Reduced Infiltration

2022-NR-ENV2-D | Nonresidential Envelope | July 2020 DRAFT CASE REPORT

Energy Solutions

Please submit comments to info@title24stakeholders.com by August 21, 2020.

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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 fall 2020. For this report, the Statewide CASE Team is requesting input on the following:

1. *What portion of buildings in Climate Zones 1 through 9 are installing continuous air barriers even though they are not required to do so;*
2. *Input on making air barrier requirements state-wide and making whole building air leakage testing a prescriptive requirement rather than a prescriptive option;*
3. *The incremental cost of an air barrier, associated with sealing;*
4. *The steps involved and periodic inspections proposed for alternate verification program;*
5. *The baseline infiltration rates used for buildings with and without air barriers;*
6. *What to do if the whole building air leakage test is failed? The proposal is for buildings that exceed an air leakage rate of 0.4* cubic feet per minute*/square feet (cfm/ft²) and but not 0.6 cfm/ft² at 75* Pascals *(Pa) to execute a diagnostic and repair program but not have to retest;*
7. *Providing the option of the residential testing procedure for small commercial buildings;*
8. *The Statewide CASE Team proposing two years of experience testing similarly sized buildings as the qualification for testing professionals;*
9. *Are there concerns with choosing square feet of conditioned space as a determinant for which type of testing is appropriate?*
10. *Should this requirement apply to warehouses with loading docks, since the savings modeled occur primarily from the hours of 5pm to 6am, when the HVAC system is off?*

Email comments and suggestions to info@title24stakeholders.com *by* ***August 21, 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 Efficiency Building Standards (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 would 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 reduced infiltration. The report contains pertinent information supporting the code change.

Measure Description

Background Information

Infiltration is the uncontrolled air leakage in buildings. Leakage comes from the interaction of holes and gaps in the building shell with wind, thermal differences, and the building's ventilation system. Reducing air leakage can significantly lower the energy costs of maintaining the desired temperature and also improve the management of moisture, sound, and odor.

Section 110.7 of Title 24, Part 6 contains a mandatory requirement to seal all openings in the building envelope that are potential sources of air leakage. However, the current requirement is only verified by visual inspection and does not ensure that building air leakage is reduced. A more reliable means of ensuring a building does not have excessive leakage is whole building air leakage testing, which pressurizes and depressurizes a building to measure the air infiltration rate. While the building is pressurized, diagnostic tests such as smoke test or infrared thermography can be used to determine the source of the leaks.

Prescriptive requirement in Section 140.3(a)9 require building in climate zones 10 through 16 to have a continuous air barrier that meets one of the following: use materials with maximum air permeance limits, use assemblies of materials and components with maximum air leakage rates, or conduct a whole building leakage test to confirm that air leakage does not exceed 0.4 cubic cfm/ft^2 measured at 75 Pa. These three options are all assumed to give a building air leakage rate below 0.4 cfm/ft^2 at 75 Pa. As shown in Section 2.2 and Section 4.1, only a whole building leakage test guarantees this leakage rate is achieved. Buildings that are not tested risk exceeding this rate because poor quality installations can result in leaks at the connections of assemblies or unintended penetrations of the building air barrier. The intent of the proposed air barrier verification requirements is to establish code requirements that hold installation contractors to high quality installations.

Whole building air leakage testing is common in California for residential buildings, but not for nonresidential buildings. The first air infiltration performance requirement for nonresidential buildings was introduced over a decade ago by the U.S. Army Corps of Engineers. Washington State has requirements, and there are also mandatory requirements in ASHRAE 90.1 – 2019 and IECC – 2021. Studies by RDH Building Science Inc. (RDH Building Science Inc. 2015), the National Institute of Standards and Technology (Emmerich and Persily 2014), and others have shown the importance of testing requirements in reducing building infiltration.

Proposed Code Change

The Statewide CASE Team is proposing a change to the prescriptive air barrier requirements in Title 24, Part 6 for nonresidential buildings. First, it would require an air barrier in all climate zones in California. Second, to verify air barrier performance it would require either air leakage testing or the implementation of an air barrier verification program during construction. These modifications would impact new construction, additions, and alterations.

Scope of Code Change Proposal

Table 1 summarizes the scope of the proposed changes and which sections of the Standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manual, and compliance documents that would be modified.

Table 1: Scope of Code Change Proposal

Measure Name	Type of Requirement	Modified Section(s) of Title 24, Part 6	Modified Title 24, Part 6 Appendices	Would Compliance Software Be Modified	Modified Compliance Document(s)
Reduced Infiltration of Building Envelopes	Prescriptive	140.3(a)9 141.0(b)2	Nonresidential Appendix 2.4	Yes, NR ACM 5.4.2	NRCC-ENV-E

Market Analysis and Regulatory Assessment

Air barrier materials have been required in Climate Zones 10-16 since the 2013 update to Title 24, Part 6 (Energy Code). Extending the requirement to the rest of California is a common sense and technically feasible extension of the current air barrier requirements and would not cause significant changes to building design. Whole building air leakage testing is common for residential buildings in California, but not for commercial buildings. However, it has been required in Washington for a decade and is now a mandatory requirement in ASHRAE 90.1-2019 and pending approval for International Energy Conservation Code (IECC) – 2021. There are already testing professionals in California able to perform the testing and when the requirement was introduced in Washington, training and business opportunities were made available. There are already testing agencies and consulting firms in California that have the capacity to test larger commercial buildings (see Section 3.2 for examples.) Also, the Air Barrier Association of America indicated they could help provide training for testing buildings.

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 proposed code change would only apply to climate zones where it was found to be cost effective. In these zones, B/C ranged between 1.6 and 8.5. See Section 5.5 for the methodology, assumptions, and results of the cost-effectiveness analysis.

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

Table 2 presents the estimated energy and demand impacts of the proposed code change that would 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 (million therms/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, and Section 4 for details on the per-unit energy savings calculations.

Table 2: First-Year Statewide Energy and Impacts

Measure	Electricity Savings (GWh/yr)	Peak Electrical Demand Reduction (MW)	Natural Gas Savings (million therms/yr)	TDV Energy Savings (TDV million kBtu/yr)
New Construction	(0.07)	0.40	0.87	291.99
Additions and Alterations	(0.01)	0.33	0.93	317.55
Total	(0.08)	0.73	1.80	609.54

While certain climate zones showed negative electric savings, every climate showed positive gas savings, and overall this measure has very significant statewide energy impacts due to the natural gas savings.

Table 3 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 6.2 and Appendix C of this report. The monetary value of avoided GHG emissions is included in TDV cost factors and is thus included in the cost-effectiveness analysis.

Table 3: First-Year Statewide GHG Emissions Impacts

	Avoided GHG Emissions (Metric Tons CO2e/yr)	Monetary Value of Avoided GHG Emissions ($2023)
TOTAL	9,809	$294,270

Water and Water Quality Impacts

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

Compliance and Enforcement

Overview of Compliance Process

The Statewide CASE Team worked with stakeholders to develop a recommended compliance and enforcement process and to identify the impacts this process would have on various market actors. The compliance process is described in Section 2.5. Impacts on market actors are described in Section 3.3 and Appendix E. The key issues related to compliance and enforcement is training for project teams to make sure the test is passed.

Field Verification and Acceptance Testing

There are two options to confirm that the continuous air barrier is installed correctly. The first option is to complete a whole building air leakage test. For small commercial buildings, whole building air leakage testing would be completed in accordance with RESNET/ANSI 380. For larger buildings, testing would be completed in accordance with ASTM E3158 by blower door fan assembly (architectural only), multi-point regression testing. The second option is for a third-party to complete field inspections to verify the continuous air barrier is installed correctly. The third-party verification program would require a verification of the entire air barrier, so the third-party verification entity would visit the site multiple times during the construction phase to inspect the air barrier when it is accessible for visual inspection. Refer to Section 2.5 and Section 7.3 for additional information. Cost estimates for testing buildings or carrying out the verification program are provided in Section 5.3.

1. Introduction

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The overall goal of this CASE Report is to present a code change proposal for reduced infiltration. 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 Berner International, Air Movement and Control Association, Air Barrier Association of America, building officials, manufacturers, contractors, building envelope professionals, and others involved in the code compliance process. The proposal incorporates feedback received during a public stakeholder workshop that the Statewide CASE Team held on November 5, 2019, and April 14, 2020.

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

- Section 2 – Measure Description of this CASE Report provides a description of the measure and its background. This section also presents a detailed description of how this code change is accomplished in the various sections and documents that make up the Title 24, Part 6 Standards.
- Section 3 – In addition to the Market Analysis section, this section includes a review of the current market structure. Section 3.2 describes the feasibility issues associated with the code change, including whether the proposed measure overlaps or conflicts with other portions of the building standards, such as fire, seismic, and other safety standards, and whether technical, compliance, or

enforceability challenges exist.

- Section 4 – 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 would 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. Statewide water consumption impacts are also reported in this section.
- Section 7 – Proposed Revisions to Code Language concludes the report with specific recommendations with ~~strikeout~~ (deletions) and <u>underlined</u> (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: California Building Energy Code Compliance (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: Analysis of Adding Air Barriers Only presents the savings attributed to requiring air barriers in Climate Zones 1-9 without requiring verification.
- Appendix H: Initial Cost Effectiveness of Air Leakage Testing shows the benefit-to-cost ratios for all the buildings analyzed, including those that were excluded from the cost-effectiveness and statewide savings analysis.
- Appendix I: Supplement Energy Savings Impacts includes the total TDV energy savings/ft^2 for each prototype building in each climate zone.

2. Measure Description

2.1 Measure Overview

This proposal would expand the current prescriptive continuous air barrier requirements to additional climate zones. It would also strengthen requirements to affirm air barriers are effective at limiting air leakage by requiring verification of the air barrier.

Currently, continuous air barriers are a prescriptive requirement in newly constructed buildings in Climate Zones 10 through 16.[1] This code change would expand this existing requirement to all climate zones for both new construction and alterations.

The proposed code change would offer two options to demonstrate the air barrier is installed correctly and is working as intended: 1) whole-building air leakage testing, or 2) field verification. The primary prescriptive pathway would require a whole-building air leakage test to confirm the air barrier is effective at limiting leakage to 0.4 cubic cfm/ft^2 when pressurized to 75 Pa. If the measured leakage is 0.4 cfm/ft^2 or below, the building passes the test and is compliant with the code. If the measured leakage is above 0.4 cfm/ft^2 the following corrective actions would be required:

1. Locate sources of leakage using a smoke tracer test or infrared imaging survey.
2. Implement corrective actions to seal leaks.
3. Report corrective actions taken and a justification for any leaks that were not sealed.

If the measured leakage is above 0.6 cfm/ft^2, the leakage test must be completed again after corrective actions are completed to verify leakage is below 0.6 cfm/ft^2.

The standard test procedure would be for the entire building to be tested according to ASTM E3158. However, the Statewide CASE Team is recommending that buildings with less than 10,000 ft^2 of conditioned space be allowed to be tested according to RESNET/ANSI 380 – the procedure for low-rise residential buildings. Also, for larger buildings with 50,000 ft^2 or more of conditioned floor area, a sectional test method approach (previously established by ASRHAE 90.1 - 2019) may be used in accordance with ASTM 3158.

[1] The continuous air barriers must either use materials with an air permeance below 0.004 cfm/ft^2 at 75 Pascals (Pa), use assemblies of materials and components with an air leakage below 0.04 cfm/ft^2 at 75 Pa, or conduct a whole building leakage test to confirm that air leakage of does not exceed a rate of 0.4 cfm/ft^2 measured at 75 Pa.

The second option to confirm the air barrier is functioning as intended is for an independent third party to complete a field verification to inspect the air barrier while it is being installed.

The proposed code changes for testing would apply to all nonresidential buildings except in Climate Zone 7, including new construction, additions, and major alterations where at least 25 percent of the envelope is affected as defined in Section 7.2. The changes for continuous air barriers would apply to the same but include Climate Zone 7. For healthcare facilities, the proposed code changes would apply to new facilities and additions but not to alterations.

The proposal would recommend revisions to the leakage rates used in the Standard Design and Proposed Design in the compliance software.

2.2 Measure History

Air leakage, or infiltration, occurs when outside air inadvertently enters a building through cracks or openings in the building envelope or through doors. Since outside air temperature is usually different than the desired indoor temperature, reducing infiltration is an effective way to reduce energy use and energy costs associated with heating, cooling, and ventilation even in mild and dry climate zones.

As demonstrated in recent literature and in the analysis conducted for this report, effective air barriers would result in significant cost-effective energy savings throughout California. Improving building infiltration is a critical step in decarbonizing California's building stock and achieving California's ambitious energy and climate goals.[2] Also, focusing on improved building envelope performance is consistent with California's loading order (CPUC 2012). California already has a performance option for single family homes in all climate zones that use verified building air leakage testing.

Reducing infiltration also improves indoor air quality. High levels of infiltration mean that unfiltered air is entering the building. On the other hand, when a building is tight, the mechanical system is able to bring in filtered air to ensure it is not polluted. This is particularly in California where fire season can lead to dangerously poor outdoor air quality.

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[2] The 2008 California Public Utilities Commission and Energy Commission Energy Action Plan establishes a goal that newly constructed nonresidential buildings be zero net energy by 2030; Senate Bill 100 requires renewable energy and zero-carbon resources to supply 100 percent of electric retail sales to end-use customers by 2045; Executive OrderB-55-18 requires the state to achieve carbon neutrality by 2045; and Assembly Bill 3232 requires the Energy Commission to assess how to reduce greenhouse gas emissions from the residential and commercial buildings by 40 percent below 1990 levels by 2030.

The current air barrier prescriptive requirement was introduced in the 2013 version of Title 24, Part 6. It gives three options for meeting the air barrier requirement: use materials that meet the air permeance requirement of less than 0.004 cfm/ft^2 at 75 Pa, using assemblies of materials and components that meet the air leakage requirement of less than 0.04 cfm/ft^2 at 75 Pa, or for the entire building to not exceed an air leakage rate of 0.40 cfm/ft^2 at 75 Pa. These three methods of achieving were assumed to give an equivalent whole building air leakage of 0.4 cfm/ft^2 at 75 Pa and so that is the fixed infiltration rate in the compliance software. It is also important to note that the Statewide CASE Team has heard from numerous stakeholders that project teams choose to meet the air barrier requirements through one of the first two options, and that testing does not occur.

As discussed in Section 2.4.4, requirements in both American Society of Heating, Refrigerating and Air-Conditioning Engineers Standard 90.1 (ASHRAE 90,1) and the International Energy Conservation Code (IECC) were updated for the most recent editions to add assurances that continuous air barriers are installed correctly and operating as intended. Washington state also includes requirements to confirm the air barrier is functioning as intended. These new requirements were developed based on research that indicates unverified air barriers do not perform as well as verified air barriers. The proposed requirements presented in this CASE Report were inspired by recent revisions to national model codes and will align California's requirements more closely with requirements in the most recent versions of ASHRAE 90.1, though California's requirements would remain less stringent because the air barrier requirements in California are prescriptive whereas requirements in ASHRAE 90. 1 are mandatory in all climate zones, including the California climate zones.

As show in Section 4.1 the requirements for materials or assemblies of materials and components typically do not achieve the same airtightness for the whole building as an air leakage requirement for the whole building that is verified by testing. While it is important to use proper air barrier materials, unintentional leakage points are likely to occur at the junctures of different assemblies and the only way to ensure that the air barrier was installed properly and is functioning as expected is to test the whole building. The Statewide CASE Team determined that an infiltration of 0.7 cfm/ft^2 at 75 Pa is more appropriate for buildings that use air barrier materials but do not test the leakage of the building. This infiltration rate attributed to using proper air barrier materials is lower than what has been used in code change proposals in other jurisdictions – NYSERDA in the "2020 NYStretch Energy Code Commercial Cost Effectiveness Analysis" attributed an infiltration rate of 1.0 cfm/ft^2 at 75 Pa to the air barrier requirements in ASHRAE 90.1-2016, which are the same as in Title 24, Part 6 currently (NYSERDA 2019).

Air barrier verification by whole building air leakage testing has been required for nonresidential buildings by the Seattle Energy Code and Washington State Energy Code (WSEC) for a decade. WSCEC-2018 Section C402.5.1.2 limits infiltration to 0.25 cfm/ft^2 at 75 Pa and provides performance credit if buildings do not exceed 0.17 cfm/ft^2 at 75 Pa (SBCC 2018).

As the industry moves toward more energy efficiency and sustainability, construction standards are acknowledging the importance of an air-tight building envelope. Passive House and Net Zero Energy standards both set strict guidelines and performance requirements for the constructed air barrier. For reference, Passive House air leakage is 0.6 air changes per hour at 50 Pascals (Passive House Institute n.d.), or typically 0.033 cfm/ft^2 (O'Donnell n.d.). Leadership in Energy and Environment Design (LEED) v4.1 provides credit in U.S. Climate Zones 3-8 for buildings that have a verified reduction of at least 25 percent in air infiltration below the ASHRAE 90.1-2016 requirement of 0.4 cfm/ft^2 at 75 Pa (USGBC 2020). Building air tightness is also required to verify performance in compliance with the BC Energy Step Code (Energy Step Code Council 2019). Maximum permitted and verified infiltration is recognized as an important part of high performance buildings.

See Section 4 for calculated savings from this measure. Beyond savings, reduced air leakage can improve occupant comfort from a standpoint of drafts, air quality/odor control, and acoustics (Gatland n.d.). In addition, minimizing air leakage can also mitigate the risk of condensation (Straube n.d.).

2.3 Summary of Proposed Changes to Code Documents

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

2.3.1 Summary of Changes to the Standards

This proposal would modify the following sections of the California Energy Code as shown below. See Section 7.2 for marked-up code language.

The following is a summary of proposed modifications:

- **Section 140.3(a):** This is the section of the nonresidential prescriptive requirements for new construction. The purpose of the proposed changes would be to update the requirements for air barrier compliance. Currently the code requires only certain climate zones to demonstrate air barrier compliance. The changes would require all climate zones except Climate Zone 7 to have such requirements for airtight materials and would also require testing of the building envelope to verify that the whole building air leakage rate meets the prescriptive value. Alternatively, an air barrier verification procedure during the course of construction could be executed. Additions would also have to comply with this requirement according to the existing standard in Section 141.0(a). If an addition is a continuation of the existing air barrier and the tested air leakage rate exceeds 0.6 cfm/ft^2 at 75 Pa, a diagnostic and repair program would have to be executed but the building would not have to be retested. These changes would improve project design and oversight and help find and address issues while the construction team is still on site.

- **Section 141.0(b)2Q:** This is the section of the nonresidential prescriptive requirements for alterations. The purpose of the proposed changes is to create air barrier and whole building air leakage testing requirements for major alterations. To trigger these requirements, an alteration must change at least 25 percent of the building envelope wall area (see Section 7.2). If less than 100 percent of the envelope wall area is altered and the tested air leakage rate exceeds 0.6 cfm/ft^2 at 75 Pa, a diagnostic and repair program would have to be executed but the building would not have to be retested. These changes would improve the design and oversight of construction air barrier assemblies for alterations and allow for a construction team to make any repairs identified during testing.

2.3.2 Summary of Changes to the Reference Appendices

This proposal would modify the sections of the Reference Appendices identified below. See Section 7.3 of this report for the detailed proposed revisions to the text of the reference appendices.

NA2.4 Field Verification and Diagnostic Testing of Whole Building Air Leakage: The proposed requirements add a specified procedure for performing the whole building air leakage test proposed. This proposal elaborates on the pre-test verification, test performance, and data analysis. This also describes the alternate field verification program if this path is pursued.

2.3.3 Summary of Changes to the Nonresidential ACM Reference Manual

This proposal would modify the following sections of the Nonresidential ACM Reference Manual as shown below. See Section 7.4 of this report for the detailed proposed revisions to the text of the ACM Reference Manual.

- **SECTION 5.4 Space Uses:** Currently the default value is 0.4 cfm/ft^2 in all climate zones even though there are no air barrier requirements in Climate Zones 1-9. The Standard Design default values would be changed to 1.1 cfm/ft^2 if there is no air barrier specified, 0.7 cfm/ft^2 for an air barrier with no verification, 0.5 cfm/ft^2 if there is continuous air barrier verification, and 0.4 cfm/ft^2 after air leakage testing is complete.

- **5.4.2 Infiltration:** design zone infiltration airflow and zone infiltration airflow would have to be modified for the Standard and Proposed Design. The Standard Design would have to be modified to reflect the new specifications laid out by NORESCO, technical consultants for the Energy Commission, to account for infiltration through all six sides of the building envelope, rather than just the walls. The Proposed Design would have to be modified to no longer have a fixed value.

2.3.4 Summary of Changes to the Nonresidential Compliance Manual

The proposed code change would modify Section 3.2.3.2 of the Nonresidential Compliance Manual to reflect the compliance requirements for air barriers assemblies and verification. Section 3.6.2.1 Additions and Section 3.6.2.2 Alterations would need to be updated to include the air barrier requirements for additions and alterations. See Section 7.5 of this report for the detailed proposed revisions to the text of the Nonresidential Compliance Manual.

2.3.5 Summary of Changes to Compliance Documents

New compliance documentation would have to be provided to demonstrate compliance with the air barrier verification requirements. The proposed code change would modify the compliance document NRCC-ENV-E.

New compliance documentation for envelope air leakage testing compliance would be required. However, it would not be extensive since a supplemental report demonstrating documentation of the air leakage testing would be required to be submitted in accordance with ASTM E3158.

The summary compliance documentation would include tested envelope area, floor area, air by volume, stories above grade, and air leakage rate. If the final tested leakage rate fell between 0.4 and 0.6 cfm/ft^2 at 75 Pa, an additional section would have to be completed to prove the visual inspection and corrective action program were completed.

