination of this data with estimates of dwelling units under low slope vs. steep slope roof by prototype. It also lists the climate zones with proposed code changes for each combination.

**Table 138: Estimated Dwelling Unit Ratios of Low Slope and Steep Slope Roof by Prototype**

| Prototype | Low slope; ≤2:12 | Climate Zones impacted – Low slope | Steep slope; >2:12 | Climate Zones impacted – Steep Slope |
|---|---|---|---|---|
| 2-Story Garden Style | 38% | CZ 9-11, 14 | 62% | CZ 2-9 |
| 3-Story Loaded Corridor | 77% | CZ 9-11, 14 | 23% | CZ 2-9 |
| 5-Story Mixed Use | 98% | CZ 13, 15 | 2% | None |
| 10-Story Mixed Use | 100% | CZ 13, 15 | 0% | None |

For alterations, the Statewide CASE Team assumed roofs are replaced every 25 years, triggering the proposed code requirements.

Table 139 and Table 140 present the estimated impacted number of multifamily dwelling units for proposed changes to the roof product emittance and reflectance values for steep sloped and low sloped roofs, respectively. Climate zones with no associated data are not impacted by this code proposal.

For steeped sloped roofs, the proposal is to remove existing reflectance requirements for high-rise multifamily units. This constitutes less than one percent of multifamily new construction units. This roof type is so uncommon, that prototypes versions do not exist to model it’s potential. As a proxy, the Statewide CASE Team looked at a similar modeling, at a dwelling unit basis, from the 3-story loaded corridor prototype.

**Table 139: Estimated New Construction and Existing Building Stock for Multifamily Buildings by Climate Zone for Buildings with Steep Sloped 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 | | | 17,126 | | |
| 2 | 1,573 | 1.16% | 18 | 101,721 | 0.01% | 15 |
| 3 | 7,630 | 1.16% | 89 | 530,089 | 0.01% | 76 |
| 4 | 3,975 | 1.16% | 46 | 278,535 | 0.01% | 40 |
| 5 | 706 | 1.16% | 8 | 44,816 | 0.01% | 6 |
| 6 | 3,370 | 1.16% | 39 | 315,784 | 0.01% | 45 |
| 7 | 3,623 | 1.16% | 42 | 291,804 | 0.01% | 42 |
| 8 | 4,738 | 1.16% | 55 | 489,337 | 0.01% | 70 |
| 9 | 11,124 | 1.16% | 129 | 1,086,699 | 0.01% | 156 |
| 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 | | 426 | 4,310,108 | | 452 |

For low sloped roofs, the proposed code update will increase stringency on high rise buildings in Climate Zones 13 and 15. The proposed code update will newly add a prescriptive requirement for low rise buildings in Climate Zones 9-11, and 14.

**Table 140: Estimated New Construction and Existing Building Stock for Multifamily Buildings by Climate Zone for Buildings with Low Sloped 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 | 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 | 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 | N/A | N/A | 489,337 | N/A | N/A |
| 9 | 11,124 | 27% | 2,996 | 1,086,699 | 1% | 12,632 |
| 10 | 3,930 | 27% | 1,058 | 316,384 | 1% | 3,678 |
| 11 | 1,122 | 27% | 302 | 81,820 | 1% | 951 |
| 12 | 6,335 | N/A | N/A | 455,265 | N/A | N/A |
| 13 | 1,849 | 62% | 1,143 | 154,048 | 2% | 2,566 |
| 14 | 840 | 27% | 226 | 79,142 | 1% | 920 |
| 15 | 547 | 62% | 338 | 40,033 | 2% | 667 |
| 16 | 339 | N/A | N/A | 27,505 | N/A | N/A |
| TOTAL | 51,966 | | 6,064 | 4,310,108 | | 21,413 |

### Submeasure B: Envelope – Roof/Ceiling Insulation

The proposed code change only impacts low-rise residential construction that do not have an attic. 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 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 141 presents the estimates of dwelling units in building with and without attics by prototype.

**Table 141: Estimated Dwelling Unit Ratios of Low Slope and Steep Slope Roof by Prototype**

| Prototype | Attic | No Attic |
|---|---|---|
| 2-Story Garden Style | 67% | 33% |
| 3-Story Loaded Corridor | 29% | 71% |

Table 142 presents the estimated impacted number of multifamily dwelling units for proposed changes to prescriptive code requirements on multifamily buildings without attics. 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 142: Estimated New Construction and Existing Building Stock for Multifamily Buildings by Climate Zone for Low Rise Buildings with No Attic**

| 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% | 66 | 17,126 | | |
| 2 | 1,573 | 25% | 389 | 101,721 | | |
| 3 | 7,630 | 25% | 1,888 | 530,089 | | |
| 4 | 3,975 | 25% | 984 | 278,535 | | |
| 5 | 706 | 25% | 175 | 44,816 | | |
| 6 | 3,370 | 25% | 834 | 315,784 | | |
| 7 | 3,623 | 25% | 897 | 291,804 | | |
| 8 | 4,738 | 25% | 1,173 | 489,337 | | |
| 9 | 11,124 | 25% | 2,753 | 1,086,699 | | |
| 10 | 3,930 | 25% | 973 | 316,384 | | |
| 11 | 1,122 | 25% | 278 | 81,820 | | |
| 12 | 6,335 | 25% | 1,568 | 455,265 | | |
| 13 | 1,849 | 25% | 458 | 154,048 | | |
| 14 | 840 | 25% | 208 | 79,142 | | |
| 15 | 547 | 25% | 135 | 40,033 | | |
| 16 | 339 | 25% | 84 | 27,505 | | |
| TOTAL | 51,966 | | 12,862 | 4,310,108 | | 0 |

### Submeasure C1: 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.

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 2.3 percent of low-rise construction. Table 144 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 29 percent of high-rise construction. Table 145 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 146 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.

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 143.

**Table 143: 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% | 3.3% | 0% |
| 5-Story Mixed Use | 38.8% | 55% | 7% |
| 10-Story Mixed Use | 0% | 30% | 70% |

**Table 144: 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 | | |
| 2 | 1,573 | 1% | 17 | 101,721 | | |
| 3 | 7,630 | 1% | 83 | 530,089 | | |
| 4 | 3,975 | 1% | 43 | 278,535 | | |
| 5 | 706 | 1% | 8 | 44,816 | | |
| 6 | 3,370 | 1% | 37 | 315,784 | | |
| 7 | 3,623 | | | 291,804 | | |
| 8 | 4,738 | | | 489,337 | | |
| 9 | 11,124 | 1% | 121 | 1,086,699 | | |
| 10 | 3,930 | 1% | 43 | 316,384 | | |
| 11 | 1,122 | | | 81,820 | | |
| 12 | 6,335 | 1% | 69 | 455,265 | | |
| 13 | 1,849 | 1% | 20 | 154,048 | | |
| 14 | 840 | | | 79,142 | | |
| 15 | 547 | | | 40,033 | | |
| 16 | 339 | | | 27,505 | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| TOTAL | 51,966 | | 444 | 4,310,108 | | 0 |

### Table 145: 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 | | |
| 3 | 7,630 | 23% | 1,717 | 530,089 | | |
| 4 | 3,975 | 23% | 895 | 278,535 | | |
| 5 | 706 | 23% | 159 | 44,816 | | |
| 6 | 3,370 | | | 315,784 | | |
| 7 | 3,623 | | | 291,804 | | |
| 8 | 4,738 | 23% | 1,066 | 489,337 | | |
| 9 | 11,124 | 23% | 2,503 | 1,086,699 | | |
| 10 | 3,930 | 23% | 884 | 316,384 | | |
| 11 | 1,122 | | | 81,820 | | |
| 12 | 6,335 | 23% | 1,426 | 455,265 | | |
| 13 | 1,849 | 23% | 416 | 154,048 | | |
| 14 | 840 | | | 79,142 | | |
| 15 | 547 | | | 40,033 | | |
| 16 | 339 | | | 27,505 | | |
| TOTAL | 51,966 | | 9,480 | 4,310,108 | | 0 |

**Table 146: Estimated New Construction and Existing Building Stock for Multifamily Buildings by Climate Zone for High Rise Buildings with High or 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 | | | 17,126 | | |
| 2 | 1,573 | | | 101,721 | | |
| 3 | 7,630 | | | 530,089 | | |
| 4 | 3,975 | | | 278,535 | | |
| 5 | 706 | | | 44,816 | | |
| 6 | 3,370 | 55% | 1,868 | 315,784 | | |
| 7 | 3,623 | 55% | 2,009 | 291,804 | | |
| 8 | 4,738 | | | 489,337 | | |
| 9 | 11,124 | | | 1,086,699 | | |
| 10 | 3,930 | | | 316,384 | | |
| 11 | 1,122 | 55% | 622 | 81,820 | | |
| 12 | 6,335 | | | 455,265 | | |
| 13 | 1,849 | | | 154,048 | | |
| 14 | 840 | 55% | 466 | 79,142 | | |
| 15 | 547 | 55% | 303 | 40,033 | | |
| 16 | 339 | 55% | 188 | 27,505 | | |
| TOTAL | 51,966 | | 5,456 | 4,310,108 | | 0 |

### Submeasure C2: 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 147 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 147: 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 148: 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 149 and Table 150 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 149: 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 | 0% | 0 |
| 2 | 912 | 13% | 119 | 18,310 | 0% | 0 |
| 3 | 4,425 | 13% | 575 | 95,416 | 0% | 0 |
| 4 | 2,305 | 13% | 300 | 50,136 | 0% | 0 |
| 5 | 409 | 13% | 53 | 8,067 | 0% | 0 |
| 6 | 1,955 | 13% | 254 | 56,841 | 0% | 0 |
| 7 | 2,101 | 0% | 0 | 52,525 | 0% | 0 |
| 8 | 2,748 | 13% | 357 | 88,081 | 0% | 0 |
| 9 | 6,452 | 13% | 839 | 195,606 | 0% | 0 |
| 10 | 2,279 | 13% | 296 | 56,949 | 0% | 0 |
| 11 | 651 | 13% | 85 | 14,728 | 0% | 0 |
| 12 | 3,674 | 13% | 478 | 81,948 | 0% | 0 |
| 13 | 1,072 | 13% | 139 | 27,729 | 0% | 0 |
| 14 | 487 | 13% | 63 | 14,246 | 0% | 0 |
| 15 | 317 | 13% | 41 | 7,206 | 0% | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 16 | 197 | 13% | 26 | 4,951 | 0% | 0 |
| TOTAL | 30,140 | | 3,645 | 775,819 | 0% | 0 |

**Table 150: 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 | 0% | 0 |
| 2 | 519 | 22% | 114 | 18,310 | 0% | 0 |
| 3 | 2518 | 22% | 554 | 95,416 | 0% | 0 |
| 4 | 1312 | 22% | 289 | 50,136 | 0% | 0 |
| 5 | 233 | 22% | 51 | 8,067 | 0% | 0 |
| 6 | 1112 | 22% | 245 | 56,841 | 0% | 0 |
| 7 | 1196 | 0% | - | 52,525 | 0% | 0 |
| 8 | 1564 | 22% | 344 | 88,081 | 0% | 0 |
| 9 | 3671 | 22% | 808 | 195,606 | 0% | 0 |
| 10 | 1297 | 22% | 285 | 56,949 | 0% | 0 |
| 11 | 370 | 22% | 81 | 14,728 | 0% | 0 |
| 12 | 2091 | 22% | 460 | 81,948 | 0% | 0 |
| 13 | 610 | 22% | 134 | 27,729 | 0% | 0 |
| 14 | 277 | 22% | 61 | 14,246 | 0% | 0 |
| 15 | 181 | 22% | 40 | 7,206 | 0% | 0 |
| 16 | 112 | 22% | 25 | 4,951 | 0% | 0 |
| TOTAL | 17,149 | | 3,510 | 775,819 | 0% | 0 |

### Submeasure D: Envelope – Fenestration Properties

The proposed code change establishes two categories of window requirements applicable to all multifamily buildings: (1) curtain wall and storefront, and (2) all other windows. Each category's prescriptive requirements must be met on an area-weighted average basis. The proposed *All-Other* category thermal properties will result in energy savings for high-rise multifamily buildings. The change to an area-weighted average, instead of using distinct fixed and operable window categories, will likely result in energy savings as designers opt for a higher portion of low U-factor fixed windows. However, this design influence impact was not quantified or estimated by the Statewide CASE

Team, as the specific causality and impact could not be measured effectively or accurately.

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.

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 punched windows are replaced every 30 years.

Table 151 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 151: 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 | 8% | 119 | 101,721 | 0.5% | 525 |
| 3 | 7,630 | 8% | 577 | 530,089 | 0.5% | 2,735 |
| 4 | 3,975 | 8% | 301 | 278,535 | 0.5% | 1,437 |
| 5 | 706 | 8% | 53 | 44,816 | 0.5% | 231 |
| 6 | 3,370 | 8% | 255 | 315,784 | 0.5% | 1,629 |
| 7 | 3,623 | 8% | 274 | 291,804 | 0.5% | 1,506 |
| 8 | 4,738 | 8% | 358 | 489,337 | 0.5% | 2,525 |
| 9 | 11,124 | 8% | 841 | 1,086,699 | 0.5% | 5,607 |
| 10 | 3,930 | 8% | 297 | 316,384 | 0.5% | 1,633 |
| 11 | 1,122 | 8% | 85 | 81,820 | 0.5% | 422 |
| 12 | 6,335 | 8% | 479 | 455,265 | 0.5% | 2,349 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 13 | 1,849 | 8% | 140 | 154,048 | 0.5% | 795 |
| 14 | 840 | 8% | 64 | 79,142 | 0.5% | 408 |
| 15 | 547 | 8% | 41 | 40,033 | 0.5% | 207 |
| 16 | 339 | 8% | 26 | 27,505 | 0.5% | 142 |
| TOTAL | 51,966 | | 3,929 | 4,310,108 | | 22,240 |

Table 152 presents the estimated impacted number of multifamily dwelling units in high-rise buildings with non-curtain wall glazing adhering to the proposed prescriptive and alterations code changes.

**Table 152: 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 | 55% | 147 | 17,126 | 1% | 137 |
| 2 | 1,573 | 55% | 872 | 101,721 | 1% | 812 |
| 3 | 7,630 | 55% | 4,230 | 530,089 | 1% | 4,230 |
| 4 | 3,975 | 55% | 2,204 | 278,535 | 1% | 2,223 |
| 5 | 706 | 55% | 391 | 44,816 | 1% | 358 |
| 6 | 3,370 | 55% | 1,868 | 315,784 | 1% | 2,520 |
| 7 | 3,623 | 55% | 2,009 | 291,804 | 1% | 2,329 |
| 8 | 4,738 | 55% | 2,627 | 489,337 | 1% | 3,905 |
| 9 | 11,124 | 55% | 6,167 | 1,086,699 | 1% | 8,672 |
| 10 | 3,930 | 55% | 2,179 | 316,384 | 1% | 2,525 |
| 11 | 1,122 | 55% | 622 | 81,820 | 1% | 653 |
| 12 | 6,335 | 55% | 3,512 | 455,265 | 1% | 3,633 |
| 13 | 1,849 | 55% | 1,025 | 154,048 | 1% | 1,229 |
| 14 | 840 | 55% | 466 | 79,142 | 1% | 632 |
| 15 | 547 | 55% | 303 | 40,033 | 1% | 319 |
| 16 | 339 | 55% | 188 | 27,505 | 1% | 219 |
| TOTAL | 51,966 | | 28,810 | 4,310,108 | | 34,395 |

Table 153 presents the estimated impacted number of dwelling units in low-rise buildings that will adhere the proposed alterations requirements.

**Table 153: Estimated Existing Building Stock for Multifamily Buildings by Climate Zone for Low Rise Buildings using the Non-Curtainwall Requirements**

| 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 | 0% | N/A | 17,126 | 1.9% | 331 |
| 2 | 1,573 | 0% | N/A | 101,721 | 1.9% | 1,967 |
| 3 | 7,630 | 0% | N/A | 530,089 | 1.9% | 10,248 |
| 4 | 3,975 | 0% | N/A | 278,535 | 1.9% | 5,385 |
| 5 | 706 | 0% | N/A | 44,816 | 1.9% | 866 |
| 6 | 3,370 | 0% | N/A | 315,784 | 1.9% | 6,105 |
| 7 | 3,623 | 0% | N/A | 291,804 | 1.9% | 5,642 |
| 8 | 4,738 | 0% | N/A | 489,337 | 1.9% | 9,461 |
| 9 | 11,124 | 0% | N/A | 1,086,699 | 1.9% | 21,010 |
| 10 | 3,930 | 0% | N/A | 316,384 | 1.9% | 6,117 |
| 11 | 1,122 | 0% | N/A | 81,820 | 1.9% | 1,582 |
| 12 | 6,335 | 0% | N/A | 455,265 | 1.9% | 8,802 |
| 13 | 1,849 | 0% | N/A | 154,048 | 1.9% | 2,978 |
| 14 | 840 | 0% | N/A | 79,142 | 1.9% | 1,530 |
| 15 | 547 | 0% | N/A | 40,033 | 1.9% | 774 |
| 16 | 339 | 0% | N/A | 27,505 | 1.9% | 532 |
| TOTAL | 51,966 | | N/A | 4,310,108 | | 83,329 |

### 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 154 presents results from the Evergreen Economics survey representing the duct condition and location as a proportion of total projects surveyed.

**Table 154: 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 155 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 impact for this measure.

### Table 155: 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 156 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 156: 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 157 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 157: 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 158 presents results from the Evergreen Economics survey representing the duct condition and location as a proportion of total projects surveyed.

**Table 158: 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 159 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 159: 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 160 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 160: 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 161 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 161: 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 162 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 160).

**Table 162: 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 $CO_2$e.

## 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 163 and Table 164 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 163: 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.<br>• Coordinate with other team members on requirements.<br>• Complete compliance documents for permit application. | • Ensure energy code is met by clients<br>• Streamline coordination with other team members.<br>• 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 and exterior wall fire-rating<br>• Specify products and construction assemblies that meet energy code<br>• Coordinate with other team members, especially the Energy Consultant, on requirements<br>• Document energy efficiency specifications, and related details such as exterior wall fire ratings, on building plans and schedules | • Provide accurate documentation of code compliance<br>• Streamline coordination with other team members.<br>• Clearly communicate required energy efficiency requirement details for construction assemblies<br>• Ensure procurement team has the information necessary to fulfill energy requirements | Additional time to document and communicate exterior wall fire-rating | Availability of training on importance of accurate and available thermal envelope details being on construction plans |
| Plans Examiner | • Be aware of differentiation within energy code exterior wall fire-rating<br>• Locate exterior wall fire ratings on plans and confirm accurate representation in compliance documentation | • Quickly and easily determine requirements based on scope<br>• Quickly and easily determine if plans/specs match documents<br>• Quickly and easily determine if Compliance documents meet requirements<br>• Quickly and easily provide correction comments that would resolve issue | Additional time to verify exterior wall fire ratings are addressed in design documents and compliance documents | • Availability of training materials on exterior wall fire-ratings<br>• Availability of training materials on locating exterior wall fire-rating indicators on building plans and specification sheets |

| 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 | • Be aware of differentiation within energy code for exterior wall fire-rating | • Quickly and easily determine if installed products and construction assemblies match compliance documents | Additional time to verify exterior wall fire-rating | Availability of training materials on how to determine a building's exterior wall fire-rating |

Table 164: 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.<br>• Coordinate with other team members on requirements.<br>• 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 |
| HVAC Designer | • Coordinate with the energy consultant<br>• Select equipment and design system to meet requirements<br>• Incorporate relevant requirements into design documents | • Quickly and easily determine requirements based on scope and meet schedule.<br>• Demonstrate compliance with code requirements<br>• Minimize costs for Client<br>• 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. |

| 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 Contractors | • Review design documents and understand relevant requirements<br>• Install HVAC systems to meet requirements.<br>• Coordinate with HERS Rater. | • Quickly and easily determine requirements based on scope and meet schedule.<br>• Demonstrate compliance with code requirements.<br>• Streamline coordination with other team members.<br>• Clearly communicate system requirements to installation crew.<br>• Complete compliance documents required for HERS Rater and 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<br>• Proposal applies existing requirements and compliance forms as for low-rise multifamily buildings and therefore many contractors will already be familiar with the process |
| HERS Rater | • Perform required testing to confirm compliance.<br>• Verify performance meets code requirements<br>• Coordinate with HVAC contractor | • Demonstrate compliance by ensuring calculations on compliance documents meet testing requirements in code.<br>• Recommend potential fixes in case requirements are not met. | Impact is expanded portfolio of projects | N/A |
| Building Inspector/ Plans Examiners | • Understand code requirement and confirm data on documents is compliant<br>• Confirm Certificates of Installation and Certificates of Verification confirm compliance<br>• Provide correction comments as necessary | • Quickly and easily determine requirements based on scope<br>• Quickly and easily determine if plans/specs match documents<br>• Quickly and easily determine if Compliance documents meet requirements<br>• 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 forms 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 165.

**Table 165: 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 Steward | 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.

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 166 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 166: 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 167. 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 167: 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 168. There is no difference in regular maintenance between the two system types.

**Table 168: 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 169 through Table 172 for new construction.

### Table 169: 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 170: 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 171: 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 172: 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 Products

**Table 173: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction – Low-Slope Increase to 0.55 ASR, 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 | 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 | $680.93 | ($94.86) | $586.06 |
| 10 | $680.93 | ($121.97) | $558.96 |
| 11 | $793.28 | ($155.85) | $637.43 |
| 12 | N/A | N/A | N/A |
| 13 | N/A | N/A | N/A |
| 14 | $704.76 | ($243.94) | $460.82 |
| 15 | N/A | N/A | N/A |
| 16 | N/A | N/A | N/A |

**Table 174: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction – Low-Slope Increase to 0.55 ASR, 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 | 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 | $531.97 | ($23.53) | $508.45 |
| 10 | $567.44 | ($35.29) | $532.15 |
| 11 | $606.85 | ($50.98) | $555.87 |
| 12 | N/A | N/A | N/A |
| 13 | N/A | N/A | N/A |
| 14 | $512.27 | ($82.35) | $429.92 |
| 15 | N/A | N/A | N/A |
| 16 | N/A | N/A | N/A |

**Table 175: 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 | 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 | $92.07 | ($23.99) | $68.08 |
| 14 | N/A | N/A | N/A |
| 15 | $115.77 | ($9.66) | $106.11 |
| 16 | N/A | N/A | N/A |

**Table 176: 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 | 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 | $18.54 | ($4.39) | $14.15 |
| 14 | N/A | N/A | N/A |
| 15 | $22.44 | ($1.93) | $20.51 |
| 16 | N/A | N/A | N/A |

### Submeasure B: Envelope – Roof/Ceiling Insulation

**Table 177: 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 | ($6.81) | ($81.31) | ($88.12) |
| 2 | ($20.43) | $10.16 | ($10.26) |
| 3 | ($119.16) | ($30.49) | ($149.65) |
| 4 | ($177.04) | $64.37 | ($112.67) |
| 5 | ($30.64) | ($50.82) | ($81.46) |
| 6 | ($190.66) | ($6.78) | ($197.44) |
| 7 | ($228.11) | ($30.49) | ($258.60) |
| 8 | $156.61 | $6.78 | $163.39 |
| 9 | $44.26 | $33.88 | $78.14 |
| 10 | $10.21 | $33.88 | $44.09 |
| 11 | $177.04 | ($88.09) | $88.95 |
| 12 | $71.50 | ($101.64) | ($30.14) |
| 13 | ($1,307.38) | $108.42 | ($1,198.96) |
| 14 | ($108.95) | ($23.72) | ($132.66) |
| 15 | ($1,927.03) | $23.72 | ($1,903.31) |
| 16 | $6.81 | ($91.48) | ($84.67) |

**Table 178: 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 | ($66.99) | ($376.45) | ($443.44) |
| 2 | $177.33 | ($223.52) | ($46.19) |
| 3 | ($59.11) | ($113.72) | ($172.83) |
| 4 | ($63.05) | ($74.51) | ($137.55) |
| 5 | ($66.99) | ($125.48) | ($192.47) |
| 6 | ($106.40) | ($23.53) | ($129.92) |
| 7 | ($200.97) | ($7.84) | ($208.81) |
| 8 | $405.88 | ($11.76) | $394.11 |
| 9 | $216.73 | ($27.45) | $189.28 |
| 10 | $232.49 | ($58.82) | $173.67 |
| 11 | $354.65 | ($247.04) | $107.61 |
| 12 | $264.02 | ($258.81) | $5.21 |
| 13 | ($1,095.47) | ($141.17) | ($1,236.64) |
| 14 | $31.52 | ($207.83) | ($176.31) |
| 15 | ($1,690.50) | ($3.92) | ($1,694.42) |
| 16 | ($39.41) | ($458.80) | ($498.20) |

### Submeasure C1: Envelope – Wall U-Factor

**Table 179: 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 | $86.60 | $396.02 | $482.63 |
| 2 | $149.96 | $323.54 | $473.50 |
| 3 | $56.98 | $257.95 | $314.93 |
| 4 | $103.47 | $214.77 | $318.24 |
| 5 | $53.33 | $276.87 | $330.20 |
| 6 | N/A | N/A | N/A |
| 7 | N/A | N/A | N/A |
| 8 | $88.43 | $134.08 | $222.51 |
| 9 | $97.54 | $151.50 | $249.04 |
| 10 | $105.75 | $176.53 | $282.28 |
| 11 | N/A | N/A | N/A |
| 12 | $186.88 | $291.65 | $478.53 |
| 13 | $168.19 | $205.43 | $373.62 |
| 14 | N/A | N/A | N/A |
| 15 | N/A | N/A | N/A |
| 16 | N/A | N/A | N/A |

### Submeasure C2: Envelope – Quality Insulation Installation

**Table 180: 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 181: 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 182: 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 | ($180.50) | $1,039.61 | $859.11 |
| 2 | $13.22 | $278.64 | $291.85 |
| 3 | ($21.88) | $247.47 | $225.60 |
| 4 | ($9.12) | $182.66 | $173.54 |
| 5 | ($43.76) | $229.92 | $186.16 |
| 6 | ($77.49) | $108.00 | $30.51 |
| 7 | ($90.71) | $91.71 | $1.01 |
| 8 | ($56.98) | $103.92 | $46.94 |
| 9 | ($31.91) | $124.55 | $92.65 |
| 10 | ($16.86) | $141.56 | $124.70 |
| 11 | $64.27 | $251.33 | $315.60 |
| 12 | $23.70 | $232.10 | $255.80 |
| 13 | $54.24 | $190.37 | $244.61 |
| 14 | $41.02 | $243.53 | $284.55 |
| 15 | $77.94 | $71.03 | $148.97 |
| 16 | $17.78 | $436.39 | $454.17 |

**Table 183: 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 | ($486.92) | $1,459.89 | $972.96 |
| 2 | ($36.11) | $457.88 | $421.77 |
| 3 | ($84.00) | $404.93 | $320.92 |
| 4 | ($70.32) | $299.32 | $228.99 |
| 5 | ($106.05) | $381.06 | $275.01 |
| 6 | ($159.65) | $180.47 | $20.82 |
| 7 | ($161.93) | $159.25 | ($2.68) |
| 8 | ($141.40) | $173.20 | $31.80 |
| 9 | ($94.65) | $208.57 | $113.92 |
| 10 | ($68.42) | $236.03 | $167.61 |
| 11 | $32.31 | $409.39 | $441.70 |
| 12 | ($29.65) | $379.17 | $349.52 |
| 13 | $19.77 | $307.75 | $327.52 |
| 14 | $12.54 | $399.21 | $411.76 |
| 15 | $83.24 | $118.09 | $201.34 |
| 16 | ($50.55) | $698.45 | $647.90 |

**Table 184: 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 | ($121.70) | $2,161.23 | $2,039.53 |
| 2 | $185.97 | $889.34 | $1,075.31 |
| 3 | ($866.03) | $1,205.58 | $339.55 |
| 4 | $131.73 | $585.08 | $716.80 |
| 5 | ($905.23) | $1,117.22 | $211.99 |
| 6 | ($76.58) | $349.39 | $272.82 |
| 7 | ($145.40) | $296.55 | $151.15 |
| 8 | $37.83 | $336.01 | $373.85 |
| 9 | $91.62 | $399.52 | $491.13 |
| 10 | $144.03 | $456.17 | $600.20 |
| 11 | $370.11 | $805.74 | $1,175.86 |
| 12 | $237.93 | $744.51 | $982.44 |
| 13 | $358.72 | $608.25 | $966.97 |
| 14 | $318.15 | $770.59 | $1,088.74 |
| 15 | $504.58 | $227.56 | $732.14 |
| 16 | $184.60 | $1,390.18 | $1,574.79 |

**Table 185: 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 | ($610.08) | $3,100.31 | $2,490.23 |
| 2 | $217.42 | $1,432.54 | $1,649.96 |
| 3 | ($15.58) | $1,251.39 | $1,235.81 |
| 4 | $134.94 | $934.52 | $1,069.46 |
| 5 | ($96.55) | $1,175.28 | $1,078.74 |
| 6 | ($182.07) | $560.20 | $378.13 |
| 7 | ($266.46) | $488.22 | $221.76 |
| 8 | ($0.76) | $539.06 | $538.30 |
| 9 | $86.29 | $642.02 | $728.30 |
| 10 | $169.53 | $731.78 | $901.31 |
| 11 | $512.39 | $1,312.52 | $1,824.91 |
| 12 | $292.31 | $1,201.54 | $1,493.84 |
| 13 | $492.25 | $974.81 | $1,467.05 |
| 14 | $425.35 | $1,246.06 | $1,671.40 |
| 15 | $752.62 | $365.85 | $1,118.47 |
| 16 | $120.50 | $2,200.63 | $2,321.12 |

**Table 186: 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 | $779.23 | $940.77 | $1,719.99 |
| 2 | $624.14 | $1,032.98 | $1,657.13 |
| 3 | $2,614.03 | $1,432.99 | $4,047.02 |
| 4 | $626.42 | $744.34 | $1,370.76 |
| 5 | $2,537.25 | $1,378.37 | $3,915.62 |
| 6 | $313.59 | $501.76 | $815.35 |
| 7 | $185.11 | $439.38 | $624.50 |
| 8 | $465.64 | $493.51 | $959.15 |
| 9 | $640.49 | $560.65 | $1,201.14 |
| 10 | $718.41 | $599.80 | $1,318.22 |
| 11 | $995.13 | $878.43 | $1,873.56 |
| 12 | $748.82 | $872.87 | $1,621.69 |
| 13 | $978.41 | $692.59 | $1,671.00 |
| 14 | $1,043.03 | $830.28 | $1,873.30 |
| 15 | $1,491.94 | $353.41 | $1,845.35 |
| 16 | $2,618.21 | $378.52 | $2,996.73 |

**Table 187: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– Alterations - Combined Fixed, Operable, Glazed Doors Category, 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 | $808.12 | $1,694.75 | $2,502.86 |
| 2 | $1,239.55 | $1,433.67 | $2,673.22 |
| 3 | $3,045.08 | $1,787.38 | $4,832.46 |
| 4 | $1,273.38 | $1,028.45 | $2,301.82 |
| 5 | $2,948.53 | $1,718.35 | $4,666.88 |
| 6 | $830.54 | $694.94 | $1,525.48 |
| 7 | $583.09 | $602.91 | $1,186.00 |
| 8 | $1,143.38 | $686.58 | $1,829.95 |
| 9 | $1,353.20 | $772.97 | $2,126.17 |
| 10 | $1,460.77 | $827.40 | $2,288.17 |
| 11 | $1,836.70 | $1,228.20 | $3,064.90 |
| 12 | $1,461.15 | $1,214.21 | $2,675.36 |
| 13 | $1,835.94 | $955.74 | $2,791.69 |
| 14 | $1,919.95 | $1,137.91 | $3,057.86 |
| 15 | $2,680.17 | $492.23 | $3,172.40 |
| 16 | $3,064.84 | $873.51 | $3,938.35 |

### 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 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 188 and Table 189.

**Table 188: 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 | $12 | $0 | $12 |
| 2 | $108 | ($0) | $108 |
| 3 | $76 | ($0) | $76 |
| 4 | $144 | $0 | $144 |
| 5 | $61 | ($0) | $61 |
| 6 | $118 | ($0) | $118 |
| 7 | $105 | $0 | $105 |
| 8 | $156 | ($0) | $156 |
| 9 | $153 | $0 | $153 |
| 10 | $166 | $0 | $167 |
| 11 | $139 | ($1) | $138 |
| 12 | $158 | $1 | $158 |
| 13 | $210 | ($0) | $210 |
| 14 | $116 | ($0) | $115 |
| 15 | $198 | $0 | $198 |
| 16 | $60 | $0 | $60 |

**Table 189: 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 | $15 | ($0) | $15 |
| 2 | $97 | ($1) | $96 |
| 3 | $75 | ($0) | $75 |
| 4 | $131 | $0 | $131 |
| 5 | $62 | ($0) | $62 |
| 6 | $114 | ($0) | $114 |
| 7 | $105 | $0 | $105 |
| 8 | $143 | ($0) | $143 |
| 9 | $136 | ($0) | $136 |
| 10 | $147 | ($0) | $147 |
| 11 | $122 | ($0) | $121 |
| 12 | $139 | ($0) | $139 |
| 13 | $185 | ($0) | $185 |
| 14 | $99 | ($0) | $99 |
| 15 | $163 | ($0) | $163 |
| 16 | $52 | ($0) | $52 |

### 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 190 and Table 191.

**Table 190: 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 | $481 | ($272) | $209 |
| 2 | $1,064 | ($237) | $827 |
| 3 | $736 | ($187) | $549 |
| 4 | $1,148 | ($154) | $994 |
| 5 | $624 | ($165) | $459 |
| 6 | $947 | ($92) | $855 |
| 7 | $814 | ($67) | $747 |
| 8 | $1,208 | ($85) | $1,123 |
| 9 | $1,228 | ($105) | $1,124 |
| 10 | $1,337 | ($130) | $1,207 |
| 11 | $1,485 | ($240) | $1,245 |
| 12 | $1,361 | ($231) | $1,131 |
| 13 | $1,695 | ($195) | $1,500 |
| 14 | $1,381 | ($205) | $1,176 |
| 15 | $1,893 | ($59) | $1,834 |
| 16 | $1,058 | ($386) | $672 |

**Table 191: 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 | $475 | ($262) | $213 |
| 2 | $969 | ($227) | $741 |
| 3 | $712 | ($173) | $539 |
| 4 | $1,041 | ($147) | $895 |
| 5 | $618 | ($151) | $467 |
| 6 | $911 | ($86) | $825 |
| 7 | $825 | ($73) | $752 |
| 8 | $1,100 | ($78) | $1,022 |
| 9 | $1,103 | ($97) | $1,006 |
| 10 | $1,197 | ($122) | $1,074 |
| 11 | $1,337 | ($244) | $1,093 |
| 12 | $1,200 | ($218) | $982 |
| 13 | $1,468 | ($184) | $1,283 |
| 14 | $1,242 | ($201) | $1,041 |
| 15 | $1,561 | ($56) | $1,504 |
| 16 | $1,022 | ($386) | $637 |

### 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 192 and Table 193.

**Table 192: 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 | $22 | $0 | $22 |
| 2 | $251 | $0 | $251 |
| 3 | $149 | $0 | $149 |
| 4 | $301 | $0 | $301 |
| 5 | $122 | $0 | $122 |
| 6 | $264 | $0 | $264 |
| 7 | $234 | $0 | $234 |
| 8 | $354 | $0 | $354 |
| 9 | $363 | $0 | $363 |
| 10 | $383 | $0 | $383 |
| 11 | $454 | $0 | $454 |
| 12 | $356 | $0 | $356 |
| 13 | $501 | $0 | $501 |
| 14 | $436 | $0 | $436 |
| 15 | $728 | $0 | $728 |
| 16 | $148 | $0 | $148 |

**Table 193: 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 | $30 | $0 | $30 |
| 2 | $225 | $0 | $225 |
| 3 | $150 | $0 | $150 |
| 4 | $272 | $0 | $272 |
| 5 | $131 | $0 | $131 |
| 6 | $259 | $0 | $259 |
| 7 | $241 | $0 | $241 |
| 8 | $325 | $0 | $325 |
| 9 | $326 | $0 | $326 |
| 10 | $342 | $0 | $342 |
| 11 | $392 | $0 | $392 |
| 12 | $306 | $0 | $306 |
| 13 | $423 | $0 | $423 |
| 14 | $386 | $0 | $386 |
| 15 | $593 | $0 | $593 |
| 16 | $150 | $0 | $150 |

# Appendix I: Marked Up Standards

# SUBCHAPTER 10
# MULTIFAMILY BUILDINGS—MANDATORY REQUIREMENTS

## SECTION 160.0 – GENERAL

Multifamily buildings shall comply with the applicable requirements of Sections 160.1 through 160.8. Sections 160.1 through 160.8 apply to attached dwelling units and common use areas in multifamily buildings. Nonresidential occupancies in mixed occupancy buildings shall comply with nonresidential requirements in Sections 120,0 through 141.1

**NOTE**: The requirements of Sections 160.1 through 160.8 apply to newly constructed buildings. Sections 180.1 through 180.4 specify which requirements of Sections 160.1 through 160.8 apply to additions or alterations.

# SECTION 160.1 – MANDATORY REQUIREMENTS FOR BUILDING ENVELOPES

(a) **Ceiling and ~~Rafter~~ Roof Insulation.** The opaque portions of ceilings and roofs separating conditioned spaces from unconditioned spaces or ambient air shall have insulation installed in direct contact with the continuous roof or ceiling which is sealed to limit infiltration and exfiltration as specified in Section 110.7, including but not limited to placing insulation either above or below the roof deck or on top of the finished ceiling. Insulation shall meet the requirements of Item~~s~~ 1 ~~through 3~~ or 2 below:

1. **Attic Roof**. Shall meet the requirements of Items A through C below:

   A. Shall be insulated to achieve a weighted average U-factor not exceeding U-0.043 or shall be insulated between wood-framing members with insulation resulting in an installed thermal resistance of R-22 or greater for the insulation alone. For vented attics, the mandatory insulation shall be installed at the ceiling level; for unvented attics, the mandatory insulation shall be placed at either ceiling or roof level; and

   B. Attic access doors shall have permanently attached insulation using adhesive or mechanical fasteners. The attic access shall be gasketed to prevent air leakage; and

   C. When loose-fill insulation is installed, the minimum installed weight per square foot shall conform with the insulation manufacturer's installed design weight per square foot at the manufacturer's labeled R-value.

2. **Non Attic Roof**. All roofs other than attic roofs shall meet the applicable requirements of items A through D below:

   A. **Metal Building**- The weighted average U-factor of the roof assembly shall not exceed 0.098.

   B. **Wood Framed and Others**- The weighted average U-factor of the roof assembly shall not exceed 0.075.

   C. **Insulation Placement**- When insulation is installed at the roof~~in nonresidential buildings,~~ fixed vents or openings to the outdoors or to unconditioned spaces shall not be installed. When the space between the ceiling and the roof is either directly or indirectly conditioned space, it shall not be considered an attic for the purposes of complying with CBC attic ventilation requirements.

   ~~D. Insulation placed on top of a suspended ceiling with removable ceiling panels shall not be used to meet the Roof/Ceiling requirement of Sections 140.3 and 141.0.~~

   **NOTE:** Vents that do not penetrate the roof deck and are instead designed for wind resistance for roof membranes are not within the scope of Section ~~120.7(a)3B~~ 160.1(a)1C.

(b) **Wall Insulation.** Opaque portions of above grade walls separating conditioned spaces from unconditioned spaces or ambient air shall meet the following applicable requirements:

1. **Metal Building-** The weighted average U-factor of the wall assembly shall not exceed 0.113.

2. **Metal Framed-** The weighted average U-factor of the wall assembly shall not exceed 0.151.

3. **Wood Framed and Others-**

   A. Nominal 2x4 inch framing shall have a weighted average U-factor of the wall assembly not exceeding 0.102.

   B. Nominal 2x6 inch framing shall have a weighted average U-factor of the wall assembly not exceeding 0.071.

   C. Other wall assemblies shall have a weighted average U-factor of the wall assembly not exceeding 0.102.

4. **Light Mass Walls-** A 6 inch or greater Hollow Core Concrete Masonry Unit shall have a U-factor not to exceed 0.440.

5. **Heavy Mass Walls-** An 8 inch or greater Hollow Core Concrete Masonry Unit shall have a U-factor not to exceed 0.690.

6. **Spandrel Panels and Curtain Wall-** The weighted average U-factor of the spandrel panels and curtain wall assembly shall not exceed 0.280.

7. **Demising Walls-**. The opaque portions of framed demising walls shall meet the requirements of Item A or B below:

   A. Wood framed walls shall be insulated to meet a U-factor not greater than 0.099.

   B. Metal Framed walls shall be insulated to meet a U-factor not greater than 0.151.

8. **Bay or Bow Window roofs and floors**. Shall be insulated to meet the wall insulation requirements of TABLE ~~150.1-A or B~~170.2-A.

(c) **Floor and Soffit Insulation.** The opaque portions of floors and soffits that separate conditioned spaces from unconditioned spaces or ambient air shall meet the applicable requirements of Items 1 through 3 below:

1. **Raised Mass Floors** - Shall have a minimum of 3 inches of lightweight concrete over a metal deck or the weighted average U-factor of the floor assembly shall not exceed 0.269.
2. **Raised Wood Floor** - shall have an overall assembly U-factor not exceeding U-0.037. In a wood framed assembly, compliance with the U-factor may be demonstrated by installing insulation with an R-value of 19 or greater.
3. **Other Floors** -The weighted average U-factor of the floor assembly shall not exceed 0.071.
4. **Heated Slab On Grade Floor-**A heated slab on grade floor shall be insulated to meet the requirements of Section 110.8(g)

**EXCEPTION to Section ~~150.0(d)~~ 160.0(c):** A building with a controlled ventilation or unvented crawlspace may omit raised floor insulation if all of the following are met:

A. The foundation walls are insulated to meet the wall insulation minimums as shown in TABLE ~~150.1-A or B~~ 170.2-A; and

B. A Class I or Class II vapor retarder is placed over the entire floor of the crawlspace; and

C. Vents between the crawlspace and outside air are fitted with automatically operated louvers that are temperature actuated; and

D. The requirements in Reference Residential Appendix RA4.5.1.

(d) **Vapor Retarder.**

1. In Climate Zones 1-16, the earth floor of unvented crawl space shall be covered with a Class I or Class II vapor retarder. This requirement shall also apply to controlled ventilation crawl space for buildings complying with the Exception to **Section ~~150.0(d)~~ 160.1(c).**
2. In Climate Zones 14 and 16, a Class I or Class II vapor retarder shall be installed on the conditioned space side of all insulation in all exterior walls, vented attics and unvented attics with air-permeable insulation.

(e) **Fenestration Products.** Fenestration separating conditioned space from unconditioned space or outdoors shall meet the requirements of either Item 1 or 2 below:

1. Fenestration, including skylight products, must have a maximum U-factor of 0.58.
2. The weighted average U-factor of all fenestration, including skylight products, shall not exceed 0.58.

**EXCEPTION 1 to Section ~~150.0(q)1~~ 160.1(e)1:** Up to ~~10 square feet of fenestration area or~~ 0.5 percent of the Conditioned Floor Area, ~~whichever is greater,~~ is exempt from the maximum U-factor requirement.

**EXCEPTION 2 to Section ~~150.0(q)1~~ 160.1(e)1:** For dual-glazed greenhouse or garden windows, up to 30 square feet of fenestration area per dwelling unit is exempt from the maximum U-factor requirement.

(f) **Installation of Fireplaces, Decorative Gas Appliances and Gas Logs.** If a masonry or factory-built fireplace is installed, it shall comply with Section 110.5, Section 4.503 of Part 11, and shall have the following:

1. Closeable metal or glass doors covering the entire opening of the firebox; and
2. A combustion air intake to draw air from the outside of the building, which is at least 6 square inches in area and is equipped with a readily accessible, operable, and tight-fitting damper or combustion-air control device; and

**EXCEPTION to Section ~~150.0(e)1B~~ 160.1(f)2:** An outside combustion-air intake is not required if the fireplace will be installed over concrete slab flooring and the fireplace will not be located on an exterior wall.

3. A flue damper with a readily accessible control.

**EXCEPTION to Section ~~150.0(e)1C~~ 160.1(f)3:** When a gas log, log lighter, or decorative gas appliance is installed in a fireplace, the flue damper shall be blocked open if required by the CMC or the manufacturer's installation instructions.

# SECTION 160.2 – MANDATORY REQUIREMENTS FOR VENTILATION AND INDOOR AIR QUALITY

(a) **General Requirements.**

1. Attached dwellings units shall comply with the requirements of subsection 160.2(b) below. Occupiable spaces other than attached dwelling units shall comply with the requirements of section 160.2(c).

2. The required outdoor air-ventilation rate and the air-distribution system design shall be clearly identified on the plans in accordance with Section 10-103 of Title 24, Part 1.

(b) **Dwelling Units.** Attached dwellings units shall comply with the requirements of subsections 1 and 2 below.

1. **Air Filtration.**

A. System types specified in subsections i, ii, and iii shall be provided with air filters in accordance with Sections ~~150.0(m)12B, 150.0(m)12C, and 150.0(m)12D~~160.2(b)1B, 160.2(b)1C, and 160.2(b)1D. System types specified in subsection i shall also comply with Section ~~150.0(m)12E~~160.2(b)1E.

i. Mechanical space conditioning systems that supply air to an occupiable space through ductwork exceeding 10 ft (3 m) in length.

ii. Mechanical supply-only ventilation systems that provide outside air to an occupiable space.

iii. The supply side of mechanical balanced ventilation systems, including heat recovery ventilation systems, and energy recovery ventilation systems that provide outside air to an occupiable space.

**EXCEPTION 1 to ~~Section 150.0(m)12~~160.2(b)1A:** Evaporative coolers are exempt from the air filtration requirements in Section ~~150.0(m)12~~160.2(b)1.

B. **System Design and Installation.**

i. The system shall be designed to ensure that all recirculated air or outdoor air supplied to the occupiable space is filtered before passing through any system thermal conditioning components.

**EXCEPTION ~~1~~ to ~~Section 150.0(m)12~~160.2(b)1Bi:** For heat recovery ventilators and energy recovery ventilators the location of the filters required by Section ~~150.0(m)12~~160.2(a)1 may be downstream of a system thermal conditioning component, provided the system is equipped with ancillary filtration upstream of the system's thermal conditioning component.

ii. All systems shall be designed to accommodate the clean-filter pressure drop imposed by the system air filter(s). The design airflow rate, and maximum allowable clean-filter pressure drop at the design airflow rate applicable to each air filter shall be determined and reported on labels according to subsection iv below.

Systems specified in Section ~~150.0(m)12~~160.2(b)1Ai shall be equipped with air filters that meet either subsection a or b below

a. Nominal two-inch minimum depth filter(s) shall be sized by the system designer, or

b. Nominal one-inch minimum depth filter(s) shall be allowed if the filter(s) are sized according to Equation ~~150.0~~160.2-A, based on a maximum face velocity of 150 ft per minute, and according to the maximum allowable clean-filter pressure drop specified in Section ~~150.0(m)12~~160.2(b)1Dii.

$$A_{face} = Q_{filter} / V_{face} \qquad \text{(Equation } \cancel{150.0}\,160.2\text{-A)}$$

where

$A_{face}$ = air filter face area, the product of air filter nominal length x nominal width, ft$^2$

$Q_{filter}$ = design airflow rate for the air filter, ft$^3$/min

$V_{face}$ = air filter face velocity $\leq$ 150, ft/min

iii. All system air filters shall be located and installed in such a manner as to be accessible for regular service by the system owner.

iv. All system air filter installation locations shall be labeled to disclose the applicable design airflow rate and the maximum allowable clean-filter pressure drop. The labels shall be permanently affixed to the air filter installation location, readily legible, and visible to a person replacing the air filter.

C. **Air Filter Efficiency**. The system shall be provided with air filter(s) having a designated efficiency equal to or greater than MERV 13 when tested in accordance with ASHRAE Standard 52.2, or a particle size efficiency rating equal to or greater than 50 percent in the 0.30-1.0 µm range, and equal to or greater than 85 percent in the 1.0-3.0 µm range when tested in accordance with AHRI Standard 680.

D. **Air Filter Pressure Drop**. All systems shall be provided with air filter(s) that conform to the applicable maximum allowable clean-filter pressure drop specified in subsections i, ii, iii, or iv below, when tested using ASHRAE Standard 52.2, or as rated using AHRI Standard 680, for the applicable design airflow rate(s) for the system air filter(s).

i. The maximum allowable clean-filter pressure drop determined by the system design for the nominal two-inch minimum depth air filter required by Section ~~150.0(m)12~~160.2(b)1Biia, or

ii. A maximum of 25 PA (0.1 inches water) clean-filter pressure drop shall be allowed for a nominal one-inch depth air filter sized according to Section ~~150.0(m)12~~160.2(b)1Biib, or

iii. For systems specified in ~~150.0(m)12~~160.2(b)1Aii, and ~~150.0(m)12~~160.2(b)1Aiii, the maximum allowable clean filter pressure drop determined by the system design.

iv. If EXCEPTION 1 to **Section** ~~150.0(m)13B~~160.3(b)5Lii or ~~D~~ii is utilized for compliance with cooling system airflow rate and fan efficacy requirements, the clean-filter pressure drop for the system air filter shall conform to the requirements given in TABLE ~~150.0-B~~160.3-A or ~~150.0-C~~160.3-B.

E. **Air Filter Product Labeling**. Systems described in ~~150.0(m)12~~160.2(b)1Ai shall be equipped with air filters that have been labeled by the manufacturer to disclose the efficiency and pressure drop ratings that demonstrate conformance with Sections ~~150.0(m)12~~160.2(b)1C and ~~150.0(m)12~~160.2(b)1D.

