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A STATEWIDE UTILITY PROGRAM

Codes and Standards Enhancement (CASE) Initiative

2019 California Building Energy Efficiency Standards

Nonresidential Ventilation & Indoor Air Quality (IAQ) – Final Report

Measure Number**:** 2019-NR-ASHRAE62.1-F

Nonresidential Mechanical

September 2017

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EXECUTIVE SUMMARY

Introduction

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

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

Measure Description

This measure proposes revising Title 24, Part 6 requirements using a combination of the requirements in Title 24, Part 4 (California Mechanical Code) and ASHRAE 62.1-2016: Ventilation for Acceptable Indoor Air Quality. The ventilation requirements in 2016 Title 24, Part 4 are based on or reference ASHRAE 62.1-2013. Therefore, aligning Title 24, Part 6 with select sections in Title 24, Part 4 will concurrently align with the corresponding section in ASHRAE 62.1-2016. All of the proposed changes would impact the mandatory requirements for ventilation in Section 120.1 of Title 24, Part 6. The specific recommendations include the following:

1. Replace Section 120.1(b) with the ASHRAE 62.2-2016 requirements which apply to high-rise residential buildings.
2. Require MERV 13 air filters for all ducted forced air system supply outdoor air or all occupancies.
3. Revise Natural Ventilation criteria to align with ASHRAE 62.1-2016.
4. Revise Mechanical Ventilation required ventilation calculation align with 130 percent of ASHRAE 62.1-2016 and include a simplified minimum ventilation rate calculation procedure.
5. Update exhaust ventilation airflow requirements.
6. Add recirculated air limitations.
7. Delete Table 120.1 – A: Minimum Ventilation Rates and add in its place the System Ventilation Efficiency table.
8. Add Table 120.1 – B: Minimum Ventilation Rates in Breathing Zone which uses the expanded list of occupancy categories at 130 percent of 62.1-2016.
9. Add Table 120.1 – C: Zone Air Distribution Effectiveness.
10. Add Table 120.1 – D: Minimum Exhaust Rates.

Scope of Code Change Proposal

Table 1 summarizes the scope of the proposed changes and which sections of the Standards, Reference Appendices, Alternative Calculation Manual (ACM) Reference Manual, and compliance documents will be modified as a result of the proposed changes.

Table 1: Scope of Code Change Proposal

Measure Name	Type of Requirement	Modified Section(s) of Title 24	Modified Title 24, Part 6 Appendices	Will Compliance Software Be Modified	Modified Compliance Document(s)
Nonresidential Indoor Air Quality (Proposal Based on ASHRAE 62.1-2016)	Mandatory	Part 6 - Section 120.1 – Nonresidential Requirements for Ventilation CALGreen Part 11 – Section 5.504.5.3 Filters	None: NA7.5.1 addresses ventilation acceptance, but will not be modified	Yes	• NRCA-MCH-02-A • NRCC-MCH-03-E • NRCC-MCH-05-E • NRCC-PRF-01-E

Market Analysis and Regulatory Impact Assessment

The proposed code change is a mandatory measure that will impact all nonresidential buildings that require a mechanically ventilated system, and by extension, all components of an air system.

A literature review in Section 5.6 Health and Productivity Cost Impacts estimates some of the large productivity gains from improved indoor air quality. Although specific cost-benefit data is not used in this report, the productivity gains are potentially greater than the costs required to improve indoor air quality.

The proposed changes to Title 24, Part 6 have a negligible impact on the complexity of the standards or the cost of enforcement. When developing this code change proposal, the Statewide CASE Team distributed a survey to mechanical design engineers and energy analysts to simplify and streamline the compliance and enforcement of this proposal. Survey results demonstrated that many respondents (65 percent of 34 respondents) are already performing the ASHRAE 62.1 ventilation rate calculations, likely to fulfill requirements of the Leadership in Energy and Environmental Design (LEED) prerequisite. Appendix D includes a summary of survey results. Additional steps were taken to keep a simplified ventilation method for multiple-zone recirculation systems as well for those less familiar with the full ASHRAE 62.1 ventilation rate procedure.

Cost-Effectiveness

This code change proposal improves indoor air quality by referencing Title 24, Part 4 and ASHRAE 62.1-2016 which is based on current research on indoor air quality. ASHRAE 62.1 is a national ventilation standard that is accepted as industry standard practice throughout the country. The typical methodology used to evaluate the cost-effectiveness of proposed changes to Title 24, Part 6 evaluates the incremental cost over a period of time relative to the energy cost savings over the same time period. This methodology is not applicable for the proposed indoor air quality measures, because the primary benefits are code simplification and health benefits, instead of achieving energy savings.

While developing this code change proposal, the Statewide CASE Team worked with the Energy Commission, the California Air Resources Board, and indoor air quality experts (such as those at

Lawrence Berkeley National Laboratory (LBNL)) to evaluate the costs and benefits of the proposed changes. In some situations, ventilation air is reduced compare to 2016 Title 24, Part 6 Standards while other occupancies have increased ventilation air. For some occupancies, calculations are required which optimize outside air in the breathing zones of a space. The cost of compliance is relatively small, and there are many benefits, including harmonization with the International Mechanical Code and ventilation design practice for the rest of the country; improved indoor air quality; and improved occupant health throughout the state. The proposed 130 percent of the ASHRAE 62.1-2016 ventilation rate will also qualify code compliant buildings for the Leadership in Energy and Environmental Design (LEED) "increased ventilation" point.[1] National standard levels and procedures provide common bases upon which to determine whether adequate ventilation is being provided. These benefits have indirect cost savings to both organizations and individuals that are not easily quantified. See Section 5 for a detailed description of the cost-effectiveness analysis.

Statewide Energy Impacts

Table 2 shows potential energy savings over the first year that the proposed code changes would be in effect based on statewide new construction estimates.

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

First-Year Electricity Savings (GWh/yr)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Water Savings (million gallons/yr)	First-Year Natural Gas Savings (million therms/yr)
2.8	0.6	N/A	0.9

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

Compliance and Enforcement

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

- Mechanical designer will need to complete more complex calculations in the design phase to determine outside air requirements and size HVAC equipment.
- Plans examiner must ensure that the proposed design meets the new ventilation requirements.
- Duties for the general contractor and subcontractors will generally remain the same to install the ventilation system. Acceptance testers must verify minimum ventilation rates and issue a certificate of acceptance, although this is not a new task for them.
- Building inspector will need to become familiar with the new ventilation rate and filter MERV 13 requirements to verify code compliance and proper installation of building features.

Although a needs analysis was conducted with the affected market actors while developing the code change proposal, the code requirements may change between the time the final CASE Report is submitted and the time the 2019 standards are adopted. The recommended compliance process and compliance documentation may also evolve with the code language. To effectively implement the

[1] https://www.usgbc.org/credits/healthcare/v4-draft/eqc1

adopted code requirements, a plan should be developed that identifies potential barriers to compliance when rolling out the code change and approaches that should be deployed to minimize the barriers.

1. INTRODUCTION

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support the California Energy Commission's (Energy Commission) efforts to update California's Building Energy Efficiency Standards (Title 24, Part 6) to include new requirements or to upgrade existing requirements for various technologies. The four California Investor Owned Utilities (IOUs) – Pacific Gas and Electric Company, San Diego Gas & Electric, Southern California Edison and SoCalGas® – and two Publicly Owned Utilities (POUs) – Los Angeles Department of Water and Power and Sacramento Municipal Utility District – sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to energy efficiency and energy performance in California buildings. This report and the code change proposal presented herein are part of the effort to develop technical and cost-effectiveness information for proposed regulations on building energy-efficient design practices and technologies.

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

The overall goal of this CASE Report is to present a code change proposal for nonresidential indoor air quality and ventilation. Proposed code changes include updating the minimum ventilation rates and calculation procedure for mechanical ventilation, revising requirements for natural ventilation, requirements for outdoor air treatment, and including exhaust ventilation requirements. The report contains pertinent information supporting the code change.

When developing the code change proposal and associated technical information presented in this report, the Statewide CASE Team worked with a number of industry stakeholders including building officials, manufacturers, builders, utility incentive program managers, Title 24, Part 6 energy analysts, and others involved in the code compliance process. The proposal incorporates feedback received during public stakeholder meetings that the Statewide CASE Team held on September 27, 2016 and March 16, 2017.

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

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

Section 4 presents the per unit energy and demand savings associated with the proposed code change. This section also describes the methodology that the Statewide CASE Team used to estimate energy and demand savings. As discussed in Section 2.2.1, the Energy Commission has a responsibility to establish requirements in which code requirements that improve building energy performance are considered in conjunction with impacts on public health and safety. This code change proposal adjusts requirements pertinent to indoor air quality to ensure that public health and safety is maintained as building envelope requirements become more stringent. This measure will result in increased energy use in some buildings. This CASE Report discusses the likely energy impacts while providing data that the Energy

Commission can use to make informed decisions about the adoption of code change proposals that improve energy performance while preserving or improving indoor air quality.

Section 5 presents information on the costs and cost benefits of the proposed code changes. The primary objective of this code change is to protect public health and safety by recommending requirements that will preserve or improve indoor air quality. As discussed in Section 2.2.1, a cost-effectiveness analysis is not required if the primary objective of the code change proposal is to protect public health and safety. Hence, this CASE Report does not include a cost-effectiveness analysis. However, the Statewide CASE Team did evaluate the energy and energy cost impacts associated with the proposed code changes. The Statewide CASE Team also investigated the cost benefits of improved health and productivity associated with improved indoor air quality.

Section 6 presents the statewide energy impacts and environmental impacts of the proposed code change for the first year after the 2019 Standards take effect. This includes the amount of energy that will be saved by California building owners and tenants.

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

2. MEASURE DESCRIPTION

2.1 Measure Overview

The proposed code change will update the ventilation and indoor air quality requirements found in Title 24, Part 6, Section 120.1 Requirements for Ventilation with ASHRAE 62.1-2016: Ventilation for Acceptable Indoor Air Quality.

Specifically, the following requirements will be added or updated in Title 24, Part 6:

A. Update the minimum ventilation categories and rates for all Title 24, Part 6 nonresidential occupancy categories.

The proposed code change will expand Title 24, Part 6 Table 120.1-A – Minimum Ventilation Rates to include and specify ventilation rates for all Title 24, Part 6 occupancy categories, referencing the rates in ASHRAE 62.1 Table 6.2.2.1 Minimum Ventilation Rates in Breathing Zone, multiplied by 130 percent. The 130 percent multiplier was chosen for the following reasons:

1. Without the 130 percent multiplier on minimum ventilation rates, concentrations of CO_2 in the space for certain occupancy categories can exceed 2,000 parts per million (ppm), which can have adverse effects on human health in as little as a 3-hour exposure sessions. More detailed information is provided in Appendix F.
2. 130 percent multiplier is in alignment with a Leadership in Energy and Environmental Design (LEED) indoor environmental quality credit. This simplifies compliance because many mechanical designers are already familiar with this calculation.
3. To keep code implementation as simple as possible, the 130 percent multiplier is recommended for all space types. It is also worth noting that the ASHRAE 62.1 Working Committee is currently, in parallel to this code change proposal, researching revised ventilation rates for space types for the next version of 62.1.

B. Revise requirements for natural ventilation.

The proposed code change will align the Title 24, Part 6 natural ventilation requirements with ASHRAE 62.1-2016. The natural ventilation rate requirements include a calculation for the floor area to be ventilated by natural ventilation based on the size and types of openings, and allow a greater floor area of the building to be naturally ventilated without the use of mechanical ventilation than is allowed in the 2016 Title 24, Part 6 requirements. Included in the proposed code change is a mechanical ventilation system that can operate in accordance with the ventilation rate procedure when natural ventilation openings are closed. It is expected that windows may be closed due to concerns with extreme outdoor temperatures, noise, security, or high outdoor contaminant levels.

C. **Revise requirements for outdoor air treatment.**

The proposed code change will add the ASHRAE 62.1 requirements for outdoor air treatment of fine particulate matter (PM) to Title 24, Part 6. The proposed code change requires ducted forced air systems to have MERV 13 filters for all building types and occupancies controlled by Title 24, Part 6 and Part 11.

D. **Include requirements for exhaust ventilation from Title 24, Part 4 in Title 24, Part 6.**

The proposed code change will incorporate the requirements for exhaust ventilation found currently in Title 24, Part 4 Section 403.7 (adopted from ASHRAE 62.1-2013, Section 6.5.1) into Title 24, Part 6. Exhaust ventilation requirements are currently included in the California Mechanical Code (Title 24, Part 4) and all other ventilation requirements are in Part 6, which is a source of confusion. After adoption of this proposal, Title 24, Part 6 will contain all ventilation requirements for occupancies regulated by the Energy Commission.

The proposed measure will apply to all nonresidential buildings, high-rise residential, and hotels and motels that are covered by Title 24, Part 6. Specifically, Title 24, Part 6 covers all buildings that are of Occupancy Group A, B, E, F, H, M, R, S, and U. The California Mechanical Code (Title 24, Part 4) includes requirements for occupancies that are not covered by Title 24, Part 6, specifically occupancies I and L (Institutional and Laboratories).

The proposed measure is a mandatory requirement for the building types listed above (A, B, E, F, H, M, R, S, and U). If the built-up HVAC unit in its entirety is altered, then the proposed measure is triggered. If the dampers in the HVAC unit are altered, the proposed measure is also triggered.

At the time of the writing of this CASE Report, the Statewide CASE Team is in communication with the Energy Commission, utility representatives, and other stakeholders to continue to refine the scope of the proposed code change.

2.2 Measure History

2.2.1 California Energy Commission's Authority and Responsibility to Regulate Indoor Air Quality in Title 24, Part 6

The Warren-Alquist Act of 1974 requires the Energy Commission to consider the impacts of any new building standards on indoor air quality (Section 25402.8). Furthermore, when enacting building standards, the Energy Commission is also required to promulgate standards that are consistent with public health and safety statutes and regulations.

In 1995, the California legislature further enacted Health and Safety Code Sections 105400 and 105410. Health and Safety Code Section 105400 states:

"The Legislature finds and declares that:

(a) The people of the State of California have a primary interest in the quality of the indoor environment in which they live.

(b) As people spend greater portions of time each day indoors, the environmental quality of our buildings becomes increasingly important.

(c) Changes in building design, materials, construction, and operation have resulted in significant changes in indoor environmental quality.

(d) Activities and use of chemical products, appliances, power equipment, wear and tear of structural decorative materials, thermal factors, and mechanical ventilation are degrading the indoor environment, thereby creating mounting dangers to the public health, safety, and welfare."

Health and Safety Code Section 105410 states:

> "The Legislature, in view of the findings and declarations specified in Section 105400, declares that the public interest shall be safeguarded by a coordinated, coherent state effort to protect and enhance the indoor environmental quality in residences, public buildings, and offices in the state."

Throughout this time, the California Air Resources Board has consistently recognized the Energy Commission's authority to establish and maintain building standards that address indoor air quality as a key tool to improve indoor air quality.

Because this proposed code change is primarily concerned with protecting and enhancing the indoor environmental quality, the Energy Commission does not require a cost-effectiveness analysis.

2.2.2 Title 24, Part 6 Ventilation Standard – Measure History

The minimum nonresidential ventilation rates have not been updated since the 1992 Title 24, Part 6 Standards. There is an opportunity to make code revisions that align with the latest science and engineering consensus about ventilation and indoor air quality. Furthermore, some of the proposed code changes, such as adding requirements for outdoor air treatment have the opportunity to improve indoor air quality.

ASHRAE 62.1 is the nonresidential building ventilation standard that is required in most states. Updating California's ventilation standards with parts of ASHRAE 62.1 would provide the auxiliary benefit of aligning California with national standards, which allows designers to leverage resources that are available throughout the country.

In 1990, the Energy Commission was directed by the California Legislature (California Energy Commission 2017) to include ventilation and indoor air quality requirements in Title 24, Part 6 to ensure that energy efficiency requirements are appropriately balanced with the need to maintain acceptable indoor air quality. ASHRAE had recently updated its indoor air quality standard, Standard 62-1989, with outdoor air rates that at least tripled those from prior versions of the Standard 62 and from those in other model codes at the time. The model code that California used at the time, the International Conference of Building Officials (ICBO) Uniform Codes, had not yet been updated to reflect the new ASHRAE outdoor ventilation rates. Instead of adopting the requirements in ICBO model codes or Standard 62-1989, the Energy Commission developed indoor air quality requirements for Title 24, Part 6 that were appropriately balanced with energy efficiency requirements. After extensive debate and multiple public hearings, Section 121- Requirements for Ventilation for the 1992 Standards was adopted. This section has remained largely unchanged since the 1992 Standards.

At about the same time, ASHRAE began updating Standard 62. Some of the same individuals who developed the California ventilation standard were also members of the committee charged with upgrading Standard 62. The new ASHRAE ventilation rate calculation procedure was published as Addendum 62n in 2003, then as part of a complete reissue of Standard 62.1 in 2004.

Standard 62.1-2004 was developed through the ANSI consensus procedure and represented the latest research in establishing ventilation rates. The ventilation rate procedure was expressly developed for use in building codes, aimed at producing minimum ventilation rates that balanced indoor air quality concerns with first cost and energy cost concerns. However, ASHRAE 62.1 is a national consensus standard where the balance between indoor air quality and energy consumption varies widely. California, with its major population centers in mild climates and its prioritized concern for indoor air quality, has had ventilation rates that, for most occupancies, have been higher than ASHRAE 62.1 rates.

See Appendix C for more detailed discussion of how the ASHRAE 62.1 ventilation rates were developed and the differences between ASHRAE 62.1, other model codes, and Title 24, Part 6.

2.3 Summary of Proposed Changes to Code Documents

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

Where applicable, in order to avoid duplication of code language in Title 24, Part 6, the code change language will refer to the existing corresponding section of Title 24, Part 4.

2.3.1 Standards Change Summary

This proposal will modify the following sections of the Title 24, Part 6 Building Energy Efficiency Standards as shown below.

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION: Add definitions for new terms that will be used in the proposed code change language.

SECTION 120.1 – REQUIREMENTS FOR VENTILATION

Subsection 120.1(b): The proposed code change replaces the current contents with requirements for high-rise residential dwellings.

Subsection 120.1(c): This is a new subsection titled "Nonresidential and Hotel/Motel Buildings," which includes natural and mechanical ventilation as well as a revised minimum ventilation table. The major change in this CASE Report proposes that MERV 13 filters are required. Subsequent subsection labels are changed due this insertion. The proposal also modifies sections of CALGreen Title 24, Part 11 as needed due the MERV 13 requirement in Part 6.

Subsection 120.1(d): Edits are made to update demand control ventilation requirements.

Subsection 120.1(g): This is a new "Recirculation Limitations" subsection.

2.3.2 Reference Appendices Change Summary

This code change proposal is not expected to modify the reference appendices. The Mechanical Systems Acceptance Tests for Outdoor Air (NA7.5.1) will not be modified.

2.3.3 Alternative Calculation Method (ACM) Reference Manual Change Summary

This proposal will modify Section 5.6.5.4 of the Nonresidential ACM Reference Manual as summarized below.

5.6.5.4 Outdoor Air Ventilation

Minimum Ventilation Rate: Input restrictions and ACM calculation methodology should be updated so that minimum ventilation rate is calculated using the proposed ventilation rate procedure in Title 24, Part 4 (ASHRAE 62.1).

2.3.4 Compliance Manual Change Summary

The proposed code change will modify the following section of the Nonresidential Compliance Manual:

- 4.3 Ventilation Requirements

2.3.5 Compliance Documents Change Summary

The proposed code change will modify the compliance documents listed below.

- NRCA-MCH-02-A
- NRCC-MCH-03-E
- NRCC-MCH-05-E
- NRCC-PRF-01-E

2.4 Regulatory Context

2.4.1 Existing Title 24, Part 6 Standards

At present, Title 24, Part 6 outlines requirements for ventilation in Section 120.1 Requirements for Ventilation of nonresidential buildings and high-rise apartments. This section describes the design requirements for minimum quantities of outdoor air for both natural ventilation and mechanical ventilation. The requirements state that each space that is not naturally ventilated shall have a mechanical system capable of providing an outdoor air rate no less than the larger of:

1. The conditioned floor area of the space times the applicable ventilation rate from Table 120.1-A; or
2. 15 cubic feet per minute (cfm) per person times the expected number of occupants.

Table 120.1-A lists ten "Types of Use" and corresponding minimum cfm per square foot of conditioned floor area are listed. If a type of use is not listed, there is an "All others" option that specifies 0.15 cfm per square foot of conditioned floor area. See Table 3.

Table 3: Existing Title 24, Part 6 Table 120.1-A Minimum Ventilation Rates

Type of Use	CFM per Square Foot of Conditioned Floor Area
Auto repair Workshops	1.50
Barber shops	0.40
Bars, cocktail lounges, and casinos	0.20
Beauty shops	0.40
Coin-operated dry cleaning	0.30
Commercial dry cleaning	0.45
High-rise residential	Ventilation Rates Specified by the CBC
Hotel guest rooms (less than 500 ft^2)	30 cfm/guest room
Hotel guest rooms (500 ft^2 or greater)	0.15
Retail stores	0.20
All others	0.15

Title 24, Part 6 currently does not have requirements for outdoor air treatment or exhaust ventilation. Requirements for these are covered in other parts of Title 24 as described in Section 2.4.2.

2.4.2 Relationship to Other Title 24 Requirements

The full ASHRAE 62.1-2013 ventilation rate procedure can be found in Title 24, Part 4 Sections 403.2 through 403.5. The Energy Commission and the Building Standards Commission are working together to clarify the language that remains in Part 4.

Portions of the ASHRAE 62.1 natural ventilation requirements can be found in Title 24, Part 4 (California Mechanical Code) Sections 402.2. Other natural ventilation requirements are found in Title 24, Part 2, Chapter 12 (California Building Code).

Requirements for air treatment can be found in CALGreen mandatory measure 5.504.5.3, which requires filters with a MERV rating of 8. Voluntary CALGreen measures A5.504.5.3.1 and A5.504.5.3.1.1 requires filters with MERV ratings of 11 and 13, respectively.

Requirements for exhaust ventilation can be found in Title 24, Part 4 (California Mechanical Code) Section 403.7.

Minimum ventilation rates in the breathing zone, for both the people and area component, can be found in Title 24, Part 4 (California Mechanical Code) Table 402.1.

However, Section 402.1 in Title 24, Part 4 currently contains language that leads to confusion about whether or not ventilation requirements should follow Title 24, Part 4 or Title 24, Part 6. The following is a suggested revision to Title 24, Part 4, Section 402.1.