Examples of the revised documents are presented in Section 7.6.

2.4 Regulatory Context

2.4.1 Existing Requirements in the California Energy Code

Title 24, Part 6 includes both mandatory and prescriptive requirements that address air leakage. Section 110.7, which applies to both residential and nonresidential buildings, requires that, “All joints, penetrations and other openings in the building envelope that are potential sources of air leakage shall be caulked, gasketed, weather stripped, or otherwise sealed to limit infiltration and exfiltration." This requirement establishes the minimum compliance for all buildings, though it is a challenging requirement to enforce and is not sufficient to ensure buildings actually achieve acceptable levels of air leakage.

Prescriptive air barrier requirements for nonresidential buildings are presented in Section 140.3(a)9. To comply with prescriptive requirements, buildings in Climate Zones 10 through 16 must have a continuous air barrier that complies with one of the following:

1. **Materials.** The continuous air barrier is composed of materials that meet air permanence requirements. That is, materials that have an air permanence of 0.004 cfm/ft^2 when tested accordance with the American Society for Testing and Materials document titled, "Standard Test Method for Air Permeance of Building Materials," 2013 (ASTM E21778-13). Alternatively, designers can use materials presented in Table 140.2-A: Materials Deemed to Comply with Section 140.3(a)9A in conjunction with sealing all joints and installing as air barriers in accordance with manufacturer instructions.
2. **Assembly.** The continuous air barrier is composed of assemblies of materials and components that meet air leakage requirements. That is, assemblies do not exceed an air leakage rate of 0.04 cfm/ft^2 when tested in accordance with ASTM E2357,[3] ASTM E1677,[4] ASTM E1680,[5] or ASTM E283.[6] Alternatively, designers can use assemblies that are deemed to comply provided joints are sealed and materials are installed according to manufacturer's instructions.
3. **Whole-building leakage testing.** The air leakage rate of the entire building is not more than 0.4 cfm/ft^2 when tested in accordance with ASTM E779.[7]

There are no prescriptive air barrier requirements for Climate Zones 1 through 9. The proposed code change would expand them to all climate zones except Climate Zone 7.

[3] ASTM E2178 is the American Society for Testing and Materials document titled, "Standard Test Method for Air Permeance of Building Materials," 2013 (ASTM E21778-13).

[4] ASTM E1677 is the American Society for Testing and Materials document titled, "Standard Specification for an Air Retarder (AR) Material or System for Low-Rise Framed Building Walls," 2011 (ASTM E1677-11).

[5] ASTM E1680 is the American Society for Testing and Materials document titled, " Standard Test Method for Rate of Air Leakage through Exterior Metal Roof Panel Systems," 2016 (ASTM E1680-16).

[6] ASTM E283 is the American Society for Testing and Materials document titled "Standard Test Method for Determining the Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen," 2012 (ASTM E283-04(2012)).

[7] ASTM E779 is the American Society for Testing and Materials document titled, "Standard Test Method for Determining Air Leakage Rate by Fan Pressurization," 2010 (ASTM E779-10).

It would also modify the requirements to include either whole building leakage testing or the implementation of an air barrier verification procedure.

Currently, the code does not include any air barrier requirements for alterations and no requirement for air leakage testing. The proposed code change would apply them to major renovations as defined in Section 7.2. The code does state that the envelope of an addition must meet the requirements of Sections 140.2 through 140.9 and therefore the air barrier requirements do apply. However, this code change proposal would also require additions to meet the air leakage requirements.

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

There are no requirements in other parts of the California Building Code that are directly related to the proposed code changes. Chapter 7: Fire and Smoke Suppression of the California Building Code (Title 24, Part 2) requires air leakage testing to confirm smoke barriers are effective at containing smoke, but the test is not a whole-building leakage test and smoke barriers are not required in all nonresidential buildings.

2.4.3 Relationship to Local, State, or Federal Laws

There are no relevant local, state, or federal laws.

2.4.4 Relationship to Industry Standards

ASHRAE 90.1-2019 includes a mandatory requirement for continuous air barriers. All buildings in all climate zones must have continuous air barriers (Section 5.4.3.1). Semi-heated spaces[8] in Climate Zones 0 through 6 and single wythe concrete masonry buildings in Climate Zone 2B are exempt. Continuous air barriers must comply with design and installation requirements. Specific intersections must be “wrapped, sealed, caulked, gasketed, or taped in an approved manner to minimize air leakage” (Section 5.4.3.1.2). The air barrier must be verified by either conducting a whole-building leakage test (Section 5.4.3.1.1) or completing a third-party verification of the design and installation (Exception to Section 5.4.3.1.1 and Section 5.9.1.1).

If completing whole-building testing, the test must confirm the air leakage rate is 0.4 cfm/ft^2 or less. If the measured leakage rate is between 0.4 and 0.6 cfm/ft^2, leaks have to be identified and sealed if sealing can be accomplished “without destruction of existing building components.” Prior to the 2019 edition, ASHRAE 90.1 and Title 24, Part 6 were aligned in that the continuous air barrier had to comply with one of three

[8] ASHRAE 90.1 defines semiheated space as, “an enclosed space within a building that is heated by a heating system whose output capacity is greater than or equal to 3.4 Btu/h·ft2 of floor area but is not a conditioned space.

options: use materials that met air permeance requirements, use assemblies that met air leakage requirements, or complete a whole-building leakage test. For the 2019 edition, ASHRAE 90.1-2019 eliminated the materials and assemblies requirements, strengthened requirements for sealing interfaces, and required the continuous air barrier to be verified using one of two methods: whole-building air leakage testing or field verification.

The 2021 version of the International Energy Conservation Code (IECC), which will be published Fall 2020, will include a whole-building testing requirement for nonresidential buildings that is consistent with the requirements in ASHRAE 90.1. However, the 2021 IECC will exempt Climate Zones 2B, 3B, 3C, and 5C, which apply to a large portion of California. The 2010 IECC will not include the field verification alternative to whole-building testing.

The state of Washington has continuous air barrier requirements that are similar to the ASHRAE 90.1-2019. Continuous air barriers that meet specified design and installation criteria are required, and the air barrier must be verified using a whole-building leakage test. The leakage rate must not exceed 0.25 cfm/ft^2. Leaks must be sealed if the measured leakage is over 0.4 cfm/ft^2. In Washington, testing is performed by personnel that are able to document a minimum of two years of experience testing in accordance with ASTM E779 or ASTM 3158 for projects of similar magnitude and the Statewide CASE Team is proposing the same qualifications.

There are many industry standards to test air leakage of materials, assemblies, and buildings. The Statewide CASE Team proposes testing according to ASTM E3158 by blower door fan assembly (architectural only), multi-point regression testing. ASTM E3158 references ASTM E779 as a method but provides additional requirements.

2.5 Compliance and Enforcement

When developing this proposal, the Statewide CASE Team considered methods to streamline the compliance and enforcement process and how negative impacts on market actors who are involved in the process could be mitigated or reduced. This section describes how to comply with the proposed code change. It also describes the compliance verification process. Appendix E presents how the proposed changes could impact various market actors.

The activities that need to occur during each phase of the project are described below:

- **Design Phase:** During the design phase, the design team develops a design that complies with the continuous air barrier requirements including using the appropriate materials or assemblies. The architect would consult with the mechanical engineer and energy modeler to determine the conditioned spaces, and as a result the location of the air barrier boundaries (represented in plan and section). Details for complicated transitions would be developed to ensure continuity of the air barrier between different envelope systems. In addition, material and system performance specifications would be established and documented in the in the envelope Nonresidential Certificate of Compliance (NRCC) form (NRCC-ENV-E). All air barrier components of the building envelope assembly would be clearly identified or noted on the construction document.

- **Permit Application Phase:** As part of the plans and energy code submittal, drawings would be submitted with the line of the air barrier clearly identified in both plan and section, as well as a calculation of the total building envelope area to be used in the whole building air leakage rate calculation. The plan and energy code submittal would include how the project is going to meet the air leakage testing or verification requirements (i.e., whole building air leakage testing , sectional air leakage testing, or verification).
- **Construction Phase:** During the construction phase, both the construction team and design team would implement quality assurance and quality control procedures to ensure that installation is in accordance with plans. The design team and installation contractor would decide on their method to comply with the air barrier verification (i.e., whole-building leakage test or field verification) before construction begins. If using the field verification approach, the third-party entity that would complete the verification would be identified and a schedule for inspections during the construction phase would be established before the first verification milestone is met. The third-party would complete its verification of the air barrier throughout the construction phase as scheduled by the general contractor. If coordinated appropriately, the air barrier field verification would cause minimal disruption to the construction team and timeline. If using the whole-building leakage test approach, the installation contractor would be aware or the leakage test and would be under contract to fix leaks if the building failed the test. Being aware that testing will occur would make the contractor more accountable for quality installation.
- **Inspection Phase:** The actual execution of the whole building air leakage test or field verification would be implemented in this phase by a third-party entity. Testing would be performed in accordance with the code-required standard. Buildings under 10,000 ft^2 of conditioned area would be tested according to RESNET/ANSI 380 and those over 50,000 ft^2 would be tested by a sectional approach. The testing agency would work with the construction team to identify the test boundaries, equipment needs and equipment setup locations, and strategies to collect both quantitative and qualitative data during the test. The construction team would coordinate preparing the building by sealing all intentional envelope openings. If the building did not achieve a leakage rate of

0.4 cfm/ft^2 or less, the installation contractor would identify and seal leaks. If required, the third party would complete the whole-building leakage test again to verify the leakage was less than 0.6 cfm/ft^2.

The third-party entity that completed either the whole-building leakage testing or the field verification would complete a newly developed field verification form that documented the air barrier complies with the code requirements. If the whole-building leakage test were pursued, the form would include the final air leakage rate per square foot of envelope area, and qualitative observations of observed air leakage paths. This form would include fields to document that leaks had been sealed if the building failed the initial leakage test.

Current requirements allow builders to comply with the continuous air barrier requirement using one of three approaches: material selection, assembly selection, or whole-building leakage testing. All three options have an existing compliance verification process. However, documentation of the whole-building leakage test approach is deficient. The Statewide CASE Team has proposed an approach to improve the compliance verification process.

The steps outlined in the “Design” and “Permit Application” phases are typical best practices for clarity of construction purposes. The recommended “Construction” phase steps are guidelines that are already considered typical best practice.

While there is almost always a learning curve for added requirements, the proposed steps to design, construct, and perform quality assurance are already industry general best practice. The greatest challenge to compliance lies in the execution of the test itself, which is already an option to comply with existing code requirements although not frequently used in California. At the beginning of implementation, contractors could face challenges preparing the building for testing. Testing agencies and blower door manufactures have provided training to contractors in Washington and have told the Statewide CASE Team that they could do the same in California to ensure that testing is smooth. Since ASHRAE, IECC, and Washington will be requiring whole-building leakage testing, efforts to ramp up testing and field verification capabilities will be happening throughout the country, not just in California.

From a code enforcement standpoint, this should not pose a substantial burden to code officials because compliance can be demonstrated with test reports, which document compliance with test methods and data from the test.

3. Market Analysis

3.1 Market Structure

The Statewide CASE Team performed a market analysis with the goal 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 to 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 during public stakeholder meetings that the Statewide CASE Team held on November 5, 2019, and April 14, 2020.

Air barrier materials, roofing/waterproofing assemblies, and glazed framing assemblies typically used on commercial buildings already meet the design requirements. Manufacturers active in this market in California include Dupont, Grace, Dowsil, Carlisle, Soprema, American Hydrotech, and Kawneer.

Air-tight assemblies and detailing are determined by building designers and consultants, then coordinated and installed by a general contractor and their subcontractors. Specification requirements dictate requirements for qualified air barrier installers, who are often qualified by the air barrier manufacturers themselves.

3.2 Technical Feasibility, Market Availability, and Current Practices

3.2.1 Current Practices

In recent decades, building codes have required air barriers to meet performance standards and the building industry has improved its approach to air barrier construction (see Section 4.1 and Table 12 for more detail). Designers are paying more attention to the design and continuity of the air barrier by collaborating with building envelope consultants. General Contractors are now more aware of air barrier material coordination and installation, and project teams often include a building envelope engineer. Envelope construction materials such as continuous insulation and pre-cast concrete are rated as air barrier materials and are used even when there is not an explicit air barrier requirement, so some buildings in Climate Zones 1-9 already meet the materials or assemblies of materials requirement in Section 140.3(a)9.

Appropriate material and assembly selection alone do not guarantee an effective air barrier; proper installation is critical as well. Whole-building leakage testing is the most effective way to confirm the air barrier is working as intended.

Some stakeholders have inquired about the percentage of newly constructed buildings in Climate zones 1 through 9 that install continuous air barriers despite air barriers not being required by Title 24, Part 6. The Statewide CASE Team is seeking feedback on this question. If readers have information, please provide feedback by emailing info@title24stakeholders.com.

3.2.2 Technical Feasibility

This proposal would not cause a significant change to building design and construction practices. Currently, Title 24, Part 6 requires buildings in Climate Zones 10 through 16 to have a continuous air barrier. Expanding the continuous air barrier requirements to additional climate zones would not require technical or market innovation. If installed correctly, continuous air barriers can meet the 0.4 cfm/ft^2 whole building leakage limit without additional modifications to designs. Contractors should be capable of installing air barriers in accordance with manufacturer's installation instructions, resulting in passing leakage rates or field verifications. Adding the leakage test or field verification would make installation contractors more accountable for high quality workmanship.

The experience of other states indicates that training contractors to prepare for these tests and finding testing agencies with access to the adequate equipment providers can be done. Washington state adopted this requirement over a decade ago and found that industry stakeholders were willing to make training accessible to contractors and testing agencies. Since the requirement for whole building air leakage testing has been implemented, multiple training and business opportunities have become available within the industry. Consulting firms and testing agencies alike have grown their departments by either training staff members or by hiring those with experience. Designers and contractors have also put an emphasis on air barrier design/construction by designating envelope quality control personnel involved on projects.

3.2.3 Whole Building Leakage Test Procedures

The Statewide CASE Team is proposing that ASTM E3158 rather than ASTM E779 be the standard used for whole building air leakage testing. ASTM E3158 is an extension of ASTM E779, which it references, and provides important additional components as shown in Table 4.

Table 4: Difference Between ASTM E3158 and ASTM E779

	ASTM E779-19	ASTM E3158-18 (as recommended in Code Language)
Summary of Test Method	Multipoint regression	Multipoint regression
Procedure	• Test pressure differential range from 10 to 60 Pa • Does not provide detailed test preparation instructions • Collect minimum of 5 data points using increments of 5 to 10 Pa	• Test pressure differential range from 10 to 100 Pa • Provides detailed test preparation instructions • Collect minimum of 10 approx. equally spaced data points
Data Analysis and Calculations	Test is invalid if pressure exponent (n) is less than 0.5 or greater than 1	• Test is invalid if the pressure exponent (n) is less than 0.45 or greater than 1.05 • R2 must be greater than 0.98
Other	Provides more information and detailed procedures for calculation and analyzing the data using multipoint regression.	Provides more information and detailed procedures for multi-zone testing using the co-pressurization method.

The Statewide CASE Team determined that buildings with less than 10,000 ft^2 of conditioned space could be tested according to the existing procedure for enclosure leakage testing of low-rise residential buildings, RESNET/ANSI 380. This is the existing threshold in Title 24, Part 6 for third party design review and for the construction phase of building commissioning. For larger buildings with 50,000 ft^2 or more of conditioned floor area, a sectional test method approach (previously established by ASRHAE 90.1 - 2019) could be used in accordance with ASTM 3158.

3.2.4 Building Pressurization and Infiltration

Buildings should be pressurized when outside air temperature is warmer than the temperature setpoint to minimize infiltration and heat gain. Similarly, buildings should be slightly depressurized or have no pressurization when outside air is colder than the temperature setpoints to minimize exfiltration and moisture buildup. Proper pressurization is difficult to maintain because it is affected by weather, wind, and the mechanical ventilation system (Trane 2002). Researchers in Minnesota – where temperature differences between outdoor air and indoor setpoints are larger than in many parts of California – found that few commercial buildings have active pressure control based on weather conditions and that buildings are often less pressurized than recommended during warm weather (Bohac and Quinnell 2016).

Researchers have found that the standard range of 5.0 to 15.0 Pa reduces the effects of infiltration, but that at these pressures air leakage can cause a building's air change rate to be elevated. Therefore, reducing infiltration has an energy impact and improves mechanical system performance (Berquist, et al. 2020). It also helps designers properly size those mechanical systems.

3.2.5 Approaches to Addressing Air Barriers that Do Not Pass Verification

As part of the proposed code language, buildings that did not meet the target air leakage rate would be subject to an inspection and repair program. This would involve a thorough review from accessible areas of envelope assemblies and sealing discontinuities in the air barrier and/or adjustment of operable envelope components (such as doors or vents) to improve the compression of seals.

Financial gain, reputation, and industry advancement are all motivating factors that would bring the key parties to the table to help construction and testing teams execute this testing requirement. The Air Barrier Association of America (ABAA) has informed the Statewide CASE Team that they will making training and certification available in California in 2020 and consulting firms have said that they typically provide trainings for contractors.

3.3 Market Impacts and Economic Assessments

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 5).[9] In 2018, total payroll was $80 billion. Nearly 17,000 establishments and 344,000 employees focus on the commercial sector.

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

Table 5 California Construction Industry, Establishments, Employment, and Payroll

Construction Sectors	Establish ments	Employ ment	Annual Payroll ($ billion)
Commercial	**17,273**	**343,513**	**$27.8**
Commercial Building Construction	4,508	75,558	$6.9
Foundation, Structure, & Building Exterior	2,153	53,531	$3.7
Building Equipment Contractors	6,015	128,812	$10.9
Building Finishing Contractors	4,597	85,612	$6.2

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

The proposed changes to reduce infiltration would likely affect commercial builders. The effects on the commercial building industry would not be felt by all firms and workers, but rather would be concentrated in specific industry subsectors. Table 6 shows the commercial building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report. Chiefly, contractors that focus on the building envelope and air barrier would be impacted by this proposal. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 3.4

Table 6: Specific Subsectors of the California Commercial Building Industry Impacted by Proposed Change to Code/Standard

Construction Subsector	Establish ments	Employ ment	Annual Payroll ($ billion)
Commercial Building Construction	4,508	75,558	$6.9
Nonresidential structural steel contractors	318	12,044	$0.9
Nonresidential Framing Contractors	148	3,991	$0.2
Nonresidential Masonry Contractors	254	5,121	$0.3
Nonresidential glass and glazing contractors	280	5,244	$0.43
Nonresidential Roofing Contractors	347	8,939	$0.62
Nonresidential Siding Contractors	25	396	$0.0
Other Nonresidential exterior contractors	277	2,879	$0.2
Nonresidential Drywall Contractors	625	22,704	$1.7

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 Title 24, Part 6) 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 7 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The proposed code changes for the 2022 code cycle would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for this measure to affect firms that focus on nonresidential construction.

There is not a North American Industry Classification System (NAICS)[10] 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.[11] 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 7 provides an upper bound indication of the size of this sector in California.

Table 7: California Building Designer and Energy Consultant Sectors

Sector	Establishments	Employment	Annual Payroll (billion $)
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.)

[10] 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.

[11] 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.

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 (Cal/OSHA). All existing health and safety rules would 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.

For healthcare facilities, the proposed code changes would apply to new facilities and additions but not to alterations.

3.3.4 Impact on Building Owners and Occupants

Commercial Buildings

The commercial building sector includes a wide array of building types, including offices, restaurants and lodging, retail, and mixed-use establishments, and warehouses (including refrigerated) (Kenney 2019). Energy use by occupants of commercial buildings also varies considerably with electricity used primarily for lighting, space cooling and conditioning, and refrigeration. Natural gas consumed primarily for heating water and for space heating. According to information published in the 2019 California Energy Efficiency Action Plan, there is more than 7.5 billion square feet of commercial floor space in California and consumes 19 percent of California's total annual energy use (Kenney 2019). The diversity of building and business types within this sector creates a challenge for disseminating information on energy and water efficiency solutions, as does the variability in sophistication of building owners and the relationships between building owners and occupants.

Building owners and occupants would benefit from lower energy bills. As discussed in Section 3.4.1, when building occupants save on energy bills, they tend to spend it elsewhere in the economy thereby creating jobs and economic growth for the California economy. The Statewide CASE Team does not expect this proposed code change to impact building owners or occupants adversely.

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

The Statewide CASE Team does not expect widespread changes to the air barrier technology markets. As noted in Section 3.2.4, the technologies that meet these proposed requirements are mature and only a portion of the market would be impacted due to the respective capacity thresholds.

3.3.6 Impact on Building Inspectors

Table 8 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 8: Employment in California State and Government Agencies with Building Inspectors

Sector	Govt.	Establishments	Employment	Annual Payroll (million $)
Administration of Housing Programs[a]	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.
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 estimates that 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, it is estimated how energy savings associated with the proposed changes in air distribution would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

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 in Reduced Infiltration 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 in Reduced Infiltration would lead to modest ongoing financial savings for California residents, which would then be available for other economic activity.

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.[12] 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.

[12] 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.

Adoption of this code change proposal would result in relatively modest economic impacts through the additional direct spending by those in the commercial building industry, architects, energy consultants, and building inspectors. The Statewide CASE Team does not anticipate that money saved by commercial building owners or other organizations affected by the proposed 2022 code cycle regulations would result in additional spending by those businesses.