2. **Ventilation and Indoor Air Quality.** All dwelling units shall meet the requirements of ASHRAE Standard 62.2, Ventilation and Acceptable Indoor Air Quality in Residential Buildings subject to the amendments specified in Section ~~150.0(o)1~~160.2(b)2A below. All dwelling units shall comply with Section ~~150.0(o)~~ 160.2(b)2B below.

A. Amendments to ASHRAE 62.2 Requirements.

i. Window operation is not a permissible method of providing the dwelling unit ventilation airflow specified in subsections ~~C, E, or F~~ iii, v, or vi below.

ii. Continuous operation of central forced air system air handlers used in central fan integrated ventilation systems is not a permissible method of providing the dwelling unit ventilation airflow required in Section 4 of ASHRAE Standard 62.2.

iii. ~~Single family detached dwelling units, and~~ Attached dwelling units not sharing ceilings or floors with other dwelling units or occupiable spaces, public garages, or commercial spaces shall have mechanical ventilation airflow provided at rates determined in accordance with ASHRAE 62.2 Sections 4.1.1 and 4.1.2 as specified in subsections ~~i, ii, and iii~~ a, b, and c below.

a. Total Required Ventilation Rate [ASHRAE 62.2:4.1.1]. The total required ventilation rate shall be calculated using Equation ~~150.0~~160.2-B

$$Q_{tot} = 0.03A_{floor} + 7.5(N_{br} + 1)$$ (Equation ~~150.0~~160.2-B)

*where*

$Q_{tot}$ = *total required ventilation rate, cfm*

$A_{floor}$ = *dwelling-unit floor area, ft*$^2$

$N_{br}$ = *number of bedrooms (not to be less than 1)*

b. Effective Annual Average Infiltration Rate. The effective annual average infiltration rate shall be determined in accordance with subsections a and b:

I. An enclosure leakage rate in cubic feet per minute at 50 Pa (0.2 inch water) ($Q_{50}$) shall be determined by either subsection 1, or subsection 2 below.

A. $Q_{50}$ shall be calculated based on the conditioned volume of the dwelling unit and a default value for dwelling unit envelope leakage of 2 air changes per hour at 50 PA (0.2 inch water) (2 ACH50) as specified by Equation ~~150.0~~160.2-C below.

$Q_{50} = V_{du}$ x 2 $ACH_{50}$ / 60 min (Equation ~~150.0~~160.2-C)

where

$Q_{50}$ = leakage rate at 50 Pa

$V_{du}$ = dwelling unit conditioned volume, $ft^3$

$ACH_{50}$ = air changes per hour at 50 Pa (0.2 inch water)

B. If dwelling unit envelope leakage less than 2 $ACH_{50}$ is confirmed by field verification and diagnostic testing, $Q_{50}$ shall be calculated according to Equation ~~150.0~~160.2-D below, using the value for dwelling unit envelope leakage less than 2 $ACH_{50}$ verified by the procedures specified in Reference Residential Appendix RA3.8.

$Q_{50} = V_{du}$ x *Verified* $ACH_{50}$ / 60 min (Equation ~~150.0~~160.2-D)

where

$Q_{50}$ = leakage rate at 50 Pa

$V_{du}$ = dwelling unit conditioned volume, $ft^3$

$ACH_{50}$ = air changes per hour at 50 Pa (0.2 inch water)

II. The Effective Annual Average Infiltration Rate ($Q_{inf}$) shall be calculated using Equation ~~150.0~~160.2-E [ASHRAE 62.2:4.1.2.1].

$Qinf = 0.052 \times Q_{50} \times wsf \times [H/Hr]z$ (Equation ~~150.0~~160.2-E)

where

$Qinf$ = effective annual infiltration rate, cfm (L/s)

$Q_{50}$ = leakage rate at 50 Pa from equation ~~150.0~~160.2-C, or equation ~~150.0~~160.2-D

$wsf$ = weather and shielding factor from Table ~~150.0-D~~ 160.2-A

$H$ = vertical distance between the lowest and highest above-grade points within the pressure boundary, ft (m)

$Hr$ = reference height, 8.2 ft (2.5 m)

$z$ = 0.4 for the purpose of calculating the Effective Annual Average Infiltration Rate

c. Required Mechanical Ventilation Rate [ASHRAE 62.2:4.1.2]

The Required Mechanical Ventilation Rate (Qfan) shall be calculated using Equation ~~150.0~~160.2-F

$Q_{fan} = Q_{tot} - \Phi (Q_{inf} \times A_{ext})$ (Equation ~~150.0~~160.2-F)

where

$Q_{fan}$ = required mechanical ventilation rate, cfm (L/s)

$Q_{tot}$ = total required ventilation rate, cfm (L/s) from Equation ~~150.0~~160.2-B.

$Q_{inf}$ = effective annual average infiltration rate, cfm (L/s) from Equation ~~150.0~~160.2-E

$A_{ext}$ = ~~1 for single-family detached homes, or~~ the ratio of exterior envelope surface area that is not attached to garages or other dwelling units to total envelope surface area for attached dwelling units not sharing ceilings or floors with other dwelling units, occupiable spaces, public garages, or commercial spaces.

$\Phi$=1 for balanced ventilation systems and $Q_{inf}/Q_{tot}$ otherwise

iv. Air filtration shall conform to the specifications in Section ~~150.0(m)12~~160.2(b)1. Compliance with ASHRAE 62.2 Sections 6.7 (Minimum Filtration) and 6.7.1 (Filter Pressure Drop) shall not be required.

v. Multifamily attached dwelling units shall have mechanical ventilation airflow provided at rates in accordance with Equation ~~150.0~~160.2-B [ASHRAE 62.2:4.1.1] and comply with one of the following subsections ~~i or ii~~ a or b below. When subsection ~~ii~~ b below is utilized for compliance, all dwelling units in the multifamily building shall use the same ventilation system type.

a. A balanced ventilation system shall provide the required dwelling-unit ventilation airflow, or

b. Continuously operating supply ventilation systems, or continuously operating exhaust ventilation systems shall be allowed to be used to provide the required dwelling unit ventilation airflow if the dwelling-unit envelope leakage is less than or equal to 0.3 cubic feet per minute at 50 Pa (0.2 inch water) per $ft^2$ of dwelling unit envelope surface area as confirmed by field verification and diagnostic testing in accordance with the procedures specified in Reference Residential Appendix RA3.8.

vi. Multifamily building central ventilation systems that serve multiple dwelling units shall be balanced to provide ventilation airflow for each dwelling unit served at a rate equal to or greater than the rate specified by Equation ~~150.0~~160.2-B [ASHRAE 62.2:4.1.1], but no more than twenty percent greater than the specified rate. These systems shall utilize balancing means to ensure the dwelling-unit airflows can be adjusted to meet this balancing requirement. These system balancing means may include but not be limited to constant air regulation devices, orifice plates, and variable speed central fans.

vii. Kitchen range hoods shall be rated for sound in accordance with Section 7.2 of ASHRAE 62.2.

**EXCEPTION to Section ~~150.0(o)1G~~160.2(b)2Avii**: Kitchen range hoods may be rated for sound at a static pressure determined at working speed as specified in HVI 916 section 7.2.

viii. Compliance with ASHRAE 62.2 Section 6.5.2 (Space Conditioning System Ducts) shall not be required.

ix. **Compliance with ASHRAE 62.2 4.4 (Control and Operation).** Compliance with ASHRAE 62.2 Section 4.4 (Control and Operation) shall require manual switches associated with dwelling unit ventilation systems to have a label clearly displaying the following text, or equivalent text: "This switch controls the indoor air quality ventilation for the home. Leave it on unless the outdoor air quality is very poor."

B. **Field Verification and Diagnostic Testing**.

i. **Airflow Performance**. The dwelling unit ventilation airflow required by Sections ~~150.0(o)1C~~160.2(b)2Aiii, ~~150.0(o)1E~~160.2(b)2Av, and ~~150.0(o)1F~~160.2(b)2Avi shall be confirmed through field verification and diagnostic testing in accordance with the applicable procedures specified in Reference Residential Appendix RA3.7 or Reference Nonresidential Appendix NA7.18.1.

ii. **Kitchen Range Hoods**. The installed kitchen range hood shall be field verified in accordance with the procedures in Reference Residential Appendix RA3.7.4.3 to confirm the model is rated by HVI to comply with the following requirements:

a. The minimum ventilation airflow rate as specified in Section 5 of ASHRAE 62.2.

b. The maximum sound rating as specified in ~~150.0(o)1G~~160.2(b)2Avii.

(c) **Common Use Areas.** All occupiable spaces shall meet the requirements of subsection 1 and either 2 or 3:

1. **Air Filtration**

A. Mechanical system types described in ~~Section 120.1(b)1A~~ subsections i, ii, and iii shall be provided with air filters to clean the outside and return air prior to its introduction into occupied spaces.

i. Mechanical space conditioning systems that supply air to an occupiable space through ductwork exceeding 10 ft (3 m) in length.

ii. Mechanical supply-only ventilation systems that provide outside air to an occupiable space.

iii. The supply side of mechanical balanced ventilation systems, including heat recovery ventilation systems, and energy recovery ventilation systems that provide outside air to an occupiable space.

B. Air Filter Efficiency. The filters shall have a designated efficiency equal to or greater than MERV 13 when tested in accordance with ASHRAE Standard 52.2, or a particle size efficiency rating equal to or greater than 50 percent in the 0.30-1.0 µm range, and equal to or greater than 85 percent in the 1.0-3.0 µm range when tested in accordance with AHRI Standard 680; and

C. Systems shall be equipped with air filters that meet either subsection i or ii below.

i. Nominal two inch minimum depth filter(s); or

ii. Nominal one inch minimum depth filter(s) shall be allowed if the filter(s) are sized according to Equation ~~120.1~~160.2-A, based on a maximum face velocity of 150 ft per minute.

2. **Natural Ventilation.** Naturally ventilated spaces shall be designed in accordance with ~~120.1(c)~~160.2(c)2A through ~~120.1(c)~~160.2(c)2C and include a mechanical ventilation system designed in accordance with ~~120.1(c)~~160.2(c)3:

**EXCEPTION 1 to ~~120.1(c)~~ 160.2(c)2:** The mechanical ventilation system shall not be required where natural ventilation openings complying with ~~120.1(c)~~160.2(c)2 are either permanently open or have controls that prevent the openings from being closed during periods of expected occupancy.

**EXCEPTION 2 to Section ~~120.1(c)~~ 160.2(c)2**: The mechanical ventilation system shall not be required where the zone is not served by a space conditioning system.

A. Floor area to be ventilated. Spaces or portions of spaces to be naturally ventilated shall be located within a distance based on the ceiling height, as specified in i, ii and iii. The ceiling height (H) to be used in i, ii or iii shall be the minimum ceiling height in the space, or for ceilings that are increasing in height as distance from the operable openings is increased, the ceiling height shall be determined as the average height of the ceiling within 20 ft from the operable opening. [ASHRAE 62.1:6.4.1]

i. Single Side Opening. For spaces with operable opening on one side of the space, the maximum distance from the operable opening shall be not more than 2H. [ASHRAE 62.1:6.4.1.1]

ii. Double Side Opening. For spaces with operable openings on two opposite sides of the space, the maximum distance from the operable opening shall be not more than 5H. [ASHRAE 62.1:6.4.1.2]

iii. Corner Opening. For spaces with operable openings on two adjacent sides of a space, the maximum distance from the operable openings shall be not more than 5H along a line drawn between the two openings that are the farthest apart. Floor area outside that line shall comply with i or ii. [ASHRAE 62.1:6.4.1.3]

iv. Ceiling Height. The ceiling height (h) to be used in Section ~~120.1~~160.2(c)2Ai through ~~120.1~~160.2 (c)2Aiii shall be the minimum ceiling height in the space.

**EXCEPTION to Section ~~120.1~~160.2(c)2Aiv:** For ceilings that are increasing in height as distance from the opening is increased, the ceiling height shall be determined as the average height of the ceiling within 20 feet from the operable openings. [ASHRAE 62.1:6.4.1.4]

B. Location and Size of Openings. Spaces or portions of spaces to be naturally ventilated shall be permanently open to operable wall openings directly to the outdoors. The openable area shall be not less than 4 percent of the net occupiable floor area. Where openings are covered with louvers or otherwise obstructed, the openable area shall be based on the net free unobstructed area through the opening. Where interior rooms, or portions of rooms, without direct openings to the outdoors are ventilated through adjoining rooms, the opening between rooms shall be permanently unobstructed and have a free area of not less than 8 percent of the area of the interior room or less than 25 square feet. [ASHRAE 62.1:6.4.2]

C. Control and Accessibility. The means to open the required operable opening shall be readily accessible to building occupants whenever the space is occupied. Controls shall be designed to coordinate operation of the natural and mechanical ventilation systems. [ASHRAE 62.1:6.4.3]

3. **Mechanical Ventilation.** Occupiable spaces shall be ventilated with a mechanical ventilation system capable of providing an outdoor airflow rate ($V_z$) to the zone no less than the larger of A or B as described below:

A. The outdoor airflow rate to the zone ($V_z$) shall be determined in accordance with Equation ~~120.1-F~~160.2-G; or

$V_z = R_a \times A_z$ (Equation ~~120.1-F~~160.2-G)

Where:

$R_a$ = Outdoor airflow rate required per unit area as determined from Table ~~120.1~~160.2-B.

$A_z$ = Zone floor area is the net occupiable floor area of the ventilation zone in square feet.

B. For spaces designed for an expected number of occupants ~~or spaces with fixed seating~~, the outdoor airflow rate to the zone ($V_z$) shall be determined in accordance with Equation ~~120.1-G~~160.2-H;

$V_z = R_p \times P_z$ (Equation ~~120.1-G~~160.2-H)

Where:

$R_p$ = 15 cubic feet per minute of outdoor airflow per person

$P_z$ = The expected number of occupants. The expected number of occupants shall be the expected number specified by the building designer. For spaces with fixed seating, the expected number of occupants shall be determined in accordance with the California Building Code.

**EXCEPTION to Section ~~120.1(c)3~~160.2(c)3: Transfer air.** The rate of outdoor air required by Section ~~120.1(c)3~~160.2(c)3 may be provided with air transferred from other ventilated space if:

i. Use of transfer air is in accordance with Section ~~120.1(g)~~160.2(c)8; and

ii. The outdoor air that is supplied to all spaces combined, is sufficient to meet the requirements of Section ~~120.1~~160.2(c)3 for each space individually.

4. **Exhaust Ventilation.** The design exhaust airflow shall be determined in accordance with the requirements in Table ~~120.1-B~~160.2-C. Exhaust makeup air shall be permitted to be any combination of outdoor air, recirculated air, or transfer air. [ASHRAE 62.1:6.5.1]

5. **Operation and Control Requirements for Minimum Quantities of Outdoor Air**.

A. **Times of occupancy.** The minimum rate of outdoor air required by Section ~~120.1~~160.2(c) shall be supplied to each space at all times when the space is usually occupied.

**EXCEPTION 1 to Section ~~120.1(d)1~~160.2(c)5A:** Demand control ventilation. In intermittently occupied spaces that do not have processes or operations that generate dusts, fumes, mists, vapors or gasses and are not provided with local exhaust ventilation (such as indoor operation of internal combustion engines or areas designated for unvented food service preparation), the rate of outdoor air may be reduced if the ventilation system serving the space is controlled by a demand control ventilation device complying with Section ~~120.1(d)4~~160.2(c)5D or by an occupant sensor ventilation control device complying with Section ~~120.1(d)5~~160.2(c)5E.

**EXCEPTION 2 to Section ~~120.1(d)1~~160.2(c)5A:** Temporary reduction. The rate of outdoor air provided to a space may be reduced below the level required by Section ~~120.1~~160.2(c) for up to 30 minutes at a time if the average rate for each hour is equal to or greater than the required ventilation rate.

B. **Pre-occupancy.** The lesser of the minimum rate of outdoor air required by Section ~~120.1~~160.2(c) or three complete air changes shall be supplied to the entire building during the 1-hour period immediately before the building is normally occupied.

C. **Required Demand Control Ventilation.** Demand ventilation controls complying with ~~120.1(d)4~~160.2(c)5D are required for a space with a design occupant density, or a maximum occupant load factor for egress purposes in the CBC, greater than or equal to 25 people per 1000 square feet (40 square feet or less per person) if the system serving the space has one or more of the following:

i. an air economizer; or

ii. modulating outside air control; or

iii. design outdoor airflow rate > 3,000 cfm.

**EXCEPTION 1 to Section ~~120.1(d)3~~160.2(c)5C:** Where space exhaust is greater than the design ventilation rate specified in Section ~~120.1(c)3~~160.2(c)3 minus 0.2 cfm per ft² of conditioned area.

**EXCEPTION 2 to Section ~~120.1(d)3~~160.2(c)5C:** Spaces that have processes or operations that generate dusts, fumes, mists, vapors, or gases and are not provided with local exhaust ventilation, such as indoor operation of internal combustion engines or areas designated for unvented food service preparation, daycare sickrooms, science labs, barber shops or beauty and nail salons shall not install demand control ventilation.

**EXCEPTION 3 to Section ~~120.1(d)3~~160.2(c)5C:** Spaces with an area of less than 150 square feet, or a design occupancy of less than 10 people as specified by Section ~~120.1(c)3~~160.2(c)3.

**D. Demand Control Ventilation Devices.**

i. For each system with demand control ventilation (DCV), CO2 sensors shall be installed in each room that meets the criteria of Section ~~120.1(d)3~~160.2(c)5C with no less than one sensor per 10,000 ft² of floor space. When a zone or a space is served by more than one sensor, a signal from any sensor indicating that CO2 is near or at the setpoint within the zone or space shall trigger an increase in ventilation.

ii. CO2 sensors shall be located in the room between 3 ft and 6 ft above the floor or at the anticipated height of the occupants' heads.

iii. Demand ventilation controls shall maintain CO2 concentrations less than or equal to 600 ppm plus the outdoor air CO2 concentration in all rooms with CO2 sensors.

**EXCEPTION to Section ~~120.1(d)4C~~ 160.2(c)5Diii:** The outdoor air ventilation rate is not required to be larger than the design outdoor air ventilation rate required by Section ~~120.1(c)3~~160.2(c)3 regardless of $CO_2$ concentration.

iv. Outdoor air CO2 concentration shall be determined by one of the following:

a. $CO_2$ concentration shall be assumed to be 400 ppm without any direct measurement; or

b. $CO_2$ concentration shall be dynamically measured using a $CO_2$ sensor located within 4 ft of the outdoor air intake.

v. When the system is operating during hours of expected occupancy, the controls shall maintain system outdoor air ventilation rates no less than the rate listed in Table ~~120.1-A~~160.2-B for DCV, times the conditioned floor area for spaces with CO2 sensors, plus the rate required by Section ~~120.1(c)3~~160.2(c)3 for other spaces served by the system, or the exhaust air rate whichever is greater.

vi. CO2 sensors shall be certified by the manufacturer to be accurate within plus or minus 75 ppm at a 600 and 1000 ppm concentration when measured at sea level and 25°C, factory calibrated, and certified by the manufacturer to require calibration no more frequently than once every 5 years. Upon detection of sensor failure, the system shall provide a signal which resets to supply the minimum quantity of outside air to levels required by Section ~~120.1(c)3~~160.2(c)3 to the zone serviced by the sensor at all times that the zone is occupied.

vii. The CO2 sensor(s) reading for each zone shall be displayed continuously, and shall be recorded on systems with DDC to the zone level.

E. **Occupant Sensor Ventilation Control Devices.** When occupancy sensor ventilation devices are required by Section ~~120.2(e)3~~160.3(a)2Diii, occupant sensors shall be used to reduce the rate of outdoor air flow when occupants are not present in accordance with the following:

i. Occupant sensors shall meet the requirements in Section 110.9(b)4 and shall have suitable coverage and placement to detect occupants in the entire space ventilated. If occupant sensors controlling lighting are used for ventilation, the ventilation signal shall be independent of daylighting, manual lighting overrides or manual control of lighting. When a single zone damper or a single zone system serves multiple rooms, there shall be an occupancy sensor in each room and the zone is not considered vacant until all rooms in the zone are vacant.

ii. One hour prior to normal scheduled occupancy, the occupancy sensor ventilation control shall allow pre-occupancy purge as described in Section ~~120.1(d)2~~160.2(c)5B.

6. **Ducting for Zonal Heating and Cooling Units.** Where a return plenum is used to distribute outdoor air to a zonal heating or cooling unit which then supplies the air to a space in order to meet the requirements of Section ~~120.1(c)3~~160.2(c)3, the outdoor air shall be ducted to discharge either:

A. Within 5 feet of the unit; or

B. Within 15 feet of the unit, substantially toward the unit, and at a velocity not less than 500 feet per minute.

7. **Design and Control Requirements for Quantities of Outdoor Air**.

A. All mechanical ventilation and space-conditioning systems shall be designed with and have installed ductwork, dampers, and controls to allow outside air rates to be operated at ~~the larger of (1)~~ the minimum levels specified in Section ~~120.1(c)3~~160.2(c)3 or (2) the rate required for make-up of exhaust systems that are required for an exempt or covered process, for control of odors, or for the removal of contaminants within the space.

B. All variable air volume mechanical ventilation and space-conditioning systems shall include dynamic controls that maintain measured outside air ventilation rates within 10 percent of the required outside air ventilation rate at both full and reduced supply airflow conditions. Fixed minimum damper position is not considered to be dynamic and is not an allowed control strategy.

C. Measured outdoor air rates of constant volume mechanical ventilation and space-conditioning systems shall be within 10 percent of the required outside air rate.

8. **Air Classification and Recirculation Limitations.** Air classification and recirculation limitations of air shall be based on the air classification as listed in Table ~~120.1-A~~160.2-B or Table ~~120.1-C~~160.2-D, and in accordance with the requirements of ~~120.1(g)1~~160.2(c)8A through ~~4~~D.

A. Class 1 Air. Recirculation or transfer of Class 1 air to any space shall be permitted; [ASHRAE 62.1:5.16.3.1]

B. Class 2 Air. Recirculation or transfer of Class 2 air shall be permitted in accordance with ~~120.1(g)A~~ 160.2(c)8Bi through ~~120.1(g)E~~160.2(c)8Bv:

i. Recirculation of Class 2 air within the space of origin shall be permitted [ASHRAE 62.1:5.16.3.2.1]:

ii. Recirculation or transfer of Class 2 to other Class 2 or Class 3 spaces shall be permitted, provided that the other spaces are used for the same or similar purpose or task and involve the same or similar pollutant sources as the Class 2 space [ASHRAE 62.1:5.16.3.2.2]; or

iii. Transfer of Class 2 air to toilet rooms [ASHRAE 62.1:5.16.3.2.3]; or

iv. Recirculation or transfer of Class 2 air to Class 4 spaces [ASHRAE 62.1:5.16.3.2.4]; or

v. Class 2 air shall not be recirculated or transferred to Class 1 spaces. [ASHRAE 62.1:5.16.3.2.5]

**EXCEPTION to Section ~~120.1(g)2E~~160.2(c)8Bv:** When using any energy recovery device, recirculation from leakage, carryover, or transfer from the exhaust side of the energy recovery device is permitted. Recirculated Class 2 air shall not exceed 10% of the outdoor air intake flow.

C. Class 3 Air. Recirculation or transfer of Class 3 air shall be permitted in accordance with ~~120.1(g)A~~160.2(c)8Ci and ~~120.1(g)B~~160.2(c)8Cii:

i. Recirculation of Class 3 air within the space of origin shall be permitted. [ASHRAE 62.1:5.16.3.3.1]

ii. Class 3 air shall not be recirculated or transferred to any other space. [ASHRAE 62.1:5.16.3.3.2].

**EXCEPTION to Section ~~120.1(g)3B~~160.2(c)8Cii:** When using any energy recovery device, recirculation from leakage, carryover, or transfer from the exhaust side of the energy recovery device is permitted. Recirculated Class 3 air shall not exceed 5% of the outdoor air intake flow.

D. Class 4 Air. Class 4 air shall not be recirculated or transferred to any space or recirculated within the space of origin. [ASHRAE 62.1:5.16.3.4]

E. Ancillary spaces. Redesignation of Class 1 air to Class 2 air shall be permitted for Class 1 spaces that are ancillary to Class2 spaces. [ASHRAE 62.1:5.16.2.3]

F. Transfer. A mixture of air that has been transferred through or returned form spaces or locations with different air classes shall be redesignated with the highest classification among the air classes mixed. [ASHRAE 62.1:5.16.2.2]

G. Classification. Air leaving each space or location shall be designated at an expected air-quality classification not less than that shown in Tables ~~120.1-A~~160.2-B, ~~120.1-B~~160.2 C or ~~120.1-C~~160.2-D. Air leaving spaces or locations that are not listed in Tables ~~120.1-A~~160.2-B, ~~120.1-B~~160.2 C or ~~120.1-C~~160.2-D shall be designated with the same classification as air from the most similar space or location listed in terms of occupant activities and building construction.

(d) **Parking Garages.** Mechanical ventilation systems for enclosed parking garages in multifamily buildings shall comply with Section 120.6(c).

*TABLE ~~150.0-D~~ 160.2-A: Infiltration Effectiveness Weather and Shielding Factors [ASHRAE 62.2:Table B1]*

| TMY3 | wsf | Weather Station | Latitude | Longitude | State |
|---|---|---|---|---|---|
| 690150 | 0.50 | Twentynine Palms | 34.30 | –116.17 | California |
| 722860 | 0.43 | March AFB | 33.90 | –117.25 | California |
| 722868 | 0.45 | Palm Springs Intl | 33.83 | –116.50 | California |
| 722869 | 0.42 | Riverside Muni | 33.95 | –117.45 | California |
| 722880 | 0.39 | Burbank–Glendale–Pasadena AP | 34.20 | –118.35 | California |
| 722885 | 0.39 | Santa Monica Muni | 34.02 | –118.45 | California |
| 722886 | 0.39 | Van Nuys Airport | 34.22 | –118.48 | California |
| 722895 | 0.55 | Lompoc (AWOS) | 34.67 | –120.47 | California |
| 722897 | 0.51 | San Luis Co Rgnl | 35.23 | –120.63 | California |
| 722899 | 0.45 | Chino Airport | 33.97 | –117.63 | California |
| 722900 | 0.38 | San Diego Lindbergh Field | 32.73 | –117.17 | California |
| 722903 | 0.39 | San Diego/Montgomery | 32.82 | –117.13 | California |
| 722904 | 0.40 | Chula Vista Brown Field NAAS | 32.58 | –116.98 | California |
| 722906 | 0.39 | San Diego North Island NAS | 32.70 | –117.20 | California |
| 722926 | 0.40 | Camp Pendleton MCAS | 33.30 | –117.35 | California |
| 722927 | 0.38 | Carlsbad/Palomar | 33.13 | –117.28 | California |
| 722930 | 0.39 | San Diego Miramar NAS | 32.87 | –117.13 | California |
| 722950 | 0.42 | Los Angeles Intl Arpt | 33.93 | –118.40 | California |
| 722956 | 0.38 | Jack Northrop Fld H | 33.92 | –118.33 | California |
| 722970 | 0.38 | Long Beach Daugherty Fld | 33.83 | –118.17 | California |
| 722976 | 0.34 | Fullerton Municipal | 33.87 | –117.98 | California |
| 722977 | 0.36 | Santa Ana John Wayne AP | 33.68 | –117.87 | California |
| 723805 | 0.51 | Needles Airport | 34.77 | –114.62 | California |
| 723810 | 0.59 | Edwards AFB | 34.90 | –117.87 | California |
| 723815 | 0.58 | Daggett Barstow–Daggett AP | 34.85 | –116.80 | California |
| 723816 | 0.62 | Lancaster Gen Wm Fox Field | 34.73 | –118.22 | California |
| 723820 | 0.57 | Palmdale Airport | 34.63 | –118.08 | California |
| 723830 | 0.68 | Sandberg | 34.75 | –118.72 | California |
| 723840 | 0.43 | Bakersfield Meadows Field | 35.43 | –119.05 | California |
| 723890 | 0.45 | Fresno Yosemite Intl AP | 36.78 | –119.72 | California |
| 723895 | 0.42 | Porterville (AWOS) | 36.03 | –119.07 | California |
| 723896 | 0.43 | Visalia Muni (AWOS) | 36.32 | –119.40 | California |
| 723910 | 0.45 | Point Mugu Nf | 34.12 | –119.12 | California |
| 723925 | 0.44 | Santa Barbara Municipal AP | 34.43 | –119.85 | California |
| 723926 | 0.43 | Camarillo (AWOS) | 34.22 | –119.08 | California |
| 723927 | 0.45 | Oxnard Airport | 34.20 | –119.20 | California |
| 723940 | 0.52 | Santa Maria Public Arpt | 34.92 | –120.47 | California |

*TABLE ~~150.0-D~~ 160.2-A: Infiltration Effectiveness Weather and Shielding Factors [ASHRAE 62.2:Table B1] (continued)*

| TMY3 | wsf | Weather Station | Latitude | Longitude | State |
|---|---|---|---|---|---|
| 723965 | 0.53 | Paso Robles Municipal Arpt | 35.67 | –120.63 | California |
| 724800 | 0.55 | Bishop Airport | 37.37 | –118.35 | California |
| 724815 | 0.46 | Merced/Macready Fld | 37.28 | –120.52 | California |
| 724830 | 0.51 | Sacramento Executive Arpt | 38.50 | –121.50 | California |
| 724837 | 0.45 | Beale AFB | 39.13 | –121.43 | California |
| 724838 | 0.50 | Yuba Co | 39.10 | –121.57 | California |
| 724839 | 0.51 | Sacramento Metropolitan AP | 38.70 | –121.58 | California |
| 724915 | 0.49 | Monterey Naf | 36.60 | –121.87 | California |
| 724917 | 0.54 | Salinas Municipal AP | 36.67 | –121.60 | California |
| 724920 | 0.50 | Stockton Metropolitan Arpt | 37.90 | –121.23 | California |
| 724926 | 0.47 | Modesto City–County AP | 37.63 | –120.95 | California |
| 724927 | 0.53 | Livermore Municipal | 37.70 | –121.82 | California |
| 724930 | 0.54 | Oakland Metropolitan Arpt | 37.72 | –122.22 | California |
| 724935 | 0.47 | Hayward Air Term | 37.67 | –122.12 | California |
| 724936 | 0.53 | Concord–Buchanan Field | 38.00 | –122.05 | California |
| 724940 | 0.60 | San Francisco Intl AP | 37.62 | –122.40 | California |
| 724945 | 0.48 | San Jose Intl AP | 37.37 | –121.93 | California |
| 724955 | 0.55 | Napa Co. Airport | 38.22 | –122.28 | California |
| 724957 | 0.49 | Santa Rosa (AWOS) | 38.52 | –122.82 | California |
| 725845 | 0.44 | Blue Canyon AP | 39.30 | –120.72 | California |
| 725846 | 0.66 | Truckee–Tahoe | 39.32 | –120.13 | California |
| 725847 | 0.64 | South Lake Tahoe | 38.90 | –120.00 | California |
| 725905 | 0.47 | Ukiah Municipal AP | 39.13 | –123.20 | California |
| 725910 | 0.50 | Red Bluff Municipal Arpt | 40.15 | –122.25 | California |
| 725920 | 0.47 | Redding Municipal Arpt | 40.52 | –122.32 | California |
| 725945 | 0.56 | Arcata Airport | 40.98 | –124.10 | California |
| 725946 | 0.60 | Crescent City Faa Ai | 41.78 | –124.23 | California |
| 725955 | 0.55 | Montague Siskiyou County AP | 41.78 | –122.47 | California |
| 725958 | 0.59 | Alturas | 41.50 | –120.53 | California |
| 745090 | 0.45 | Mountain View Moffett Fld NAS | 37.40 | –122.05 | California |
| 745160 | 0.67 | Travis Field AFB | 38.27 | –121.93 | California |
| 746120 | 0.52 | China Lake Naf | 35.68 | –117.68 | California |
| 747020 | 0.50 | Lemoore Reeves NAS | 36.33 | –119.95 | California |
| 747185 | 0.46 | Imperial | 32.83 | –115.58 | California |
| 747187 | 0.46 | Palm Springs Thermal AP | 33.63 | –116.17 | California |
| 747188 | 0.48 | Blythe Riverside Co Arpt | 33.62 | –114.72 | California |

*TABLE ~~120.1-A~~ 160.2-B – Minimum Ventilation Rates for Multifamily Common Use Areas*

| Occupancy Category | Area Outdoor Air Rate[1] $R_a$ cfm/ft² | Min Air Rate for DC cfm/ft² V[2] | Air Class | Notes |
|---|---|---|---|---|
| ~~**Educational Facilities**~~ | | | | |
| Daycare (through age 4) | 0.21 | 0.15 | 2 | |
| ~~Daycare sickroom~~ | ~~0.15~~ | | ~~3~~ | |
| ~~Classrooms (ages 5-8)~~ | ~~0.38~~ | ~~0.15~~ | ~~1~~ | |
| ~~Classrooms (age 9 -18)~~ | ~~0.38~~ | ~~0.15~~ | ~~1~~ | |
| ~~Lecture/postsecondary classroom~~ | ~~0.38~~ | ~~0.15~~ | ~~1~~ | ~~F~~ |
| ~~Lecture hall (fixed seats)~~ | ~~-~~ | ~~0.15~~ | ~~1~~ | ~~F~~ |
| ~~Art classroom~~ | ~~0.15~~ | | ~~2~~ | |
| ~~Science laboratories~~ | ~~0.15~~ | | ~~2~~ | |
| ~~University/college laboratories~~ | ~~0.15~~ | | ~~2~~ | |
| ~~Wood/metal shop~~ | ~~0.15~~ | | ~~2~~ | |
| ~~Computer lab~~ | ~~0.15~~ | | ~~1~~ | |
| ~~Media center~~ | ~~0.15~~ | | ~~1~~ | ~~A~~ |
| ~~Music/theater/dance~~ | ~~1.07~~ | ~~0.15~~ | ~~1~~ | ~~F~~ |
| Multiuse assembly | 0.50 | 0.15 | 1 | F |
| ~~**Food and Beverage Service**~~ | | | | |
| ~~Restaurant d~~Dining rooms | 0.50 | 0.15 | 2 | |
| ~~Cafeteria/fast-food dining~~ | ~~0.50~~ | ~~0.15~~ | ~~2~~ | |
| Bars, cocktail lounges | 0.50 | 0.20 | 2 | |
| Kitchen (cooking) | 0.15 | | 2 | |
| ~~**General**~~ | | | | |
| Break rooms | 0.50 | 0.15 | 1 | F |
| Coffee stations | 0.50 | 0.15 | 1 | F |
| Conference/meeting | 0.50 | 0.15 | 1 | F |
| Corridors | 0.15 | | 1 | F |
| Occupiable storage rooms for liquids or gels | 0.15 | | 2 | B |
| ~~**Hotels, Motels, Resorts, Dormitories**~~ | | | | |
| ~~Bedroom/living room~~ | ~~0.15~~ | | ~~1~~ | ~~F~~ |
| ~~Barracks sleeping areas~~ | ~~0.15~~ | | ~~1~~ | ~~F~~ |
| Laundry rooms, central | 0.15 | | 2 | |
| ~~Laundry rooms within dwelling units~~ | ~~0.15~~ | | ~~1~~ | |
| Lobbies/pre-function | 0.50 | 0.15 | 1 | F |

| | | | | |
|---|---|---|---|---|
| ~~Multipurpose assembly~~ | ~~0.50~~ | | ~~1~~ | ~~F~~ |
| ~~**Office Buildings**~~ | | | | |
| Breakrooms | 0.50 | 0.15 | 1 | |
| ~~Main entry lobbies~~ | ~~0.50~~ | ~~0.15~~ | ~~1~~ | ~~F~~ |
| Occupiable storage rooms for dry materials | 0.15 | | 1 | |
| Office space | 0.15 | | 1 | F |
| Reception areas | 0.15 | | 1 | F |
| Telephone/data entry | 0.15 | | 1 | F |
| ~~**Miscellaneous Spaces**~~ | | | | |
| ~~Bank vaults/safe deposit~~ | ~~0.15~~ | | ~~2~~ | ~~F~~ |
| ~~Banks or bank lobbies~~ | ~~0.15~~ | | ~~1~~ | ~~F~~ |
| Computer (not printing) | 0.15 | | 1 | F |
| Freezer and refrigerated spaces (<50ºF) | - | | 2 | E |
| ~~General manufacturing (excludes heavy industrial and process using chemicals)~~ | ~~0.15~~ | | ~~3~~ | |
| ~~Pharmacy (prep. Area)~~ | ~~0.15~~ | | ~~2~~ | |
| ~~Photo studios~~ | ~~0.15~~ | | ~~1~~ | |
| Shipping/receiving | 0.15 | | 2 | B |
| ~~Sorting, packing, light assembly~~ | ~~0.15~~ | | ~~2~~ | |
| ~~Telephone closets~~ | ~~0.15~~ | | ~~1~~ | |
| ~~Transportation waiting~~ | ~~0.50~~ | ~~0.15~~ | ~~1~~ | ~~F~~ |
| ~~Warehouses~~ | ~~0.15~~ | | ~~2~~ | ~~B~~ |
| All others | 0.15 | | 2 | |
| ~~**Public Assembly Spaces**~~ | | | | |
| ~~Auditorium seating area~~ | ~~1.07~~ | ~~0.15~~ | ~~1~~ | ~~F~~ |
| ~~Places of religious worship~~ | ~~1.07~~ | ~~0.15~~ | ~~1~~ | ~~F~~ |
| ~~Courtrooms~~ | ~~0.19~~ | ~~0.15~~ | ~~1~~ | ~~F~~ |
| ~~Legislative chambers~~ | ~~0.19~~ | ~~0.15~~ | ~~1~~ | ~~F~~ |
| ~~Libraries (reading rooms and stack areas)~~ | ~~0.15~~ | | ~~1~~ | |
| ~~Lobbies~~ | ~~0.50~~ | ~~0.15~~ | ~~1~~ | ~~F~~ |
| ~~Museums (children's)~~ | ~~0.25~~ | ~~0.15~~ | ~~1~~ | |
| ~~Museums/galleries~~ | ~~0.25~~ | ~~0.15~~ | ~~1~~ | ~~F~~ |

| | | | | |
|---|---|---|---|---|
| ~~**Residential**~~ | | | | |
| ~~Common corridors~~ | ~~0.15~~ | | ~~1~~ | ~~F~~ |
| ~~**Retail**~~ | | | | |
| ~~Sales (except as below)~~ | ~~0.25~~ | ~~0.20~~ | ~~2~~ | |
| ~~Mall common areas~~ | ~~0.25~~ | ~~0.15~~ | ~~1~~ | ~~F~~ |
| ~~Barbershop~~ | ~~0.40~~ | | ~~2~~ | |
| ~~Beauty and nail salons~~ | ~~0.40~~ | | ~~2~~ | |
| ~~Pet shops (animal areas)~~ | ~~0.25~~ | ~~0.15~~ | ~~2~~ | |
| ~~Supermarket~~ | ~~0.25~~ | ~~0.20~~ | ~~1~~ | ~~F~~ |
| ~~Coin-operated laundries~~ | ~~0.30~~ | | ~~2~~ | |
| ~~**Sports and Entertainment**~~ | | | | |
| Gym, sports arena (play area) | 0.50 | 0.15 | 2 | E |
| ~~Spectator areas~~ | ~~0.50~~ | ~~0.15~~ | ~~1~~ | ~~F~~ |
| Swimming (pool) | 0.15 | | 2 | C |
| Swimming (deck) | 0.50 | 0.15 | 2 | C |
| Disco/dance floors | 1.50 | 0.15 | 2 | F |
| Health club/aerobics room/weight rooms | 0.15 | | 2 | |
| ~~Health club/weight rooms~~ | ~~0.15~~ | | ~~2~~ | |
| ~~Bowling alley (seating)~~ | ~~1.07~~ | ~~0.15~~ | ~~1~~ | |
| ~~Gambling casinos~~ | ~~0.68~~ | ~~0.15~~ | ~~1~~ | |
| Game arcades | 0.68 | 0.15 | 1 | |
| ~~Stages, studios~~ | ~~0.50~~ | ~~0.15~~ | ~~1~~ | ~~D, F~~ |

General:

[1] Ra was determined as being the larger of the area method and the default per person method. The occupant density used in the per person method was assumed to be one half of the maximum occupant load assumed for egress purposes in the CBC.

[2]If this column specifies a minimum cfm/ft$^2$ then it shall be used to comply with Section ~~120.1(d)4E~~ 160.2(c)5E.

Specific Notes:

A ~~– For high-school and college libraries, the values shown for "Public Assembly Spaces – Libraries" shall be used..~~ Not used.

B – Rate may not be sufficient where stored materials include those having potentially harmful emissions.

C – Rate does not allow for humidity control. "Deck area" refers to the area surrounding the pool that is capable of being wetted during pool use or when the pool is occupied. Deck area that is not expected to be wetted shall be designated as an occupancy category.

D ~~– Rate does not include special exhaust for stage effects such as dry ice vapors and smoke~~ Not used.

E – Where combustion equipment is intended to be used on the playing surface or in the space, additional dilution ventilation, source control, or both shall be provided.

F – Ventilation air for this occupancy category shall be permitted to be reduced to zero when the space is in occupied-standby mode

*TABLE ~~120.1-B~~ 160.2-C – Minimum Exhaust Rates*

*[ASHRAE 62.1: TABLE 6.5]*

| Occupancy Category | Exhaust Rete, cfm/unit | Exhaust Rate, cfm/ft$^2$ | Air Class | Notes |
|---|---|---|---|---|
| ~~Arenas~~ | ~~-~~ | ~~0.50~~ | ~~1~~ | ~~B~~ |
| ~~Art classrooms~~ | ~~-~~ | ~~0.70~~ | ~~2~~ | |
| ~~Auto repair rooms~~ | ~~-~~ | ~~1.5~~ | ~~2~~ | ~~A~~ |
| ~~Barber shops~~ | ~~-~~ | ~~0.50~~ | ~~2~~ | |
| ~~Beauty and nail salons~~ | ~~-~~ | ~~0.60~~ | ~~2~~ | |
| ~~Cells with toilet~~ | ~~-~~ | ~~1.00~~ | ~~2~~ | |
| Copy, printing rooms | - | 0.50 | 2 | |
| ~~Darkrooms~~ | ~~-~~ | ~~1.00~~ | ~~2~~ | |
| ~~Educational science laboratories~~ | ~~-~~ | ~~1.00~~ | ~~2~~ | |
| Janitor closets, trash rooms, recycling | - | 1.00 | 3 | |
| Kitchenettes | - | 0.30 | 2 | |
| Kitchens – commercial | - | 0.70 | 2 | |
| Locker rooms for athletic or industrial facilities | - | 0.50 | 2 | |
| All other locker rooms | - | 0.25 | 2 | |
| Shower rooms | 20/50 | - | 2 | G, H |
| ~~Paint spray booths~~ | ~~-~~ | ~~-~~ | ~~4~~ | ~~F~~ |
| Parking garages | - | 0.75 | 2 | C |
| Pet shops (animal areas) | - | 0.90 | 2 | |
| ~~Refrigerating machinery rooms~~ | ~~-~~ | ~~-~~ | ~~3~~ | ~~F~~ |
| Soiled laundry storage rooms | - | 1.00 | 3 | F |
| Storage rooms, chemical | - | 1.50 | 4 | F |
| Toilets – private | 25/50 | - | 2 | E |
| Toilets – public | 50/70 | - | 2 | D |
| ~~Woodwork shop/classrooms~~ | ~~-~~ | ~~0.50~~ | ~~2~~ | |

*TABLE ~~120.1-B~~ 160.2-C – Minimum Exhaust Rates*

*[ASHRAE 62.1: TABLE 6.5]*

| Occupancy Category | Exhaust Rete, cfm/unit | Exhaust Rate, $cfm/ft^2$ | Air Class | Notes |
|---|---|---|---|---|

Notes:

A ~~– Stands where engines are run shall have exhaust systems that directly connect to the engine exhaust and prevent escape of fumes.~~ Not used.

B ~~– Where combustion equipment is intended to be used on the playing surface, additional dilution ventilation, source control, or both shall be provided.~~ Not used.

C – Exhaust shall not be required where two or more sides comprise walls that are at least 50% open to the outside.

D – Rate is per water closet, urinal, or both. Provide the higher rate where periods of heavy use are expected to occur. The lower rate shall be permitted to be used otherwise.

E – Rate is for a toilet room intended to be occupied by one person at a time. For continuous systems operation during hours of use, the lower rate shall be permitted to be used. Otherwise the higher rate shall be used.

F – See other applicable standards for exhaust rate.

G – For continuous system operation, the lower rate shall be permitted to be used. Otherwise the higher rate shall be used.

H – Rate is per showerhead

# SECTION 160.3 – MANDATORY REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS IN MULTIFAMILY BUILDINGS

Space conditioning systems serving multifamily dwelling units and common use areas shall comply with the applicable requirements of Sections 160.3(a) through 160.3(c).

(a) **Controls –** Space conditioning systems serving dwelling units and common use areas in multifamily buildings shall comply with applicable requirements of Sections 160.3(a)1 or 160.3(a)2.

1. **Dwelling Unit Thermostats.** All heating or cooling systems, including heat pumps, not controlled by a central energy management control system (EMCS) shall have a setback thermostat, as specified in Section 110.2(c).

2. **Common Use Area Controls**. All heating or cooling systems serving common use areas of multifamily buildings shall comply with application requirements of Sections 160.3(a)2A through 160.3(a)2J.

A. **Thermostatic Controls for Each Zone.** The supply of heating and cooling energy to each space-conditioning zone ~~or dwelling unit~~ shall be controlled by an individual thermostatic control that responds to temperature within the zone and that meets the applicable requirements of Section ~~120.2(b)~~160.3(a)2B. An Energy Management Control System (EMCS) may be installed to comply with the requirements of one or more thermostatic controls if it complies with all applicable requirements for each thermostatic control.

**EXCEPTION to Section ~~120.2(a)~~160.3(a)2A:** An independent perimeter heating or cooling system may serve more than one zone without individual thermostatic controls if:

i. All zones are also served by an interior cooling system; and

ii. The perimeter system is designed solely to offset envelope heat losses or gains; and

iii. The perimeter system has at least one thermostatic control for each building orientation of 50 feet or more; and

iv. The perimeter system is controlled by at least one thermostat located in one of the zones served by the system.

B. **Criteria for Zonal Thermostatic Controls.** The individual thermostatic controls required by Section ~~120.2(a~~)160.3(a)2A shall meet the following requirements as applicable:

i. Where used to control comfort heating, the thermostatic controls shall be capable of being set, locally or remotely, down to 55°F or lower.

ii. Where used to control comfort cooling, the thermostatic controls shall be capable of being set, locally or remotely, up to 85°F or higher.

iii. Where used to control both comfort heating and comfort cooling, the thermostatic controls shall meet Items ~~1~~i and ~~2~~ii and shall be capable of providing a temperature range or dead band of at least 5°F within which the supply of heating and cooling energy to the zone is shut off or reduced to a minimum.

**EXCEPTION 1 to Section ~~120.2(b)3~~160.3(a)2Biii:** Systems with thermostats that require manual changeover between heating and cooling modes.

~~**EXCEPTION 2 to Section 120.2(b)3:** Systems serving healthcare facilities.~~

iv. Thermostatic controls for all single zone air conditioners and heat pumps, shall comply with the requirements of Section 110.2(c) and 110.12(a) and, if equipped with DDC to the Zone level, with the Automatic Demand Shed Controls of Section 110.12(b).

~~**EXCEPTION 1 to Section 120.2(b)4:** Systems serving exempt process loads that must have constant temperatures to prevent degradation of materials, a process, plants or animals.~~

**EXCEPTION ~~2~~ 1 to Section ~~120.2(b)4~~160.3(a)2Biv:**Package terminal air conditioners, package terminal heat pumps, room air conditioners, and room air-conditioner heat pumps.

~~**EXCEPTION 3 to Section 120.2(b)4:** Systems serving healthcare facilities.~~

C. **Heat Pump Controls.** All heat pumps with supplementary electric resistance heaters shall be installed with controls that comply with Section 110.2(b).

D. **Shut-off and Reset Controls for Space-conditioning Systems.** Each space-conditioning system shall be installed with controls that comply with the following:

i. The control shall be capable of automatically shutting off the system during periods of nonuse and shall have:

a. An automatic time switch control device complying with Section 110.9, with an accessible manual override that allows operation of the system for up to 4 hours; or

b. An occupancy sensor; or

c. A 4-hour timer that can be manually operated.

~~**EXCEPTION to Section 120.2(e)1:** Mechanical systems serving retail stores and associated malls, restaurants, grocery stores, churches, and theaters equipped with 7-day programmable timers.~~

ii. The control shall automatically restart and temporarily operate the system as required to maintain:

a. A setback heating thermostat setpoint if the system provides mechanical heating; and

**EXCEPTION to Section ~~120.2(e)2A~~160.3(a)2Diia:** Thermostat setback controls are not required in ~~nonresidential~~ multifamily buildings in areas where the Winter Median of Extremes outdoor air temperature determined in accordance with Section ~~140.4(b)3~~170.2(c)1C is greater than 32°F.

b. A setup cooling thermostat setpoint if the system provides mechanical cooling.

**EXCEPTION to Section ~~120.2(e)2B~~160.3(a)2Diib:** Thermostat setup controls are not required in ~~nonresidential~~ multifamily buildings in areas where the Summer Design Dry Bulb 0.5 percent temperature determined in accordance with Section ~~140.4(b)3~~170.2(c)1C is less than 100°F.

iii. **Occupancy Sensing Zone Controls**. Space conditioning systems serving room(s) that are required to have occupant sensing controls in accordance with Section ~~130.1(c)~~160.5(b)4C, and where the Table ~~120.1-A~~160.2-B occupancy category permits ventilation air to be reduced to zero when the space is in occupied-standby mode, shall meet the following:

a. The zone shall be placed in occupied standby mode when all room(s) served by the zone are unoccupied for more than 5 minutes; and

b. During occupied standby mode.