> *"Ventilation air supply, exhaust, and makeup air requirements for occupancies* A, B, E, F, H, M, R, S, and U *regulated by the California Energy Commission are found in Title 24, Part 6, Section 120.1."*

2.4.3 Relationship to State or Federal Laws

There are no federal laws that address ventilation rates or indoor air quality.

2.4.4 Relationship to Industry Standards

The industry standard for ventilation requirements used by most states outside of California is ASHRAE 62.1. The proposed change would adapt many parts of the ASHRAE 62.1 into Title 24, Part 6, thereby aligning with the ventilation standard that most of the country uses.

The International Mechanical Code for commercial buildings includes provisions for ventilation that follow ASHRAE 62.1 standard for ventilation rate procedure.

For new construction projects pursuing LEED certification, one of the mandatory requirements is a mechanical ventilation system that is designed using the ventilation rate procedure defined in ASHRAE 62.1. One of the LEED voluntary ventilation credits (indoor environmental quality) requires 130 percent of the ASHRAE 62.1 ventilation rates.

2.5 Compliance and Enforcement

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

This code change proposal will affect all new construction commercial buildings that must follow 2019 Title 24, Part 6. Changes to the compliance process are summarized below:

- **Design Phase**: The mechanical designer will need to complete more complex calculations in the design phase to determine outside air requirements and size equipment. These calculations must be done in the design phase, because they are integral to the design of the system itself. The energy consultant must model buildings to meet the new code requirements, and know what to request to be successful in guiding compliance to the energy code. The compliance documents will also be more complex and may require a spreadsheet-type calculation to be submitted. There is also the potential benefit for designers in California to leverage resources in use throughout the country. MERV 13 filters must be specified after making sure the selected

HVAC equipment can accommodate them. Duct system designs must be sized to cost effectively handle increase pressure drop through filters.

- **Permit Application Phase**: Since the calculations are more complicated, it may take plans examiners more time to confirm the calculations were performed correctly. The compliance documents will also change, and the plans examiner will need to be familiar with these new documents.
- **Construction Phase**: Generally, duties for the builder/general contractor and installer/specialty subcontractor will remain the same. The builder/general contractor coordinates the construction and installation of the ventilation system as well as manages installers and subcontractors. The installer/specialty subcontractor coordinates with the general contractor to properly install the ventilation system. Installed filters must be verified as being MERV 13.
- **Inspection Phase**: The building inspector will need to become familiar with the new ventilation rate requirements to verify code compliance and proper installation of building features. Acceptance test providers will need to revamp programs to the new code requirements, and establish verification training in line with new requirements.

The proposed code change to follow the ASHRAE 62.1 ventilation rate procedure requires that air distribution effectiveness and ventilation efficiency be computed. The proposed calculation to determine minimum required ventilation air supply rates is more complicated, which may require building officials or their consultants to spend more time on calculation submissions.

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

3. Market Analysis

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. The Statewide CASE Team considered how the proposed standard may impact the market in general and individual market actors. The Statewide CASE Team gathered information about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, Energy Commission staff, and a wide range of industry players who were invited to participate in Utility-Sponsored Stakeholder Meetings held on September 27, 2016 and March 16, 2017.

3.1 Market Structure

3.1.1 Modified Minimum Ventilation Rates and Ventilation Rate Procedure

The proposed code change is a mandatory measure that affects all market actors who perform ventilation rate calculations, including energy analysts and mechanical design engineers. These calculations impact all nonresidential new construction. The ASHRAE 62.1 ventilation rate procedure is more complex than the current Title 24, Part 6 ventilation rate requirements, and may require more time to complete. However, the ASHRAE 62.1 ventilation rate procedure is a prerequisite for LEED certification and as such, many energy analysts and mechanical designers are already familiar with the calculation methodology. Furthermore, projects located in other states, but designed by a California engineering design firm, use the ASHRAE 62.1 ventilation rate procedure to calculate ventilation rates. The simplified procedure for calculating minimum ventilation rates for multiple-zone recirculating systems is presented in the code change language as an alternative. As such, design engineers have an option of using either the procedure currently found in ASHRAE 62.1-2016, or the alternative simplified procedure.

A number of entities that have identified the risks associated with inadequate indoor air quality including federal agencies such as the U.S. Environmental Protection Agency (EPA) and U.S. Department of Energy (DOE), and state agencies such as the California Air Resources Board, the California Department of Public Health, and California Division of Occupational Safety and Health. There is broad support of the requirements contained in ASHRAE 62.1-2016 as an appropriate response to the health risks from poor indoor air quality.

3.1.2 Natural Ventilation Procedure

The proposed code change is a mandatory measure that affects all market actors who design natural ventilation systems, and affects architects, energy analysts, and mechanical design engineers. These market actors will need to comply with the new requirements, including the required new size of openings and calculation methodology.

The code change includes a requirement that natural ventilation openings must be permanently open or have controls that prevent the openings from being closed during periods of expected occupancy. This may require the installation of window actuators and their associated controls. Vendors include WindowMaster, Ultraflex Control Systems, and Automated Fenestration Inc.

3.1.3 Outdoor Air Treatment

The proposed code change is a mandatory measure that affects market actors who specify and manufacture outdoor air treatment products. Filters are specified by mechanical design engineers for outdoor air treatment. Principal manufacturers of particulate matter filters include Camfil, AAF Flanders and Purafil. Filters are a well-established technology and readily available from multiple manufacturers. Static pressure drop through filters is always included in the design and sizing of duct systems

3.2 Technical Feasibility, Market Availability and Current Practices

3.2.1 Modified Minimum Ventilation Rates and Ventilation Rate Procedure

The proposed code change impacts all new and “gut rehab” nonresidential buildings that require a mechanically ventilated system. For dedicated outside air systems (DOAS), the size and peak system airflow rate is affected by a change in the minimum ventilation rates; a mechanical designer may specify a smaller or larger DOAS than would have been specified with the current Title 24, Part 6 requirements.

For systems that are not DOAS, the system’s peak airflow rate depends on heating and cooling loads, and not on the minimum ventilation rates that are being modified by the proposed code change. Therefore, the system sizing and cost should not change with the proposed code change. Minimum outdoor air dampers must be set to provide the air required by ASHRAE 62.1.

The ASHRAE 62.1 ventilation rate procedure is a prerequisite for LEED certification, and as such, most energy analysts and mechanical designers are already familiar with the calculation methodology. Furthermore, projects located in other states, but designed by a California engineering design firm, use the ASHRAE 62.1 ventilation rate procedure to calculate ventilation rates.

For some occupancy categories and space types, the required minimum ventilation rate and energy use may increase. However, increased ventilation will improve indoor air quality, and this is a trend that many green building rating systems, including the LEED and WELL building standards, are moving towards.

3.2.2 Natural Ventilation Procedure

The proposed code change will require some design engineers to change the way natural ventilation systems are designed, but there are no technical feasibility or market availability issues. There are also no constructability or inspection challenges, and no impacts and potential challenges on building/system longevity, occupant comfort, aesthetic, or other tradeoffs.

3.2.3 Outdoor Air Treatment

The proposed code change impacts all new construction nonresidential buildings requiring a mechanically ventilated system. MERV 13 particle filters are required which is an upgrade from the current level of MERV 8. The market for filtration is well established, and there is ample ability for the market to ramp up and supply the components necessary for the proposed code change after an initial period of adjustment.

Contaminates in outdoor air that require treatment are discussed in Section 6.2.1 Outdoor Air Treatment of ASHRAE Standard 62.1-2016. The proposed change will mitigate small particle pollution. As shown in Figure 1 and Figure 2 most of California contains regions that are classified as nonattainment for PM 10 and PM 2.5.

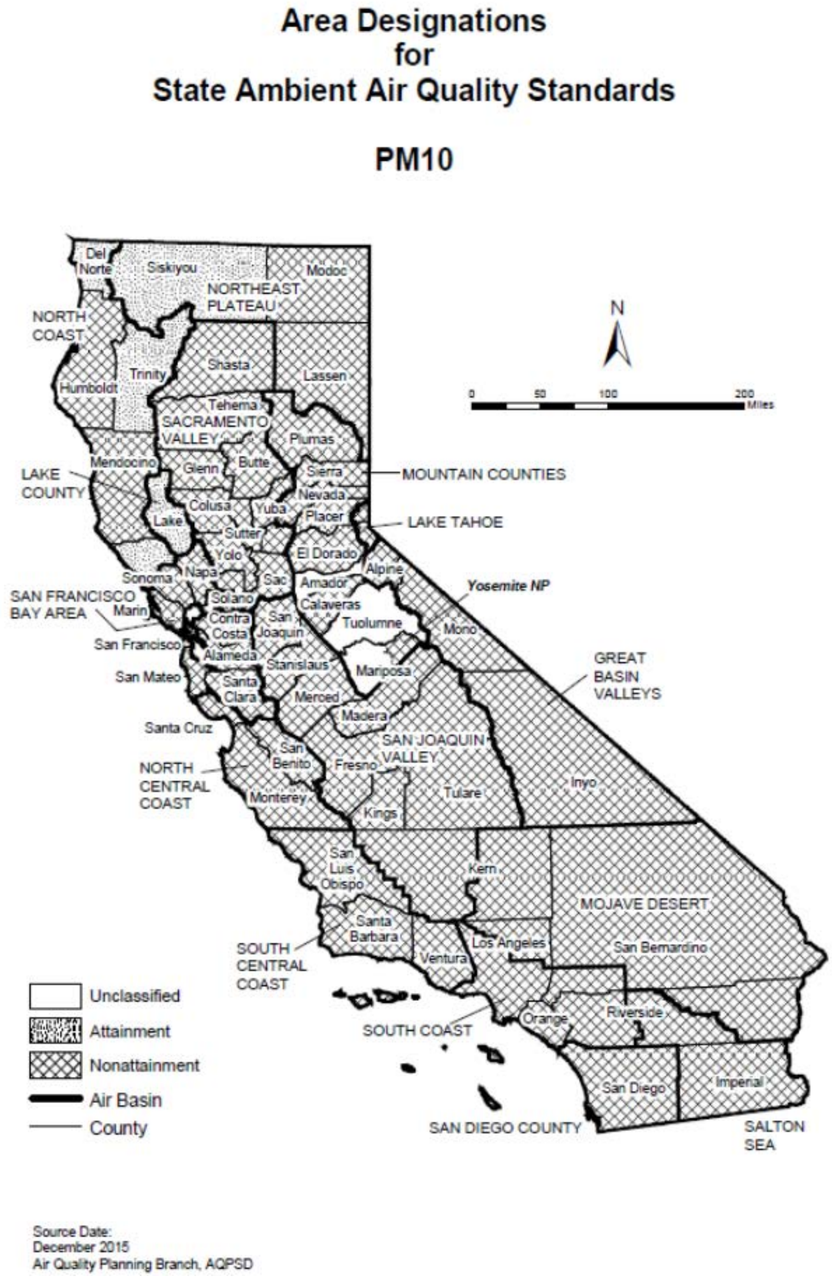

Figure 1: Area designations for State ambient air quality standards – PM-10.

Source: Air Quality Planning Branch, AQPSD.

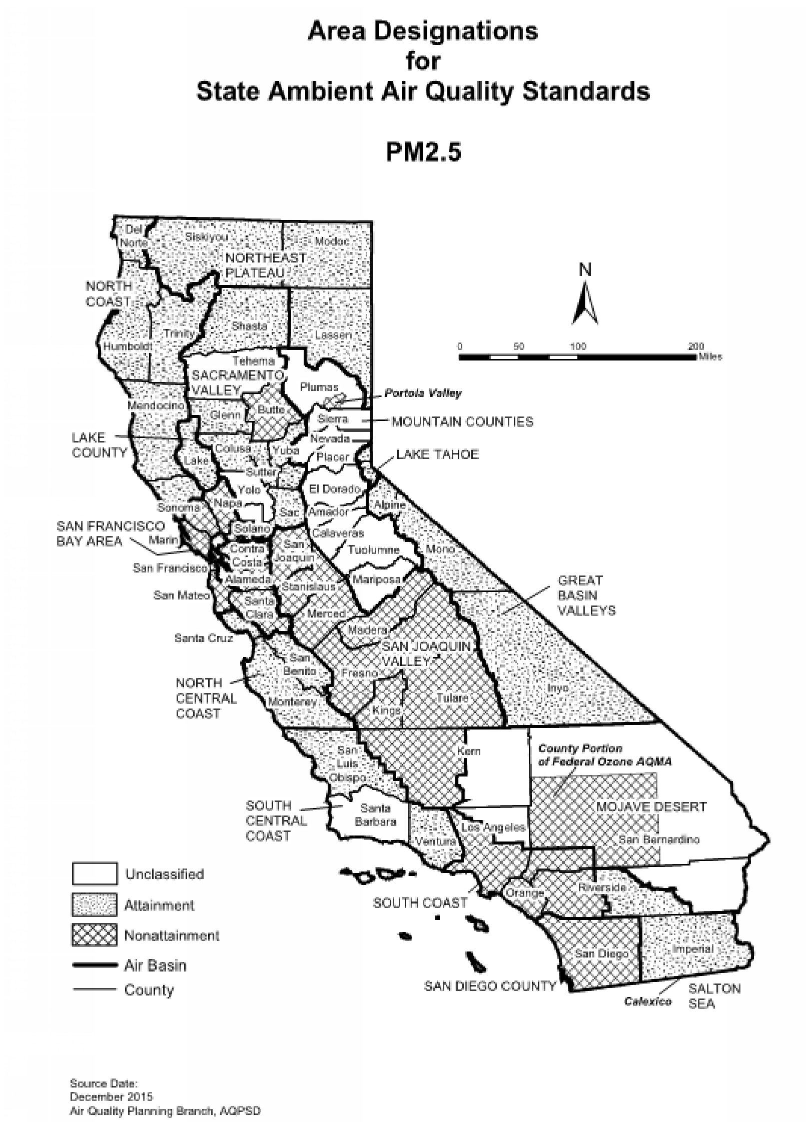

Figure 2: Area designations for State ambient air quality standards – PM-2.5.

Source: Air Quality Planning Branch, AQPSD.

The proposed requirement of MERV 13 achieves a high level of PM reduction using a readily available type of filter. As shown in Table 4, MERV 13 achieves high levels of filtration. The existing MERV 8 filter requirement does not perform well, especially in the PM 1.0 to 3.0 range. The Cities of Los Angeles and San Francisco have adopted ordinances requiring MERV 13 for new dwellings near busy roadways.[2] California outdoor air quality is out of compliance with EPA standards in PM 10.0 and PM 2.5. Requiring MERV 13 addresses problems with small particle pollution. Table 4 displays the

[2] http://www.latimes.com/local/lanow/la-me-ln-freeway-pollution-filters-20170709-story.html

https://www.sfdph.org/dph/files/EHSdocs/AirQuality/Article38DevGuidance.pdf performance of MERV filters from 1 to 16. By using MERV 13 the PM 10.0 and 2.5 problems are mitigated with 85 and 90 levels of filtration.

Table 4: MERV filtration efficiency[3]

Standard 52.2 Minimum Efficiency Reporting Value (MERV)	Composite Average Particle Size Efficiency, % in Size Range, µm			
	Range 1 (0.3-1.0)	Range 2 (1.0-3.0)	Range 3 (3.0-10.0)	Average Arrestance, %
1	n/a	n/a	$E_3 < 20$	$A_{avg} < 65$
2	n/a	n/a	$E_3 < 20$	$65 \le A_{avg} < 70$
3	n/a	n/a	$E_3 < 20$	$70 \le A_{avg} < 75$
4	n/a	n/a	$E_3 < 20$	$75 \le A_{avg}$
5	n/a	n/a	$20 \le E_3 < 35$	n/a
6	n/a	n/a	$35 \le E_3 < 50$	n/a
7	n/a	n/a	$50 \le E_3 < 70$	n/a
8	n/a	$20 \le E_2$	$70 \le E_3$	n/a
9	n/a	$35 \le E_2$	$75 \le E_3$	n/a
10	n/a	$50 \le E_2 < 65$	$80 \le E_3$	n/a
11	$20 \le E_1$	$65 \le E_2 < 80$	$85 \le E_3$	n/a
12	$35 \le E_1$	$80 \le E_2$	$90 \le E_3$	n/a
13	$50 \le E_1$	$85 \le E_2$	$90 \le E_3$	n/a
14	$75 \le E_1 < 85$	$90 \le E_2$	$95 \le E_3$	n/a
15	$85 \le E_1 < 95$	$90 \le E_2$	$95 \le E_3$	n/a
16	$95 \le E_1$	$95 \le E_2$	$95 \le E_3$	n/a

There are concerns related to space constraints for requiring MERV 13 filters in all ducted systems, including in smaller off-the-shelf package units (less than 10 tons). However, vendors indicated that there are two-inch MERV 13 filter options widely available that work adequately in smaller fan coils and packaged units. There are also concerns related to the increased energy use associated with installing outdoor air treatment equipment. However, enhanced air filtration will improve indoor air quality and economic productivity in employees. Furthermore, the green building industry has experienced a trend toward improving indoor air quality. For example, in the WELL[4] building standard, MERV 13 filters are required in the ventilation system to filter outdoor air. The energy impacts of requiring MERV 13 are addressed in Section 3.1.3.

Ground Ozone pollution is also addressed in Section 6.2.1 Outdoor Air Treatment of ASHRAE 62.1-2016:

> "Air-cleaning devices for ozone shall be provided, when the most recent three-hour average annual fourth-highest daily maximum eight-hour ozone concentration exceeds 0.107 ppm. … Such air-cleaning devices shall have a volumetric ozone removal efficiency of not less than 40% … "

[3] http://www.mechreps.com/PDF/Merv_Rating_Chart.pdf

[4] https://www.wellcertified.com/standard

As shown in Figure 4, most of California has a nonattainment status with the state standard of 0.09 ppm 1-Hour Average and 0.070 ppm Annual Average.[5]

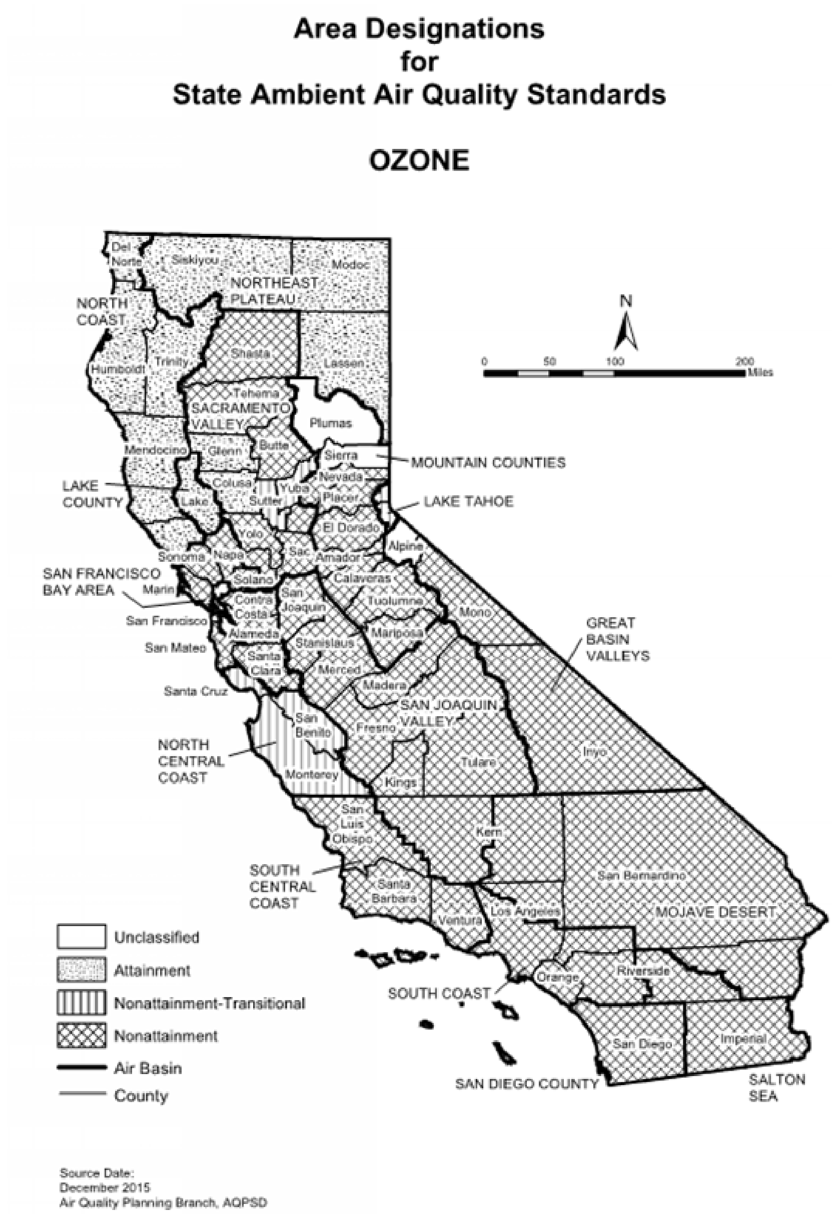

Figure 3: Area designations for State ambient air quality standards – Ozone.

Source: Air Quality Planning Branch, AQPSD.