Table 9: Estimated Impact that Adoption of the Proposed Measure would have on the California Commercial Construction Sector

Type of Economic Impact	Employment (jobs)	Labor Income ($ million)	Total Value Added ($ million)	Output ($ million)
Total Economic Impacts	255	$16.40	$24.13	$40.84
Direct Effects (Additional spending by Commercial Builders)	154	$10.19	$13.50	$22.33
Indirect Effect (Additional spending by firms supporting Commercial Builders)	34	$2.44	$3.88	$7.49
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	67	$3.77	$6.75	$11.02

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

3.4.1 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.

3.4.2 Creation or Elimination of Businesses in California

The proposed code changes for the 2022 code cycle would apply to all businesses incorporated in California, regardless of whether the business is located inside or outside of the state.[13] Therefore, the Statewide CASE Team does not anticipate that

[13] 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.

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.

3.4.3 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 incorporated inside or outside of the state.[14] Therefore, the Statewide CASE Team does not anticipate that the proposed measures 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.

3.4.4 Increase or Decrease of Investments in the State of California

The Statewide CASE Team analyzed national data on corporate profits and capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI).[15] As Table 10 shows, between 2015 and 2019, NPDI as a percentage of corporate profits ranged from 26 to 35 percent, with an average of 31 percent. While only an approximation of the proportion of business income used for net capital investment, the Statewide CASE Team believes it provides a reasonable estimate of the proportion of proprietor income that would be reinvested by business owners into expanding their capital stock.

Table 10: Net Domestic Private Investment and Corporate Profits, U.S.

Year	Net Domestic Private Investment by Businesses, Billions of Dollars	Corporate Profits After Taxes, Billions of Dollars	Ratio of Net Private Investment to Corporate Profits
2015	$609.2	$1,740.3	35%
2016	$456.0	$1,739.8	26%
2017	$509.3	$1,813.6	28%
2018	$618.2	$1,843.7	34%
2019	$580.9	$1,827.0	32%

[14] 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.

[15] Net private domestic investment is the total amount of investment in capital by the business sector that is used to expand the capital stock, rather than maintain or replace due to depreciation. Corporate profit is the money left after a corporation pays its expenses.

		5-Year Average	**31%**

Source: (Federal Reserve Economic Data n.d.)

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. Nevertheless, the Statewide CASE Team is able to derive a reasonable estimate of the change in investment by California businesses by multiplying the sum of Business Income estimated in Table 10 above by 31 percent.

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

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

3.4.5.1 Cost of Enforcement

Cost to the State

State government already has budget for code development, education, and compliance enforcement. While state government would be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, these activities are already covered by existing state budgets. The costs to state government are small when compared to the overall costs savings and policy benefits associated with the code change proposals. This proposal may increase costs to construct state buildings such as large offices, but as shown in Section 4, all submeasures are cost effective.

Cost to Local Governments

All proposed code changes to Title 24, Part 6 would result in changes to compliance determinations. Local governments would need to train building department staff on the revised Title 24, Part 6 Standards. While this re-training is an expense to local governments, it is not a new cost associated with the 2022 code change cycle. The building code is updated on a triennial basis, and local governments plan and budget for retraining every time the code is updated. There are numerous resources available to local governments to support compliance training that can help mitigate the cost of retraining, including tools, training and resources provided by the IOU Codes and Standards program (such as Energy Code Ace). As noted in Section 2.5 and Appendix E, the Statewide CASE Team considered how the proposed code change might impact various market actors involved in the compliance and enforcement process and aimed to minimize negative impacts on local governments.

3.4.6 Impacts on Specific Persons

While the objective of any of the Statewide CASE Team's proposal is to promote energy efficiency, there is the potential that a proposed update to the 2022 code cycle may result in unintended consequences. The Statewide CASE Team does not believe there would be negative impacts towards one any specific persons as a result of this code change proposal.

4. Energy Savings

4.1 Key Assumptions for Energy Savings Analysis

The energy and cost analysis presented in this report used the TDV factors that are consistent with the TDV factors presented during the Energy Commission's March 27, 2020 workshop on compliance metrics (California Energy Commission 2020). The electricity TDV factors include the 15 percent retail adder and the natural gas TDV factors include the impact of methane leakage on the building site. The electricity TDV factors used in the energy savings analyses were obtained via email from Energy and Environmental Economics, Inc. (E3), the contractor that is developing the 2022 TDV factors for the Energy Commission, in a spreadsheet titled "Electric TDVs 2022 - 15 pct Retail Adj Scaled by Avoided Costs.xlsx". The natural gas TDV factors used in the energy savings analyses were obtained from E3 in a spreadsheet titled "2022_TDV_Policy_Compliant_CH4Leak_FlatRtlAdd_20191210.xlsx". The electricity demand factors used in the energy savings analysis were obtained from E3 in a spreadsheet titled "2022 TDV Demand Factors.xlsx". The final TDV factors that the Energy Commission released in June 2020 use 20-year global warming potential (GWP) values instead of the 100-year GWP values that were used to derive the current TDV factors. The 20-year GWP values increased the TDV factors slightly. As a result, the TDV energy savings presented in this report are lower than the values that are expected if the final TDV that use 20-year GWP values were used in the analysis. The proposed code changes will be more cost effective using the revised TDV. Energy savings presented in kWh and therms are not affected by TDV or demand factors.

The Statewide CASE Team will consider the need to re-evaluate energy savings and cost-effectiveness analyses using the final TDV factors for the results that will be presented in the Final CASE Report.

The Energy Commission has not provided guidance on analyses they would like to see regarding the impact of proposed code changes relative to the source energy metric that was developed for the 2022 code cycle. Pending guidance from the Energy Commission, the Final CASE Reports may include analyses on the source energy metric.

Table 11 presents the leakage rates that are relevant to the proposed code change. This table presents the leakage values that the Statewide CASE Team used to evaluate the energy savings associated with the proposed revisions to the infiltration requirements for nonresidential building for the 2022 code cycle. It also includes recommendations on the infiltration rates to include in the 2022 compliance software.

Table 11: Recommended Leakage Rates for 2022 CASE Analysis

#	Scenario	Recommended Infiltration Rate to be used in Compliance Software (cfm/ft^2 at 75Pa; infiltration through 6 sides)	Energy Modeling for 2022 CASE Proposals	Option to Select in Compliance Software
A	No continuous air barrier	1.1	Use for baseline conditions in Climate Zones 1-9, which represents minimal compliance with 2019 code.	Option 1
B	Continuous air barrier – no field verification or whole building leakage testing	0.7	Use for baseline conditions in Climate Zones 10-16, which represents minimal compliance with 2019 code.	Option 2
C	Continuous air barrier – field verification/inspection	0.5	N/A: not used for energy modeling in CASE analysis.	Option 3
D	Continuous air barrier – whole-building leakage testing, default credit	0.4	Use as proposed conditions for all climate zones. This is what we are recommending as a primary prescriptive pathway, which aligns with ASHRAE 90.1-2019, IECC, and Washington State code.	Standard Design
E	Continuous air barrier – whole-building leakage testing, actual result	Tested result under 0.4	N/A: not used for energy modeling in CASE analysis.	Option 4

The Statewide CASE Team developed the recommended leakage rates presented in Table 11 based primarily on information presented in the 2015 report from RDH Building Engineering Ltd (RDH) and Building Science Inc. (RDH Building Engineering Ltd.; Building Science Consulting Inc. 2015) and the 2014 report from the National Institute of Standards and Technology (NIST) (Emmerich and Persily 2014). The Statewide CASE Team also discussed potential leakage rate assumptions with researchers from RDH and NIST. Experts from both RDH and NIST concur that the recommended rates are reasonable. See below for a discussion and justification for each of the five leakage rate scenarios.

It is also important to note that when evaluating the cost-effectiveness of air leakage testing in addition to air barrier material requirements, a baseline infiltration rate of 1.0 cfm/ft^2 at 75 Pa was used for air barrier material requirements by both IECC (R. Hart, et al. 2015) and NYSERDA (NYSERDA 2019). The Statewide CASE Team therefore thinks that even though some buildings in Climate Zones 1-9 likely have air barriers, an infiltration rate of 1.1 cfm/ft^2 is conservative enough to account for variations in airtightness.

Scenario A: No Continuous Air Barrier

When there is no continuous air barrier, the Statewide CASE Team recommends using a baseline leakage rate of 1.1 cfm/ft^2 at 75 Pa through the entire building envelope. This is based on three data points described below: 1.4, 0.9, and 1.0 cfm/ft^2 at 75 Pa.

The first data point comes from RDH in their Study of Part 3 Building Airtightness from buildings built before 2000. As shown in Figure 1, most buildings constructed before 2000 have an air tightness between 2 and 12 L/s.m^2 at 75 Pa or between 0.4 and 2.4 cfm/ft^2 at 75 Pa through six sides. The first data point is the mid-point between these two values. RDH researchers suggested that buildings from vintages before 2000 would be the best representation of buildings where no code requirements exist. Some of these buildings had no continuous air barrier and others may have voluntarily elected to install a continuous air barrier and have leakage tested. Buildings in the test group built after 2000 were typically pursuing above-code programs that awarded credit for air tightness, or the design team was trying to make buildings tight to test design strategies, or the building was actually tested for compliance and had a target.

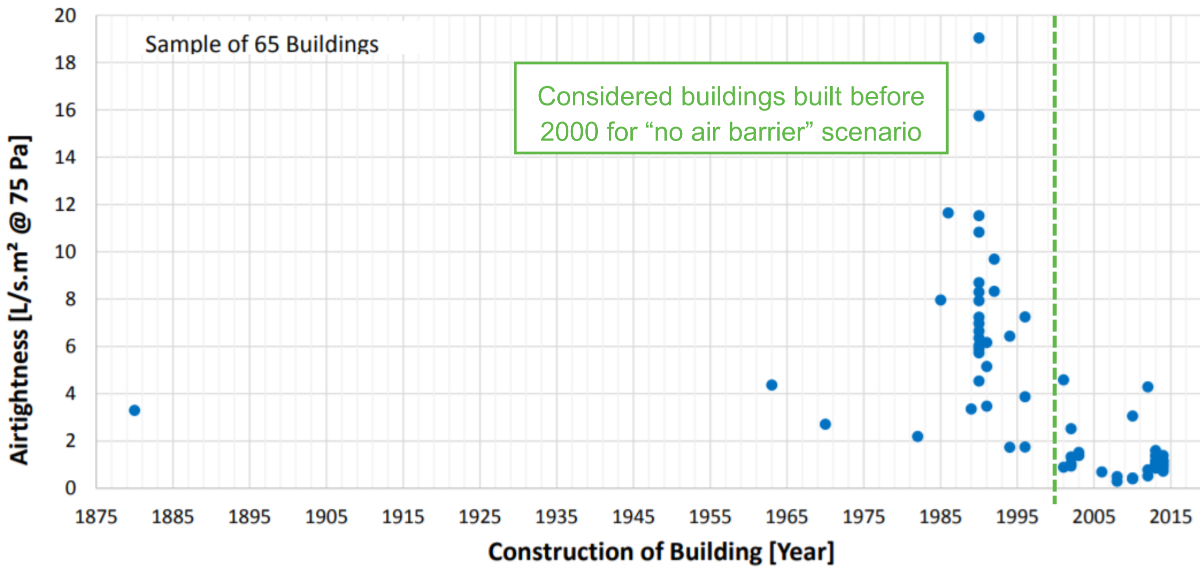

Figure 1. Airtightness of commercial buildings versus original year of construction.

Source: (RDH Building Science Inc. 2015)

The second data point, 0.9 cfm/ft^2 at 75 Pa, comes from the NIST 2014. This is the mean airtightness of "all old data" in Table 5 (16.7 m^3/h*m^2 equates to 0.91 cfm/ft^2). Researches at NIST suggested the data set called "all old data" is more representative of buildings that do not have air barriers than the "all new data" set or the "all buildings" data set. Although the "all old data" includes some buildings that have air barriers, a larger portion of the older data is from buildings without air barriers. However, some of the buildings from this older data set do have air barriers, so the value is likely too low to represent air tightness of buildings with no air barrier.

Table 12: Summary of Building Airtightness Data – 6-sided at 75 Pa (m^3/h*m^2)

Dataset	Qty	Mean	Std Dev	Min	Max
Efficiency Vermont	36	6.4	10.3	0.7	32.3
ASHRAE RP 1478	16	5.3	3.7	1.0	13.6
Washington	18	7.2	2.8	2.0	11.6
Other VT/NH	79	9.8	7.3	0.9	31.5
Other	10	5.4	4.1	1.6	13.6
All new data	159	6.6	5.4	0.5	32.3
All old data	228	16.7	12.7	1.6	77.9
All buildings	387	13.1	11.4	0.5	77.9

Source: (Emmerich and Persily 2014). Convert to cfm/ft^2 by multiplying by 0.055.

The final datapoint, 1.0 cfm/ft^2 (18.6 m^3/h*m^2) at 75 Pa, is also from the NIST report. This is the value found in the 141 buildings in locations with less than 2000 heating degree-days, regardless of whether there was an air barrier or whether the building was aiming to achieve a specific leakage rate. These buildings are in mild climate zones which makes the data applicable to California.

Taking these datapoints into consideration, the Statewide CASE Team is recommending that the baseline leakage rate for buildings with no continuous air barrier should be 1.1 cfm/ft^2 at 75 Pa.

For reference, the Energy Commission used a baseline infiltration rate of 1.8 cfm/ft^2 at 75 Pa when proposing air barrier requirements for California Climate Zones 10-16 for the 2013 code cycle. This number was based on assumptions the ASHRAE 90.1 envelope subcommittee used when evaluating requirements for continuous air barriers (Suyeyasu 2011). This assumption was based on best available data at the time.

Scenario B: Continuous Air Barrier, Not Verified (no field verification or whole building leakage testing).

When there is a continuous air barrier requirement that has not been verified through field verification or whole-building leakage testing, the Statewide CASE Team recommends using a baseline leakage rate of 0.7 cfm/ft^2 through the entire building envelope measured at 75 Pa. This is based on three data points: 0.7, 0.71, and 0.69 cfm/ft^2 at 75 Pa.

The first data point comes from the RDH analysis (RDH Building Engineering Ltd.; Building Science Consulting Inc. 2015) and is the mean infiltration rate of all commercial buildings tested (sample size of 134 buildings). The buildings tested include both buildings that are likely to be more airtight than the average because they were tested to meet performance targets or air-sealing and buildings that are likely less airtight than the average building because they were identified as particularly leaky and needing air sealing work.

The second data point, 0.71 cfm/ft^2 (3.57 L/s*m^2) at 75Pa, also comes from the above RDH report and is the average infiltration rate for buildings tested in British Columbia (BC). The RDH researchers indicated that buildings in Canada that were tested all have air barriers but there were no air leakage performance requirements in place. Figure 2 presents the average airtightness of all Canadian buildings. The Statewide CASE Team chose the average infiltration rate for BC as most representative of California, although BC is cooler, given a similar emphasis on building performance.

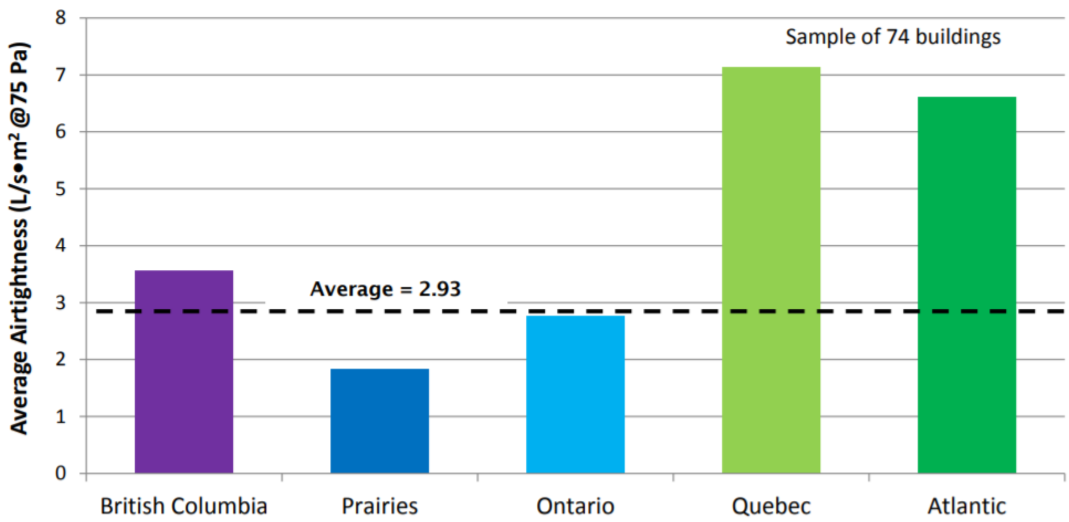

Figure 2: Average airtightness of Canadian buildings by location.

Source: (RDH Building Science Inc. 2015). Appeared as Figure 3.30 in report.

The final datapoint, 0.69 cfm/ft^2 (12.6 m^3/h*m^2) at 75 Pa, is from the NIST report and is the average leakage measured in the 152 buildings in locations with more than 2000 heating degree-days. This data set included all buildings regardless of design strategies to reduce air leakage. However, given leakage is more noticeable in cooler climates, it is likely that many of the buildings in cooler climate zones have air barriers. This data set also includes buildings that were aiming to minimize leakage to comply with code requirements or achieve credit for incentive programs. Although the NIST analysis did evaluate leakage rates for buildings with and without air barriers, the data for buildings that included air barriers is more indicative of buildings that have the air barrier and the air barrier is verified.

For reference, PNNL used a leakage rate of 1.0 cfm/ft^2 envelope area at 75 Pa to represent the leakage rate of buildings that are subject to mandatory air barrier requirements with no verification process in place. This analysis evaluated the reduced infiltration prescriptive option proposal for the 2018 IECC that requires buildings to achieve a verified infiltration rate less than 0.25 cfm/ft^2 envelope area at 75 Pa (R. Hart, et al. 2015). However, during the Utility Sponsored Stakeholder meeting, former staff from PNNL indicated that these building had infiltration rates in the 0.4 to 0.8 cfm/ft^2 range when tested and that 0.8 cfm/ft^2 seemed an appropriate baseline.

Scenario C: Continuous Air Barrier Plus Field Verification.

Statewide CASE Team recommends an infiltration rate of 0.5 cfm/ft^2 at 75 Pa when there is a continuous air barrier that is field verified. This rate is between the value used for Scenario B (continuous air barrier with no verification) and Scenario D (continuous air barrier verified with whole-building leakage test). Testing professionals emphasized that field verification would certainly improve building infiltration rate but would not guarantee performance the same way that a test does. The recommended leakage rate is consistent with the mean infiltration rate of the “all new data” values in Table 12 when excluding buildings in Washington – 0.45cfm/ft^2 at 75 Pa. These are buildings where attention was paid to the air barrier for efficiency or research purposes, but they were not being tested for code compliance. This approach is consistent with that used in ASHRAE 90.1-2019, where the air barrier verification program is assigned a higher infiltration rate (0.6cfm/ft^2 at 75 Pa) than a whole building air infiltration test (0.4cfm/ft^2 at Pa).

The leakage rates for buildings where the air barrier is verified through a visual inspection are expected to perform better than an unverified air barrier, but not as well as buildings that undergo whole-building leakage testing.

Scenario D: Continuous Air Barrier Plus Whole-building Leakage Testing – Standard Default Credit.

The Statewide CASE Team recommends using an infiltration rate of 0.4 cfm/ft^2 at 75 Pa when there is a continuous air barrier plus a whole-building leakage test. The RDH analysis evaluated air leakage of buildings in two jurisdictions that have mandatory air leakage testing requirements and target leakage rates. At the time testing was completed, the state of Washington had a requirement to test buildings and to achieve a leakage rate of 0.4 cfm/ft^2 at 75 Pa. Researchers found “the average airtightness of these buildings is significantly lower than for the dataset as a whole, and the variation in performance is also significantly reduced” (Ricketts, Impact of Large Building Airtightness 2016). Nearly all the buildings met the performance requirement, and the average leakage of all buildings that were subject to the code requirement was lower than the performance target. When the state of Washington introduced its whole building air leakage testing requirement it was not mandatory to meet the target of 0.4 cfm/ft^2 at 75 Pa, yet the Washington buildings in the RDH database had an average infiltration rate of 0.26 cfm/ft^2 at 75 Pa and median infiltration rate of 0.20 cfm/ft^2 at 75 Pa (see Figure 3). RDH also evaluated buildings that complied with the United States Army Core of Engineers (USACE) requirements that new military buildings built after 2012 be tested and achieve an airtightness of 0.25 cfm/ft^2 at 75 Pa. Of the 260 buildings tested, only 19 did not meet the performance requirement, indicating that it is technically feasible to achieve airtightness performance requirements.

Although there is evidence from the state of Washington that buildings achieve lower leakage rates when an airtightness target is established, the Statewide CASE Team feels it is appropriate to use the target value as a default as opposed to a lower value that would be supported by test data from Washington. The proposed leakage target of 0.4 cfm/ft^2 at 75 Pa is consistent with the current prescriptive option in Title 24, Part 6, as well as the mandatory maximum permitted infiltration rate in ASHRAE 90.1-2019 and the mandatory air barrier option in IECC- 2018.