I. Automatically setup the operating cooling temperature set point by 2°F or more and setback the operating heating temperature set point by 2°F or more; or

II. For multiple zone systems with Direct Digital Controls (DDC) to the zone level, setup the operating cooling temperature setpoint by 0.5°F or more and setback the operating heating temperature setpoint by 0.5°F or more.

c. During occupied-standby mode, all airflow to the zone shall be shut off whenever the space temperature is between the active heating and cooling setpoints.

**EXCEPTION 1 to Sections ~~120.2(e)1, 2, and 3~~160.3(a)2Di,ii, and iii:** Where it can be demonstrated to the satisfaction of the enforcing agency that the system serves an area that must operate continuously.

**EXCEPTION 2 to Sections ~~120.2(e)1, 2, and 3~~160.3(a)2Di,ii, and iii:** Systems with full load demands of 2 kW or less, if they have a readily accessible manual shut-off switch.

~~**EXCEPTION 3 to Sections 120.2(e)1 and 2:** Systems serving hotel/motel guest rooms, if they have a readily accessible manual shut-off switch.~~

~~**EXCEPTION to Section 120.2(e):** Systems serving healthcare facilities.~~

E. **Dampers for Air Supply and Exhaust Equipment.** Outdoor air supply and exhaust equipment shall be installed with dampers that automatically close upon fan shutdown.

**EXCEPTION 1 to Section ~~120.2(f)~~160.3(a)2E:** Equipment that serves an area that must operate continuously.

**EXCEPTION 2 to Section ~~120.2(f)~~160.3(a)2E:** Gravity and other nonelectrical equipment that has readily accessible manual damper controls.

**EXCEPTION 3 to Section ~~120.2(f)~~160.3(a)2E:** At combustion air intakes and shaft vents.

**EXCEPTION 4 to Section ~~120.2(f)~~160.3(a)2E:** Where prohibited by other provisions of law.

F. **Isolation Area Devices**. Each space-conditioning system serving multiple zones with a combined conditioned floor area of more than 25,000 square feet shall be designed, installed, and controlled to serve isolation areas.

i. Each zone, or any combination of zones not exceeding 25,000 square feet, shall be a separate isolation area.

ii. Each isolation area shall be provided with isolation devices, such as valves or dampers that allow the supply of heating or cooling to be reduced or shut-off independently of other isolation areas.

iii. Each isolation area shall be controlled by a device meeting the requirements of Section ~~120.2(e)1~~160.3(a)2Di.

**EXCEPTION to Section ~~120.2(g)~~160.3(a)2F:** Zones designed to be conditioned continuously.

G. **Automatic Demand Shed Controls.** See Section 110.12 for requirements for Automatic Demand Shed Controls.

H. **Economizer Fault Detection and Diagnostics (FDD).** All newly installed air handlers with a mechanical cooling capacity greater than 54,000 Btu/hr and an installed air economizer shall include a stand-alone or integrated Fault Detection and Diagnostics (FDD) system in accordance with Subsections ~~120.2(i)1~~160.3(a)2Hi through ~~120.2(i)8~~160.3(a)2Hviii

i. The following temperature sensors shall be permanently installed to monitor system operation: outside air, supply air, and when required for differential economizer operation, a return air sensor; and

ii. Temperature sensors shall have an accuracy of ±2°F over the range of 40°F to 80°F; and

iii. The controller shall have the capability of displaying the value of each sensor; and

iv. The controller shall provide system status by indicating the following conditions:

a. Free cooling available;

b. Economizer enabled;

c. Compressor enabled;

d. Heating enabled, if the system is capable of heating; and

e. Mixed air low limit cycle active.

v. The unit controller shall allow manual initiation of each operating mode so that the operation of cooling systems, economizers, fans, and heating systems can be independently tested and verified; and

vi. Faults shall be reported in one of the following ways:

a. Reported to an Energy Management Control System regularly monitored by facility personnel.

b. Annunciated locally on one or more zone thermostats, or a device within five (5) feet of zone thermostat(s), clearly visible, at eye level, and meeting the following requirements:

I. On the thermostat, device, or an adjacent written sign, display instructions to contact appropriate building personnel or an HVAC technician; and

II. In buildings with multiple tenants, the annunciation shall either be within property management offices or in a common space accessible by the property or building manager.

c. Reported to a fault management application which automatically provides notification of the fault to remote HVAC service provider.

vii. The FDD system shall detect the following faults:

a. Air temperature sensor failure/fault;

b. Not economizing when it should;

c. Economizing when it should not;

d. Damper not modulating; and

e. Excess outdoor air.

viii. The FDD System shall be certified by the Energy Commission as meeting requirements of Sections ~~120.2(i)1~~160.3(a)2Hi through ~~120.2(i)7~~160.3(a)2Hvii in accordance with Section 110.0 and JA6.3.

**EXCEPTION to ~~120.2(i)8~~160.3(a)2Hviii:** FDD algorithms based in Direct Digital Control systems are not required to be certified to the Energy Commission.

I. **Direct Digital Controls (DDC).** Direct Digital Controls to the zone shall be provided as specified by Table ~~120.2-A~~160.3-C.

The provided DDC system shall meet the control logic requirements of Sections ~~120.1(d)~~ 160.3(a)2E and ~~120.2(h)~~160.3(a)2G, and be capable of the following:

i. Monitoring zone and system demand for fan pressure, pump pressure, heating and cooling;

ii. Transferring zone and system demand information from zones to air distribution system controllers and from air distribution systems to heating and cooling plant controllers;

iii. Automatically detecting the zones and systems that may be excessively driving the reset logic and generate an alarm or other indication to the system operator;

iv. Readily allow operator removal of zones(s) from the reset algorithm;

v. For new buildings, trending and graphically displaying input and output points; and

vi. Resetting heating and cooling setpoints in all non-critical zones upon receipt of a signal from a centralized contact or software point as described in Section ~~120.2(h)~~160.3(a)2G.

J. **Optimum Start/Stop Controls.** Space conditioning systems with DDC to the zone level shall have optimum start/stop controls. The control algorithm shall, as a minimum, be a function of the difference between space temperature and occupied setpoint, the outdoor air temperature, and the amount of time prior to scheduled occupancy. Mass radiant floor slab systems shall incorporate floor temperature onto the optimum start algorithm.

**EXCEPTION to Section ~~120.2(k)~~160.3(a)2J:** Systems that must operate continuously.

(b) **Space Conditioning and Distribution Systems Serving Individual Dwelling Units.**

1. **Building Cooling and Heating Loads.** Building heating and cooling loads shall be determined using a method based on any one of the following:

A. The ASHRAE Handbook, Equipment Volume, Applications Volume, and Fundamentals Volume; or

B. The SMACNA Residential Comfort System Installation Standards Manual; or

C. The ACCA Manual J.

The cooling and heating loads are two of the criteria that shall be used for equipment sizing and selection.

**NOTE:** Heating systems are required to have a minimum heating capacity adequate to meet the minimum requirements of the CBC. The furnace output capacity and other specifications are published in the Commission's directory of certified equipment or other directories approved by the Commission.

2. **Design conditions**. For the purpose of sizing the space-conditioning (HVAC) system, the indoor design temperatures shall be 68°F for heating and 75°F for cooling. Outdoor design conditions shall be selected from Reference Joint Appendix JA2, which is based on data from the ASHRAE Climatic Data for Region X. The outdoor design temperatures for heating shall be no lower than the Heating Winter Median of Extremes values. The outdoor design temperatures for cooling shall be no greater than the 1.0 percent Cooling Dry Bulb and Mean Coincident Wet Bulb values.

3. **Outdoor Condensing Units**.

A. **Clearances.** Installed air conditioner and heat pump outdoor condensing units shall have a clearance of at least five (5) feet (1.5 meters) from the outlet of any dryer vent.

B. **Liquid Line Drier.** Installed air conditioner and heat pump systems shall be equipped with liquid line filter driers if required, as specified by manufacturer's instructions.

4. **Central Forced-Air Heating Furnaces**.

A. **Temperature Rise**. Central forced-air heating furnace installations shall be configured to operate in conformance with the furnace manufacturer's maximum inlet-to-outlet temperature rise specifications.

5. **Air-Distribution and Ventilation System Ducts, Plenums, and Fans.**

A. **CMC Compliance.**

i. All air-distribution system ducts and plenums, including, but not limited to, mechanical closets and air-handler boxes, shall meet the requirements of the CMC Sections 601.0, 602.0, 603.0, 604.0, 605.0 and ANSI/SMACNA-006-2006 HVAC Duct Construction Standards Metal and Flexible 3rd Edition, incorporated herein by reference.

ii. Portions of supply-air and return-air ducts and plenums of a space heating or cooling system shall either be insulated to:

a. a minimum installed level of R-6.0, or

b. a minimum installed level of R-4.2 when the duct system is located entirely in conditioned space as confirmed through visual inspection~~field verification and diagnostic testing in accordance with the requirements of Reference Residential Appendix RA3.1.4.3.8~~.

**EXCEPTION 1 to Section ~~150.0(m)1B~~ 160.3(b)Aii:** Portions of the duct system located in wall cavities are not required to be insulated if the following conditions are met:

a. The cavity, duct or plenum is located entirely inside the building's thermal envelope as confirmed by visual inspection.

b. At all locations where portions of non-insulated cavities, ducts, or plenums make a transition into unconditioned space, the transition shall be air-sealed to prevent air infiltration into the cavity and be insulated to a minimum of R-~~6~~8 as confirmed by visual inspection.

**EXCEPTION 2 to Section ~~150.0(m)1B~~160.3(b)Aii:** Portions of the duct system completely exposed and surrounded by directly conditioned space are not required to be insulated.

iii. Connections of metal ducts and the inner core of flexible ducts shall be mechanically fastened.

iv. Openings shall be sealed with mastic, tape, or other duct-closure system that meets the applicable requirements of UL 181, UL 181A or UL 181B or aerosol sealant that meets the requirements of UL 723. If mastic or tape is used to seal openings greater than 1/4 inch, the combination of mastic and either mesh or tape shall be used.

v. Building cavities, support platforms for air handlers, and plenums designed or constructed with materials other than sealed sheet metal, duct board or flexible duct shall not be used for conveying conditioned air. Building cavities and support platforms may contain ducts. Ducts installed in cavities and support platforms shall not be compressed to cause reductions in the cross-sectional area of the ducts.

**EXCEPTION to Section ~~150.0(m)1~~160.3(b)A**: Ducts and fans integral to a wood heater or fireplace.

**B. Factory-Fabricated Duct Systems.**

i. All factory-fabricated duct systems shall comply with UL 181 for ducts and closure systems, including collars, connections, and splices, and be labeled as complying with UL 181. UL 181 testing may be performed by UL laboratories or a laboratory approved by the Executive Director.

ii. All pressure-sensitive tapes, heat-activated tapes, and mastics used in the manufacture of rigid fiberglass ducts shall comply with UL 181 and UL 181A.

iii. All pressure-sensitive tapes and mastics used with flexible ducts shall comply with UL 181 and UL 181B.

iv. Joints and seams of duct systems and their components shall not be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and drawbands.

C. **Field-Fabricated Duct Systems.**

i. Factory-made rigid fiberglass and flexible ducts for field-fabricated duct systems shall comply with UL 181. All pressure-sensitive tapes, mastics, aerosol sealants, or other closure systems used for installing field-fabricated duct systems shall meet the applicable requirements of UL 181, UL 181A, and UL 181B.

ii. Mastic sealants and mesh.

a. Sealants shall comply with the applicable requirements of UL 181, UL 181A, and UL 181B, and be nontoxic and water resistant.

b. Sealants for interior applications shall be tested in accordance with ASTM C731 and D2202, incorporated herein by reference.

c. Sealants for exterior applications shall be tested in accordance with ASTM C731, C732, and D2202, incorporated herein by reference.

d. Sealants and meshes shall be rated for exterior use.

iii. Pressure-sensitive tape. Pressure-sensitive tapes shall comply with the applicable requirements of UL 181, UL 181A, and UL 181B.

iv. Joints and seams of duct systems and their components shall not be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and drawbands.

v. Drawbands used with flexible duct.

a. Drawbands shall be either stainless-steel worm-drive hose clamps or UV-resistant nylon duct ties.

b. Drawbands shall have a minimum tensile strength rating of 150 pounds.

c. Drawbands shall be tightened as recommended by the manufacturer with an adjustable tensioning tool.

vi. Aerosol-sealant closures.

a. Aerosol sealants shall meet the requirements of UL 723 and be applied according to manufacturer specifications.

b. Tapes or mastics used in combination with aerosol sealing shall meet the requirements of this section.

**D. Duct Insulation R-value Ratings.** All duct insulation product R-values shall be based on insulation only (excluding air films, vapor retarder, or other duct components) and tested C-values at 75°F mean temperature at the installed thickness, in accordance with ASTM C518 or ASTM C177, incorporated herein by reference, and certified pursuant to Section 110.8.

**E. Duct Insulation Thickness.** The installed thickness of duct insulation used to determine its R-value shall be determined as follows:

i. For duct board, duct liner, and factory-made rigid ducts not normally subjected to compression, the nominal insulation thickness shall be used.

ii. For duct wrap, installed thickness shall be assumed to be 75 percent (25 percent compression) of nominal thickness.

iii. For factory-made flexible air ducts, the installed thickness shall be determined by dividing the difference between the actual outside diameter and nominal inside diameter by two.

**F. Duct Labeling.** Insulated flexible duct products installed to meet this requirement shall include labels, in maximum intervals of 3 feet, showing the thermal performance R-value for the duct insulation itself (excluding air films, vapor retarder, or other duct components), based on the tests in Section ~~150.0(m)4~~160.3(b)5D and the installed thickness determined by Section ~~150.0(m)5C~~160.3(b)5Eiii**.**

**G. Backdraft Dampers.** All fan systems, regardless of volumetric capacity, that exchange air between the building conditioned space and the outside of the building shall be provided with backdraft or automatic dampers to prevent unintended air leakage through the fan system when the fan system is not operating.

H. **Gravity Ventilation Dampers.** All gravity ventilating systems that serve conditioned space shall be provided with either automatic or readily accessible, manually operated dampers in all openings to the outside except combustion inlet and outlet air openings and elevator shaft vents.

**I.** **Protection of Insulation.** Insulation shall be protected from damage, including that due to sunlight, moisture, equipment maintenance, and wind but not limited to the following: Insulation exposed to weather shall be suitable for outdoor service (e.g., protected by aluminum, sheet metal, painted canvas, or plastic cover). Cellular foam insulation shall be protected as above or painted with a coating that is water retardant and provides shielding from solar radiation that can cause degradation of the material.

J. **Porous Inner Core Flex Duct.** Flexible ducts having porous inner cores shall have a non-porous layer or air barrier between the inner core and the outer vapor barrier.

K. **Duct System Sealing and Leakage Testing.** When space conditioning systems utilize forced air duct systems to supply conditioned air to an occupiable space, the ducts shall be sealed, as confirmed through field verification and diagnostic testing, in accordance with all applicable procedures specified in Reference Residential Appendix RA3.1, and the leakage compliance criteria specified in Reference Residential Appendix TABLE RA3.1-2~~, and conforming to one of the following Subsections A, B, or C as applicable:~~

For multifamily dwellings with the air-handling unit installed and the ducts connected directly to the air handler, regardless of duct system location:

i. The total leakage of the duct system shall not exceed 12 percent of the nominal system air handler airflow as determined utilizing the procedures in Reference Residential Appendix Section RA3.1.4.3.1; or

ii. The duct system leakage to outside shall not exceed 6 percent of the nominal system air handler airflow as determined utilizing the procedures in Reference Residential Appendix Section RA3.1.4.3.4.

L. **~~Space Conditioning~~ System Airflow Rate and Fan Efficacy.** Space conditioning systems that utilize forced air ducts to supply cooling to an occupiable space shall:

i. **Static Pressure Probe.** Have a hole for the placement of a static pressure probe (HSPP), or a permanently installed static pressure probe (PSPP) in the supply plenum downstream of the air conditioning evaporator coil. The size, location, and labeling of the HSPP or PSPP shall conform to the requirements specified in Reference Residential Appendix RA3.3.1.1 as confirmed by field verification and diagnostic testing; and

**EXCEPTION to ~~150.0(m)13A~~160.3(b)5Li:** Systems that cannot conform to the specifications for hole location in Reference Residential Appendix Figure RA3.3-1 shall not be required to provide holes as described in Figure RA3.3-1.

ii. **Single Zone Central Forced Air Systems**. Demonstrate, in every control mode, airflow greater than or equal to 350 CFM per ton of nominal cooling capacity through the return grilles, and an air-handling unit fan efficacy less than or equal to the maximum W/CFM specified in subsections ~~i~~a or ~~ii~~b below. The airflow rate and fan efficacy requirements in this section shall be confirmed by field verification and diagnostic testing in accordance with the procedures given in Reference Residential Appendix RA3.3.

a. 0.45 W/CFM for gas furnace air-handling units.

b. 0.58 W/CFM for air-handling units that are not gas furnaces.

iii. **Zonally Controlled Central Forced Air Systems.** Zonally controlled central forced air cooling systems shall be capable of simultaneously delivering, in every zonal control mode, an airflow from the dwelling, through the air handler fan and delivered to the dwelling, of greater than or equal to 350 CFM per ton of nominal cooling capacity, and operating at an air-handling unit fan efficacy of less than or equal to the maximum W/CFM specified in subsections ~~i~~a or ~~ii~~b below. The airflow rate and fan efficacy requirements in this section shall be confirmed by field verification and diagnostic testing in accordance with the applicable procedures specified in Reference Residential Appendix RA3.3.

a. 0.45 W/CFM for gas furnace air-handling units.

b. 0.58 W/CFM for air-handling units that are not gas furnaces.

**EXCEPTION 1 to Section ~~150.0(m)13C~~160.3(b)5Liii:** Multispeed or variable speed compressor systems, or single speed compressor systems that utilize the performance compliance approach, shall demonstrate compliance with the airflow (cfm/ton) and fan efficacy (Watt/cfm) requirements of Section ~~150.0(m)13C~~160.3(b)5Liii by operating the system at maximum compressor capacity and system fan speed with all zones calling for conditioning, rather than in every zonal control mode.

**EXCEPTION 2 to Section ~~150.0(m)13C~~160.3(b)5Liii:** Gas furnace air-handling units manufactured prior to July 3, 2019 shall comply with a fan efficacy value less than or equal to 0.58 w/cfm as confirmed by field verification and diagnostic testing in accordance with the procedures given in Reference Residential Appendix RA3.3.

iv. **Small Duct High Velocity Forced Air Systems.** Demonstrate, in every control mode, airflow greater than or equal to 250 CFM per ton of nominal cooling capacity through the return grilles, and an air-handling unit fan efficacy less than or equal to 0.62 W/CFM as confirmed by field verification and diagnostic testing in accordance with the procedures given in Reference Residential Appendix RA3.3

**EXCEPTION 1 to Section ~~150.0(m)13B and D~~160.3(b)5Lii and iv:** Standard ducted systems without zoning dampers may comply by meeting the applicable requirements in TABLE ~~150.0-B~~160.3-A or ~~150.0-C~~160.3-B as confirmed by field verification and diagnostic testing in accordance with the procedures in Reference Residential Appendix Sections RA3.1.4.4 and RA3.1.4.5. The design clean-filter pressure drop requirements specified by Section ~~150.0(m)12Div~~160.2(b)1Div for the system air filter(s) shall conform to the requirements given in TABLE ~~150.0-B~~160.3-A or ~~150.0-C~~160.3-B.

**EXCEPTION 2 to ~~150.0(m)13B and D~~160.3(b)5Lii and iv:** Multispeed compressor systems or variable speed compressor systems shall verify airflow (cfm/ton) and fan efficacy (Watt/cfm) for system operation at the maximum compressor speed and the maximum air handler fan speed.

~~**EXCEPTION 3 to 150.0(m)13B:** Gas furnace air-handling units manufactured prior to July 3, 2019 shall comply with a fan efficacy value less than or equal to 0.58 w/cfm as confirmed by field verification and diagnostic testing in accordance with the procedures given in Reference Residential Appendix RA3.3.~~

6. Piping for space conditioning systems, solar water-heating system collector loop, and distribution piping for steam and hydronic heating system, shall meet the requirements of Section ~~120.3(c)~~160.3(c)1.

(c) **Serving Multiple Dwelling Units and Common Use Area Space-Conditioning Systems.** ~~Nonresidential, high-rise residential, and hotel/motel buildings~~ Multifamily common use areas shall comply with the applicable requirements of Sections ~~120.2(a)~~160.3(a)2A through ~~120.2(k)~~160.3(a)2I.

1. **Pipe Insulation**. ~~Nonresidential, high-rise residential, and hotel/motel buildings~~ Multifamily buildings shall comply with the applicable requirements of Sections ~~120.3(a)~~160.3(c)1A through ~~120.3(c)~~160.3(c)1C.

A. **General Requirements.** The piping conditions listed below for space-conditioning ~~and service water-heating~~ systems with fluid normal operating temperatures listed in 160.3-D, shall have at least the amount of insulation specified in ~~Subsection (c)~~ Section 160.3(c)1C:

i. **Space Cooling Systems.** All refrigerant suction, chilled water, and brine fluid distribution systems.

ii. **Space Heating Systems.** All refrigerant, steam, steam condensate and hot water fluid distribution systems.

~~iii. **Service water-heating systems.**~~

~~a. Recirculating system piping, including the supply and return piping to the water heater.~~

~~b. The first 8 feet of hot and cold outlet piping, including piping between a storage tank and a heat trap, for a nonrecirculating storage system.~~

~~c. Pipes that are externally heated.~~

Insulation conductivity shall be determined in accordance with ASTM C335 at the mean temperature listed in 160.3-D, and shall be rounded to the nearest 1/100 Btu-inch per hour per square foot per °F. Fluid distribution systems include all elements that are in series with the fluid flow, such as pipes, pumps, valves, strainers, coil u-bends, and air separators, but not including elements that are not in series with the fluid flow, such as expansion tanks, fill lines, chemical feeders, and drains.

B. **Insulation Protection.** Pipe Insulation shall be protected from damage due to sunlight, moisture, equipment maintenance, and wind. Protection shall, at minimum, include the following:

i. Pipe insulation exposed to weather shall be protected by a cover suitable for outdoor service. The cover shall be water retardant and provide shielding from solar radiation that can cause degradation of the material. Adhesive tape shall not be used to provide this protection.

ii. Pipe insulation covering chilled water piping and refrigerant suction piping located outside the conditioned space shall include, or be protected by, a Class I or Class II vapor retarder. All penetrations and joints shall be sealed.

iii. Pipe insulation buried below grade must be installed in a water proof and non-crushable casing or sleeve.

**C. Insulation Thickness**

i. For insulation with a conductivity in the range shown in 160.3-D for the applicable fluid temperature range, the insulation shall have the applicable minimum thickness or R-value shown in 160.3-D.

ii. For insulation with a conductivity outside the range shown in 160.3-D for the applicable fluid temperature range, the insulation shall have a minimum R-value shown in 160.3-D or thickness as calculated with:

*MINIMUM INSULATION THICKNESS EQUATION*

$$T = PR\left[\left(1+\frac{t}{PR}\right)^{\frac{K}{k}} - 1\right]$$

*WHERE:*

*T = Minimum insulation thickness for material with conductivity K, inches.*

*PR = Pipe actual outside radius, inches.*

*t = Insulation thickness from 160.3-D, inches.*

*K = Conductivity of alternate material at the mean rating temperature indicated in 160.3-D for the applicable fluid temperature range, in Btu-inch per hour per square foot per °F.*

*k = The lower value of the conductivity range listed in 160.3-D for the applicable fluid temperature range, Btu-inch per hour per square foot per °F.*

**EXCEPTION 1 to Section ~~120.3~~160.3(c)1:** Factory-installed piping within space-conditioning equipment certified under Section 110.1 or 110.2.

**EXCEPTION 2 to Section ~~120.3~~160.3(c)1:** Piping that conveys fluids with a design operating temperature range between 60°F and 105°F.

**EXCEPTION 3 to Section ~~120.3~~160.3(c)1:** Where the heat gain or heat loss to or from piping without insulation will not increase building source energy use.

**EXCEPTION 4 to Section ~~120.3~~160.3(c)1:** Piping that penetrates framing members shall not be required to have pipe insulation for the distance of the framing penetration. Metal piping that penetrates metal framing shall use grommets, plugs, wrapping or other insulating material to assure that no contact is made with the metal framing.

2. **Requirements for Air Distribution System, Ducts, and Plenum.** ~~Nonresidential, high-rise residential, and hotel/motel buildings~~ Multifamily common use areas shall: ~~comply with the applicable requirements of Sections 120.4(a) through 120.4(f).~~

~~**EXCEPTION to Section 120.5:** Systems serving healthcare facilities.~~

A. **CMC Compliance.** All air distribution system ducts and plenums, including, but not limited to, building cavities, mechanical closets, air-handler boxes and support platforms used as ducts or plenums, shall meet the requirements of the CMC Sections 601.0, 602.0, 603.0, 604.0, 605.0, and ANSI/SMACNA-006-2006 HVAC Duct Construction Standards Metal and Flexible 3rd Edition, incorporated herein by reference. Connections of metal ducts and the inner core of flexible ducts shall be mechanically fastened. Openings shall be sealed with mastic, tape, aerosol sealant, or other duct-closure system that meets the applicable requirements of UL 181, UL 181A, or UL 181B. If mastic or tape is used to seal openings greater than 1/4 inch, the combination of mastic and either mesh or tape shall be used.

B. Portions of supply-air and return-air ducts conveying heated or cooled air located in one or more of the following spaces shall be insulated to a minimum installed level of R-8:

iii. Outdoors; or

iv. In a space between the roof and an insulated ceiling; or

v. In a space directly under a roof with fixed vents or openings to the outside or unconditioned spaces; or

vi. In an unconditioned crawlspace; or

vii. In other unconditioned spaces.

Portions of supply-air ducts that are not in one of these spaces, including ducts buried in concrete slab, shall be insulated to a minimum installed level of R-4.2 or be enclosed in directly conditioned space.

C. **Duct and Plenum Materials.**

**i. Factory-fabricated duct systems.**

a. All factory-fabricated duct systems shall comply with UL 181 for ducts and closure systems, including collars, connections, and splices, and be labeled as complying with UL 181. UL 181 testing may be performed by UL laboratories or a laboratory approved by the Executive Director.

b. All pressure-sensitive tapes, heat-activated tapes, and mastics used in the manufacture of rigid fiberglass ducts shall comply with UL 181 and UL 181A.

c. All pressure-sensitive tapes and mastics used with flexible ducts shall comply with UL 181 and UL 181B.

d. Joints and seams of duct systems and their components shall not be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and drawbands.

ii. **Field-fabricated duct systems.**

a. Factory-made rigid fiberglass and flexible ducts for field-fabricated duct systems shall comply with UL 181. All pressure-sensitive tapes, mastics, aerosol sealants, or other closure systems used for installing field-fabricated duct systems shall meet the applicable requirements of UL 181, UL 181A, and UL 181B.

b. Mastic sealants and mesh.

I. Sealants shall comply with the applicable requirements of UL 181, UL 181A, and UL 181B, and be nontoxic and water resistant.

II. Sealants for interior applications shall pass ASTM C731 (extrudability after aging) and D2202 (slump test on vertical surfaces), incorporated herein by reference.

III. Sealants for exterior applications shall pass ASTM C731, C732 (artificial weathering test), and D2202, incorporated herein by reference.

IV. Sealants and meshes shall be rated for exterior use.

c. Pressure-sensitive tape. Pressure-sensitive tapes shall comply with the applicable requirements of UL 181, UL 181A, and UL 181B.

d. Joints and seams of duct systems and their components shall not be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and drawbands.

e. Drawbands used with flexible duct.

I. Drawbands shall be either stainless-steel worm-drive hose clamps or UV-resistant nylon duct ties.

II. Drawbands shall have a minimum tensile strength rating of 150 pounds.

III. Drawbands shall be tightened as recommended by the manufacturer with an adjustable tensioning tool.

f. Aerosol-sealant closures.

I. Aerosol sealants shall meet the requirements of UL 723 and be applied according to manufacturer specifications.

II. Tapes or mastics used in combination with aerosol sealing shall meet the requirements of this section.

D. All duct insulation product R-values shall be based on insulation only (excluding air films, vapor retarders, or other duct components) and tested C-values at 75°F mean temperature at the installed thickness, in accordance with ASTM C518 or ASTM C177, incorporated herein by reference, and certified pursuant to Section 110.8.

E. The installed thickness of duct insulation used to determine its R-value shall be determined as follows:

i. For duct board, duct liner, and factory-made rigid ducts not normally subjected to compression, the nominal insulation thickness shall be used.

ii. For duct wrap, installed thickness shall be assumed to be 75 percent (25 percent compression) of nominal thickness.

iii. For factory-made flexible air ducts, the installed thickness shall be determined by dividing the difference between the actual outside diameter and nominal inside diameter by two.

F. Insulated flexible duct products installed to meet this requirement must include labels, in maximum intervals of 3 feet, showing the thermal performance R-value for the duct insulation itself (excluding air films, vapor retarder, or other duct components), based on the tests in Section ~~120.4(c)~~160.3(c)2D and the installed thickness determined by Section ~~120.4(d)3~~ 160.3(c)2Eiii.

G. Insulation shall be protected from damage, including that due to sunlight, moisture, equipment maintenance, and wind but not limited to the following: Insulation exposed to weather shall be suitable for outdoor service e.g., protected by aluminum, sheet metal, painted canvas, or plastic cover. Cellular foam insulation shall be protected as above or painted with a coating that is water retardant and provides shielding from solar radiation that can cause degradation of the material.

3. **~~Required~~ Mechanical Acceptance Testing.** ~~Nonresidential, high-rise residential, and hotel/motel buildings~~ Multifamily common use areas shall comply with ~~the applicable requirements of Sections 120.5(a) and 120.5(b).~~the following:

~~**EXCEPTION to Section 120.5:** Systems serving healthcare facilities.~~

A. Before an occupancy permit is granted the following equipment and systems shall be certified as meeting the Acceptance Requirements for Code Compliance, as specified by the Reference Nonresidential Appendix NA7. A Certificate of Acceptance shall be submitted to the enforcement agency that certifies that the equipment and systems meet the acceptance requirements:

i. Outdoor air ventilation systems shall be tested in accordance with NA7.5.1

ii. Constant volume, single zone air conditioning and heat pump unit controls shall be tested in accordance with NA7.5.2.

iii. Duct systems shall be tested in accordance with NA7.5.3 where either:

a. They are new duct systems that meet the criteria of Sections ~~140.4(l)1~~170.2(c)4Ji, ~~140.4(l)2~~170.2(c)4Jii, and ~~140.4(l)3~~170.2(c)4Jiii; or

b. They are part of a system that meets the criteria of Section ~~141.0(b)2D~~180.2(b)2Bii.

iv. Air economizers shall be tested in accordance with NA7.5.4.

**EXCEPTION to Section ~~120.5(a)4~~160.3(c)3Aiv**: Air economizers installed by the HVAC system manufacturer and certified to the Commission as being factory calibrated and tested are exempt from the Functional Testing section of the Air Economizer Controls acceptance test as described in NA7.5.4.2.

v. Demand control ventilation systems required by Section ~~120.1(c)3~~160.2(c)3 shall be tested in accordance with NA7.5.5

vi. Supply fan variable flow controls shall be tested in accordance with NA7.5.6

vii. Hydronic system variable flow controls shall be tested in accordance with NA7.5.7 and NA7.5.9

viii. Boiler or chillers that require isolation controls as specified by Section ~~140.4(k)2~~170.2(c)4Iii or ~~140.4(k)3~~170.2(c)4Iiii shall be tested in accordance with NA7.5.7

ix. Hydronic systems with supply water temperature reset controls shall be tested in accordance with NA7.5.8

x. Automatic demand shed controls shall be tested in accordance with NA7.5.10.

xi. Fault Detection and Diagnostics (FDD) for Packaged Direct-Expansion Units shall be tested in accordance with NA7.5.11.

xii. Automatic Fault Detection and Diagnostics (FDD) for air handling units and zone terminal units shall be tested in accordance with NA7.5.12.

xiii. Distributed Energy Storage DX AC Systems shall be tested in accordance with NA7.5.13.

xiv. Thermal Energy Storage (TES) Systems shall be tested in accordance with NA7.5.14.

xv. Supply air temperature reset controls shall be tested in accordance with NA7.5.15.

xvi. Water-cooled chillers served by cooling towers with condenser water reset controls shall be tested in accordance with NA7.5.16.

xvii. When an Energy Management Control System is installed, it shall functionally meet all of the applicable requirements of Part 6.

xviii. Occupant Sensing Zone Controls shall be tested in accordance with NA7.5.17.

B. When certification is required by Title 24, Part 1, Section 10-103.2, the acceptance testing specified by Section ~~120.5(a)~~ 160.3(c)3A shall be performed by a Certified Mechanical Acceptance Test Technician (CMATT). If the CMATT is operating as an employee, the CMATT shall be employed by a Certified Mechanical Acceptance Test Employer. The CMATT shall disclose on the Certificate of Acceptance a valid CMATT certification identification number issued by an approved Acceptance Test Technician Certification Provider. The CMATT shall complete all Certificate of Acceptance documentation in accordance with the applicable requirements in Section 10-103(a)4.

*TABLE ~~150.0-B~~160.3-A: Return Duct Sizing for Single Return Duct Systems*

| Return duct length shall not exceed 30 feet and shall contain no more than 180 degrees of bend. If the total bending exceeds 90 degrees, one bend shall be a metal elbow. Return grille devices shall be labeled in accordance with the requirements in Section ~~150.0(m)12Biv~~160.2(b)1Biv to disclose the grille's design airflow rate and a maximum allowable clean-filter pressure drop of 25 Pa (0.1 inches water) for the air filter when tested using ASHRAE Standard 52.2, or as rated in accordance with AHRI Standard 680 for the design airflow rate for the return grille. | | |
|---|---|---|
| **System Nominal Cooling Capacity (Ton)*** | **Return Duct Minimum Nominal Diameter (inch)** | **Minimum Total Return Filter Grille Nominal Area (inch$^2$)** |
| 1.5 | 16 | 500 |
| 2.0 | 18 | 600 |
| 2.5 | 20 | 800 |
| ***Not applicable to systems with nominal cooling capacity greater than 2.5 tons or less than 1.5 ton** | | |

*TABLE ~~150.0-C~~160.3-B: Return Duct Sizing for Multiple Return Duct Systems*

| Each return duct length shall not exceed 30 feet and shall contain no more than 180 degrees of bend. If the total bending exceeds 90 degrees, one bend shall be a metal elbow. Return grille devices shall be labeled in accordance with the requirements in Section ~~150.0(m)12Biv~~160.2(b)1Biv to disclose the grille's design airflow rate and a maximum allowable clean-filter pressure drop of 25 Pa (0.1 inches water) for the air filter when tested using ASHRAE Standard 52.2, or as rated in accordance with AHRI Standard 680 for the design airflow rate for the return grille. | | | |
|---|---|---|---|
| **System Nominal Cooling Capacity (Ton)*** | **Return Duct 1 Minimum Nominal Diameter (inch)** | **Return Duct 2 Minimum Nominal Diameter (inch)** | **Minimum Total Return Filter Grille Nominal Area (inch$^2$)** |
| 1.5 | 12 | 10 | 500 |
| 2.0 | 14 | 12 | 600 |
| 2.5 | 14 | 14 | 800 |
| 3.0 | 16 | 14 | 900 |
| 3.5 | 16 | 16 | 1000 |
| 4.0 | 18 | 18 | 1200 |
| 5.0 | 20 | 20 | 1500 |
| ***Not applicable to systems with nominal cooling capacity greater than 5.0 tons or less than 1.5 tons.** | | | |

TABLE ~~120.2-A~~160.3-C DDC Applications and Qualifications

| Building Status | Applications | Qualifications |
|---|---|---|
| Newly Constructed Buildings | Air handling system and all zones served by the system | Individual systems supplying more than three zones and with design heating or cooling capacity of 300 kBtu/h and larger |
| Newly Constructed Buildings | Chilled water plant and all coils and terminal units served by the system | Individual plants supplying more than three zones and with design cooling capacity of 300 kBtu/h (87.9 kW) and larger |
| Newly Constructed Buildings | Hot water plant and all coils and terminal units served by the system | Individual plants supplying more than three zones and with design heating capacity of 300 kBtu/h (87.9 kW) and larger |
| Additions or Alterations | Zone terminal unit such as VAV box | Where existing zones served by the same air handling, chilled water, or hot water systems that have DDC |
| Additions or Alterations | Air handling system or fan coil | Where existing air handling system(s) and fan coil(s) served by the same chilled or hot water plant have DDC |
| Additions or Alterations | New air handling system and all new zones served by the system | Individual systems with design heating or cooling capacity of 300 kBtu/h and larger and supplying more than three zones and more than 75 percent of zones are new |
| Additions or Alterations | New or upgraded chilled water plant | Where all chillers are new and plant design cooling capacity is 300 kBtu/h (87.9 kW) and larger |
| Additions or Alterations | New or upgraded hot water plant | Where all boilers are new and plant design heating capacity is 300 kBtu/h (87.9 kW) and larger |

*TABLE ~~120.3-A~~160.3-D PIPE INSULATION THICKNESS FOR SPACE CONDITIONING SYSTEMS*

| Fluid Operating Temperature Range (°F) | Insulation Conductivity: Conductivity (in Btu·in/h·ft²·°F) | Insulation Conductivity: Mean Rating Temperature (°F) | | Nominal Pipe Diameter (in inches): < 1 | 1 to <1.5 | 1.5 to < 4 | 4 to < 8 | 8 and larger |
|---|---|---|---|---|---|---|---|---|
| **Space heating ~~and Service Water Heating~~ Systems (Steam, Steam Condensate, Refrigerant, Space Heating, Service Hot Water)** | | | | **Minimum Pipe Insulation Required (Thickness in inches or R-value)** | | | | |
| Above 350 | 0.32-0.34 | 250 | Inches | 4.5 | 5.0 | 5.0 | 5.0 | 5.0 |
| | | | R-value | R 37 | R 41 | R 37 | R 27 | R 23 |
| 251-350 | 0.29-0.32 | 200 | Inches | 3.0 | 4.0 | 4.5 | 4.5 | 4.5 |
| | | | R-value | R 24 | R 34 | R 35 | R 26 | R 22 |
| 201-250 | 0.27-0.30 | 150 | Inches | 2.5 | 2.5 | 2.5 | 3.0 | 3.0 |
| | | | R-value | R 21 | R 20 | R 17.5 | R 17 | R 14.5 |
| 141-200 | 0.25-0.29 | 125 | Inches | 1.5 | 1.5 | 2.0 | 2.0 | 2.0 |
| | | | R-value | R 11.5 | R 11 | R 14 | R 11 | R 10 |
| 105-140 | 0.22-0.28 | 100 | Inches | 1.0 | 1.5 | 1.5 | 1.5 | 1.5 |
| | | | R-value | R 7.7 | R 12.5 | R 11 | R 9 | R 8 |
| | | | | **Nominal Pipe Diameter (in inches)** | | | | |
| | | | | **< 1** | **1 to <1.5** | **1.5 to < 4** | **4 to < 8** | **8 and larger** |
| **Space cooling systems (chilled water, refrigerant and brine)** | | | | **Minimum Pipe Insulation Required (Thickness in inches or R-value)[1]** | | | | |
| 40-60 | 0.21-0.27 | 75 | Inches | ~~Nonres 0.5~~ / ~~Res~~ 0.75 | ~~Nonres 0.5~~ / ~~Res~~ 0.75 | 1.0 | 1.0 | 1.0 |
| | | | R-value | ~~Nonres R 3~~ / ~~Res~~ R 6 | ~~Nonres R 3~~ / ~~Res~~ R 5 | R 7 | R 6 | R 5 |
| Below 40 | 0.20-0.26 | 50 | Inches | 1.0 | 1.5 | 1.5 | 1.5 | 1.5 |
| | | | R-value | R 8.5 | R 14 | R 12 | R 10 | R 9 |

Footnote to TABLE ~~120.3-A~~160.3-D:

1. These thickness are based on energy efficiency considerations only. Issues such as water vapor permeability or surface condensation sometimes require vapor retarders or additional insulation.

## SECTION 160.4 – MANDATORY REQUIREMENTS FOR WATER HEATING SYSTEMS

(a) Systems using gas or propane water heaters to serve individual dwelling units shall include the following components:

1. A dedicated 125 volt, 20 amp electrical receptacle that is connected to the electric panel with a 120/240 volt 3 conductor, 10 AWG copper branch circuit, within 3 feet from the water heater and accessible to the water heater with no obstructions. In addition, all of the following:

   A. Both ends of the unused conductor shall be labeled with the word "spare" and be electrically isolated; and

   B. A reserved single pole circuit breaker space in the electrical panel adjacent to the circuit breaker for the branch circuit in A above and labeled with the words "Future 240V Use"; and

2. A Category III or IV vent, or a Type B vent with straight pipe between the outside termination and the space where the water heater is installed; and

3. A condensate drain that is no more than 2 inches higher than the base of the installed water heater, and allows natural draining without pump assistance, and

4. A gas supply line with a capacity of at least 200,000 Btu/hr.

(b) Water heating recirculation loops serving multiple dwelling units shall meet the requirements of Section 110.3(c)~~5~~4.

(c) Solar water-heating systems and collectors shall be certified and rated by the Solar Rating and Certification Corporation (SRCC), the International Association of Plumbing and Mechanical Officials, Research and Testing (IAPMO R&T), or by a listing agency that is approved by the Executive Director.

(d) Instantaneous water heaters with an input rating greater than 6.8 kBTU/hr (2kW) shall meet the requirements of Section 110.3(c)7

(e) **~~Mandatory Requirements for~~ Commercial Boilers**

1. Combustion air positive shut-off shall be provided on all newly installed boilers as follows:

   A. All boilers with an input capacity of 2.5 MMBtu/h (2,500,000 Btu/h) and above, in which the boiler is designed to operate with a nonpositive vent static pressure.

   B. All boilers where one stack serves two or more boilers with a total combined input capacity per stack of 2.5 MMBtu/h (2,500,000 Btu/h).

2. Boiler combustion air fans with motors 10 horsepower or larger shall meet one of the following for newly installed boilers:

   A. The fan motor shall be driven by a variable speed drive, or

   B. The fan motor shall include controls that limit the fan motor demand to no more than 30 percent of the total design wattage at 50 percent of design air volume.

3. Newly installed boilers with an input capacity 5 MMBtu/h (5,000,000 Btu/h) and greater shall maintain excess (stack-gas) oxygen concentrations at less than or equal to 5.0 percent by volume on a dry basis over firing rates of 20 percent to 100 percent. Combustion air volume shall be controlled with respect to firing rate or flue gas oxygen concentration. Use of a common gas and combustion air control linkage or jack shaft is prohibited.

   **EXCEPTION to Section ~~120.9(c)~~ 160.4(e)3:** Boilers with steady state full-load thermal efficiency 85 percent or higher.

(f) **Insulation for Piping and Tanks**

1. **Storage tank insulation.** Unfired hot water tanks, such as storage tanks and backup storage tanks for solar water-heating systems, shall be externally wrapped with insulation having an installed thermal resistance of R-12 or greater or have internal insulation of at least R-16 and a label on the exterior of the tank showing the insulation R-value.

2. ~~Piping shall be insulated as follows:~~All domestic hot water piping shall be insulated as specified in Section 609.11 of the California Plumbing Code. In addition, the following piping conditions shall have a minimum insulation wall thickness of 1 inch or a minimum insulation R-value of 7.7:

A. The first 5 feet (1.5 meters) of cold water pipes from the storage tank.

B. All hot water piping with a nominal diameter equal to or greater than 3/4 inch (19 millimeter) and less than 1 inch.

C. All hot water piping with a nominal diameter less than 3/4 inch that is:

i. Associated with a domestic hot water recirculation system;

ii. From the heating source to the kitchen fixtures;

iii. From the heating source to a storage tank or between storage tanks; or

iv. Buried below grade.

~~**EXCEPTION 1 to Section 150.0(j)2:** Factory-installed piping within space-conditioning equipment certified under Section 110.1 or 110.2.~~

**EXCEPTION ~~2~~1 to Section ~~150.0(j)2~~160.4(f)2:** Piping that penetrates framing members shall not be required to have pipe insulation for the distance of the framing penetration. Piping that penetrates metal framing shall use grommets, plugs, wrapping or other insulating material to assure that no contact is made with the metal framing. Insulation shall abut securely against all framing members.

**EXCEPTION ~~3~~2 to Section ~~150.0(j)2~~160.4(f)2:** Piping installed in interior or exterior walls shall not be required to have pipe insulation if all of the requirements are met for compliance with Quality Insulation Installation (QII) as specified in the Reference Residential Appendix RA3.5.

**EXCEPTION ~~4~~3 to Section ~~150.0(j)2~~160.4(f)2:** Piping surrounded with a minimum of 1 inch of wall insulation, 2 inches of crawlspace insulation, or 4 inches of attic insulation, shall not be required to have pipe insulation.

3. **Insulation Protection.** Pipe Insulation shall be protected from damage due to sunlight, moisture, equipment maintenance, and wind. Protection shall, at minimum, include the following:

A. Pipe insulation exposed to weather shall be protected by a cover suitable for outdoor service. The cover shall be water retardant and provide shielding from solar radiation that can cause degradation of the material. Adhesive tape shall not be used to provide this protection.

B. Pipe insulation covering chilled water piping and refrigerant suction piping located outside the conditioned space shall include, or be protected by, a Class I or Class II vapor retarder. All penetrations and joints shall be sealed.

C. Pipe insulation buried below grade must be installed in a water proof and non-crushable casing or sleeve.

## SECTION 160.5 – MANDATORY LIGHTING REQUIREMENTS FOR INDOOR AND OUTDOOR SPACES.

The design and installation of all lighting systems, lighting controls, and equipment in the following functional areas shall comply with the applicable ~~residential~~ lighting requirements of Section ~~150.0(k)~~160.5(a)..

1. ~~High-rise residential~~ Multifamily dwelling units.
2. Outdoor lighting attached to ~~a high-rise residential or hotel/motel~~ multifamily building and separately controlled from the inside of a dwelling unit ~~or guest room~~.

~~3. Fire station dwelling accommodations.~~

~~4. Hotel and motel guest rooms. Additionally, hotel and motel guest rooms shall meet the requirements of Section 130.1(c)8 and Section 130.5(d)4.~~

3~~5~~. Dormitory and Senior housing dwelling accommodations.

In buildings containing these functional areas, all other functional areas, such as common use areas, shall comply with the applicable ~~nonresidential~~ lighting and controlled receptacle requirements of Sections 160.5(b) through 160.5(e).

(a) **Dwelling Unit Lighting.**

1. Luminaire Requirements.

A. **Luminaire Efficacy.** All installed luminaires shall meet the requirements in TABLE ~~150.0~~160.5-A.

B. **Blank Electrical Boxes.** The number of electrical boxes that are more than 5 feet above the finished floor and do not contain a luminaire or other device shall be no greater than the number of bedrooms. These electrical boxes must be served by a dimmer, vacancy sensor control, or fan speed control.

C. **Recessed Downlight Luminaires in Ceilings.** In addition to complying with ~~150.0(k)1A~~160.5(a)1A, luminaires recessed into ceilings shall meet all of the following requirements:

i. Be listed, as defined in Section 100.1, for zero clearance insulation contact (IC) by Underwriters Laboratories or other nationally recognized testing/rating laboratory; and

ii. Have a label that certifies the luminaire is airtight with air leakage less than 2.0 CFM at 75 Pascals when tested in accordance with ASTM E283. An exhaust fan housing shall not be required to be certified airtight; and

iii. Be sealed with a gasket or caulk between the luminaire housing and ceiling, and have all air leak paths between conditioned and unconditioned spaces sealed with a gasket or caulk; and

iv. For luminaires with hardwired ballasts or drivers, allow ballast or driver maintenance and replacement to be readily accessible to building occupants from below the ceiling without requiring the cutting of holes in the ceiling; and

v. Shall not contain screw base sockets.

D. **Electronic Ballasts for Fluorescent Lamps.** Ballasts for fluorescent lamps rated 13 watts or greater shall be electronic and shall have an output frequency no less than 20 kHz.

E. **Night Lights, Step Lights and Path Lights.** Night lights, step lights and path lights shall not be required to comply with TABLE ~~150.0~~160.5-A or be controlled by vacancy sensors provided they are rated to consume no more than 5 watts of power and emit no more than 150 lumens.

F. **Lighting Integral to Exhaust Fans.** Lighting integral to exhaust fans shall meet the applicable requirements of Section ~~150.0(k)~~160.5(a).

**EXCEPTION to Section ~~150.0(k)1F~~160.5(a)1F:** Lighting installed by the manufacturer in kitchen exhaust hoods.

G. **Screw based luminaires.** Screw based luminaires shall contain lamps that comply with Reference Joint Appendix JA8.

**EXCEPTION to Section ~~150.0(k)1G~~160.5(a)1G**: Luminaires with hard-wired ballasts for high intensity discharge lamps.

H. **Light Sources in Enclosed or Recessed Luminaires.** Lamps and other separable light sources that are not compliant with the JA8 elevated temperature requirements, including marking requirements, shall not be installed in enclosed or recessed luminaires.

I. **Light Sources in Drawers, Cabinets, and Linen Closets.** Light sources internal to drawers, cabinetry or linen closets shall not be required to comply with TABLE ~~150.0~~160.5-A or be controlled by vacancy sensors provided that they are rated to consume no more than 5 watts of power and emit no more than 150

2. Interior Lighting **Switching Devices and Controls.**

A. All forward phase cut dimmers used with LED light sources shall comply with NEMA SSL 7A.

B. Exhaust fans shall be controlled separately from lighting systems.

**EXCEPTION to Section ~~150.0(k)2B~~160.5(a)2B:** Lighting integral to an exhaust fan may be on the same control as the fan provided the lighting can be turned OFF in accordance with the applicable provisions in Section ~~150.0(k)2~~160.5(a)2 while allowing the fan to continue to operate.