[5] https://www.arb.ca.gov/research/aaqs/common-pollutants/ozone/ozone.htm

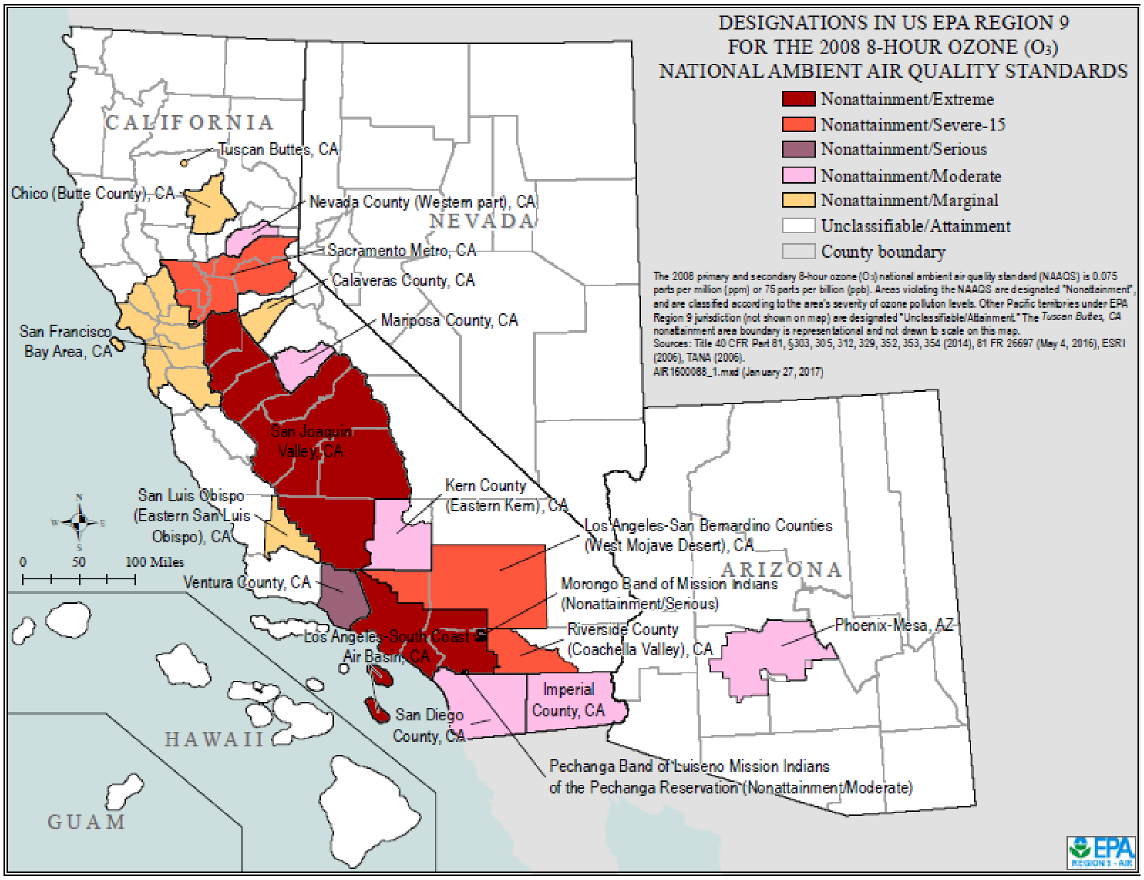

Figure 4: EPA 2008 Region 9 Ozone Nonattainment Map for 0.107 ppm.

Source: EPA, https://www3.epa.gov/region9/air/maps/pdfs/air1100018-7.pdf.

The Statewide CASE Team could not find a standard test method that would allow a third-party verification of the 40 percent removal requirement. A pilot study done by LBNL titled "Ozone Removal by Filters Containing Activated Carbon: A Pilot Study" showed that ozone removal levels exceeded the 40 percent target.[6]

Table 5: LBNL Pilot Study Test Results[7]

Table 2. Ozone removal performance of the filter banks.

Days After Filter Installation	Filter Bank	Activated Carbon in Prefilters	Upstream Ozone (ppb)	Downstream Ozone (ppb)	% Ozone Removal*
67	EFB 1	Y	27	8	70%
67	EFB-2	Y	22**	8	60%
67	RFB	N	21	21	0%
81	EFB 1	Y	23	8	70%
81	EFB-2	Y	22	10	60%
81	RFB	N	23	22	0%

[6] https://www.osti.gov/scitech/servlets/purl/1050670/

[7] https://buildings.lbl.gov/publications/ozone-removal-filters-containing

This study provides interesting and preliminary data, but cannot provide the bases for a proposed change to the Title 24, Part 6 Standards. It can be the bases for the possible use in an advanced "healthy" building. Since there is no consensus test standard for ozone removing filters, there is no certified listing of filter models and their ozone filtration effectiveness to support a Title 24 requirement. Another unknown is the ozone levels in the breathing zones of buildings with high MERV filtration of outdoor air. It can be hypothesized that ozone in the breathing zone is low, due to the highly reactive nature of ozone. But, there is concern that the products of ozone reactions are both complex and toxic.

Although treatment of ozone in outdoor air used to meet IAQ requirements is an important issue, it will not be included in this cycle's code change. It is recommended that the field research, test standard, and Title 20 listing of ozone filters be conducted to support the future adoption ozone filtration requirements.

3.3 Market Impacts and Economic Assessments

3.3.1 Impact on Builders

It is expected that builders will not be impacted significantly by any one proposed code change or the collective effect of all of the proposed changes to Title 24, Part 6. Builders could be impacted by change in demand for new buildings and by construction costs. Demand for new buildings is driven more by factors such as the overall health of the economy and population growth than the cost of construction. The cost of complying with Title 24, Part 6 requirements represents a very small portion of the total building value. Increasing the building cost by a fraction of a percent is not expected to have a significant impact on the builders' profits or demand for new buildings.

See Appendix B for further details on how the compliance process will impact builders.

3.3.2 Impact on Building Designers and Energy Consultants

Adjusting design practices to comply with changing building codes practices is within the normal practices of building designers. Building codes (including the California Building Code and model national building codes published by the International Code Council, the International Association of Plumbing and Mechanical Officials, and ASHRAE 90.1) are typically updated on a three-year revision cycle. As discussed in Section 3.3.1, all market actors, including building designers and energy consultants, should (and do) plan for training and education that may be required to adjust design practices to accommodate compliance with new building codes. As a whole, the measures the Statewide CASE Team is proposing for the 2019 code cycle aim to provide designers and energy consultants with opportunities to comply with code requirements in multiple ways, thereby providing flexibility in ways that requirements can be met.

See Appendix B for further details on how the compliance process will impact building designers and energy consultants.

3.3.3 Impact on Occupational Safety and Health

The proposed code change does not alter any existing federal, state, or local regulations pertaining to safety and health, including rules enforced by the California Division of Occupational Safety and Health. All existing health and safety rules will remain in place. Complying with the proposed code change is not anticipated to have adverse impacts on the safety or health of occupants, or those involved with the construction, commissioning, and maintenance of the building.

This proposal will increase the minimum amount of outside air required for most space types that are readily occupied as compared with the current ventilation requirements in Title 24, Part 6. Most current literature indicates that increasing ventilation rates will decrease respiratory illness and associated sick leave, reduce sick building syndrome symptoms, and improve productivity. Hence, the proposed measure requires 30 percent higher than the current ASHRAE 62.1 ventilation rates.

3.3.4 Impact on Building Owners and Occupants

The primary first cost associated with this measure is for those buildings located in regions with high levels of particulate matter. In these regions, MERV filters are required to reduce particulates. However, these costs are offset by less illness and employee absenteeism.

There is some concern that this proposal will increase carbon dioxide levels in some occupancies to levels (> 2,000 PPM) that may significantly impact cognitive performance. To date there have been three studies that have found this connection, but may not involve enough subjects to be considered conclusive (Kajtar et al. 2006; Satish et al. 2012; Maddalena et al. 2014). The ASHRAE 62.1 ventilation standard only allows carbon dioxide levels to rise to this level in the "Housing, Public and Common Areas: Multi-family, Dormitory" occupancy category; as such, the Statewide CASE team increased the minimum ventilation rate required for this occupancy category compared to what was specified by ASHRAE 62.1.

The installation of MERV filters may require additional maintenance and replacements. Generally, MERV filters are replaced every three months which was used in the economic analysis to assess the impact of filtration requirements.

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

The proposed code change will have little to no impact on building component retailers. Particle filter manufacturers may need to increase the amount of their product that is manufactured or distributed.

3.3.6 Impact on Building Inspectors

The proposed code change will impact building inspectors by requiring an update to the compliance document NRCA-MCH-02-A. Care will be taken to ensure the updates to this document are clear and allow the inspection to be streamlined wherever possible.

3.3.7 Impact on Statewide Employment

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

3.4 Economic Impacts

3.4.1 Creation or Elimination of Jobs

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

3.4.2 Creation or Elimination of Businesses in California

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

Table 6 lists industries that will likely benefit from the proposed code change classified by their North American Industry Classification System (NAICS) Code.

Table 6: Industries Receiving Energy Efficiency Related Investment, by North American Industry Classification System (NAICS) Code

Industry	NAICS Code
Residential Building Construction	2361
Nonresidential Building Construction	2362
Plumbing, Heating, and Air-Conditioning Contractors	23822
Ventilation, Heating, Air-Conditioning, & Commercial Refrigeration Equip. Manf.	3334
Engineering Services	541330
Building Inspection Services	541350
Environmental Consulting Services	541620

3.4.3 Competitive Advantages or Disadvantages for Businesses in California

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

3.4.4 Increase or Decrease of Investments in the State of California

The proposed changes to the building code are not expected to impact investments in California on a macroeconomic scale, nor are they expected to affect investments by individual firms. The allocation of resources for the production of goods in California is not expected to change as a result of this code change proposal. In addition, certified acceptance testers from other states that utilize the ASHRAE 62.1 methodology may more easily be able to perform their work in California, and vice versa.

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

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

3.4.5.1 Cost of Enforcement

Cost to the State

State government already has budget for code development, education, and compliance enforcement. While state government will be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, these activities are already covered by existing state budgets. The costs to state government are small when compared to the overall costs savings and policy benefits associated with the code change proposals. This proposed code change will affect the design of state buildings, resulting in improved indoor air quality in these spaces and decreased employee absenteeism.

Cost to Local Governments

All revisions to Title 24, Part 6 will result in changes to compliance determinations. Local governments will need to train building department staff on the revised Title 24, Part 6 Standards. While this re-training is an expense to local governments, it is not a new cost associated with the 2019 code change cycle. The building code is updated on a triennial basis, and local governments plan and budget for retraining every time the code is updated. 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 B, the Statewide CASE Team considered how the proposed code change might impact various market actors involved in the compliance and enforcement process and aimed to minimize negative impacts on local governments.

3.4.6 Impacts on Specific Persons

The proposed changes to Title 24, Part 6 are not expected to have a differential impact on any groups relative to the state population as a whole, including migrant workers, commuters, or persons by age, race, or religion. Given construction costs are not well correlated with building prices, the proposed code changes are not expected to have an impact on financing costs for businesses.

4. ENERGY SAVINGS

4.1 Key Assumptions for Energy Savings Analysis

The following are the key assumptions used in the energy savings analysis:

- Prototype buildings: small school, large school, small office, medium office, small hotel, large retail, warehouse.
- Zone air distribution effectiveness (E_z): 0.8
- Occupant densities are those of each prototype.
- The OpenStudio interface to the EnergyPlus whole building simulation program was used to quantify energy savings and peak electricity demand reductions resulting from the proposed measure. The OpenStudio models were generated from CBECC-Com initially to align with the energy use of 2016 Title 24, Part 6 Standards. Enhancements will need to be made to the Energy Commission approved simulation program (CBECC-Com) to perform the ASHRAE 62.1 ventilation rate procedure calculations.
- The large school, small office, medium office, small hotel, and large retail prototype buildings did not have ventilation space types in the model and needed to be upgraded to include them. A space type breakdown for these building types, listed in the National Commercial Construction Characteristics (NC3), was used. The NC3 dataset comprises 343 buildings that were constructed or designed between 2001 and 2007. An average ventilation rate weighted by the space type breakdown was used for both the baseline and proposed models. The space type breakdown for each prototype building can be found in Appendix E.

4.2 Energy Savings Methodology

4.2.1 Modified Minimum Ventilation Rates and Ventilation Rate Procedure

To assess the energy, demand, and energy cost impacts, the Statewide CASE Team developed the following analysis steps:

1. Selected prototype models that best match statewide construction forecasts for 2020 by building type.
2. Used the NC3 database to determine what spaces types by percentage makeup each prototype building.
3. Calculated the change in ventilation by space type and area between current requirements of Title 24 and the proposed code change to determine the prototype building's whole building ventilation adjustment.
4. Run the prototype energy models in all 16 California climates with and without the ventilation adjustment.
5. Scale the energy, demand, and energy cost savings by building type to the statewide construction forecast for 2020 in Appendix A.

Step 1: Select Prototype Models

This code change will affect all building types. The prototypes selected include small school, large school, small office, medium office, small hotel, large retail, and warehouse. These prototypes represent both the major forecasted building area and align with the building type categories available from the NC3 database.

Table 7 presents the details of the prototype buildings used in the analysis. Appendix A presents details on the space types contained within the prototype buildings.

Table 7: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype ID	Occupancy Type (Residential, Retail, Office, etc.)	Area (ft^2)	Number of Stories	Statewide Area (million ft^2)
Prototype 1	Small School	24,413	1	15.3
Prototype 2	Large School	210,886	2	5.6
Prototype 3	Small Office	5,502	1	10.9
Prototype 4	Medium Office	53,628	3	42.4
Prototype 5	Small Hotel	42,554	4	9.5
Prototype 6	Large Retail	240,000	1	51.1
Prototype 7	Warehouse	49,495	1	30.7

Step 2: Apply Space Type Estimates to Prototypes

Since most of the prototype buildings did not have space types in the model, the NC3 dataset was used to determine typical space type breakdowns. Details of the space type breakdown can be found in Appendix E. This calculation allows for a space by space break down of each prototype to align with the procedures for calculating ventilation being proposed.

Step 3: Calculate Ventilation Adjustment

Based on the space type breakdowns from Step 2, the weighted average minimum ventilation rates were calculated, comparing baseline rates with proposed rates from the proposed code change. Calculations were done outside the prototype energy models, following the current minimum ventilation requirements in 2016 Title 24, Part 6, and the new proposed code change procedure.

Table 8 presents an analysis on the impacts to minimum ventilation rates with the proposed code change. For all spaces types except schools, the ventilation rates are lower as compared to Title 24, Part 6 ventilation rates. Note that the ventilation rate reductions from this proposal are after applying the 130 percent multiplier to the ASHRAE 62.1 rates. The space by space ventilation changes calculated for each prototype are included in Appendix E.

Table 8: Weighted Average Minimum Ventilation Rates for Different Building Types

Building Type	Restaurant	Retail	Warehouse	School	Hotel	Office
Percent of Statewide New Construction	**9%**	**22%**	**19%**	**13%**	**6%**	**32%**
Baseline Blended Minimum Ventilation Rate (cfm/sf)	0.323	0.328	0.160	0.316	0.209	0.233
Proposed Blended Minimum Ventilation Rate (cfm/sf)	0.313	0.231	0.089	0.337	0.142	0.202
Proposed Airflow Rate Percent of Baseline Flow Rate (%)	97%	70%	56%	107%	68%	87%
Overall Proposed Airflow Rate Percent of Baseline Flow Rate	80%					

Step 4: Run Prototype Energy Models

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

The energy models for the current standard and the proposed code change were run in all climate zones with diverse characteristics. Final energy savings, energy cost savings, and peak demand reductions were calculated using a TDV (Time Dependent Valuation) methodology.

Step 5: Statewide Impact

The impacts of these prototype models were then applied to the statewide construction forecast for 2020 from Appendix A and as described in Section 6 of this CASE Report.

4.2.2 Natural Ventilation Procedure Example – Small School Prototype

An analysis comparing the natural ventilation requirements of 2016 Title 24, Part 6 (the baseline) and ASHRAE 62.1-2016 (the proposed change) was completed using the small school prototype model. The analysis determined that the proposed code change would increase the number of spaces that are allowed to be naturally ventilated, which in turn can reduce the load for mechanical ventilation.

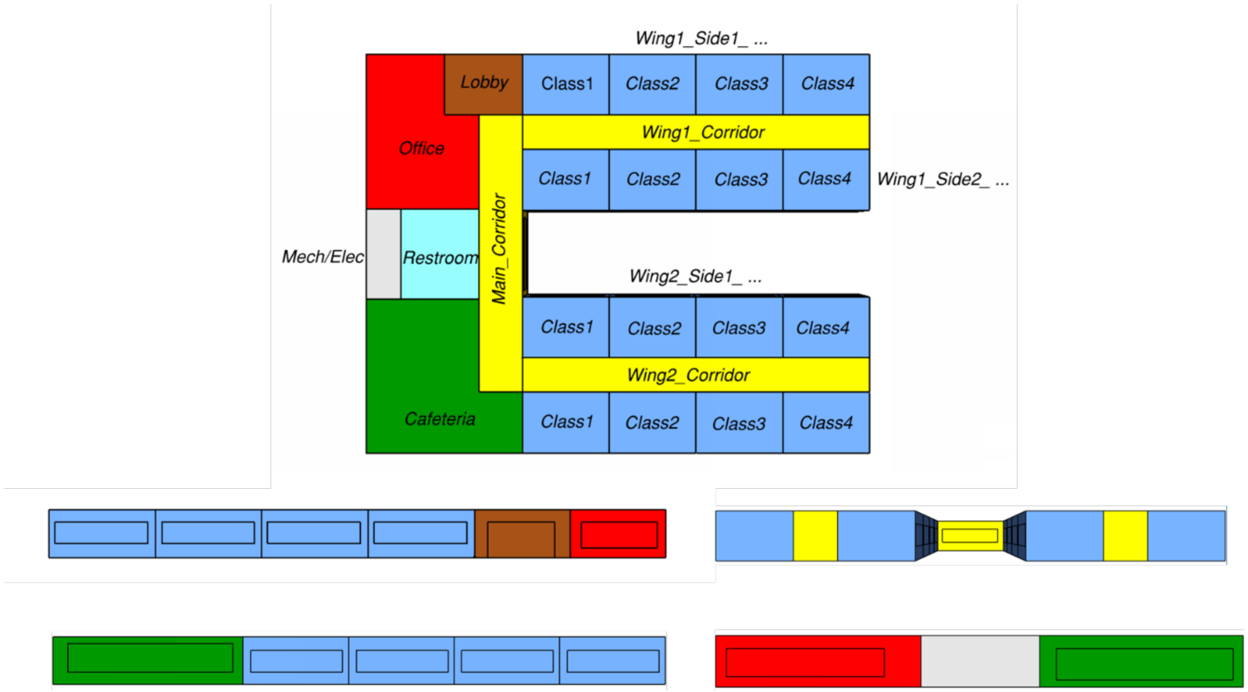

Figure 5: Floor plan and elevation views of small school prototype

The key requirements of the Title 24, Part 6 natural ventilation procedure include:

- The space must be within 20 feet of the operable opening, and
- The openable area cannot be less than five percent of the floor area of the naturally ventilated space.

The key requirements of the proposed code change (the ASHRAE 62.1 natural ventilation procedure) include:

- The maximum distance of the opening to the naturally ventilated space be a function of the minimum ceiling height (*H*) and the type of opening:
    - Single Side Opening: The maximum distance from the operable openings cannot be more than 2*H*.
    - Double Side Opening: The maximum distance from the operable openings cannot be more than 5*H*.
    - Corner Opening: The maximum distance from the operable openings cannot be more than 5*H* from the corner of the two openings.
- The openable area cannot be less than four percent of the floor area of the naturally ventilated space.

Using the small school prototype model, the geometry was analyzed to determine the number and type of openings in each space, the openable area as a percentage of the space area, and whether or not the space would be allowed to be naturally ventilated in the absence of mechanical ventilation. The ceiling height in the prototype model is approximately 13 feet. The results of the analysis are shown below:

Table 9: Spaces Within Small School Prototype Where Natural Ventilation Is Allowed

Color Key	Model Space Name	Area of Space (ft^2)	# of Openings	Type of Opening	Area of Openings (ft^2)	Opening Area / Space Area (%)	Designed Maximum Distance from Opening (ft): Title 24, Part 6	Designed Maximum Distance from Opening (ft): ASHRAE 62.1	Allowable Maximum Distance from Opening (ft): Title 24, Part 6	Allowable Maximum Distance from Opening (ft): ASHRAE 62.1	Natural Ventilation Allowed?
	Cafeteria	2,860	2	Corner	915	32%	44	72	20	65	Neither
	Lobby	678	1	Single Side	228	34%	24	24	20	26	ASHRAE 62.1
	Main_Corridor	1,722	1	Single Side	181	10%	42	42	20	26	Neither
	Mech/Elec	446	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Office	2,201	2	Corner	553	25%	43	73	20	65	Neither
	Restroom	1,005	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Wing1_Corridor	1,722	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Wing1_Side1_Class1[a]	753	1	Single Side	193	26%	23	23	20	26	ASHRAE 62.1
	Wing2_Corridor	1,722	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

a. Classrooms are identical; Wing1_Side1_Class1 serves as a representative for all classrooms.

ASHRAE 62.1 calculates the designed maximum distance from the corner of two openings to the farthest distance in the space. Title 24, Part 6 calculates the designed maximum distance from any opening to the farthest distance in the space.

It can be concluded that the proposed code change would increase the number of spaces that are allowed to be naturally ventilated in the small school prototype model, which in turn reduces electricity use for mechanical ventilation.

4.2.3 Outdoor Air Treatment

The current Title 24, Part 11 CALGreen mandatory measure 5.504.5.3 requires filters with a MERV rating of 8 which the following analysis sets as the baseline. As previously discussed, the proposal is to require MERV 13. The incremental energy use associated with outdoor air treatment through the use of filters is calculated by the following equation:

$$BHP = \frac{(cfm)(TSP)}{(C)(\mu_{fan})(\mu_{motor})}$$

Where:

BHP = brake horsepower (hp)
cfm = supply airflow rate (cfm)
TSP = total static pressure (in WG)
C = conversion constant, 6,356 [(in WG)(cfm)/(hp)]
μ_{fan} = fan efficiency (%)
μ_{motor} = motor efficiency (%)

The small school prototype building model has a supply airflow rate of 25,623 cfm. Assuming a fan efficiency and motor efficiency of 65 percent and 90 percent, respectively, the associated incremental electrical demand compared to no filters is calculated as follows (1 hp = 0.7457 kW) in Table 10.

Table 10: Example Filtration Incremental Fan Electrical Demand due to Filters

TSP (in. WG)	BHP	kW
0.27 (clean filter, MERV 8)	1.86	1.39
0.41 (clean filter, MERV 13)	2.83	2.11
1 (dirty filter)	6.89	5.14

According to engineering standard practice (McDonald 2017), a clean filter's initial resistance should have a pressure drop between 0.27 and 0.41 inches water gauge (in WG) depending on filtration efficiency; a dirty filter's final resistance should be 1.0 in WG, at which point the filter should be replaced. However, the reality is that there is significant variation in pressure drop among filters from different manufacturers (such as Flanders and Camfil) that have the same MERV rating, so the values shown in Table 8 are presented as examples of the impact of MERV 8 and 13 energy impacts. With the implementation of the Title 20 test and list requirements, it will easy to determine the TSP of filters that are being selected.

In the energy impacts analysis to follow, it is assumed that the filters will be replaced before they become dirty and have a 1.0 TSP. The average difference in pressure drop during the filter's life will be used to compare the energy impacts of MERV 8 versus MERV 13 filters. Table 31 in

Appendix G calculates the average pressure drop over the life of a filter to be 0.085 in. WG using nine steps to the final level of 1.0.

Appendix F presents the calculation using the annual hours of occupancy for Title 24, Part 6 Schools from Appendix 5.4B of the Nonresidential Alternative Calculation Method (ACM) Reference Manual, which assumes fans will be operated for 1,808 hours. The result is that there is an additional 790 kWh per year in electricity consumption when MERV 8 filters are replaced by MERV 13 filters.