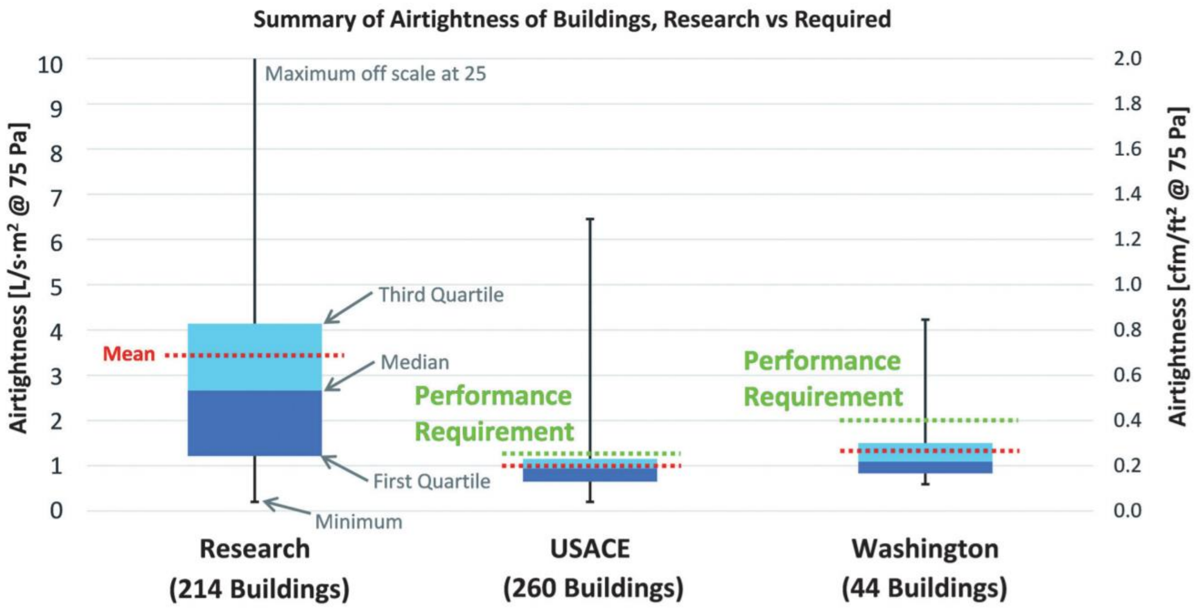

Figure 3: Distribution of airtightness performance of buildings tested for research purposes, and for compliance with United States Army Core of Engineers and Washington state airtightness requirements.

Source: (Ricketts, Impact of Large Building Airtightness 2016).

Scenario E: Continuous Air Barrier Plus Whole-building Leakage Testing – Actual Test Result.

The Statewide CASE Team is proposing a performance option to enter the air leakage test result that is below 0.4 cfm/ft^2 and receive compliance credit. The intent is to encourage project teams to achieve a higher level of building airtightness and additional flexibility with this compliance option. However, if a project team chooses an infiltration rate below 0.4 cfm/ft^2 at 75 Pa and does not achieve it the compliance run would have to be adjusted with the tested value and the energy penalty either absorbed by the budget or the building would have to make it up somewhere.

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 13. The ApartmentHighRise and HotelSmall prototypes were excluded because the Statewide CASE Team is still reconciling the nonresidential and residential requirements for these two building types. The Assembly, and SchoolPrimary prototypes were excluded from the statewide savings and cost effectiveness determination because the modeling needs further investigation – see the cost-effectiveness results in Appendix H. The Refrigerated Warehouse prototype was excluded because the measure would not apply to this building type. However, other than the Grocery prototype, cost effectiveness was completed for all of the prototypes.

Table 13: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name	Number of Stories	Floor Area (square feet)	Description
ApartmentHighRise	10	93,632	10 story apartment building with a basement and elevator penthouse, 75 residential units and other common spaces including lobby, office, multipurpose room, exercise center, laundry, and storage
Assembly	1	34,007	5-zone assembly building DEER prototype model provided by SCE
Grocery	1	50,002	6-Zone Grocery Store DEER prototype model provided by SCE
Hospital	5	249,985	5-Story Hospital ASHRAE prototype model provided
HotelSmall	4	42,554	4 story Hotel with 77 guest rooms. WWR-11%
OfficeLarge	12	498,589	12 story + 1 basement office building with 5 zones and a ceiling plenum on each floor. WWR-0.40
OfficeMedium	3	53,628	3 story office building with 5 zones and a ceiling plenum on each floor. WWR-0.33
OfficeMediumLab	3	53,628	3 story office building with 5 zones and a ceiling plenum on each floor. WWR-0.33
OfficeSmall	1	5,502	1 story, 5 zone office building with pitched roof and unconditioned attic. WWR- 0.24
RestaurantFastFood	1	2,501	Fast food restaurant with a small kitchen and dining areas. 14% WWR. Pitched roof with an unconditioned attic.
RetailLarge	1	240,000	Big-box type Retail building with WWR -12% and SRR-0.82%

Prototype Name	Number of Stories	Floor Area (square feet)	Description
RetailMixedUse	1	9,375	Retail building with WWR -10%. Roof is adiabatic
RetailStandAlone	1	24,563	Similar to a Target or Walgreens.7% WWR on the front façade, none on other sides. SRR of 2.1%.
RetailStripMall	1	9,375	Strip Mall building with WWR -10%
SchoolPrimary	1	24,413	Elementary school with WWR of 0.36
SchoolSecondary	2	210,866	High school with WWR of 35% and SRR 1.4%
Warehouse	1	49,495	Single story high ceiling warehouse. Includes one office space. WWR- 0.7%, SRR-5%

The Statewide CASE Team estimated energy and demand impacts by simulating the proposed code change using EnergyPlus. The baseline models were sourced from the 2022 Research Version of the California Building Energy Code Compliance software for Commercial buildings (CBECC-Com) for each prototypical building. CBECC-Com generates two models based on user inputs: the Standard Design and the Proposed Design. 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 Nonresidential ACM Reference Manual. 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. There is an existing Title 24, Part 6 requirement that covers the building system in question and applies to both new construction and alterations, so the Standard Design is minimally compliant with the 2019 Title 24, Part 6 requirements. As discussed above, the Standard Design in CBECC-Com for the 2019 code assumes infiltration rates that are not representative of the 2019 code requirements, so the Statewide CASE Team revised the Standard Design infiltration rate assumptions to represent minimal compliance with the 2019 code.

In Climate Zones 10 through16, buildings are required to have continuous air barriers, so the Standard Design in these climate zones was assumed to have an infiltration rate of 0.7 cfm/ft^2 at 75 Pa when measured through the entire envelope (six sides). In Climate Zones 1-9 and for alterations there is no air barrier requirement in the 2019 code, so the Statewide CASE Team therefore used an infiltration rate of 1.1 cfm/ft^2 for new construction in Climates Zones 1-9 and for alterations in all 16 climate zones.

The Proposed Design was identical to the Standard Design in all ways except for the revisions that represent the proposed changes to the code. Table 14 presents precisely which parameters were modified and what values were used in the Standard Design and Proposed Design. The proposed conditions assume an infiltration rate of 0.4 cfm/ft^2 at 75 Pa in all 16 climate zones. The impacts of the proposed measure are climate-specific and so all climate zones were modeled.

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.

CBECC-Com uses EnergyPlus as a simulation engine. EnergyPlus can model infiltration two ways – assuming all infiltration occurs through the walls (i.e. four sides) or assuming infiltration occurs through the entire building envelope (i.e. six sides). CBECC-Com uses the infiltration through walls approach, but the Energy Commission recently identified an error in how CBECC-Com was applying leakage rates, that are typically reported based on leakage through the entire six-sided envelope. The software inadvertently applied six-sided leakage rates to calculations that assume leakage through walls only. This results in an underestimation of whole-building infiltration. The Energy Commission has indicated they will be releasing an updated version of the 2019 version of CBECC-Com that addresses this error. CBECC-Com will continue to use the infiltration through walls only approach, but the infiltration rates, which are typically reported in infiltration through the entire envelope area, will be adjusted to account for infiltration through walls only before being entered into the simulation tool. The leakage value per square foot of the six-sided envelope area will be tripled to arrive at the leakage rate per square foot of the four-sided envelope. For example, if a building has an infiltration rate of 0.4 cfm/ft^2 at 75 Pa through the entire envelope, the leakage rate is 1.2 cfm/ft^2 at 75 Pa through the walls. The Statewide CASE Team used the revised approach to simulate the impacts of the proposed code change.

The leakage rates through the entire envelope (six sides) that the Statewide CASE Team used in the analysis are presented above in Table 11. These infiltration rates for the six sides of the building envelope were converted to four-sided infiltration through the walls only by multiplying the cfm/ft^2 for the six sides by a factor of three (e.g., 0.4 cfm /ft^2 at 75 Pa for the envelope becomes 1.2 cfm/ft^2 at 75 Pa through the walls). EnergyPlus uses infiltration values using SI units at standard pressure (4 Pa), so the infiltration values were converted from cfm/ft^2 at 75 Pa to m^3/(s*m^2) at 4 Pa to model the effects in EnergyPlus. See Table 14 for the infiltration parameters used in the analysis.

Table 14: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change

Prototype ID	Climate Zone	Parameter Name	Standard Design Parameter Value $[m^3/(s*m^2)]/(cfm/ft^2)$	Proposed Design Parameter Value $[m^3/(s*m^2)]/(cfm/ft^2)$
New Construction - Nonresidential Buildings	10-16	Building Infiltration	0.0012/0.7	0.0007/0.4
New Construction - Nonresidential Buildings	1-9	Building Infiltration	0.0019/1.1	0.0007/0.4
Alterations - Nonresidential Buildings	All	Building Infiltration	0.0019/1.1	0.0007/0.4

EnergyPlus calculates whole-building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/yr) and therms per year (therms/yr). The Statewide CASE team then applied the hourly 2022 time dependent valuation (TDV) factors to calculate annual TDV energy use (TDV kBtu/yr) and annual peak electricity demand reductions measured in kilowatts (kW). The Statewide CASE team then applied present value dollar (2023 PV$) factors and nominal dollar factors to calculate present value and nominal cost savings.

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

Per-unit energy impacts for nonresidential buildings are presented in savings per square foot. Annual energy and peak demand impacts for each prototype building were translated into impacts per square foot by dividing by the floor area of the prototype building. This step allows for an easier comparison of savings across different building types and enables a calculation of statewide savings using the construction forecast that is published in terms of floor area by building type.

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 (California Energy Commission 2020). The Statewide Construction Forecasts estimate new construction that would 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, so the Energy Commission provided guidance on which prototypical buildings to use for each Building Type ID when calculating statewide energy impacts. Table 15 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.

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

Table 15: Nonresidential Building Types and Associated Prototype Weighting

Building Type ID from Statewide Construction Forecast	Building Prototype for Energy Modeling	Weighting Factors for Statewide Impacts Analysis
Small Office	OfficeSmall	100%
Large Office	OfficeMedium	50%
	OfficeLarge	50%
Restaurant	RestaurantFastFood	100%
Retail	RetailStandAlone	10%
	RetailLarge	75%
	RetailStripMall	5%
	RetailMixedUse	10%
Grocery Store	Grocery	100%
Non-Refrigerated Warehouse	Warehouse	100%
Refrigerated Warehouse	RefrigWarehouse	N/A
Schools	SchoolPrimary	60%
	SchoolSecondary	40%
Colleges	OfficeSmall	5%
	OfficeMedium	15%
	OfficeMediumLab	20%
	PublicAssembly	5%
	SchoolSecondary	30%
	ApartmentHighRise	25%
Hospitals	Hospital	100%
Hotel/Motels	HotelSmall	100%

4.3 Per-Unit Energy Impacts Results

Example energy savings and peak demand reductions per unit are presented in Table 16 and Table 17. The per-unit savings for the OfficeLarge are presented because this building type has the largest forecasted construction area. See Appendix I for per unit savings for all other building types. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. For the OfficeLarge prototype, per-unit savings for the first year are expected to range from -0.023 to 0.036 kWh/yr and 0.002 to 0.021 therms/yr depending upon climate zone. Demand reductions/increases are expected to range between -0.002 W/ft^2 and 0.027 W/ft^2 depending on climate zone. The new construction savings for Climate Zone 1-9 correspond to a baseline infiltration rate of 1.1 cfm/ft^2 at 75 Pa and the savings for Climate Zone 10-16 correspond to a baseline infiltration rate of 0.7 cfm/ft^2 at 75 Pa. The alterations savings correspond to a baseline infiltration rate of 1.1 cfm/ft^2 at 75 Pa. For alterations, the estimated savings are conservative since the model uses 2019 CBECC default values instead of vintage building construction type and HVAC system efficiencies.

This measure is not expected to have significant demand management impacts for mixed fuel buildings.

In the Warehouse prototype schedule, the off hours are from 5pm to 6am and therefore that is when the infiltration is occurring. The Statewide CASE Team therefore decided to use the savings from the warehouse prototype with the assumption that loading docks are not likely to be open from 5pm to 6am. The Statewide CASE Team is looking for feedback from stakeholders on these assumptions.

Table 16: First-Year Energy Impacts Per Square Foot – New Construction – OfficeLarge Prototype Building

Climate Zone	Electricity Savings (kWh/ft^2)	Peak Electricity Demand Reductions (W/ft^2)	Natural Gas Savings (therms/ft^2)	TDV Energy Savings (TDV kBtu/ft^2)
1	(0.020)	(0.002)	0.021	4.924
2	0.018	0.000	0.011	4.186
3	(0.023)	(0.002)	0.017	4.094
4	(0.001)	0.003	0.009	3.337
5	(0.003)	0.003	0.013	3.353
6	(0.007)	0.027	0.010	2.937
7	(0.022)	0.003	0.005	0.801
8	(0.013)	(0.000)	0.003	0.903
9	0.016	0.016	0.007	3.256
10	0.012	0.004	0.004	1.686
11	0.013	0.004	0.008	3.161
12	0.032	0.004	0.006	2.826
13	0.013	0.003	0.004	2.075
14	0.024	0.003	0.009	3.438
15	0.036	0.005	0.002	2.121
16	(0.003)	(0.003)	0.012	3.206

Table 17: First-Year Energy Impacts Per Square Foot – Alterations – OfficeLarge Prototype Building

Climate Zone	Electricity Savings (kWh/ft²/yr)	Peak Electricity Demand Reductions (W/ft²)	Natural Gas Savings (therms/ft²/yr)	TDV Energy Savings (TDV kBtu/ft²/yr)
1	(0.020)	(0.002)	0.021	4.924
2	0.018	0.000	0.011	4.186
3	(0.023)	(0.002)	0.017	4.094
4	(0.001)	0.003	0.009	3.337
5	(0.003)	0.003	0.013	3.353
6	(0.007)	0.027	0.010	2.937
7	(0.022)	0.003	0.005	0.801
8	(0.013)	(0.000)	0.003	0.903
9	0.016	0.016	0.007	3.256
10	0.021	0.007	0.008	3.373
11	0.031	0.008	0.020	7.319
12	0.033	0.003	0.012	5.043
13	0.026	0.002	0.010	4.578
14	0.051	0.004	0.021	7.736
15	0.086	0.014	0.005	4.807
16	(0.019)	(0.015)	0.028	6.959

5. Cost and Cost Effectiveness

5.1 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. 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. The TDV cost impacts are presented in nominal dollars and in 2023 present value dollars and represent the energy cost savings realized over 30 years.

The proposed code change applies to new construction as well as additions and alterations. The energy cost savings for additions and alterations were estimated as being the same as the energy cost savings for new construction in Climate Zones 1-9 where there is no air barrier requirement. However, the Statewide CASE Team believes that this is a conservative estimate, since older vintage buildings do not have the same improvements in water barriers and continuous insulation. These improvements reduce infiltration rate even when there is no air barrier requirement.

5.2 Energy Cost Savings Results

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 18 and Table 19 and 2023 dollars in Table 20: and Table 21 for the OfficeLarge prototype. The nominal savings tables will be updated in the Final CASE Report with the newest nominal values. For new construction, Climate Zones 1-9 have a baseline infiltration rate of 1.1 cfm/ft^2 at 75 Pa and Climate Zones 10-16 have a baseline infiltration rate of 0.7 cfm/ft^2. Additions and alterations all have a baseline infiltration rate of 1.1 cfm/ft^2.

The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods, however this measure does not have significant electricity savings.

Table 18: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction – Large Office

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	($0.09)	$1.68	$1.59
2	$0.30	$0.89	$1.19
3	($0.06)	$1.38	$1.32
4	$0.20	$0.77	$0.97
5	$0.01	$1.04	$1.05
6	$0.09	$0.79	$0.89
7	($0.10)	$0.40	$0.30
8	$0.00	$0.28	$0.28
9	$0.32	$0.57	$0.89
10	$0.16	$0.30	$0.46
11	$0.20	$0.71	$0.91
12	$0.30	$0.46	$0.76
13	$0.21	$0.35	$0.56
14	$0.23	$0.76	$0.98
15	$0.32	$0.21	$0.53
16	($0.00)	$1.01	$1.01

Table 19: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations – OfficeLarge

Climate Zone	15/30-Year TDV Electricity Cost Savings (Nominal $)	15/30-Year TDV Natural Gas Cost Savings (Nominal $)	Total 15/30-Year TDV Energy Cost Savings (Nominal $)
1	($0.09)	$1.68	$1.59
2	$0.30	$0.89	$1.19
3	($0.06)	$1.38	$1.32
4	$0.20	$0.77	$0.97
5	$0.01	$1.04	$1.05
6	$0.09	$0.79	$0.89
7	($0.10)	$0.40	$0.30
8	$0.00	$0.28	$0.28
9	$0.32	$0.57	$0.89
10	$0.28	$0.66	$0.94
11	$0.46	$1.65	$2.11
12	$0.40	$1.01	$1.41
13	$0.43	$0.82	$1.25
14	$0.49	$1.74	$2.23
15	$0.73	$0.46	$1.19
16	($0.10)	$2.35	$2.24

Table 20: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction – OfficeLarge

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	($0.06)	$0.82	$0.76
2	$0.21	$0.43	$0.64
3	($0.04)	$0.67	$0.63
4	$0.14	$0.38	$0.51
5	$0.01	$0.51	$0.52
6	$0.06	$0.39	$0.45
7	($0.07)	$0.20	$0.12
8	$0.00	$0.14	$0.14
9	$0.22	$0.28	$0.50
10	$0.11	$0.15	$0.26
11	$0.14	$0.35	$0.49
12	$0.21	$0.22	$0.44
13	$0.15	$0.17	$0.32
14	$0.16	$0.37	$0.53
15	$0.22	$0.10	$0.33
16	($0.00)	$0.49	$0.49

Table 21: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations – OfficeLarge

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	($0.06)	$0.82	$0.76
2	$0.21	$0.43	$0.64
3	($0.04)	$0.67	$0.63
4	$0.14	$0.38	$0.51
5	$0.01	$0.51	$0.52
6	$0.06	$0.39	$0.45
7	($0.07)	$0.20	$0.12
8	$0.00	$0.14	$0.14
9	$0.22	$0.28	$0.50
10	$0.20	$0.32	$0.52
11	$0.32	$0.81	$1.13
12	$0.28	$0.49	$0.78
13	$0.30	$0.40	$0.71
14	$0.34	$0.85	$1.19
15	$0.51	$0.23	$0.74
16	($0.07)	$1.14	$1.07

5.3 Incremental First Cost

The Statewide CASE Team used two baselines and therefore used two sets of incremental costs. The first baseline is for buildings that already have air barrier requirements – nonresidential new construction in Climate Zones 10-16. For these buildings, the only incremental cost that the Statewide CASE Team considered was the cost of whole building air leakage testing. There is not expected to be an increase in construction costs – there is no change in the materials being used, only an emphasis on ensuring the existing requirements of Section 110.7 of Title 24, Part 6 are met: "All joints, penetrations and other openings in the building envelope that are potential sources of air leakage shall be caulked, gasketed, weather stripped, or otherwise sealed to limit infiltration and exfiltration."

The Statewide CASE Team divided the building prototypes into two categories: those with more than and less than 10,000 ft^2 of conditioned space. This is the existing threshold in Title 24, Part 6 for third party design review and for the construction phase of building commissioning. Given their familiarity with RESNET/ANSI 380 the Statewide CASE Team reached out to five HERS Raters that cover North California, Fresno, the Central Valley, San Diego, and Los Angeles to estimate the price of testing the prototype buildings under 10,000 ft^2 according to RESNET/ANSI 380. The HERS Raters gave a range of cost for the testing and chose the average value when determining the cost for each building prototype – see Table 22.

Table 22: Cost of Testing Buildings under 10,000 ft^2 of Conditioned Area

Building Prototype	Conditioned floor area	Range of testing cost	Average testing cost
OfficeSmall	5503 ft^2	$400-600	$500
RestaurantFastFood	2501 ft^2	$500-700	$600
RetailMixedUse	9376 ft^2	$600-1000	$800
RetailStripMall	9376 ft^2	$600-1000	$800

The Statewide CASE Team spoke with professionals from three testing agencies, two of which have offices inside and outside of California, to determine the cost of testing buildings over 10,000 ft^2. The cost of testing includes preparation and coordination, executing the test, and data analysis. Testing professionals provided the cost of testing buildings from 10,000 - 400,000 ft^2 of envelope area – see Table 23. Note that some of the buildings in Table 22 have greater than 10,000 ft^2 of envelope area but have less than 10,000 ft^2 of conditioned floor area.

Table 23: Cost of Testing Buildings over 10,000 ft² of conditioned area

Envelope Area (6 sides)	Cost from Agency 1 (\$/ft²)	Cost from Agency 2 (\$/ft²)	Cost from Agency 3 (\$/ft²)	Average Cost (\$/ft²)
10,000 ft²	\$0.30	\$0.40	\$0.64	\$0.45
25,000 ft²	\$0.15	\$0.22	\$0.29	\$0.22
50,000 ft²	\$0.12	\$0.14	\$0.15	\$0.14
100,000 ft²	\$0.11	\$0.09	\$0.09	\$0.10
200,000 ft²	\$0.10	\$0.05	\$0.07	\$0.07
400,000 ft²	\$0.10	\$0.03	\$0.06	\$0.06

The average cost was then plotted and fitted to a power curve in order to determine the cost of testing for each prototype building based on the exact envelope area – see Figure 4.