C. Lighting shall have readily accessible wall-mounted controls that allow the lighting to be manually turned ON and OFF.

**EXCEPTION to Section ~~150.0(k)2C~~160.5(a)2C:** Ceiling fans may provide control of integrated lighting via a remote control.

D. Lighting controls and equipment shall be installed in accordance with the manufacturer's instructions.

E. No controls shall bypass a dimmer, occupant sensor or vacancy sensor function where that dimmer or sensor has been installed to comply with Section ~~150.0(k)~~160.5(a).

F. Lighting controls shall comply with the applicable requirements of Section 110.9.

G. An Energy Management Control System (EMCS) may be used to comply with control requirements in Section ~~150.0(k)~~160.5(a) if at a minimum it provides the functionality of the specified controls in accordance with Section 110.9, meets the installation certificate requirements in Section ~~130.4~~ 160.5(e), meets the EMCS requirements in Section ~~130.0(e)~~160.5(b)4, and complies with all other applicable requirements in Section ~~150.0(k)2~~160.5(a)2.

H. A multiscene programmable controller may be used to comply with dimmer requirements in Section ~~150.0(k)~~ 160.5(a) if at a minimum it provides the functionality of a dimmer in accordance with Section 110.9, and complies with all other applicable requirements in Section ~~150.0(k)2~~160.5(a)2.

I. In bathrooms, ~~garages,~~ dwelling unit laundry rooms, and utility rooms, at least one luminaire in each of these spaces shall be controlled by an occupant or vacancy sensor providing automatic-off functionality. If an occupant sensor is installed, it shall be initially configured to manual-on operation using the manual control required under Section ~~150.0(k)2C~~160.5(a)2C.

J. Luminaires that are or contain light sources that meet Reference Joint Appendix JA8 requirements for dimming, and that are not controlled by occupancy or vacancy sensors, shall have dimming controls.

**EXCEPTION 1 to Section ~~150.0(k)2K~~160.5(a)2J:** Luminaires in closets less than 70 square feet.

**EXCEPTION 2 to Section ~~150.0(k)2K~~160.5(a)2J:** Luminaires in hallways.

K. Undercabinet lighting shall be controlled separately from ceiling-installed lighting such that one can be turned on without turning on the other.

*TABLE ~~150.0~~160.5-A CLASSIFICATION OF DWELLING UNIT HIGH EFFICACY LIGHT SOURCES*

| **High Efficacy Light Sources**<br>Light sources shall comply with one of the columns below: | |
|---|---|
| Light sources in this column other than those installed in ceiling recessed downlight luminaires are classified as high efficacy and are **not** | Light sources in this column are only considered to be high efficacy if they are certified to the Commission as High |

| | |
|---|---|
| required to comply with Reference Joint Appendix JA8 | Efficacy Light Sources in accordance with Reference Joint Appendix JA8 and marked as required by JA8. |
| 1. Pin-based linear fluorescent or compact fluorescent light sources using electronic ballasts.<br>2. Pulse-start metal halide light sources.<br>3. High pressure sodium light sources.<br>4. Luminaires with hardwired high frequency generator and induction lamp.<br>5. LED light sources installed outdoors.<br>6. Inseparable SSL luminaires containing colored light sources that are installed to provide decorative lighting. | 8. All light sources installed in ceiling recessed downlight luminaires. Note that ceiling recessed downlight luminaires shall not have screw bases regardless of lamp type as described in Section ~~150.0(k)1C~~160.5(a)1C.<br>9. Any light source not otherwise listed in this table. |

(b) **Common Use Area Lighting.** The design and installation of all lighting systems and equipment in multifamily common use areas ~~nonresidential, high-rise residential, hotel/motel buildings~~, outdoor lighting, and electrical power distribution systems within the scope of Section 100.0(a) shall comply with the applicable provisions of Sections ~~130.0~~160.5(b)1 through ~~130.5~~160.5(e).

**NOTE:** The requirements of Section~~s~~ ~~130.0~~160.5(b)~~ through~~ ~~130.5~~ apply to newly constructed buildings. Section ~~141.0~~180.1 and 180.2 specif~~ies~~y which requirements of Sections ~~130.0~~160.5(b)1 through ~~130.5~~160.5(e)also apply to additions and alterations to existing buildings.

1. **Luminaire classification and power**. Luminaires shall be classified and their wattage determined as follows:

A. Luminaire wattage shall be labeled as follows:

i. High intensity discharge luminaires, having an integral electronic ballast, with a maximum relamping rated wattage of 150 watts.

ii. Low-voltage luminaires (except low voltage track systems), ≤ 24 volts, with a maximum relamping rated wattage of 50 watts.

iii. Compact fluorescent luminaires, having an integral electronic ballast, with a maximum relamping rated wattage of 42 watts.

a. The maximum rated wattage or relamping rated wattage of a luminaire shall be listed on a permanent, preprinted, factory-installed label, as specified by UL 1574, 1598, 2108, or 8750, as applicable; and

b. The factory-installed maximum rated wattage or relamping rated wattage label shall not consist of peel-off or peel-down layers or other methods that allow the rated wattage to be changed after the luminaire has been shipped from the manufacturer.

**EXCEPTION to Section ~~130.0(c)1B~~ 160.5(b)1Aiiib**: Peel-down labels may be used only for the following luminaires when they can accommodate a range of lamp wattages without changing the luminaire housing, ballast, transformer or wiring. Qualifying luminaires shall have a single lamp, and shall have integrated ballasts or transformers. Peel-down labels must be layered such that the rated wattage reduces as successive layers are removed.

B. For luminaires with line voltage lamp holders not containing permanently installed ballasts or transformers, the wattage of such luminaires shall be determined as follows:

i. The maximum rated wattage of the luminaire; and

ii. For recessed luminaires with line-voltage medium screw base sockets, wattage shall not be less than 50 watts per socket, or the rated wattage of the installed JA8 compliant lamps.

C. For luminaires with permanently installed or remotely installed ballasts, the wattage of such luminaires shall be the operating input wattage of the rated lamp/ballast combination published in the ballast manufacturer's catalogs based on independent testing lab reports as specified by UL 1598.

D. For inseparable SSL luminaires and SSL luminaires with remotely mounted drivers, the maximum rated wattage shall be the maximum rated input wattage of the SSL luminaire as specified in Section ~~130.0(c)1~~ 160.5(c)1A when tested in accordance with UL 1598, 2108, 8750, or IES LM-79.

E. For LED tape lighting and LED linear lighting with LED tape lighting components, the maximum rated wattage shall be the sum of the installed length of the tape lighting times its rated linear power density in watts per linear feet, or the maximum rated input wattage of the driver or power supply providing power to the lighting system, with tape lighting tested in accordance with UL 2108, 8750, or IES LM-79,

F. For modular lighting systems that allow the addition or relocation of luminaires without altering the wiring of the system, shall be determined as follows:

i. The wattage shall be the greater of:

c. 30 watts per linear foot of track or plug-in busway; or

d. the rated wattage of all of the luminaires included in the system, where the luminaire wattage is determined as specified in Section ~~130.0(c)1~~ 160.5(c)1A; or

ii. For line-voltage lighting track and plug-in busway served by a track lighting integral current limiter or a dedicated track lighting supplementary overcurrent protection panel, the wattage shall be determined as follows:

a. The volt-ampere rating of current limiter as specified by UL 1077;

b. The sum of the ampere (A) rating of all of the current protection devices times the branch circuit voltages for track lighting supplementary overcurrent protection panel ; or

iii. For other modular lighting systems with power supplied by a driver, power supply or transformer, including but not limited to low-voltage lighting systems, the wattage of the system shall be the maximum rated input wattage of the driver, power supply or transformer published in the manufacturer's catalogs, as specified by UL 2108 or 8750.

**EXCEPTION to Section ~~130.0(c)6~~160.5(b)1F:** For power-over-Ethernet lighting systems, power provided to installed non-lighting devices may be subtracted from the total power rating of the power-over-Ethernet system.

G. For all other lighting equipment not addressed by Sections ~~130.0(c)2~~160.5(b)1B through ~~6~~F, the wattage of the lighting equipment shall be the maximum rated wattage of the lighting equipment, or operating input wattage of the system, labeled in accordance with Section ~~130.0(c)1~~160.5(b)1A, or published in manufacturer's catalogs, based on independent testing lab reports as specified by UL 1574, 1598, 2108, 8750, or IES LM-79.

2. **Lighting Controls**. All lighting controls and equipment shall comply with the applicable requirements in Sections 110.9, ~~130.1~~160.5(b)5 and ~~130.2~~160.5(c), and shall be installed in accordance with any applicable manufacturer instructions.

3. **Energy Management Control System (EMCS)**. An EMCS may be installed to comply with the requirements of one or more lighting controls if it meets the following minimum requirements:

A. Provides all applicable functionality for each specific lighting control or system for which it is installed in accordance with Sections 110.9, ~~130.1~~160.5(b)5 and ~~130.2~~160.5(c); and

B. Complies with all applicable Lighting Control Installation Requirements in accordance with Section ~~130.4~~160.5(e) for each specific lighting control or system for which it is installed; and

C. Complies with all applicable application requirements for each specific lighting control or system for which it is installed, in accordance with Part 6.

4. **Mandatory Indoor Lighting Controls**. ~~Nonresidential, high-rise residential,~~ Multifamily common use areas ~~and hotel/motel buildings~~ shall comply with the applicable requirements of Sections ~~130.1(a)~~160.5.(b)4A through ~~130.1(f)~~ 160.5(b)4F, in addition to the applicable requirements of Sections 110.9.

A. **Manual Area Controls.** Each area enclosed by ceiling-height partitions shall provide lighting controls that allow the lighting in that area to be manually turned on and off. The manual control shall:

i. Be readily accessible; and

**EXCEPTION to Section ~~130.1(a)1~~160.5(b)4Ai:** Public restrooms having two or more stalls, parking areas, stairwells, and corridors may use a manual control not accessible to unauthorized personnel.

ii. Be located in the same enclosed area with the lighting it controls; and

**EXCEPTION 1 to Section ~~130.1(a)2~~160.5(b)4Aii:** For ~~malls and atria, auditorium areas, retail merchandise sales areas, wholesale showroom areas, commercial and industrial storage areas, general commercial and industrial work areas, convention centers, arenas, psychiatric and secure areas in healthcare facilities, and other~~ areas where placement of a manual area control poses a health and safety hazard, the manual area control may instead be located so that a person using the control can see the lights or area controlled by that control, or visually signal or display the current state of the controlled lighting.

~~**EXCEPTION 2 to Section 130.1(a)2160.5(b)4Aii:** In healthcare facilities, for restrooms and bathing rooms intended for a single occupant, the lighting control may be located outside the enclosed area but directly adjacent to the door.~~

iii. Provide separate control of general~~, floor display,~~ wall display, window display, case display, ornamental, and special effects lighting, such that each type of lighting can be turned on or off without turning on or off other types of lighting, and without turning on or off any other equipment.

**EXCEPTION to Section ~~130.1(a)~~160.5(b)4A:** Up to 0.2 watts per square foot of indoor lighting may be continuously illuminated to allow for means of egress illumination consistent with California Building Code Section 1008. Egress lighting complying with this wattage limitation is not required to comply with manual area control requirements if:

i. The area is designated for means of egress on the plans and specifications submitted to the enforcement agency under Section 10-103(a)2 of Part 1; and

ii. The controls for the egress lighting are not accessible to unauthorized personnel.

B. **Multi-Level Lighting Controls.** The general lighting of any enclosed area 100 square feet or larger with a connected lighting load that exceeds 0.5 watts per square foot shall provide multi-level lighting controls that allow the level of lighting to be adjusted up and down. The multi-level controls shall provide the number of control steps and meet the uniformity requirements specified in TABLE ~~130.1-A~~160.5-B.

**EXCEPTION 1 to Section ~~130.1(b)~~ 160.5(b)4B:** An area enclosed by ceiling height partitions that has only one luminaire with no more than two lamps.

**EXCEPTION 2 to Section ~~130.1(b)~~ 160.5(b)4B:** Restrooms.

**EXCEPTION 3 to Section ~~130.1(b)~~ 160.5(b)4B:** ~~Healthcare facilities.~~ Parking garages, parking areas, loading and unloading areas, stairwells, and corridors shall have a minimum of one control step between 20-60 percent of full rated power, regardless of luminaire type.

C. **Automatic Shut-OFF Controls.** All installed indoor lighting shall be equipped with controls able to automatically reduce lighting power when the space is typically unoccupied.

~~**EXCEPTION to Section 130.1(c):** Healthcare facilities.~~

i. In addition to lighting controls installed to comply with Sections ~~130.1(a)~~ 160.5(b)4A and ~~(b)~~B, all installed indoor lighting shall be equipped with controls that meet the following requirements:

a. Shall be controlled with an occupant sensing control, automatic time-switch control, or other control capable of automatically shutting OFF all of the lighting when the space is typically unoccupied; and

b. Separate controls for the lighting on each floor, other than lighting in stairwells; and

c. Separate controls for a space enclosed by ceiling height partitions not exceeding 5,000 square feet; and

~~**EXCEPTION to Section 130.1(c)1C:** In the following function areas the area controlled may not exceed 20,000 square feet: Malls, auditoriums, single tenant retail, industrial, convention centers, and arenas;~~

d. Separate controls for general, display, and ornamental, ~~and display case~~ lighting; and

e. For automatic time-switch controls, may include a manual-on mode.

**EXCEPTION 1 to Section ~~130.1(c)1~~160.5(b)4Ci:** Where the lighting is serving an area that is in continuous use, 24 hours per day/365 days per year.

**EXCEPTION 2 to Section ~~130.1(c)1~~160.5(b)4Ci**: Lighting complying with Section ~~130.1(c)5~~160.5(b)4Cv or ~~7~~vii.

**EXCEPTION 3 to Section ~~130.1(c)1~~160.5(b)4Ci:** Up to 0.1 watts per square foot of lighting in any area within a building may be continuously illuminated, provided that the area is designated for means of egress on the plans and specifications submitted to the enforcement agency under Section 10-103(a)2 of Part 1.

**EXCEPTION 4 to Section ~~130.1(c)1~~160.5(b)4Ci**: Electrical equipment rooms subject to Article 110.26(D) of the California Electrical Code.

**EXCEPTION 5 to Section ~~130.1(c)1~~160.5(b)4Ci**: Illumination provided by lighting equipment that is designated for emergency lighting, connected to an emergency power source or battery supply, and is intended to function in emergency mode only when normal power is absent.

ii. Countdown timer switches may be used to comply with the automatic shut-OFF control requirements in **Section ~~130.1(c)1~~160.5(b)4Ci** only in closets less than 70 square feet~~, and server aisles in server rooms~~. The maximum timer setting shall be 10 minutes for closets~~, and 30 minutes for server aisles~~.

iii. If an automatic time-switch control, other than an occupant sensing control, is installed to comply with **Section ~~130.1(c)1~~160.5(b)4Ci**, it shall incorporate a manual override lighting control that:

a. Complies with ~~130.1(a)~~160.5(b)4A; and

b. Allows the lighting to remain ON for no more than 2 hours when an override is initiated.

~~**EXCEPTION to Section 130.1(c)3B:** In the following function areas, the override time may exceed 2 hours: Malls, auditoriums, single tenant retail, industrial, and arenas where captive-key override is utilized.~~

iv. If an automatic time-switch control, other than an occupant sensing control, is installed to comply with Section ~~130.1(c)1~~160.5(b)4Ci, it shall incorporate an automatic holiday "shut-OFF" feature that turns OFF all loads for at least 24 hours, and then resumes the normally scheduled operation.

~~**EXCEPTION to Section 130.1(c)4:** In retail stores and associated malls, restaurants, grocery stores, churches, and theaters, the automatic time-switch control is not required to incorporate an automatic holiday shut-OFF feature.~~

v. ~~**Areas where Occupant Sensing Controls are required to shut OFF All Lighting**.~~ In offices 250 square feet or smaller, multipurpose rooms of less than 1,000 square feet, ~~classrooms of any size,~~ conference rooms of any size, and restrooms of any size, lighting shall be controlled with occupant sensing controls to automatically shut OFF all of the lighting when the room is unoccupied.

In areas required by Section ~~130.1(b)~~160.5(b)4B to have multi-level lighting controls, the occupant sensing controls shall function either as a:

a. Partial-ON Occupant Sensor capable of automatically activating between 50-70 percent of controlled lighting power, or

b. Vacancy Sensor, where all lighting responds to a manual ON input only.

In areas not required by Section ~~130.1(b)~~160.5(b)4B to have multi-level lighting controls, the occupant sensing controls shall function either as a:

a. Occupant Sensor; or

b. Partial-ON Occupant Sensor, or

c. Vacancy Sensor, where all lighting responds to a manual ON input only.

In addition, controls shall be provided that allow the lights to be manually shut-OFF in accordance with Section ~~130.1(a)~~160.5(b)4A regardless of the sensor status.

**vi.** ~~**Areas where full or partial OFF occupant sensing controls are required.** Lighting installed in the following areas shall meet the following requirements in addition to complying with Section 130.1(c)1~~160.5(b)4Ci.

~~a. In aisle ways and open areas in warehouses, lighting shall be controlled with occupant sensing controls that automatically reduce lighting power by at least 50 percent when the areas are unoccupied. The occupant sensing controls shall independently control lighting in each aisle way, and shall not control lighting beyond the aisle way being controlled by the sensor.~~

~~**EXCEPTION 1 to Section 130.1(c)6A:** In aisle ways and open areas in warehouses in which the installed lighting power is 80 percent or less of the value allowed under the Area Category Method, occupant sensing controls shall reduce lighting power by at least 40 percent.~~

~~**EXCEPTION 2 to Section 130.1(c)6A:** When metal halide lighting or high pressure sodium lighting is installed in warehouses, occupant sensing controls shall reduce lighting power by at least 40 percent.~~

~~a.~~ Lighting installed in corridors and stairwells shall meet with requirements of Section 160.5(b)4Ci and be controlled by occupant sensing controls that separately reduce the lighting power in each space by at least 50 percent when the space is unoccupied. The occupant sensing controls shall be capable of automatically turning the lighting fully ON only in the separately controlled space, and shall be automatically activated from all designed paths of egress.

**vii.** ~~**Areas where partial OFF occupant sensing controls are required**~~**.** Lighting installed in the following areas shall meet the following requirements instead of complying with Section ~~130.1(c)1~~160.5(b)4Ci.

a. Lighting in stairwells and common use area corridors that provide access to ~~guestrooms and~~ dwelling units ~~of high-rise residential buildings and hotel/motels~~ shall be controlled with occupant sensing controls that automatically reduce lighting power by at least 50 percent when the areas are unoccupied. The occupant sensing controls shall be capable of automatically turning the lighting fully ON only in the separately controlled space, and shall be automatically activated from all designed paths of egress.

**EXCEPTION to Section ~~130.1(c)7A~~160.5(b)4Cviia:** In corridors and stairwells in which the installed lighting power is 80 percent or less of the value allowed under the Area Category Method, occupant sensing controls shall reduce power by at least 40 percent.

b. In parking garages, parking areas and loading and unloading areas, general lighting shall be controlled by occupant sensing controls having at least one control step between 20 percent and 50 percent of design lighting power. No more than 500 watts of rated lighting power shall be controlled together as a single zone. A reasonably uniform level of illuminance shall be achieved in accordance with the applicable requirements in TABLE ~~130.1-A~~160.5-B. The occupant sensing controls shall be capable of automatically turning the lighting fully ON only in the separately controlled space, and shall be automatically activated from all designed paths of egress.

Interior areas of parking garages are classified as indoor lighting for compliance with Section ~~130.1(c)7B~~160.5(b)4Cviiib. Parking areas on the roof of a parking structure are classified as outdoor hardscape and shall comply with the applicable provisions in Section ~~130.2~~ 160.5(c).

**EXCEPTION to Section ~~130.1(c)7B~~160.5(b)4Cviiib:** Metal halide luminaires with a lamp plus ballast mean system efficacy of greater than 75 lumens per watt, used for general lighting in parking garages, parking areas and loading and unloading areas, shall be controlled by occupant sensing controls having at least one control step between 20 percent and 60 percent of design lighting power.

**EXCEPTION 2 to Section ~~130.1(c)~~160.5(b)4C:** Lighting providing means of egress illumination, as the term is used in the California Building Code, shall be configured to provide no less than the amount of light required by California Building Code Section 1008 while in the partial-off mode.

D. **Automatic Daylighting Controls.** The general lighting in skylit daylit zones and primary sidelit daylit zones, as well as the general lighting in the combined primary and secondary sidelit daylit zones in parking garages, shall provide controls that automatically adjust the power of the installed lighting up and down to keep the total light level stable as the amount of incoming daylight changes. For skylight located in an atrium, the skylit daylit zone definition shall apply to the floor area directly under the atrium and the top floor area directly adjacent to the atrium.

i. All skylit daylit zones, primary sidelit daylit zones, and the combined primary and secondary sidelit daylit zones in parking garages shall be shown on the plans.

**NOTE:** Parking areas on the roof of a parking structure are outdoor hardscape, not skylit daylit areas.

ii. The automatic daylighting controls shall provide separate control for luminaires in each type of daylit zone. Luminaires that fall in both a skylit and sidelit daylit zone shall be controlled as part of the skylit zone.

iii. The automatic daylighting controls shall:

a. For spaces required to install multilevel controls under Section ~~130.1(b)~~160.5(b)4B, adjust lighting via continuous dimming or the number of control steps provided by the multilevel controls;

b. For each space, ensure the combined illuminance from the controlled lighting and daylight is not less than the illuminance from controlled lighting when no daylight is available;

c. For areas other than parking garages, ensure that when the daylight illuminance is greater than 150 percent of the design illuminance received from the general lighting system at full power, the general lighting power in that daylight zone shall be reduced by a minimum of 65 percent; and

d. For parking garages, ensure that when illuminance levels measured at the farthest edge of the secondary sidelit zone away from the glazing or opening are greater than 150 percent of the illuminance provided by the controlled lighting when no daylight is available, the controlled lighting power consumption is zero.

iv. When photosensors are located within the daylit zone, at least one photosensor shall be located so that they are not readily accessible to unauthorized personnel.

v. The location where calibration adjustments are made to the automatic daylighting controls shall be readily accessible to authorized personnel but may be inside a locked case or under a cover which requires a tool for access.

**EXCEPTION 1 to Section ~~130.1(d)~~160.5(b)4D:** Areas under skylights where it is documented that existing adjacent structures or natural objects block direct sunlight for more than 1,500 daytime hours per year between 8a.m. and 4p.m.

**EXCEPTION 2 to Section ~~130.1(d)~~160.5(b)4D** Areas adjacent to vertical glazing below an overhang, where the overhang covers the entire width of the vertical glazing, no vertical glazing is above the overhang, and the ratio of the overhang projection to the overhang rise is greater than 1.5 for South, East and West orientations or greater than 1 for North orientations.

**EXCEPTION 3 to Section ~~130.1(d)~~160.5(b)4D:** Rooms in which the combined total installed general lighting power in the Skylit Daylit Zone and Primary Sidelit Daylit Zone is less than 120 Watts, or parking garage areas where the total combined general lighting power in the sidelit daylight zones is less than 60 watts.

**EXCEPTION 4 to Section ~~130.1(d)~~160.5(b)4D:** Rooms that have a total glazing area of less than 24 square feet, or parking garage areas with a combined total of less than 36 square feet of glazing or opening.

**EXCEPTION 5 to Section ~~130.1(d)~~160.5(b)4D:** For parking garages, luminaires located in the daylight adaptation zone and luminaires for only dedicated ramps. Daylight adaptation zone and dedicated ramps are defined in Section 100.1.

~~**EXCEPTION 6 to Section 130.1(d):** Luminaires in sidelit daylit zones in retail merchandise sales and wholesale showroom areas.~~

E. **Demand Responsive Controls.** See Section 110.12 for requirements for demand responsive lighting controls.

F. **Control Interactions.** Each lighting control installed to comply with Section ~~130.1~~160.5(b)4 shall permit or incorporate the functions of the other lighting controls required by this Section.

i. For general lighting, the manual area control shall permit the level or amount of light provided while the lighting is on to be set or adjusted by the controls specified in Sections ~~130.1(b), (c), (d), and (e)~~ 160.5(b)4B, C, D, and E..

ii. The manual area control shall permit the shutoff control to turn the lighting down or off.

iii. The multi-level lighting control shall permit the automatic daylighting control to adjust the electric lighting level in response to changes in the amount of daylight in the daylit zone.

iv. The multi-level lighting control shall permit the demand responsive control to adjust the lighting during a demand response event and to return it to the level set by the multilevel control after the event.

v. The shutoff control shall permit the manual area control to turn the lighting on. If the on request occurs while an automatic time switch control would turn the lighting off, then the on request shall be treated as an override request consistent with Section ~~130.1(c)3~~160.5(c)4Ciii.

vi. The automatic daylighting control shall permit the multi-level lighting control to adjust the level of lighting.

vii. For lighting controlled by multi-level lighting controls and by occupant sensing controls that provide an automatic-on function, the controls shall provide a partial-on function that is capable of automatically activating between 50-70 percent of controlled lighting power.

*TABLE ~~130.1-A~~160.5-B MULTI-LEVEL LIGHTING CONTROLS AND UNIFORMITY REQUIREMENTS*

<table>
<tr><th>Luminaire Type</th><th colspan="4">Minimum Required Control Steps<br>( percent of full rated power[1] )</th><th>Uniform level of illuminance shall be achieved by:</th></tr>
<tr><td>Line-voltage sockets except GU-24</td><td colspan="5" rowspan="4">Continuous dimming 10-100 percent</td></tr>
<tr><td>Low-voltage incandescent systems</td></tr>
<tr><td>LED luminaires and LED source systems</td></tr>
<tr><td>GU-24 rated for LED</td></tr>
<tr><td>GU-24 sockets rated for fluorescent > 20 watts</td><td colspan="5" rowspan="2">Continuous dimming 20-100 percent</td></tr>
<tr><td>Pin-based compact fluorescent > 20 watts[2]</td></tr>
<tr><td>GU-24 sockets rated for fluorescent ≤ 20 watts</td><td colspan="4" rowspan="3">Minimum one step between<br>30-70 percent</td><td rowspan="3">Stepped dimming; or<br>Continuous dimming; or<br>Switching alternate lamps in a luminaire</td></tr>
<tr><td>Pin-based compact fluorescent ≤ 20 watts[2]</td></tr>
<tr><td>Linear fluorescent and U-bent fluorescent ≤ 13 watts</td></tr>
<tr><td rowspan="2">Linear fluorescent and U-bent fluorescent > 13 watts</td><td colspan="4">Minimum one step in each range:</td><td rowspan="2">Stepped dimming; or<br>Continuous dimming; or<br>Switching alternate lamps in each luminaire, having a minimum of 4 lamps per luminaire illuminating the same area and in the same manner</td></tr>
<tr><td>20-40 %</td><td>50-70 %</td><td>75-85 %</td><td>100 %</td></tr>
<tr><td>Track Lighting</td><td colspan="4">Minimum one step between<br>30 – 70 percent</td><td>Step dimming; or<br>Continuous dimming; or<br>Separately switching circuits in multi-circuit track with a minimum of two circuits.</td></tr>
<tr><td>HID > 20 watts</td><td colspan="4" rowspan="3">Minimum one step between<br>50 - 70 percent</td><td rowspan="3">Stepped dimming; or<br>Continuous dimming; or<br>Switching alternate lamps in each luminaire, having a minimum of 2 lamps per luminaire, illuminating the same area and in the same manner.</td></tr>
<tr><td>Induction > 25 watts</td></tr>
<tr><td>Other light sources</td></tr>
</table>

| |
|---|
| 1. Full rated input power of ballast and lamp, corresponding to maximum ballast factor<br><br>2. Includes only pin based lamps: twin tube, multiple twin tube, and spiral lamps |
| ~~**EXCEPTION 1 to Table 130.1-A Minimum Required Control Steps:** Classrooms with a connected general lighting load of 0.7 watts per square feet or less shall have a minimum of one control step between 30-70 percent of full rated power, regardless of luminaire type.~~<br><br>~~**EXCEPTION 2 to** TABLE 130.1-A **-A Minimum Required Control Steps:** Library stack aisles, aisle ways and open areas in warehouses, Parking garages, parking areas, loading and unloading areas, stairwells, and corridors shall have a minimum of one control step between 20-60 percent of full rated power, regardless of luminaire type.~~ |

(c) **Outdoor Lighting and Controls Equipment.** ~~Nonresidential, high-rise residential and hotel/motel~~ Multifamily common use areas ~~buildings~~ shall comply with the applicable requirements of Sections ~~130.2(a)~~ 160.5(c)1 through ~~130.2(c)~~ 160.5(c)2.

1. **Luminaire Cutoff Requirements.** All outdoor luminaires of 6,200 initial luminaire lumens or greater, shall comply with Backlight, Uplight, and Glare (collectively referred to as "BUG" in accordance with IES TM-15-11, Addendum A) requirements as follows:

A. Maximum zonal lumens for Backlight, Uplight, and Glare shall be in accordance with Title 24, Part 11, Section 5.106.8.

**EXCEPTION 1 to Section ~~130.2(b)~~ 160.5(c)1:** Signs.

**EXCEPTION 2 to Section ~~130.2(b)~~ 160.5(c)1:** Lighting for building facades, public monuments, statues, and vertical surfaces of bridges.

**EXCEPTION 3 to Section ~~130.2(b)~~ 160.5(c)1:** Lighting not permitted by a health or life safety statute, ordinance, or regulation to be a cutoff luminaire.

**EXCEPTION 4 to Section ~~130.2(b)~~ 160.5(c)1:** Temporary outdoor lighting.

**EXCEPTION 5 to Section ~~130.2(b)~~ 160.5(c)1:** Replacement of existing pole mounted luminaires in hardscape areas meeting all of the following conditions:

A. Where the existing luminaire does not meet the luminaire BUG requirements in Section ~~130.2(b)~~ 160.5(c)1; and

B. Spacing between existing poles is greater than six times the mounting height of the existing luminaires; and

C. Where no additional poles are being added to the site; and

D. Where new wiring to the luminaires is not being installed; and

E. Provided that the connected lighting power wattage is not increased.

**EXCEPTION 6 to Section ~~130.2(b)~~ 160.5(c)1:** Luminaires that illuminate the public right of way on publicly maintained roadways, sidewalks, and bikeways that are owned or maintained by the local municipality or utility.

**EXCEPTION 7 to Section ~~130.2(b)~~ 160.5(c)1:** Outdoor lighting attached to a ~~high-rise residential or hotel/motel~~ multifamily building and separately controlled from the inside of a dwelling unit ~~or guest room~~.

2. **Controls for Outdoor Lighting.** Outdoor lighting shall be independently controlled from other electrical loads, and the controls for outdoor lighting shall meet the following functional requirements:

**EXCEPTION 1 to Section ~~130.2(c)~~ 160.5(c)2:** Outdoor lighting not permitted by a health or life safety statute, ordinance, or regulation to be turned OFF or reduced.

**EXCEPTION 2 to Section ~~130.2(c)~~ 160.5(c)2:** Lighting in tunnels required to be illuminated 24 hours per day and 365 days per year.

A. **Daylight Availability.** All installed outdoor lighting shall be controlled by a photo control, astronomical time-switch control, or other control capable of automatically shutting OFF the outdoor lighting when daylight is available.

B. **Automatic Scheduling Controls.**

i. Automatic scheduling controls shall be capable of reducing the outdoor lighting power by at least 50 percent and no more than 90 percent, and separately capable of turning the lighting OFF, during scheduled unoccupied periods.

ii. Automatic scheduling controls shall allow scheduling of a minimum of two nighttime periods with independent lighting levels, and may include an override function that turns lighting ON during its scheduled dim or OFF state for no more than two hours when an override is initiated.

iii. Acceptance tests of outdoor lighting controls shall verify the scheduled occupied and unoccupied periods, as specified in Section ~~130.4(a)6~~ 160.5(e)6.

iv. Automatic scheduling controls shall be installed for all outdoor lighting, and may be installed in combination with motion sensing controls or other outdoor lighting controls.

C. **Motion Sensing Controls.**

i. Motion sensing controls shall be capable of reducing the outdoor lighting power of each controlled luminaire by at least 50 percent and no more than 90 percent, and separately capable of turning the luminaire OFF, during unoccupied periods.

ii. Motion sensing controls shall be capable of reducing the lighting to its dim or OFF state no longer than 15 minutes after the area has been vacated, and of returning the lighting to its ON state when the area becomes occupied.

iii. No more than 1,500 watts of lighting power shall be controlled by a single sensor.

iv. Motion sensing controls shall be installed for the following luminaires, and may be installed for other outdoor lighting and in combination with other outdoor lighting controls:

a. Outdoor luminaires other than Building Façade, Ornamental Hardscape, or Outdoor Dining, ~~or Outdoor Sales Frontage lighting~~, where the bottom of luminaire is mounted 24 feet or less above grade; and,

b. Outdoor wall mounted luminaires installed for Building Façade, Ornamental Hardscape or Outdoor Dining lighting that have a bilaterally symmetric distribution as described in the IES Handbook (typically referred to as "wall packs") mounted 24 feet above grade or lower.

**EXCEPTION 1 to Section ~~130.2(c)3~~160.5(c)2iii:** Luminaires with a maximum rated wattage of 40 watts each are not required to have motion sensing controls.

**EXCEPTION 2 to Section ~~130.2(c)3~~160.5(c)2iii:** Applications listed as Exceptions to Section ~~140.7(a)~~170.2(e)2A are not required to have motion sensing controls.

**EXCEPTION 3 to Section ~~130.2(c)3~~160.5(c)2iii:** Lighting subject to a health or life safety statute, ordinance, or regulation may have a minimum time-out period longer than 15 minutes or a minimum dimming level above 50 percent when necessary to comply with the applicable law.

(d) **Sign Lighting Controls.** All sign lighting shall meet the requirements below as applicable:

1. **Indoor Signs.** All indoor sign lighting other than exit sign lighting shall be controlled with an automatic time-switch control or astronomical time-switch control.

2. **Outdoor Signs.** Outdoor sign lighting shall meet the following requirements as applicable:

A. All outdoor sign lighting shall be controlled with a photocontrol in addition to an automatic time-switch control, or an astronomical time-switch control.

**EXCEPTION to Section ~~130.3(a)2A~~160.5(d)2A:** Outdoor signs in tunnels, and signs in large permanently covered outdoor areas that are intended to be continuously lit, 24 hours per day and 365 days per year.

B. All outdoor sign lighting that is ON both day and night shall be controlled with a dimmer that provides the ability to automatically reduce sign lighting power by a minimum of 65 percent during nighttime hours. Signs that are illuminated at night and for more than 1 hour during daylight hours shall be considered ON both day and night.

**EXCEPTION to Section ~~130.3(a)2B~~160.5(d)2B:** Outdoor signs in tunnels and large covered areas that are intended to be illuminated both day and night.

3. **Demand Responsive Electronic Message Center (EMC) Control.** See Section 110.12 for requirements for demand responsive EMC controls.

(e) Lighting Control Acceptance and Installation Certificate Requirement. ~~Nonresidential buildings other than healthcare facilities, high-rise residential~~ Multifamily common use area ~~buildings, and hotel/motel buildings~~ shall comply with the applicable requirements of Sections ~~130.4(a)~~160.5(e)1 through ~~130.4(c)~~ 160.5(e)3. ~~Healthcare facilities shall comply with the applicable acceptance and installation documentation requirements of OSHPD.~~

1. **Lighting Control Acceptance Requirements.** Before an occupancy permit is granted, indoor and outdoor lighting controls serving the building, area, or site shall be certified as meeting the Acceptance Requirements for Code Compliance in accordance with Section ~~130.4(a)~~160.5(e) A Certificate of Acceptance shall be submitted to the enforcement agency under Section 10-103(a) of Part 1, that:

A. Certifies that all of the lighting acceptance testing necessary to meet the requirements of Part 6 is completed;

B. Certifies that the applicable procedures in Reference Nonresidential Appendix NA7.6 and NA7.8 have been followed;

C. Certifies that automatic daylight controls comply with Section ~~130.1(d)~~160.5(b)4D and Reference Nonresidential Appendix NA7.6.1;

D. Certifies that lighting shut-OFF controls comply with Section ~~130.1(c)~~ 160.5(b)4C and Reference Nonresidential Appendix NA7.6.2;

E. Certifies that demand responsive controls comply with Section ~~130.1(e)~~ 160.5(b)4E and Reference Nonresidential Appendix NA7.6.3; and

F. Certifies that outdoor lighting controls comply with the applicable requirements of Section ~~130.2(c)~~160.5(c)2 and Reference Nonresidential Appendix NA7.8; and

G. Certifies that lighting systems receiving the Institutional Tuning Power Adjustment Factor comply with Section ~~140.6(a)2J~~170.2(e)1Aiij and Reference Nonresidential Appendix NA7.7.6.2.

2. **Lighting Control Installation Certificate Requirements.** To be recognized for compliance with Part 6 an Installation Certificate shall be submitted in accordance with Section 10-103(a) for any lighting control system, Energy Management Control System, track lighting integral current limiter, track lighting supplementary overcurrent protection panel, interlocked lighting system, lighting Power Adjustment Factor, or additional wattage available for a videoconference studio, in accordance with the following requirements, as applicable:

A. Certification that when a lighting control system is installed to comply with lighting control requirements in Part 6 it complies with the applicable requirements of Section 110.9; and complies with Reference Nonresidential Appendix NA7.7.1.

B. Certification that when an Energy Management Control System is installed to function as a lighting control required by Part 6 it functionally meets all applicable requirements for each application for which it is installed, in accordance with Sections 110.9~~, 130.0 through 130.5, 140.6 through 150.0, and 150.2~~ and 160.5; and complies with Reference Nonresidential Appendix NA7.7.2.

C. Certification that interlocked lighting systems used to serve an approved area comply with Section ~~140.6(a)1~~170.2(e)1A; and comply with Reference Nonresidential Appendix NA7.7.5.

D. Certification that lighting controls installed to earn a lighting Power Adjustment Factor (PAF) comply with Section ~~140.6(a)2~~170.2(e)1B; and comply with Reference Nonresidential Appendix NA7.7.6.

E. Certification that additional lighting wattage installed for a videoconference studio complies with Section ~~140.6(c)2Gvii~~170.2(e)1CigVI; and complies with Reference Nonresidential Appendix NA7.7.7.

3. When certification is required by Title 24, Part 1, Section 10-103.1, the acceptance testing specified by Section ~~130.4~~ 160.5(e) shall be performed by a Certified Lighting Controls Acceptance Test Technician (CLCATT). If the CLCATT is operating as an employee, the CLCATT shall be employed by a Certified Lighting Controls Acceptance Test Employer. The CLCATT shall disclose on the Certificate of Acceptance a valid CLCATT certification identification number issued by an approved Acceptance Test Technician Certification Provider. The CLCATT shall complete all Certificate of Acceptance documentation in accordance with the applicable requirements in Section 10-103(a)4.

## SECTION 160.6 – MANDATORY REQUIREMENTS FOR ELECTRIC POWER DISTRIBUTION SYSTEM

~~Nonresidential, high-rise residential and hotel/motel buildings~~ Multifamily buildings shall comply with the applicable requirements of ~~Sections 130.5(a) through 130.5(e)~~ Sections 160.6(a) through 160.6(e).

(a) **Service Electrical Metering.** Each electrical service or feeder that provides power to the common use areas (interior and exterior) shall have a permanently installed metering system which measures electrical energy use in accordance with ~~TABLE 130.5-A~~TABLE 160.6-A.

**EXCEPTION 1 to ~~Section 130.5(a)~~** Section 160.6(a)**:** Service or feeder for which the utility company provides a metering system that indicates instantaneous kW demand and kWh for a utility-defined period.

~~**EXCEPTION 2 to Section 130.5(a): Electrical power distribution systems subject to California Electrical Code Article 517.**~~

*TABLE ~~130.5-A~~ 160.6-A MINIMUM REQUIREMENTS FOR METERING OR SUBMETERING OF ELECTRICAL LOAD*

| **Metering Functionality** | **Electrical Services[1] rated 50 kVA or less** | **Electrical Services[1] rated more than 50kVA and less than or equal to 250 kVA** | **Electrical Services[1] rated more than 250 kVA and less than or equal to 1000kVA** | **Electrical Services[1] rated more than 1000kVA** |
|---|---|---|---|---|
| Instantaneous (at the time) kW demand | Required | Required | Required | Required |
| Historical peak demand (kW) | Not required | Not required | Required | Required |
| Tracking kWh for a user-definable period. | Required | Required | Required | Required |
| kWh per rate period | Not required | Not required | Not required | Required |

*[1] "Electrical Services" applies to the main building entrance rating or to the submeter service. For a building with master and submetering, this applies to the submetering service size.*

(b) **Separation of Electrical Circuits for Electrical Energy Monitoring**. Electrical power distribution systems shall be designed so that measurement devices can monitor the electrical energy usage of load types according to ~~TABLE 130.5-B~~ TABLE 160.6-B.

**EXCEPTION 1 to ~~Section 130.5(b)~~ Section 160.6(b):** For each separate load type, up to 10 percent of the connected load may be of any type.

~~**EXCEPTION 2 to Section 130.5(b)**: Electrical power distribution systems subject to California Electrical Code Article 517.~~

**EXCEPTION 2 to Section 160.6(b):** Submetered electrical power distribution systems that provide power to occupancy spaces of group R.

~~*TABLE 130.5-B*~~ *TABLE 160.6-B* *MINIMUM REQUIREMENTS FOR SEPARATION OF ELECTRICAL LOAD*

| **Electrical Load Type** | **Electrical Services[1] rated 50 kVA or less** | **Electrical Services[1] rated more than 50kVA and less than or equal to 250 kVA** | **Electrical Services[1] rated more than 250 kVA and less than or equal to 1000kVA** | **Electrical Services[1] rated more than 1000kVA** |
|---|---|---|---|---|
| Lighting including exit and egress lighting and exterior lighting | Not required | All lighting in aggregate | All lighting disaggregated by floor, type or area | All lighting disaggregated by floor, type or area |
| HVAC systems and components including chillers, fans, heaters, furnaces, package units, cooling towers, and circulation pumps associated with HVAC | Not required | All HVAC in aggregate | All HVAC in aggregate and each HVAC load rated at least 50 kVA | All HVAC in aggregate and each HVAC load rated at least 50kVA |
| Domestic and service water system pumps and related systems and components | Not required | All loads in aggregate | All loads in aggregate | All loads in aggregate |
| Plug load including appliances rated less than 25 kVA | Not required | All plug load in aggregate<br>Groups of plug loads exceeding 25 kVA connected load in an area less than 5000 sf | All plug load separated by floor, type or area<br>Groups of plug loads exceeding 25 kVA connected load in an area less than 5000 sf | All plug load separated by floor, type or area<br>All groups of plug loads exceeding 25 kVA connected load in an area less than 5000 sf |
| Elevators, escalators, moving walks, and transit systems | Not required | All loads in aggregate | All loads in aggregate | All loads in aggregate |
| ~~Other individual non-HVAC loads or appliances rated 25kVA or greater~~ | ~~Not required~~ | ~~All loads in aggregate~~ | ~~All loads in aggregate~~ | ~~All loads in aggregate~~ |
| ~~Industrial and commercial load centers 25 kVA or greater including theatrical lighting installations and commercial kitchens~~ | ~~Not required~~ | ~~All loads in aggregate~~ | ~~All loads in aggregate~~ | ~~All loads in aggregate~~ |
| Renewable power source (net or total) | Each group | Each group | Each group | Each group |
| Loads associated with renewable power source | Not required | All loads in aggregate | All loads in aggregate | All loads in aggregate |
| Charging stations for electric vehicles | All loads in aggregate | All loads in aggregate | All loads in aggregate | All loads in aggregate |

[1] *"Electrical Services" applies to the main building entrance rating or to the submeter service. For a building with master and submetering, this applies to the submetering service size.*

(c) **Voltage Drop.** The maximum combined voltage drop on both installed feeder conductors and branch circuit conductors to the farthest connected load or outlet shall not exceed 5 percent.

**EXCEPTION to ~~Section 130.5(c)~~ Section 160.6(c):** Voltage drop permitted by California Electrical Code Sections 647.4, 695.6 and 695.7.

(d) **Circuit Controls for 120-Volt Receptacles and Controlled Receptacles**. In all ~~buildings~~ common use areas, both controlled and uncontrolled 120 volt receptacles shall be provided in office areas, lobbies, conference rooms, kitchen areas in office spaces, and copy rooms. ~~Additionally, hotel/motel guest rooms shall comply with Section 130.5(d)4.~~ Controlled receptacles shall meet the following requirements, as applicable:

1. Install a control capable of automatically shutting OFF the controlled receptacles when the space is typically unoccupied, either at the receptacle or circuit level. When an automatic time switch control is installed it shall incorporate an override control that allows the controlled receptacle to remain ON for no more than 2 hours when an override is initiated and an automatic holiday "shut-OFF" feature that turns OFF all loads for at least 24 hours and then resumes the normally scheduled operation. Countdown timer switches shall not be used to comply with the automatic time switch control requirements; and

2. Install at least one controlled receptacle within 6 feet from each uncontrolled receptacle, or install a splitwired receptacle with at least one controlled and one uncontrolled receptacle. Where receptacles are installed in modular furniture in open office areas, at least one controlled receptacle shall be installed at each workstation; and

3. Provide a permanent and durable marking for controlled receptacles or circuits to differentiate them from uncontrolled receptacles or circuits; and

~~4. For hotel and motel guest rooms, install controlled receptacles for at least one-half of the 120-volt receptacles in each guestroom. Electric circuits serving controlled receptacles in guestrooms shall have captive card key controls, occupancy sensing controls, or automatic controls so the power is switched off no longer than 30 minutes after the guestroom has been vacated.~~

**NOTE:** A hardwired power strip controlled by an occupant sensing control may be used to comply with ~~Section 130.5(d)~~ Section 160.6(d). Plug-in strips and other plug-in devices shall not be used to comply with the requirements of this Section.

**EXCEPTION 1 to ~~Section 130.5(d)~~ Section 160.6(d):** Receptacles that are only for the following purposes:

A. Receptacles specifically for refrigerators and water dispensers in kitchen areas.

B. Receptacles located a minimum of six feet above the floor that are specifically for clocks.

C. Receptacles for network copiers, fax machines, A/V and data equipment other than personal computers in copy rooms.

D. Receptacles on circuits rated more than 20 amperes.

E. Receptacles connected to an uninterruptible power supply (UPS) that are intended to be in continuous use, 24 hours per day/365 days per year, and are marked to differentiate them from other uncontrolled receptacles or circuits.

~~**EXCEPTION 2 to Section 130.5(d):** Receptacles in healthcare facilities.~~

(e) **Demand responsive controls and equipment.** See Section 110.12 for requirements for demand responsive controls and equipment.

**NOTE:** Definitions of terms and phrases in ~~Section 130.5~~ Section 160.6 are determined as specified in Section 100.1(b). Terms and phrases not found in Section 100.1(b) shall be defined as specified in Title 24, Part 3, Article 100 of the California Electrical Code.

## SECTION 160.7 – MANDATORY REQUIREMENTS FOR PROCESSES

(a) **Elevators** in multifamily buildings~~.~~ ~~S~~shall meet the requirements of section 120.6(f).

(b) **Residential Pools**~~. Any residential pool system or equipment installed~~ serving multifamily buildings shall comply with the applicable requirements of Section 110.4~~, as well as the requirements listed in this section~~**.**

## SECTION 160.8 – MANDATORY REQUIREMENTS FOR SOLAR READY BUILDINGS

**(a) Solar Ready Buildings.** ~~S~~ Newly constructed multifamily buildings shall meet the requirements of Section 110.10 applicable to the building project.

# SUBCHAPTER 11
# MULTIFAMILY BUILDINGS - PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES

## SECTION 170.0 – GENERAL

Multifamily buildings shall comply with the applicable requirements of Sections 170.0 through 170.2. Sections 170.0 through 170.2 apply to attached dwelling units and common use areas in multifamily buildings. Nonresidential occupancies in mixed occupancy buildings shall comply with nonresidential requirements in Sections 120,1 through 141.0.

(a) ~~Low-rise residential~~ Multifamily buildings shall meet all of the following:

1. The applicable requirements of Sections 110.0 through 110.10.

2. The applicable requirements of Section ~~150.0~~160.0 (mandatory features).

3. Either the performance standards (170.1) or the prescriptive standards (170.2) set forth in this section for the Climate Zone in which the building is located. Climate zones are shown in Reference Joint Appendix JA2 – Weather/Climate Data.

**EXCEPTION to Section ~~150.1(a)3~~ 170.0 (a)3:** If a single ~~contiguous subdivision or tract~~ development falls in more than one Climate Zone, all buildings in the subdivision or tract may be designed to meet the performance or prescriptive standards for the Climate Zone that contains 50 percent or more of the dwelling units.

**NOTE:** The Commission periodically updates, publishes, and makes available to interested persons and local enforcement agencies precise descriptions of the Climate Zones, as specified in Reference Joint Appendix JA2 – Weather/Climate Data.

**NOTE:** The requirements of Sections ~~150.0(a)~~ 170.1(a) through ~~150.0(r)~~ 170.2(e) apply to newly constructed buildings and Sections ~~150.2(a)~~180.1 and ~~150.2(b)~~180.2 specif~~ies~~y changes to the requirements of Sections ~~150.0(a)~~ 170.1(a) through ~~150.1(c)~~ 170.2(e) that apply to additions or alterations.

# SECTION 170.1 – PERFORMANCE APPROACH

A building complies with the performance approach if the energy budget calculated for the Proposed Design Building under Subsection (b) is no greater than the energy budget calculated for the Standard Design Building under Subsection (a).