4.3 Per-Unit Energy Impacts Results

4.3.1 Modified Minimum Ventilation Rates and Ventilation Rate Procedure

Energy savings and peak demand reductions per prototype building are presented in Table 11. These results are shown for each prototype building. Not all prototype buildings show an energy savings in all climate zones. Two major scenarios increase energy use in some buildings, and these are:

- Schools – overall the fresh air for schools will slightly increase from the changes in this case measure.
- Non-Economizer Prototypes – all buildings without airside economizers, which includes small offices which use low capacity single zone rooftop packaged units, will have a slight reduction in ventilation rates. This will reduce the shoulder-season free cooling of those buildings since they lack full airside economizing.

The results were normalized by square footage of each prototype and applied to the statewide forecast for construction from Appendix A.

The per unit TDV energy cost savings over the 15-year period of analysis are presented in Table 11. These are presented as the discounted present value of the energy cost savings over the analysis period. These calculations utilize the 2019 TDV values which further increased the contribution of peak hours for electricity compared with the 2016 TDV factors. Schools show an increase in energy use while other building types show savings in most Climate Zones.

Table 11: First-Year Energy Impacts per Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
SMALL SCHOOL				
1	2,250	(1.2)	(1,892)	(279,219)
2	(7,859)	(13.0)	(1,305)	(623,547)
3	(5,625)	(4.9)	(1,353)	(489,215)
4	(8,311)	(10.2)	(1,137)	(606,711)
5	(5,670)	(5.1)	(1,484)	(483,650)
6	(9,300)	(10.0)	(978)	(589,279)
7	(8,520)	(5.3)	(847)	(515,971)
8	(10,270)	(15.6)	(797)	(629,147)
9	(11,656)	(18.1)	(800)	(790,067)

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
10	(10,420)	(15.0)	(776)	(658,148)
11	(12,276)	(20.5)	(1,023)	(891,074)
12	(10,000)	(17.8)	(1,124)	(707,884)
13	(11,667)	(13.8)	(994)	(662,775)
14	(11,675)	(24.4)	(992)	(747,431)
15	(23,237)	(24.8)	(489)	(1,049,450)
16	(3,520)	(2.8)	(1,578)	(430,037)
LARGE SCHOOL				
1	(1,836)	(0.7)	(3,423)	(681,389)
2	(2,536)	(10.6)	(2,123)	(555,269)
3	(1,428)	(2.0)	(1,884)	(415,531)
4	(2,253)	(1.7)	(1,546)	(463,709)
5	(1,536)	(0.0)	(1,860)	(394,302)
6	(1,822)	(7.0)	(769)	(253,224)
7	(1,192)	(2.8)	(540)	(165,701)
8	(2,611)	(8.5)	(727)	(318,593)
9	(3,775)	(12.5)	(949)	(456,498)
10	(3,747)	(7.0)	(1,010)	(403,077)
11	(5,545)	(13.9)	(1,793)	(669,745)
12	(3,795)	(9.6)	(1,837)	(559,716)
13	(5,295)	(5.8)	(1,781)	(600,231)
14	(5,189)	0.9	(1,694)	(587,368)
15	(9,717)	(15.3)	(521)	(513,595)
16	(1,158)	(1.3)	(2,623)	(550,416)
SMALL OFFICE				
1	(292)	0.0	213	32,796
2	(242)	0.3	128	23,862
3	(408)	0.1	105	10,814
4	(283)	0.2	87	15,787
5	(417)	0.1	112	10,760
6	(381)	0.4	46	2,747
7	(500)	0.2	24	(6,029)
8	(286)	0.4	38	5,587
9	(200)	0.3	47	13,138
10	(125)	0.4	52	15,979
11	78	0.2	117	36,130
12	(97)	0.2	117	29,735
13	58	0.2	109	33,677

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
14	44	0.3	106	30,557
15	489	0.1	20	27,942
16	(203)	0.1	214	37,876
MEDIUM OFFICE				
1	628	0.3	1,159	232,495
2	1,356	3.1	786	227,607
3	494	0.9	625	141,436
4	1,192	1.8	517	180,845
5	508	1.1	748	156,158
6	614	3.1	301	101,933
7	256	(0.1)	154	51,313
8	1,261	2.8	252	126,799
9	2,061	4.5	309	195,087
10	2,433	3.6	309	197,543
11	3,050	4.8	631	277,997
12	2,092	3.8	634	242,298
13	3,022	4.1	589	263,109
14	2,781	5.6	561	241,586
15	6,517	7.2	112	284,688
16	658	0.8	1,035	225,970
SMALL HOTEL				
1	708	0.2	1,386	273,962
2	1,133	2.9	876	231,987
3	297	1.7	700	146,859
4	997	2.8	600	180,345
5	572	0.9	717	148,349
6	283	4.3	274	86,187
7	(300)	0.7	164	33,385
8	636	3.8	254	108,375
9	1,578	5.1	353	186,966
10	1,775	3.6	403	186,130
11	2,575	6.7	735	284,954
12	1,533	4.1	749	242,192
13	2,414	4.4	710	258,780
14	2,470	6.6	687	260,475
15	5,822	6.8	178	268,828
16	211	1.4	1,237	250,514
LARGE RETAIL				

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	56,686	(0.2)	4,637	2,499,381
2	41,616	16.6	2,835	2,018,217
3	36,893	2.0	2,257	1,397,510
4	32,743	19.7	1,910	1,711,088
5	34,232	7.7	2,330	1,312,648
6	20,131	34.2	1,112	1,017,911
7	21,268	3.4	840	763,795
8	26,734	13.5	1,009	1,176,540
9	32,862	30.2	1,149	1,801,697
10	38,635	34.8	1,197	1,943,752
11	59,450	62.4	2,685	3,125,979
12	45,871	40.3	2,657	2,390,403
13	57,155	39.7	2,472	2,731,078
14	57,344	79.1	2,507	2,573,720
15	72,972	70.9	578	2,942,097
16	91,815	8.4	5,859	4,166,275
WAREHOUSE				
1	28	0.01	2,523	477,310
2	3	(0.06)	1,570	316,387
3	(31)	(0.01)	1,399	279,015
4	(39)	(0.09)	1,186	239,819
5	(39)	(0.01)	1,211	238,497
6	(111)	(0.02)	598	121,331
7	(156)	(0.09)	491	96,852
8	(69)	(0.07)	617	128,117
9	0	(0.06)	774	164,743
10	22	0.23	773	163,802
11	(206)	0.03	1,529	294,680
12	14	0.02	1,512	308,192
13	(278)	(0.09)	1,418	281,198
14	(97)	0.01	1,287	264,197
15	222	0.29	445	101,956
16	56	(0.01)	2,307	476,971

4.3.2 Natural Ventilation Procedure

The proposed code change would allow two spaces to be naturally ventilated in the small school prototype model, which in turn reduces the load for mechanical ventilation, thereby increasing energy savings. The results below show the spaces and whether or not natural ventilation is allowed using the existing Title 24, Part 6 requirements or the proposed ASHRAE 62.1 requirements.

Table 12: Small School Spaces That Allow Natural Ventilation

Model Space Name	Natural Ventilation Allowed?
Cafeteria	Neither
Lobby	ASHRAE 62.1
Main Corridor	Neither
Mechanical/Electrical	N/A
Office	Neither
Restroom	N/A
Wing1 Corridor	N/A
Wing1 Side1 Class1	ASHRAE 62.1
Wing2 Corridor	N/A

5. Lifecycle Cost and Cost-Effectiveness

5.1 Overview

The primary objective of this code change is to protect public health and safety by recommending requirements that will result in the preservation or improvement of indoor air quality. As discussed in Section 2.2.1, a cost-effectiveness analysis is not required if the primary objective of the code change proposal is to protect public health and safety. Hence, this CASE Report does not include a cost-effectiveness analysis. The Statewide CASE Team evaluated the energy and energy cost impacts associated with the proposed code changes. The Statewide CASE Team summarized the cost benefits of improved health and productivity associated with improved indoor air quality in Section 5.7.

5.2 Energy Cost Savings Methodology

TDV energy is a normalized format for comparing electricity and natural gas cost savings that takes into account the cost of electricity and natural gas consumed during each hour of the year. The TDV values are based on long-term discounted costs (30 years for all residential measures and nonresidential envelope measures and 15 years for all other nonresidential measures). In this case, the period of analysis used is 15 years. The TDV cost impacts are presented in 2020 present valued dollars. The TDV energy estimates are based on present-valued cost savings but are normalized in terms of "TDV kBtu." Peak demand reductions are presented in peak power reductions (kW). The Energy Commission derived the 2020 TDV values that were used in the analyses for this report (E3 2016).

5.3 Energy Cost Savings Results

Per-unit energy cost savings over the 15-year period of analysis are presented Table 13 for new construction. Business revenues are expected to increase due to improvements in occupant health and decreased absenteeism. The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

Table 13 includes energy impacts from the updated minimum ventilation rates and ventilation rate procedure for the prototype buildings. The revised natural ventilation requirements and new outdoor air treatment requirements are not included since their primary purpose is to improve indoor air quality. Despite the occurrence of energy costs (negative savings) in some prototypes in some climate zones the overall statewide impact is positive. While it is not necessary that savings occur from a mandatory human health measure it does help mitigate cost concerns.

Table 13: TDV Energy Cost Savings over 15-Year Period of Analysis – Per Prototype Building

Climate Zone	15-Year TDV Electricity Cost Savings (2020 PV $)	15-Year TDV Natural Gas Cost Savings (2020 PV $)	Total 15-Year TDV Energy Cost Savings (2020 PV $)
SMALL SCHOOL			
1	$5,889	($30,739)	($24,850)
2	($33,563)	($21,933)	($55,496)
3	($20,959)	($22,581)	($43,540)
4	($34,649)	($19,348)	($53,997)
5	($18,622)	($24,423)	($43,045)
6	($35,935)	($16,511)	($52,446)
7	($31,546)	($14,375)	($45,921)
8	($42,339)	($13,655)	($55,994)
9	($56,425)	($13,891)	($70,316)
10	($44,994)	($13,581)	($58,575)
11	($61,415)	($17,891)	($79,306)
12	($43,524)	($19,478)	($63,002)
13	($41,450)	($17,537)	($58,987)
14	($48,807)	($17,714)	($66,521)
15	($84,481)	($8,920)	($93,401)
16	($10,988)	($27,285)	($38,273)
LARGE SCHOOL			
1	($4,504)	($56,140)	($60,644)
2	($12,771)	($36,648)	($49,419)
3	($4,288)	($32,694)	($36,982)
4	($14,035)	($27,236)	($41,270)
5	($3,968)	($31,125)	($35,093)
6	($8,740)	($13,797)	($22,537)
7	($5,036)	($9,711)	($14,747)
8	($15,249)	($13,105)	($28,355)

Climate Zone	15-Year TDV Electricity Cost Savings (2020 PV $)	15-Year TDV Natural Gas Cost Savings (2020 PV $)	Total 15-Year TDV Energy Cost Savings (2020 PV $)
9	($23,615)	($17,013)	($40,628)
10	($17,765)	($18,109)	($35,874)
11	($27,690)	($31,918)	($59,607)
12	($17,061)	($32,753)	($49,815)
13	($21,353)	($32,068)	($53,421)
14	($21,698)	($30,578)	($52,276)
15	($36,056)	($9,654)	($45,710)
16	($3,207)	($45,780)	($48,987)
SMALL OFFICE			
1	($653)	$3,572	$2,919
2	($145)	$2,268	$2,124
3	($904)	$1,866	$962
4	($162)	$1,567	$1,405
5	($984)	$1,942	$958
6	($584)	$828	$244
7	($965)	$429	($537)
8	($189)	$687	$497
9	$321	$848	$1,169
10	$476	$946	$1,422
11	$1,093	$2,122	$3,216
12	$530	$2,116	$2,646
13	$1,009	$1,988	$2,997
14	$776	$1,943	$2,720
15	$2,108	$378	$2,487
16	($412)	$3,783	$3,371
MEDIUM OFFICE			
1	$1,604	$19,088	$20,692
2	$6,856	$13,401	$20,257
3	$1,837	$10,751	$12,588
4	$7,028	$9,067	$16,095
5	$1,485	$12,413	$13,898
6	$3,660	$5,412	$9,072
7	$1,782	$2,784	$4,567
8	$6,731	$4,554	$11,285

Climate Zone	15-Year TDV Electricity Cost Savings (2020 PV $)	15-Year TDV Natural Gas Cost Savings (2020 PV $)	Total 15-Year TDV Energy Cost Savings (2020 PV $)
9	$11,821	$5,542	$17,363
10	$12,031	$5,550	$17,581
11	$13,498	$11,244	$24,742
12	$10,291	$11,274	$21,565
13	$12,797	$10,619	$23,417
14	$11,379	$10,123	$21,501
15	$23,256	$2,081	$25,337
16	$1,984	$18,127	$20,111
SMALL HOTEL			
1	$1,461	$22,922	$24,383
2	$5,485	$15,162	$20,647
3	$816	$12,255	$13,070
4	$5,421	$10,630	$16,051
5	$1,071	$12,132	$13,203
6	$2,701	$4,970	$7,671
7	($14)	$2,985	$2,971
8	$5,027	$4,618	$9,645
9	$10,258	$6,382	$16,640
10	$9,303	$7,263	$16,566
11	$12,227	$13,134	$25,361
12	$8,153	$13,402	$21,555
13	$10,183	$12,849	$23,031
14	$10,713	$12,469	$23,182
15	$20,614	$3,312	$23,926
16	$626	$21,669	$22,296
LARGE RETAIL			
1	$144,539	$77,906	$222,445
2	$129,352	$50,269	$179,621
3	$84,723	$39,655	$124,378
4	$118,037	$34,250	$152,287
5	$76,709	$40,117	$116,826
6	$70,453	$20,141	$90,594
7	$52,635	$15,343	$67,978
8	$86,360	$18,352	$104,712

Climate Zone	15-Year TDV Electricity Cost Savings (2020 PV $)	15-Year TDV Natural Gas Cost Savings (2020 PV $)	Total 15-Year TDV Energy Cost Savings (2020 PV $)
9	$139,500	$20,851	$160,351
10	$151,215	$21,778	$172,994
11	$229,572	$48,640	$278,212
12	$164,568	$48,178	$212,746
13	$197,897	$45,169	$243,066
14	$183,055	$46,006	$229,061
15	$251,055	$10,791	$261,847
16	$267,196	$103,602	$370,798
WAREHOUSE			
1	$60	$42,420	$42,481
2	$147	$28,011	$28,158
3	($67)	$24,899	$24,832
4	($21)	$21,365	$21,344
5	($85)	$21,312	$21,226
6	($112)	$10,911	$10,798
7	($369)	$8,988	$8,620
8	$196	$11,206	$11,402
9	$606	$14,056	$14,662
10	$552	$14,026	$14,578
11	($1,274)	$27,500	$26,227
12	$133	$27,296	$27,429
13	($728)	$25,754	$25,027
14	($88)	$23,601	$23,513
15	$951	$8,123	$9,074
16	$1,848	$40,602	$42,450

The Statewide CASE Team estimated the incremental construction costs, which represents the incremental cost of the measure if a building meeting the proposed standard were built today.

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

Implementation of the ASHRAE 62.1-2016 minimum ventilation rates and ventilation rate procedure should not alter the first costs of other parts of the HVAC system between the baseline and proposed code change, because the system's peak airflow rate, for multiple-zone recirculating systems, depends on heating and cooling loads, and not on the minimum ventilation rates that are being changed in this measure. However, for DOAS, the peak system airflow rate would increase.

The remaining sub-measures, including revised requirements for natural ventilation, outdoor air treatment, and exhaust air, do not require a cost-effectiveness analysis.

5.4 Lifetime Incremental Maintenance 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 period of analysis. The present value of equipment and maintenance costs (savings) was calculated using a three percent discount rate (d), which is consistent with the discount rate used when developing the 2019 TDV. The present value of maintenance costs that occurs in the nth year is calculated as follows:

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

The expected useful life, frequency of replacement, and maintenance procedures related to changing the ventilation rates and implementing the ventilation rate procedure relative to the baseline should be the same, because the outside air minimum airflow rate damper position is the only element being altered in HVAC systems other than DOAS.

5.5 Lifecycle Cost-Effectiveness

The Statewide CASE Team did not perform a lifecycle cost-effectiveness analysis for the proposed code changes. See Section 2.2.1 for an explanation of why a cost-effectiveness analysis is not required for this measure.

5.6 Health and Productivity Cost Impacts

The following section summarizes the literature available on health and productivity impacts associated with increased ventilation rates, the use of natural ventilation, and higher-efficiency filtration.

A report by the Energy Commission, entitled "Indoor Air Quality Regulation in California Title 24, Part 6 Standards – Energy Commission Authority and Responsibility" (California Energy Commission 2017), presents strong rationale for the protection and enhancement of indoor air quality. The report cites that the California Air Resources Board concluded in 2005 that the impact of indoor air pollutants on public health and safety was several orders of magnitude greater than outdoor air pollutants. A causal link was found between indoor air pollutants and asthma, cancer, many forms of irritation, sick building syndrome, respiratory disease, work loss and reduced productivity, lung damage, breathing difficulties, nausea, tremors, drowsiness, dizziness, impacts to neurodevelopmental outcomes in unborn children, dermal allergic sensitization, and headaches. The report states that increased ventilation, source removal and control, and air cleaning and purification are important components for reducing the health hazards of inadequate indoor air quality.

A recent Harvard study concluded that the health benefits associated with higher ventilation rates far exceeds the increased energy costs (MacNaughton et al. 2015). The study concluded that by doubling the ASHRAE 62.1 ventilation rates, energy costs were less than $50 per person per year in all climate zones; this same increase in ventilation improved the performance of workers by 8 percent (equivalent to $6,500 per person per year). The benefits are compounded by decreased absenteeism and improved health. A report by Fisk (1999) published as Chapter 4 in the Indoor Air Quality Handbook estimates the magnitude of productivity gains from improved indoor air quality.

Some of these estimates include large potential annual savings and productivity gains from reduced respiratory disease, reduced allergies and asthma, and reduced symptoms of sick building syndrome. The study cites several approaches to reduce disease transmission, allergies and asthma, and sick building symptoms, including increasing ventilation rates and improving air filtration. The study provides two sample calculations for the economic impact of improved air quality:

- Assuming that (a) the average salary of an employee is $40,000, (b) increased ventilation reduces sick building symptoms by 25 percent, and (c) these symptoms are responsible for a 1 percent drop in productivity, then the productivity increase is $100 per person (25 percent x 1 percent x $40,000). The costs with increasing ventilation rates from 5 cfm/person to 20 cfm/person were estimated to be approximately $6 per person.
- Assuming that (a) the average salary of an employee is $40,000, (b) improved filtration reduces allergic symptoms experienced by 20 percent of the work force, and (c) reduction in allergic symptoms improves productivity by 1 percent of allergic workers, then the average productivity gain is averaged to be $80 per person (20 percent x 1 percent x $40,000). The study cites that the annual cost of purchasing high-efficiency filters is approximately $23 per person and the increased annual fan energy was estimated to be $1 per person.

These two studies demonstrate that the potential productivity gains far outweigh the costs of improved indoor air quality.

Another study (Maddalena et al. 2014) showed the importance of avoiding low ventilation rates per person and low ventilation rates per floor area in order to minimize reduction in cognitive performance. In the study, even if occupants did not notice a difference in perceived air quality associated with lower ventilation rates, there were still moderate but statistically significant decreases in decision-making performance, similar to having a blood alcohol level of 0.05 percent (similar to consuming two to three drinks). This decrease in performance occurred without the subjects even being aware, demonstrated by the lack of effects on perceived air quality or sick building syndromes experienced by occupants.

Further, subjects evaluated air quality as less pleasant when CO_2 concentrations increased to 3,000 ppm. At this concentration, mental tasks require more effort and the capacity to concentrate declines (Kajtar and Herczeg 2012). Another study showed that at 2,500 ppm, large and statistically significant reductions occurred in decision-making performance (Satish et al. 2012). The mechanism for why decision-making ability decreases as a function of CO_2 levels in the space is not well understood. Nevertheless, the decrease in performance can be economically significant for employers.

As a result of the above findings it is clear that to protect human health and productivity, ventilation should be prioritized over energy savings. This proposal attempts to maintain the 1.3 higher California minimum ventilation levels while adopting the ventilation rate procedure in Title 24, Part 4 that is being maintained by the ASHRAE Standing Standard Project Committee 62.1 for Ventilation for Acceptable Indoor Air Quality. This approach is approximated by adopting the ventilation rate procedures and increasing the ventilation value by 30 percent.

6. First-Year Statewide Impacts

6.1 Overview

The primary objective of this code change is to protect public health and safety through sub-measures that preserve and improve indoor air quality. Another objective for this code change is to revise Title 24, Part 6 requirements using the ventilation requirements found in Title 24, Part 4 and ASHRAE 62.1, and the current research on indoor air quality. Therefore, balancing energy savings requirements with indoor air quality requirements can result in an increase in energy use.

Measure History provides the Energy Commission's authority and responsibility for regulating indoor air quality.

6.2 Statewide Energy Savings and Lifecycle Energy Cost Savings

The Statewide CASE Team calculated the first-year statewide savings by multiplying the per unit savings, which are presented in Section 4.3, by the statewide new construction forecast for 2020, which is presented in more detail in Appendix A. The first-year energy impacts represent the first-year annual savings from all buildings that were completed in 2020. The lifecycle energy cost savings represent the energy cost savings over the entire 15-year analysis period. Results are presented in Table 14.

Small school, large school, small office, medium office, small hotel, large retail, and warehouse prototype buildings were modeled, and their statewide energy savings are presented in Table 14. Most of the building prototypes show a positive energy and TDV savings. Of the prototype buildings, only schools in all climate zones and small offices in one climate zone show negative TDV savings. Schools will have slightly higher ventilation rate in ASHRAE 62.1 compared to Title 24, Part 6 and small offices have reduced ventilation.

Using the results from the prototype models, and given data regarding the new construction forecast for 2020, the Statewide CASE Team estimates that the proposed code change will result in annual statewide electricity savings of 2.8 GWh with an associated demand reduction of 0.6 MW. Natural gas use is expected to decrease by 0.9 million therms. The energy savings for buildings constructed in 2020 are associated with a present valued energy cost savings of approximately PV $26.2 million in (discounted) energy costs over the 15-year period of analysis.