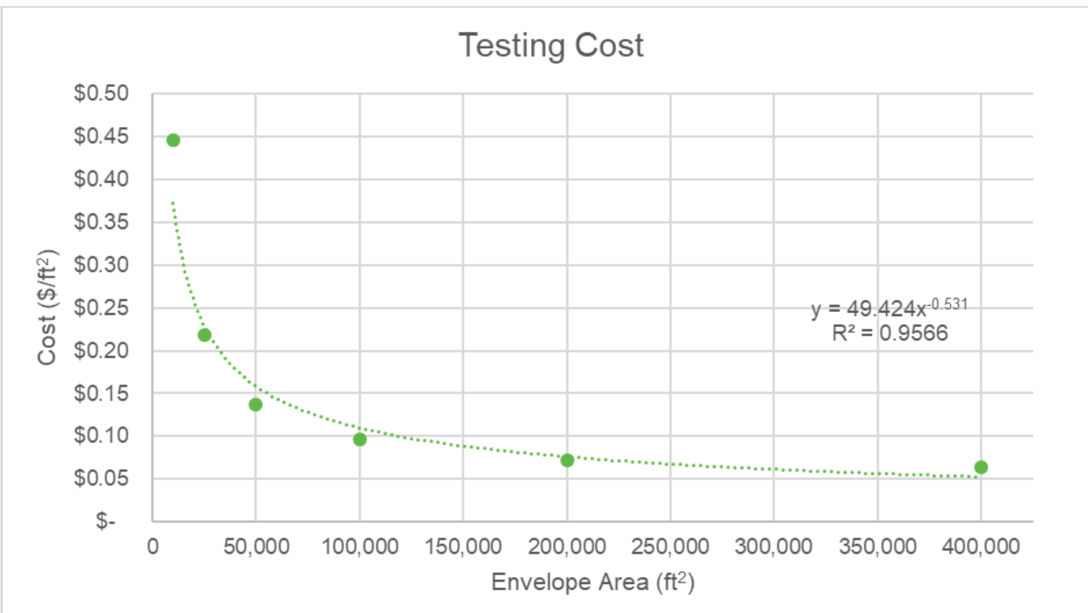

Figure 4: Cost of testing large nonresidential buildings with power trendline.

The cost of testing was determined for each building prototype with more than 10,000 ft² of conditioned space was then determined based on envelope surface area (those building not mentioned in Table 22). The cost of testing for each building prototype is in shown in Table 24. Morrison Hershfield also estimated the cost of executing the air verification program and that is shown in Table 24 to give a comparison. The cost of the verification program was not used for cost-effectiveness purposes.

Table 24: Cost of Whole Building Air Leakage Testing for Each Prototype

Building Prototype	Conditioned Floor Area (ft^2)	Envelope Surface Area (ft^2)	Cost per Square Foot of Total Envelope Surface Area	Cost of Testing Entire Prototypical Building	Cost of Verification Program
ApartmentHighRise	93,632	60,268	$0.14	$8,625.80	$26,000
Assembly	34,007	79,079	$0.12	$9,797.80	$18,000
Grocery	50,002	122,366	$0.10	$12,024.06	$18,000
Hospital	249,985	136,316	$0.09	$12,648.56	$18,000
HotelSmall	42,554	39,846	$0.18	$7,104.26	$18,000
OfficeLarge	498,589	201,452	$0.08	$15,191.27	$26,000
OfficeMedium	53,628	57,046	$0.15	$8,406.32	$18,000
OfficeMediumLab	53,628	57,048	$0.15	$8,406.46	$18,000
OfficeSmall	5,502	15,922	$0.03	$500.00	$3,000
RestaurantFastFood	2,501	7,574	$0.08	$600.00	$3,000
RetailLarge	240,000	530,052	$0.05	$23,913.50	$18,000
RetailMixedUse	9,375	24,274	$0.03	$800.00	$3,000
RetailStandAlone	24,563	62,060	$0.14	$8,745.13	$18,000
RetailStripMall	9,375	25,549	$0.03	$800.00	$5,000
SchoolPrimary	24,413	62,777	$0.14	$8,792.41	$18,000
SchoolSecondary	210,866	320,494	$0.06	$18,887.19	$26,000
Warehouse	49,495	125,870	$0.10	$12,184.32	$15,000

The second baseline is for buildings that have no air barrier requirements – nonresidential new construction in Climate Zones 1-9 and additions and alterations. For these buildings, the Statewide CASE Team considered the incremental cost of installing an air barrier in addition to the cost of whole building air leakage testing. Contractors and testing professionals told the Statewide CASE Team that an appropriate baseline for not having an air barrier would be either two layers of building paper or a layer of building paper and a layer of loosely laid Tyvek, and a proposed case with an air barrier would have the layer of Tyvek be air sealed – so the primary incremental costs are labor for air sealing and possibly the cost of going from a layer of building paper to a layer of Tyvek.

The Statewide CASE Team spoke to a Tyvek specialist based in Washington and another based in California who were both be familiar with the implementation of air barrier requirements. The Tyvek specialists said that there has generally been a shift from 60-minute Grade D building paper to higher performance wraps such as Tyvek and that the cost to make Tyvek act as an air barrier is small and only requires a couple extra items and further sealing. One specialist estimated that installing an entire weather and air barrier Tyvek system would cost $0.40-$0.55/ft^2 of wall area. The Statewide CASE Team estimated that the cost of air sealing the Tyvek wrap was approximately 5 percent of the total cost, or $0.02-$0.03/ft^2 of wall area. The other specialist estimated the incremental material cost of going from building paper to Tyvek to be $0.06/ft^2. The Statewide CASE Team therefore assumed an average incremental cost of $0.05/ft^2 of wall area to account both the case of a loose layer Tyvek needing to be air sealed ($0.02/ft^2) and replacing a layer of building paper with Tyvek that is air sealed ($0.08/ft^2). The incremental cost of the air barrier and the total cost of the air barrier and whole building air leakage testing can be found in Table 25.

Table 25: Total Incremental Cost for Buildings without Air Barriers

Building Prototype	Gross Wall Area Above Ground (ft^2)	Cost of Air Barrier	Total Cost	Air Barrier Percent of Total Cost
ApartmentHighRise	43,244	$2,162.21	$10,788.01	20%
Assembly	11,065	$553.25	$10,351.06	5%
Grocery	22,362	$1,118.11	$13,142.17	9%
Hospital	55,810	$2,790.51	$15,439.07	18%
HotelSmall	18,242	$912.11	$8,016.36	11%
OfficeLarge	124,738	$6,236.89	$21,428.16	29%
OfficeMedium	21,290	$1,064.48	$9,470.79	11%
OfficeMediumLab	21,290	$1,064.48	$9,470.93	11%
OfficeSmall	3,031	$151.53	$651.53	23%
RestaurantFastFood	2,001	$100.05	$700.05	14%
RetailLarge	50,005	$2,500.24	$26,413.74	9%
RetailMixedUse	5,524	$276.19	$1,076.19	26%
RetailStandAlone	12,671	$633.53	$9,378.66	7%
RetailStripMall	6,799	$339.93	$1,139.93	30%
SchoolPrimary	13,951	$697.57	$9,489.98	7%
SchoolSecondary	64,245	$3,212.26	$22,099.45	15%
Warehouse	26,880	$1,344.00	$13,528.32	10%

5.4 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:

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

As noted in Section 3.2, proper building air tightness reduces the risk of condensation and improves building envelope longevity. This proposal is not expected to cause an incremental maintenance cost and if anything would reduce maintenance costs. Reducing infiltration has been shown to reduce the chance of condensation and therefore also mold and rot (Straube n.d.).

5.5 Cost Effectiveness

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 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 26 and

Table 27 for new construction and alterations, respectively, for the OfficeLarge prototype. A summary of the benefit-to-cost ratio for each building prototype used in every climate zone is presented in Table 28 and Table 29 for new construction and alterations, respectively. Numbers in red are below the cost effectiveness threshold of 1.0 and numbers in red with parenthesis are negative. The construction weighted benefit-to-cost ratio for each climate zone is shown in Table 30 and was the basis for excluding Climate Zone 7 as it was shown to not be cost effective. The construction weighted benefit-to-cost ratio for each climate zone was calculated using Equation 1.

Equation 1: Constructed Weighted Benefit-To-Cost Ratio for Each Climate Zone

$$\sum BCR_{prot(i),CZ(i)} * Forecast_{prot(i),CZ(i)} / Forecast_{CZ(i)}$$

Where:

$BCR_{prot(i),CZ(i)}$ = the B/C ratio for a particular prototype the climate zone of interest

$Forecast_{prot(i),CZ(i)}$ = the construction forecast for a particular prototype in the climate zone of interest

$Forecast_{CZ(i)}$ = the total construction forecast in the climate zone of interest

The ApartmentHighRise and HotelSmall prototypes were excluded because the Statewide CASE Team is still reconciling the nonresidential and residential requirements. The Assembly, Grocery, and SchoolPrimary prototypes were excluded from the statewide savings and cost effectiveness determination because the results need further investigation and did not include these prototypes in the construction weighed benefit-to-cost ratios for each climate zone shown in Table 30 or in the statewide savings in Section 6.1. Hospitals were excluded for additions and alterations. Initial cost effectiveness calculations for all prototypes are shown in Appendix H.

The proposed measure results in cost savings over the 30-year period of analysis relative to the existing conditions. The proposed code change is cost effective in every climate zone, except Climate Zone 7. Climate Zone 7 was excluded because of the number of prototypes for which it is not cost effective and because it is only cost effective when excluding the results of the prototypes mentioned above and is not cost effective for alterations and additions (see Table 30).

Table 26: 30-Year Cost Effectiveness Per Square Foot – New Construction – OfficeLarge

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	$0.76	$0.04	17.65
2	$0.64	$0.04	15.00
3	$0.63	$0.04	14.67
4	$0.51	$0.04	11.96
5	$0.52	$0.04	12.01
6	$0.45	$0.04	10.52
7	$0.12	$0.04	2.87

8	$0.14	$0.04	3.23
9	$0.50	$0.04	11.67
10	$0.26	$0.03	8.52
11	$0.49	$0.03	15.98
12	$0.44	$0.03	14.28
13	$0.32	$0.03	10.49
14	$0.53	$0.03	17.38
15	$0.33	$0.03	10.72
16	$0.49	$0.03	16.21

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016). 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 27: 30-Year Cost Effectiveness Per Square Foot – Alterations – OfficeLarge

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	$0.76	$0.04	17.65
2	$0.64	$0.04	15.00
3	$0.63	$0.04	14.67
4	$0.51	$0.04	11.96
5	$0.52	$0.04	12.01
6	$0.45	$0.04	10.52
7	$0.12	$0.04	2.87
8	$0.14	$0.04	3.23
9	$0.50	$0.04	11.67
10	$0.52	$0.04	12.09
11	$1.13	$0.04	26.22
12	$0.78	$0.04	18.07
13	$0.71	$0.04	16.41
14	$1.19	$0.04	27.72
15	$0.74	$0.04	17.23
16	$1.07	$0.04	24.94

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016). 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 Benefit-to-Cost ratio is infinite.

Table 28: Benefit-to-Cost Ratio over 30-Year Period of Analysis – New Construction

Building Prototype	CZ01	CZ02	CZ03	CZ04	CZ05	CZ06	CZ07	CZ08	CZ09	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Hospital	10.5	8.3	11.9	10.3	8.6	9.8	4.2	4.8	8.4	5.5	9.1	6.5	5.8	12.9	6.9	7.9
OfficeLarge	17.6	15.0	14.7	12.0	12.0	10.5	2.9	3.2	11.7	8.5	16.0	14.3	10.5	17.4	10.7	16.2
OfficeMedium	4.9	2.7	3.4	2.8	2.2	1.3	0.5	1.1	2.2	1.4	3.5	1.7	2.1	3.4	2.4	3.6
OfficeMediumLab	6.5	4.0	5.7	4.3	4.1	2.8	2.0	1.7	3.0	1.7	3.8	3.4	2.3	3.9	1.6	3.8
OfficeSmall	2.1	2.5	1.8	2.2	0.0	0.0	(0.3)	2.1	2.1	1.6	5.6	3.1	5.1	5.3	4.2	4.1
RestaurantFastFood	5.2	3.0	4.5	3.2	3.0	1.2	0.8	1.5	2.5	1.5	3.1	2.1	2.1	3.2	2.2	2.6
RetailLarge	2.6	(0.0)	7.2	(0.1)	1.2	1.6	0.5	0.3	2.0	(0.4)	2.0	0.6	0.7	(0.4)	0.4	1.4
RetailMixedUse	6.9	7.8	2.9	1.9	1.4	0.5	(1.6)	1.3	1.5	5.9	5.8	1.3	2.6	8.1	2.8	6.2
RetailStandAlone	1.7	2.3	1.2	0.9	1.1	0.6	(0.1)	1.5	0.4	0.6	3.3	2.9	2.3	1.1	1.3	1.6
RetailStripMall	8.1	3.2	1.0	1.4	2.4	(1.8)	0.7	2.4	(2.3)	1.7	7.1	1.8	6.9	6.1	6.9	7.6
SchoolSecondary	7.3	4.0	6.1	3.8	4.1	2.8	1.5	1.6	2.9	1.8	4.9	2.6	3.0	4.9	2.6	7.0
Warehouse	5.1	2.2	3.8	2.1	2.6	1.6	1.1	0.8	1.1	0.7	1.9	1.2	1.0	1.8	0.4	2.4

Table 29: Benefit-to-Cost Ratio over 30-Year Period of Analysis – Alterations

Building Prototype	CZ01	CZ02	CZ03	CZ04	CZ05	CZ06	CZ07	CZ08	CZ09	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
OfficeLarge	17.6	15.0	14.7	12.0	12.0	10.5	2.9	3.2	11.7	12.1	26.2	18.1	16.4	27.7	17.2	24.9
OfficeMedium	4.9	2.7	3.4	2.8	2.2	1.3	0.5	1.1	2.2	2.9	7.3	3.5	4.5	7.3	5.0	7.5
OfficeMediumLab	6.5	4.0	5.7	4.3	4.1	2.8	2.0	1.7	3.0	3.5	7.9	5.5	4.6	7.6	4.2	6.4
OfficeSmall	2.1	2.5	1.8	2.2	0.0	0.0	(0.3)	2.1	2.1	2.9	9.5	5.2	7.7	9.2	7.5	7.2
RestaurantFastFood	5.2	3.0	4.5	3.2	3.0	1.2	0.8	1.5	2.5	2.9	6.1	4.1	4.2	6.7	4.4	5.4
RetailLarge	2.6	(0.0)	7.2	(0.1)	1.2	1.6	0.5	0.3	2.0	0.1	0.2	(0.7)	2.0	3.4	2.1	2.7
RetailMixedUse	6.9	7.8	2.9	1.9	1.4	0.5	(1.6)	1.3	1.5	5.1	11.1	4.8	5.2	10.1	6.6	10.2
RetailStandAlone	1.7	2.3	1.2	0.9	1.1	0.6	(0.1)	1.5	0.4	0.8	2.2	3.1	3.2	2.6	2.4	3.4
RetailStripMall	8.1	3.2	1.0	1.4	2.4	(1.8)	0.7	2.4	(2.3)	(1.4)	11.0	2.2	10.1	4.9	8.9	13.3
SchoolSecondary	7.3	4.0	6.1	3.8	4.1	2.8	1.5	1.6	2.9	3.8	10.0	5.3	5.8	10.4	5.3	13.0
Warehouse	5.1	2.2	3.8	2.1	2.6	1.6	1.1	0.8	1.1	1.5	3.6	2.4	1.9	3.5	1.0	4.8

Table 30: Construction-Weighted Average Benefit-to-Cost Ratio for Each Climate Zone

Climate Zone	New Construction B/C Ratio	Alterations B/C Ratio
1	6.7	6.5
2	4.5	4.3
3	6.6	6.3
4	4.2	3.8
5	4.0	3.7
6	3.3	2.8
7	1.2	0.9
8	1.6	1.4
9	4.0	3.5
10	1.7	2.5
11	4.6	6.7
12	3.5	4.7
13	2.9	4.6
14	4.5	7.6
15	2.3	3.9
16	4.5	7.5

6. First-Year Statewide Impacts

6.1 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 would 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 would be impacted by the proposal (by climate zone and building type).

The Statewide CASE Team assumed that buildings will have a major alteration to the building envelope every 50 years, at which point it will be appropriate to improve the air tightness of the building. The Statewide CASE Team assumed that alterations will not have existing air barriers, since it became a prescriptive requirement in 2013. Therefore, the Statewide CASE Team assumed that all alterations, regardless of climate zone, will have a baseline infiltration rate of 1.1 cfm/ft^2 at 75 Pa. This assumption is based on the fact that when the envelope is renovated the same improvements in weather barriers and insulation would be applied as in new construction for climate zones where there is no air barrier requirement.

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. As noted, some stakeholders have inquired about the percentage of buildings in climate zones 1 through 9 that install continuous air barriers even though it is not required in Title 24, Part 6. This information will inform naturally occurring market adoption rates, and is a helpful data point to understand market impacts. If readers have data that would help the Statewide CASE Team answer this questions, please send it to info@title24stakeholders.com.

Table 31 and Table 32 present the first-year statewide energy and energy cost savings from newly constructed buildings by climate zone. Table 33 presents first-year statewide savings from new construction, additions, and alterations. The ApartmentHighRise and HotelSmall prototypes were excluded from the analysis because the Statewide CASE Team is still reconciling the nonresidential and residential requirements. The Assembly, Grocery, and SchoolPrimary prototypes were excluded from the statewide savings and because the results need further investigation. Refrigerated warehouses were also excluded from the statewide energy impacts.

Table 31: Statewide Energy and Energy Cost Impacts – New Construction

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (million square feet	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 (million 2023 PV$)
1	0.5	(0.01)	(0.00)	0.01	$0.43
2	3.2	(0.01)	0.00	0.03	$1.42
3	15.5	(0.25)	0.05	0.25	$10.97
4	8.0	(0.06)	0.01	0.07	$3.17
5	1.5	(0.03)	0.00	0.02	$0.62
6	10.8	(0.10)	0.06	0.07	$3.03
7	NA	NA	NA	NA	NA
8	15.6	0.03	0.02	0.04	$2.83
9	26.0	(0.05)	0.14	0.14	$9.01
10	13.8	0.09	0.01	0.04	$2.33
11	2.9	0.04	0.01	0.02	$1.36
12	16.5	0.11	0.04	0.08	$4.73
13	5.7	0.07	0.01	0.02	$1.64
14	3.3	0.01	0.00	0.03	$1.35
15	1.9	0.04	0.01	0.00	$0.41
16	1.0	0.00	0.00	0.01	$0.48
TOTAL	126.3	(0.11)	0.37	0.84	$43.76

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

Table 32: Statewide Energy and Energy Cost Impacts – Alterations

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (million square feet)	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 (million 2023 PV$)
1	0.4	(0.01)	(0.00)	0.01	$0.35
2	2.6	(0.01)	0.00	0.02	$1.18
3	12.5	(0.23)	0.04	0.21	$8.99
4	6.4	(0.06)	0.01	0.05	$2.59
5	1.3	(0.03)	0.00	0.01	$0.52
6	9.6	(0.09)	0.06	0.07	$2.76
7	NA	NA	NA	NA	NA
8	13.8	0.02	0.02	0.04	$2.49
9	22.5	(0.06)	0.12	0.12	$7.75
10	13.8	0.11	0.02	0.09	$4.89
11	2.5	0.06	(0.00)	0.04	$2.23
12	13.5	0.00	0.00	0.14	$7.26
13	4.7	0.13	0.02	0.04	$2.89
14	3.2	0.05	0.02	0.05	$3.07
15	1.9	0.10	0.01	0.01	$0.95
16	1.0	0.00	(0.00)	0.02	$1.00
TOTAL	109.8	(0.01)	0.33	0.93	$48.90

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

Table 33: Statewide Energy and Energy Cost Impacts – New Construction, Alterations, and Additions

Construction Type	First-Year 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)
New Construction	(0.11)	0.37	0.84	$43.76
Additions and Alterations	(0.01)	0.33	0.93	$48.90
TOTAL	(0.11)	0.71	1.77	$92.66

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

6.2 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. 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 34 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 9,626 metric tons of carbon dioxide equivalents (metric tons CO2e) would be avoided.

Table 34: First-Year Statewide GHG Emissions Impacts

	Avoided GHG Emissions (Metric Tons CO2e/yr)[a]	Monetary Value of Avoided GHG Emissions ($2023)[a,b]
TOTAL	9,626	$288,775

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

b. Assumes the following emission factors: 240.4 MTCO2e/GWh and 5,44.4 MTCO2e/million therms.

6.3 Statewide Water Use Impacts

The proposed code change would not result in water savings.

6.4 Statewide Material Impacts

The proposed code change would not result in material impacts, since it is primarily geared towards improving sealing and detailing at envelope assembly interfaces.

6.5 Other Non-Energy Impacts

Air tightness improves occupant comfort from a standpoint of drafts, air quality/odor control, and acoustics (Gatland n.d.). In addition to this, minimizing air leakage can also mitigate the risk of condensation (Straube n.d.).

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 documents are marked with red underlining (new language) and ~~strikethroughs~~ (deletions).

7.2 Standards

Section 100.1(a) Definitions

ASTM E1680 is the American Society for Testing and Materials document titled, " Standard Test Method for Rate of Air Leakage through Exterior Metal Roof Panel Systems," 2016 (ASTM E1680-16).