(a) **Energy Budget for the Standard Design Building.** The energy budget for the Standard Design Building is determined by applying the mandatory and prescriptive requirements to the Proposed Design Building. The energy budget is the sum of the TDV energy for space-conditioning, indoor lighting, mechanical ventilation, service water heating, and covered process loads.

(b) **Energy Budget for the Proposed Design Building.** The energy budget for a Proposed Design Building is determined by calculating the TDV energy for the Proposed Design Building. The energy budget is the sum of the TDV energy for space-conditioning, indoor lighting, mechanical ventilation and service water heating and covered process loads.

(c) **Calculation of Energy Budget.** The TDV energy for both the Standard Design Building and the Proposed Design Building shall be computed by Compliance Software certified for this use by the Commission. The processes for Compliance Software approval by the Commission are documented in the ACM Approval Manual.

(d) **Compliance Demonstration Requirements for Performance Standards.**

1. **Certificate of Compliance and Application for a Building Permit**. The application for a building permit shall include documentation pursuant to Sections 10-103(a)1 and 10-103(a)2 which demonstrates, using an approved calculation method, that the building has been designed so that its Energy Efficiency Design Rating and the total EDR meets or exceeds the Standard design EDR for the applicable Climate Zone.

   ~~**EXCEPTION to Section 150.1(b)3A: Multiple Orientation**: A permit applicant may demonstrate compliance with the energy budget requirements of Section 150.1(a)and (b) for any orientation of the same building model if the documentation demonstrates that the building model with its proposed designs and features would comply in each of the four cardinal orientations.~~

2. **Field Verification of Individual Dwelling Unit Systems**. When performance of installed features, materials, components, manufactured devices or systems above the minimum specified in Section ~~150.1(c)~~170.2 is necessary for the building to comply with Section ~~150.1(b)~~170.1, or is necessary to achieve a more stringent local ordinance, field verification shall be performed in accordance with the applicable requirements in the following subsections, and the results of the verification(s) shall be documented on applicable Certificates of Installation pursuant to Section 10-103(a)3 and applicable Certificates of Verification pursuant to Section 10-103(a)5.

   A. **SEER Rating.** When performance compliance requires installation of a space conditioning system with a SEER rating that is greater than the minimum SEER rating required by TABLE ~~150.1-A or B~~170.2-H, the installed system shall be field verified in accordance with the procedures specified in Reference Residential Appendix RA3.4.4.1.

   B. **EER Rating.** When performance compliance requires installation of a space conditioning system with an EER rating greater than the standard design value for EER, the installed system shall be field verified in accordance with the procedures specified in Reference Residential Appendix RA3.4.4.1.

   C. **Low Leakage Air Handler.** When performance compliance requires installation of a low leakage air-handling unit, the installed air handling unit shall be field verified in accordance with the procedures specified in Reference Residential Appendix RA3.1.4.3.9.

   D. **HSPF Rating.** When performance compliance requires installation of a heat pump system with an HSPF rating that is greater than the minimum HSPF rating required by TABLE ~~150.1-A or B~~170.2-H, the installed system shall be field verified in accordance with the procedures specified in Reference Residential Appendix RA3.4.4.1.

   E. **Heat Pump - Rated Heating Capacity.** When performance compliance requires installation of a heat pump system, the heating capacity values at 47 degrees F and 17 degrees F shall be field verified in accordance with the procedures specified in Reference Residential Appendix RA3.4.4.2.

   F. **Whole House Fan**. When performance compliance requires installation of a whole-house fan, the whole house fan ventilation airflow rate and fan efficacy shall be field verified in accordance with the procedures specified in Reference Residential Appendix RA3.9.

G. **Central Fan Ventilation Cooling System**. When performance compliance requires installation of a central fan ventilation cooling system, the installed system shall be field verified in accordance with the procedures in Reference Residential Appendix RA3.3.4.

H. **~~Building~~Dwelling Unit Enclosure Air Leakage**. When performance compliance requires a building enclosure leakage rate that is lower than the standard design, the building enclosure shall be field verified in accordance with the procedures specified in Reference Residential Appendix RA3.8.

I. **Quality Insulation Installation (QII).** When performance compliance requires field verification of QII, the building insulation system shall be field verified in accordance with the procedures in Reference Residential Appendix RA3.5.

## SECTION 170.2 – PRESCRIPTIVE APPROACH

Multifamily ~~B~~buildings, including both dwelling units and common use areas, that comply with the prescriptive standards shall be designed, constructed, and equipped to meet all of the requirements for the appropriate Climate Zone shown in TABLE ~~150.1-A or B~~ 170.2-A. In TABLE ~~150.1-A or B~~ 170.2-A, ~~a NA (not allowed) means that feature is not permitted in a particular Climate Zone and~~ a NR (no requirement) means that there is no prescriptive requirement for that feature in a particular Climate Zone. Installed components shall meet the following requirements:

(a) **Envelope Component Requirements**.

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

A. **Roofing Products.** All roofing products shall meet the requirements of Section 110.8 and the applicable requirements of Subsection i through iii:

i. ~~Low-rise residential buildings with l~~Low-sloped roofs; in Climate Zones 13 and 15 shall have a minimum aged solar reflectance of 0.63 and a minimum thermal emittance of 0.75 or a minimum SRI of 75.

ii. Low-sloped roofs in Climate Zones 9, 10, 11, ~~13,~~ and 14 ~~and 15~~ shall have a minimum aged solar reflectance of 0.55 and a minimum thermal emittance of 0.75, or a minimum SRI of 64.

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

**EXCEPTION 1 to Section ~~150.1(c)11~~ 170.2(a)1A:** Building integrated photovoltaic panels and building integrated solar thermal panels are exempt from the minimum requirements for solar reflectance and thermal emittance or SRI.

**EXCEPTION 2 to Section ~~150.1(c)11~~ 170.2(a)1A:** Roof constructions with a weight of at least 25 lb/ft² are exempt from the minimum requirements for solar reflectance and thermal emittance or SRI.

B. **Roof Insulation.** Roofs shall have an overall assembly U-factor no greater than the applicable value in TABLE ~~150.1-A or B~~ 170.2-A, meeting option i, ii, or iii below..~~and w~~Where required by Section 110.8 and ~~120.7(a)3~~160.1(a), insulation shall be placed in direct contact with a continuous roof or drywall ceiling.

i. Option A: ~~RESERVED~~A minimum U-factor for roof assemblies above conditioned space without attic.

ii. Option B: A minimum R-value of insulation installed between the roof rafters in contact with the roof deck and an additional layer of ceiling insulation located between the attic and the conditioned space when meeting Section ~~150.1(c)9A~~170.2(c)3Bi; or

iii. Option C: A minimum R-value of ceiling insulation located between the attic and the conditioned space when meeting Section ~~150.1(c)9B~~170.2(c)3Bii.

C. **Radiant Barrier.** A radiant barrier required in TABLE ~~150.1-A or B~~ 170.2-A shall meet the requirements specified in Section 110.8(j), and shall meet the installation criteria specified in the Reference Residential Appendix RA4**.**

2. **Wall Insulation**

A. Exterior walls shall have an overall assembly U-factor no greater than the applicable value in TABLE ~~140.3-B, C or D~~ 170.2-A.

B. Demising walls shall meet the requirements of Section ~~120.7(b)7~~160.1(b)7. ~~Vertical windows in demising walls between conditioned and unconditioned spaces shall have an area-weighted average U-factor no greater than the applicable value in TABLE140.3-B, C or D.~~

3. **Fenestration.**

A. Vertical ~~windows~~ fenestration and glazed doors in exterior walls shall comply with subsections i, ii, and iii:

i. Percent window area shall be limited in accordance with the applicable requirements of ~~i and ii~~ a and b below:

a. A total no greater than 20 percent of the conditioned floor area; and.

a. ~~a west-facing area no greater than 40 percent of the gross west-facing exterior wall area, or 6 feet times the west-facing display perimeter, whichever is greater; and~~

b. A total area no greater than 40 percent of the gross exterior wall area~~, or 6 feet times the display perimeter, whichever is greater; and~~

**NOTE:** Demising walls are not exterior walls, and therefore demising wall area is not part of the gross exterior wall area ~~or display perimeter~~, and windows in demising walls are not part of the window area.

**ii.** **~~Window~~Fenestration Properties.** Installed fenestration products, including glazed doors, shall have an area weighted average U-factor, ~~and~~ Relative Solar Heat Gain Coefficient (RSHGC), and Visual Transmittance (VT) meeting the applicable fenestration values in TABLE ~~150.1-A or B~~ 170.2-A and shall be determined in accordance with Sections 110.6(a)2 and 110.6(a)3.

**EXCEPTION 1 to Section ~~150.1(c)3A~~170.2(a)3Aii:** For each dwelling unit up to 3 square feet of new glazing area installed in doors ~~and up to 3 square feet of new tubular skylights area with dual-pane diffusers~~ shall not be required to meet the U-factor, ~~and~~ RSHGC, and VT requirements of TABLE ~~150.1-A or B~~ 170.2-A.

**EXCEPTION ~~3~~2 to Section ~~150.1(c)3A~~170.2(a)3Aii:** For fenestration containing chromogenic type glazing:

a. The lower-rated labeled U-factor, ~~and~~ RSHGC, and VT shall be used with automatic controls to modulate the amount of solar gain and light transmitted into the space in multiple steps in response to daylight levels or solar intensity;

b. Chromogenic glazing shall be considered separately from other fenestration; and

c. Area-weighted averaging with other fenestration that is not chromatic shall not be permitted and shall be determined in accordance with Section 110.6(a).

**EXCEPTION ~~4~~ 3to Section ~~150.1(c)3A~~170.2(a)3Aii:** For dwelling units containing unrated site-built fenestration that meets the maximum area restriction, the U-factor and RSHGC can be determined in accordance with the Nonresidential Reference Appendix NA6 or use default values in TABLE 110.6-A and TABLE 110.6-B.

iii. **Shading.** Where TABLE ~~150.1-A or B~~ 170.2-A requires a Maximum RSHGC, the requirements shall be met with an area-weighted average RSHGC excluding the effects of interior shading, no greater than the applicable value in ~~TABLE 140.3-B, C or D~~ 170.2-A.

For the purposes of this paragraph, the RSHGC of a vertical window is:

d. The Solar Heat Gain Coefficient of the window; or

e. Relative Solar Heat Gain Coefficient is calculated using EQUATION 140.3-A, if the window has an overhang that extends beyond each side of the window jamb by a distance equal to the overhang's horizontal projection.

**EXCEPTION 1 to Section ~~140.3(a)5C~~170.2(a)3Aiii:** An area-weighted average Relative Solar Heat Gain Coefficient of 0.56 or less shall be used for windows:

a. That are in the first story of exterior walls that form a display perimeter; and

b. For which codes restrict the use of overhangs to shade the windows.

**EXCEPTION 2 to Section ~~140.3(a)5C~~170.2(a)3Aiii:** For vertical glazing containing chromogenic type glazing:

i. the lower-rate labeled RSHGC shall be used with automatic controls to modulate the amount of heat flow into the space in multiple steps in response to daylight levels or solar intensity; and

ii. chromogenic glazing shall be considered separately from other glazing; and

iii. area-weighted averaging with other glazing that is not chromogenic shall not be permitted.

**NOTE:** Demising walls are not exterior walls, and therefore ~~windows~~fenestration in demising walls are not subject to SHGC requirements.

a. An exterior operable shading louver or other exterior shading device that meets the required SHGC; or

b. A combination of Items ~~A and B~~ ii and iii to achieve the same performance as achieved in Section ~~150.1(c)3A~~170.2(a)3Aii.

c. For south-facing glazing only, optimal overhangs shall be installed so that the south-facing glazing is fully shaded at solar noon on August 21 and substantially exposed to direct sunlight at solar noon on December 21.

d. Exterior shading devices must be permanently secured with attachments or fasteners that are not intended for removal.

**EXCEPTION to Section ~~150.1(c)4E~~170.2(a)3Aiiid**: Where the California Building Code (CBC) requires emergency egress or where compliance would conflict with Health and Safety regulations.

**B.** **Demising Wall Fenestration**. Vertical fenestration in demising walls between conditioned and unconditioned spaces shall have an area-weighted average U-factor no greater than the applicable value in TABLE 170.2-A.

C. **Skylights shall**:

i. Have an area no greater than 5 percent of the gross exterior roof area Skylight Roof Ratio (SRR); and

**EXCEPTION to Section ~~140.3(a)6A~~170.2(a)3Ci:** Buildings with an atria over 55 feet high shall have a skylight area no greater than 10 percent of the gross exterior roof area.

ii. Have an Area-Weighted Performance Rating U-factor no greater than the applicable value in TABLE ~~140.3-B, C or D~~170.2-A.

~~**EXCEPTION to Section 140.3(a)6B:** For skylights containing chromogenic type glazing:~~

~~a. the lower-rate labeled U-factor shall be used with automatic controls to modulate the amount of U-factor heat flow into the space in multiple steps in response to daylight levels or solar intensity; and~~

~~b. chromogenic glazing shall be considered separately from other glazing; and~~

~~c. area-weighted averaging with other glazing that is not chromogenic shall not be permitted.~~

**EXCEPTION 2 to Section ~~150.1(c)3A~~170.2(a)3Bii:** For each dwelling unit up to 16 square feet of new skylight area with a maximum U-factor of 0.55 and a maximum SHGC of 0.30.

iii. Solar Heat Gain Coefficient. Have an area-weighted performance rating Solar Heat Gain Coefficient no greater than the applicable value in TABLE ~~140.3-B, C or D~~170.2-A.

**EXCEPTION to Section ~~140.3(a)6C~~ 170.2(a)3Cii and 170.2(a)3Ciii:** For skylights containing chromogenic type glazing:

a. the lower-rated labeled SHGC shall be used with automatic controls to modulate the amount of heat flow into the space in multiple steps in response to daylight levels or solar intensity; and

b. chromogenic glazing shall be considered separately from other glazing; and

c. area-weighted averaging with other glazing that is not chromogenic shall not be permitted.

~~iv. Visible Transmittance. Have an Area-Weighted Performance Rating VT no less than the applicable value in TABLE 140.3-B or C; and~~

~~**EXCEPTION to Section 140.3(a)6D:** For skylights containing chromogenic type glazing:~~

~~a. the higher-rated labeled VT shall be used with automatic controls to modulate the amount of light transmitted into the space in multiple steps in response to daylight levels or solar intensity and;~~

~~b. chromogenic glazing shall be considered separately from other glazing; and~~

~~c. area-weighted averaging with other glazing that is not chromogenic shall not be permitted.~~

iv. Haze Value. Have a glazing material or diffuser that has a measured haze value greater than 90 percent, determined according to ASTM D1003, or other test method approved by the Energy Commission.

**EXCEPTION to Section 140.3(a)6E:** Skylights designed and installed to exclude direct sunlight entering the occupied space by the use of fixed or automated baffles or the geometry of the skylight and light well.

4. All exterior doors other than glazed doors that separate conditioned space from unconditioned space or from ambient air shall have a U-factor not greater than the applicable value in TABLE ~~140.3-B, C or D~~ 170.2-A. Doors that are more than one-half glass in area are considered Glazed Doors.

   **EXCEPTION to Section ~~150.1(c)5~~170.2(a)4:** Swinging doors ~~between the garage and conditioned space~~ that are required to have fire protection are not required to meet the applicable door value in TABLE 150.1-A or B.

5. Raised-floors shall be insulated such that the floor assembly has an assembly U-factor equal to or less than shown in TABLE ~~150.1-A or B~~ 170.2-A, or shall be insulated between wood framing with insulation having an R-value equal to or greater than shown in TABLE ~~150.1-A or B~~ 170.2-A.

   **EXCEPTION to Section ~~150.1(c)1C~~170.2(a)5:** Raised-floor insulation may be omitted if the foundation walls are insulated to meet the wall insulation minimums shown in TABLE ~~150.1-A or B~~ 170.2-A~~, and a vapor retarder is placed over the entire floor of the crawl space, and the vents are fitted with automatically operated louvers, and the requirements of Reference Residential Appendix RA4.5.1 are met~~.

   ~~B. Slab floor perimeter insulation shall be installed with a U-factor equal to or less than or R-value equal to or greater than shown in TABLE 150.1-A or B. The minimum depth of concrete-slab floor perimeter insulation shall be 16 inches or the depth of the footing of the building, whichever is less.~~

   ~~**EXCEPTION to Section 150.1(c)1:** The insulation requirements of TABLE 150.1-A and TABLE 150.1-B may also be met by ceiling, roof deck, wall, or floor assemblies that meet the required maximum U-factors using a U-factor calculation method that considers the thermal effects of all elements of the assembly and is approved by the Executive Director.~~

6. All buildings 40,000 sq.ft. or greater shall comply with the Quality Insulation Installation (QII) requirements shown in TABLE ~~150.1-A or B~~ 170.2-A. When QII is required, insulation installation shall meet the criteria specified in Reference Appendix RA3.5.

*TABLE ~~150.1-B~~170.2-A ENVELOPE COMPONENT PACKAGE – Multifamily Standard Building Design*

| Multifamily | | | | Climate Zone | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** |
| **Building Envelope Insulation** | **Roofs/Ceilings** | **Option A** | Metal Building U-factor | 0.098 | 0.098 | 0.098 | 0.098 | 0.098 | 0.098 | 0.098 | 0.098 | 0.098 | 0.098 | 0.098 | 0.098 | 0.098 | 0.098 | 0.098 | 0.098 |
| | | | Wood Framed and Other U-factor | 0.075 | 0.075 | 0.075 | 0.075 | 0.075 | 0.075 | 0.075 | 0.075 | 0.075 | 0.075 | 0.075 | 0.075 | 0.075 | 0.075 | 0.075 | 0.075 |
| | | **Option B** (meets § 150.1(c)9A) | Below Roof Deck Insulation [1,2] (With Air Space) | NR | NR | NR | R19 | NR | NR | NR | R19 | R19 | R13 | R19 | R19 | R19 | R19 | R19 | R13 |
| | | | Ceiling Insulation | R 38 | R 38 | R 30 | R 38 | R 30 | R 30 | R 30 | R 38 | R 38 | R 38 | R 38 | R 38 | R 38 | R 38 | R 38 | R 38 |
| | | | Radiant Barrier | NR | REQ | REQ | NR | REQ | REQ | REQ | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| | | **Option C** (meets | Ceiling Insulation | R38 | R 30 | R 30 | R 30 | R 30 | R 30 | R 30 | R 30 | R 30 | R 30 | R 38 | R 38 | R 38 | R 38 | R 38 | R 38 |
| | | | Radiant Barrier | NR | REQ | REQ | REQ | REQ | REQ | REQ | REQ | REQ | REQ | REQ | REQ | REQ | REQ | REQ | NR |
| | **Walls** | ~~Above Grade~~ | Metal-Building, any fire rating | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.057 | 0.057 | 0.057 | 0.057 | 0.057 | 0.057 |
| | | | Framed,(wood, metal, and others) >1hr fire rating | 0.059 | 0.059 | 0.059 | 0.059 | 0.059 | 0.059 | 0.059 | 0.059 | 0.059 | 0.059 | 0.042 | 0.059 | 0.059 | 0.042 | 0.042 | 0.042 |
| | | | Framed (wood, metal and others), ≤1hr fire rating[3] | U 0.051 | U 0.051 | U 0.051 | U 0.051 | U 0.051 | U 0.065 | U 0.065 | U 0.051 | U 0.051 | U 0.051 | U 0.051 | U 0.051 | U 0.051 | U 0.051 | U 0.051 | U 0.051 |
| | | | ~~Mass Wall Interior~~ Mass Light [4,5] | U 0.077 R 13 | U 0.077 R 13 | U 0.077 R 13 | U 0.077 R 13 | U 0.077 R 13 | U 0.077 R 13 | U 0.077 R 13 | U 0.077 R 13 | U 0.077 R 13 | U 0.077 R 13 | U 0.077 R 13 | U 0.077 R 13 | U 0.077 R 13 | U 0.077 R 13 | U 0.077 R 13 | U 0.059 R 17 |
| | | | ~~Mass Wall Exterior[5]~~ | ~~U 0.125 R 8.0~~ | ~~U 0.125 R 8.0~~ | ~~U 0.125 R 8.0~~ | ~~U 0.125 R 8.0~~ | ~~U 0.125 R 8.0~~ | ~~U 0.125 R 8.0~~ | ~~U 0.125 R 8.0~~ | ~~U 0.125 R 8.0~~ | ~~U 0.125 R 8.0~~ | ~~U 0.125 R 8.0~~ | ~~U 0.125 R 8.0~~ | ~~U 0.125 R 8.0~~ | ~~U 0.125 R 8.0~~ | ~~U 0.125 R 8.0~~ | ~~U 0.125 R 8.0~~ | ~~U 0.077 R 13~~ |

| Multifamily | | | Climate Zone | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| | | Mass Heavy | 0.253 | 0.650 | 0.650 | 0.650 | 0.650 | 0.690 | 0.690 | 0.690 | 0.690 | 0.650 | 0.184 | 0.253 | 0.211 | 0.184 | 0.184 | 0.160 |
| | ~~Below Grade~~ | ~~Below Grade Interior~~ | ~~U 0.077 R 13~~ | ~~U 0.077 R 13~~ | ~~U 0.077 R 13~~ | ~~U 0.077 R 13~~ | ~~U 0.077 R 13~~ | ~~U 0.077 R 13~~ | ~~U 0.077 R 13~~ | ~~U 0.077 R 13~~ | ~~U 0.077 R 13~~ | ~~U 0.077 R 13~~ | ~~U 0.077 R 13~~ | ~~U 0.077 R 13~~ | ~~U 0.077 R 13~~ | ~~U 0.077 R 13~~ | ~~U 0.077 R 13~~ | ~~U 0.067 R 15~~ |
| | ~~Below Grade~~ | ~~Below Grade Exterior~~ | ~~U 0.200 R 5.0~~ | ~~U 0.200 R 5.0~~ | ~~U 0.200 R 5.0~~ | ~~U 0.200 R 5.0~~ | ~~U 0.200 R 5.0~~ | ~~U 0.200 R 5.0~~ | ~~U 0.200 R 5.0~~ | ~~U 0.200 R 5.0~~ | ~~U 0.200 R 5.0~~ | ~~U 0.200 R 5.0~~ | ~~U 0.200 R 5.0~~ | ~~U 0.200 R 5.0~~ | ~~U 0.200 R 5.0~~ | ~~U 0.100 R 10~~ | ~~U 0.100 R 10~~ | ~~U 0.053 R 19~~ |
| Floors/Soffits | | ~~Slab Perimeter~~ | ~~NR~~ | ~~NR~~ | ~~NR~~ | ~~NR~~ | ~~NR~~ | ~~NR~~ | ~~NR~~ | ~~NR~~ | ~~NR~~ | ~~NR~~ | ~~NR~~ | ~~NR~~ | ~~NR~~ | ~~NR~~ | ~~NR~~ | ~~U 0.58 R 7.0~~ |
| Floors/Soffits | | ~~Raised~~ Wood Framed | U 0.037 R 19 | U 0.037 R 19 | U 0.037 R 19 | U 0.037 R 19 | U 0.037 R 19 | U 0.037 R 19 | U 0.037 R 19 | U 0.037 R 19 | U 0.037 R 19 | U 0.037 R 19 | U 0.037 R 19 | U 0.037 R 19 | U 0.037 R 19 | U 0.037 R 19 | U 0.037 R 19 | U 0.037 R 19 |
| Floors/Soffits | | ~~Concrete Raised~~ Raised Mass | U 0.092 R 8.0 | U 0.092 R 8.0 | U 0.269 R 0 | U 0.269 R 0 | U-0.269 R 0 | U 0.269 R 0 | U 0.269 R 0 | U 0.269 R 0 | U 0.269 R 0 | U 0.269 R 0 | U 0.092 R 8.0 | U 0.138 R 4.0 | U 0.092 R 8.0 | U 0.092 R 8.0 | U 0.138 R 4.0 | U 0.092 R 8.0 |
| Floors/Soffits | | Other | 0.048 | 0.039 | 0.071 | 0.071 | 0.071 | 0.071 | 0.071 | 0.071 | 0.071 | 0.071 | 0.039 | 0.071 | 0.071 | 0.039 | 0.039 | 0.039 |
| Quality Insulation Installation (QII) | | | Yes | Yes | Yes | Yes | Yes | Yes | NR | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Roofing Products | Low-sloped | Aged Solar Reflectance | NR | NR | NR | NR | NR | NR | NR | ~~NR~~0.55 | ~~NR~~0.55 | ~~NR~~0.55 | ~~NR~~0.55 | NR | 0.63 | ~~NR~~0.55 | 0.63 | NR |
| Roofing Products | Low-sloped | Thermal Emittance | NR | NR | NR | NR | NR | NR | NR | ~~NR~~0.75 | ~~NR~~0.75 | ~~NR~~0.75 | ~~NR~~0.75 | NR | 0.75 | ~~NR~~0.75 | 0.75 | NR |

| Multifamily | | | Climate Zone | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** |
| | **Steep-sloped** | Aged Solar Reflectance | NR | NR | NR | NR | NR | NR | NR | NR | NR | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | NR |
| | | Thermal Emittance | NR | NR | NR | NR | NR | NR | NR | NR | NR | 0. 75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | NR |
| Fenestration | Curtain Wall/ Storefront | Maximum U-factor | 0.38 | 0.38 | | | | | | | | | | | | | | |
| | | Maximum SHGC | 0.35 | 0.25 | | | | | | | | | | | | | | |
| | | Minimum VT | 0.37 | 0.37 | | | | | | | | | | | | | | |
| | All Other Fenestrations | Maximum U-factor | 0.30 | 0.30 | | | | | | | | | | | | | | |
| | | Maximum SHGC | ~~NR~~0.35 | 0.23 | ~~NR~~0.23 | 0.23 | ~~NR~~0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | ~~NR~~ 0.23 |
| | Maximum ~~Total Area~~ Window to Floor Ratio | | 20% | 20% | 20% | 20% | 20% | 20% | 20% | 20% | 20% | 20% | 20% | 20% | 20% | 20% | 20% | 20% |
| | Maximum Window to Wall Ratio | | 40% | 40% | 40% | 40% | 40% | 40% | 40% | 40% | 40% | 40% | 40% | 40% | 40% | 40% | 40% | 40% |
| | ~~Maximum West Facing Area~~ | | ~~NR~~ | ~~5%~~ | ~~NR~~ | ~~5%~~ | ~~NR~~ | ~~5%~~ | ~~5%~~ | ~~5%~~ | ~~5%~~ | ~~5%~~ | ~~5%~~ | ~~5%~~ | ~~5%~~ | ~~5%~~ | ~~5%~~ | ~~NR~~ |
| | Maximum Skylight Roof Ratio | | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% |
| ~~Door~~ Exterior Doors | Maximum U-factor | ~~Maximum U-factor~~ Dwelling Unit Entry | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| | | Common Use Area Entry Non-Swinging | 0.50 | 1.45 | 1.45 | 1.45 | 1.45 | 1.45 | 1.45 | 1.45 | 1.45 | 1.45 | 1.45 | 1.45 | 1.45 | 1.45 | 1.45 | 0.50 |
| | | Common Use Area Entry Swinging | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 |

Footnote requirements to TABLE ~~150.1-B~~170.2-A:

1. Install the specified R-value with an air space present between the roofing and the roof deck. Such as standard installation of concrete or clay tile.
2. R-values shown for below roof deck insulation are for wood-frame construction with insulation installed between the framing members. Alternatives including insulation above rafters or above roof deck shall comply with the performance standards.
3. Assembly U-factors for exterior framed walls can be met with cavity insulation alone or with continuous insulation alone, or with both cavity and continuous insulation that results in an assembly U-factor equal to or less than the U-factor shown. Use Reference Joint Appendices JA4 Table 4.3.1, 4.3.1(a), or Table 4.3.4 to determine alternative insulation products to be less than or equal to the required maximum U-factor.

4. Mass wall has a heat capacity greater than or equal to 7.0 Btu/h-ft$^2$.

~~5. "Interior" denotes insulation installed on the inside surface of the wall. "Exterior" denotes insulation installed on the exterior surface of the wall.~~

~~6. Below grade "interior" denotes insulation installed on the inside surface of the wall; and~~

~~Below grade "exterior" denotes insulation installed on the outside surface of the wall.~~

(b) **Minimum Daylighting Requirement for Large Enclosed Spaces.** In Climate Zones 2 through 15, conditioned enclosed spaces, and unconditioned enclosed spaces, that are greater than 5,000 ft² and that are directly under a roof with ceiling heights greater than 15 feet, shall meet the following requirements:

1. A combined total of at least 75 percent of the floor area, as determined in building floor plan (drawings) view, shall be within one or more of the following:

   A. Primary Sidelight Daylight Zone in accordance with Section ~~130.1(d)1B~~160.5(b)4Dib, or

   B. The total floor area in the space within a horizontal distance of 0.7 times the average ceiling height from the edge of rough opening of skylights.

2. All Skylit Daylit Zones and Primary Sidelit Daylit Zones shall be shown on building plans.

3. General lighting in daylit zones shall be controlled in accordance with Section ~~130.1(d)~~160.5(b)4D.

4. The total skylight area is at least 3 percent of the total floor area in the space within a horizontal distance of 0.7 times the average ceiling height from the edge of rough opening of skylights; or the product of the total skylight area and the average skylight visible transmittance is no less than 1.5 percent of the total floor area in the space within a horizontal distance of 0.7 times the average ceiling height from the edge of rough opening of skylights.

5. All skylights shall have a glazing material or diffuser that has a measured haze value greater than 90 percent, tested according to ASTM D1003 (notwithstanding its scope) or another test method approved by the Commission.

6. ~~Skylights for conditioned and unconditioned spaces shall have an area-weighted average Visible Transmittance (VT) no less than the applicable value required by Section 140.3(a)6D.~~

~~**EXCEPTION 1 to Section 140.3(c):** Auditoriums, churches, movie theaters, museums, and refrigerated warehouses.~~

**EXCEPTION ~~2~~1 to Section ~~140.3(c)~~170.2(b):** In buildings with unfinished interiors, future enclosed spaces for which there are plans to have:

A. A floor area of less than or equal to 5,000 square feet; or

B. Ceiling heights of less than or equal to 15 feet. This exception shall not be used for S-1 or S-2 (storage), or for F-1 or F-2 (factory) occupancies.

**EXCEPTION ~~3~~2 to Section ~~140.3(c)~~170.2(b):** Enclosed spaces having a designed general lighting system with a lighting power density less than 0.5 watts per square foot.

**EXCEPTION ~~4~~3 to Section ~~140.3(c)~~170.2(b):** Enclosed spaces where it is documented that permanent architectural features of the building, existing structures or natural objects block direct beam sunlight on at least half of the roof over the enclosed space for more than 1500 daytime hours per year between 8 a.m. and 4 p.m.

(c) **Space Conditioning Systems**. All space heating and space cooling equipment shall comply with minimum Appliance Efficiency Regulations as specified in Sections 110.0 through 110.2 ~~A building complies with this section by being designed with and having constructed and installed a space-conditioning system(s) that meets~~ and the applicable requirements of Subsections 1 through 4.

1. **Sizing and Equipment Selection**. ~~Mechanical heating and mechanical cooling equipment serving healthcare facilities shall be sized to meet the design heating and cooling loads as calculated according to the subsection (b).~~ Mechanical heating and mechanical cooling equipment serving ~~high-rise residential~~ multifamily buildings~~, hotel/motel buildings and nonresidential buildings other than healthcare facilities~~, shall be the smallest size, within the available options of the desired equipment line, necessary to meet the design heating and cooling loads of the building, as calculated according to ~~Subsection (b)~~ Section 170.2(c)2

   **EXCEPTION 1 to Section ~~140.4(a)~~170.2(c)1:** Where it can be demonstrated to the satisfaction of the enforcing agency that oversizing will not increase building TDV energy use.

   **EXCEPTION 2 to Section ~~140.4(a)~~170.2(c)1:** Standby equipment with controls that allow the standby equipment to operate only when the primary equipment is not operating.

   **EXCEPTION 3 to Section ~~140.4(a)~~170.2(c)1:** Multiple units of the same equipment type, such as multiple chillers and boilers, having combined capacities exceeding the design load, if they have controls that sequence or otherwise optimally control the operation of each unit based on load.

2. **Calculations**. In making equipment sizing calculations under ~~Subsection (a)~~Section 170.2(c)1, all of the following rules shall apply:

A. **Heating and cooling loads.** Heating and cooling system design loads shall be determined in accordance with ~~the procedures described in subsection A or B below:~~

i. ~~For systems serving high-rise residential buildings, hotel/motel buildings, and nonresidential multifamily buildings other than healthcare facilities,~~ the method in the 2017 ASHRAE Handbook, Fundamentals shall be used, or as specified in a method approved by the Commission.

~~ii. For system serving healthcare facilities the method in the California Mechanical Code shall be used.~~

B. **Indoor design conditions.** Indoor design temperature and humidity conditions for comfort applications shall be determined ~~in accordance with subsection A or B below:~~

~~a. For systems serving high-rise residential buildings, hotel/motel buildings, and nonresidential buildings other than healthcare facilities,~~ using ASHRAE Standard 55 or the 2017 ASHRAE Handbook, Fundamentals Volume, except that winter humidification and summer dehumidification shall not be required.

~~b. For system serving healthcare facilities the method in Section 320.0 of the California Mechanical Code shall be used~~.

C. **Outdoor design conditions.** Outdoor design conditions shall be in accordance with ~~subsection A or B below:~~

~~a. For systems serving high-rise residential multifamily buildings, hotel/motel buildings, and nonresidential buildings other than healthcare facilities~~ the design conditions from Reference Joint Appendix JA2 shall be used, which is based on data from the ASHRAE Climatic Data for Region X. Heating design temperatures shall be no lower than the Heating Winter Median of Extremes values. Cooling design temperatures shall be no greater than the 0.5 percent Cooling Dry Bulb and Mean Coincident Wet Bulb values.

~~b. For system serving healthcare facilities the method in Section 320.0 of the California Mechanical Code shall be used.~~

**EXCEPTION to Section ~~140.4(b)3~~170.2(c)1C:** Cooling design temperatures for cooling towers shall be no greater than the 0.5 percent Cooling Design Wet bulb values.

D. **Ventilation.** Outdoor air ventilation loads shall be calculated using the ventilation rates required in Section ~~120.1(c)3~~160.2(c)3.

E. **Envelope**. Envelope heating and cooling loads shall be calculated using envelope characteristics, including square footage, thermal conductance, Solar Heat Gain Coefficient or shading coefficient, and air leakage, consistent with the proposed design.

F. **Lighting.** Lighting heating and cooling loads shall be based on actual design lighting levels or power densities as specified in Section ~~140.6~~170.2(e)1.

G. **People.** Occupant density shall be based on the expected occupancy of the building and shall be the same as determined under Section ~~120.1(c)3A~~160.2(c)3A, if used. Sensible and latent heat gains shall be as listed in the 2017 ASHRAE Handbook- Fundamentals, Chapter 18.

H. **Process loads.** Loads caused by a process shall be based upon actual information on the intended use of the building.

I. **Miscellaneous equipment.** Equipment loads other than process loads shall be calculated using design data compiled from one or more of the following sources:

i. Actual information based on the intended use of the building; or

ii. Published data from manufacturer's technical publications or from technical societies, such as the ASHRAE Handbook, Applications Volume; or

iii. Other data based on the designer's experience of expected loads and occupancy patterns.

J. **Internal heat gains.** Internal heat gains may be ignored for heating load calculations.

K. **Safety factor.** Calculated design loads based on ~~140.4(b)1~~ 170.2(c)1 A through ~~10~~K may be increased by up to 10 percent to account for unexpected loads or changes in space usage.

L. **Other loads.** Loads such as warm-up or cool-down shall be calculated from principles based on the thermal capacity of the building and its contents, the degree of setback, and desired recovery time; or may be assumed to be no more than 30 percent for heating and 10 percent for cooling of the steady-state design loads. In addition, the steady-state load may include a safety factor in accordance with Section ~~140.4(b)11~~170.2(c)1K.

3. All space heating and space cooling equipment serving individual dwelling units shall ~~comply with minimum Appliance Efficiency Regulations as specified in Sections 110.0 through 110.2 and~~ meet all applicable requirements of Sections ~~150.0~~ 160.3(b) and ~~150.1(c)7A~~ 170.2(c)2.

A. ~~**Refrigerant Charge**.~~ When refrigerant charge verification or fault indicator display is shown as required by TABLE ~~150.1-A or B~~170.2-H, the system shall comply with either ~~150.1(c)7Ai~~170.2(c)3Ai or ~~150.1(c)7Aii~~170.2(c)3Aii:

i. A~~a~~ir-cooled air conditioners and air-source heat pumps, including but not limited to ducted split systems, ducted packaged systems, small duct high velocity systems, and mini-split systems, shall comply with subsections a~~,~~ and b~~ and c~~, unless the system is of a type that cannot be verified using the specified procedures:

a. Have measurement access holes (MAH) installed according to the specifications in the Reference Residential Appendix Section RA3.2.2.3; and

~~b. System airflow rate in accordance with subsection I or II below, shall be confirmed through field verification and diagnostic testing in accordance with all applicable procedures specified in Reference Residential Appendix Section RA3. 3 or an approved alternative procedure as specified by RA1; and~~

~~I. For small duct high velocity systems the system airflow rate shall be greater than or equal to 250 cfm per ton; or~~

~~II. For all other air-cooled air conditioner or air-source heat pump systems the system airflow rate shall be greater than or equal to 350 cfm per ton.~~

**EXCEPTION to Section ~~150.1(c)7Aia~~170.2(c)3Aia:** Systems that cannot conform to the specifications for hole location in Reference Residential Appendix Figure RA3.2-1, shall not be required to provide holes as described in Figure RA3.2-1.

b. The installer shall charge the system according to manufacturer's specifications. Refrigerant charge shall be verified according to one of the following options, as applicable:

I. The installer and rater shall perform the standard charge procedure as specified by Reference Residential Appendix Section RA3.2.2 or an approved alternative procedure as specified by RA1; or

II. The system shall be equipped with a fault indicator display (FID) device that meets the specifications of Reference Joint Appendix JA6. The installer shall verify the refrigerant charge and FID device in accordance with the procedures in Reference Residential Appendix Section RA3.4.2. The HERS Rater shall verify FID device in accordance with the procedures in Section RA3.4.2; or

III. The installer shall perform the weigh-in charging procedure as specified by Reference Residential Appendix Section RA3.2.3.1 provided the system is of a type that can be verified using the RA3.2.2 standard charge verification procedure and RA3.3 airflow rate verification procedure or approved alternatives in RA1. The HERS Rater shall verify the charge using RA3.2.2 and RA3.3 or approved alternatives in RA1.

**EXCEPTION 1 to Section ~~150.1(c)7Aib~~170.2(c)3Aib:** Standard ducted systems without zoning dampers may comply with the minimum airflow rate by meeting the applicable requirements in TABLE ~~150.0-B~~160.3-A and TABLE ~~150.0-C~~160.3-B.as confirmed by field verification and diagnostic testing in accordance with the procedures in Reference Residential Appendix Section RA3.1.4.4 and RA3.1.4.5. The design clean-filter pressure drop requirements of Section ~~150.0(m)12~~160.2(a)1D for the system air filter device(s) shall conform to the requirements given in TABLE ~~150.0-B~~160.3-A and TABLE ~~150.0-C~~160.3-B.

**EXCEPTION ~~1~~2 to ~~150.1(c)7Aic~~170.2(c)3Aib**: When the outdoor temperature is less than 55 degrees F and the installer utilizes the weigh-in charging procedure in Reference Residential Appendix Section RA3.2.3.1 to verify the refrigerant charge, the installer may elect to utilize the HERS Rater verification procedure in Reference Residential Appendix Section RA3.2.3.2. If the HERS Rater verification procedure in Section RA3.2.3.2 is used for compliance, the system's thermostat shall conform to the specifications in Section 110.12. Ducted systems shall comply with minimum system airflow rate requirement in Section ~~150.1(c)7Aib~~170.2(c)3Aib**.**

ii. Air-cooled air conditioners and air-source heat pumps, including but not limited to ducted split systems, ducted packaged systems, small duct high velocity systems and mini-split systems, which are of a type that cannot comply with the requirements of ~~150.1(c)7Ai~~170.2(c)3Ai shall comply with subsections a ~~and b~~, as applicable.

a. The installer shall confirm the refrigerant charge using the weigh-in charging procedure specified in Reference Residential Appendix Section RA3.2.3.1, as verified by a HERS Rater according to the procedures specified in Reference Residential Appendix Section RA3.2.3.2; and

~~b. Systems that utilize forced air ducts shall comply with the minimum system airflow rate requirement in Section 150.1(c)7Aib provided the system is of a type that can be verified using the procedures in RA3.3 or an approved alternative procedure in RA1.~~

**EXCEPTION to Section ~~150.1(c)7A~~170.2(c)3A:** Packaged systems for which the manufacturer has verified correct system refrigerant charge prior to shipment from the factory are not required to have refrigerant charge confirmed through field verification and diagnostic testing. The installer of these packaged systems shall certify on the Certificate of Installation that the packaged system was pre-charged at the factory and has not been altered in a way that would affect the charge. Ducted systems shall comply with minimum system airflow rate requirement in ~~150.1(c)7Aib~~170.2(c)3Aib, provided that the system is of a type that can be verified using the procedure specified in RA3.3 or an approved alternative in RA1.

B. **Space Conditioning Distribution Systems.** All space conditioning systems shall meet all applicable requirements of ~~A or B~~ i or ii below:

i. High performance attics. Air handlers or ducts are allowed to be in ventilated attic spaces when the roof and ceiling insulation level meet Option B in TABLE ~~150.1-A or B~~170.2-H. ~~Duct insulation levels shall meet the requirements in TABLE 150.1-A or B.~~

ii. Duct and air handlers located in conditioned space. Duct systems and air handlers of HVAC systems shall be located in conditioned space, and confirmed by field verification and diagnostic testing to meet the criterion of Reference Residential Appendix RA3.1.4.3.8. ~~Duct insulation levels shall meet the requirements in TABLE 150.1-A or B.~~

~~**NOTE:** Gas heating appliances installed in conditioned spaces must meet the combustion air requirements of the California Mechanical Code Chapter 7, as applicable.~~

**C. Central Fan Integrated Ventilation Systems.** Central forced air system fans used to provide outside air, shall have an air-handling unit fan efficacy less than or equal to the maximum W/CFM specified in ~~A or B~~i or ii below. The airflow rate and fan efficacy requirements in this section shall be confirmed through field verification and diagnostic testing in accordance with all applicable procedures specified in Reference Residential Appendix RA3.3. Central Fan Integrated Ventilation Systems shall be certified to the Energy Commission as Intermittent Ventilation Systems as specified in Reference Residential Appendix RA3.7.4.2.

i. 0.45 W/CFM for gas furnace air-handling units; or

ii. 0.58 W/CFM for air-handling units that are not gas furnaces.

**EXCEPTION to Section 151.0(c)10A:** Gas furnace air-handling units manufactured prior to July 3, 2019 shall comply with a fan efficacy value less than or equal to 0.58 w/cfm as confirmed by field verification and diagnostic testing in accordance with the procedures given in Reference Residential Appendix RA3.3.

D. **HVAC System Bypass Ducts.** Bypass ducts that deliver conditioned supply air directly to the space conditioning system return duct airflow shall not be used.

4. **Central Systems Serving Multiple Dwelling Units and Common Use Area Space Conditioning Systems.** A building complies with this section by being designed with and having constructed and installed a space-conditioning system that meets the applicable requirements of Subsections ~~(a)~~A through ~~(o)~~M.

A. **Fan Systems.** Each fan system having a total fan system motor nameplate horsepower exceeding 5 hp used for space conditioning shall meet the requirements of Items ~~1, 2, and 3~~i, ii, and iii below. Total fan system power demand equals the sum of the power demand of all fans in the system that are required to operate at design conditions in order to supply air from the heating or cooling source to the conditioned space, and to return it back to the source or to exhaust it to the outdoors.

i. **Fan Power Limitation**. At design conditions each fan system shall not exceed the allowable fan system power of option 1 or 2 as specified in Table ~~140.4-A~~170.2-B

*TABLE ~~140.4-A~~170.2-B Fan Power Limitation*

| | Limit | Constant Volume | Variable Volume |
|---|---|---|---|
| Option 1: Fan system motor nameplate hp | Allowable motor nameplate hp | hp ≤ $cfm_s$ x 0.0011 | hp ≤ $cfm_s$ x 0.0015 |
| Option 2: Fan system bhp | Allowable fan system bhp | bhp ≤ $cfm_s$ x 0.00094 + *A* | bhp ≤ $cfm_s$ x 0.0013 + *A* |

[1]$cfm_s$ = maximum design supply airflow rate to conditioned spaces served by the system in cubic feet per minute

hp = maximum combined motor nameplate horsepower for all fans in the system

bhp = maximum combined fan-brake horsepower for all fans in the system

*A* = sum of (PD x $cfm_D$/4131)

PD = each applicable pressure drop adjustment from Table 140.4 – B, in inches of water

$cfm_D$ = the design airflow through each applicable device from Table 140.4 – B, in cubic feet per minute

*TABLE ~~140.4-B~~170.2-C – Fan Power Limitation Pressure Drop Adjustment*

| Device | Adjustment Credits |
|---|---|
| Return or exhaust systems required by code or accreditation standards to be fully ducted, or systems required to maintain air pressure differentials between adjacent rooms | 0.5 in. of water |
| Return and/or exhaust airflow control devices | 0.5 in. of water |
| Exhaust filters, scrubbers, or other exhaust treatment | The pressure drop of device calculated at fan system design condition |
| Particulate Filtration Credit: MERV 16 and greater and electronically enhanced filters | Pressure drop calculated at 2 x clean filter pressure drop at fan system design condition |
| Carbon and other gas-phase air cleaners | Clean filter pressure drop at fan system design condition |
| Biosafety cabinet | Pressure drop of device at fan system design condition |
| Energy recovery device, other than coil runaround loop | For each airstream [(2.2 x Energy Recovery Effectiveness) – 0.5] in. of water |
| Coil runaround loop | 0.6 in. of water for each airstream |
| Exhaust systems serving fume hoods | 0.35 in. of water |

ii. **Variable air volume (VAV) systems.**

a. Static Pressure Sensor Location. Static pressure sensors used to control variable air volume fans shall be placed in a position such that the controller set point is no greater than one-third the total design fan static pressure, except for systems with zone reset control complying with Section ~~140.4(c)2B~~ 170.2(c)4Aiib. If this results in the sensor being located downstream of any major duct split, multiple sensors shall be installed in each major branch with fan capacity controlled to satisfy the sensor furthest below its setpoint; and

b. Setpoint Reset. For systems with direct digital control of individual zone boxes reporting to the central control panel, static pressure setpoints shall be reset based on the zone requiring the most pressure; i.e., the set point is reset lower until one zone damper is nearly wide open.

iii. **Fractional HVAC Motors for Fans.** HVAC motors for fans that are less than1 hp and 1/12 hp or greater shall be electronically-commutated motors or shall have a minimum motor efficiency of 70 percent when rated in accordance with NEMA Standard MG 1-2006 at full load rating conditions. These motors shall also have the means to adjust motor speed for either balancing or remote control. Belt-driven fans may use sheave adjustments for airflow balancing in lieu of a varying motor speed.

**EXCEPTION 1 to Section ~~140.4(c)3~~170.2(c)4Aiii:** Motors in fan-coils and terminal units that operate only when providing heating to the space served.

**EXCEPTION 2 to Section ~~140.4(c)3~~170.2(c)4Aiii:** Motors in space conditioning equipment certified under Section 110.1 or 110.2

**EXCEPTION 1 to ~~140.4(c)~~170.2(c)4A:** fan system power caused solely by process loads.

~~**EXCEPTION 2 to 140.4(c):** Systems serving healthcare facilities.~~

B. Each space-conditioning zone shall have controls designed in accordance with ~~1 or 2~~i or ii:

i. Each space-conditioning zone shall have controls that prevent:

a. Reheating; and

b. Recooling; and

c. Simultaneous provisions of heating and cooling to the same zone, such as mixing or simultaneous supply of air that has been previously mechanically heated and air that has been previously cooled either by cooling equipment or by economizer systems; or

ii. Zones served by variable air-volume systems that are designed and controlled to reduce, to a minimum, the volume of reheated, recooled, or mixed air are allowed only if the controls meet all of the following requirements:

a. For each zone with direct digital controls (DDC):

I. The volume of primary air that is reheated, recooled or mixed air supply shall not exceed the larger of:

A. 50 percent of the peak primary airflow; or

B. The design zone outdoor airflow rate as specified by Section ~~120.1(c)3~~160.2(c)3.

II. The volume of primary air in the deadband shall not exceed the larger of:

A. 20 percent of the peak primary airflow; or

B. The design zone outdoor airflow rate as specified by Section ~~120.1(c)3~~160.2(c)3.

III. The first stage of heating consists of modulating the zone supply air temperature setpoint up to a maximum setpoint no higher than 95ºF while the airflow is maintained at the dead band flow rate.

IV. The second stage of heating consists of modulating the airflow rate from the dead band flow rate up to the heating maximum flow rate.

b. For each zone without DDC, the volume of primary air that is reheated, re-cooled, or mixed air supply shall not exceed the larger of the following:

I. 30 percent of the peak primary airflow; or

II. The design zone outdoor airflow rate as specified by Section ~~120.1(c)3~~160.2(c)3.

**EXCEPTION 1 to Section ~~140.4(d)~~170.2(c)4B:** Zones with special pressurization relationships or cross-contamination control needs.

**EXCEPTION 2 to Section ~~140.4(d)~~170.2(c)4B**Zones served by space-conditioning systems in which at least 75 percent of the energy for reheating, or providing warm air in mixing systems, is provided from a site-recovered or site-solar energy source.

**EXCEPTION 3 to Section ~~140.4(d)~~170.2(c)4B:** Zones in which specific humidity levels are required to satisfy exempt process loads. Computer rooms or other spaces where the only process load is from IT equipment may not use this exception.