Table 14: Statewide Energy and Energy Cost Impacts for Prototype Models

Climate Zone	Statewide Construction in 2020 (million square feet)	First Year Electricity Savings (GWh)	First Year Peak Electrical Demand Reduction (MW)	First Year Natural Gas Savings (million therms)	Lifecycle Present Valued Energy Cost Savings (PV $ million)
SMALL SCHOOL					
1	0.1	0.01	(0.00)	(0.01)	(0.08)
2	0.4	(0.13)	(0.22)	(0.02)	(0.94)
3	1.5	(0.35)	(0.30)	(0.08)	(2.70)
4	0.9	(0.32)	(0.39)	(0.04)	(2.06)

Climate Zone	Statewide Construction in 2020 (million square feet)	First Year Electricity Savings (GWh)	First Year Peak Electrical Demand Reduction (MW)	First Year Natural Gas Savings (million therms)	Lifecycle Present Valued Energy Cost Savings (PV $ million)
5	0.2	(0.04)	(0.04)	(0.01)	(0.32)
6	1.0	(0.38)	(0.41)	(0.04)	(2.15)
7	1.1	(0.38)	(0.24)	(0.04)	(2.02)
8	1.5	(0.61)	(0.93)	(0.05)	(3.35)
9	1.5	(0.71)	(1.09)	(0.05)	(4.26)
10	2.1	(0.88)	(1.27)	(0.07)	(4.96)
11	0.5	(0.27)	(0.45)	(0.02)	(1.75)
12	2.2	(0.90)	(1.60)	(0.10)	(5.67)
13	1.2	(0.57)	(0.67)	(0.05)	(2.88)
14	0.4	(0.18)	(0.38)	(0.02)	(1.02)
15	0.4	(0.36)	(0.39)	(0.01)	(1.45)
16	0.4	(0.06)	(0.05)	(0.03)	(0.64)
TOTAL	**15.3**	**(6.1)**	**(8.4)**	**(0.6)**	**(36.2)**
LARGE SCHOOL					
1	0.0	(0.00)	(0.00)	(0.000)	(0.01)
2	0.2	(0.00)	(0.01)	(0.002)	(0.04)
3	0.7	(0.00)	(0.01)	(0.007)	(0.13)
4	0.4	(0.00)	(0.00)	(0.003)	(0.07)
5	0.1	(0.00)	(0.00)	(0.001)	(0.01)
6	0.5	(0.00)	(0.02)	(0.002)	(0.05)
7	0.4	(0.00)	(0.00)	(0.001)	(0.03)
8	0.6	(0.01)	(0.03)	(0.002)	(0.09)
9	0.8	(0.01)	(0.04)	(0.003)	(0.15)
10	0.6	(0.01)	(0.02)	(0.003)	(0.09)
11	0.1	(0.00)	(0.01)	(0.001)	(0.04)
12	0.7	(0.01)	(0.03)	(0.006)	(0.16)
13	0.3	(0.01)	(0.01)	(0.002)	(0.07)
14	0.1	(0.00)	0.00	(0.001)	(0.02)
15	0.1	(0.00)	(0.01)	(0.000)	(0.02)
16	0.2	(0.00)	(0.00)	(0.002)	(0.04)
TOTAL	**5.6**	**(0.1)**	**(0.2)**	**(0.0)**	**(1.0)**
SMALL OFFICE					
1	0.1	(0.003)	0.000	0.002	0.033
2	0.3	(0.012)	0.014	0.006	0.102
3	0.9	(0.064)	0.016	0.016	0.150

Climate Zone	Statewide Construction in 2020 (million square feet)	First Year Electricity Savings (GWh)	First Year Peak Electrical Demand Reduction (MW)	First Year Natural Gas Savings (million therms)	Lifecycle Present Valued Energy Cost Savings (PV $ million)
4	0.6	(0.030)	0.025	0.009	0.150
5	0.1	(0.009)	0.002	0.002	0.020
6	0.8	(0.055)	0.057	0.007	0.035
7	1.1	(0.096)	0.035	0.005	(0.103)
8	1.1	(0.057)	0.077	0.007	0.099
9	1.1	(0.039)	0.067	0.009	0.229
10	1.2	(0.028)	0.089	0.012	0.319
11	0.3	0.005	0.013	0.007	0.204
12	1.9	(0.033)	0.070	0.040	0.900
13	0.8	0.008	0.030	0.015	0.412
14	0.2	0.002	0.012	0.004	0.099
15	0.3	0.024	0.007	0.001	0.122
16	0.3	(0.010)	0.007	0.011	0.170
TOTAL	**10.9**	**(0.4)**	**0.5**	**0.2**	**2.9**
MEDIUM OFFICE					
1	0.1	0.00	0.00	0.00	0.03
2	1.0	0.03	0.06	0.02	0.39
3	6.9	0.06	0.12	0.08	1.63
4	2.3	0.05	0.08	0.02	0.70
5	0.5	0.00	0.01	0.01	0.12
6	4.4	0.05	0.25	0.02	0.74
7	2.2	0.01	(0.00)	0.01	0.19
8	6.4	0.15	0.34	0.03	1.35
9	8.6	0.33	0.72	0.05	2.79
10	2.2	0.10	0.14	0.01	0.71
11	0.4	0.02	0.04	0.00	0.19
12	4.5	0.18	0.32	0.05	1.81
13	0.8	0.04	0.06	0.01	0.34
14	0.5	0.03	0.06	0.01	0.22
15	0.3	0.03	0.04	0.00	0.13
16	1.2	0.02	0.02	0.02	0.47
TOTAL	**42.4**	**1.1**	**2.2**	**0.3**	**11.8**
SMALL HOTEL					
1	0.0	0.001	0.000	0.001	0.018

Climate Zone	Statewide Construction in 2020 (million square feet)	First Year Electricity Savings (GWh)	First Year Peak Electrical Demand Reduction (MW)	First Year Natural Gas Savings (million therms)	Lifecycle Present Valued Energy Cost Savings (PV $ million)
2	0.3	0.008	0.020	0.006	0.142
3	1.7	0.011	0.067	0.027	0.503
4	0.7	0.015	0.042	0.009	0.246
5	0.1	0.002	0.003	0.002	0.039
6	0.8	0.005	0.076	0.005	0.137
7	0.7	(0.005)	0.011	0.003	0.046
8	1.1	0.016	0.098	0.007	0.247
9	1.3	0.047	0.152	0.010	0.491
10	0.7	0.030	0.061	0.007	0.283
11	0.2	0.011	0.028	0.003	0.105
12	1.1	0.039	0.104	0.019	0.551
13	0.4	0.022	0.041	0.007	0.214
14	0.1	0.008	0.021	0.002	0.074
15	0.2	0.022	0.026	0.001	0.092
16	0.2	0.001	0.006	0.005	0.098
TOTAL	**9.5**	**0.2**	**0.8**	**0.1**	**3.3**
LARGE RETAIL					
1	0.2	0.04	(0.00)	0.003	0.15
2	1.2	0.21	0.09	0.015	0.93
3	5.4	0.82	0.04	0.050	2.77
4	3.0	0.40	0.24	0.024	1.88
5	0.6	0.08	0.02	0.006	0.28
6	4.7	0.40	0.67	0.022	1.78
7	3.0	0.26	0.04	0.010	0.85
8	6.8	0.76	0.38	0.029	2.97
9	7.2	0.98	0.91	0.034	4.80
10	5.7	0.92	0.83	0.028	4.12
11	1.2	0.29	0.31	0.013	1.38
12	6.1	1.16	1.02	0.067	5.40
13	2.6	0.63	0.44	0.027	2.67
14	1.1	0.27	0.37	0.012	1.06
15	1.0	0.30	0.29	0.002	1.09
16	1.4	0.53	0.05	0.034	2.14
TOTAL	**51.1**	**8.1**	**5.7**	**0.4**	**34.3**
WAREHOUSE					

Climate Zone	Statewide Construction in 2020 (million square feet)	First Year Electricity Savings (GWh)	First Year Peak Electrical Demand Reduction (MW)	First Year Natural Gas Savings (million therms)	Lifecycle Present Valued Energy Cost Savings (PV $ million)
1	0.0	0.000	0.000	0.002	0.040
2	0.6	0.000	(0.001)	0.019	0.348
3	3.8	(0.002)	(0.001)	0.102	1.815
4	1.5	(0.001)	(0.002)	0.034	0.604
5	0.3	(0.000)	(0.000)	0.007	0.117
6	2.8	(0.006)	(0.001)	0.033	0.588
7	1.2	(0.003)	(0.002)	0.011	0.191
8	4.0	(0.005)	(0.005)	0.048	0.882
9	4.3	0.000	(0.005)	0.064	1.203
10	3.4	0.001	0.015	0.050	0.941
11	0.9	(0.004)	0.001	0.026	0.451
12	4.0	0.001	0.001	0.117	2.128
13	1.8	(0.009)	(0.003)	0.048	0.856
14	0.7	(0.001)	0.000	0.016	0.300
15	0.7	0.003	0.004	0.006	0.129
16	0.7	0.001	(0.000)	0.032	0.580
TOTAL	**30.7**	**(0.03)**	**(0.00)**	**0.6**	**11.2**
STATEWIDE TOTAL	**165.4**	**2.8**	**0.6**	**0.9**	**26.2**

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

b. Energy cost savings from all buildings completed statewide in 2020 accrued during 15-year period of analysis.

6.3 Statewide Water Use Impacts

The proposed code change will not result in water savings.

6.4 Statewide Material Impacts

The proposed code change will not result in impacts from material use.

6.5 Other Non-Energy Impacts

Other non-energy impacts, such as impact on indoor air quality and occupant health, are described in Section 5.6 of this report.

7. Proposed Revisions to Code Language

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

See the 2019 Title 24, Part 6 CASE Report entitled "Proposals Based on ASHRAE 90.1-2016" for details on the proposed code change for occupant sensor ventilation requirements. The proposed occupant sensor ventilation requirements apply to Table 120.1-A Minimum Ventilation Rates. The column "Occupied Standby Controls" is only included for clarity in this CASE Report.

7.1 Title 24 Standards, Part 6

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

AIR, AMBIENT is the air surrounding a building, or the source of outdoor air brought into a building.

AIR, EXHAUST is air removed from a space and discharged to outside the building by means of mechanical or natural ventilation systems.

AIR, INDOOR is the air in an enclosed occupiable space.

AIR, MAKEUP is any combination of outdoor and transfer air intended to replace exhaust air and exfiltration.

AIR, OUTDOOR is ambient air, and ambient air that enters a building through a ventilation system, through intentional openings for natural ventilation, or by infiltration.

AIR, PRIMARY is air supplied to the ventilation zone prior to mixing with any locally recirculated air.

AIR, RECIRCULATED is air removed from a space and reused as supply air.

AIR, RETURN is air removed from a space to be recirculated or exhausted.

AIR, SUPPLY is air delivered by mechanical or natural ventilation to a space and composed of any combination of outdoor air, recirculated air, or transfer air.

AIR, TRANSFER is air moved from one indoor space to another.

AIR, VENTILATION is that portion of supply air that is outdoor air plus any recirculated air that has been treated for the purpose of maintaining acceptable indoor air quality.

BREATHING ZONE is the region within an occupied space between planes, 3 and 72 inches and 1800 millimeters) above the floor and more than 2 feet (600 millimeters) from the walls or fixed air-conditioning equipment.

CONCENTRATION is the quantity of one constituent dispersed within a defined amount of another.

CONTAMINANT is an unwanted airborne constituent with the potential to reduce acceptability of the air.

CONTAMINANT MIXTURE is two or more contaminants that target the same organ system.

INDUSTRIAL SPACE is an indoor environment where the primary activity is production or manufacturing processes.

MECHANICAL VENTILATION is ventilation provided by mechanically powered equipment such as motor-driven fans and blowers, but not by devices such as wind-driven turbine ventilators and mechanically operated windows.

NATURAL VENTILATION is ventilation provided by thermal, wind, or diffusion effects through doors, windows, or other intentional openings in the building.

NET OCCUPIABLE AREA is the floor area of an occupiable space defined by the inside surfaces of its walls but excluding shafts, column enclosures, and other permanently enclosed, inaccessible, and unoccupiable areas. Obstructions in the space, such as furnishings, display or storage racks, and other obstructions, whether temporary or permanent, are considered to be part of the net occupiable area.

NONTRANSIENT is occupancy of a dwelling unit or sleeping unit for more than 30 days.

OCCUPIABLE SPACE is an enclosed space intended for human activities, excluding those spaces that are intended primarily for other purposes, such as storage rooms and equipment rooms, and that are only occupied occasionally and for short periods of time.

ODOR is a quality of gases, liquids, or particles that stimulates the olfactory organ.

UNOCCUPIED MODE is when a zone is not scheduled to be occupied.

VENTILATION is the process of supplying air to or removing air from a space for the purpose of controlling air contaminant levels, humidity, or temperature within the space.

VENTILATION, ZONE is any indoor area that requires ventilation and comprises one or more spaces with the same occupancy category, occupant density, zone air distribution effectiveness, and design zone primary airflow per unit area.

VOLUME, SPACE is the total volume of an occupiable space enclosed by the building envelope, plus that of any spaces permanently open to the occupiable space, such as a ceiling attic used as a ceiling return plenum.

SECTION 120.1 – REQUIREMENTS FOR VENTILATION

Nonresidential, high-rise residential, and hotel/motel buildings shall comply with the requirements of Section 120.1(a) through 120.1(e)

The Statewide CASE Team does not propose changes.

(a) General Requirements.

Note: The Energy Commission staff revised subsection (b) cover high-rise residential and deleted the existing section.

~~(b) Design Requirements for Minimum Quantities of Outdoor Air.~~

~~Every space in a building shall be designed to have outdoor air ventilation according to Item 1 or 2 below:~~

~~**1. Natural ventilation.**~~

~~A. Naturally ventilated spaces shall be permanently open to and within 20 feet of operable wall or roof openings to the outdoors, the openable area of which is not less than 5 percent of the conditioned floor area of the naturally ventilated space. Where openings are covered with louvers or otherwise obstructed, openable area shall be based on the free unobstructed area through the opening.~~

EXCEPTION to Section 120.1(b)1A: Naturally ventilated spaces in high-rise residential units and guest rooms shall be open to and within 25 feet of operable wall or roof openings to the outdoors.

B. The means to open required operable openings shall be readily accessible to building occupants whenever the space is occupied.

2. **Mechanical ventilation.** Each space that is not naturally ventilated under Item 1 above shall be ventilated with a mechanical system capable of providing an outdoor air rate no less than the larger of:

A. The conditioned floor area of the space times the applicable ventilation rate from TABLE 120.1-A; or

B. 15 cfm per person times the expected number of occupants.

For meeting the requirement in Section 120.1(b)2B for spaces without fixed seating, the expected number of occupants shall be either the expected number specified by the building designer or one half of the maximum occupant load assumed for egress purposes in the CBC, whichever is greater. For spaces with fixed seating, the expected number of occupants shall be determined in accordance with the CBC.

EXCEPTION to Section 120.1(b)2: Transfer air. The rate of outdoor air required by Section 120.1(b)2 may be provided with air transferred from other ventilated spaces if:

A. None of the spaces from which air is transferred have any unusual sources of indoor air contaminants; and

B. The outdoor air that is supplied to all spaces combined, is sufficient to meet the requirements of Section 120.1(b)2 for each space individually.

(c) **Nonresidential and Hotel/Motel Buildings.** All occupiable spaces shall meet the requirements of subsection 1and either 2 or 3:

1. **Outdoor Air Treatment.** The system shall be provided with air filter(s) to clean the outdoor air at any location prior to its introduction into occupied spaces. The filter(s) shall have a designated efficiency equal to or greater than MERV 13 when tested in accordance with ASHRAE Standard 52.2, or a particle size efficiency rating equal to or greater than 50 percent in the 0.30-1.0 µm range, and equal to or greater than 85 percent in the 1.0-3.0 µm range when tested in accordance with AHRI Standard 680; and

2. **Natural Ventilation.** Naturally ventilated spaces shall be designed in accordance with 120.1(c)2A through 120.1(c)2C and include a mechanical ventilation system designed in accordance with 120.2(c)3:

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

i. **Single Side Opening.** For spaces with operable opening on one side of the space, the maximum distance from the operable opening shall be not more than 2H.

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

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

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

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

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

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

1. **Mechanical Ventilation.** Occupiable spaces shall be ventilated with a mechanical ventilation system capable of providing an outdoor air intake flow (V_{ot}) to the zone in accordance with the applicable requirements of A through D as described below:

   A. Zone Outdoor Airflow. The zone outdoor airflow (V_{oz}) provide to the ventilation zone by the supply air distribution system shall be determined in accordance with Equation 120.1-A;

   $V_{oz} = V_{bz}/E_z$ (Equation 120.1-A)

   Where:

   E_z = Zone Air Distribution Effectiveness. E_z shall not be greater than the default value determined using Table 120.1-C.

   V_{bz} = Breathing Zone Outdoor Airflow. The outdoor airflow required in the breathing zone (V_{bz}) of the occupiable space(s) in a ventilation zone shall be not less than the value determined in accordance with Equation 120.1-B.

   $V_{bz} = R_p \times P_z + R_a \times A_z$ (Equation 120.1-B)

   Where:

   V_{bz} = Volume of ventilation air required to be delivered t the breathing zone

   R_p = Outdoor airflow rate required per person as specified in Table 120.1-B

   P_z = Design zone population for spaces without fixed seating, the expected number of occupants shall be either the expected number specified by the building designer or one half of the maximum occupant load assumed for egress purposes in the California Building Code, whichever is greater. For spaces with fixed seating, the expected number of occupants shall be determined in accordance with the California Building Code.

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

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

   B. Single-Zone Systems. For ventilation systems wherein on or more air handlers supply a mixture of outdoor air and recirculated air to only one ventilation zone, the outdoor air intake flow (V_{ot}) shall be determined in accordance with Equation 120.1-C.

$V_{ot} = V_{oz}$ (Equation 120.1-C)

C. 100 percent Outdoor Air Systems. For ventilation system wherein one or more air handlers supply only outdoor iar to one or more ventilation zones, the outdoor air intake flow (V_{ot}) shall be determined in accordance with Equation 120.1-D.

$V_{ot} = \Sigma_{all}$ zones x Voz (Equation 120.1-D)

D. Multiple Zone Recirculating Systems. For ventilation systems wherein one or more air handlers supply a mixture of outdoor air and recirculated air to more than one ventilation zone, the outdoor air intake flow (V_{ot}) shall be calculated using Equation 120.1-E in accordance with the applicable subsections of 120.1(c)3Di through 120.1(c)3Div.

$V_{ot} = V_{ou} / E_v$ (Equation 120.1-E)

i. Uncorrected Outdoor Air Intake. The uncorrected outdoor air intake (V_{ou}) flow shall be determined in accordance with Equation 120.1-F.

$V_{ou} = D \Sigma_{all\ zones}(R_p \times P_z) + \Sigma_{all\ zones}(R_a \times A_z)$ (Equation 120.1-F)

ii. Occupant Diversity. The occupant diversity ration (D) shall be determined in accordance with Equation 120.1-G.

$D = P_s / \Sigma_{all\ zones} P_z$ (Equation 120.1-G)

Where P_s is the total population in the area served by the system

EXCEPTION to Section 120.1(c)3Dii: Alternative methods to account for occupant diversity shall be permitted, provided the resulting V_{ou} value is no less than that determined using Equitation 120.1-F

iii. Design System Population. Design system population (P_s) shall equal the largest number (peak) number of people expected to occupy all ventilation zones served by the ventilation system.

iv. System Ventilation Efficiency. The system ventilation efficiency (E_v) shall be determined in accordance with a or b below:

a. System ventilation efficiency shall be determined in accordance with Table 120.1-A; or

120.1-A SYSTEM VENTILATION EFFICIENCY

System Ventilation Efficiency (E_V)	Occupant Diversity (D)
0.88D + 0.22	less than 0.60
0.75	equal to or greater than 0.60

b. When the system ventilation efficiency is not determined by using Table 120.1-A, E_v shall be equal to the lowest calculated value of the zone ventilation efficiency (E_{vz}) using equation 120.1-H, and in accordance with I through V below:

$E_v = \text{minimum}(E_{vz})$ (Equation 120.1-H)

I. Zone Primary Airflow. The zone primary airflow (V_{pz}) to the ventilation zone, including outdoor air and recirculated air shall be calculated using Equation 120.1-I.

$V_{pz} = V_{oz} \times 1.5$ (Equation 120.1-I)

Where:

V_{oz} = zone outdoor airflow provided to the ventilation zone by the supply air distribution system as calculated using equation 120.1-A.

II. Average Outdoor Air Fraction. At the primary air handler, the fraction of outdoor air intake flow in the system primary airflow (X_s) shall be calculated using Equation 120.1-J.

$X_s = V_{ou} / V_{ps}$ (Equation 120.1-J)

Where:

V_{ou} = the uncorrected outdoor air intake as determined in Section 120.1(b)3Di.

V_{ps} = the system primary airflow is found at the conditioned analyzed.

III. Primary outdoor air fraction required in the primary air supplied to the ventilation zone prior to the introduction of secondary recirculation airflow shall be calculated using Equation 120.1-H and Equation 120.1-K.

$Z_{pz} = V_{oz} / V_{pz}$ (Equation 120.1-K)

IVI. For single supply systems, where all the ventilation air is a mixture of outdoor air and recirculated air from a single location, the zone ventilation efficiency shall be calculated using Equation 120.1-L; or

$E_{vz} = 1 + X_s - Z_{pz}$ (Equation 120.1-L)

VI. Secondary recirculation systems that provide all or part of their ventilation by recirculating air from other zones without directly mixing it with outdoor air, the zone ventilation efficiency shall be calculated using Equations 120.1-M through .

$E_{vz} = (F_a + X_s \times F_b – Z_{pz} \times E_p \times F_c) / F_a$ (Equation 120.1-M)

Where:

F_a = Fraction of supply air to the zone from sources outside the zone: $F_a = E_p + (1-E_p) \times E_r$ (Equation 120.1-N)

E_p = Primary air fraction to the zone $E_p = V_{pz} / V_{dz}$ (E_p = 1 for single duct and single zone systems). (Equation 120.1-O)

E_r = In the systems with secondary recirculation of return air, faction of secondary recirculated air to the zone that is representative of average system return air rather than air directly recirculated from the zone.

F_b = Fraction of supply air to the zone from fully mixed primary air: $F_b = E_p$ (Equation 120.1-P)

F_c = Fraction of outdoor air to the zone from sources outside the zone: $F_c = 1-(1-E_z) \times (1- E_r) \times (1-E_p)$ (Equation 120.1-Q)

V_{dz} = Zone Discharge Airflow: The expected discharge (supply) airflow to the zone that includes primary airflow and locally recirculated airflow.

V_{pz} = Zone Primary Airflow. The zone primary airflow (V_{pz}) to the ventilation zone, including outdoor air and recirculated air shall be calculated using Equation 120.1-I

2. Exhaust Ventilation. The design exhaust airflow shall be determined in accordance with the requirements in Table 120.1-D. Exhaust makeup air shall be permitted to any combination of outdoor air, recirculated air, or transfer air.