Section 140.3(a)

9. Air Barrier. To meet the requirement of TABLE 140.3-B, all buildings shall have a continuous air barrier that is designed and constructed to control air leakage into, and out of, the building's conditioned space.

A. **Design.** Construction documents shall include air barrier boundaries, interconnections and penetrations, and associated square foot calculations for all sides of the air barrier.

B. **Acceptable Materials and Assemblies.** The air barrier shall be sealed at all joints and penetrations for its entire area and shall be composed of either:

~~A~~ i. Materials that have an air permeance not exceeding 0.004 cfm/ft^2, under a pressure differential of 0.3 in. of water (1.57 psf) (0.02 L/sec-m^2 at 75 pa), when tested in accordance with ASTM E2178; or

EXCEPTION to Section 140.3(a)9~~A~~Bi: Materials in TABLE 140.3-~~A~~B shall be deemed to comply with Section 140.3(a)9 ~~A~~B provided if all joints are sealed and all of the materials are installed as air barriers in accordance with the manufacturer's instructions.

TABLE 140.3-A MATERIALS DEEMED TO COMPLY WITH SECTION 140.3(a)9~~A~~B

	MATERIALS AND THICKNESS		MATERIALS AND THICKNESS
1	Plywood – min. 3/8 inches thickness	9	Built up roofing membrane
2	Oriented strand board – min. 3/8 inches thickness	10	Modified bituminous roof membrane
3	Extruded polystyrene insulation board – min. 1/2 inches thickness	11	Fully adhered single-ply roof membrane

4	Foil-back polyisocyanurate insulation board – min. 1/2 inches thickness	12	A Portland cement or Portland sand parge, or a gypsum plaster, each with min. 5/8 inches thickness
5	Closed cell spray foam with a minimum density of 2.0 pcf and a min. 2.0 inches thickness	13	Cast-in-place concrete, or precast concrete
6	Open cell spray foam with a density no less than 0.4 pcf and no greater than 1.5 pcf, and a min. 5.5 inches thickness	14	Fully grouted concrete block masonry
7	Exterior or interior gypsum board - min. 1/2 inches thickness	15	Sheet steel or sheet aluminum
8	Cement board – min. 1/2 inches thickness	---	---------------------------------

B ii. Assemblies of materials and components that have an average air leakage not exceeding 0.04 cfm/ft^2, under a pressure differential of 0.3 in. of water (1.57 psf) (0.2 L/m^2 at 75 pa), when tested in accordance with ASTM E2357, ASTM E1677, ASTM E1680, or ASTM E283; or

EXCEPTION to Section 140.3(a)9Bii: The following materials shall be deemed to comply with Section 140.3(a)9B if all joints are sealed and all of the materials are installed as air barriers in accordance with the manufacturer's instructions:

i. Concrete masonry walls that have at least two coatings of paint or at least two coatings of sealer coating.

ii. Concrete masonry walls with integral rigid board insulation.

iii. Structurally Insulated Panels.

iv. Portland cement or Portland sand parge, or stucco, or a gypsum plaster, each with min. 1/2 inches thickness

C. **Verification.** The entire building shall meet one of the following requirements:

i. The entire building has aAn air leakage rate that meets one of the following requirements not exceeding 0.4 cfm/ft^2 of building shell area at a pressure differential of 0.3 in of water (1.57 psf) (2.0 L/ m^2 at 75 pa), when the entire building is tested, after completion of construction, in accordance with ASTM E779 NA2.4, or another test method approved by the Commission; or

ii. For buildings that have more than 50,000ft^2 of conditioned floor area, a sectional test method of co-pressurizing representative test floors and taking data from the specific floors is permitted to achieve the requirement in Section 140.3(a)9Ci. when following the procedures in Sections NA2.4.2-2.4.7. Representative test floors must meet the following conditions:

a. The entire floor area of all stories that have any spaces directly under a roof.

b. The entire floor area of all stories that have a building entrance or loading dock.

Representative above-grade wall sections of the building totaling at least 25% of the wall area enclosing the remaining conditioned space. Floor areas in parts a) and b) shall not be included in the 25%; or

iii. If the air leakage requirements of either Section 140.3(a)9Ci or 140.3(a)9Cii are not met, a Visual Inspection and Diagnostic Evaluation shall been completed in accordance with NA2.4.7, all observed leaks shall be sealed where such sealing can be made without destruction of existing building components, and buildings where the tested leakage rate exceeded 0.6 cfm/ft^2 of building shell area at 75 pa have been re-tested to confirm leakage is below 0.6 cfm/ft^2 of building shell at 75 pa.

iv. Verification of the design and installation of the continuous air barrier conducted by an independent third party in accordance with NA 2.5.

Exception to Section 140.3(a)9C: Buildings in Climate Zone 7 need not comply with Section 140.3(a)9C.

EXCEPTION to Section 140.3(a)9: Relocatable Public School Buildings.

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

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

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

				Climate Zone															
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Envelope	Maximum U-factor	**Roofs/ Ceilings**	Metal Building	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
			Wood Framed and Other	0.028	0.028	0.034	0.028	0.034	0.034	0.039	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
		Walls	**Metal Building**	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.057	0.057	0.057	0.057	0.057	0.057
			Metal-framed	0.069	0.069	0.069	0.069	0.069	0.069	0.105	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.048	0.069
			Mass, Light[1]	0.170	0.170	0.170	0.170	0.170	0.227	0.227	0.227	0.196	0.170	0.170	0.170	0.170	0.170	0.170	0.170
			Mass, Heavy[1]	0.160	0.160	0.160	0.184	0.211	0.690	0.690	0.690	0.690	0.690	0.184	0.253	0.211	0.184	0.184	0.160
			Wood-framed and Other	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.042	0.059	0.059	0.042	0.042	0.042
		Floors / Soffits	Raised Mass[1]	0.045	0.045	0.058	0.058	0.058	0.069	0.092	0.092	0.092	0.069	0.058	0.058	0.058	0.045	0.058	0.037
			Other	0.034	0.034	0.039	0.039	0.039	0.039	0.071	0.039	0.039	0.039	0.039	0.039	0.039	0.034	0.039	0.034
	Roofing	**Low-sloped**	Aged Solar Reflectance	NR	NR	NR	NR	NR	NR	NR	NR	0.55	0.55	0.55	NR	0.55	0.55	0.55	NR
			Thermal Emittance	NR	NR	NR	NR	NR	NR	NR	NR	0.75	0.75	0.75	NR	0.75	0.75	0.75	NR
		Steep-Sloped	Aged Solar Reflectance	NR	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	NR
			Thermal Emittance	NR	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0. 75	0.75	0.75	0.75	0.75	0.75	NR
	Air Barrier			REQ	REQ	REQ	REQ	REQ	REQ	NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ
	Exterior Doors, Maximum U-factor		Non-Swinging	0.50	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	0.50
			Swinging	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70

Section 141.0(b)2

Q. Existing building envelope wall where at least 25% or more of the wall area is being altered must comply with Section 140.3(a)9.

i. If less than 100% of the wall area is being altered, where the building is tested in accordance with the procedures for whole building air leakage in NA2.4 and the tested leakage rate exceeds 0.6 cfm/ft^2 of building shell area at 75 pa, a Visual Inspection and Diagnostic Evaluation shall been completed in accordance with NA2.4.7 and all observed leaks shall be sealed where such sealing can be made without destruction of existing building components.

ii. Buildings where the tested leakage rate exceeded 0.6 cfm/ft^2 of building shell area at 75 pa have been re-tested to confirm leakage is below 0.6 cfm/ft^2 of building shell at 75 pa.

Exception to Section 141.0(b)2Q Alterations to wall cavities that are insulated to full depth with insulation having a minimum nominal value of R-3.0/in. provided the alteration will not increase the energy use of the building.

Exception to Section 141.0(b)2Q healthcare facilities.

7.3 Reference Appendices

NA2.4 Field Verification and Diagnostic Testing of Whole Building Air Leakage

NA2.4.1 Purpose and Scope

The purpose of this test procedure is to measure the air leakage rate through a building envelope.

1. The air barrier testing agency shall meet the following qualifications:
    a. Accepted by the building owner or building owner's representative and authorities having jurisdiction to perform testing and investigations of the whole building air barrier.
    b. Qualified personnel to perform testing and inspections required under work of the code should have:
        i. Continuous air barrier pressure testing personnel: able to document a minimum 2 years of experience testing in accordance with ASTM E779 or ASTM E3158 for projects of similar magnitude. For buildings under 10,000 ft^2 of conditioned floor area, 2 years of experience testing in accordance with (RESNET)/ANSI/ICC3 380-2019 shall be accepted.
        ii. Infrared thermographer: ANST Level I certified to perform infrared diagnostic evaluation or documented minimum 2 years of

experience performing infrared thermography equivalent in scope and quality by this Section.

2. This enclosure leakage procedure is applicable to nonresidential buildings.
   a. Buildings that have less than 10,000 ft^2 of conditioned floor area may perform the whole-building air leakage test in accordance with Residential Energy Services Network (RESNET)/ANSI/ICC3 380-2019 Guidelines and RA3.8 rather than those in NA2.4.2-2.4.7.
   b. Buildings that have more than 50,000 ft^2 of conditioned floor area, a sectional test method of co-pressurizing representative test floors and taking data from the specific floors is permitted when following the procedures in Sections NA2.4.2-2.4.7. Representative test floors must meet the following conditions as adopted from ASHRAE 90.1-2019 Exceptions to 5.4.3.1.1:
      i. The entire floor area of all stories that have any spaces directly under a roof.
      ii. The entire floor area of all stories that have a building entrance or loading dock.
      iii. Representative above-grade wall sections of the building totaling at least 25% of the wall area enclosing the remaining conditioned space. Floor areas in parts a) and b) shall not be included in the 25%.
      iv. When interpreting the data and determining the final air leakage rate, the measured air leakage is area-weighted by the surface areas of the building envelope.
3. The measurement procedure shall be based on the specifications of ASTM E3158 by blower door fan assembly (architectural only) and multi-point regression testing as further specified in Sections NA2.4.2, NA2.4.3, NA2.4.4. NA2.4.5, NA2.4.6, NA2.4.7 below.

NA2.4.2 Instrument Specifications

The instrumentation for the enclosure leakage measurements shall conform to the specifications in ASTM E3158.

NA2.4.3 Pre-Test Inspection (to occur the day before testing day)

1) Visually review the building for completion of air barrier components.
2) Meet with electrical and mechanical (or controls) subcontractors to review electrical needs for testing equipment and shutdown/sealing plan for mechanical systems and ductwork.

3) Contractor to provide dedicated electrical service for running of fans during the air leakage testing (minimum of 1 non-GFCI circuit 120V/20A per fan required).

4) Review weather forecasts and verify appropriate test conditions.

NA2.4.3 Pre-Test Set Up (To be performed by General Contractor)

1. Seal all intentional penetrations where they penetrate the air barrier (i.e. louvers, vents, etc.).
2. Fill plumbing traps with water. Toilets, sinks, floor drains, waterless urinals must be primed. Airtight caps on drains are acceptable.
3. Shut off the HVAC system – or leave in “pilot” mode (to avoid introducing air movement that is not included in the calculations). Any automated pressure relief dampers must either be disabled, sealed or set to a pressure well above 75 Pa.
4. Disable combustion equipment or leave in “pilot” position.
5. Seal all intentional openings in building envelope so that they are air-tight. Acceptable sealing materials include but are not limited to carpet protection plastic, adhesive grill mask and tape and plastic (4 mil poly sheeting or thicker). Intentional openings include, but are not limited to, the following:
    a. Supply air intakes
    b. Make-up air and other intakes/louvers
    c. Exhaust ducts/vents/louvers
    d. Plumbing exhausts
    e. Pressure relief dampers or louvers
    f. Fume hoods
    g. Other exhaust vents (kitchen, bathroom, dryer, etc.)
    h. Any other locations where air leakage can occur within the mechanical system during inactive periods
    i. Any other intentional opening in the building envelope other than doors and operable windows
6. Close and lock exterior windows and doors. Close any vents within window frames.
7. Prop interior doors open to create a single uniform zone.
8. Where drop ceilings are installed in a location that constitutes a barrier to air flow between the testing equipment and the plane of air tightness of the space being tested, remove ceiling tiles at a rate of one per 500 ft2 to prevent movement of

tiles during test and to ensure a uniform pressure within plenum space. Additional tiles can be removed to ensure a uniform pressure distribution in the plenum space.

9. Install exterior electrical box caps (if applicable).

NA2.4.4 Run Preliminary Test

Pressurize the building to 75 Pa to approximate if building is expected to pass test and to confirm that pre-test set up is complete and that temporary sealing stays in place while under pressure.

NA2.4.5 Enclosure Measurement Procedures

Pressurization Test

1. Reference ASTM E3158-18 for Whole Building Air Leakage Testing.
2. Record interior and exterior weather conditions.
3. Record average wind speeds.
4. Record interior and exterior temperatures before the testing begins.
5. Record site elevation in feet above sea level.
6. Measure bias pressures with fans off and covered.
7. Perform a multi-point pressurization test from at least +25 to +50 Pa (leakage is reported at 75 Pa, as attained or extrapolated).
8. Record a minimum of 5 points between minimum and maximum induced pressures.
9. Measure bias pressures at end of multi-point test with fans off and covered.
10. Record interior and exterior temperatures.
11. If the pressure exponent n is less than 0.45 or greater than 1.0 per Section 9.5.1 of ASTM E3158-18, then the pressurization test is invalid and shall be repeated.

Depressurization Test

12. Reverse direction of fans.
13. Measure bias pressures with fans off and covered.
14. Perform a multi-point depressurization test from at least -25 to -50 Pa (optional).
15. Record a minimum of 5 points between minimum and maximum induced pressures.
16. Measure bias pressures at end of multi-point test with fans off and covered.
17. Record interior and exterior temperatures after the testing is complete.

18. If the pressure exponent n is less than 0.45 or greater than 1.0 per Section 9.5.1 of ASTM 3158-18, then the depressurization test is invalid and shall be repeated.

NA2.4.6 Determination of Test Results

1. Calculate the building envelope air leakage in accordance with guidelines in ASTM E3158-18 multi-point regression tests or the relevant building envelope area when testing in sections.
2. If the building envelope air leakage rate exceeds 0.4 cfm/ft^2 but is less than 0.6 cfm/ft^2, a visual inspection of the air barrier shall be conducted in accordance with NA2.4.7. Any leaks observed should be sealed where such sealing can be made without destruction of existing building components. An additional report identifying the corrective actions taken to seal air leaks should be submitted to the building owner and code official, and any further requirement to meet the air leakage rate will be waived.
3. If the building envelope air leakage rate exceeds 0.6 cfm/ft^2, a visual inspection of the air barrier shall be conducted in accordance with NA 2.4.7, and any leaks noted should be repaired. The building will then be re-tested until either the building envelope air leakage rate less than 0.4 cfm/ft^2, or the building envelope air leakage rate is in the range of 0.4 cfm/ft^2 but is less than 0.6 cfm/ft^2 and a visual inspection and repair program is executed.

   Exception to NA2.4.6 3. Alterations where less than 100% of the wall area is being altered or additions that are an extension of the existing air barrier, if the building is tested in accordance with the procedures for whole building air leakage in NA2.4 and the tested leakage rate exceeds 0.6 cfm/ft^2 of building shell area at 75 pa, a Visual Inspection and Diagnostic Evaluation shall been completed in accordance with NA2.4.7 and all observed leaks shall be sealed where such sealing can be made without destruction of existing building components. An additional report identifying the corrective actions taken to seal air leaks should be submitted to the building owner and code official, and any further requirement to meet the air leakage rate will be waived.

NA2.4.7 Visual Inspection and Diagnostic Evaluation of Air Leakage After Test Failure

Visual Inspection

1. Ensure that all temporary seals and covers for intentional openings such as at louvers, exhaust/intake vents, fireplaces, and rooftop units are properly sealed and not damaged or loosened during the construction.
2. Ensure that all plumbing-traps are filled with water.
3. Ensure that all operable windows, trickle-vents, and doors are properly shut and

locked.

4. Ensure that all mechanical systems are shut-off and any mechanical dampers set to the closed position.

Diagnostic Evaluation

5. Identify locations with air leakage using infrared thermography or smoke pens in accordance with ASTM E1186-17, while the building is maintained at a minimum 25 Pa pressure (during pressurization) or –25 Pa (during depressurization). The following locations shall be evaluated:
   - **a.** The perimeter of windows and doors.
   - b. Around operable window hardware and door hardware
   - c. Penetrations through the roof, wall, and floor assemblies along the plane of the intended air-barrier.
   - d. Electrical outlets located on exterior-facing walls.
   - e. Lighting and other electrical penetrations through the roof level ceiling.
   - f. Above- and below-grade vestibules.
   - g. Stairs leading to unconditioned space.

NA2.4.8 Reporting

1. Generate report in accordance with ASTM E3158 reporting instructions.
2. The report shall include information on the tested building envelope area, conditioned floor area, conditioned air-by-volume, stories above grade, and air leakage rates.
3. Results shall be reported at the upper 95 percent confidence interval.

NA 2.5 Verification of Continuous Air Barrier

An independent third-party verification shall be conducted in accordance with the following requirements:

- a. A design review shall be conducted to verify and document compliance with the requirements Section 140.3(a)9, specifically:
  - i. All air barrier components are identified on construction documents
  - ii. All joints, interconnections, and penetrations of the continuous air barrier components are identified on construction documents
  - iii. The continuous air barrier extends on all surfaces of the building envelope (walls, roof, and lowest floor)
  - iv. The continuous air barrier is designed to resist positive and negative pressures from wind, stack effect, and mechanical

ventilation.

v. The compliance documents indicate the intent to verify the continuous air barrier by way of on-site visual inspection.

b. Inspection shall occur during construction when the continuous air barrier is accessible for a visual inspection. The entire continuous air barrier shall be inspected. The third-party entity conducting the verification shall coordinate with the construction team to schedule site visits such that the entire continuous air barrier is verified.

c. Inspection of the continuous air barrier materials and assemblies shall verify the following are installed correctly:

i. Transitions to adjacent air barrier systems – including but not limited to roof parapet transitions, glazed framing systems to adjacent framed wall assemblies transitions, plaza waterproofing to podium transitions, vertical wall to soffit transitions

ii. Detailing of penetrations through air barrier systems.

iii. Building assemblies used as ducts or plenums

iv. Contractor internal quality control/quality assurance

7.4 ACM Reference Manual

5.4 Space Uses

5.4.2 Infiltration: design zone infiltration airflow and zone infiltration airflow would have to be modified for the Standard and Proposed Design. The Standard Design would have to be modified to reflect the new specifications laid out by NORESCO, technical consultants for the Energy Commission, to account for infiltration through all six sides of the building envelope, rather than just the walls. The Proposed Design would have to be modified to no longer have a fixed value.

Infiltration Data	
Applicability	All projects
Definition	Information needed to characterize the infiltration rate in buildings. The required information will depend on the infiltration method selected above. For the effective leakage area method, typical inputs are leakage per exterior wall area in ft² or other suitable units and information to indicate the height of the building and

	how shielded the site is from wind pressures. Only zones with exterior wall area are assumed to be subject to infiltration.
Units	A data structure is required to define the effective leakage area model. Infiltration shall be calculated each hour using the following equation: $Infiltration = I_{design} * F_{schedule} * (A + B * \|t_{zone} - t_{odb}\| + C * ws + D * ws^2)$ Where: *Infiltration* = zone infiltration airflow ($m^3/s\text{-}m^2$) I_{design} = design zone infiltration airflow ($m^3/s\text{-}m^2$) $F_{schedule}$ = fractional adjustment from a prescribed schedule, based on HVAC availability schedules in Appendix 5.4B(unitless) t_{zone} = zone air temperature (°C) t_{odb} = outdoor dry bulb temperature (°C) *ws* = the wind speed (m/s) *A* = overall coefficient (unitless) *B* = temperature coefficient (1/°C) *C* = wind speed coefficient (s/m) *D* = wind speed squared coefficient (s^2/m^2)
Input Restrictions	For the proposed design, I_{design} shall have a fixed value of 0.0448 cfm/ft^2 (0.000228 $m^3/s\text{-}m^2$) times the gross wall area exposed to ambient outdoor air. A, B and D shall be fixed at zero. C shall be fixed at 0.10016 hr/mile (0.224 s/m). For nonresidential spaces with operable windows that do not have mechanical system interlocks, the CBECC software shall automatically increase infiltration to the space by 0.15 cfm/ft^2 whenever the outside air temperature is between 50°F and 90°F and when the HVAC system is operating. High-rise dwelling units are exempt from mechanical system interlocks.
Standard Design	The standard design shall use the equation listed above, with coefficients A, B, and D set to 0. C shall be set to 0.10016 hr/mile (0.224 s/m). I_{design} shall be 0.0448 cfm/ft^2.

7.5 Compliance Manuals

Chapter 3.2.3.2 of the compliance manual would have to be revised. Currently, the code states in Section 3.2.3.2 that "the reduction in air leakage can be met with a continuous air barrier that seals all joints and openings in the building envelope and is composed of one of the following:

1. Materials having a maximum air permeance of 0.004 cfm/ft^2
2. Assemblies and materials of components having an air leakage not exceeding 0.04 cfm/ ft^2
3. An entire building having an air leakage rate not exceeding 0.4 cfm/ ft^2"

We propose a modification that would require one of the first two selections for all climate zones, and in addition require:

"An entire building having an air leakage rate not exceeding 0.4 cfm/ft^2 at a pressure differential of 75 pascals when tested in accordance with ASTM E3158 by blower door fan assembly (architectural only), multi-point regression testing.