**EXCEPTION 4 to Section ~~140.4(d)~~170.2(c)4B:** Zones with a peak supply-air quantity of 300 cfm or less.

~~**EXCEPTION 5 to Section 140.4(d):** Systems serving healthcare facilities.~~

C. **Economizers**.

i. Each cooling air handler that has a design total mechanical cooling capacity over 54,000 Btu/hr, or chilled-water cooling systems without a fan or that use induced airflow that has a cooling capacity greater than the systems listed in TABLE ~~140.4-C~~170.2-D, shall include either:

a. An air economizer capable of modulating outside-air and return-air dampers to supply 100 percent of the design supply air quantity as outside-air; or

b. A water economizer capable of providing 100 percent of the expected system cooling load, at outside air temperatures of 50°F dry-bulb and 45°F wet-bulb and below.

**EXCEPTION 1 to Section ~~140.4(e)1~~170.2(c)4Ci:** Where special outside air filtration and treatment, for the reduction and treatment of unusual outdoor contaminants, makes compliance infeasible.

**EXCEPTION 2 to Section ~~140.4(e)1~~170.2(c)4Ci:** Where the use of outdoor air for cooling will affect other systems, such as humidification~~,~~ or dehumidification, ~~or supermarket refrigeration systems~~, so as to increase overall building TDV energy use.

**EXCEPTION 3 to Section ~~140.4(e)1~~170.2(c)4Ci:** Systems serving ~~high-rise residential living quarters and hotel/motel guest rooms~~ dwelling units.

**EXCEPTION 4 to Section ~~140.4(e)1~~170.2(c)4Ci:** Where comfort cooling systems have the cooling efficiency that meets or exceeds the cooling efficiency improvement requirements in TABLE ~~140.4-D~~170.2-E.

**EXCEPTION 5 to Section 140.4(e)1:** Fan systems primarily serving computer rooms. See Section 140.9(a) for computer room economizer requirements.

**EXCEPTION 6 to Section ~~140.4(e)1~~170.2(c)4Ci:** Systems design to operate at 100 percent outside air at all times.

*TABLE ~~140.4-C~~170.2-D CHILLED WATER SYSTEM COOLING CAPACITY*

| Climate Zones | Total Building Chilled Water System Capacity, Minus Capacity of the Cooling units with Air Economizers | |
|---|---|---|
| | Building Water-Cooled Chilled Water System | Air-Cooled Chilled Water Systems or District Chilled Water Systems |
| 15 | ≥ 960,000 Btu/h (280 kW) | ≥ 1,250,000 Btu/h (365 kW) |
| 1-14 | ≥720,000 Btu/h (210 kW) | ≥940,000 Btu/h (275 kW) |
| 16 | ≥1,320,000 Btu/h (385 kW) | ≥1,720,000 Bu/h (505 kW) |

*TABLE ~~140.4-D~~ 170.2-E ECONOMIZER TRADE-OFF TABLE FOR COOLING SYSTEMS*

| Climate Zone | Efficiency Improvement [a] |
|---|---|
| 1 | 70% |
| 2 | 65% |
| 3 | 65% |
| 4 | 65% |
| 5 | 70% |
| 6 | 30% |
| 7 | 30% |
| 8 | 30% |
| 9 | 30% |
| 10 | 30% |
| 11 | 30% |
| 12 | 30% |
| 13 | 30% |
| 14 | 30% |
| 15 | 30% |
| 16 | 70% |

[a] If a unit is rated with an IPLV, IEER or SEER, then to eliminate the required air or water economizer, the applicable minimum cooling efficiency of the HVAC unit must be increased by the percentage shown. If the HVAC unit is only rated with a full load metric, such as EER or COP cooling, then that metric must be increased by the percentage shown.

ii. If an economizer is required by Section ~~140.4(e)1~~170.2(c)4Ci, and an air economizer is used to meet the requirement, then it shall be:

a. Designed and equipped with controls so that economizer operation does not increase the building heating energy use during normal operation; and

**EXCEPTION to Section ~~140.4(e)2A~~ 170.2(c)4Ciia:** Systems that provide 75 percent of the annual energy used for mechanical heating from site-recovered energy or a site-solar energy source.

b. Capable of providing partial cooling even when additional mechanical cooling is required to meet the remainder of the cooling load.

c. Designed and equipped with a device type and high limit shut off complying with TABLE ~~140.4-E~~170.2-F.

*TABLE ~~140.4-E~~170.2-F AIR ECONOMIZER HIGH LIMIT SHUT OFF CONTROL REQUIREMENTS*

| **Device Type**[a] | **Climate Zones** | **Required High Limit (Economizer Off When):** | |
|---|---|---|---|
| | | **Equation**[b] | **Description** |
| Fixed Dry Bulb | 1, 3, 5, 11-16 | $T_{OA} > 75°F$ | Outdoor air temperature exceeds 75°F |
| | 2, 4, 10 | $T_{OA} > 73°F$ | Outdoor air temperature exceeds 73°F |
| | 6, 8, 9 | $T_{OA} > 71°F$ | Outdoor air temperature exceeds 71°F |
| | 7 | $T_{OA} > 69°F$ | Outdoor air temperature exceeds 69°F |
| Differential Dry Bulb | 1, 3, 5, 11-16 | $T_{OA} > T_{RA}°F$ | Outdoor air temperature exceeds return air temperature |
| | 2, 4, 10 | $T_{OA} > T_{RA}$-2°F | Outdoor air temperature exceeds return air temperature minus 2°F |
| | 6, 8, 9 | $T_{OA} > T_{RA}$-4°F | Outdoor air temperature exceeds return air temperature minus 4°F |
| | 7 | $T_{OA} > T_{RA}$-6°F | Outdoor air temperature exceeds return air temperature minus 6°F |
| Fixed Enthalpy[c] + Fixed Drybulb | All | $h_{OA} > 28$ Btu/lb[c] or $T_{OA} > 75°F$ | Outdoor air enthalpy exceeds 28 Btu/lb of dry air[c] or<br>Outdoor air temperature exceeds 75°F |

[a] Only the high limit control devices listed are allowed to be used and at the setpoints listed. Others such as Dew Point, Fixed Enthalpy, Electronic Enthalpy, and Differential Enthalpy Controls, may not be used in any Climate Zone for compliance with Section ~~140.4(e)1~~170.2(c)4Ci unless approval for use is provided by the Energy Commission Executive Director.

[b] Devices with selectable (rather than adjustable) setpoints shall be capable of being set to within 2°F and 2 Btu/lb of the setpoint listed.

[c] At altitudes substantially different than sea level, the Fixed Enthalpy limit value shall be set to the enthalpy value at 75°F and 50% relative humidity. As an example, at approximately 6,000 foot elevation, the fixed enthalpy limit is approximately 30.7 Btu/lb.

d. The air economizer and all air dampers shall have the following features:

I. **Warranty.** 5-year Manufacturer warranty of economizer assembly.

II. **Damper reliability testing.** Suppliers of economizers shall certify that the economizer assembly, including but not limited to outdoor air damper, return air damper, drive linkage, and actuator, have been tested and are able to open and close against the rated airflow and pressure of the system for 60,000 damper opening and closing cycles.

III. **Damper leakage.** Economizer outdoor air and return air dampers shall have a maximum leakage rate of 10 cfm/sf at 250 Pascals (1.0 in. of water) when tested in accordance with AMCA Standard 500-D. The economizer outside air and return air damper leakage rates shall be certified to the Energy Commission in accordance with Section 110.0.

IV. **Adjustable setpoint.** If the high-limit control is fixed dry-bulb or fixed enthalpy + fixed dry-bulb then the control shall have an adjustable setpoint.

V. **Sensor accuracy.** Outdoor air, return air, mixed air, and supply air sensors shall be calibrated within the following accuracies.

A. Drybulb and wetbulb temperatures accurate to ±2°F over the range of 40°F to 80°F;

B. Enthalpy accurate to ±3 Btu/lb over the range of 20 Btu/lb to 36 Btu/lb;

C. Relative humidity (RH) accurate to ±5 percent over the range of 20 percent to 80 percent RH;

VI. **Sensor calibration data.** Data used for control of the economizer shall be plotted on a sensor performance curve.

VII. **Sensor high limit control.** Sensors used for the high limit control shall be located to prevent false readings, including but not limited to being properly shielded from direct sunlight.

VIII. **Relief air system.** Relief air systems shall be capable of providing 100 percent outside air without over-pressurizing the building.

e. The space conditioning system shall include the following:

I. Unit controls shall have mechanical capacity controls interlocked with economizer controls such that the economizer is at 100 percent open position when mechanical cooling is on and does not begin to close until the leaving air temperature is less than 45ºF.

II. Direct Expansion (DX) units greater than 65,000 Btu/hr that control the capacity of the mechanical cooling directly based on occupied space temperature shall have a minimum of 2 stages of mechanical cooling capacity.

III. DX units not within the scope of Section ~~140.4(e)2E,B~~ 170.2(c)4Ciib shall (i) comply with the requirements in TABLE ~~140.4-F~~170.2-G, and (ii) shall have controls that do not false load the mechanical cooling system by limiting or disabling the economizer or by any other means except at the lowest stage of mechanical cooling capacity.

*TABLE ~~140.4-F~~170.2-G DIRECT EXPANSION (DX) UNIT REQUIREMENTS FOR COOLING STAGES AND COMPRESSOR DISPLACEMENT*

| Cooling Capacity | Minimum Number of Mechanical Cooling Stages | Minimum Compressor Displacement |
|---|---|---|
| ≥ 65,000 Btu/h and < 240,000 Btu/h | 3 stages | ≤ 35% full load |
| ≥ 240,000 Btu/h | 4 stages | ≤ 25% full load |

iii. Systems that include a water economizer to meet Section ~~140.4(e)1~~ 170.2(c)4Cishall include the following:

a. Maximum pressure drop. Precooling coils and water-to-water heat exchangers used as part of a water economizer shall either have a waterside pressure drop of less than 15 feet of water, or a secondary loop shall be installed so that the coil or heat exchanger pressure drop is not contributing to pressure drop when the system is in the normal cooling (non-economizer) mode.

b. Economizer systems shall be integrated with the mechanical cooling system so that they are capable of providing partial cooling even when additional mechanical cooling is required to meet the remainder of the cooling load. Controls shall not false load the mechanical cooling system by limiting or disabling the economizer or by any other means, such as hot gas bypass, except at the lowest stage of mechanical cooling.

D. **Supply Air Temperature Reset Controls.** Space-conditioning systems supplying heated or cooled air to multiple zones shall include controls that automatically reset supply-air temperatures. Air distribution systems serving zones that are likely to have constant loads shall be designed for the air flows resulting from the fully reset supply air temperature. Supply air temperature reset controls shall be:

i. In response to representative building loads or to outdoor air temperature; and

ii. At least 25 percent of the difference between the design supply-air temperature and the design room air temperature.

**EXCEPTION 1 to Section ~~140.4(f)~~170.2(c)4D:** Systems that meet the requirements of Section ~~140.4(d)1~~170.2(c)3Bi, without using Exception 1 to that section.

**EXCEPTION 2 to Section ~~140.4(f)~~170.2(c)4D:** Where supply-air temperature reset would increase overall building energy use.

**EXCEPTION 3 to Section ~~140.4(f)~~170.2(c)4D:** Systems supplying zones in which specific humidity levels are required to satisfy process loads. Computer Rooms or other spaces with only IT equipment may not use this exception.

~~**EXCEPTION 4 to Section 140.4(f):** Systems serving healthcare facilities.~~

E. **Electric Resistance Heating.** Electric resistance heating systems shall not be used for space heating.

**EXCEPTION 1 to Section ~~140.4(g)~~170.2(c)4E:** Where an electric-resistance heating system supplements a heating system in which at least 60 percent of the annual energy requirement is supplied by site-solar or recovered energy.

**EXCEPTION 2 to Section ~~140.4(g)~~170.2(c)4E:** Where an electric-resistance heating system supplements a heat pump heating system, and the heating capacity of the heat pump is more than 75 percent of the design heating load calculated in accordance with Section ~~140.4(a)~~170.2(c)1 at the design outdoor temperature specified in Section ~~140.4(b)4~~170.2(c)2.

**EXCEPTION 3 to Section ~~140.4(g)~~170.2(c)4E:** Where the total capacity of all electric-resistance heating systems serving the entire building is less than 10 percent of the total design output capacity of all heating equipment serving the entire building.

**EXCEPTION 4 to Section ~~140.4(g)~~170.2(c)4E:** Where the total capacity of all electric-resistance heating systems serving the entire building, excluding those allowed under Exception 2, is no more than 3 kW.

~~**EXCEPTION 5 to Section 140.4(g):** Where an electric resistance heating system serves an entire building that is not a high-rise residential or hotel/motel building; and has a conditioned floor area no greater than 5,000 square feet; and has no mechanical cooling; and is in an area where natural gas is not currently available.~~

**EXCEPTION ~~6~~5 to Section ~~140.4(g)~~170.2(c)4E:** heating systems serving as emergency backup to gas heating equipment.

**F.** **Heat Rejection Systems.** Heat rejection equipment used in comfort cooling systems such as air-cooled condensers, open cooling towers, closed-circuit cooling towers, and evaporative condensers shall include the following:

i. **Fan Speed Control.** Each fan powered by a motor of 7.5 hp (5.6 kW) or larger shall have the capability to operate that fan at 2/3 of full speed or less, and shall have controls that automatically change the fan speed to control the leaving fluid temperature or condensing temperature or pressure of the heat rejection device.

**EXCEPTION 1 to Section ~~140.4(h)1~~170.2(c)4Fi:** Heat rejection devices included as an integral part of the equipment listed in TABLE 110.2-A through TABLE 110.2-I.

**EXCEPTION 2 to Section ~~140.4(h)1~~170.2(c)4Fi:** Condenser fans serving multiple refrigerant circuits.

**EXCEPTION 3 to Section ~~140.4(h)1~~170.2(c)4Fi:** Condenser fans serving flooded condensers.

**EXCEPTION 4 to Section ~~140.4(h)1~~170.2(c)4Fi:** Up to one third of the fans on a condenser or tower with multiple fans where the lead fans comply with the speed control requirement.

ii. **Tower Flow Turndown.** Open cooling towers configured with multiple condenser water pumps shall be designed so that all cells can be run in parallel with the larger of:

a. The flow that is produced by the smallest pump; or

b. 50 percent of the design flow for the cell.

iii. **Limitation on Centrifugal Fan Cooling Towers.** Open cooling towers with a combined rated capacity of 900 gpm and greater at 95°F condenser water return, 85°F condenser water supply, and 75°F outdoor wet-bulb temperature, shall use propeller fans and shall not use centrifugal fans.

**EXCEPTION 1 to Section ~~140.4(h)3~~170.2(c)4Fiii:** Cooling towers that are ducted (inlet or discharge) or have an external sound trap that requires external static pressure capability.

**EXCEPTION 2 to Section ~~140.4(h)3~~170.2(c)4Fiii:** Cooling towers that meet the energy efficiency requirement for propeller fan towers in Section 110.2, TABLE 110.2-G.

iv. **Multiple Cell Heat Rejection Equipment.** Multiple cell heat rejection equipment with variable speed fan drives shall:

a. Operate the maximum number of fans allowed that comply with the manufacturer's requirements for all system components, and

b. Control all operating fans to the same speed. Minimum fan speed shall comply with the minimum allowable speed of the fan drive as specified by the ~~manufactures~~ manufacturer's recommendation. Staging of fans is allowed once the fans are at their minimum operating speed.

v. **Cooling tower efficiency.** Axial fan, open-circuit cooling towers serving condenser water loops for chilled water plants with a total of 900 gpm or greater, shall have a rated efficiency of no less than 60 gpm/hp when rated in accordance with the conditions as listed in Table 110.2-G.

**EXCEPTION 1 to Section ~~140.4(h)5~~170.2(c)4Fv:** Replacement of existing cooling towers that are inside an existing building or on an existing roof.

**EXCEPTION 2 to Section ~~140.4(h)5~~170.2(c)4Fv:** Cooling towers serving buildings in Climate Zone 1 or 16.

G. **Minimum Chiller Efficiency.** Chillers shall meet or exceed Path B from TABLE 110.2-D

**EXCEPTION 1 to Section ~~140.4(i)~~170.2(c)4G:** Chillers with electrical service > 600V.

**EXCEPTION 2 to Section ~~140.4(i)~~170.2(c)4G:** Chillers attached to a heat recovery system with a design heat recovery capacity > 40 percent of the design chiller cooling capacity.

**EXCEPTION 3 to Section ~~140.4(i)~~170.2(c)4G:** Chillers used to charge thermal energy storage systems where the charging temperature is < 40 °F.

**EXCEPTION 4 to Section ~~140.4(i)~~170.2(c)4G:** In buildings with more than 3 chillers, only 3 chillers are required to meet the Path B efficiencies

H. **Limitation of Air-Cooled Chillers.** Chilled water plants shall not have more than 300 tons provided by air-cooled chillers.

**EXCEPTION 1 to Section ~~140.4(j)~~170.2(c)4H:** Where the water quality at the building site fails to meet manufacturer's specifications for the use of water-cooled chillers.

**EXCEPTION 2 to Section ~~140.4(j)~~170.2(c)4H:** Chillers that are used to charge a thermal energy storage system with a design temperature of less than 40 degrees F (4 degrees C).

~~**EXCEPTION 3 to Section 140.4(j):** Systems serving healthcare facilities~~

I. **Hydronic System Measures**.

i. **Hydronic Variable Flow Systems.** HVAC chilled and hot water pumping shall be designed for variable fluid flow and shall be capable of reducing pump flow rates to no more than the larger of: a) 50 percent or less of the design flow rate; or b) the minimum flow required by the equipment manufacturer for the proper operation of equipment served by the system.

**EXCEPTION 1 to Section ~~140.4(k)1~~170.2(c)4I:** Systems that include no more than three control valves.

**EXCEPTION 2 to Section ~~140.4(k)1~~170.2(c)4I:** Systems having a total pump system power less than or equal to 1.5 hp.

ii. **Chiller Isolation.** When a chilled water system includes more than one chiller, provisions shall be made so that flow through any chiller is automatically shut off when that chiller is shut off while still maintaining flow through other operating chiller(s). Chillers that are piped in series for the purpose of increased temperature differential shall be considered as one chiller.

iii. **Boiler Isolation.** When a hot water plant includes more than one boiler, provisions shall be made so that flow through any boiler is automatically shut off when that boiler is shut off while still maintaining flow through other operating boiler(s).

iv. **Chilled and Hot Water Temperature Reset Controls.** Systems with a design capacity exceeding 500,000 Btu/hr supplying chilled or heated water shall include controls that automatically reset supply water temperatures as a function of representative building loads or outside air temperature.

**EXCEPTION 1 to Section ~~140.4(k)41~~170.2(c)4Iiv:** Hydronic systems that use variable flow to reduce pumping energy in accordance with Section ~~140.4(k)1~~170.2(c)4Ii.

~~**EXCEPTION 2 to Section 140.4(k)41:** Systems serving healthcare facilities.~~

**v. Water-Cooled Air Conditioner and Hydronic Heat Pump Systems.** Water circulation systems serving water-cooled air conditioners, hydronic heat pumps, or both, that have total pump system power exceeding 5 hp shall have flow controls that meet the requirements of Section ~~140.4(k)6~~170.2(c)4Ivi. Each such air conditioner or heat pump shall have a two-position automatic valve interlocked to shut off water flow when the compressor is off.

**vi. Variable Flow Controls.**

a. Variable Speed Drives. Individual pumps serving variable flow systems and having a motor horsepower exceeding 5 hp shall have controls or devices (such as variable speed control) that will result in pump motor demand of no more than 30 percent of design wattage at 50 percent of design water flow. The pumps shall be controlled as a function of required differential pressure.

b. Pressure Sensor Location and Setpoint.

c. For systems without direct digital control of individual coils reporting to the central control panel, differential pressure shall be measured at the most remote heat exchanger or the heat exchanger requiring the greatest differential pressure.

d. For systems with direct digital control of individual coils with a central control panel, the static pressure set point shall be reset based on the valve requiring the most pressure, and the setpoint shall be no less than 80 percent open. Pressure sensors may be mounted anywhere.

**EXCEPTION 1 to Section ~~140.4(k)6~~170.2(c)4Ivi:** Heating hot water systems.

**EXCEPTION 2 to Section ~~140.4(k)6~~170.2(c)4Ivi:** Condenser water systems serving only water-cooled chillers.

**vii. Hydronic Heat Pump (WLHP) Controls.** Hydronic heat pumps connected to a common heat pump water loop with central devices for heat rejection and heat addition shall have controls that are capable of providing a heat pump water supply temperature deadband of at least 20°F between initiation of heat rejection and heat addition by the central devices.

**EXCEPTION to Section ~~140.4(k)7~~170.2(c)4Ivii:** Where a system loop temperature optimization controller is used to determine the most efficient operating temperature based on real-time conditions of demand and capacity, dead bands of less than 20°F shall be allowed**.**

J. **Air Distribution System Duct Leakage Sealing.** Duct systems ~~shall be sealed in accordance with 1 or 2 below: Systems~~ serving ~~high-rise residential~~ multifamily buildings~~, hotel/motel buildings and nonresidential buildings other than healthcare facilities, the duct system~~ shall be sealed to a leakage rate not to exceed 6 percent of the nominal air handler airflow rate as confirmed through field verification and diagnostic testing, in accordance with the applicable procedures in Reference Nonresidential Appendices NA1 and NA2 if the criteria in Subsections ~~A, B and C~~i, ii, and iii below are met:

i. The duct system provides conditioned air to an occupiable space for a constant volume, single zone, space-conditioning system; and

ii. The space conditioning system serves less than 5,000 square feet of conditioned floor area; and

iii. The combined surface area of the ducts located in the following spaces is more than 25 percent of the total surface area of the entire duct system:

a. Outdoors; or

b. In a space directly under a roof that

I. Has a U-factor greater than the U-factor of the ceiling, or if the roof does not meet the requirements of Section ~~140.3(a)1B~~170.2(a)1, or

II. Has fixed vents or openings to the outside or unconditioned spaces; or

c. In an unconditioned crawlspace; or

d. In other unconditioned spaces.

**K.** **Fan Control.** Each cooling system listed in TABLE ~~140.4-G~~170.2-H shall be designed to vary the indoor fan airflow as a function of load and shall comply with the following requirements:

iv. DX and chilled water cooling systems that control the capacity of the mechanical cooling directly based on occupied space temperature shall (i) have a minimum of 2 stages of fan control with no more than 66 percent speed when operating on stage 1; and (ii) draw no more than 40 percent of the fan power at full fan speed, when operating at 66 percent speed.

v. All other systems, including but not limited to DX cooling systems and chilled water systems that control the space temperature by modulating the airflow to the space, shall have proportional fan control such that at 50 percent air flow the power draw is no more than 30 percent of the fan power at full fan speed.

vi. Systems that include an air side economizer to meet ~~140.4(e)1~~170.2(c)4Ci shall have a minimum of two speeds of fan control during economizer operation.

**EXCEPTION 1 to Section ~~140.4(m)~~170.2(c)4K:** Modulating fan control is not required for chilled water systems with all fan motors <1 HP, or for evaporative systems with all fan motors < 1 HP, if the systems are not used to provide ventilation air and all indoor fans cycle with the load.

~~**EXCEPTION 2 to Section 140.0(m):** Systems serving healthcare facilities.~~

L. Mechanical System Shut-off. Any directly conditioned common use area ~~space~~ with operable wall or roof openings to the outdoors shall be provided with interlock controls that disable or reset the temperature setpoint to 55°F for mechanical heating and disable or reset the temperature setpoint to 90°F for mechanical cooling to that space when any such opening is open for more than 5 minutes.

**EXCEPTION 1 to Section ~~140.4(n)~~170.2(c)4L:** Interlocks are not required on doors with automatic closing devices**.**

**EXCEPTION 2 to Section ~~140.4(n)~~170.2(c)4L:** Any space without a thermostatic control (thermostat or a space temperature sensor used to control heating or cooling to the space).

~~**EXCEPTION 3 to Section 140.4(n):** Healthcare facilities.~~

~~**EXCEPTION 4 to Section 140.4(n):** High-rise residential dwelling units.~~

M. Exhaust System Transfer Air. Conditioned supply air delivered to any space with mechanical exhaust shall not exceed the greater of:

i. The supply flow required to meet the space heating or cooling load; or

ii. The ventilation rate required by the authority having jurisdiction, the facility Environmental Health and Safety Department, or by Section ~~120.1(c)3~~160.2(c)3; or

iii. The mechanical exhaust flow minus the available transfer air. Available transfer air shall be from another conditioned space or return air plenums on the same floor and same smoke or fire compartment, and that at their closest point are within 15 feet of each other.

~~**EXCEPTION 1 to Section 140.4(o):** Biosafety level classified laboratories 3 or higher.~~

~~**EXCEPTION 2 to Section 140.4(o):** Vivarium spaces.~~

**EXCEPTION ~~3~~1 to Section ~~140.4(o)~~170.2(c)4M:** Spaces that are required by applicable codes and standards to be maintained at a positive pressure differential relative to adjacent spaces.

**EXCEPTION ~~4~~2 to Section ~~140.4(o)~~170.2(c)4M:** Spaces where the highest amount of transfer air that could be used for exhaust makeup may exceed the available transfer airflow rate and where the spaces have a required negative pressure relationship.

~~**EXCEPTION 5 to Section 140.4(o):** Healthcare facilities.~~

(d) **Water Heating Systems.** Water-heating systems shall meet the requirements of either ~~A B or C~~ 1 or 2.

1. For recirculation distribution systems serving individual dwelling units, only Demand Recirculation Systems with manual on/off control as specified in the Reference Appendix RA4.4.9 shall be used. ~~: For systems serving individual dwelling units, t~~The water heating system shall meet the requirement of either ~~i, ii, iii, iv, or v~~A, B, C, D, or E:

   A. One or more gas or propane instantaneous water heater with an input of 200,000 Btu per hour or less and no storage tank.

   B. A single gas or propane storage type water heater with an input of 75,000 Btu per hour or less, rated volume less than or equal to 55 gallons and that meets the requirements of Sections 110.1 and 110.3. The dwelling unit shall have installed fenestration products with a weighted average U-factor no greater than 0.24, and in addition one of the following shall be installed:

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

      ii. A drain water heat recovery system that is field verified as specified in the Reference Appendix RA3.6.9.

   C. A single gas or propane storage type water heater with an input of 75,000 Btu per hour or less, rated volume of more than 55 gallons.

   D. A single heat pump water heater. The storage tank shall be located in the garage or conditioned space. In addition, one of the following:

      i. A compact hot water distribution system as specified in the Reference Appendix RA4.4.6 and a drain water heat recovery system that is field verified as specified in the Reference Appendix RA3.6.9; or

      ii. For Climate Zones 2 through 15, a photovoltaic system capacity of 0.3 kWdc larger than the requirement specified in Section ~~150.1(c)14~~170.2(d); or

      iii. For Climate Zones 1 and 16, a photovoltaic system capacity of 1.1 kWdc larger than the requirement specified in Section ~~150.1(c)14~~170.2(d).

   E. A single heat pump water heater that meets the requirements of NEEA Advanced Water Heater Specification Tier 3 or higher. The storage tank shall be located in the garage or conditioned space. In addition, for Climate Zones 1 and 16, a photovoltaic system capacity of 0.3 kWdc larger than the requirement specified in Section ~~150.1(c)14~~170.2(d) or a compact hot water distribution system as specified in the Reference Appendix RA4.4.6.

2. For systems serving multiple dwelling units, a central water-heating system that includes the following components shall be installed:

   A. Gas or propane water heating system; and

   B. A recirculation system that meets the requirements of Sections 110.3(c)2 and 110.3(c)~~5~~4, includes two or more separate recirculation loops serving separate dwelling units, and is capable of automatically controlling the recirculation pump operation based on measurement of hot water demand and hot water return temperature; and

      **EXCEPTION to Section ~~150.1(c)8Bii~~170.2(d)2B:** Buildings with eight or fewer dwelling units may use a single recirculation loop.

   C. A solar water-heating system meeting the installation criteria specified in Reference Residential Appendix RA4 and with a minimum solar savings fraction of either a or b below:

      i. A minimum solar savings fraction of 0.20 in Climate Zones 1 through 9 or a minimum solar savings fraction of 0.35 in Climate Zones 10 through 16; or

      ii. A minimum solar savings fraction of 0.15 in Climate Zones 1 through 9 or a minimum solar savings fraction of 0.30 in Climate Zones 10 through 16. In addition, a drain water heat recovery system that is field verified as specified in the Reference Appendix RA3.6.9.

      iii. A water-heating system serving multiple dwelling units determined by the Executive Director to use no more energy than the one specified in subsection B above.

*TABLE ~~150.1-B~~170.2-H MECHANICAL COMPONENT PACKAGE – Multifamily Standard Building Design*

| Multifamily | | | | Climate Zone 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dwelling Unit HVAC System | Space Heating [8] | Electric-Resistance Allowed | | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No |
| | | If gas, AFUE | | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN |
| | | If Heat Pump, HSPF [7] | | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN |
| | Space cooling | SEER | | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN | MIN |
| | | Refrigerant Charge Verification or Fault Indicator Display | | NR | REQ | NR | NR | NR | NR | NR | REQ | REQ | REQ | REQ | REQ | REQ | REQ | REQ | NR |
| | Central System Air Handlers | Central Fan Integrated Ventilation System Fan Efficacy | | REQ | REQ | REQ | REQ | REQ | REQ | REQ | REQ | REQ | REQ | REQ | REQ | REQ | REQ | REQ | REQ |
| | ~~Ducts[9]~~ Duct Insulation | ~~Roof/Ceiling Options B~~ ~~Duct and/or air handler outside of conditioned space~~ | ~~Duct Insulation~~ Ducts in Unconditioned Space | R-8 | R-8 | R- 6 | R-8 | R- 6 | R- 6 | R- 6 | R-8 | R-8 | R-8 | R-8 | R-8 | R-8 | R-8 | R-8 | R-8 |
| | | | ~~§150.1(c)9A~~ | ~~NA~~ | ~~NA~~ | ~~NA~~ | ~~NA~~ | ~~NA~~ | ~~NA~~ | ~~NA~~ | ~~NA~~ | ~~NA~~ | ~~NA~~ | ~~NA~~ | ~~NA~~ | ~~NA~~ | ~~NA~~ | ~~NA~~ | ~~NA~~ |
| | | ~~Roof/Ceiling Option C~~ ~~Ducts and air handlers in conditioned space~~ | ~~Duct Insulation~~ | ~~R-6~~ | ~~R-6~~ | ~~R-6~~ | ~~R-6~~ | ~~R-6~~ | ~~R-6~~ | ~~R-6~~ | ~~R-6~~ | ~~R-6~~ | ~~R-6~~ | ~~R-6~~ | ~~R-6~~ | ~~R-6~~ | ~~R-6~~ | ~~R-6~~ | ~~R-6~~ |
| | | | ~~§150.1(c)9B~~ | ~~REQ~~ | ~~REQ~~ | ~~REQ~~ | ~~REQ~~ | ~~REQ~~ | ~~REQ~~ | ~~REQ~~ | ~~REQ~~ | ~~REQ~~ | ~~REQ~~ | ~~REQ~~ | ~~REQ~~ | ~~REQ~~ | ~~REQ~~ | ~~REQ~~ | ~~REQ~~ |
| Water Heating | All Buildings | | | System Shall meet Section ~~150.1(c)8~~170.2(c) | | | | | | | | | | | | | | | |

Footnote requirements to TABLE ~~150.1-B~~170.2-H:

7. HSPF means "heating seasonal performance factor."

8. A supplemental heating unit may be installed in a space served directly or indirectly by a primary heating system, provided that the unit thermal capacity does not exceed 2 kilowatts or 7,000 Btu/hr and is controlled by a time-limiting device not exceeding 30 minutes.

~~9. For duct and air handler location: REQ denotes location in conditioned space. When the table indicates ducts and air handlers are in conditioned space, a HERS verification is required as specified by Reference Residential Appendix RA3.1.4.3.8.~~

(e) **Lighting.** Dwelling unit lighting shall meet the applicable mandatory requirements of Section 160.6.

1. **Interior Common Use Area Lighting.** A building complies with this section if:

   i. The Calculation of Adjusted Indoor Lighting Power of all proposed building areas combined, calculated under Subsection ~~(a)~~ A is no greater than the Calculation of Allowed Indoor Lighting Power, Specific Methodologies calculated under Subsection (c); and

   ii. The Calculation of Allowed Indoor Lighting Power, General Rules comply with Subsection ~~(b)~~B; and

   iii. General lighting complies with the Automatic Daylighting Controls in Secondary Daylit Zone requirements in Subsection ~~(d)~~D.

   The prescriptive limits on indoor lighting power are the smaller of the Actual and Allowed Indoor Lighting Power values determined in accordance with item i.

   A. **Calculation of Adjusted Indoor Lighting Power.** The adjusted indoor Lighting Power of all proposed building areas is the total watts of all planned permanent and portable lighting systems in all areas of the proposed building; subject to the applicable adjustments under Subdivisions 1 through 4 of this subsection.

      i. **Two interlocked lighting systems**: No more than two lighting systems may be used for an area, and if there are two they must be interlocked. Where there are two interlocked lighting systems, the watts of the lower wattage system may be excluded from the Adjusted Indoor Lighting Power if:

         a. An Installation Certificate detailing compliance with Section ~~140.6(a)1~~170.2(e)1A is submitted in accordance with Section 10-103 and Section ~~130.4~~160.5(e); and

         b. The area or areas served by the interlocking systems is an auditorium, ~~a convention center,~~ a conference room, a multipurpose room, or a theater; and

         c. The two lighting systems are interlocked with a Nonprogrammable Double-Throw Switch to prevent simultaneous operation of both systems.

         For compliance with Part 6 a Nonprogrammable Double-Throw Switch is an electrical switch commonly called a "single pole double throw" or "three-way" switch that is wired as a selector switch allowing one of two loads to be enabled. It can be a line voltage switch or a low voltage switch selecting between two relays. It cannot be overridden or changed in any manner that would permit both loads to operate simultaneously.

      ii. **Reduction of wattage through controls.** In calculating Adjusted Indoor Lighting Power, the installed watts of a luminaire providing general lighting in an area listed in TABLE ~~140.6-A~~170.2-I may be reduced by the product of (i) the number of watts controlled as described in TABLE ~~140.6-A~~170.2-I, times (ii) the applicable Power Adjustment Factor (PAF), if all of the following conditions are met:

         a. An Installation Certificate is submitted in accordance with Section ~~130.4(b)~~160.5(e)1B; and

         b. Luminaires and controls meet the applicable requirements of Section 110.9, and Sections ~~130.0~~ 160.5 through ~~130.5~~160.6; and

         c. The controlled lighting is permanently installed general lighting systems and the controls are permanently installed nonresidential-rated lighting controls.

         When used for determining PAFs for general lighting in offices, furniture mounted luminaires that comply with all of the following conditions shall qualify as permanently installed general lighting systems:

         I. The furniture mounted luminaires shall be permanently installed no later than the time of building permit inspection; and

         II. The furniture mounted luminaires shall be permanently hardwired; and

         III. The furniture mounted lighting system shall be designed to provide indirect general lighting; and

IV. Before multiplying the installed watts of the furniture mounted luminaire by the applicable PAF, 0.3 watts per square foot of the area illuminated by the furniture mounted luminaires shall be subtracted from installed watts of the furniture mounted luminaires; and

V. The lighting control for the furniture mounted luminaire complies with all other applicable requirements in Section ~~140.6(a)2~~170.2(e)1Aii.

d. At least 50 percent of the light output of the controlled luminaire is within the applicable area listed in TABLE ~~140.6-A~~170.2-I. Luminaires on lighting tracks shall be within the applicable area in order to qualify for a PAF.

e. Only one PAF from TABLE ~~140.6-A~~170.2-I may be used for each qualifying luminaire. PAFs shall not be added together unless allowed in TABLE ~~140.6-A~~170.2-I.

f. Only lighting wattage directly controlled in accordance with Section ~~140.6(a)2~~170.2(e)1Aii shall be used to reduce the installed watts as allowed by Section ~~140.6(a)2~~170.2(e)1Aii for calculating the Adjusted Indoor Lighting Power. If only a portion of the wattage in a luminaire is controlled in accordance to Section ~~140.6(a)2~~170.2(e)1Aii, then only that portion of controlled wattage may be reduced in calculating Adjusted Indoor Lighting Power.

g. Lighting controls used to qualify for a PAF shall be designed and installed in addition to manual, multilevel, and automatic lighting controls required in Section ~~130.1~~160.5(b)4, and in addition to any other lighting controls required by any provision of Part 6. PAFs shall not be available for lighting controls required by Part 6.

h. To qualify for the PAF for daylight dimming plus OFF control, the daylight control and controlled luminaires shall comply with Section ~~130.1(d)~~160.5(b)4D, ~~130.4(a)3~~160.5(e)1C and ~~130.4(a)7~~160.5(e)1G, and shall additionally turn lights completely OFF when the daylight available in the daylit zone is greater than 150 percent of the illuminance received from the general lighting system at full power. The PAF shall apply only to the luminaires in the primary sidelit daylit zone and the skylit daylit zone.

i. To qualify for the PAF for an occupant sensing control controlling the general lighting in ~~large~~ open plan office areas above workstations, in accordance with TABLE ~~140.6-A~~170.2-I, the following requirements shall be met:

I. The open plan office area shall be greater than 250 square feet; and

II. This PAF shall be available only in office areas which contain workstations; and

III. Controlled luminaires shall only be those that provide general lighting directly above the controlled area, or furniture mounted luminaires that comply with Section ~~140.6(a)2~~170.2(e)1Aii and provide general lighting directly above the controlled area; and

IV. Qualifying luminaires shall be controlled by occupant sensing controls that meet all of the following requirements, as applicable:

A. Infrared sensors shall be equipped by the manufacturer, of fitted in the field by the installer, with lenses or shrouds to prevent them from being triggered by movement outside of the controlled area.

B. Ultrasonic sensors shall be tuned to reduce their sensitivity to prevent them from being triggered by movements outside of the controlled area.

C. All other sensors shall be installed and adjusted as necessary to prevent them from being triggered by movements outside of the controlled area.

j. To qualify for the PAF for an Institutional Tuning in TABLE ~~140.6-A~~170.2-I, the tuned lighting system shall comply with all of the following requirements:

I. The lighting controls shall limit the maximum output or maximum power draw of the controlled lighting to 85 percent or less of full light output or full power draw; and

II. The means of setting the limit is accessible only to authorized personnel; and

III. The setting of the limit is verified by the acceptance test required by Section ~~130.4(a)7~~160.5(e)1G; and

I. The construction documents specify which lighting systems shall have their maximum light output or maximum power draw set to no greater than 85% of full light output or full power draw.

k. To qualify for the PAF for a Demand Responsive Control in TABLE ~~140.6-A~~170.2-I, a Demand Responsive Control shall meet all of the following requirements:

I. The common use area of the building shall be 10,000 square feet or smaller; and

II. The controlled lighting shall be capable of being automatically reduced in response to a demand response signal; and

III. Lighting shall be reduced in a manner consistent with uniform level of illumination requirements in TABLE ~~130.1-A~~160.5-B; and

IV. Spaces that are non-habitable shall not be used to comply with this requirement, and spaces with a lighting power density of less than 0.5 watts per square foot shall not be counted toward the building's total lighting power.

l. To qualify for the PAFs for clerestory fenestration, horizontal slats, or light shelves in TABLE ~~140.6-A~~170.2-I, the daylighting design shall meet the requirements in Section 140.3(d). The PAFs shall only apply to lighting in a primary or secondary sidelit daylit zone where continuous dimming daylighting controls meeting the requirements of Section ~~130.1(d)~~160.5(b)4D) are installed.

iii. **Lighting wattage excluded.** The watts of the following indoor lighting applications may be excluded from Adjusted Indoor Lighting Power. (Indoor lighting not listed below shall comply with all applicable nonresidential indoor lighting requirements in Part 6.):

a. Lighting installed by the manufacturer in walk-in coolers or freezers, vending machines, and food preparation equipment~~, and scientific and industrial equipment~~.

b. Lighting that is required for exit signs subject to the CBC. Exit signs shall meet the requirements of the Appliance Efficiency Regulations.

c. Exit way or egress illumination that is normally off and that is subject to the CBC.

~~d. In high-rise residential buildings: Lighting in dwelling units (Lighting in high-rise residential dwelling units shall comply with Section 130.0(b). (Indoor lighting not in dwelling units shall comply with all applicable nonresidential lighting requirements in Part 6.)~~

d. Temporary lighting systems. (As defined in Section 100.1.)

e. Lighting systems in qualified historic buildings, as defined in the California Historical Building Code (Title 24, Part 8), are exempt from the Lighting Power Density allowances, if they consist solely of historic lighting components or replicas of historic lighting components. If lighting systems in qualified buildings contain some historic lighting components or replicas of historic components, combined with other lighting components, only those historic or historic replica components are exempt. All other lighting systems in qualified historic buildings shall comply with the Lighting Power Density allowances.

f. Lighting for signs: Lighting for signs shall comply with Section 140.8.

g. Lighting in elevators where the lighting meets the requirements in Section 120.6(f).

h. Lighting connected to a Life Safety Branch or Critical Branch, as specified in Section 517 of the California Electrical Code.

iv. **Luminaire Classification and Power Adjustment**

a. Luminaire Classification and Power shall be determined in accordance with Section ~~130.0(c)~~ 160.5(c)1.

b. Small Aperture Tunable-White and Dim-to-Warm Luminaires Lighting Power Adjustment. For qualifying small aperture tunable-white and dim-to-warm LED luminaires, the adjusted indoor lighting power of these luminaires shall be calculated by multiplying their maximum rated wattage by 0.75. Qualifying luminaires shall meet all of the following:

I. Small Aperture. Qualifying luminaires longer than 18 inches shall be no wider than four inches. Qualifying luminaires with a length of 18 inches or less shall be no wider than eight inches.

II. Color Changing. Qualifying tunable-white luminaires shall be capable of a color change greater than or equal to 2000 Kelvin correlated color temperature (CCT). Qualifying dim-to-warm luminaires shall be capable of color change greater than or equal to 500 Kelvin CCT.

III. Controls. Qualifying luminaires shall be connected to controls that allows color changing of the luminaires.

c. Tailored Method Display Lighting Mounting Height Lighting Power Adjustment. For wall display luminaires or floor display luminaires meeting Tailored Method Section ~~140.6(c)3G~~170.2(e)1Ciig and H and where the bottom of luminaires are 10 feet 7 inches and greater above the finished floor, the adjusted indoor lighting power of these luminaires shall be calculated by multiplying their maximum rated wattage and the appropriated mounting height adjustment factor from TABLE ~~140.6-E~~170.2-L. Luminaire mounting height is the distance from the finished floor to the bottom of the luminaire. General lighting shall not qualify for a mounting height multiplier.

**B. Calculation of Allowed Indoor Lighting Power: General Rules.**

i. The allowed Indoor Lighting Power allotment for conditioned areas shall be calculated separately from the allowed Lighting Power allotment for unconditioned areas. Each allotment is applicable solely to the area to which it applies, and there shall be no trade-offs between conditioned and unconditioned area allotments.

ii. Allowed Indoor Lighting Power allotment shall be calculated separately from the allowed Outdoor Lighting Power allotment. Each allotment is applicable solely to the area to which it applies, and there shall be no trade-offs between the separate Indoor and Outdoor allotments.

iii. The Allowed Indoor Lighting Power allotment for general lighting shall be calculated as follows:

a. The Area Category Method, as described in Section ~~140.6(c)2~~170.2(e)1Ci, shall be used either by itself for all common use areas in the building, or when some areas in the building use the Tailored Method described in Section ~~140.6(c)3~~170.2(e)1Cii. Under the Area Category Method (either by itself or in conjunction with the Tailored Method), as described more fully in Section ~~140.6(c)2~~170.2(e)1Ci, and subject to the adjustments listed there, the allowed Indoor Lighting Power allotment for general lighting shall be calculated for each area in the building as follows:

I. For conditioned areas, by multiplying the conditioned square feet of the area times the applicable allotment of watts per square foot for the area shown in TABLE ~~140.6-C~~170.2-J (or TABLE ~~140.6-D~~170.2-K if the Tailored Method is used for that area).

II. For unconditioned areas, by multiplying the unconditioned square feet of the area times the applicable allotment of watts per square foot for the area shown in TABLE ~~140.6-C~~170.2-J (or TABLE ~~140.6-D~~170.2-K if the Tailored Method is used for that area).

The Allowed Indoor Lighting Power allotment for general lighting for one area for which the Area Category Method was used may be increased up to the amount that the Allowed Indoor Lighting Power allotment for general lighting for another area using the Area Category Method or Tailored Method is decreased, except that such increases and decreases shall not be made between conditioned and unconditioned space.

b. The Tailored Method, as described in Section ~~140.6(c)3~~170.2(e)1Cii, shall be used either by itself for all areas in the building, or when some areas in the building use the Area Category

Method described in Section ~~140.6(c)2~~170.2(e)1Ci. Under the Tailored Method (either by itself or in conjunction with the Area Category Method) as described more fully in Section ~~140.6(c)3~~170.2(e)1Cii, and subject to the adjustments listed there, allowed Indoor Lighting Power allotment for general lighting shall be calculated for each area in the building as follows:

I. For conditioned areas, by multiplying the conditioned square feet of the area times the applicable allotment of watts per square foot for the area shown in TABLE ~~140.6-D~~170.2-K (or TABLE ~~140.6-C~~170.2-J if the Area Category Method is used for that area);

II. For unconditioned areas, by multiplying the unconditioned square feet of the area times the applicable allotment of watts per square foot for the area shown in TABLE ~~140.6-D~~170.2-J (or TABLE ~~140.6-C~~170.2-J if the Area Category Method is used for that area);

The Allowed Indoor Lighting Power allotment for general lighting for one area for which the Tailored Method was used may be increased up to the amount that the Allowed Indoor Power Lighting for general lighting for another area is decreased, but only if the Tailored Method or Area Category Method was used for the other area, except that such increases and decreases shall not be made between conditioned and unconditioned space.

c. If the Area Category Method is used for an area, the Tailored Method may not be used for that area. If the Tailored Method is used for an area, the Area Category Method may not be used for that area.

C. **Calculation of Allowed Indoor Lighting Power: Specific Methodologies.** The allowed indoor Lighting Power for each ~~building type, or each~~ common use primary function area shall be calculated using only one of the methods in Subsection ~~1, 2 or 3~~ i, ii, or iii below as applicable.

i. **Area Category Method.** Requirements for using the Area Category Method include all of the following:

a. The Area Category Method shall be used only for primary function areas, as defined in Section 100.1, that are listed in TABLE ~~140.6-C~~170.2-J. For primary function areas not listed, selection of a reasonably equivalent type shall be permitted.

~~b. Primary Function Areas in TABLE 140.6-C170.2-J shall not apply to a complete building. Each primary function area shall be determined as a separate area.~~

c. For purposes of compliance with Section ~~140.6(c)2~~170.2(e)1Ci, an "area" shall be defined as all contiguous areas that accommodate or are associated with a single primary function area listed in TABLE ~~140.6-C~~170.2-J.

d. Where areas are bounded or separated by interior partitions, the floor area occupied by those interior partitions may be included in a Primary Function Area.

~~e. If at the time of permitting for a newly constructed building, a tenant is not identified for a multi-tenant area, a maximum of 0.4 watts per square foot shall be allowed for the lighting in each area in which a tenant has not been identified. The area shall be classified as Unleased Tenant Area.~~

e. ~~Under the Area Category Method, t~~The allowed indoor Lighting Power for each primary function area is the Lighting Power Density value in TABLE ~~140.6-C~~170.2-J times the square feet of the primary function area. The total allowed indoor Lighting Power for the building is the sum of all allowed indoor Lighting Power for all areas in the building.

f. In addition to the allowed indoor Lighting Power calculated according to Sections ~~140.6(c)2A through F~~170.2(e)1Cia through f, the building may add additional lighting power allowances for qualifying lighting systems as specified in the Qualifying Lighting Systems column in TABLE ~~140.6-C~~170.2-J under the following conditions:

I. Only primary function areas having a lighting system as specified in the Qualifying Lighting Systems column in TABLE ~~140.6-C~~170.2-J and in accordance with the corresponding footnote of the TABLE shall qualify for the additional lighting power allowances; and

II. The additional lighting power allowances shall be used only if the plans clearly identify all applicable task areas and the lighting equipment designed to illuminate these tasks; and

III. Tasks that are performed less than two hours per day or poor quality tasks that can be improved are not eligible for the additional lighting power allowances; and

IV. The additional lighting power allowances shall not utilize any type of luminaires that are used for general lighting in the building; and

~~V. The additional lighting power allowances shall not be used when using the Complete Building Method, or when the Tailored Method is used for any area in the building; and~~

V. The additional lighting power allowed is the smaller of:

A. the lighting power density listed in the "Allowed Additional Lighting LPD" column in TABLE ~~140.6-C~~170.2-J, times the square feet of the primary function, or

B. the Adjusted Indoor Lighting Power of the applicable lighting; and

VI. In addition to all other additional lighting power allowed under Sections ~~140.6(c)2Gi~~ 170.2(e)1CigI through ~~vi~~V, up to 1.0 watts per square foot of additional lighting power shall be allowed in a videoconferencing studio, as defined in Section 100.1, provided the following conditions are met:

A. A completed and signed Installation Certificate is prepared and submitted in accordance with Section ~~130.4(b)~~160.5(e)1B, specifically detailing compliance with the applicable requirements of Section ~~140.6(c)2Gvii~~170.2(e)1CigVI; and

B. The Videoconferencing Studio is a room with permanently installed videoconferencing cameras, audio equipment, and playback equipment for both audio-based and video-based two-way communication between local and remote sites; and

C. General lighting is switched in accordance with TABLE ~~130.1-A~~160.5-B; and

D. Wall wash lighting is separately switched from the general lighting system; and

E. All of the lighting in the studio, including general lighting and additional lighting power allowed by Section ~~140.6(c)2Gvii~~170.2(e)1CigVI is controlled by a multiscene programmable control system (also known as a scene preset control system).