(cd) Operation and Control Requirements for Minimum Quantities of Outdoor Air.

1. **Times of occupancy.** The minimum rate of outdoor air required by Section 120.1(b)2 shall be supplied to each space at all times when the space is usually occupied.

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

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

2. **Pre-occupancy.** The lesser of the minimum rate of outdoor air required by Section 120.1(b)2 or three complete air changes shall be supplied to the entire building during the 1-hour period immediately before the building is normally occupied

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

   A. ~~They have~~ an air economizer; or ~~and~~

   B. modulating outside air control; ~~They serve a space with a design occupant density, or a maximum occupant load factor for egress purposes in the CBC, greater than or equal to 25 people per 1000 square feet (40 square feet or less per person); and~~

   C. design outdoor airflow > 3,000 cfm ~~They are either:~~

      ~~i. Single zone systems with any controls; or~~

      ~~ii. Multiple zone systems with Direct Digital Controls (DDC) to the zone level.~~

   ~~**EXCEPTION 1 to Section 120.1(c)3:** Classrooms, call centers, office spaces served by multiple zone systems that are continuously occupied during normal business hours with occupant density greater than 25 people per 1000 ft² as specified by Section 120.1(b)2B, healthcare facilities and medical buildings, and public areas of social services buildings are not required to have demand control ventilation.~~

   EXCEPTION 1~~2~~ to Section 120.1(~~c~~d)3: Where space exhaust is greater than the design ventilation rate specified in Section 120.1(b)2B minus 0.2 cfm per ft² of conditioned area.

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

   EXCEPTION 3~~4~~ to Section 120.1(~~c~~d)3: Spaces with an area of less than 150 square feet, or a design occupancy of less than 10 people as specified by Section 120.1(b)2B.

   ~~**EXCEPTION 5 to Section 120.1(c)3:** Spaces with an area of less than 1,500 square feet complying with Section 120.1(c)5.~~

4. **Demand Control Ventilation Devices.**

   A. For each system with demand control ventilation, CO_2 sensors shall be installed in each room that meets the criteria of Section 120.1(~~c~~d)3 with no less than one sensor per 10,000 ft² of floor space. When a zone or a space is served by more than one sensor, a signal from any sensor indicating that

CO_2 is near or at the setpoint within ~~a~~ the zone or space, shall trigger an increase in ventilation ~~to the space~~;

B. CO_2 sensors shall be located in the room between 3 ft and 6 ft above the floor or at the anticipated height of the occupants' heads;

C. Demand ventilation controls shall maintain CO_2 concentrations less than or equal to 600 ppm plus the outdoor air CO_2 concentration in all rooms with CO_2 sensors;

EXCEPTION to Section 120.1(~~c~~d)4C: The outdoor air ventilation rate is not required to be larger than the design outdoor air ventilation rate required by Section 120.1(~~b~~c)2 regardless of CO_2 concentration.

D. Outdoor air CO_2 concentration shall be determined by one of the following:

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

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

E. When the system is operating during hours of expected occupancy, the controls shall maintain system outdoor air ventilation rates no less than the rate calculated in Section 120.1(c)3 ~~listed in Table 120.1-A times the conditioned floor area for spaces with CO_2 sensors, plus the rate required by Section 120.1(b)2~~ for other spaces served by the system, or the exhaust air rate whichever is greater;

F. CO_2 sensors shall be certified by the manufacturer to be accurate within plus or minus 75 ppm at a 600 and 1000 ppm concentration when measured at sea level and 25°C, factory calibrated, and certified by the manufacturer to require calibration no more frequently than once every 5 years. Upon detection of sensor failure, the system shall provide a signal which resets to supply the minimum quantity of outside air to levels required by Section 120.1(~~b~~c)3~~2~~ to the zone serviced by the sensor at all times that the zone is occupied.

G. The CO_2 sensor(s) reading for each zone shall be displayed continuously, and shall be recorded on systems with DDC to the zone level.

5. **Occupant Sensor Ventilation Control Devices.** When occupancy sensor ventilation devices are required by Section 120.2(e)3 ~~or when meeting EXCEPTION 5 to Section 120.1(c)3~~, occupant sensors shall be used to reduce the rate of outdoor air flow when occupants are not present in accordance with the following:

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

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

C. Within 30 minutes after being vacant for all rooms served by a zone damper on a multiple zone system, and the space temperature is between the heating and cooling setpoints, then no outside air is required and supply air shall be zero.

D. Within 30 minutes after being vacant for all rooms served by a single zone system, the single zone system shall cycle off the supply fan when the space temperature is between the heating and cooling setpoints.

E. In spaces equipped with an occupant sensor, when vacant during hours of expected occupancy and the occupied ventilation rate required by Section 120.1(~~bc~~)~~2~~3 is not provided, then the system or zone controls shall cycle or operate to maintain the average outdoor air rate over an averaging period of 120 minutes equal to 25percent of the rate ~~listed in~~ ~~TABLE 120.1-A~~.

~~**Exception to 120.1(c)5:** If Demand Control Ventilation is implemented as required by Section 120.1(4).~~

(~~d~~e) Ducting for Zonal Heating and Cooling Units. Where a return plenum is used to distribute outdoor air to a zonal heating or cooling unit which then supplies the air to a space in order to meet the requirements of Section 120.1(c~~b~~)2, the outdoor air shall be ducted to discharge either:

1. Within 5 feet of the unit; or
2. Within 15 feet of the unit, substantially toward the unit, and at a velocity not less than 500 feet per minute.

(ef) Design and Control Requirements for Quantities of Outdoor Air.

1. All mechanical ventilation and space-conditioning systems shall be designed with and have installed ductwork, dampers, and controls to allow outside air rates to be operated at the larger of (1) the minimum levels specified in Section 120.1(c~~b~~) or (2) the rate required for make-up of exhaust systems that are required for an exempt or covered process, for control of odors, or for the removal of contaminants within the space.
2. All variable air volume mechanical ventilation and space-conditioning systems shall include dynamic controls that maintain measured outside air ventilation rates within 10 percent of the required outside air ventilation rate at both full and reduced supply airflow conditions. Fixed minimum damper position is not considered to be dynamic and is not an allowed control strategy.
3. Measured outdoor air rates of constant volume mechanical ventilation and space-conditioning systems shall be within 10 percent of the required outside air rate.

~~*TABLE 120.1-A MINIMUM VENTILATION RATES*~~

~~**TYPE OF USE**~~	~~**CFM PER SQUARE FOOT OF CONDITIONED FLOOR AREA**~~
~~Auto Repair Workshops~~	~~1.50~~
~~Barber Shops~~	~~0.40~~
~~Bars, cocktail lounges, and casinos~~	~~0.20~~
~~Beauty shops~~	~~0.40~~
~~Coin-operated dry cleaning~~	~~0.30~~
~~Commercial dry cleaning~~	~~0.45~~
~~High-rise residential~~	~~Ventilation Rates Specified by the CBC~~
~~Hotel guest rooms (less than 500 ft²)~~	~~30 cfm/guest room~~
~~Hotel guest rooms (500 ft² or greater)~~	~~0.15~~
~~Retail stores~~	~~0.20~~
~~All others~~	~~0.15~~

(g) Recirculation Limitations. Recirculation of air shall be limited based on the air classification as listed in Table 120.1-B or Table 120.1-D, and in accordance with the requirements of 120.1(g)1 through 5.

1. Class 1 Air. Recirculation or transfer of Class 1 air to any space shall be permitted;
2. Class 2 Air. Recirculation or transfer of Class 2 air shall be permitted:

   A. To other Class 2 or Class 3 spaces provided that the other spaces are used for the same or similar purpose or task and involve the same or similar pollutant sources as the Class 2 space; or

   B. To toilet rooms; or

C. To Class 4 spaces; or

D. To Class 1 spaces when using any energy recovery device. The recirculation of Class 2 air from leakage, carryover, or transfer from the exhaust side of the energy recovery device shall not exceed 10% of the outdoor air intake flow.

3. Class 3 Air. Recirculation or transfer of Class 3 air shall be permitted to any other spaces when using any energy recovery device. The recirculation of Class 3 air from leakage, carryover, or transfer from the exhaust side of the energy recovery device shall not exceed 5% of the outdoor air intake flow.

4. Class 4 Air. Recirculation or transfer of Class 4 air shall not be permitted.

5. Ancillary spaces. Redesignation of Class 1 air to Class 2 air shall be permitted for Class 1 spaces that are ancillary to Class 2 spaces.

6. Transfer. A mixture of air that has been transferred through or returned form spaces or locations with different air classes shall be redesignated with the highest classification among the air classes mixed.

7. Classification. Air leaving spaces or locations that are not listed in Table 120.1-B or Table 120.1-D shall be designated with the same classification as air from the most similar space or location listed in terms of occupant activities and building construction.

Table 120.1-B – Minimum Ventilation Rates in Breathing Zone

Occupancy Category	People Outdoor Air Rate R_p cfm/person	Area Outdoor Air Rate R_a cfm/ft²	Air Class	Notes
Correctional Facilities				
Cell	5	0.12	2	
Dayroom	5	0.006	1	
Guard Stations	5	0.006	1	
Booking/waiting	7.5	0.006	2	
Educational Facilities				
Daycare (through age 4)	10	0.18	2	
Daycare sickroom	10	0.18	3	
Classrooms (ages 5-8)	10	0.12	1	
Classrooms (age 9 plus)	10	0.12	1	
Lecture classroom	7.5	0.06	1	F
Lecture hall (fixed seats)	7.5	0.06	1	F
Art classroom	10	0.18	2	
Science laboratories	10	0.18	2	
University/college laboratories	10	0.18	2	
Wood/metal shop	10	0.18	2	
Computer lab	10	0.12	1	

Media center	10	0.12	1	A
Music/theater/dance	10	0.06	1	F
Multiuse assembly	7.5	0.06	1	F
Food and Beverage Service				
Restaurant dining rooms	7.5	0.18	2	
Cafeteria/fast-food dining	7.5	0.18	2	
Bars, cocktail lounges	7.5	0.18	2	
Kitchen (cooking)	7.5	0.12	2	
General				
Break rooms	5	0.06	1	F
Coffee Stations	5	0.06	1	F
Conference/meeting	5	0.06	1	F
Corridors	-	0.06	1	F
Occupiable storage rooms for liquids or gels	5	0.12	2	B
Hotels, Motels, Resorts, Dormitories				
Bedroom/living room	5	0.06	1	F
Barracks sleeping areas	5	0.06	1	F
Laundry rooms, central	5	0.12	2	
Laundry rooms within dwelling units	5	0.12	1	
Lobbies/pre-function	7.5	0.06	1	F
Multipurpose assembly	5	0.06	1	F
Office Buildings				
Breakrooms	5	0.12	1	
Main entry lobbies	5	0.06	1	F
Occupiable storage rooms for dry materials	5	0.06	1	
Office space	5	0.06	1	F
Reception areas	5	0.06	1	F
Telephone/data entry	5	0.06	1	F
Miscellaneous Spaces				
Bank vaults/safe deposit	5	0.06	2	F
Banks or bank lobbies	7.5	0.06	1	F
Computer (not printing)	5	0.06	1	F
Freezer and refrigerated spaces (<50oF)	10	0	2	E
General manufacturing (excludes heavy industrial and process using	10	0.18	3	

Pharmacy (prep. Area)	5	0.18	2	
Photo studios	5	0.12	1	
Shipping/receiving	10	0.12	2	B
Sorting, packing, light assembly	7.5	0.12	2	
Telephone closets	-	0.00	1	
Transportation waiting	7.5	0.06	1	F
Warehouses	10	0.06	2	B
Public Assembly Spaces				
Auditorium seating area	5	0.06	1	F
Places of religious worship	5	0.06	1	F
Courtrooms	5	0.06	1	F
Legislative chambers	5	0.06	1	F
Libraries	5	0.12	1	
Lobbies	5	0.06	1	F
Museums (children's)	7.5	0.12	1	
Museums/galleries	7.5	0.06	1	F
Residential				
Common corridors	-	0.06	1	F
Retail				
Sales (except as below)	7.5	0.12	2	
Mall common areas	7.5	0.06	1	F
Barbershop	7.5	0.06	2	F
Beauty and nail salons	20	0.12	2	
Pet shops (animal areas)	7.5	0.18	2	
Supermarket	7.5	0.06	1	F
Coin-operated laundries	7.5	0.12	2	
Sports and Entertainment				
Gym, sports arena (play area)	20	0.18	2	E
Spectator areas	7.5	0.06	1	F
Swimming (pool & deck)	-	0.48	2	C
Disco/dance floors	20	0.06	2	F
Health club/aerobics room	20	0.06	2	
Health club/weight rooms	20	0.06	2	
Bowling alley (seating)	10	0.12	1	
Gambling casinos	7.5	0.18	1	

Game arcades	7.5	0.18	1	
Stages, studios	10	0.06	1	D, F

General Notes:

Air Density. Volumetric airflow rates are based on dry air density of 0.75lbda/ft^3 at a barometric pressure of 1 atm and an air temperature of 70^{o}F. Rates shall be permitted to be adjusted for actual density.

Item Specific Notes:

A – For high-school and college libraries, the values shown for “Public Assembly Spaces – Libraries” shall be used. B – Rate may not be sufficient where stored materials include those having potentially harmful emissions.

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

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

Table 120.1-C – Zone Air Distribution Effectiveness

Air Distribution Configuration	**E_z**
Ceiling supply of cool air	1.0
Ceiling supply of warm air and floor return	1.0
Ceiling supply of warm air 15^{o}F or more above the space temperature and ceiling return	0.8
Ceiling supply of warm air less than 15^{o}F above space temperature and ceiling return provided that the 150 fpm supply air jet reaches to within 4.5 ft of floor level (see note 5)	1.0
Floor supply of cool air and ceiling return, provided low-velocity displacement ventilation achieves unidirectional flow and thermal stratification, or underfloor air distribution systems where the vertical throw is less than or equal to 50 fpm at a height of 4.5 ft above the floor	1.2
Floor supply of warm air and floor return	1.0
Floor supply of warm air and ceiling return	0.7
Makeup supply drawn in om the opposite side of the room from the exhaust, return or both.	0.8
Makeup supply drawn in near to the exhaust, return, or both locations	0.5
Notes: 1. Cool air is air cooler than space temperature. 2. Warm air is air warmer than space temperature. 3. Ceiling supply includes any point above the breathing zone. 4. Floor supply includes any point belowthe breathing zone. 5. For lower velocity supply air, E_z = 0.8.	

Table 120.1-D – Minimum Exhaust Rates

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

Notes:
A – Stands where engines are run shall have exhaust systems that directly connect to the engine exhaust and prevent escape of fumes.
B – Where combustion equipment is intended to be used on the playing surface, additional dilution ventilation, source control, or both shall be provided.
C – Exhaust shall not be required where two or more sides comprise walls that are at least 50% open to the outside.
D – Rate is per water closet, urinal, or both. Provide the higher rate where periods of heavy use are expected to occur. The lower rate shall be permitted to be used otherwise.
E – Rate is for a toilet room intended to be occupied by one person at a time. For continuous systems operation during hours of use, the lower rate shall be permitted to be used. Otherwise the higher rate shall be used.
F – See other applicable standards for exhaust rate.
G – For continuous system operation, the lower rate shall be permitted to be used. Otherwise the higher rate shall be used.

7.2 California Green Building Standards Code, Part 11

Chapter 5 – Nonresidential Mandatory Measures

Section 5.504.5.3 Filters. In mechanically ventilated buildings provide regularly occupied areas of the building with air filtration media for outside and return air that provides a Minimum Efficiency Reporting Value (MERV) of ~~8~~13. MERV ~~8~~13 filters shall be installed prior to occupancy, and recommendations for maintenance with filters of the same value shall be included in the operation and maintenance manual.

Exceptions:

~~1. An ASHRAE 10-percent to 15-percent efficiency filter shall be permitted for an HVAC unit meeting the 2013 California Energy Code having 60,000 Btu/h or less capacity per fan coil if the energy use of the air delivery system is 0.4 W/cfm or less at design air flow.~~

~~2.~~ Existing mechanical Equipment.

Appendix A5 – Nonresidential Voluntary Measures

A5.504.5.3.1 Filters, Tier 1. In mechanically ventilated buildings, provide regularly occupied areas of the building with air filtration media for outside and return air prior to occupancy that provides at least a Minimum Efficiency Reporting Value (MERV) of ~~11~~15.

A5.504.5.3.1.1 Filters, Tier 2. In mechanically ventilated buildings, provide regularly occupied areas of the building with air filtration media for outside and return air prior to occupancy that provides at least a Minimum Efficiency Reporting Value (MERV) of ~~13~~16.

7.3 Reference Appendices

NA7.5.1 Outdoor Air addresses ventilation acceptance, but will not be modified.

7.4 Nonresidential ACM Reference Manual

Section 5.6.5.4 Outdoor Air Ventilation – Input Restrictions should be updated so that minimum ventilation rates are larger than the applicable ventilation rate calculated in the proposed code change.

7.5 Compliance Manuals

Chapter 4.3 Ventilation Requirements of the Nonresidential Compliance Manual will need to be revised. The ASHRAE 62.1-2016 User's Manual should be used as a reference.

7.6 Compliance Documents

Documents NRCA-MCH-02-A, NRCC-MCH-03-E, NRCC-MCH-05-E, and NRCC-PRF-01-E will need to be revised.

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Appendix A: STATEWIDE SAVINGS METHODOLOGY

The projected nonresidential new construction forecast that will be impacted by the proposed code change in 2020 is presented in Table 15. The projected nonresidential existing statewide building stock that will be impacted by the proposed code change as a result of additions and alterations in 2020 is presented in Table 16.

To calculate first-year statewide savings, the Statewide CASE Team multiplied the per-unit savings by statewide new construction estimates for the first year the standards will be in effect (2020). The Energy Commission Demand Analysis Office provided the Statewide CASE Team with the nonresidential new construction forecast. The raw data presented annual total building stock and new construction estimates for twelve building types by forecast climate zones (FCZ). The Statewide CASE Team completed the following steps to refine the data and develop estimates of statewide floor space that will be impacted by the proposed code changes:

1. Translated data from FCZ data into building standards climate zones (BSCZ). Since Title 24, Part 6 uses BSCZ, the Statewide CASE Team converted the construction forecast from FCZ to BSCZ using conversion factors supplied by the Energy Commission. The conversion factors, which are presented in Table 17 represent the percentage of building square footage in FCZ that is also in BSCZ. For example, looking at the first column of conversion factors in Table 17, 22.5 percent of the building square footage in FCZ 1 is also in BSCZ 1 and 0.1 percent of building square footage in FCZ 4 is in BSCZ 1. To convert from FCZ to BSCZ, the total forecasted construction for a specific building type in each FCZ was multiplied by the conversion factors for BSCZ 1, then all square footage from all FCZs that are found to be in BSCZ 1 are summed to arrive at the total construction for that building type in BSCZ 1. This process was repeated for every climate zone and every building type. See Table 19 for an example calculation to convert from FCZ to BSCZ. In this example, construction BSCZ 1 is made up of building floorspace from FCZs 1, 4, and 14.
2. Redistributed square footage allocated to the "Miscellaneous" building type. The building types included in the Energy Commissions' forecast are summarized in Table 18. The Energy Commission's forecast allocated 18.5 percent of the total square footage from nonresidential new construction and existing building stock in 2020 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 will be realized from this floor space. 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 in such a way that the percentage of building floor space in each climate zone, net of the miscellaneous square footage, will remain constant. See Table 20 for an example calculation.
3. Made assumptions about the percentage of nonresidential new construction in 2020 that will be impacted by the proposed code change by building type and climate zone. The Statewide CASE Team's assumptions are presented in Table 21 and Table 22 and discussed further below.