If the test rate exceeds a leakage rate of 0.4 cfm/ft^2 but is less than 0.6 cfm/ft^2, a visual inspection of the air barrier shall be conducted, and any leaks noted should be sealed to the extent practical. An additional report identifying the corrective actions taken to seal air leaks should be submitted to the design professional, building owner and code official, and any further requirement to meet the air leakage rate would be waived.

If the test rate exceeds a leakage rate of 0.6 cfm/ft^2, a visual inspection of the air barrier shall be conducted, and any leaks noted should be repaired. The building would then be re-tested until either the building envelope air leakage rate less than 0.4 cfm/ft^2, or the building envelope air leakage rate is in the range of 0.4 cfm/ft^2 but is less than 0.6 cfm/ft2 and a visual inspection and repair program is executed."

Testing shall be carried out by third party professionals that have at least two years of experience testing similarly sized buildings.

7.6 Compliance Documents

Compliance documents NRCC-ENV-E and NRCC-PRF-01 would need to be revised. A description of the building envelope would be included along with a new table prompting the air barrier materials or assemblies used to meet the requirements – the certificate of installation would be triggered to confirm the materials or assemblies. The air barrier needs to be listed in the opaque surface construction assembly table.

The NRCC-ENV-E would also include a section for air barrier verification and the user would choose how they are going to meet the verification requirements. The alterations section of the NRCC-ENV-E form would have to be updated to trigger whole building air leakage testing if the alteration meets the specification in Section 7.2.

A new field verification form (NRCV-ENV) would have to be added to report a summary of the test results along with a detailed report according to ASTM E3158 reporting instructions. The summary would include the infiltration rate, as well as the tested surface area, conditioned floor area, air by volume, and stories above grade. Leakage results would be submitted to the code official and building owner.

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Appendix A: Statewide Savings Methodology

To calculate first-year statewide savings, the Statewide CASE Team multiplied the per-unit savings by statewide construction estimates for the first year the standards would be in effect (2023). The projected nonresidential new construction forecast that would be impacted by the proposed code change in 2023 is presented in Table 35. The projected nonresidential existing statewide building stock that would be impacted by the proposed code change as a result of additions and alterations in 2023 is presented in Table 36. This section describes how the Statewide CASE Team developed these estimates.

The Energy Commission Building Standards Office provided the nonresidential construction forecast, which is available for public review on the Energy Commission's website: https://www.energy.ca.gov/title24/participation.html.

The construction forecast presents total floorspace of newly constructed buildings in 2023 by building type and climate zone. The building types included in the Energy Commissions' forecast are summarized in. This table also identifies the prototypical buildings that were used to model the energy use of the proposed code changes. This mapping was required because the building types the Energy Commission defined in the construction forecast are not identical to the prototypical building types that the Energy Commission requested that the Statewide CASE Team use to model energy use. This mapping is consistent with the mapping that the Energy Commission used in the Final Impacts Analysis for the 2019 code cycle (California Energy Commission 2018).

The Energy Commission's forecast allocated 19 percent of the total square footage of new construction in 2023 to the miscellaneous building type, which is a category for all space types that do not fit well into another building category. It is likely that the Title 24, Part 6 requirements apply to the miscellaneous building types, and savings would be realized from this floorspace. The new construction forecast does not provide sufficient information to distribute the miscellaneous square footage into the most likely building type, so the Statewide CASE Team redistributed the miscellaneous square footage into the remaining building types so that the percentage of building floorspace in each climate zone, net of the miscellaneous square footage, would remain constant. See Table 37 for a sample calculation for redistributing the miscellaneous square footage among the other building types.

After the miscellaneous floorspace was redistributed, the Statewide CASE Team made assumptions about the percentage of newly constructed floorspace that would be impacted by the proposed code change. Table 38 presents the assumed percentage of floorspace that would be impacted by the proposed code change by building type. If a proposed code change does not apply to a specific building type, it is assumed that zero percent of the floorspace would be impacted by the proposal. If the assumed percentage is non-zero, but less than 100 percent, it is an indication that no buildings would be impacted by the proposal. Table 39 presents percentage of floorspace assumed to be impacted by the proposed change by climate zone. The ApartmentHighRise and HotelSmall prototypes were excluded from the analysis because the Statewide CASE Team is still reconciling the nonresidential and residential requirements. The Assembly, Grocery, and SchoolPrimary prototypes were excluded from the statewide savings because the results need further investigation. Refrigerated warehouse was also excluded because the requirement would not apply. Hospital was excluded for additions and alterations because the requirement would not apply. The proposed requirement does not apply to Climate Zone 7 because it was not shown to be cost effective in that climate zone. Otherwise it was assumed that the proposal would affect 100 percent of new construction. The Statewide CASE Team assumed that that buildings would have a major alteration to the air barrier or the amount of conditioned space every 50 years that would trigger the whole building air leakage testing requirements. Therefore, it was assumed that the proposed change would apply to two percent of the existing floor space each year.

Table 35: Estimated New Nonresidential Construction Impacted by Proposed Code Change in 2023, by Climate Zone and Building Type (Million Square Feet)

Climate Zone	New Construction in 2023 (Million Square Feet)											
	Hospital	Office Large	Office Medium	Office Medium Lab	Restaurant Fast Food	Retail Large	Retail Mixed Use	Retail Stand Alone	Retail Strip Mall	School Secondary	Warehouse	Total NR
1	0.1	0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.5
2	0.3	0.4	0.5	0.0	0.3	0.1	0.6	0.1	0.1	0.2	0.6	3.2
3	1.2	2.4	2.6	0.2	1.0	0.5	2.7	0.4	0.4	0.9	3.0	15.2
4	0.6	1.3	1.3	0.1	0.5	0.2	1.4	0.2	0.2	0.4	1.5	7.9
5	0.1	0.2	0.2	0.0	0.1	0.1	0.3	0.0	0.0	0.1	0.3	1.5
6	0.6	1.7	1.7	0.1	0.7	0.5	1.9	0.3	0.3	0.5	2.3	10.6
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.9	2.5	2.6	0.1	0.9	0.7	2.8	0.4	0.4	0.6	3.3	15.3
9	1.6	4.7	4.8	0.2	1.5	1.1	4.3	0.6	0.6	1.0	5.2	25.8
10	0.9	1.0	1.0	0.1	1.3	0.8	2.7	0.4	0.4	0.8	4.3	13.8
11	0.3	0.2	0.2	0.0	0.3	0.1	0.5	0.1	0.1	0.2	0.8	2.9
12	1.3	2.0	2.1	0.2	1.8	0.5	2.9	0.4	0.4	0.9	3.9	16.5
13	0.6	0.3	0.4	0.1	0.7	0.2	1.2	0.2	0.2	0.5	1.4	5.7
14	0.2	0.3	0.4	0.0	0.3	0.2	0.6	0.1	0.1	0.2	0.9	3.3
15	0.1	0.1	0.1	0.0	0.2	0.1	0.4	0.1	0.1	0.1	0.7	1.9
16	0.1	0.1	0.1	0.0	0.1	0.1	0.2	0.0	0.0	0.1	0.3	1.0
TOTAL	8.6	17.2	18.1	1.2	9.7	5.2	22.5	3.0	3.0	6.4	28.6	125.1

Table 36: Estimated Existing Nonresidential Floorspace Impacted by Proposed Code Change in 2023 (Alterations), by Climate Zone and Building Type (Million Square Feet)

Climate Zone	Existing Buildings in 2023 (Million Square Feet)											
	Hospital	Office Large	Office Medium	Office Medium Lab	Restaurant Fast Food	Retail Large	Retail Mixed Use	Retail Stand Alone	Retail Strip Mall	School Secondary	Warehouse	Total NR
1	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.4
2	0.0	0.4	0.4	0.0	0.3	0.1	0.5	0.1	0.1	0.2	0.5	2.6
3	0.0	2.3	2.4	0.2	0.9	0.4	2.3	0.3	0.3	0.9	2.5	12.6
4	0.0	1.2	1.3	0.1	0.5	0.2	1.2	0.2	0.2	0.5	1.3	6.5
5	0.0	0.2	0.2	0.0	0.1	0.0	0.2	0.0	0.0	0.1	0.2	1.3
6	0.0	1.5	1.6	0.1	0.7	0.4	1.8	0.3	0.3	0.6	2.2	9.6
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	2.3	2.4	0.2	0.9	0.6	2.6	0.4	0.4	0.9	3.2	13.8
9	0.0	4.0	4.2	0.3	1.4	1.0	4.0	0.5	0.5	1.4	5.0	22.5
10	0.0	1.0	1.1	0.2	1.3	0.8	2.9	0.4	0.4	0.9	4.6	13.8
11	0.0	0.2	0.2	0.0	0.3	0.1	0.5	0.1	0.1	0.2	0.8	2.5
12	0.0	1.8	1.9	0.2	1.5	0.4	2.6	0.4	0.4	1.0	3.3	13.5
13	0.0	0.3	0.3	0.1	0.7	0.2	1.1	0.1	0.1	0.5	1.3	4.7
14	0.0	0.3	0.3	0.0	0.3	0.2	0.7	0.1	0.1	0.2	1.0	3.2
15	0.0	0.1	0.1	0.0	0.2	0.1	0.4	0.1	0.1	0.1	0.7	1.9
16	0.0	0.1	0.1	0.0	0.1	0.1	0.2	0.0	0.0	0.1	0.3	1.0
TOTAL	0.0	15.7	16.7	1.4	9.0	4.5	21.0	2.8	2.8	7.6	26.8	109.8

Table 37: Example of Redistribution of Miscellaneous Category - 2023 New Construction in Climate Zone 1

Building Type	2020 Forecast (Million Square Feet) [A]	Distribution Excluding Miscellaneous Category [B]	Redistribution of Miscellaneous Category (Million Square Feet) [C] = B × [D = 0.145]	Revised 2020 Forecast (Million Square Feet) [E] = A + C
Small Office	0.036	7%	0.010	0.046
Large Office	0.114	21%	0.031	0.144
Restaurant	0.015	3%	0.004	0.020
Retail	0.107	20%	0.029	0.136
Grocery Store	0.029	5%	0.008	0.036
Non-Refrigerated Warehouse	0.079	15%	0.021	0.101
Refrigerated Warehouse	0.006	1%	0.002	0.008
Schools	0.049	9%	0.013	0.062
Colleges	0.027	5%	0.007	0.034
Hospitals	0.036	7%	0.010	0.046
Hotel/Motels	0.043	8%	0.012	0.055
Miscellaneous **[D]**	0.145	N/A	0.000	0.145
TOTAL	0.686	100%	0.147	0.83370

Table 38: Percent of Floorspace Impacted by Proposed Measure, by Building Type

Building Type Building sub-type	Composition of Building Type by Subtypes[a]	Percent of Square Footage Impacted[b]	
		New Construction	Existing Building Stock (Alterations)[c]
Small Office	N/A	100%	2%
Restaurant	N/A	100%	2%
Retail	N/A	100%	2%
Stand-Alone Retail	10%	100%	2%
Large Retail	75%	100%	2%
Strip Mall	5%	100%	2%
Mixed-Use Retail	10%	100%	2%
Food	N/A	0%	0%
Non-Refrigerated Warehouse	N/A	100%	2%
Refrigerated Warehouse	N/A	0%	2%
Schools	N/A	40%	1%
Small School	60%	0%	0%
Large School	40%	100%	2%
College	N/A	70%	1%
Small Office	5%	100%	2%
Medium Office	15%	100%	2%
Medium Office/Lab	20%	100%	2%
Public Assembly	5%	0%	0%
Large School	30%	100%	2%
High-Rise Apartment	25%	0%	0%
Hospital	N/A	100%	0%
Hotel/Motel	N/A	0%	0%
Offices	N/A	100%	2%
Medium Office	50%	100%	2%
Large Office	50%	100%	2%

a. Presents the assumed composition of the main building type category by the building subtypes. All 2022 CASE Reports assumed the same percentages of building subtypes.

b. When the building type is composed of multiple subtypes, the overall percentage for the main building category was calculated by weighing the contribution of each subtype.

c. Percent of existing floorspace that would be altered during the first year the 2022 standards are in effect.

Table 39: Percent of Floorspace Impacted by Proposed Measure, by Climate Zone

Climate Zone	Percent of Square Footage Impacted	
	New Construction	Existing Building Stock (Alterations)[a]
1	78%	1%
2	79%	1%
3	80%	1%
4	81%	1%
5	80%	1%
6	83%	2%
7	0%	0%
8	83%	2%
9	85%	2%
10	81%	2%
11	78%	1%
12	81%	1%
13	76%	1%
14	82%	2%
15	79%	2%
16	80%	1%

a. Percent of existing floorspace that would be altered during the first year the 2022 standards are in effect.

Appendix B: Embedded Electricity in Water Methodology

There are no 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 United States Environmental Protection Agency (U.S. EPA) Emissions & Generation Resource Integrated Database (eGRID) for the Western Electricity Coordination Council California (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 million therms.

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/MTCO_2e.

Water Use and Water Quality Impacts Methodology

There are no impacts to water quality or water use.

Appendix D: California Building Energy Code Compliance (CBECC) Software Specification

The Statewide CASE Team recommends that the software be updated so there are four infiltration rate options in addition to the Standard Design. The four options are presented in Table 40. Option 1 is necessary because the continuous air barrier requirements are prescriptive. If using the performance approach, designers should have the option of not installing a continuous air barrier at all and using a higher infiltration rate. Option 2 is available if using the performance approach and a continuous air barrier is added, but not verified through any means. Option 3 would be used in the performance approach if a designer verifies the barrier using the field verification approach. The Standard Design would assume verification using whole-building air leakage testing and assumes the building achieves a leakage rate of 0.4 cfm/ft^2. Option 4 would be available for designers that complete a whole-building test and achieve a lower leakage rate than 0.4 cfm/ft^2.

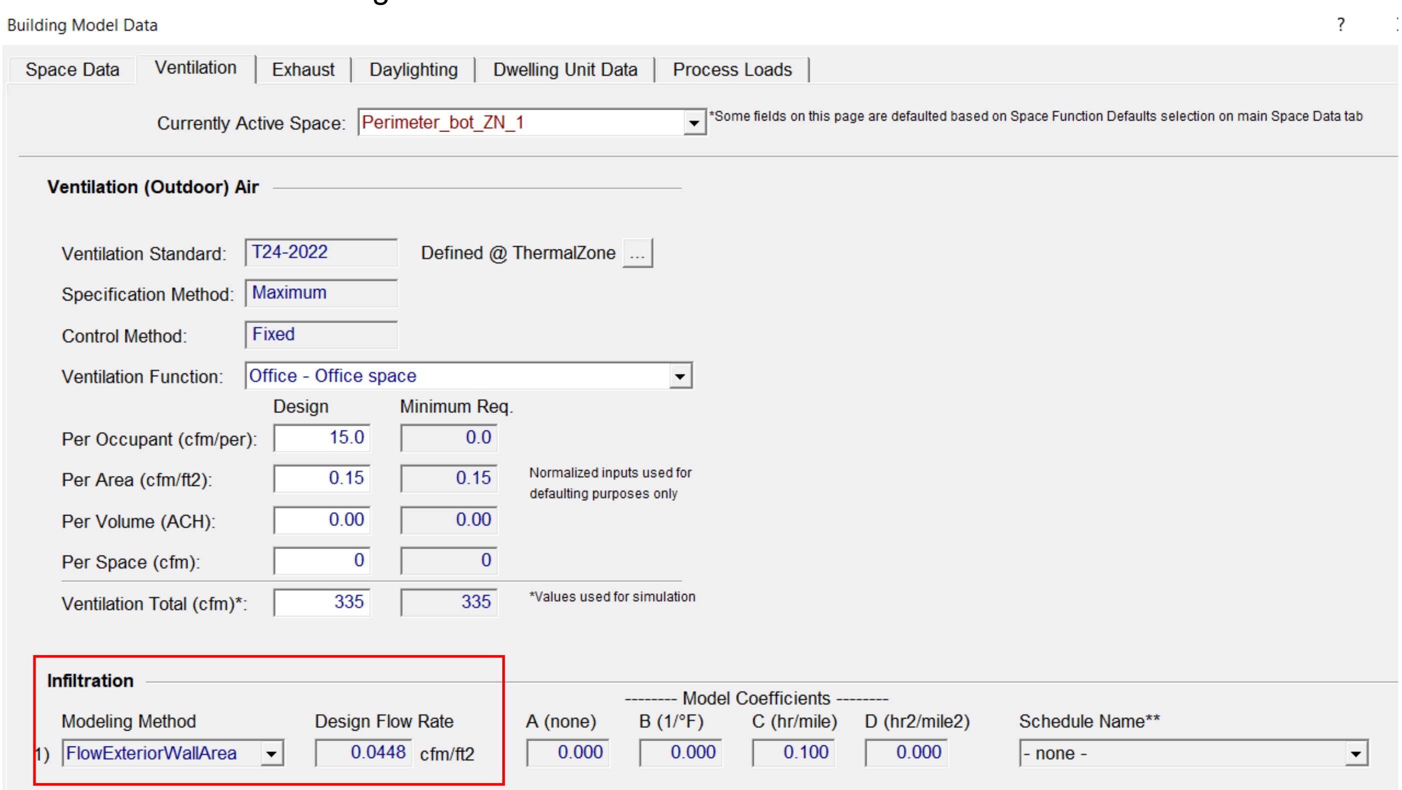

Figure 5: Input for infiltration rate in CBECC-Com software.

Table 40: Recommended Leakage Rates for Compliance Software.

#	Scenario	Recommended Infiltration Rate to be used in Compliance Software (cfm/ft^2 at 75Pa; infiltration through 6 sides)	Option to Select in Compliance Software
A	No continuous air barrier	1.1	Option 1
B	Continuous air barrier – no field verification or whole building leakage testing	0.7	Option 2
C	Continuous air barrier – field verification/inspection	0.5	Option 3
D	Continuous air barrier –whole-building leakage testing, default credit	0.4	Standard Design
E	Continuous air barrier –whole-building leakage testing, actual result	Tested result under 0.4	Option 4

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 41 identifies the market actors who would play a role in complying with the proposed change, the tasks for which they would 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 in Table 41 is a summary of key feedback the Statewide CASE Team received when speaking to market actors about the compliance implications of the proposed code changes. 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 code change would require the General Contractor to fit testing or periodic third party site visits into the construction schedule and ensure that the building is properly prepared before the test. This particularly means sealing all intentional openings in the building. It would require coordination with the testing agency or consulting firm that performs the testing. General Contractors would need training to know how to properly prepare the building. New documentation would be required for the permit application stage and the construction and inspection phases.

Table 41: Roles of Market Actors in the Proposed Compliance Process

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Workflow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Architect	• Designing the building envelope according to relevant Title 24, Part 6 standards. • Incorporating NRCC-ENV-E features into the plans and specifications	• Creating a building that is compliant with the energy efficiency standards. • Providing satisfactory plans to building owners.	Would need to design buildings such that the air barrier materials meet the requirements of the code, and that the continuity of the air barrier is clearly defined in drawings.	• Easy to understand code language, including and especially exceptions • Easy to complete compliance documents
Building Owner	Ensure all parties involved in the building design and construction follow Title 24, Part 6	Creating a building that is compliant with the energy efficiency standards.	• Would need to hire professionals with experience reviewing air barrier design and construction • Would need to account for testing agency and test preparation cost	The Statewide CASE Team will propose changes to building code to clearly indicate what the testing requirement is, as well as educate owner on market factors

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Workflow	Opportunities to Minimize Negative Impacts of Compliance Requirement
General Contractor	• Constructing building in accordance with building plans. • Coordinate with other contractors completing of compliance documents. • Adhere to current Title 24, Part 6 requirements.	• Follow requirements in Title 24, Part 6 in order to meet compliance. • Ensure a quick and efficient completion of compliance documents. • Coordinate a quick and efficient building construction	• Would need to work with design team to coordinate installation of air barrier materials, as well as proper quality control program. • Work with testing agency to coordinate test and prepare the building.	The Statewide CASE Team will propose changes to building code to clearly indicate what the testing requirement is, as well as educate owner on market factors
Building Inspector	Ensure all parts of the building envelope comply with Title 24, Part 6 standards	Creating a building that is compliant with the energy efficiency standards.	Would need to work with design team and general contractor to understand air barrier construction details and coordination, and inspect per contract documents	The Statewide CASE Team will propose changes to building code to clearly indicate what specifically a building inspector is required to review.

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Workflow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Testing Agent or Consultant	Carries out the whole building air leakage test and leakage diagnoses	Determining the infiltration of the building	• Would need to work with design team and general contractor to understand air barrier construction details. • Coordinate building preparation for test. • Document results (including diagnostic investigations of air leakage paths) per required format	The Statewide CASE Team will propose changes to building code to clearly indicate what the testing requirement is, as well as the required format and information for the submitted documentation
Energy Consultant/Documentation Author	• Calculating and demonstrating how the building air barrier meets Title 24, Part 6 requirements • Providing the documentation for the permit application in the NRCC-ENV-E	• Ensure compliance with Title 24, Part 6 • Calculate the most cost-effective method of compliance • Obtain a permit for the project	The consultant would need to communicate what infiltration rate is expected for the building and how it was determined to the rest of the project team	The Statewide CASE Team is proposing a performance option for buildings to gain credit if they have a verified leakage below 0.4 cfm/ft^2 and is also providing a buffer for buildings that only want to meet the prescriptive requirement of 0.4 cfm/ft^2 by not requiring retesting until 0.6 cfm/ft^2

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, and
- Technical and market feasibility

The Statewide CASE Team hosted two stakeholder meetings for Reduced Infiltration via webinar. 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: presentations found here (Statewide CASE Team 2019) and (Statewide CASE Team 2020), summaries are found here (Statewide CASE Team 2019) and (Statewide CASE Team 2020), meeting notes are found here (Statewide CASE Team 2019) and (Statewide CASE Team 2020).