**ii. Tailored Method.** Requirements for using the Tailored Method include all of the following:

a. The Tailored Method shall be used only for primary function areas listed in TABLE ~~140.6-D~~170.2-K, as defined in Section 100.1.

b. Allowed Indoor Lighting Power allotments for general lighting shall be determined according to Section ~~140.6(c)3F~~170.2(e)1Ciif, as applicable.

c. For compliance with Section ~~140.6(c)3~~170.2(e)1Cii, an "area" shall be defined as all contiguous areas that accommodate or are associated with a single primary function area listed in TABLE ~~140.6-D~~170.2-K.

d. Where areas are bounded or separated by interior partitions, the floor area occupied by those interior partitions may be included in a Primary Function Area.

e. In addition to the allowed indoor Lighting Power allotments for general lighting calculated according to Section ~~140.6(c)3F~~170.2(e)1Ciiif, as applicable, the building may add additional lighting power allowances for wall display lighting, ~~floor display lighting and~~ task lighting,and ornamental/special effects lighting, ~~and very valuable display cases lighting~~ according to Section ~~140.6(c)3G~~ 170.20(e)1Ciig through ~~J~~j.

f. Determine allowed indoor Lighting Power allotments for general lighting for primary function areas listed in TABLE ~~140.6-D~~170.2-K as follows:

I. Use the General Illumination Level (Lux) listed in Column 2 of TABLE ~~140.6-D~~170.2-K to determine the Allowed General Lighting Power Density allotments for the area.

II. Determine the room cavity ratio (RCR) for the area. The RCR shall be calculated according to the applicable equation in TABLE ~~140.6-F~~170.2-M.

III. Find the allowed General Lighting Power Density allotments in TABLE ~~140.6-G~~170.2-N that is applicable to the General Illuminance Level (Lux) from Column 2 of TABLE ~~140.6-D~~170.2-K (as described in Item i.) and the RCR determined in accordance with TABLE ~~140.6-F~~170.2-M (as described in Item ii).

IV. Determine the square feet of the area in accordance with Section ~~140.6(c)3C~~ 170.2(e)1Ciic and ~~D~~d.

~~V.~~ Multiply the allowed Lighting Power Density allotment, as determined in accordance with Item iii by the square feet of each primary function area, as determined in accordance with Item iv. The product is the Allowed Indoor Lighting Power allotment for general lighting for the area.

g. Determine additional allowed power for wall display lighting according to column 3 of TABLE ~~140.6-D~~170.2-K for each primary function area as follows:

~~I. Floor displays shall not qualify for wall display allowances.~~

I. Qualifying wall lighting shall:

A. Be mounted within 10 feet of the wall having the wall display. When track lighting is used for wall display, and where portions of that lighting track are more than 10 feet from the wall and other portions are within 10 feet of the wall, portions of track more than 10 feet from the wall shall not be used for the wall display allowance.

B. Be a lighting system type appropriate for wall lighting. Lighting systems appropriate for wall lighting are lighting track adjacent to the wall, wall-washer luminaires, luminaires behind a wall valance or wall cove, or accent light. (Accent luminaires are adjustable or fixed luminaires with PAR, R, MR, AR, or luminaires providing directional display light.)

i. Additional allowed power for wall display lighting is available only for lighting that illuminates walls having wall displays. The length of display walls shall include the length of the perimeter walls, including but not limited to closable openings and permanent full height interior partitions. Permanent full height interior partitions are those that (I) extend from the floor to within two feet of the ceiling or are taller than ten feet and (II) are permanently anchored to the floor.

ii. For wall display lighting where the bottom of the luminaire is greater than 10 feet 6 inches above the finished floor, the mounting height adjustment factor from TABLE ~~140.6-E~~170.2-L can be used to adjust the installed luminaire wattage as specified in Section ~~140.6(a)4C~~170.2(e)1Aivc.

iii. The allowed power for wall display lighting shall be the smaller of:

a. the “wall display lighting power density” determined in accordance with TABLE ~~140.6-D~~170.2-K, multiplied by the wall display lengths determined in accordance with Item iii; and

b. The Adjusted Indoor Lighting Power used for the wall display lighting systems.

iv. Lighting internal to display cases that are attached to a wall or directly adjacent to a wall are counted as wall display lighting as specified in Section ~~140.6(c)3G~~170.2(e)1Ciig. All other lighting internal to display cases are counted as floor display lighting as specified in Section ~~140.6(c)3H~~170.2(e)1Ciih, or as very valuable display case lighting as specified in Section ~~140.6(c)3J~~170.2(e)1Ciij.

h. Determine additional allowed power for ~~floor display lighting and~~ task lighting as follows:

~~I. Displays that are installed against a wall shall not qualify for the floor display lighting power allowances.~~

~~II. Lighting internal to display cases that are not attached to a wall and not directly adjacent to a wall, shall be counted as floor display lighting in accordance with Section 140.6(c)3H; or very valuable display case lighting in accordance with Section 140.6(c)3J.~~

~~III. Additional allowed power for floor display lighting, and additional allowed power for task lighting, may be used by qualifying floor display lighting systems, qualifying task lighting systems, or a combination of both. For floor areas qualifying for both floor display and task lighting power allowances, the additional allowed power shall be used only once for the same floor area, so that the allowance shall not be additive.~~

~~IV. Qualifying floor display lighting shall:~~

~~A. Be mounted no closer than 2 feet to a wall.~~

~~B. Consist of only (I) directional lamp types, such as PAR, R, MR, AR; or (II) luminaires providing directional display light.~~

~~C. If track lighting is used, shall be only track heads that are classified as direction lighting types.~~

Qualifying task lighting shall:

I. Be located immediately adjacent to and capable of illuminating the task for which it is installed.

II. Be of a type different from the general lighting system.

III. Be separately switched from the general lighting system.

~~IV. If there are illuminated floor displays, floor display lighting power shall be used only if allowed by column 4 of TABLE 140.6.~~

~~V. The square footage of floor displays or the square footage of task areas shall be determined in accordance with Section 140.6(c)3C and Dd, except that any floor area designed to not have floor displays or tasks, such as floor areas designated as a path of egress, shall not be included for the floor display allowance.~~

~~VI. For floor display lighting where the bottom of the luminaire is greater than 10.6 feet above the finished floor, multiply the floor display installed watts by the appropriate mounting height adjustment factor from TABLE 140.6 to calculate the Adjusted Indoor Lighting Power as specified in Section 140.6(a)4C.~~

~~VII. The allowed power for floor display lighting for each applicable area shall be the smaller of:~~

~~A. The allowed floor display and task lighting power determined in accordance with Section 140.6(c) by the floor square footage determined in accordance with Section 140.6(c); and~~

~~B. The Adjusted Indoor Lighting Power used for the floor display lighting systems.~~

i. Determine additional allowed power for ornamental/special effects lighting as follows:

I. Qualifying ornamental lighting includes luminaires such as chandeliers, sconces, lanterns, neon and cold cathode, light emitting diodes, theatrical projectors, moving lights and light color panels when any of those lights are used in a decorative manner that does not serve as display lighting or general lighting.

II. Additional lighting power for ornamental/special effects lighting shall be used only if allowed by Column 5 of TABLE ~~140.6-D~~170.2-K.

III. Additional lighting power for ornamental/special effects lighting shall be used only in areas having ornamental/special effects lighting. The square footage of the floor area shall be determined in accordance with Section ~~140.6(c)3C~~170.2(e)1Ciic and ~~D~~d, and it shall not include floor areas not having ornamental/special effects lighting.

IV. The additional allowed power for ornamental/special effects lighting for each applicable area shall be the smaller of:

A. The product of the "allowed ornamental/special effects lighting power" determined in accordance with Section ~~140.6(c)3Kii~~170.2(e)1CiikII, multiplied by the floor square footage determined in accordance with Section ~~140.6(c)3Kiii~~170.2(e)1CiikIII; and

B. The Adjusted Indoor Lighting Power of allowed ornamental/special effects lighting.

~~j. Determine additional allowed power for very valuable display case lighting as follows:~~

~~I. Additional allowed power for very valuable display case lighting shall be available only for display cases in appropriate function areas in retail merchandise sales, museum and religious worship.~~

~~I. To qualify for additional allowed power for very valuable display case lighting, a case shall contain jewelry, coins, fine china, fine crystal, precious stones, silver, small art objects and artifacts, and/or valuable collections the display of which involves customer inspection of very fine detail from outside of a locked case.~~

~~II. Qualifying lighting includes internal display case lighting or external lighting employing highly directional luminaires specifically designed to illuminate the case or inspection area without spill light, and shall not be fluorescent lighting unless installed inside of a display case.~~

~~III. If there is qualifying very valuable display case lighting, in accordance with Section 140.6(c)3Jii, the smallest of the following separate lighting power for display cases presenting very valuable display items is permitted:~~

~~A. The product of the area of the primary function and 0.55 watt per square foot; or~~

~~B. The product of the area of the display case and 8 watts per square foot; or~~

C. ~~The Adjusted Indoor Lighting Power of lighting for very valuable displays~~.

D. **Automatic Daylighting Controls in Secondary Daylit Zones.** All luminaires providing general lighting that is in, or partially in a Secondary Sidelit Daylit Zone, and that is not in a Primary Sidelit Daylit Zone shall:

i. Be controlled independently from all other luminaires by automatic daylighting controls that meet the applicable requirements of Section 110.9; and

ii. Be controlled in accordance with the applicable requirements in Section ~~130.1(d)~~160.5(b)4D; and

iii. All Secondary Sidelit Daylit Zones shall be shown on the plans submitted to the enforcing agency.

**EXCEPTION 1 to Section ~~140.6(d)~~170.2(e)1D:** Luminaires in Secondary Sidelit Daylit Zone(s) in an enclosed space in which the combined total general lighting power in Secondary Daylit Zone(s) is less than 120 watts, or where the combined total general lighting power in Primary and Secondary Daylit Zone(s) is less than 240 watts.

**EXCEPTION 2 to Section ~~140.6(d)~~170.2(e)1D:** Luminaires in parking garages complying with Section ~~130.1(d)3~~160.5(b)4Diii.

**EXCEPTION 3 to Section ~~140.6(d)~~170.2(e)1D:** Areas adjacent to vertical glazing below an overhang, where there is no vertical glazing above the overhang and where the ratio of the overhang projection to the overhang rise is greater than 1.5 for South, East and West orientations, or where the ratio of the overhang projection to the overhang rise is greater than 1 for North orientations.

**EXCEPTION 4 to Section ~~140.6(d)~~170.2(e)1D:** Rooms that have a total glazing area of less than 24 square feet, or parking garage areas with a combined total of less than 36 square feet of glazing or opening.

~~**EXCEPTION 5 to Section 140.6(d):** Luminaires in sidelit daylit zones in retail merchandise sales and wholesale showroom areas.~~

*TABLE ~~140.6-A~~170.2-I LIGHTING POWER ADJUSTMENT FACTORS (PAF)*

<table>
<tr><th>TYPE OF CONTROL</th><th colspan="2">TYPE OF AREA</th><th>FACTOR</th></tr>
<tr><td colspan="4">a. To qualify for any of the Power Adjustment Factors in this table, the installation shall comply with the applicable requirements in Section ~~140.6~~170.2(e)1Aii<br>b. Only one PAF may be used for each qualifying luminaire unless combined below.<br>c. Lighting controls that are required for compliance with Part 6 shall not be eligible for a PAF</td></tr>
<tr><td>1. Daylight Dimming plus OFF Control</td><td colspan="2">Luminaires in skylit daylit zone or primary sidelit daylit zone</td><td>0.10</td></tr>
<tr><td rowspan="3">2. Occupant Sensing Controls in Large Open Plan Offices</td><td rowspan="3">In open plan offices > 250 square feet: One sensor controlling an area that is:</td><td>No larger than 125 square feet</td><td>0.40</td></tr>
<tr><td>From 126 to 250 square feet</td><td>0.30</td></tr>
<tr><td>From 251 to 500 square feet</td><td>0.20</td></tr>
<tr><td rowspan="2">3.Institutional Tuning</td><td colspan="2">Luminaires in non-daylit areas.<br>Luminaires that qualify for other PAFs in this table may also qualify for this tuning PAF.</td><td>0.10</td></tr>
<tr><td colspan="2">Luminaires in daylit areas.<br>Luminaires that qualify for other PAFs in this table may also qualify for this tuning PAF.</td><td>0.05</td></tr>
<tr><td>4. Demand Responsive Control</td><td colspan="2">All building types of 10,000 square feet or smaller.<br>Luminaires that qualify for other PAFs in this table may also qualify for this demand responsive control PAF</td><td>0.05</td></tr>
<tr><td>5. Clerestory Fenestration</td><td colspan="2">Luminaires in daylit areas adjacent to the clerestory.<br>Luminaires that qualify for daylight dimming plus OFF control may also qualify for this PAF.</td><td>0.05</td></tr>
<tr><td>6. Horizontal Slats</td><td colspan="2">Luminaires in daylit areas adjacent to vertical fenestration with interior or exterior horizontal slats.<br>Luminaires that qualify for daylight dimming plus OFF control may also qualify for this PAF.</td><td>0.05</td></tr>
<tr><td>7.Light Shelves</td><td colspan="2">Luminaires in daylit areas adjacent to clerestory fenestration with interior or exterior light shelves. This PAF may be combined with the PAF for clerestory fenestration.<br>Luminaires that qualify for daylight dimming plus OFF control may also qualify for this PAF</td><td>0.10</td></tr>
</table>

*TABLE ~~140.6-C~~170.2-J AREA CATEGORY METHOD - LIGHTING POWER DENSITY VALUES (WATTS/FT²)*

| Primary Function Area | | Allowed Lighting Power Density for General Lighting ($W/ft^2$) | Additional Lighting Power[1] | |
|---|---|---|---|---|
| | | | Qualified Lighting Systems | Additional Allowance ($W/ft^2$, unless noted otherwise) |
| ~~Auditorium Area~~ | | ~~0.70~~ | ~~Ornamental~~ | ~~0.30~~ |
| | | | ~~Accent, display and feature[3]~~ | ~~0.20~~ |
| Auto Repair / Maintenance Area | | 0.55 | Detailed Task Work[7] | 0.20 |
| ~~Audience Seating Area~~ | | ~~0.60~~ | ~~Ornamental~~ | ~~0.30~~ |
| ~~Beauty Salon Area~~ | | ~~0.80~~ | ~~Detailed Task Work[7]~~ | ~~0.20~~ |
| | | | ~~Ornamental~~ | ~~0.30~~ |
| ~~Civic Meeting Place Area~~ | | ~~1.00~~ | ~~Ornamental~~ | ~~0.30~~ |
| Classroom, Lecture, Training, Vocational Area | | 0.70 | White or Chalk Board[1] | 4.50 W/ft |
| ~~Commercial/Industrial~~ Storage | ~~Warehouse~~ | 0.45 | - | - |
| | ~~Shipping & Handling~~ | ~~0.60~~ | ~~-~~ | ~~-~~ |
| ~~Convention,~~ Conference, Multipurpose and Meeting Area | | 0.85 | Ornamental | 0.30 |
| Copy Room | | 0.50 | - | - |
| Corridor Area | | 0.60 | - | - |
| Dining Area | Bar/Lounge and Fine Dining | 0.55 | Ornamental | 0.30 |
| | Cafeteria/Fast Food | 0.40 | | |
| | Family and Leisure | 0.50 | | |
| Electrical, Mechanical, Telephone Rooms | | 0.40 | Detailed Task Work[7] | 0.20 |
| Exercise/Fitness Center and Gymnasium Area | | 0.50 | - | - |
| ~~Hotel Function Area~~ | | ~~0.85~~ | ~~Ornamental~~ | ~~0.30~~ |
| ~~Museum Area~~ | ~~Exhibition/Display~~ | ~~0.60~~ | ~~Accent, display and feature[3]~~ | ~~0.50~~ |
| | ~~Restoration Room~~ | ~~0.75~~ | ~~Detailed Task Work[7]~~ | ~~0.20~~ |
| ~~Financial Transaction Area~~ | | ~~0.80~~ | ~~Ornamental~~ | ~~0.30~~ |
| ~~General/Commercial & Industrial Work Area~~ | ~~Low Bay~~ | ~~0.60~~ | ~~Detailed Task Work[7]~~ | ~~0.20~~ |
| | ~~High Bay~~ | ~~0.65~~ | ~~Detailed Task Work[7]~~ | ~~0.20~~ |
| | ~~Precision~~ | ~~0.85~~ | ~~Precision Specialized Work[9]~~ | ~~0.70~~ |
| ~~Library~~ | ~~Reading Area~~ | ~~0.80~~ | ~~Ornamental~~ | ~~0.30~~ |
| | ~~Stacks Area~~ | ~~1.10~~ | ~~-~~ | ~~-~~ |
| Main Entry Lobby | | 0.85 | Ornamental | 0.30 |
| Locker Room | | 0.45 | - | - |
| Lounge, Breakroom, or Waiting Area | | 0.65 | Ornamental | 0.30 |
| Concourse and Atria Area | | 0.90 | Ornamental | 0.30 |
| Office Area | > 250 square feet | 0.65 | Portable lighting for office areas[6] | 0.20 |
| | ≤ 250 square feet | 0.70 | | |
| | Open plan office | 0.60 | | |
| Parking Garage Area | Parking Zone | 0.10 | First ATM | 100 W |
| | | | Additional ATM | 50 W each |
| | Dedicated Ramps | 0.25 | - | - |
| | Daylight Adaptation Zones[2] | 0.50 | - | - |

| | | | | |
|---|---|---|---|---|
| ~~Pharmacy Area~~ | | ~~1.10~~ | ~~Specialized Task Work[8]~~ | ~~0.35~~ |
| ~~Retail Sales Area~~ | ~~Grocery Sales~~ | ~~1.05~~ | ~~Accent, display and feature[3]~~ | ~~0.20~~ |
| | | | ~~Decorative~~ | ~~0.15~~ |
| | ~~Retail Merchandise Sales~~ | ~~1.00~~ | ~~Accent, display and feature[3]~~ | ~~0.20~~ |
| | | | ~~Decorative~~ | ~~0.15~~ |
| | ~~Fitting Room~~ | ~~0.60~~ | ~~External Illuminated Mirror[5]~~ | ~~40 W/ea~~ |
| | | | ~~Internal Illuminated Mirror[5]~~ | ~~120 W/ea~~ |
| Theater Area | Motion picture | 0.60 | Ornamental | 0.30 |
| | ~~Performance~~ | ~~1.00~~ | | |
| Kitchen/Food Preparation Area | | 0.95 | - | - |
| ~~Scientific Laboratory Area~~ | | ~~1.00~~ | ~~Specialized Task Work[8]~~ | ~~0.35~~ |
| ~~Healthcare Facility and Hospitals~~ | ~~Exam/Treatment Room~~ | ~~1.15~~ | ~~-~~ | ~~-~~ |
| | ~~Imaging Room~~ | ~~1.00~~ | ~~-~~ | ~~-~~ |
| | ~~Medical Supply Room~~ | ~~0.55~~ | ~~-~~ | ~~-~~ |
| | ~~Nursery~~ | ~~0.95~~ | ~~Tunable white or dim-to-warm[10]~~ | ~~0.10~~ |
| | ~~Nurse's Station~~ | ~~0.75~~ | ~~Tunable white or dim-to-warm[10]~~ | ~~0.10~~ |
| | ~~Operating Room~~ | ~~1.90~~ | ~~-~~ | ~~-~~ |
| | ~~Patient Room~~ | ~~0.55~~ | ~~Decorative~~ | ~~0.15~~ |
| | | | ~~Tunable white or dim-to-warm[10]~~ | ~~0.10~~ |
| | ~~Physical Therapy Room~~ | ~~0.85~~ | ~~Tunable white or dim-to-warm[10]~~ | ~~0.10~~ |
| | ~~Recovery Room~~ | ~~0.90~~ | ~~Tunable white or dim-to-warm[10]~~ | ~~0.10~~ |
| Laundry Area | | 0.45 | - | - |
| ~~Religious Worship Area~~ | | ~~0.95~~ | ~~Ornamental~~ | ~~0.30~~ |
| Restrooms | | 0.65 | Accent, display and feature[3] | 0.20 |
| | | | Decorative[4] | 0.15 |
| ~~Transportation Function~~ | ~~Baggage Area~~ | ~~0.40~~ | ~~-~~ | ~~-~~ |
| | ~~Ticketing Area~~ | ~~0.45~~ | ~~Accent, display and feature[3]~~ | ~~0.20~~ |
| ~~Sports Arena – Playing Area~~ | ~~Class I Facility[13]~~ | ~~2.25~~ | ~~-~~ | ~~-~~ |
| | ~~Class II Facility[13]~~ | ~~1.45~~ | ~~-~~ | ~~-~~ |
| | ~~Class III Facility[13]~~ | ~~1.10~~ | ~~-~~ | ~~-~~ |
| | ~~Class IV Facility[13]~~ | ~~0.75~~ | ~~-~~ | ~~-~~ |
| Stairwell | | 0.50 | Accent, display and feature[3] | 0.20 |
| | | | Decorative[4] | 0.15 |
| Videoconferencing Studio | | 0.90 | Videoconferencing | 1.00 |
| All other | | 0.40 | - | - |
| Aging Eye/Low-vision[11] | Main Entry Lobby | 0.85 | Ornamental | 0.30 |
| | | | Transition Lighting OFF at night[12] | 0.95 |

| | | | | |
|---|---|---|---|---|
| | Stairwell | 0.80 | - | - |
| | Corridor Area | 0.80 | Decorative[4] | 0.15 |
| | Lounge/Waiting Area | 0.75 | Ornamental | 0.30 |
| | Multipurpose Room | 0.95 | Ornamental | 0.30 |
| | ~~Religious Worship Area~~ | ~~1.00~~ | ~~Ornamental~~ | ~~0.30~~ |
| | Dining | 0.80 | Ornamental | 0.30 |
| | Restroom | 0.80 | Accent, display and feature[3] | 0.20 |

Footnotes for this table are listed below.

1. White board or chalk board. – Directional lighting dedicated to a white board or chalk board.

~~2. Daylight Adaptation Zones shall be no longer than 66 feet from the entrance to the parking garage.~~

3. Accent, display and feature lighting – luminaires shall be adjustable or directional.

4. Decorative lighting – primary function shall be decorative and not to provide general lighting.

5. Illuminated mirrors. Lighting shall be dedicated to the mirror.

6. Portable lighting in office areas includes under shelf or furniture-mounted supplemental task lighting qualifies when controlled by a time clock or an occupancy sensor.

7. Detailed task work – Lighting provides high level of visual acuity required for activities with close attention to small elements and/or extreme close up work.

~~8. Specialized task work – Lighting provides for small-scale, cognitive or fast performance visual tasks; lighting required for operating specialized equipment associated with pharmaceutical/laboratorial activities.~~

~~9. Precision specialized work – Lighting for work performed within a commercial or industrial environment that entails working with low contrast, finely detailed, or fast moving objects.~~

~~10. Tunable white luminaires capable of color change greater than or equal to 2000K CCT, or dim-to-warm luminaires capable of color change greater than or equal to 500K CCT, connected to controls that allows color changing of the luminaires.~~

11. Aging Eye/Low-vision areas can be documented as being designed to comply with the light levels in ANSI/IES RP-28 and are or will be licensed by local or state authorities for either senior long-term care, adult day care, senior support, and/or people with special visual needs.

12. Transition lighting OFF at night. Lighting power controlled by astronomical time clock or other control to shut off lighting at night. Additional LPD only applies to area within 30 feet of an exit. Not applicable to lighting in daylit zones.

~~13. Class I Facility is used for competition play for 5000 or more spectators. Class II Facility is used for competition play for up to 5000 spectators. Class III Facility is used for competition play for up to 2000 spectators. Class IV Facility is normally used for recreational play and there is limited or no provision for spectators.~~

*TABLE ~~140.6-D~~170.2-K TAILORED METHOD LIGHTING POWER ALLOWANCES*

| 1 | 2 | 3 | ~~4~~ | 5 |
|---|---|---|---|---|
| **Primary Function Area** | **General Illumination Level (Lux)** | **Wall Display Lighting Power Density (W/ft)** | ~~**Allowed Combined Floor Display Power and Task Lighting Power Density (W/ft²)**~~ | **Allowed Ornamental/ Special Effect Lighting Power Density (W/ft²)** |
| ~~Auditorium Area~~ | ~~300~~ | ~~3.00~~ | ~~0.20~~ | ~~0.40~~ |
| ~~Convention,~~ Conference, Multipurpose, and Meeting Center Areas | 300 | 2.00 | ~~0.35~~ | 0.40 |
| Dining Areas | 200 | 1.25 | ~~0.50~~ | 0.40 |
| ~~Exhibit, Museum Areas~~ | ~~150~~ | ~~11.50~~ | ~~0.80~~ | ~~0.40~~ |
| ~~Hotel Area:~~ | | | | |
| ~~Ballroom/Events~~ | ~~400~~ | ~~1.80~~ | ~~0.12~~ | ~~0.40~~ |
| ~~Lobby~~ | ~~200~~ | ~~3.50~~ | ~~0.20~~ | ~~0.40~~ |
| Main entry lobby | 200 | 3.50 | ~~0.20~~ | 0.40 |
| ~~Religious Worship Area~~ | ~~300~~ | ~~1.30~~ | ~~0.40~~ | ~~0.40~~ |
| ~~Retail Sales~~ | | | | |
| ~~Grocery~~ | ~~600~~ | ~~6.80~~ | ~~0.70~~ | ~~0.40~~ |
| ~~Merchandise Sales, and Showroom Areas~~ | ~~500~~ | ~~11.80~~ | ~~0.80~~ | ~~0.40~~ |
| ~~Theater Area:~~ | | | | |
| ~~Motion picture~~ | ~~200~~ | ~~2.00~~ | ~~0.20~~ | ~~0.40~~ |
| ~~Performance Arts~~ | ~~200~~ | ~~7.50~~ | ~~0.20~~ | ~~0.40~~ |

*TABLE ~~140.6-E~~170.2-L TAILORED WALL AND FLOOR DISPLAY MOUNTING HEIGHT ADJUSTMENT FACTORSFACTORS*

| **Height in feet above finished floor and bottom of luminaire(s)** | ~~**Floor Display or**~~ **Wall Display Mounting Height Adjustment Factor** |
|---|---|
| < 10’-7” | 1.00 |
| 10’-7” to 14’-0” | 0.85 |
| >14’-0” to 18’-0” | 0.75 |
| > 18’-0” | 0.70 |

*TABLE ~~140.6-F~~170.2-M ROOM CAVITY RATIO (RCR) EQUATIONS*

| |
|---|
| Determine the Room Cavity Ratio for TABLE ~~140.6-G~~170.2-N using one of the following equations. |
| Room cavity ratio for rectangular rooms $$RCR = \frac{5 \times H \times (L + W)}{L \times W}$$ |
| Room cavity ratio for irregular-shaped rooms $$RCR = \frac{2.5 \times H \times P}{A}$$ |
| Where: L =Length of room; W = Width of room; H =Vertical distance from the work plane to the centerline of the lighting fixture; P = Perimeter of room, and A = Area of room |

*TABLE ~~140.6-G~~170.2-N TAILORED METHOD GENERAL LIGHTING POWER ALLOWED – BY ILLUMANCE AND ROOM CAVITY RATIO*

| | General Lighting Power Density (W/ft²) for the following RCR values[b]values[b] | | | |
|---|---|---|---|---|
| **General Illuminance Level (lux)[a]** | **RCR ≤ 2.0** | **RCR > 2.0 and ≤ 3.5** | **RCR > 3.5 and ≤ 7.0** | **RCR > 7.0** |
| 150 | 0.40 | 0.45 | 0.60 | 00.75 |
| 200 | 0.45 | 0.55 | 0.75 | 1.00 |
| 300 | 0.65 | 0.80 | 1.00 | 1.40 |
| 400 | 0.75 | 0.95 | 1.25 | 1.50 |
| 500 | 0.90 | 1.05 | 1.45 | 1.85 |
| 600 | 1.08 | 1.24 | 1.64 | 2.38 |

[a] Illuminance values from Column 2 of TABLE ~~140.6-D~~170.2-K.
[b] RCR values are calculated using applicable equations in TABLE ~~140.6-F~~170.2-M.

2. **Outdoor Lighting.**

A. A~~n~~ multifamily or mixed occupancy outdoor lighting installation complies with this section if it meets the requirements in Subsections ~~(b)~~B and ~~(c)~~C, and the actual outdoor lighting power installed is no greater than the allowed outdoor lighting power calculated under Subsection ~~(d)~~D. The allowed outdoor lighting shall be calculated according to Outdoor Lighting Zone in Title 24, Part 1, Section 10-114.

**EXCEPTIONS to Section ~~140.7(a)~~170.2(e)2A:** When more than 50 percent of the light from a luminaire falls within one or more of the following applications, the lighting power for that luminaire shall be exempt from Section ~~140.7~~170.2(e)2~~:~~

i. Temporary outdoor lighting.

ii. Lighting required and regulated by the Federal Aviation Administration, and the Coast Guard.

iii. Lighting for public streets, roadways, highways, and traffic signage lighting, including lighting for driveway entrances occurring in the public right-of-way owned or maintained by the local municipality or utility.

iv. Lighting for sports and athletic fields, and children's playgrounds.

~~v. Lighting for industrial sites, including but not limited to, rail yards, maritime shipyards and docks, piers and marinas, chemical and petroleum processing plants, and aviation facilities.~~

vi. Lighting of public monuments.

vii. Lighting of signs complying with the requirements of Sections ~~130.3~~160.5(d) and 140.8.

viii. Lighting of stairs, wheelchair elevator lifts for American with Disabilities Act (ADA) compliance, and ramps that are other than parking garage ramps.

ix. Landscape lighting.

~~x. In theme parks: outdoor lighting only for themes and special effects.~~

xi. Lighting for outdoor theatrical and other outdoor live performances, provided that these lighting systems are additions to area lighting systems and are controlled by a multiscene or theatrical cross-fade control station accessible only to authorized operators.

xii. Outdoor lighting systems for qualified historic buildings, as defined in the California Historic Building Code (Title 24, Part 8), if they consist solely of historic lighting components or replicas of historic lighting components. If lighting systems for qualified historic buildings contain some historic lighting components or replicas of historic components, combined with other lighting components, only those historic or historic replica components are exempt. All other outdoor lighting systems for qualified historic buildings shall comply with Section ~~140.7~~170.2(e)2.

B. **Outdoor Lighting Power Trade-offs.** Outdoor lighting power trade-offs shall be determined as follows:

i. Allowed lighting power determined according to Section ~~140.7(d)1~~ 170.2(e)2Di for general hardscape lighting allowance may be traded to specific applications in Section ~~140.7(d)2~~ 170.2(e)2Dii, provided the hardscape area from which the lighting power is traded continues to be illuminated in accordance with Section ~~140.7(d)1A~~170.2(e)2Dia.

ii. Allowed lighting power determined according to Section ~~140.7(d)2~~ 170.2(e)2Dii for additional lighting power allowances for specific applications shall not be traded between specific applications, or to hardscape lighting in Section ~~140.7(d)1~~ 170.2(e)2Di.

iii. Trading off lighting power allowances between outdoor and indoor areas shall not be permitted.

C. **Calculation of Actual Lighting Power.** The wattage of outdoor luminaires shall be determined in accordance with Section ~~130.0(c)~~160.5(c)1.

D. **Calculation of Allowed Lighting Power.** The allowed lighting power shall be the combined total of the sum of the general hardscape lighting allowance determined in accordance with Section ~~140.7(d)1~~ 170.2(e)2Di, and the sum of the additional lighting power allowance for specific applications determined in accordance with Section ~~140.7(d)2~~ 170.2(e)2Dii.

i. **General Hardscape Lighting Allowance**. Determine the general hardscape lighting power allowances as follows:

a. The general hardscape area of a site shall include parking lot(s), roadway(s), driveway(s), sidewalk(s), walkway(s), bikeway(s), plaza(s), bridge(s), tunnel(s), and other improved area(s) that are illuminated. Roadway(s) that are illuminated by a lighting system owned or operated by the local municipality or utility shall not be included in the area calculations. In plan view of the site, determine the illuminated hardscape area, which is defined as any hardscape area that is within a square pattern around each luminaire or pole that is ten times the luminaire mounting height with the luminaire in the middle of the pattern, less any areas that are within a building, beyond the hardscape area, beyond property lines, or obstructed by a structure. The illuminated hardscape area shall include portions of planters and landscaped areas that are within the lighting application and are less than or equal to 10 feet wide in the short dimensions and are enclosed by hardscape or other improvement on at least three sides. Multiply the illuminated hardscape area by the Area Wattage Allowance (AWA) from TABLE ~~140.7-A~~ 170.2-O for the appropriate Lighting Zone.

b. Determine the perimeter length of the general hardscape area. The total perimeter shall not include portions of hardscape that is not illuminated according to Section 140.7(d)1A. Multiply the hardscape perimeter by the Linear Wattage Allowance (LWA) for hardscape from Table 140.7-A for the appropriate lighting zone. The perimeter length for hardscape around landscaped areas and permanent planters shall be determined as follows:

I. Landscaped areas completely enclosed within the hardscape area, and which have a width or length less than 10 feet wide, shall not be added to the hardscape perimeter length.

II. Landscaped areas completely enclosed within the hardscape area, and which width or length is a minimum of 10 feet wide, the perimeter of the landscaped areas or permanent planter shall be added to the hardscape perimeter length.

III. Landscaped edges that are not abutting the hardscape shall not be added to the hardscape perimeter length.

b. Determine the Initial Wattage Allowance (IWA) for general hardscape lighting from TABLE ~~140.7-A~~ 170.2-O for the appropriate lighting zone. The hardscape area shall be permitted one IWA per site.

c. The general hardscape lighting allowance shall be the sum of the allowed watts determined from ~~(A), (B) and (C)~~a and b above.

ii. **Additional Lighting Power Allowance for Specific Applications.** Additional lighting power for specific applications shall be the smaller of the additional lighting allowances for specific applications determined in accordance with TABLE 140.7-B170.2-P for the appropriate lighting zone, or the actual installed lighting power meeting the requirements for the allowance.

*TABLE ~~140.7-A~~ 170.2-O GENERAL HARDSCAPE MULTIFAMILY LIGHTING POWER ALLOWANCE*

<table>
<tr><th rowspan="2">Type of Power Allowance</th><th>Lighting Zone 0[3]</th><th>Lighting Zone 1[3]</th><th colspan="2">Lighting Zone 2[3]</th><th colspan="2">Lighting Zone 3[3]</th><th>Lighting Zone 4[3]</th></tr>
<tr><td>Asphalt/Concrete</td><td>Asphalt/Concrete</td><td>Asphalt</td><td>Concrete[2]</td><td>Asphalt</td><td>Concrete[2]</td><td>Asphalt/Concrete</td></tr>
<tr><td>Area Wattage Allowance (AWA)</td><td rowspan="3">No allowance[1]</td><td>0.018 W/ft²</td><td>0.023 W/ft²</td><td>0.025 W/ft²</td><td>0.025 W/ft²</td><td>0.03 W/ft²</td><td>0.03 W/ft²</td></tr>
<tr><td>Linear Wattage Allowance (LWA)</td><td>0.15 W/lf</td><td>0.17 W/lf</td><td>0.4 W/lf</td><td>0.25 W/lf</td><td>0.4 W/lf</td><td>0.35 W/lf</td></tr>
<tr><td>Initial Wattage Allowance (IWA)</td><td>180 W</td><td>250 W</td><td>250 W</td><td>350 W</td><td>350 W</td><td>400 W</td></tr>
</table>

[1]Continuous lighting is explicitly prohibited in Lighting Zone 0. A single luminaire of 15 Watts or less may be installed at an entrance to a parking area, trail head, fee payment kiosk, outhouse, or toilet facility, as required to provide safe navigation of the site infrastructure. Luminaires installed shall meet the maximum zonal lumen limits as specified in Section ~~130.2(b)~~160.5(c)1.

[2]Where greater than 50% of the paved surface of a parking lot is finished with concrete. This does not extend beyond the parking lot, and does not include any other General Hardscape areas.

[3]Narrow band spectrum light sources with a dominant peak wavelength greater than 580 nm – as mandated by local, state, or federal agencies to minimize the impact on local, active professional astronomy or nocturnal habitat of specific local fauna – shall be allowed a 2.0 lighting power allowance multiplier.

*TABLE ~~140.7-B~~ 170.2-P ADDITIONAL MULTIFAMILY LIGHTING POWER ALLOWANCE FOR SPECIFIC APPLICATIONS*

*All area and distance measurements in plan view unless otherwise noted.*

| Lighting Application | Lighting Zone 0 | Lighting Zone 1 | Lighting Zone 2 | Lighting Zone 3 | Lighting Zone 4 |
|---|---|---|---|---|---|
| **WATTAGE ALLOWANCE PER APPLICATION. Use all that apply as appropriate.** | | | | | |
| **Building Entrances or Exits.** Allowance per door. Luminaires qualifying for this allowance shall be within 20 feet of the door. | Not applicable | 9 watts | 15 watts | 19 watts | 21 watts |
| **Primary Entrances to Senior Care Facilities, ~~Police Stations, Healthcare Facilities, Fire Stations, and Emergency Vehicle Facilities.~~** Allowance per primary entrance(s) only. Primary entrances shall provide access for the general public and shall not be used exclusively for staff or service personnel. This allowance shall be in addition to the building entrance or exit allowance above. Luminaires qualifying for this allowance shall be within 100 feet of the primary entrance. | Not applicable | 20 watts | 40 watts | 57 watts | 60 watts |
| ~~**Drive Up Windows.** Allowance per customer service location. Luminaires qualifying for this allowance shall be within 2 mounting heights of the sill of the window.~~ | ~~Not applicable~~ | ~~16 watts~~ | ~~30 watts~~ | ~~50 watts~~ | ~~75 watts~~ |
| ~~**Vehicle Service Station Uncovered Fuel Dispenser.** Allowance per fueling dispenser. Luminaires qualifying for this allowance shall be within 2 mounting heights of the dispenser.~~ | ~~Not applicable~~ | ~~55 watts~~ | ~~77 watts~~ | ~~81 watts~~ | ~~135 watts~~ |
| **ATM Machine Lighting.** Allowance per ATM machine. Luminaires qualifying for this allowance shall be within 50 feet of the dispenser. | Not applicable | 100 watts for first ATM machine, 35 watts for each additional ATM machine. | | | |
| ~~**WATTAGE ALLOWANCE PER UNIT LENGTH (w/linear ft). May be used for one or two frontage side(s) per site.**~~ | | | | | |
| ~~**Outdoor Sales Frontage.** Allowance for frontage immediately adjacent to the principal viewing location(s) and unobstructed for its viewing length. A corner sales lot may include two adjacent sides provided that a different principal viewing location exists for each side. Luminaires qualifying for this allowance shall be located between the principal viewing location and the frontage outdoor sales area.~~ | ~~Not applicable~~ | ~~No Allowance~~ | ~~11 W/linear ft~~ | ~~19 W/linear ft~~ | ~~25 W/linear ft~~ |
| **WATTAGE ALLOWANCE PER HARDSCAPE AREA (W/ft$^2$). May be used for any illuminated hardscape area on the site.** | | | | | |
| **Hardscape Ornamental Lighting.** Allowance for the total site illuminated hardscape area. Luminaires qualifying for this allowance shall be rated for 100 watts or less as determined in accordance with Section ~~130.0(d),~~ 160.5(b)2and shall be post-top luminaires, lanterns, pendant luminaires, or chandeliers. | Not applicable | No Allowance | 0.007 W/ft$^2$ | 0.013 W/ft$^2$ | 0.019 W/ft$^2$ |
| **WATTAGE ALLOWANCE PER SPECIFIC AREA (W/ft$^2$). Use as appropriate provided that none of the following specific applications shall be used for the same area.** | | | | | |
| **Building Facades.** Only areas of building façade that are illuminated shall qualify for this allowance. Luminaires qualifying for this allowance shall be aimed at the façade and shall be capable of illuminating it without obstruction or interference by permanent building features or other objects. | Not applicable | No Allowance | 0.100 W/ft$^2$ | 0.170 W/ft$^2$ | 0.225 W/ft$^2$ |
| ~~**Outdoor Sales Lots.** Allowance for uncovered sales lots used exclusively for the display of vehicles or other merchandise for sale. Driveways, parking lots or other non sales areas shall be considered hardscape areas even if these areas are completely surrounded by sales lot on all sides. Luminaires qualifying for this allowance shall be within 5 mounting heights of the sales lot area.~~ | ~~Not applicable~~ | ~~0.060 W/ft²~~ | ~~0.210 W/ft²~~ | ~~0.280 W/ft²~~ | ~~0.485 W/ft²~~ |
| ~~**Vehicle Service Station Hardscape.** Allowance for the total illuminated hardscape area less area of buildings, under canopies, off property, or obstructed by signs or structures. Luminaires qualifying for this allowance shall be illuminating the hardscape area and shall not be within a building, below a canopy, beyond property lines, or obstructed by a sign or other structure.~~ | ~~Not applicable~~ | ~~0.006 W/ft²~~ | ~~0.068 W/ft²~~ | ~~0.138 W/ft²~~ | ~~0.200 W/ft²~~ |
| ~~**Vehicle Service Station Canopies.** Allowance for the total area within the drip line of the canopy. Luminaires qualifying for this allowance shall be located under the canopy.~~ | ~~Not applicable~~ | ~~0.220 W/ft²~~ | ~~0.430 W/ft²~~ | ~~0.580 W/ft²~~ | ~~1.010 W/ft²~~ |
| ~~**Sales Canopies.** Allowance for the total area within the drip line of the canopy. Luminaires qualifying for this allowance shall be located under the canopy.~~ | ~~Not applicable~~ | ~~No Allowance~~ | ~~0.470 W/ft²~~ | ~~0.622 W/ft²~~ | ~~0.740 W/ft²~~ |

| | | | | | |
|---|---|---|---|---|---|
| ~~Non-sales~~ **Canopies and Tunnels.** Allowance for the total area within the drip line of the canopy or inside the tunnel. Luminaires qualifying for this allowance shall be located under the canopy or tunnel. | Not applicable | 0.057 W/ft² | 0.137 W/ft² | 0.270 W/ft² | 0.370 W/ft² |
| **Guard Stations.** Allowance up to 1,000 square feet per vehicle lane. Guard stations provide access to secure areas controlled by security personnel who stop and may inspect vehicles and vehicle occupants, including identification, documentation, vehicle license plates, and vehicle contents. Qualifying luminaires shall be within 2 mounting heights of a vehicle lane or the guardhouse. | Not applicable | 0.081 W/ft² | 0.176 W/ft² | 0.325 W/ft² | 0.425 W/ft² |
| **Student Pick-up/Drop-off zone.** Allowance for the area of the student pick-up/drop-off zone, with or without canopy, for preschool through 12th grade school campuses. A student pick-up/drop off zone is a curbside, controlled traffic area on a school campus where students are picked-up and dropped off from vehicles. The allowed area shall be the smaller of the actual width or 25 feet, times the smaller of the actual length or 250 feet. Qualifying luminaires shall be within 2 mounting heights of the student pick-up/drop-off zone. | Not applicable | No Allowance | 0.056 W/ft² | 0.200 W/ft² | No Allowance |
| **Outdoor Dining.** Allowance for the total illuminated hardscape of outdoor dining. Outdoor dining areas are hardscape areas used to serve and consume food and beverages. Qualifying luminaires shall be within 2 mounting heights of the hardscape area of outdoor dining. | Not applicable | 0.004 W/ft² | 0.030 W/ft² | 0.050 W/ft² | 0.075 W/ft² |
| **Special Security Lighting for Retail Parking and Pedestrian Hardscape.** This additional allowance is for illuminated retail parking and pedestrian hardscape identified as having special security needs. This allowance shall be in addition to the building entrance or exit allowance. | Not applicable | 0.004 W/ft² | 0.005 W/ft² | 0.010 W/ft² | No Allowance |

(f) **Photovoltaic Requirements**. All ~~low-rise residential~~ multifamily buildings up to three habitable stories shall have a photovoltaic (PV) system meeting the minimum qualification requirements as specified in Joint Appendix JA11, with annual electrical output equal to or greater than the ~~dwelling's~~ buildings annual electrical usage as determined by Equation ~~150.1-C~~170.2-A:

*EQUATION ~~150.1-C~~170.2-A ANNUAL PHOTOVOLTAIC ELECTRICAL OUTPUT*

$$kW_{PV} = (CFA \text{ x } A)/1000 + (NDwell \text{ x } B)$$

WHERE:

$kW_{PV}$ = kWdc size of the PV system

CFA = Conditioned floor area

NDwell = Number of dwelling units

A = Adjustment factor from Table ~~150.1-C~~170.2-Q

B = Dwelling adjustment factor from Table ~~150.1-C~~170.2-Q

**EXCEPTION 1 to Section ~~150.1(c)14~~170.2(f):** No PV is required if the effective annual solar access is restricted to less than 80 contiguous square feet by shading from existing permanent natural or manmade barriers external to the ~~dwelling~~building, including but not limited to trees, hills, and adjacent structures. The effective annual solar access shall be 70 percent or greater of the output of an unshaded PV array on an annual basis.

**EXCEPTION 2 to Section ~~150.1(c)14~~170.2(f):** In climate zone 15, the PV size shall be the smaller of a size that can be accommodated by the effective annual solar access or a PV size required by the Equation ~~150.1-C~~170.2-A, but no less than 1.5 Watt DC per square foot of conditioned floor area.

**EXCEPTION 3 to Section 150.1(c)14:** In all climate zones, for ~~dwelling units~~ multifamily buildings with two habitable stories, the PV size shall be the smaller of a size that can be accommodated by the effective annual solar access or a PV size required by the Equation 150.1-C, but no less than 1.0 Watt DC per square foot of conditioned floor area

**EXCEPTION 4 to Section 150.1(c)14:** In all climate zones, for ~~low-rise residential~~ multifamily buildings ~~dwellings with three habitable stories and single family dwellings~~ with three ~~or more~~ habitable stories, the PV size shall be the smaller of a size that can be accommodated by the effective annual solar access or a PV size required by the Equation 150.1-C, but no less than 0.8 Watt DC per square foot of conditioned floor area.

~~**EXCEPTION 5 to Section 150.1(c)14:** For a dwelling unit plan that is approved by the planning department prior to January 1, 2020 with available solar ready zone between 80 and 200 square feet, the PV size is limited to the lesser of the size that can be accommodated by the effective annual solar access or a size that is required by the Equation 150.1-C.~~

**EXCEPTION 6 to Section ~~150.1(c)14~~170.2(f):** PV sizes from Equation ~~150.1-C~~170.2-A may be reduced by 25 percent if installed in conjunction with a battery storage system. The battery storage system shall meet the qualification requirements specified in Joint Appendix JA12 and have a minimum capacity of 7.5 kWh.

*Table ~~150.1-C~~ 170.2-Q– CFA and Dwelling adjustment Factors*

| Climate Zone | A - CFA | B - Dwelling Units |
|---|---|---|
| 1 | 0.793 | 1.27 |
| 2 | 0.621 | 1.22 |
| 3 | 0.628 | 1.12 |
| 4 | 0.586 | 1.21 |
| 5 | 0.585 | 1.06 |
| 6 | 0.594 | 1.23 |
| 7 | 0.572 | 1.15 |
| 8 | 0.586 | 1.37 |
| 9 | 0.613 | 1.36 |
| 10 | 0.627 | 1.41 |
| 11 | 0.836 | 1.44 |
| 12 | 0.613 | 1.40 |
| 13 | 0.894 | 1.51 |
| 14 | 0.741 | 1.26 |
| 15 | 1.56 | 1.47 |
| 16 | 0.59 | 1.22 |

# SUBCHAPTER 12
# MULTIFAMILY BUILDINGS - ADDITIONS, ALTERATIONS, AND REPAIRS TO EXISTING MULTIFAMILY BUILDINGS

## SECTION 180.0 – GENERAL

Additions, alterations, and repairs to existing ~~nonresidential, high-rise residential, and hotel/motel~~ attached dwelling units and common use areas in multifamily buildings, existing outdoor lighting for these occupancies, and internally and externally illuminated signs, shall meet the requirements specified in Sections 100.0 through 110.10, and ~~120.0~~ 160.1 through ~~130.5~~ 170.2 that are applicable to the building project, and either the performance compliance approach (energy budgets) in Section ~~141.0(a)2~~ 180.1(b) (for additions) or ~~141.0(b)3~~ 180.2(c) (for alterations), or the prescriptive compliance approach in Section ~~141.0(a)1~~180.1(a) (for additions) or ~~141.0(b)2~~ 180.2(b) (for alterations), for the Climate Zone in which the building is located. Climate zones are shown in FIGURE 100.1-A.

Covered process requirements for additions, alterations and repairs to existing ~~nonresidential, high-rise residential, and hotel/motel~~ multifamily buildings are specified in Section 141.1.

Nonresidential occupancies in mixed occupancy buildings shall comply with nonresidential requirements in Sections 120.0 through 141.1.

~~**EXCEPTION to Section 141.0:** Alterations to healthcare facilities are not required to comply with this Section.~~

**NOTE:** For alterations that change the occupancy classification of the building, the requirements specified in Section ~~141.0(b)~~180.2 apply to the occupancy after the alterations.

## SECTION 180.1 – ADDITIONS

Additions to existing ~~low-rise residential~~ multifamily buildings shall meet the requirements of Sections 110.0 through 110.9, Sections ~~150.0(a)~~ 160.0 through ~~(q)~~160.7, and either Section ~~150.2(a)1~~180.1(a) or ~~2~~(b).