4. Made assumptions about the percentage of the existing nonresidential building stock in 2020 that will be impacted by the proposed code change (additions and alterations) by building type and climate zone. The Statewide CASE Team's assumptions are presented in Table 21 and Table 22 discussed further below.
5. Calculated nonresidential floor space that will be impacted by the proposed code change in 2020 by building type and climate zone for both new construction and alterations. Results are presented in Table 14 and Table 15

Table 15: Estimated New Nonresidential Construction Impacted by Proposed Code Change in 2020, by Climate Zone and Building Type (Million ft^2)

Climate Zone	New Construction in 2020 (Million Square Feet)											
	OFF-SMALL	**REST**	**RETAIL**	**FOOD**	**NWHSE**	**RWHSE**	**SCHOOL**	**COLLEGE**	**HOSP**	**HOTEL**	**OFF-LRG**	**TOTAL**
1	0.06	0.02	0.11	0.04	0.05	0.00	0.08	0.03	0.00	0.03	0.07	**0.49**
2	0.26	0.12	0.89	0.23	0.60	0.05	0.41	0.16	0.00	0.30	1.04	**4.06**
3	0.86	0.49	3.95	0.92	3.57	0.23	1.51	0.73	0.00	1.66	6.93	**20.85**
4	0.59	0.26	2.14	0.56	1.35	0.12	0.93	0.37	0.00	0.66	2.34	**9.32**
5	0.11	0.05	0.42	0.11	0.26	0.02	0.18	0.07	0.00	0.13	0.45	**1.81**
6	0.79	0.58	3.31	0.83	2.72	0.12	1.00	0.46	0.00	0.77	4.37	**14.94**
7	1.06	0.32	2.04	0.63	1.14	0.01	1.08	0.38	0.00	0.67	2.20	**9.52**
8	1.10	0.83	4.78	1.19	3.86	0.16	1.46	0.64	0.00	1.11	6.39	**21.52**
9	1.08	0.92	5.05	1.23	4.13	0.14	1.48	0.75	0.00	1.28	8.62	**24.67**
10	1.23	0.80	3.83	1.08	3.28	0.07	2.07	0.55	0.00	0.74	2.17	**15.83**
11	0.35	0.11	0.81	0.28	0.80	0.09	0.54	0.14	0.00	0.18	0.41	**3.70**
12	1.87	0.54	4.39	1.16	3.76	0.28	2.20	0.68	0.00	1.10	4.50	**20.48**
13	0.76	0.25	1.79	0.60	1.53	0.25	1.19	0.28	0.00	0.40	0.79	**7.84**
14	0.20	0.15	0.76	0.20	0.64	0.02	0.38	0.10	0.00	0.14	0.54	**3.14**
15	0.27	0.11	0.66	0.23	0.72	0.02	0.38	0.07	0.00	0.17	0.27	**2.90**
16	0.28	0.17	0.96	0.26	0.67	0.04	0.41	0.17	0.00	0.19	1.25	**4.38**
TOTAL	**10.86**	**5.71**	**35.88**	**9.52**	**29.09**	**1.63**	**15.29**	**5.57**	**0.00**	**9.53**	**42.36**	**165.44**

Table 16: Estimated Existing Nonresidential Floor Space Impacted by Proposed Code Change in 2020 (Alterations), by Climate Zone and Building Type (Million ft^2)

Climate Zone	Alterations in 2020 (Million Square Feet)											
	OFF-SMALL	REST	RETAIL	FOOD	NWHSE	RWHSE	SCHOOL	COLLEGE	HOSP	HOTEL	OFF-LRG	TOTAL
1	2.73	0.88	4.78	1.62	2.38	0.13	3.53	1.45	0.00	1.67	2.84	**22.01**
2	12.17	4.54	36.30	9.60	25.39	2.01	19.78	8.62	0.00	12.78	42.20	**173.38**
3	38.63	18.17	151.04	35.13	131.95	9.12	76.78	36.14	0.00	60.60	253.74	**811.30**
4	27.68	10.22	87.74	22.82	59.86	5.08	45.31	19.83	0.00	29.44	98.68	**406.67**
5	5.38	1.98	17.04	4.43	11.62	0.99	8.80	3.85	0.00	5.72	19.16	**78.96**
6	38.56	25.66	151.51	37.93	141.00	5.72	67.06	30.07	0.00	42.09	185.70	**725.30**
7	45.42	13.19	91.67	27.80	61.31	0.56	44.03	19.19	0.00	39.02	100.79	**443.00**
8	53.32	36.68	216.43	53.96	198.41	7.91	94.33	41.39	0.00	59.71	269.76	**1031.92**
9	48.16	38.63	208.86	51.10	187.63	6.38	83.68	44.08	0.00	58.70	325.38	**1052.58**
10	57.16	36.87	181.33	50.35	193.92	3.72	86.58	28.52	0.00	41.29	97.29	**777.02**
11	14.71	4.26	32.27	11.02	35.01	4.07	21.73	7.13	0.00	7.24	15.55	**153.00**
12	74.91	21.41	178.69	47.18	159.80	12.34	92.47	33.71	0.00	46.57	175.87	**842.94**
13	31.99	9.62	69.46	23.37	59.41	10.14	49.08	14.54	0.00	15.15	27.86	**310.63**
14	9.42	6.98	34.78	9.34	36.18	1.10	16.30	5.10	0.00	7.24	22.63	**149.08**
15	11.93	4.65	28.37	9.43	34.97	0.91	13.82	3.25	0.00	7.11	10.82	**125.26**
16	12.29	7.16	41.58	11.18	32.67	1.81	17.73	8.69	0.00	8.82	46.72	**188.66**
TOTAL	**484.47**	**240.90**	**1531.85**	**406.27**	**1371.51**	**71.99**	**741.00**	**305.55**	**0.00**	**443.15**	**1694.99**	**7291.69**

Table 17 Translation from Forecast Climate Zone (FCZ) to Building Standards Climate Zone (BSCZ)

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

Table 18: Description of Building Types and Sub-types (Prototypes) in Statewide Construction Forecast

Energy Commission Building Type ID	Energy Commission Description	Prototype Description			
		Prototype ID	Floor Area (ft^2)	Stories	Notes
OFF-SMALL	Offices less than 30,000 square feet	Small Office	5,502	1	Five zone office model with unconditioned attic and pitched roof.
REST	Any facility that serves food	Small Restaurant	2,501	1	Similar to a fast food joint with a small kitchen and dining areas.
RETAIL	Retail stores and shopping centers	Stand-Alone Retail	24,563	1	Stand-alone store similar to Walgreens or Banana Republic.
		Large Retail	240,000	1	Big box retail building, similar to a Target or Best Buy store.
		Strip Mall	9,375	1	Four-unit strip mall retail building. West end unit is twice as large as other three.
		Mixed-Use Retail	9,375	1	Four-unit retail representing the ground floor units in a mixed-use building. Same as the strip mall with adiabatic ceilings.
FOOD	Any service facility that sells food and or liquor	N/A	N/A	N/A	N/A
NWHSE	Non-refrigerated warehouses	Warehouse	49,495	1	High ceiling warehouse space with small office area.
RWHSE	Refrigerated warehouses	N/A	N/A	N/A	N/A
SCHOOL	Schools K-12, not including colleges	Small School	24,413	1	Similar to an elementary school with classrooms, support spaces and small dining area.
		Large School	210,886	2	Similar to high school with classrooms, commercial kitchen, auditorium, gymnasium and support spaces.
COLLEGE	Colleges, universities, community colleges	Small Office	5,502	1	Five zone office model with unconditioned attic and pitched roof.
		Medium Office	53,628	3	Five zones per floor office building with plenums on each floor.
		Medium Office/Lab		3	Five zones per floor building with a combination of office and lab spaces.
		Public Assembly		2	TBD
		Large School	210,886	2	Similar to high school with classrooms, commercial kitchen, auditorium, gymnasium and support spaces.
		High-Rise Apartment	93,632	10	75 residential units along with common spaces and a penthouse. Multipliers are used to represent typical floors.
HOSP	Hospitals and other health-related facilities	N/A	N/A	N/A	N/A
HOTEL	Hotels and motels	Hotel	42,554	4	Hotel building with common spaces and 77 guest rooms.
MISC	All other space types that do not fit another category	N/A	N/A	N/A	N/A
OFF-LRG	Offices larger than 30,000 square feet	Medium Office	53,628	3	Five zones per floor office building with plenums on each floor.
		Large Office	498,589	12	Five zones per floor office building with plenums on each floor. Middle floors represented using multipliers.

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

Climate Zone	**Total Statewide Small Office Square Footage in 2020 by FCZ** (Million Square Feet) **[A]**	**Conversion Factor FCZ to BSCZ 1 [B]**	**Small Office Square Footage in BSCZ 1** (Million Square Feet) **[C] = A x B**
1	0.204	22.5%	0.046
2	0.379	0.0%	0.000
3	0.857	0.0%	0.000
4	1.009	0.1%	0.001
5	0.682	0.0%	0.000
6	0.707	0.0%	0.000
7	0.179	0.0%	0.000
8	1.276	0.0%	0.000
9	0.421	0.0%	0.000
10	0.827	0.0%	0.000
11	0.437	0.0%	0.000
12	0.347	0.0%	0.000
13	1.264	0.0%	0.000
14	0.070	2.9%	0.002
15	0.151	0.0%	0.000
16	0.035	0.0%	0.000
Total	**8.844**		**0.049**

Table 20: Example of Redistribution of Miscellaneous Category - 2020 New Construction in Climate Zone 1

Building Type	**2020 Forecast (Million Square Feet) [A]**	**Distribution Excluding Miscellaneous Category [B]**	**Redistribution of Miscellaneous Category (Million ft^2) [C] = B × 0.11**	**Revised 2020 Forecast (Million ft^2) [D] = A + C**
Small office	0.049	12%	0.013	0.062
Restaurant	0.016	4%	0.004	0.021
Retail	0.085	20%	0.022	0.108
Food	0.029	7%	0.008	0.036
Non-refrigerated warehouse	0.037	9%	0.010	0.046
Refrigerated warehouse	0.002	1%	0.001	0.003
Schools	0.066	16%	0.017	0.083
College	0.028	7%	0.007	0.035
Hospital	0.031	7%	0.008	0.039
Hotel/motel	0.025	6%	0.007	0.032
Miscellaneous	**0.111**	N/A	N/A	N/A
Large offices	0.055	13%	0.014	0.069
Total	0.534	100%	**0.111**	0.534

Table 21: Percent of Floor Space Impacted by Proposed Measure, by Building Type

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

a. Presents the assumed composition of the main building type category by the building sub-types. All 2019 CASE Reports assumed the same percentages of building sub-types.

b. When the building type comprises multiple sub-types, the overall percentage for the main building category was calculated by weighing the contribution of each sub-type.

c. Percent of existing floor space that will be altered during the first-year the 2019 Standards are in effect.

Table 22: Percent of Floor Space Impacted by Proposed Measure, by Climate Zone

Climate Zone	Percent of Square Footage Impacted	
	New Construction	Existing Building Stock (Alterations) [a]
1	100%	100%
2	100%	100%
3	100%	100%
4	100%	100%
5	100%	100%
6	100%	100%
7	100%	100%
8	100%	100%
9	100%	100%
10	100%	100%
11	100%	100%
12	100%	100%
13	100%	100%
14	100%	100%
15	100%	100%
16	100%	100%

a. Percent of existing floor space that will be altered during the first year the 2019 standards are in effect.

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

This section discusses how the recommended compliance process, which is described in Section 2.5, could impact various market actors. The Statewide CASE Team asked stakeholders for feedback on how the measure would impact various market actors during public stakeholder meetings that were held on September 27, 2016 and March 16, 2017. In addition, a targeted survey was sent to mechanical designers, engineers, and contractors to gather feedback on familiarity with ASHARE 62.1-2016 calculations and thoughts on the code change proposal. The key results from feedback received during stakeholder meetings and other target outreach efforts are detailed below.

Table 23 identifies the market actors who will play a role in complying with the proposed change, the tasks for which they will be responsible, their objectives in completing the tasks, how the proposed code change could impact their existing work flow, and ways that negative impacts could be mitigated.

Table 23: Roles of Market Actors in the Proposed Compliance Process

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Mechanical Designer	Specify product and performance requirements for ventilation components; develop ventilation system layouts of ductwork and piping; draw sections of ventilation components of project; complete relevant compliance documents for ventilation; submit submittal package for permit.	• Follow Title 24, Part 6 in order to meet minimum ventilation rate requirements. • Coordination with: o Energy consultant: Complete documents and interpret Part 6 language. o Plans examiner: Address questions and comments raised by the plans examiner. o Builder/general contractor: Ensure ventilation product selection is in alignment with specifications. • Success is defined as designing a ventilation system that meets the minimum code requirements, with the design passing plan check and field inspection without comments.	Mechanical designer must design to the new proposed ventilation requirements and perform necessary calculations. Mechanical designer must coordinate with energy consultant to verify compliance documents are documenting system design properly for permit submittal.	Clear and easy to understand code language and compliance documents.
Energy Consultant	Perform energy modeling and ventilation load calculations; advise mechanical designers on compliant project approach; complete compliance documents.	• Calculate minimum ventilation rates and energy use attributed to ventilation for the space types of the project. • Coordination with: o Mechanical designer: Assist with completion of ventilation calculations and compliance documents. • Success is defined as code requirements being successfully met, with the design passing plan check and field inspection without comments.	Energy consultant must create energy models that incorporate the proposed ventilation calculations and document the code requirements clearly with the certificate of compliance documents.	Clear and easy to understand code language and compliance documents.

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Builder/General Contractor	Coordinates with design team and installers to manage construction and installation of the project; schedules inspections; coordinates verification and inspection visits with building department.	• Coordinates the construction and installation of the ventilation system. May request clarification from the mechanical design team. Manage installers and subcontractors. • Coordination with: o Mechanical designer: Attain clarification regarding mechanical drawings. o Subcontractors/installers: Ensure work is properly installed. o Plans examiner: May obtain building permit on behalf of owner by submitting drawings. o Building inspector: Coordinates inspections with the Building Department. • Success is defined as delivering a project within scope and budget goals, field inspections passed on first visit, and owner being satisfied with project.	No major changes to workflow are expected.	Drawings that are clear and easy to understand so that less coordination is required with the design team, such that the project passes inspection on first visit.

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Installer/Specialty Subcontractor	Coordinate with general contractor to properly install specialized building features (e.g., ventilation system).	• Installation of the ventilation system. Signs and uploads documents to HERS registry. Present for verification and inspection with building department. • Coordination with: o General contractor: Coordinate to ensure that what is being installed is what is required from the design. o Building inspector: Be present during inspection to answer any questions. • Success is defined as field inspections passing on the first visit, and general contractor and owner satisfaction with the installation of the system.	No major changes to workflow are expected.	Code language that is clear and easy to understand. However, this is less crucial for the installer/specialty subcontractor because directives are provided by the general contractor.
Plans Examiner	Review permit submittal package for code compliance including building sections and details, systems, forms, and issuance of construction permit.	• Confirm that mechanical schedule is in compliance with the Energy Efficiency Standards. • Coordination with: o Mechanical designer: Attain clarification regarding mechanical drawings. • Success is defined as confirmation that drawings are in compliance with the Energy Efficiency Standards, confidence that energy documentation was completed correctly, and ability to find and verify registered documents online.	Plans examiner must ensure that the proposed design meets the new ventilation requirements.	Clear and easy to understand code language so that plans examiner can quickly and easily show that drawings are in compliance and match compliance documents.

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Building Inspector	Make multiple site visits to verify code compliance and proper installation of building features; issue certificate of occupancy.	• Confirm that ventilation system is installed correctly. • Coordination with: o General contractor: Verify code compliance and proper installation of ventilation system. • Success is defined as issuing the certificate of occupancy with as few reinspections as possible.	Building inspector must ensure that the installation meets proposed ventilation requirements.	Clear and easy to understand code language so that building inspector can easily show that building is in compliance with code as is verified by the certificate of acceptance forms.
Building Owner	Work with architect and designers to define project desires including program, aesthetic, schedule and budget; completion of Owner's Project Requirements document; ultimately responsible for obtaining permit, although owner's representative often facilitates the process; receives Part 6 compliance documentation with certificate of occupancy; receives training on systems as part of commissioning requirements.	• Coordination with: o Architect and designers: Define project desires. • Success is defined as realizing a project within desired schedule and budget.	No major changes to workflow are expected.	Clear and easy to understand code for all other market actors so that project is delivered on time and on budget.
Acceptance Testers	One or more site visits to outside air controls and flow via acceptance tests; signing certificate of acceptance.	• Conduct ventilation acceptance tests according to Title 24, Part 6 procedures. • Coordinate with the installer primarily, and possibly the mechanical designer. • Success is defined as verifying minimum ventilation rates, and issuing a certificate of acceptance with as few reinspections as possible.	Acceptance tester must ensure that outside air controls and flow meet updated acceptance tests, and document them with the certificate of acceptance forms to be verified by the building inspector and provided to the building owner.	Ensure that acceptance test forms and testing procedures are clear and understandable.

Appendix C: Background on the Development of ASHRAE 62.1 Ventilation Rates and Ventilation Rate Procedure

The following sections discuss how the ASHRAE 62.1 ventilation rates were developed, and the differences between the current ASHRAE procedure and the procedure used in previous versions of Standard 62, other model codes, and Title 24, Part 6.

Two Component Approach and Additivity

The contaminants in indoor spaces that ventilation is intended to dilute are generated primarily by two types of sources:

- Occupants (bioeffluents) and their activities (e.g., use of office machinery such as copy machines); and
- Off-gassing from building materials and furnishings.

There is little doubt or controversy about the existence of these two sources; the difficulty is how to determine the magnitude of the ventilation rate required to dilute each source and how the contaminants generated by various sources interact with each other. For a space of a given occupancy type experiencing typical occupant activities and constructed with typical materials and furnishings, the strength of occupant/activity sources is approximately proportional to the number of occupants. This has been widely confirmed by research (discussed in subsequent paragraphs). Less fully supported by research is the premise that for each space type, the source strength of building materials and furnishings is approximately proportional to the room floor area.

How the individual contaminants emanating from these sources interact with each other and with the sensation and irritation of occupants is even less understood and more controversial. The impact of contaminants on people can be:

- Additive (1+2=3);
- Independent, strongest source dominates (1+2=2);
- Synergistic (1+2=4); or
- Antagonistic (1+2=1)

While all four effects occur in buildings, the majority of research suggests that additivity is the predominant form of interaction (impact on people). This means that while the chemical nature of the various contaminants in indoor air may differ, they tend to behave in an additive fashion with respect to their impact on occupant perception of odor and irritation. Therefore, the ventilation rate required to control both people-related sources (V_p) and building-related or area-based sources (V_a) is the sum of the ventilation required to control each of them alone at the breathing zone (V_{bz}):

$$V_{bz} = V_p + V_a$$

If it is assumed that the occupant component is proportional to the number of people and the building area component is proportional to the building area, the additivity concept for the ventilation required in the breathing zone of a space can be expressed by the following equation:

$$V_{bz} = R_p\, P_z + R_a\, A_z$$

The concept of additivity has been demonstrated in both laboratory (Iwashita and Kumara 1995) (Lauridsen et al. 1988) and field settings (Wargocki et al. 1996, 307-312). In these studies, the researchers measured the level of perceived indoor air quality from humans and different types of building materials and furnishings alone and in combination. They then compared the total source strength (when the sources were combined) with the sum of the individual source strengths. In general, the agreement was close, though of course not perfect.

The results of other studies have questioned the appropriateness of additivity (Bluyssen and Cornelissen 1998, 161-168); these particular studies are also the subject of debate and conclude that additivity needs to be studied more, not discarded.

While one can debate this research, additivity is more productively considered as simply a calculation method to deal with two types of sources: those that depend primarily on the number of people (contaminants from occupants and their associated activities) and those that depend primarily on building floor area (contaminants from building materials and furnishings).

Note that the current Title 24, Part 6 ventilation standards also have the same two components (people and building area), but the larger of the two is used, not the sum of the two. This assumes independent impacts on perception (1+2=2) of the two pollutant sources, which is not supported by the majority of current research.

Determining Component Ventilation Rates

Once the form of the equation was selected, the next step was to determine the values of each component (R_p and R_a) for each occupancy category. The rates were based largely on research, experience, and judgment as described below:

- *Research on the Occupant Component:* There have been a number of laboratory and field studies on the amount of ventilation air required to dilute occupant-generated odors and irritants (Berg-Munch, Clausen, and Fanger 1986, 195-200; Cain et al. 1983, 1183-1197; Fanger and Berg-Munch 1983, 45-50; Iwashita et al. 1990, 9-19). These studies have consistently shown that about 15 cfm (7.5 L/s) will satisfy a substantial majority (about 80 percent) of unadapted persons (visitors) in the space. Later studies showed that a significant adaptation occurs for bioeffluents (Berg-Munch, Clausen, and Fanger 1986, 195-200), but less for building materials (Gunnarsen and Fanger 1988, 157-167) (Gunnarsen 1990, 599-604). While the data for adapted occupants are less extensive, two 1983 studies (Cain et al. 1983, 1183-1197) (Fanger and Berg-Munch 1983, 45-50) showed that about 5 cfm (2.5 L/s) will satisfy a substantial majority of adapted occupants.
- *Research on the Building Component:* Several studies have examined the source strengths associated with sensory pollutants from the building itself. Results indicated a wide range of building source strengths. This is not too surprising, given the breadth of building designs and usages. When these source strengths are converted to ventilation requirements required to satisfy about 80 percent unadapted visitors to a space, the mean value for offices and classrooms is about 0.39 cfm/ft^2 (2.0 L/s-m^2), 0.53 cfm/ft^2 (2.7 L/s-m^2) for kindergartens, and 0.66 cfm/ft^2 (3.3 L/s-m^2) for assembly halls (Fanger et al. 1988, 7-19; Pejtersen et al. 1990, 537-542; Pejtersen et al. 1991 221-224; Thorstensen et al. 1990, 531-536). More recent research supports these values (Wargocki et al. 2002).
- *Research on Overall Rates in Office Buildings*: By far, office buildings were the most common subject of field studies. Several field studies indicate that an outdoor air supply of 20 cfm (10 L/s) per person is very likely to be associated with lower rates of sick building syndrome symptoms (and presumably more acceptable perceived indoor air quality) in office spaces (Mendell 1993, 227-236) (Seppanen et al. 1999, 226-252) (Apte, Fisk, and Daisey 2000, 246-257). These measured ventilation rates include the combined impacts of occupant and building sources as well as some degree of ventilation system efficiency.
- *Experience*: Experience with successful existing buildings was considered, including buildings built under the 1981 Standards when outdoor air rates were one-third or less of the rates

required after 1989. However, this experience, already largely anecdotal, must be tempered by the fact that actual ventilation rates in buildings are unlikely to be equal to the values required by the standards at the time they were built. Research indicates that actual ventilation rates measured in buildings typically do not correspond to rates required by the version of Standard 62.1 effective at the time, the building code under which the building was designed, or even to the design values indicated on construction drawings (Persily and Gorfain 2004). One study encompassing about 3,000 individual ventilation rate measurements in more than a dozen office buildings found that about half the measured outdoor air ventilation rates were below the design values. The European Audit Project study of 56 office buildings in nine countries found that ventilation rates varied by a factor of two above or below the designed ventilation rates (Bluyssen et al. 1995). Nevertheless, anecdotal experience provides a useful reality test to limit proposed ventilation rates so that they are neither overly high nor low.

- *Judgement:* Because of the limited breadth of available research (most focus only on offices, for instance) and the imprecise nature of research results and anecdotal experience in existing buildings, ventilation rates were, to a very large extent, determined based on the experience and judgment of the committee members who developed the standard over the last ten years. It should be noted that prior versions of the standard, and the Title 24, Part 6 ventilation standards, were even more reliant on committee judgment since less research was available at the time.

The development of the ventilation rate table began first with offices, since they were the subject of the most research.

Starting with the occupant ventilation component (R_p), the fact that the standard was targeted for use in building codes as a minimum standard led to the decision to use 5 cfm (2.5 L/s) per person as the base rate, since research has shown that this rate will satisfy a substantial majority of adapted occupants. This value is based on occupant-related contaminants from adults at a sedentary activity level consistent with office spaces, and therefore must be adjusted upwards for other occupancy categories where the occupants are more active. It also must be adjusted upwards in some occupancy categories to account for contaminants generated by occupant activities, such as art and science classrooms.

Table 24: Occupant Component of Ventilation Rate

Category	Occupant Ventilation Component (R_p)	Discussion
0	0 cfm (0 L/s) per person	Applies to spaces where the ventilation requirements are assumed to be so dominated by building-related sources, due to the typically very low and transient nature of the occupancy, that the occupant component may be ignored. Examples include storage rooms and warehouses.
1	5 cfm (2.5 L/s) per person	Applies to spaces where primarily adults are involved in passive activities similar to sedentary office work.
2	7.5 cfm (3.5 L/s) per person	Applies to spaces where occupants are involved in higher levels of activity (though not strenuous), thereby producing higher levels of bioeffluents, or are involved in activities associated with increased contaminant generation. Examples include lobbies and retail stores.
3	10 cfm (5 L/s) per person	Applies to spaces where occupants are involved in more strenuous levels of activity (though not at an exercise-like level), or are involved in activities associated with even higher contaminant generation. Examples include most classrooms and other school occupancies.
4	20 cfm (10 L/s) per person	Applies to spaces where occupants are involved in very high levels of activity, or are involved in activities associated with very high contaminant generation. Examples include beauty salons, dance floors, and exercise rooms. Hair sprays, shampoos, etc., are considered occupant-related rather than building-related.