Meeting Name	Meeting Date	Event Page from Title24stakeholders.com
First Round of Nonresidential HVAC and Envelope Utility-Sponsored Stakeholder Meeting	Tuesday, November 5, 2019	https://title24stakeholders.com/event/nonresidential-hvac-and-envelope-part-2-reduced-infiltration-hvac-controls-air-efficiency-doas/
Second Round of Nonresidential HVAC and Envelope Utility-Sponsored Stakeholder Meeting	Tuesday, April 14, 2020	https://title24stakeholders.com/event/nonresidential-hvac-air-distribution-controls-reduced-infiltration-utility-sponsored-stakeholder-meeting/

The first round of utility-sponsored stakeholder meetings occurred from September to November 2019 and 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 February 2020 and provided updated details on proposed code changes. The second round of meetings introduced early results of energy, cost effectiveness, and incremental cost analyses, 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 (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. The Statewide CASE Team engaged with testing professionals at Morrison Hershfield, RDH, Simpson Gumpertz & Heger, and Vermont Energy Investment Corporation, researchers at the National Institute of Standards and Technology and the Pacific Northwest National Laboratory, as well as the Air Barrier Association of America, National Environmental Balancing Bureau, and ASHRAE 90.1 Envelope Subcommittee to develop this measure and the infiltration rates for the different air barrier scenarios. The Statewide CASE Team collected cost information three consulting firms and five HERS Raters for the cost of whole building air leakage testing.

Appendix G: Analysis of Adding Air Barriers Only

The Statewide CASE Team evaluated the cost effectiveness (Table 44) and TDV energy savings per ft^2 (Table 45) for each building prototype and the first-year savings potential of requiring air barriers without verification for new construction in Climate Zones 1-9 and for additions and alterations in all climate zones. Consistent with other analyses for this report, the ApartmentHighRise and HotelSmall prototypes were excluded from because the Statewide CASE Team is still reconciling the nonresidential and residential requirements. The Assembly, Grocery, and SchoolPrimary prototypes were excluded from the statewide savings because the results need further investigation. Refrigerated Warehouse was excluded because the requirement would not apply. Hospital was excluded for additions and alterations because the requirement would not apply.

The estimated first-year statewide energy impacts for requiring air barriers in Climate Zones 1-9 for new construction and in all climate zones for additions and alterations is shown in Table 42. This is a little under half of the TDV energy savings estimated for the measure in Table 2. Table 43 contains estimated savings from requiring air barrier verification for new construction in Climate Zones 1-9 and for additions and alterations in all climate zones except Climate Zone 7.

Table 42: First-Year Statewide Energy and Impacts – Air Barrier Without Verification

Measure	Electricity Savings (GWh/yr)	Peak Electrical Demand Reduction (MW)	Natural Gas Savings (million therms/yr)	TDV Energy Savings (TDV million kBtu/yr)
New Construction	(0.3)	0.1	0.4	112.2
Additions and Alterations	(0.2)	0.1	0.5	167.3
Total	(0.5)	0.2	0.9	279.5

Table 43: First-Year Statewide Energy and Impacts – Air Barrier Verification

Measure	Electricity Savings (GWh/yr)	Peak Electrical Demand Reduction (MW)	Natural Gas Savings (million therms/yr)	TDV Energy Savings (TDV million kBtu/yr)
New Construction	(0.2)	0.2	0.3	105.2
Additions and Alterations	0.2	0.3	0.4	155.5
Total	(0.0)	0.5	0.7	260.7

Table 44: Require Air Barrier where Not Currently Required – New Construction (CZ 1-9) and Additions/Alterations (All CZ)– Benefit-to-Cost Ratio

Climate Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Hospital	39.1	31.3	42.7	40.4	29.4	31.8	13.7	15.3	25.9	28.1	58.8	36.7	40.9	65.0	38.3	46.5
OfficeLarge	35.5	22.8	29.5	21.5	21.6	13.1	1.1	7.6	28.0	32.2	58.1	27.3	42.4	48.2	25.8	46.2
OfficeMedium	25.2	13.9	18.2	13.9	11.6	6.8	2.7	5.9	11.5	14.7	37.5	17.8	22.8	38.4	25.6	38.9
OfficeMediumLab	34.3	20.1	28.5	19.9	20.1	14.5	9.9	8.3	15.6	17.5	41.1	21.4	22.6	36.9	24.8	27.5
OfficeSmall	4.7	6.1	4.9	5.6	(0.5)	0.2	(0.6)	4.1	5.3	7.2	22.4	12.1	16.2	22.3	18.4	17.6
RestaurantFastFood	20.6	12.0	17.8	12.8	11.5	3.8	3.4	5.8	9.8	11.6	24.3	16.5	17.0	27.4	17.6	22.3
RetailLarge	14.9	(5.6)	17.3	(4.1)	(0.0)	(9.3)	4.0	(4.5)	(0.3)	4.8	(17.4)	(13.4)	13.7	39.8	18.3	15.4
RetailStandAlone	19.9	7.0	8.7	7.7	10.3	4.5	(8.8)	11.9	1.2	3.2	(12.9)	6.9	15.6	24.0	17.2	27.3
RetailStripMall	12.1	(1.8)	4.6	(4.2)	4.3	(7.5)	3.8	4.4	(3.5)	(8.7)	19.9	3.1	17.7	1.9	13.6	26.7
SchoolSecondary	28.9	15.9	23.7	14.0	16.4	11.1	6.1	6.3	12.0	15.5	40.1	21.2	22.4	42.9	20.9	48.4
Warehouse	27.6	11.8	20.2	10.1	13.9	8.8	6.3	5.4	7.1	8.7	19.7	13.1	9.9	19.1	6.4	26.9

Table 45: Require Air Barrier where Not Currently Required – New Construction (CZ 1-9) and Additions/Alterations (All CZ) – TDV Energy Savings per Square Foot (TDV kBtu/ft²)

Climate Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
OfficeLarge	2.9	1.8	2.4	1.7	1.8	1.1	0.1	0.6	2.3	2.6	4.7	2.2	3.4	3.9	2.1	3.8
OfficeMedium	3.3	1.8	2.3	1.8	1.5	0.9	0.3	0.8	1.5	1.9	4.8	2.3	2.9	5.0	3.3	5.0
OfficeMediumLab	4.4	2.6	3.7	2.6	2.6	1.9	1.3	1.1	2.0	2.3	5.3	2.8	2.9	4.8	3.2	3.6
OfficeSmall	0.8	1.1	0.9	1.0	(0.1)	0.0	(0.1)	0.7	1.0	1.3	4.0	2.2	2.9	4.0	3.3	3.1
RestaurantFastFood	5.4	3.1	4.6	3.3	3.0	1.0	0.9	1.5	2.6	3.0	6.3	4.3	4.4	7.1	4.6	5.8
RetailLarge	1.0	(0.4)	1.2	(0.3)	(0.0)	(0.6)	0.3	(0.3)	(0.0)	0.3	(1.2)	(0.9)	0.9	2.7	1.2	1.0
RetailStandAlone	2.8	4.8	1.1	1.0	1.8	(0.0)	(0.9)	1.1	(0.3)	0.6	5.1	2.9	2.5	3.0	3.4	4.1
RetailStripMall	3.3	1.2	1.5	1.3	1.7	0.8	(1.5)	2.0	0.2	0.5	(2.2)	1.1	2.6	4.0	2.9	4.6
SchoolPrimary	2.8	(0.4)	1.1	(1.0)	1.0	(1.8)	0.9	1.0	(0.8)	(2.1)	4.7	0.7	4.2	0.4	3.2	6.3
Warehouse	2.9	1.6	2.3	1.4	1.6	1.1	0.6	0.6	1.2	1.5	4.0	2.1	2.2	4.2	2.1	4.8

Appendix H: Initial Cost Effectiveness of Air Leakage Testing

The Statewide CASE Team performed a cost-effectiveness analysis for all nonresidential building types, shown in Table 46 and Table 47. Consistent with other analyses for this report, the ApartmentHighRise and HotelSmall prototypes were excluded from the analysis because the Statewide CASE Team is still reconciling the nonresidential and residential requirements. Currently 95 percent of the ApartmentHighRise prototype is residential and 85 percent of the HotelSmall prototype is residential. The Assembly, Grocery, and SchoolPrimary prototypes were excluded from the statewide savings because the results need further investigation. Grocery is not shown below because the Statewide CASE Team is still investigating how to modify the infiltration rate for the model. These tables are the same as Table 28 and Table 29 but include the results from the excluded building types.

Table 46: Benefit-to-Cost Ratio over 30-Year Period of Analysis – New Construction

Building Prototype	CZ01	CZ02	CZ03	CZ04	CZ05	CZ06	CZ07	CZ08	CZ09	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
ApartmentHighRise	5.9	2.7	2.6	2.5	1.5	(0.1)	(0.6)	0.7	1.6	1.3	3.9	1.9	2.5	3.6	2.1	4.6
Assembly	3.0	1.8	3.6	1.7	2.8	1.5	1.5	0.4	0.8	0.5	1.1	0.8	0.5	1.0	0.3	1.9
Hospital	10.5	8.3	11.9	10.3	8.6	9.8	4.2	4.8	8.4	5.5	9.1	6.5	5.8	12.9	6.9	7.9
HotelSmall	3.9	2.1	2.8	2.0	2.0	1.1	0.4	1.0	1.7	1.0	2.3	1.3	1.7	2.6	1.6	2.4
OfficeLarge	17.6	15.0	14.7	12.0	12.0	10.5	2.9	3.2	11.7	8.5	16.0	14.3	10.5	17.4	10.7	16.2
OfficeMedium	4.9	2.7	3.4	2.8	2.2	1.3	0.5	1.1	2.2	1.4	3.5	1.7	2.1	3.4	2.4	3.6
OfficeMediumLab	6.5	4.0	5.7	4.3	4.1	2.8	2.0	1.7	3.0	1.7	3.8	3.4	2.3	3.9	1.6	3.8
OfficeSmall	2.1	2.5	1.8	2.2	0.0	0.0	(0.3)	2.1	2.1	1.6	5.6	3.1	5.1	5.3	4.2	4.1
RestaurantFastFood	5.2	3.0	4.5	3.2	3.0	1.2	0.8	1.5	2.5	1.5	3.1	2.1	2.1	3.2	2.2	2.6
RetailLarge	2.6	(0.0)	7.2	(0.1)	1.2	1.6	0.5	0.3	2.0	(0.4)	2.0	0.6	0.7	(0.4)	0.4	1.4
RetailMixedUse	6.9	7.8	2.9	1.9	1.4	0.5	(1.6)	1.3	1.5	5.9	5.8	1.3	2.6	8.1	2.8	6.2
RetailStandAlone	1.7	2.3	1.2	0.9	1.1	0.6	(0.1)	1.5	0.4	0.6	3.3	2.9	2.3	1.1	1.3	1.6
RetailStripMall	8.1	3.2	1.0	1.4	2.4	(1.8)	0.7	2.4	(2.3)	1.7	7.1	1.8	6.9	6.1	6.9	7.6
SchoolPrimary	0.7	0.2	0.1	0.2	0.4	0.1	(0.1)	0.1	0.2	0.1	0.4	0.1	0.2	0.4	0.3	0.5
SchoolSecondary	7.3	4.0	6.1	3.8	4.1	2.8	1.5	1.6	2.9	1.8	4.9	2.6	3.0	4.9	2.6	7.0
Warehouse	5.1	2.2	3.8	2.1	2.6	1.6	1.1	0.8	1.1	0.7	1.9	1.2	1.0	1.8	0.4	2.4

Table 47: Benefit-to-Cost Ratio over 30-Year Period of Analysis – Additions/Alterations

Building Prototype	CZ01	CZ02	CZ03	CZ04	CZ05	CZ06	CZ07	CZ08	CZ09	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
ApartmentHighRise	5.9	2.7	2.6	2.5	1.5	(0.1)	(0.6)	0.7	1.6	2.5	7.3	3.6	4.8	7.0	4.0	8.6
Assembly	3.0	1.8	3.6	1.7	2.8	1.5	1.5	0.4	0.8	1.0	2.4	1.8	1.2	2.2	0.7	4.4
Hospital	10.5	8.3	11.9	10.3	8.6	9.8	4.2	4.8	8.4	9.6	18.1	12.0	12.2	22.4	12.5	14.8
HotelSmall	3.9	2.1	2.8	2.0	2.0	1.1	0.4	1.0	1.7	1.9	4.8	2.5	3.4	5.4	3.3	5.0
OfficeLarge	17.6	15.0	14.7	12.0	12.0	10.5	2.9	3.2	11.7	12.1	26.2	18.1	16.4	27.7	17.2	24.9
OfficeMedium	4.9	2.7	3.4	2.8	2.2	1.3	0.5	1.1	2.2	2.9	7.3	3.5	4.5	7.3	5.0	7.5
OfficeMediumLab	6.5	4.0	5.7	4.3	4.1	2.8	2.0	1.7	3.0	3.5	7.9	5.5	4.6	7.6	4.2	6.4
OfficeSmall	2.1	2.5	1.8	2.2	0.0	0.0	(0.3)	2.1	2.1	2.9	9.5	5.2	7.7	9.2	7.5	7.2
RestaurantFastFood	5.2	3.0	4.5	3.2	3.0	1.2	0.8	1.5	2.5	2.9	6.1	4.1	4.2	6.7	4.4	5.4
RetailLarge	2.6	(0.0)	7.2	(0.1)	1.2	1.6	0.5	0.3	2.0	0.1	0.2	(0.7)	2.0	3.4	2.1	2.7
RetailMixedUse	6.9	7.8	2.9	1.9	1.4	0.5	(1.6)	1.3	1.5	5.1	11.1	4.8	5.2	10.1	6.6	10.2
RetailStandAlone	1.7	2.3	1.2	0.9	1.1	0.6	(0.1)	1.5	0.4	0.8	2.2	3.1	3.2	2.6	2.4	3.4
RetailStripMall	8.1	3.2	1.0	1.4	2.4	(1.8)	0.7	2.4	(2.3)	(1.4)	11.0	2.2	10.1	4.9	8.9	13.3
SchoolPrimary	0.7	0.2	0.1	0.2	0.4	0.1	(0.1)	0.1	0.2	0.2	0.9	0.4	0.5	0.9	0.7	1.0
SchoolSecondary	7.3	4.0	6.1	3.8	4.1	2.8	1.5	1.6	2.9	3.8	10.0	5.3	5.8	10.4	5.3	13.0
Warehouse	5.1	2.2	3.8	2.1	2.6	1.6	1.1	0.8	1.1	1.5	3.6	2.4	1.9	3.5	1.0	4.8

Appendix I: Supplemental Energy Savings Impacts Table

The Statewide CASE Team performed a savings analysis for all nonresidential building types, with the TDV energy savings/ft^2 shown in Table 48 and Table 49 . Consistent with other analyses for this report, the ApartmentHighRise and HotelSmall prototypes were excluded from the analysis because the Statewide CASE Team is still reconciling the nonresidential and residential requirements. Currently 95 percent of the ApartmentHighRise prototype is residential and 85 percent of the HotelSmall prototype is residential. The Assembly, Grocery, and SchoolPrimary prototypes were excluded from the statewide savings because the results need further investigation. Grocery is not shown below because the Statewide CASE Team is still investigating how to modify the infiltration rate for the model.

Table 48: Total TDV Energy Savings Per Ft^2 (TDV kBtu/ft^2) – New Construction

Building Prototype	CZ01	CZ02	CZ03	CZ04	CZ05	CZ06	CZ07	CZ08	CZ09	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
ApartmentHighRise	4.4	2.0	2.0	1.9	1.1	(0.1)	(0.5)	0.5	1.2	0.8	2.3	1.1	1.5	2.2	1.3	2.8
Assembly	5.9	3.5	7.1	3.4	5.4	2.9	2.9	0.9	1.7	0.9	2.1	1.6	1.0	1.9	0.6	3.5
Hospital	4.9	3.9	5.6	4.8	4.0	4.6	2.0	2.2	3.9	2.1	3.5	2.5	2.2	5.0	2.6	3.0
HotelSmall	4.8	2.5	3.4	2.5	2.4	1.3	0.5	1.2	2.1	1.1	2.5	1.4	1.8	2.8	1.7	2.6
OfficeLarge	4.9	4.2	4.1	3.3	3.4	2.9	0.8	0.9	3.3	1.7	3.2	2.8	2.1	3.4	2.1	3.2
OfficeMedium	5.6	3.1	3.9	3.2	2.5	1.4	0.5	1.3	2.5	1.4	3.5	1.7	2.2	3.4	2.5	3.6
OfficeMediumLab	7.5	4.5	6.5	4.9	4.8	3.2	2.3	1.9	3.5	1.7	3.8	3.5	2.4	4.0	1.7	3.8
OfficeSmall	1.6	1.9	1.4	1.7	0.0	0.0	(0.2)	1.6	1.6	0.9	3.3	1.8	3.0	3.1	2.5	2.4
RestaurantFastFood	9.5	5.4	8.1	5.8	5.4	2.2	1.5	2.7	4.5	2.3	4.8	3.2	3.3	5.0	3.5	4.0
RetailLarge	1.8	(0.0)	5.2	(0.1)	0.9	1.2	0.4	0.2	1.4	(0.3)	1.3	0.4	0.5	(0.2)	0.2	0.9
RetailMixedUse	5.1	5.8	2.2	1.4	1.0	0.4	(1.2)	0.9	1.1	3.2	3.2	0.7	1.4	4.5	1.6	3.5
RetailStandAlone	4.3	5.8	3.1	2.2	2.8	1.4	(0.2)	3.8	1.0	1.4	7.6	6.6	5.2	2.4	3.0	3.8
RetailStripMall	6.4	2.5	0.8	1.1	1.9	(1.4)	0.6	1.9	(1.8)	0.9	4.0	1.0	3.8	3.4	3.8	4.2
SchoolPrimary	1.8	0.6	0.3	0.4	1.0	0.2	(0.2)	0.3	0.4	0.3	0.9	0.2	0.5	0.9	0.7	1.2
SchoolSecondary	5.0	2.7	4.1	2.6	2.8	1.9	1.0	1.1	2.0	1.0	2.9	1.5	1.7	2.8	1.5	4.0
Warehouse	9.1	3.9	6.8	3.8	4.6	2.8	1.9	1.3	2.0	1.1	3.0	1.9	1.5	2.9	0.6	3.9

Table 49: Total TDV Energy Savings Per Ft^2 (TDV kBtu/ft2) – Additions/Alterations

Building Prototype	CZ01	CZ02	CZ03	CZ04	CZ05	CZ06	CZ07	CZ08	CZ09	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
ApartmentHighRise	4.4	2.0	2.0	1.9	1.1	(0.1)	(0.5)	0.5	1.2	1.9	5.5	2.7	3.6	5.3	3.0	6.4
Assembly	5.9	3.5	7.1	3.4	5.4	2.9	2.9	0.9	1.7	1.9	4.8	3.6	2.3	4.4	1.4	8.7
Hospital	4.9	3.9	5.6	4.8	4.0	4.6	2.0	2.2	3.9	4.5	8.5	5.6	5.7	10.5	5.9	6.9
HotelSmall	4.8	2.5	3.4	2.5	2.4	1.3	0.5	1.2	2.1	2.4	5.9	3.1	4.1	6.6	4.0	6.1
OfficeLarge	4.9	4.2	4.1	3.3	3.4	2.9	0.8	0.9	3.3	3.4	7.3	5.0	4.6	7.7	4.8	7.0
OfficeMedium	5.6	3.1	3.9	3.2	2.5	1.4	0.5	1.3	2.5	3.3	8.4	4.0	5.1	8.4	5.8	8.6
OfficeMediumLab	7.5	4.5	6.5	4.9	4.8	3.2	2.3	1.9	3.5	4.0	9.1	6.3	5.3	8.7	4.9	7.4
OfficeSmall	1.6	1.9	1.4	1.7	0.0	0.0	(0.2)	1.6	1.6	2.2	7.3	4.0	5.9	7.1	5.8	5.6
RestaurantFastFood	9.5	5.4	8.1	5.8	5.4	2.2	1.5	2.7	4.5	5.3	11.1	7.5	7.7	12.1	8.0	9.8
RetailLarge	1.8	(0.0)	5.2	(0.1)	0.9	1.2	0.4	0.2	1.4	0.1	0.1	(0.5)	1.4	2.4	1.5	1.9
RetailMixedUse	5.1	5.8	2.2	1.4	1.0	0.4	(1.2)	0.9	1.1	3.8	8.3	3.6	3.9	7.5	4.9	7.6
RetailStandAlone	4.3	5.8	3.1	2.2	2.8	1.4	(0.2)	3.8	1.0	1.9	5.4	7.7	7.9	6.5	5.8	8.4
RetailStripMall	6.4	2.5	0.8	1.1	1.9	(1.4)	0.6	1.9	(1.8)	(1.1)	8.7	1.7	8.0	3.8	7.0	10.5
SchoolPrimary	1.8	0.6	0.3	0.4	1.0	0.2	(0.2)	0.3	0.4	0.5	2.3	0.9	1.3	2.3	1.7	2.5
SchoolSecondary	5.0	2.7	4.1	2.6	2.8	1.9	1.0	1.1	2.0	2.6	6.8	3.6	4.0	7.1	3.6	8.8
Warehouse	9.1	3.9	6.8	3.8	4.6	2.8	1.9	1.3	2.0	2.7	6.5	4.2	3.3	6.3	1.7	8.6