(a) **Prescriptive approach.** The envelope and lighting of the addition; any newly installed space-conditioning system, electrical power distribution system, or water-heating system; any addition to an outdoor lighting system; and any new sign installed in conjunction with an indoor or outdoor addition shall meet the applicable requirements of Sections 110.0 and 160.0 through ~~120.7~~170.2~~, 120.9 through 130.5, and 140.2 through 140.9~~.

1. **Envelope.**

   A. Additions ~~that are greater than 700 square feet~~ shall meet the requirements of Section ~~150.1(c)~~170.2(a), with the following modifications:

      i. Framed Walls Extension Extensions of existing wood-framed walls may retain the dimensions of the existing walls and shall install cavity insulation of R-15 in a 2x4 framing and R-21 in a 2x6 framing.

      ii. The maximum allowed fenestration area shall be the greater of 175 square feet or 20 percent of the addition floor area, ~~and the maximum allowed west-facing fenestration area shall be the greater of 70 square feet or the requirements of Section 150.1(c).~~

      iii. When existing siding of a wood-framed wall is not being removed or replaced, cavity insulation of R-15 in a 2x4 framing and R-21 in a 2x6 framing shall be installed and continuous insulation is not required.

iv. Additions that consist of the conversion of existing spaces from unconditioned to conditioned space shall not be required to perform the air sealing part of QII when the existing air barrier is not being removed or replaced. ~~the following as part of QII:~~

~~a. Existing window and door headers shall not be required to be insulated.~~

~~b. Air sealing shall not be required when the existing air barrier is not being removed or replaced.~~

B. Additions that are 700 square feet or less shall meet the requirements of Section ~~150.1(c)~~170.2(a), , with the following modifications.

~~i.~~ Roof and ceiling insulation in an attic shall be insulated to R-38 in climate zones 1, 11-16 or R-30 in climate zones 2-10~~; and~~

ii. Radiant Barrier. Radiant barriers shall be installed in attics with exposed attic deck undersides in climate zones 2-15~~; and~~

iii. Quality Insulation Installation (QII) requirements of Section ~~150.1(c)1E~~ 170.2(a)6 do not apply.

iv. Fenestration products must meet the U-factor, RSGHC, and VT requirements of TABLE 180.2-A

~~v. Extensions of existing wood-framed walls may retain the dimensions of the existing walls and shall install cavity insulation of R-15 in a 2x4 framing and R-21 in a 2x6 framing; and~~

~~vi. When existing siding of a wood-framed wall is not being removed or replaced, cavity insulation of R-15 in a 2x4 framing and R-21 in a 2x6 framing shall be installed and continuous insulation is not required~~

~~vii. In Climate Zones 2, 4 and 6-15; the maximum allowed west-facing fenestration area shall not be greater than 60 square feet; and shall also comply with either a or b below:~~

~~a. For additions that are 700 square feet or less but greater than 400 square feet, the maximum allowed fenestration area limit is the greater of 120 square feet or 25 percent of the conditioned floor area of the addition; or~~

~~b. For additions that are 400 square feet or less, the maximum allowed fenestration area is the greater of 75 square feet or 30 percent of the conditioned floor area of the addition.~~

**EXCEPTION 1 to Section ~~150.2(a)1B~~180.1(a)1B:** Insulation in an enclosed rafter ceiling shall meet the requirements of Section ~~150.0~~ 160.1(a).

**EXCEPTION 2 to Section ~~150.2(a)1B~~180.1(a)1B:** ~~a~~Additions that increase the area of the roof by 2,000 square feet or less are exempt from the requirements of Section ~~110.10~~ 160.8

2. **Mechanical Ventilation for Indoor Air Quality.**

A. Additions to an existing dwelling unit that increase the conditioned floor area of the ~~existing dwelling unit~~ building by more than 1,000 square feet shall have mechanical ventilation airflow in accordance with Sections ~~150.0(o)1C~~160.2(b)2iii, ~~150.0(o)1E~~60.2(b)v, or ~~150.0(o)1F~~ 160.2(b)2vi as applicable. The d mechanical ventilation airflow rate shall be based on the conditioned floor area of the entire dwelling unit comprised of the existing dwelling unit conditioned floor area plus the addition conditioned floor area.

B. New dwelling units that are additions to an existing building shall have mechanical ventilation airflow provided in accordance with Sections ~~150.0(o)1C~~160.2(b)2iii, ~~150.0(o)1E~~60.2(b)v, or ~~150.0(o)1F~~ 160.2(b)2vi as applicable. The mechanical ventilation airflow rate shall be based on the conditioned floor area of the new dwelling unit.

3. **Water Heater.** When ~~a second~~ additional water heat~~er~~ing equipment is installed as part of the addition, one of the following types of water heaters shall be installed:

A. A water-heating system that meets the requirements of Section ~~150.1(c)8~~170.2(c); or

B. A water-heating system determined by the Executive Director to use no more energy than the one specified in Item ~~i~~ A above

(b) **Performance approach.** Performance calculations shall meet the requirements of Section ~~150.1(a)~~ 170.0 through ~~(c)~~170.2(a), pursuant to the applicable requirements in Items ~~A, B, and C~~1, 2, and 3 below**.**

1. **For additions alone.** The addition complies if the addition alone meets the energy budgets as specified in Section ~~150.1(b)~~170.1.

2. **Existing plus alteration plus addition.** The standard design for existing plus alteration plus addition energy use is the combination of the existing building's unaltered components to remain; existing building altered components that are the more efficient, in TDV energy, of either the existing conditions or the requirements of Section ~~150.2(b)2~~180.2(c); plus the proposed addition's energy use meeting the requirements of Section ~~150.2(a)1~~180.1(a). The proposed design energy use is the combination of the existing building's unaltered components to remain and the altered components' energy features, plus the proposed energy features of the addition.

   **EXCEPTION to Section ~~150.2(a)2B~~180.1(b)2:** Existing structures with a minimum R-11 insulation in framed walls showing compliance with Section ~~150.2(a)2~~ 180.1(b)are exempt from showing compliance with Section ~~150.0(c).~~160.1(b).

# SECTION 180.2 – ALTERATIONS

Alterations to components of existing ~~nonresidential, high-rise residential, hotel/motel, or relocatable public school~~ multifamily buildings, including alterations made in conjunction with a change in building occupancy to a ~~nonresidential, high-rise residential, or hotel/motel~~ multifamily occupancy shall meet item ~~1~~(a), and either Item ~~2~~(b) or ~~3~~(c) below:

**EXCEPTION 1 to Section ~~141.0(b)~~180.2:** When heating, cooling or service water heating for an alteration are provided by expanding existing systems, the existing systems and equipment need not comply with Sections 110.0 through 110.10, ~~through 120.9~~160.0 through 160.7, and Section ~~140.4~~170.2(c) or ~~140.5~~170.2(d).

**EXCEPTION 2 to Section ~~141.0(b)~~180.2:** When existing heating, cooling or service water heating systems or components are moved within a building, the existing systems or components need not comply with Sections 110.0 through 110.10, ~~through 120.9~~160.0 through 160.7, and Section ~~140.4~~170.2(c) or ~~140.5~~170.2(d).

**EXCEPTION 3 to Section ~~141.0(b)~~180.2:** Where an existing system with electric reheat is expanded when adding variable air volume (VAV) boxes to serve an alteration, total electric reheat capacity may be expanded not to exceed 20 percent of the existing installed electric capacity in any one permit and the system need not comply Section ~~140.4(g)~~170.2(b)4E. Additional electric reheat capacity in excess of 20 percent may be added subject to the requirements of the Section ~~140.4(g)~~170.2(b)4E.

**EXCEPTION 4 to Section ~~141.0(b)~~180.2:** The requirements of Section ~~120.2(i)~~160.3(a)2H shall not apply to alterations of space-conditioning systems or components.

~~**NOTE:** Relocation or moving of a relocatable public school building is not, by itself, considered an alteration for the purposes of Title 24, Part 6.~~

(a) **Mandatory Requirements.** Altered components in a ~~nonresidential, high-rise residential, or hotel/motel~~ multifamily building shall meet the minimum requirements in this Section.

~~1. **Roof/Ceiling Insulation.** The opaque portions of the roof/ceiling that separate conditioned spaces from unconditioned spaces or ambient air shall meet the requirements of Section 141.0(b)2Biii180.2(b)1B.~~

~~2. **Wall Insulation.** For the altered opaque portion of walls separating conditioned spaces from unconditioned spaces or ambient air shall meet the applicable requirements of Items 1 through 4 below: Section 160.1(b).~~

~~A. **Metal Building.** A minimum of R-13 insulation between framing members, or the weighted average U-factor of the wall assembly shall not exceed U-0.113.~~

~~B. **Metal Framed.** A minimum of R-13 insulation between framing members, or the weighted average U-factor of the wall assembly shall not exceed U-0.217.~~

~~C. **Wood Framed and Others.** A minimum of R-11 insulation between framing members, or the weighted average U-factor of the wall assembly shall not exceed U-0.110.~~

~~D. **Spandrel Panels and Curtain Walls.** A minimum of R-4, or the weighted average U-factor of the wall assembly shall not exceed U-0.280.~~

~~**EXCEPTION to Section 141.0(b)1B:** Light and heavy mass walls.~~

3. **Floor Insulation.** For the altered portion of raised floors that separate conditioned spaces from unconditioned spaces or ambient air shall meet the applicable requirements of Items ~~1~~A through ~~3~~C below:

A. **Raised Framed Floors.** A minimum of R-11 insulation between framing members, or the weighted average U-factor of the floor assembly shall not exceed the U-factor of U-0.071.

B. **Raised Mass Floors.** A minimum of R-6 insulation, or the weighted average U-factor of the floor assembly shall not exceed the U-factor of U-0.111.

~~C. **Raised Mass Floors in Other Occupancies.** No minimum U-factor requirement.~~

(b) **Prescriptive approach.** The altered component and any newly installed equipment serving the alteration shall meet the applicable requirements of Sections 110.0 through 110.9 and all applicable requirements of Section ~~150.0(a)~~ 160.0 through 160.3(b)J, ~~(l); 150.0(m) through 150.0 (m)10~~, ~~Section 150.0(o) through (q)~~ and 160.5; and

1. **Envelope -**

A. **Roofing Products**. Existing roofs being replaced, recovered or recoated, of a ~~nonresidential, high-rise residential and hotels/motels~~ multifamily building shall meet the requirements of Section 110.8(i). Roofs with more than 50 percent of the roof area or more than 2,000 square feet of roof, whichever is less, being altered the requirements of i through iii below apply:

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

ii. Low-sloped roofs in Climate Zones 13 and 15 shall have a 3-year aged solar reflectance equal or greater than 0.63 and a thermal emittance equal or greater than 0.75, or a minimum SRI of 75.

~~**EXCEPTION 1 to Section 150.2(b)1Iii:** Buildings with no ducts in the attic.~~

~~**EXCEPTION 2 to Section 150.2(b)1Iii:** The aged solar reflectance can be met by using insulation at the roof deck specified in TABLE 150.2-B.~~

iii. Steep-sloped roofs Climate Zones 2 through 15 shall have a minimum aged solar reflectance of 0.20 and a minimum thermal emittance of 0.75, or a minimum SRI of 16.

**EXCEPTION ~~3~~ 1 to Section ~~141.0(b)2Bi and ii~~180.2(b)1Aiii:** The following shall be considered equivalent to Subsection iii:

a. Air-space of 1.0 inch (25 mm) is provided between the top of the roof deck to the bottom of the roofing product; or

b. The installed roofing product has a profile ratio of rise to width of 1 to 5 for 50 percent or greater of the width of the roofing product; or

c. Existing ducts in the attic are insulated and sealed according to Section ~~150.1(c)9~~170.2(c)3B; or

d. Buildings with at least R-38 ceiling insulation; or

e. Buildings with a radiant barrier in the attic meeting the requirements of Section ~~150.1(c)2~~170.2(a)1C; or

f. Buildings that have no ducts in the attic; or

g. ~~In Climate Zones 10-15,~~ R-2or greater insulation above the roof deck.

**EXCEPTION 1 to Section ~~141.0(b)2Bi and ii~~180.2(b)1A:** Roof area covered by building integrated photovoltaic panels and building integrated solar thermal panels are not required to meet the minimum requirements for solar reflectance, thermal emittance, or SRI.

**EXCEPTION 2 to Section ~~141.0(b)2Bi and ii~~180.2(b)1A:** Roof constructions with a weight of at least 25 lb/ft² are not required to meet the minimum requirements for solar reflectance, thermal emittance, or SRI.

B. **Roof/Ceiling Insulation**.

i. **Attic Roof** Ceilings and rafter roofs in an alteration shall be insulated to achieve a weighted average U-factor not exceeding 0.054 or shall be insulated between wood-framing members with insulation resulting in an installed thermal resistance of R-19 or greater.

ii. **Non Attic Roof**. ~~For nonresidential buildings, high-rise residential buildings and hotels/motels, w~~When low-sloped roofs are exposed to the roof deck or to the roof recover boards~~, and meets Section 141.0(b)2Bia or iia~~, the exposed area shall be insulated to ~~the levels specified in TABLE 141.0-C~~ R-14 continuous insulation or a U-factor of 0.55.

**EXCEPTION to Section ~~141.0(b)2Biii~~180.2(b)1Bii**

a. Existing roofs that are insulated with at least R-7 insulation or that has a U-factor lower than 0.089 are not required to meet the R-value requirement of ~~TABLE 141.0-C.~~180.2(b)1Bi

b. If mechanical equipment is located on the roof and will not be disconnected and lifted as part of the roof replacement, insulation added may be limited to the maximum insulation thickness that will allow a height of 8 inches (203 mm) from the roof membrane surface to the top of the base flashing.

c. If adding the required insulation will reduce the base flashing height to less than 8 inches (203 mm) at penthouse or parapet walls, the insulation added may be limited to the maximum insulation thickness that will allow a height of 8 inches (203 mm) from the roof membrane surface to the top of the base flashing, provided that the conditions in Subsections i through iv apply:

I. The penthouse or parapet walls are finished with an exterior cladding material other than the roofing covering membrane material; and

II. The penthouse or parapet walls have exterior cladding material that must be removed to install the new roof covering membrane to maintain a base flashing height of 8 inches (203 mm); and

~~III. For nonresidential buildings, the ratio of the replaced roof area to the linear dimension of affected penthouse or parapet walls shall be less than 25 square feet per linear foot for Climate Zones 2, and 10 through 16, and less than 100 square feet per linear foot for Climate Zones 1, and 3 through 9; and~~

III. ~~For high-rise residential buildings, hotels or motels,~~ T~~t~~he ratio of the replaced roof area to the linear dimension of affected penthouse or parapet walls shall be less than 25 square feet per linear foot for all Climate Zones.

d. Tapered insulation may be used which has a thermal resistance less than ~~that prescribed in TABLE 141.0-C~~ R-14 at the drains and other low points, provided that the thickness of insulation is increased at the high points of the roof so that the average thermal resistance equals or exceeds ~~the value that is specified in TABLE 141.0-C~~ R-14.

C. Fenestration alterations other than repair ~~and those subject to Section 141.0(b)2~~ shall meet the requirements below:

**NOTE:** Glass replaced in an existing sash and frame or sashes replaced in an existing frame are considered repairs. In these cases, Section ~~141.0(e)~~ 180.2(b) requires that the replacement be at least equivalent to the original in performance.

i. ~~**Fenestration replacement**. New manufactured f~~Fenestration products installed to replace existing fenestration products of the same total area shall meet the U-factor, ~~and~~ RSHGC ~~Solar Heat Gain Coefficient~~, and VT requirements of ~~Sections 150.1(c)3A, and 150.1(c)4~~ TABLE 180.2-A.

**EXCEPTION 1 to Section ~~141.0(b)2Ai~~180.2(b)1Ci:** In an alteration, where 150 square feet or less of the entire building's vertical fenestration is replaced, RSHGC and VT requirements of TABLE ~~141.0-A~~ 180.2-A shall not apply.

ii. Alterations that add vertical fenestration and skylight area shall meet the total fenestration area requirements of section 170.2(a) and the ~~and west facing fenestration area~~ U-factor, ~~and~~ RSHGC ~~Solar Heat Gain Coefficient~~, and VT requirements of ~~Section 150.1(c) and~~ TABLE ~~150.1-A or B~~ 180.2-A.

**EXCEPTION 1 to Section ~~150.2(b)1A~~180.2(b)1Cii:** Alterations that add fenestration area of up to ~~75~~ 50 square feet shall not be required to meet the total fenestration area ~~and west-facing fenestration area~~ requirements of Sections ~~150.1(c)3B and C~~170.2(a), nor the U-factor, RSHGC, and VT requirements of TABLE 180.2-A.

**EXCEPTION 2 to Section ~~150.2(b)1A~~180.2(b)1Cii:** Alterations that add up to 16 square feet of new skylight area per dwelling unit with a maximum U-factor of 0.55 and a maximum RSHGC of 0.30 area shall not be required to meet the total fenestration area ~~and west-facing fenestration area~~ requirements of Sections ~~150.1(c)3B and C~~170.2(a)3.

*Table ~~141.0-A~~ 180.2-A Altered Vertical Fenestration Maximum U-Factor and Maximum ~~R~~SHGC*

| **Climate Zone** | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ~~**U-factor**~~ | ~~0.47~~ | ~~0.47~~ | ~~0.58~~ | ~~0.47~~ | ~~0.58~~ | ~~0.47~~ | ~~0.47~~ | ~~0.47~~ | ~~0.47~~ | ~~0.47~~ | ~~0.47~~ | ~~0.47~~ | ~~0.47~~ | ~~0.47~~ | ~~0.47~~ | ~~0.47~~ |
| | ~~**RSHGC**~~ | ~~0.41~~ | ~~0.31~~ | ~~0.41~~ | ~~0.31~~ | ~~0.41~~ | ~~0.31~~ | ~~0.31~~ | ~~0.31~~ | ~~0.31~~ | ~~0.31~~ | ~~0.31~~ | ~~0.31~~ | ~~0.31~~ | ~~0.31~~ | ~~0.31~~ | ~~0.41~~ |
| | ~~**VT**~~ | ~~See TABLE 140.3-B, C, and D for all Climate Zones~~ | | | | | | | | | | | | | | | |
| **Curtainwall/ Storefront** | **U-factor** | 0.38 | 0.38 | | | | | | | | | | | | | | |
| | **RSHGC** | 0.35 | 0.25 | | | | | | | | | | | | | | |
| | **VT** | 0.46 | 0.46 | | | | | | | | | | | | | | |
| **Fixed Windows** | **U-factor** | 0.30 | 0.30 | | | | | | | | | | | | | | |
| | **RSHGC** | 0.35 | 0.24 | | | | | | | | | | | | | | |
| | **VT** | NR | NR | | | | | | | | | | | | | | |
| **Operable Windows** | **U-factor** | 0.40 | 0.40 | | | | | | | | | | | | | | |
| | **RSHGC** | 0.35 | 0.21 | | | | | | | | | | | | | | |
| | **VT** | NR | NR | | | | | | | | | | | | | | |
| **Glazed Doors** | **U-factor** | 0.45 | 0.45 | | | | | | | | | | | | | | |
| | **RSHGC** | 0.35 | 0.23 | | | | | | | | | | | | | | |
| | **VT** | 0.17 | 0.17 | | | | | | | | | | | | | | |
| **Skylights** | **U-factor** | 0.55 | | | | | | | | | | | | | | | |
| | **RSHGC** | 0.30 | | | | | | | | | | | | | | | |
| | **VT** | NR | | | | | | | | | | | | | | | |

2. **Space Conditioning Systems**.

A. **Space Conditioning Systems Serving Individual Dwelling Units**.

i. Entirely New or Complete Replacement Space-Conditioning Systems installed as part of an alteration, shall include all the system heating or cooling equipment, including but not limited to . condensing unit and cooling or heating coil for split systems; or complete replacement of a package unit; plus entirely new or replacement duct system (Section ~~150.2(b)1Diia~~180.2(b)2Aiib); plus a new or replacement air handler.

Entirely New or complete replacement space-conditioning systems shall:

a. Meet the requirements of Sections ~~150.0(h), 150.**0(i)** 160.3(a)1, 150.0(j)2, 150.0(j)3, 150.0(m)1 through 150.0(m)10; 150.0(m)12; 150.0(m)13C, 150.1(c)6, 150.1(c)7, 150.1(c)10~~ 160.2(a)1, 160.3(a)1, 160.3(b)1 through 3, 160.3(b)5, 160.3(b)6, 160.3(c)1, and 170.2(c)3A and TABLE ~~150.2-A~~180.2-B; and

~~b. Be limited to natural gas, liquefied petroleum gas, or the existing fuel type.~~

~~**EXCEPTION to Section 150.2(b)1Cii 180.2(c)2Ai:** When the fuel type of the replaced heating system was natural gas or liquefied petroleum gas, the new or complete replacement space-conditioning system may be a heat pump.~~

ii. **Altered Duct Systems - Duct Sealing**: In all Climate Zones, when more than 40 feet of new or replacement space-conditioning system ducts are installed, the ducts shall comply with the applicable requirements of subsections i and ii below. Additionally, when altered ducts, air-handling units, cooling or heating coils, or plenums are located in garage spaces, the system shall comply with subsection 150.2(b)1Diic regardless of the length of any new or replacement space-conditioning ducts installed in the garage space.

a. New ducts located in unconditioned space shall meet the applicable requirements of Sections ~~150.0(m)1~~ 160.3(b)5A through ~~150.0(m)11~~K, and the duct insulation requirements of TABLE ~~150.2-A~~180.2-B, and

*TABLE ~~150.2-A~~180.2-B DUCT INSULATION R-VALUE*

| | | |
|---|---|---|
| **Climate Zone** | 1 through 10, 12&13 | 11, 14 through 16 |
| **Duct R-Value** | R-6 | R-8 |

b. The altered duct system, regardless of location, shall be sealed as confirmed through field verification and diagnostic testing in accordance with all applicable procedures for duct sealing of altered existing duct systems as specified in the Reference Residential Appendix RA3.1, utilizing the leakage compliance criteria specified in Subsection a or b below.

I. **Entirely New or Complete Replacement Duct System.** If the new ducts form an entirely new or complete replacement duct system directly connected to the air handler, the duct system shall meet one of the following requirements:

~~II. For single family dwellings, the measured duct leakage shall be equal to or less than 5 percent of the system air handler airflow as confirmed by field verification and diagnostic testing utilizing the procedures in Reference Residential Appendix Section RA3.1.4.3.1.~~

~~III. For multifamily dwellings, regardless of duct system location,~~

A. The total leakage of the duct system shall not exceed 12 percent of the nominal system air handler airflow as determined utilizing the procedures in Reference Residential Appendix Section RA3.1.4.3.1, or

B. The duct system leakage to outside shall not exceed 6 percent of the nominal system air handler airflow as determined utilizing the procedures in Reference Residential Appendix Section RA3.1.4.3.4.

C. Entirely new or complete replacement duct systems installed as part of an alteration shall be constructed of at least 75 percent new duct material, and up to 25 percent may consist of reused parts from the dwelling unit's existing duct system, including but not limited to registers, grilles, boots, air handler, coil, plenums, duct material; if the reused parts are accessible and can be sealed to prevent leakage.

D. Entirely new or complete replacement duct systems shall also conform to the requirements of Sections ~~150.0(m)12~~160.2(a)1 and **~~150.0(m)13~~160.3(b)5L**.

IV. **Extension of an Existing Duct System**. If the new ducts are an extension of an existing duct system serving ~~single family or~~ multifamily dwellings, the combined new and existing duct system shall meet one of the following requirements:

A. The measured duct leakage shall be equal to or less than 15 percent of nominal system air handler airflow as confirmed by field verification and diagnostic testing utilizing the procedures in Reference Residential Appendix Section RA3.1.4.3.1; or

B. The measured duct leakage to outside shall be equal to or less than 10 percent of nominal system air handler airflow as confirmed by field verification and diagnostic testing utilizing the procedures in Reference Residential Appendix Section RA3.1.4.3.4; or

C. If it is not possible to meet the duct sealing requirements of either Section ~~150.2(b)1DiibI~~180.2(b)2AiibIV, A or B~~150.2(b)1DiibII~~, then all accessible leaks shall be sealed and verified through a visual inspection and a smoke test by a certified HERS Rater utilizing the methods specified in Reference Residential Appendix RA3.1.4.3.5.

**EXCEPTION to Section ~~150.2(b)1Diib~~180.2(b)2AiibIV: Duct Sealing.** Existing duct systems that are extended, which are constructed, insulated or sealed with asbestos.

V. **Altered Ducts and Duct System Components in Garage Spaces.** When new or replacement space-conditioning ducts, air-handling units, cooling or heating coils, or plenums are located in a garage space, compliance with either I or II below is required.

A. The measured system duct leakage shall be less than or equal to 6 percent of system air handler airflow as determined utilizing the procedures in Reference Residential Appendix Section RA3.1.4.3.1, or

B. All accessible leaks located in the garage space shall be sealed and verified through a visual inspection and a smoke test by a certified HERS Rater utilizing the methods specified in Reference Residential Appendix RA3.1.4.3.5.

**iii. Altered Space-Conditioning System**

**a. Duct Sealing.** In all Climate Zones, when a space-conditioning system serving a ~~single family or~~ multifamily dwelling is altered by the installation or replacement of space-conditioning system equipment, including replacement of the air handler, outdoor condensing unit of a split system air conditioner or heat pump, or cooling or heating coil; the duct system that is connected to the altered space-conditioning system equipment shall be sealed, as confirmed through field verification and diagnostic testing in accordance with the applicable procedures for duct sealing of altered existing duct systems as specified in Reference Residential Appendix RA3.1 and the leakage compliance criteria specified in subsection i, ii, or iii below. ~~Additionally, when altered ducts, air-handling units, cooling or heating coils, or plenums are located in garage spaces, the system shall comply with Section 150.2(b)1Diic~~ regardless of the length of any new or replacement space-conditioning ducts installed in the garage space.

I. The measured duct leakage shall be equal to or less than 15 percent of system air handler airflow as determined utilizing the procedures in Reference Residential Appendix Section RA3.1.4.3.1; or

II. The measured duct leakage to outside shall be equal to or less than 10 percent of system air handler airflow as determined utilizing the procedures in Reference Residential Appendix Section RA3.1.4.3.4; or

III. If it is not possible to meet the duct sealing requirements of either Section ~~150.2(b)1Ei or Section 150.2(b)1Eii~~180.2(b)2AiiiaI or II, then, all accessible leaks shall be sealed and verified through a visual inspection and a smoke test by a certified HERS Rater utilizing the methods specified in Reference Residential Appendix RA3.1.4.3.5.

**EXCEPTION 1 to Section ~~150.2(b)1Eii~~180.2(b)2Aiiia: Duct Sealing.** Duct systems that are documented to have been previously sealed as confirmed through field verification and diagnostic testing in accordance with procedures in the Reference Residential Appendix RA3.1.

**EXCEPTION 2 to Section ~~150.2(b)1Eii~~180.2(b)2Aiiia: Duct Sealing.** Duct systems with less than 40 linear feet as determined by visual inspection.

**EXCEPTION 3 to Section ~~150.2(b)1Eii~~180.2(b)2Aiiia: Duct Sealing.** Existing duct systems constructed, insulated or sealed with asbestos.

**iv. Altered Space-Conditioning System Mechanical Cooling.** When a space-conditioning system is an air conditioner or heat pump that is altered by the installation or replacement of refrigerant-containing system components such as the compressor, condensing coil, evaporator coil, refrigerant metering device or refrigerant piping, the altered system shall comply with the following requirements:

a. All thermostats associated with the system shall be replaced with setback thermostats meeting the requirements of Section 110.2(c).

b. In Climate Zones 2, 8, 9, 10, 11, 12, 13, 14, and 15, air-cooled air conditioners and air-source heat pumps, including but not limited to ducted split systems, ducted package systems, small duct high velocity air systems, and minisplit systems, shall comply with subsections a and b, unless the system is of a type that cannot be verified using the specified procedures. Systems that cannot comply with the requirements of Section ~~150.2(b)1Fii~~ 180.2(b)2Aivb shall comply with Section ~~150.2(b)1Fiii~~ 180.2(b)2Aivc.

I. Minimum system airflow rate shall comply with the applicable subsection I or II below as confirmed through field verification and diagnostic testing in accordance with the procedures specified in Reference Residential Appendix Section RA3.3 or an approved alternative procedure as specified in Section RA1.;

A. Small duct high velocity systems shall demonstrate a minimum system airflow rate greater than or equal to 250 cfm per ton of nominal cooling capacity; or

B. All other air-cooled air conditioner or air-source heat pump systems shall demonstrate a minimum system airflow rate greater than or equal to 300 cfm per ton of nominal cooling capacity; and

II. The installer shall charge the system according to manufacturer's specifications. Refrigerant charge shall be verified according to one of the following options, as applicable.

A. The installer and rater shall perform the standard charge verification procedure as specified in Reference Residential Appendix Section RA3.2.2, or an approved alternative procedure as specified in Section RA1; or

B. The system shall be equipped with a fault indicator display (FID) device that meets the specifications of Reference Joint Appendix JA6. The installer shall verify the refrigerant charge and FID device in accordance with the procedures in Reference Residential Appendix Section RA3.4.2. The HERS Rater shall verify FID device in accordance with the procedures in Section RA3.4.2; or

C. The installer shall perform the weigh-in charging procedure as specified by Reference Residential Appendix Section RA3.2.3.1 provided the system is of a type that can be verified using the RA3.2.2 standard charge verification procedure and RA3.3 airflow rate verification procedure or approved alternatives in RA1. The HERS Rater shall verify the charge using RA3.2.2 and RA3.3 or approved alternatives in RA1

**EXCEPTION 1 to Section ~~150.2(b)1Fiia~~180.2(b)2AivbI**: Systems unable to comply with the minimum airflow rate requirement shall demonstrate compliance using the procedures in Section RA3.3.3.1.5; and the system's thermostat shall conform to the specifications in Section 110.12.

**EXCEPTION 2 to Section ~~150.2(b)1Fiia~~180.2(b)2AivbI:** Entirely new or complete replacement space conditioning systems, as specified by Section ~~150.2(b)1C~~180.2(b)2Ai, without zoning dampers may comply with the minimum airflow rate by meeting the applicable requirements in TABLE ~~150.0-B~~160.3-A or ~~150.0-C~~160.3-B as confirmed by field verification and diagnostic testing in accordance with the procedures in Reference Residential Appendix Section RA3.1.4.4 and RA3.1.4.5. The design clean-filter pressure drop requirements of Section ~~150.0(m)12~~160.2(a)1C for the system air filter device(s) shall conform to the requirements given in TABLE ~~150.0-B~~160.3-A and ~~150.0-C~~160.3-B.

**EXCEPTION 1 to Section ~~150.2(b)1Fiib~~180.2(b)2AivbII**: When the outdoor temperature is less than 55 degrees F and the installer utilizes the weigh-in charging procedure in Reference Residential Appendix Section RA3.2.3.1to demonstrate compliance, the installer may elect to utilize the HERS Rater verification procedure in Reference Residential Appendix Section RA3.2.3.2. If the HERS Rater verification procedure in Section RA3.2.3.2 is used for compliance, the system's thermostat shall conform to the specifications in Section 110.12. Ducted systems shall comply with the minimum system airflow rate requirements in Section ~~150.2(b)1Fiia~~180.2(b)2AivbI.

**EXCEPTION to Section ~~150.2(b)1Fii~~180.2(b)2Aivb:** Entirely new or complete replacement packaged systems for which the manufacturer has verified correct system refrigerant charge prior to shipment from the factory are not required to have refrigerant charge confirmed through field verification and diagnostic testing. The installer of these packaged systems shall certify on the Certificate of Installation that the packaged system was pre-charged at the factory and has not been altered in a way that would affect the charge. Ducted systems shall comply with minimum system airflow rate requirement in Section ~~150.2(b)1Fiia~~ 180.2(b)2AivbI, provided that the system is of a type that can be verified using the procedure specified in RA3.3 or an approved alternative in RA1.

v. **Altered Space-Conditioning System.** Replacement space-conditioning systems shall be limited to natural gas, liquefied petroleum gas, or the existing fuel type.

**EXCEPTION to Section ~~150.2(b)1G~~180.2(b)2Av:** When the fuel type of the replaced heating system was natural gas or liquefied petroleum gas, the replacement space-conditioning system may be a heat pump

B. **Central Systems Serving Multiple Dwelling Units and Common Use Area Space Conditioning Systems**

i. New or Replacement Space-Conditioning Systems or Components other than new or replacement space-conditioning system ducts shall meet the requirements of Section ~~140.4~~170.2(c)1, 2, and 4, applicable to the systems or components being altered. For compliance with Section ~~140.4(c)~~1170.2(c)4A, additional fan power adjustment credits are available as specified in TABLE ~~141.0-D~~180.2-C.

*TABLE ~~141.0-D~~180.2-C Fan Power Limitation Pressure Drop Adjustment*

| Device | Adjustment Credits |
|---|---|
| Particulate Filtration Credit: MERV 9 through 12 | 0.5 in. of water |
| Particulate Filtration Credit: MERV 13 through 15 | 0.9 in. of water |

~~**EXCEPTION 1 to Section 141.0(b)2C**. Subsection (b)2C does not apply to replacements of equivalent or lower capacity electric resistance space heaters for high-rise residential apartment units.~~

**EXCEPTION ~~2~~1 to Section ~~141.0(b)2C~~180.2(b)2Bi**. ~~Subsection (b)2C~~ does not apply to replacement of electric reheat of equivalent or lower capacity electric resistance space heaters, when natural gas is not available.

**EXCEPTION ~~3~~2 to Section ~~141.0(b)2C~~180.2(b)2Bi**. Section ~~140.4(n)~~170.2(c)4L is not applicable to new or replacement space conditioning systems.

ii. **Altered Duct Systems.** When new or replacement space-conditioning system ducts are installed to serve an existing building, the new ducts shall meet the requirements of Section ~~120.4~~160.3(c)2. If the space conditioning system meets the criteria of Section ~~140.4(l)1~~170.2(c)4Ji, the duct system shall be sealed as confirmed through field verification and diagnostic testing in accordance with the procedures for duct sealing of an existing duct system as specified in Reference Nonresidential Appendix NA2, to meet one of the following requirements:

a. If the new ducts form an entirely new or replacement duct system directly connected to the air handler, the measured duct leakage shall be equal to, or less than 6 percent of the system air handler airflow as confirmed by field verification and diagnostic testing utilizing the procedures in Reference Nonresidential Appendix Section NA2.1.4.2.1.

b. Entirely new or replacement duct systems installed as part of an alteration shall be constructed of at least 75 percent new duct material, and up to 25 percent may consist of reused parts from the building's existing duct system, including registers, grilles, boots, air handlers, coils, plenums, and ducts, if the reused parts are accessible and can be sealed to prevent leakage.

c. If the new ducts are an extension of an existing duct system, the combined new and existing duct system shall meet one of the following requirements:

I. The measured duct leakage shall be equal to or less than 15 percent of the system air handler airflow as confirmed by field verification and diagnostic testing utilizing the procedures in Reference Nonresidential Appendix Section NA2.1.4.2.1; or

II. If it is not possible to comply with the duct leakage criterion in Subsection 141.0(b)2Diia, then all accessible leaks shall be sealed and verified through a visual inspection and a smoke test performed by a certified HERS Rater utilizing the methods specified in Reference Nonresidential Appendix NA2.1.4.2.2.

**EXCEPTION to Section ~~141.0(b)2Dii~~ 180.2(b)2Biic: Duct Sealing.** Existing duct systems that are extended, which are constructed, insulated or sealed with asbestos are exempt from the requirements of subsection ~~141.0(b)2Dii~~180.2(b)2Biic.

iii. **Altered Space-Conditioning Systems.** When a space-conditioning system is altered by the installation or replacement of space-conditioning system equipment (including replacement of the air handler, outdoor condensing unit of a split system air conditioner or heat pump, or cooling or heating coil:

a. For all altered units where the existing thermostat does not comply with the requirements for demand responsive controls specified in Section 110.12, the existing thermostat shall be replaced with a demand responsive thermostat that complies with Section 110.12. All newly installed space-conditioning systems requiring a thermostat shall be equipped with a demand responsive thermostat that complies with Section 110.12; and

b. The duct system that is connected to the new or replaced space-conditioning system equipment shall be sealed, if the duct system meets the criteria of Section ~~140.4(l)1~~ 170.2(c)4Ji, as confirmed through field verification and diagnostic testing, in accordance with the applicable procedures for duct sealing of altered existing duct systems as specified in Reference Nonresidential Appendix NA2, and conforming to the applicable leakage compliance criteria in Section ~~141.0(b)2D~~180.2(b)2Bii.

**EXCEPTION 1 to Section ~~141.0(b)2Eii~~180.2(b)2Biiib: Duct Sealing**. Buildings altered so that the duct system no longer meets the criteria of Section ~~140.4(l)1~~ 170.2(c)4Ji are exempt from the requirements of Subsection ~~141.0(b)2Eii~~180.2(b)2Biiib.

**EXCEPTION 2 to Section ~~141.0(b)2Eii~~180.2(b)2Biiib: Duct Sealing**. Duct systems that are documented to have been previously sealed as confirmed through field verification and diagnostic testing in accordance with procedures in the Reference Nonresidential Appendix NA2 are exempt from the requirements of Subsection ~~141.0(b)2Eii~~180.2(b)2Biiib.

**EXCEPTION 3 to Section ~~141.0(b)2Eii~~180.2(b)2Biiib: Duct Sealing**. Existing duct systems constructed, insulated or sealed with asbestos are exempt from the requirements of Subsection ~~141.0(b)2Eii~~180.2(b)2Biiib.

3. **Hot Water Systems**. Altered or replacement service water-heating systems or components shall meet the applicable requirements below:

A. **Pipe Insulation.** For newly installed piping, the insulation requirements of Section ~~150.0(j)2~~160.4(f)2 shall be met. For existing accessible piping the applicable requirements of Section ~~150.0(j)2~~160.4(f)2Ai, iii, and iv shall be met.

B. **Distribution System.** For recirculation distribution system serving individual dwelling units, only Demand Recirculation Systems with manual on/off control as specified in the Reference Appendix RA4.4.9 shall be installed.

C. **Water heating system.** The water heating system shall meet one of the following:

i. A natural gas or propane water-heating system; or

ii. For Climate Zones 1 through 15, a single heat pump water heater. The storage tank shall not be located outdoors and be placed on an incompressible, rigid insulated surface with a minimum thermal resistance of R-10. The water heater shall be installed with a communication interface that meets either the requirements of 110.12(a); or

iii. For Climate Zones 1 through 15, a single heat pump water heater that meets the requirements of NEEA Advanced Water Heater Specification Tier 3 or higher. The storage tank shall not be located outdoors; or

iv. If no natural gas is connected to the existing water heater location, a consumer electric water heater.; or

v. A water-heating system determined by the executive director to use no more energy than the one specified in Item a. above; or if no natural gas is connected to the existing water heater location, a water-heating system determined by the executive director to use no more energy than the one specified in Item d. above.

4. **Lighting**.

D. **Dwelling Unit Lighting.** The altered lighting system shall meet the lighting requirements of Section ~~150.0(k)~~160.5(a).The altered luminaires shall meet the luminaire efficacy requirements of Section ~~150.0(k)~~160.5(a).and TABLE ~~150.0-A~~160.3-A. Where existing screw base sockets are present in ceiling-recessed luminaires, removal of these sockets is not required provided that new JA8 compliant trim kits or lamps designed for use with recessed downlights or luminaires are installed.

E. **Common Use Area Lighting**.

i. Spaces with lighting systems installed for the first time shall meet the requirements of Sections 110.9, ~~130.0~~160.5(b)1, ~~130.1~~ 160.5(b)4, ~~130.2~~160.5(c)2, ~~130.4~~160.5(e), ~~140.3(c)~~170.2(b), ~~140.6~~170.2(e)1, and ~~140.7~~ 170.2(e)2.

ii. When the requirements of Section ~~130.1(d)~~160.5(b)4D are triggered by the addition of skylights to an existing building and the lighting system is not recircuited, the daylighting control need not meet the multi-level requirements in Section ~~130.1(d)~~160.5(b)4D.

iii. New internally and externally illuminated signs shall meet the requirements of Sections 110.9, ~~130.3~~160.5(d) and 140.8.

iv. **Altered Indoor Lighting Systems**. Alterations to indoor lighting systems that include 10% or more of the luminaires serving an enclosed space shall meet the requirements of i, ii, or iii below:

a. The alteration shall comply with the indoor lighting power requirements specified in Section ~~140.6~~170.2(e)1 and the lighting control requirements specified in TABLE ~~141.0-F~~ 180.2-D;

b. The alteration shall not exceed 80% of the indoor lighting power requirements specified in Section ~~140.6~~170.2(e)1, and shall comply with the lighting control requirements specified in TABLE ~~141.0-F~~ 180.2-D; or

c. The alteration shall be a one-for-one luminaire alteration within a building or tenant space of 5,000 square feet or less, the total wattage of the altered luminaires shall be at least 40% lower compared to their total pre-alteration wattage, and the alteration shall comply with the lighting control requirements specified in TABLE ~~141.0-F~~ 180.2-D.

Alterations to indoor lighting systems shall not prevent the operation of existing, unaltered controls, and shall not alter controls to remove functions specified in Section ~~130.1~~160.5(b)4.

Alterations to lighting wiring are considered alterations to the lighting system. Alterations to indoor lighting systems are not required to separate existing general, floor, wall, display, or ornamental lighting on shared circuits or controls. New or completely replaced lighting circuits shall comply with the control separation requirements of Section ~~130.1(a)4~~ 160.5(b)4Aiv and ~~130.1(c)1D~~160.5(b)4Cid.

**EXCEPTION 1 to Section ~~141.0(b)2I~~180.2(b)4Eiv.** Alteration of portable luminaires, luminaires affixed to moveable partitions, or lighting excluded as specified in Section 140.6(a)3~~140.6~~170.2(e)1Aiii.

**EXCEPTION 2 to Section ~~141.0(b)2I~~180.2(b)4Eiv.** Any enclosed space with only one luminaire.

**EXCEPTION 3 to Section ~~141.0(b)2I~~180.2(b)4Eiv.** Any alteration that would directly cause the disturbance of asbestos, unless the alteration is made in conjunction with asbestos abatement.

**EXCEPTION 4 to Section ~~141.0(b)2I~~180.2(b)4Eiv.** Acceptance testing requirements of Section ~~130.4~~ 160.5(e) are not required for alterations where lighting controls are added to control 20 or fewer luminaires.

**EXCEPTION 5 to Section ~~141.0(b)2I~~180.2(b)4Eiv.** Any alteration limited to adding lighting controls or replacing lamps, ballasts, or drivers.

**EXCEPTION 6 to Section ~~141.0(b)2I~~180.2(b)4Eiv.** One-for-one luminaire alteration of up to 50 luminaires either per complete floor of the building or per complete tenant space, per annum.

v. Alterations to existing outdoor lighting systems in a lighting application listed in TABLE ~~140.7-A~~ 170.2-O or ~~140.7-B~~ 170.2-P shall meet the applicable requirements of Sections ~~130.0~~160.6, ~~130.2(a), 130.2(b)~~160.5(c)1, and ~~130.4~~160.5(e), and:

a. In alterations that increase the connected lighting load, the added or altered luminaires shall meet the applicable requirements of Section ~~130.2(c)~~ 160.5(c)2 and the requirements of Section ~~140.7~~170.2(e)2 for general hardscape lighting or for the specific lighting applications containing the alterations; and

b. In alterations that do not increase the connected lighting load, where the greater of 5 luminaires or 10 percent of the existing luminaires are replaced in a general hardscape or a specific lighting application, the alterations shall meet the following requirements:

I. In parking lots and outdoor sales lots where the bottom of the luminaire is mounted 24 feet or less above the ground, the replacement luminaires shall comply with Section ~~130.2(c)1~~160.5(c)2A AND Section ~~130.2(c)3~~160.5(c)2C;

II. For all other lighting applications and where the bottom of the luminaire is mounted greater than 24 feet above the ground, the replacement luminaires shall comply with Section ~~130.2(c)1~~160.5(c)2A AND EITHER comply with Section ~~130.2(c)2~~160.5(c)2B or be controlled by lighting control systems, including motion sensors, that automatically reduces lighting power by at least 40 percent in response to the area being vacated of occupants; and

c. In alterations that do not increase the connected lighting load, where the greater of 5 luminaires or 50 percent of the existing luminaires are replaced in general hardscape or a specific application, the replacement luminaires shall meet the requirements of subsection ii above and the requirements of Section ~~140.7~~170.2(e)2 for general hardscape lighting or specific lighting applications containing the alterations.

**EXCEPTION to Section ~~141.0(b)2Liii~~ 180.2(b)4Evc.** Alterations where the replacement luminaires have at least 40 percent lower power consumption compared to the original luminaires are not required to comply with the lighting power allowances of Section ~~140.7~~170.2(e)2.

**EXCEPTION to Section ~~141.0(b)2L~~180.2(b)4Ev.** Acceptance testing requirements of Section ~~130.4~~ 160.5(e) are not required for alterations where controls are added to 20 or fewer luminaires.

vi. Alterations to existing internally and externally illuminated signs that increase the connected lighting load, replace and rewire more than 50 percent of the ballasts, or relocate the sign to a different location on the same site or on a different site shall meet the requirements of Section 140.8.

**EXCEPTION to Section ~~141.0(b)2M~~180.2(b)4Evi.** Replacement of parts of an existing sign, including replacing lamps, the sign face or ballasts, that do not require rewiring or that are done at a time other than when the sign is relocated, is not an alteration subject to the requirements of Section ~~141.0(b)2M~~180.2(b)4Evi.

*TABLE ~~141.0-F~~ 180.2-D – Control Requirements for Indoor Lighting System Alterations for Common Use Areas*

| **Control Specifications** | | **Projects complying with Section ~~141.0(b)2I~~180.2(b)4Eiv** | **Projects complying with Sections ~~141.0(b)2Iii~~ 180.2(b)4Eiv b and ~~141.0(b)2Liii~~ 180.2(b)4Evb** |
|---|---|---|---|
| **Manual Area Controls** | ~~130.1(a)1~~160.5(b)4Ai | Required | Required |
| | ~~130.1(a)2~~160.5(b)4Aii | Required | Required |
| | ~~130.1(a)3~~160.5(b)4Aii | Only required for new or completely replaced circuits | Only required for new or completely replaced circuits |
| **Multi-Level Controls** | ~~130.1(b)~~ 160.5(b)4B | Required | Not Required |
| **Automatic Shut Off Controls** | ~~130.1(c)1~~160.5(c)4Ci | Required; ~~130.1(c)1D~~ 160.5(b)4Cid only required for new or completely replaced circuits | Required; ~~130.1(c)1D~~ 160.5(b)4Cid only required for new or completely replaced circuits |
| | ~~130.1(c)2~~160.5(c)4Cii | Required | Required |
| | ~~130.1(c)3~~160.5(c)4Ciii | Required | Required |
| | ~~130.1(c)4~~160.5(c)4Civ | Required | Required |
| | ~~130.1(c)5~~160.5(b)4Cv | Required | Required |
| | ~~130.1(c)6~~160.5(b)4Cvi | Required | Required |
| | ~~130.1(c)7~~160.5(b)4Cvii | Required | Required |
| | ~~130.1(c)8~~160.5(b)4Cviii | Required | Required |
| **Daylighting Controls** | ~~130.1(d)~~160.5(b)4D | Required | Not Required |
| **Demand Responsive Controls** | ~~130.1(e)~~ 160.5(b)4E | Required | Not Required |

(c) **Performance approach**.

The altered component(s) and any newly installed equipment serving the alteration shall meet the applicable requirements of subsections ~~A, B, and C~~ 1, 2, and 3 below.

1. The altered components shall meet the applicable requirements of Sections 110.0 through 110.9, Section ~~150.0(a)~~ 160.0 through 160.3(b)J, ~~(l); 150.0(m) through 150.0 (m)10~~, ~~Section 150.0(o) through (q)~~ and 160.5. Entirely new or complete replacement space-conditioning systems, and entirely new or complete replacement duct systems, as these terms are used in Sections Section ~~150.2(b)1C~~180.2(b)2Ai, and 150.2(b)1Diia, shall comply with the requirements of Sections ~~150.0(m)12~~160.2(a)1 and ~~150.0(m)13~~160.3(b)5L.

2. The standard design for an altered component shall be the higher efficiency of existing conditions or the requirements of Section ~~141.0(b)2~~180.2(b). For components not being altered, the standard design shall be based on the unaltered existing conditions such that the standard and proposed designs for these components are identical. When the third party verification option is specified, all components proposed for alteration, for which the additional credit is taken, must be verified. The Executive Director shall determine the qualifications required by the third party inspector.

3. The proposed design shall be based on the actual values of the altered components.

**NOTES TO SECTION ~~150.2(b)2~~ 180.2(c):**

A. If an existing component must be replaced with a new component, that component is considered an altered component for the purpose of determining the standard design altered component energy budget and must meet the requirements of Section ~~150.2(b)2B~~180.2(c)2.

B. The standard design shall assume the same geometry and orientation as the proposed design.

C. The "existing efficiency level" modeling rules, including situations where nameplate data is not available, are described in the applicable Residential or Nonresidential ACM Approval Manual.

**EXCEPTION 1 to Section ~~150.2(b)~~180.2(c):** Any dual-glazed greenhouse or garden window installed as part of an alteration complies with the U-factor requirements in Section ~~150.1(c)3~~170.2.

**EXCEPTION 2 to Section ~~150.2(b)~~180.2(c):** Where the space in the attic or rafter area is not large enough to accommodate the required R-value, the entire space shall be filled with insulation provided such installation does not violate Section 1203.2 of Title 24, Part 2.

## SECTION 180.3 – REPAIRS

Repairs shall not increase the preexisting energy consumption of the repaired component, system, or equipment.

## SECTION 180.4 – WHOLE BUILDING

Any addition or alteration may comply with the requirements of Title 24, Part 6 by meeting the requirements for the entire building.