To determine the building component (R_a), the committee reviewed the available research on occupant perception of odors from non-occupant sources in offices, schools and other building types. The mean ventilation rate noted in the studies of office buildings to achieve 80 percent satisfaction by adapted occupants was 0.4 cfm/ft^2 (2 L/s-m^2), and the lowest value was about 0.03 cfm/ft^2 (0.15 L/s-m^2).

Based on these data, and again in the context of establishing code minimum requirements, the value of 0.06 cfm/ft^2 (0.30 L/s- m^2) was identified as the base rate to handle building sources for offices. When combined with the base occupant rate of 5 cfm (2.5 L/s) per person, typical occupant densities, and ventilation system efficiencies (more on ventilation efficiency below), this building component rate results in an overall ventilation rate of about 20 cfm (10 L/s) per person for office spaces, consistent with engineering experience and the office building research discussed above.

Table 25: Building Component of Ventilation Rate

Category	Building Component (Ra)	Discussion
1	0.06 cfm/ft^2 (0.3 L/s-m^2)	Applies to spaces where building-related contaminants are generated at rates similar to office spaces. Examples include conference rooms and lobbies.
2	0.12 cfm/ft^2 (0.6 L/s-m^2)	Applies to spaces where building-related contaminants are generated at rates significantly higher than those for offices. Examples include typical classrooms and museums.
3	0.18 cfm/ft^2 (0.9 L/s-m^2)	Applies to spaces where building-related contaminants are assumed to be generated at an even higher rate. Examples include laboratories and art classrooms.
4	0.30 cfm/ft^2 (1.5 L/s-m^2)	These last two categories apply to three unusual spaces, all in the sports and entertainment category, for which there is no people-based ventilation requirement (R_p = 0). For that reason, and because of their unique natures, the building ventilation requirements are elevated to five to eight times the base rate.
5	0.48 cfm/ft^2 (2.4 L/s-m^2)	

The next step was to determine occupant and building rates for the other occupancy categories listed in the ventilation rate procedure table. As noted above, there are insufficient hard research results to identify specific values of R_p and R_a for each space type. Therefore, most of the rates are based on professional judgment, engineering experience, and a subjective assessment of the relative contaminant source strength from materials within the space relative to the base office occupancy.

To reflect the inherently approximate nature of ventilation rates determined in this fashion, the values of R_p and R_a for each occupancy type are based on simple multiples of the base rates.

Title 24, Part 6 ventilation rate components can be summarized as:

- The occupant component is 15 cfm/person. This is the rate associated with the satisfaction of visitors (not adapted occupants) to a space. It can be argued that it is not appropriate for a code minimum rate to focus on visitors' first impressions but rather on occupant perception, as the Standard 62 occupant rate does. The Energy Commission's adoption of the 15 cfm/person criteria helps to ensure indoor air quality is preserved.
- The building component varies by occupancy type, but for most occupancy types is 0.15 cfm/square foot. At the times these rates were developed, there was little research to support the values.

Ventilation Efficiency

The breathing zone is that region within an occupied space between three planes: three and 72 inches above the floor and more than two feet from the walls or air supply register. The breathing zone is the region within an occupied space to which ventilation air must be supplied. This concept is defined to clarify the difference between moving air through the ventilation system ductwork and actually getting it to where the occupants breathe.

The ability of the ventilation system to deliver outdoor air to the breathing zone can be described by two factors: zone air distribution effectiveness and system ventilation efficiency as applied to multiple space recirculating systems.

- *Zone Air Distribution Effectiveness:* Concerns have long been expressed about inefficiencies in the mixing of ventilation air within rooms and the possibility that ventilation air was not getting to the breathing zone of the space. Several terms have been used to describe this performance, including zone air distribution effectiveness (used in the current standard), ventilation effectiveness (used in Standard 62-2001), and air change effectiveness (used in ASHRAE Standard 129 and most research projects). These terms have slightly different definitions but essentially measure the same effect: the system's ability to deliver air from the supply air outlet to the space's breathing zone. There has been a significant amount of research on ventilation effectiveness in the lab and in the field. In addition, ASHRAE has issued a standard test method (ASHRAE Standard 129-1997) for measuring air change effectiveness. The table of default values for zone air distribution effectiveness in Standard 62.1 is based on this research as well as engineering judgment for applications where research is less complete. The research has shown, without exception, that spaces supplied with air cooler than the room air have an air change effectiveness near one (E ~1) regardless of the design of the air distribution system. This includes overhead supply and return systems even when serving spaces are partitioned into cubicles. The reason is that the cool air is denser than the room air and naturally falls, while heat sources in the room (e.g., people, computers) create plumes of warm air that rise toward the ceiling. The combination causes air to naturally mix. Poor zone air distribution effectiveness (E_z) results mostly from warm air supply systems.
- *System Ventilation Efficiency for Multiple Zone Recirculating Systems:* Systems that serve multiple spaces and that recirculate air from one or more of these spaces have an inherent inefficiency if the percentage of outdoor air required is not the same for each space. This is because the percentage of outdoor air in the supply air is the same for all spaces, so spaces that require a high ratio of outdoor air to supply air will be underventilated if outdoor air rates at the air handling unit are not set to meet the high demand zone. Adjustment for this effect was first introduced in the 1989 version of the standard. Equation 6-1 (sometimes called the "multiple spaces equation") in that standard was derived for single-path supply air systems, such as central variable air volume or constant volume systems with terminal reheat. The current standard uses the same approach for single-path systems, but the equation has been rearranged to use the term system ventilation efficiency. Because many designers considered the multiple spaces equation too complex, it has been simplified into a default table of system ventilation efficiency values.[8] The concept has also been expanded in Appendix A of the current standard to allow multiple recirculation paths to be taken into account, improving the system ventilation efficiency of systems, such as dual fan/dual duct systems and systems with fan-powered terminal units.

Title 24, Part 6 ventilation requirements that allow transfer air to meet ventilation requirements (Exception to Section 120.1(b)2) are ignoring ventilation system efficiency. The use of transfer air effectively treats all systems as having a ventilation efficiency of 1.0. This makes Title 24, Part 6 easier to use and ensures that on average there is sufficient outdoor air; however, some zones have above the minimum outdoor air and others do not have enough outdoor air to meet the ventilation

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[8] ASHRAE Standard 62.1-2016 Table 6.2.5.2 System Ventilation Efficiency.

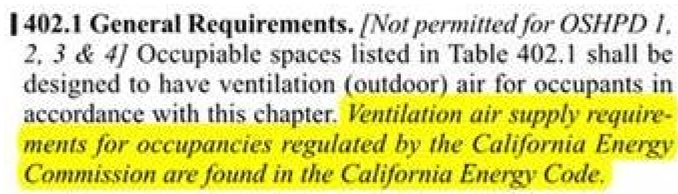
targets. ASHRAE 62.1 addresses the non-uniform distribution of outdoor air throughout the building by the system ventilation efficiency table, or more precisely, via the multiple spaces equation.

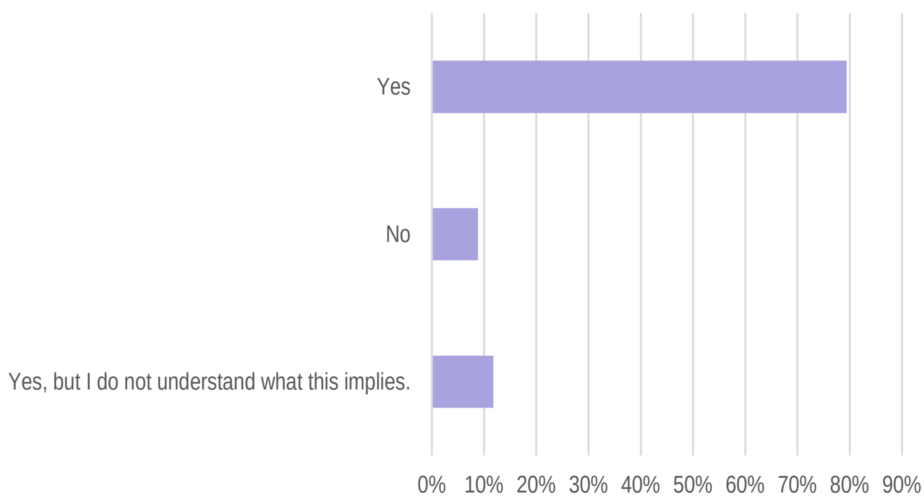
Appendix D: Feedback Survey for California Ventilation Rate Calculations

The Statewide CASE Team created a survey to gather information on current industry practices regarding the design of ventilation supply, exhaust, and makeup air in Title 24, Part 4 – California Mechanical Code (ASHRAE 62.1) and Title 24, Part 6 – California Energy Code. The Statewide CASE Team sought input from mechanical designers to determine if there was confusion with the language in the ventilation sections of Title 24, Part 4 and Part 6.

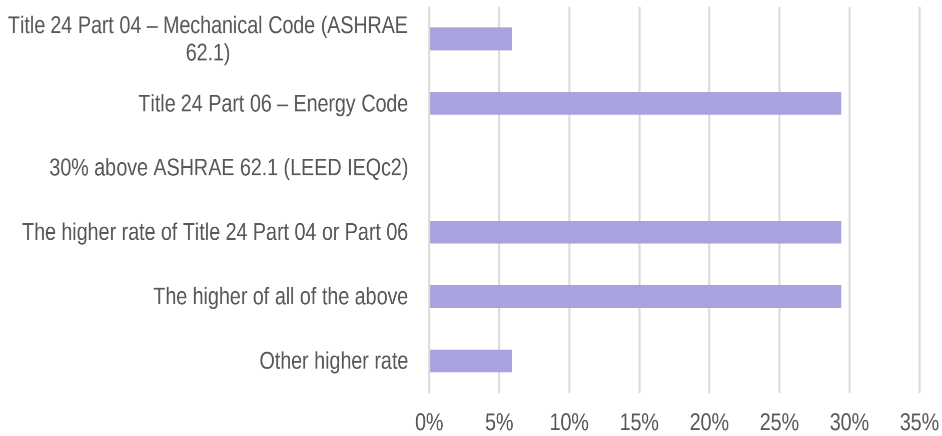
The survey has been open since late October 2016. The following is a summary of the survey results from the 34 respondents to date.

Question 1. *Are you familiar with the code section 402.1 from Title 24, Part 4 – Mechanical Code, which states that "ventilation air supply requirements for occupancies regulated by the California Energy Commission are found in the California Energy Code"?*

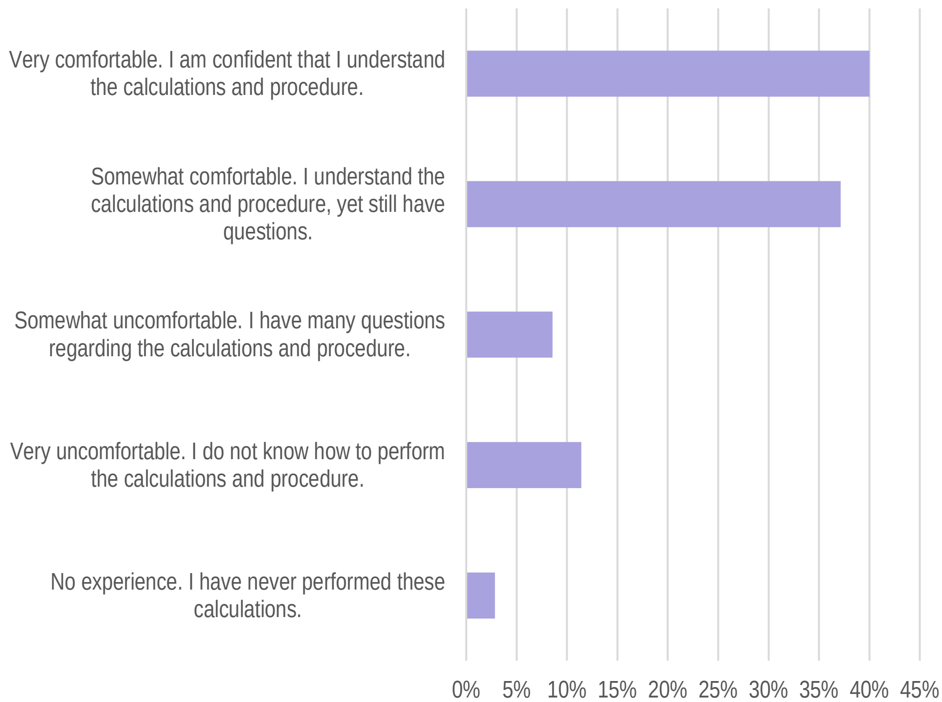

402.1 General Requirements. *[Not permitted for OSHPD 1, 2, 3 & 4]* Occupiable spaces listed in Table 402.1 shall be designed to have ventilation (outdoor) air for occupants in accordance with this chapter. *Ventilation air supply requirements for occupancies regulated by the California Energy Commission are found in the California Energy Code.*



Question 2. *Which ventilation air supply rate calculations do you (or your firm) currently design to for permitting?*



Question 3. *How comfortable are you with the Title 24, Part 4 – Mechanical Code (ASHRAE 62.1) ventilation rate procedure for multi-zone systems, including the "multiple spaces equation"?*



Appendix E: SPACE TYPE BREAKDOWN FOR DIFFERENT BUILDING TYPES

The National Commercial Construction Characteristics (NC3)[9] dataset was used to determine a typical space type breakdown for the following building types.

Table 26: Space Type Breakdown of Various Building Types from NC3 Dataset

Title 24 Occupancy Category	Restaurant	Retail	Warehouse	School	Hotel	Office	Baseline Effective Outdoor Air Flow Rate Per sf, (cfm/sf)	Proposed Effective Outdoor Air Flow Rate Per sf, (cfm/sf)
Assembly (non-Concentrated) - Dining Area	36.01%	0.79%	0.00%	1.63%	3.23%	1.50%	0.500	0.559
Kitchen, Commercial Food Preparation	24.68%	1.39%	0.00%	1.66%	1.15%	1.59%	0.150	0.180
Assembly (Concentrated) - Lobby, Main Entry	11.38%	1.30%	0.64%	5.00%	8.52%	5.93%	0.500	0.295
Commercial and Industrial Storage Areas (conditioned or unconditioned)	9.97%	12.91%	94.62%	10.45%	2.39%	13.25%	0.150	0.085
Corridors, Restrooms, Stairs, and Support Areas	11.08%	4.02%	1.84%	19.08%	16.72%	16.55%	0.150	0.078
Office (250 square feet in floor area or less)	3.57%	3.03%	1.23%	4.03%	1.05%	22.29%	0.150	0.111
Retail - Merchandise Sales, Wholesale Showroom	0.91%	44.59%	0.10%	0.18%	0.19%	0.00%	0.250	0.318
Electrical, Mechanical, Telephone Rooms	0.78%	0.76%	0.27%	3.26%	2.61%	2.81%	0.150	0.000
Assembly (non-Concentrated) - Gymnasium/Sports Arena	0.73%	0.08%	0.00%	5.52%	0.92%	0.63%	0.500	1.101
Office (Greater than 250 square feet in floor area)	0.45%	1.07%	0.04%	0.93%	0.30%	14.09%	0.150	0.111
Auto Repair Area	0.20%	7.41%	0.37%	0.41%	0.46%	0.00%	1.500	0.000
Assembly (non-Concentrated) - Lounge, Recreation	0.18%	1.39%	0.64%	1.46%	0.66%	3.64%	0.500	0.559
Laundry	0.07%	0.04%	0.00%	0.03%	1.21%	0.14%	0.150	0.189
Medical and Clinical Care	0.00%	0.84%	0.00%	0.10%	0.00%	0.61%	0.150	0.111
Library - Library, Reading Areas	0.00%	0.00%	0.00%	0.14%	0.00%	0.44%	0.150	0.221
Exercise Room	0.00%	0.00%	0.00%	0.14%	0.98%	0.00%	0.150	0.338
Library - Library, Stacks	0.00%	0.00%	0.00%	0.35%	0.00%	0.00%	0.150	0.189
Assembly (Concentrated) - Auditorium Area	0.00%	0.00%	0.00%	1.35%	0.00%	0.00%	1.071	0.542
Hotels and Apartments - Hotel/Motel Guest Room	0.00%	0.00%	0.00%	0.00%	57.74%	0.00%	0.150	0.094
Financial Transaction Area	0.00%	0.02%	0.00%	0.00%	0.00%	0.14%	0.150	0.127
Laboratory, Scientific	0.00%	0.11%	0.00%	0.86%	0.00%	0.11%	0.150	0.299
Locker/Dressing Room	0.00%	0.15%	0.00%	1.05%	0.19%	0.00%	0.150	0.254

[9] https://www.energycodes.gov/sites/default/files/documents/ta_commercial_building_construction_characteristics.pdf

Assembly (non-Concentrated) - Convention, Conference, Multipurpose and Meeting Center Areas	0.00%	0.15%	0.24%	3.70%	1.69%	10.19%	0.500	0.295
Classrooms, Lecture, Training, Vocational Areas	0.00%	0.17%	0.00%	38.69%	0.00%	0.77%	0.375	0.481
Retail - Grocery Sales Areas	0.00%	19.77%	0.00%	0.00%	0.00%	0.00%	0.250	0.240
Garage, Parking - Parking Garage Area Dedicated Ramps	0.00%	0.00%	0.00%	0.00%	0.00%	0.72%	0.150	0.000
General Commercial and Industrial Work Areas, High Bay	0.00%	0.00%	0.00%	0.00%	0.00%	1.85%	0.150	0.143
Housing, Public and Common Areas: Multi-family, Dormitory	0.00%	0.00%	0.00%	0.00%	0.00%	2.31%	0.150	0.156
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**		

Table 27: NC3 Dataset Building Type Cross Reference to Statewide Construction Forecast

NC3 Building Types	Retail			Warehouse		School		Hotel	Office			**TOTAL**
Statewide Construction Forecast for 2020 (Appendix A)												
Climate Zone	**REST**	**FOOD**	**RETAIL**	**NWHSE**	**RWHSE**	**SCHOOL**	**COLLEGE**	**HOTEL**	**OFF-SMALL**	**OFF-LRG**	**HOSP**	
1	0.021	0.036	0.108	0.046	0.003	0.083	0.028	0.032	0.062	0.069	0.000	**0.489**
2	0.116	0.234	0.890	0.596	0.048	0.412	0.164	0.296	0.263	1.044	0.000	**4.062**
3	0.485	0.918	3.951	3.573	0.231	1.513	0.731	1.664	0.859	6.928	0.000	**20.853**
4	0.264	0.555	2.138	1.353	0.119	0.931	0.369	0.661	0.587	2.343	0.000	**9.319**
5	0.051	0.108	0.415	0.263	0.023	0.181	0.072	0.128	0.114	0.455	0.000	**1.809**
6	0.577	0.828	3.311	2.717	0.118	1.000	0.458	0.771	0.788	4.366	0.000	**14.935**
7	0.317	0.628	2.042	1.143	0.011	1.076	0.377	0.674	1.055	2.200	0.000	**9.524**
8	0.830	1.189	4.779	3.860	0.164	1.459	0.642	1.108	1.097	6.392	0.000	**21.519**
9	0.918	1.225	5.048	4.133	0.138	1.480	0.754	1.275	1.076	8.623	0.000	**24.670**
10	0.802	1.075	3.831	3.283	0.075	2.066	0.551	0.738	1.233	2.170	0.000	**15.826**
11	0.108	0.275	0.807	0.800	0.095	0.538	0.139	0.179	0.349	0.412	0.000	**3.701**
12	0.538	1.158	4.394	3.759	0.279	2.197	0.676	1.104	1.871	4.504	0.000	**20.478**
13	0.250	0.603	1.789	1.533	0.246	1.191	0.276	0.402	0.757	0.790	0.000	**7.837**
14	0.153	0.204	0.757	0.641	0.023	0.376	0.097	0.139	0.201	0.544	0.000	**3.135**
15	0.106	0.226	0.665	0.718	0.021	0.380	0.073	0.167	0.270	0.272	0.000	**2.898**
16	0.170	0.258	0.957	0.670	0.042	0.406	0.167	0.189	0.278	1.247	0.000	**4.382**
TOTAL	**5.706**	**9.519**	**35.882**	**29.088**	**1.635**	**15.288**	**5.574**	**9.527**	**10.860**	**42.359**	**0.000**	**165.438**

Appendix F: COMPARISON OF SPACE VENTILATION RATES AND CO_2 CONCENTRATIONS

The ASHRAE 62.1 ventilation rate procedure has a conditioned floor area calculation which accounts for materials off-gassing in the space as well as a people calculation that accounts for bioeffluents (and in some cases human activity resulting in added emissions). Originally, CO_2 was used as a proxy for bioeffluents and CO_2 levels were kept below a certain threshold so that the space did not smell of bioeffluents. Over time, there has been research that indicates that CO_2 levels can adversely affect human performance so that limiting CO_2 is also desirable for productivity in the workplace.

From the current Title 24, Part 6 (2016) standards, the CO_2 levels are relatively constant since there is a fixed 15 CFM per person outdoor air flow requirement. The ASHRAE 62.1-2016 standard adds the people outdoor air rate and the area outdoor air rate so the required outdoor air rate (cfm/sf) varies by space type and occupant density.

For these calculations, the occupancy used is one half of the maximum occupant load assumed for egress purposes in the CBC as is common practice. This occupant density is given in Table 28 below.

Table 28: Estimated Average Occupancy

TYPE OF USE	CA Building Code Max Occupancy for Egress Table 1004.1.2 (person/1,000sf)	Estimated Average Occupancy at 1/2 of Max
All Others (including unleased tenant space in multi-tenant facilities)	10	5
Assembly (Concentrated) - Auditorium Area	143	71
Assembly (Concentrated) - Lobby, Main Entry	67	33
Assembly (Concentrated) - Religious Worship Area	143	71
Assembly (Concentrated) - Theater, Motion Picture	143	71
Assembly (Concentrated) - Theater, Performance	143	71
Assembly (Concentrated) - Waiting Area	67	33
Assembly (non-Concentrated) - Bar, Cocktail Lounge and Casino Areas	67	33
Assembly (non-Concentrated) - Convention, Conference, Multipurpose and Meeting Center Areas	67	33
Assembly (non-Concentrated) - Dining Area	67	33
Assembly (non-Concentrated) - Exhibit, Museum Areas	67	33
Assembly (non-Concentrated) - Gymnasium/Sports Arena	67	33
Assembly (non-Concentrated) - Lounge, Recreation	67	33
Auto Repair Area	10	5
Barber Shop	10	5
Beauty or Nail Salon Area	10	5

TYPE OF USE	CA Building Code Max Occupancy for Egress Table 1004.1.2 (person/1,000sf)	Estimated Average Occupancy at 1/2 of Max
Civic Meeting Place Area	67	33
Classrooms - Art, Science and Wood/Metal	50	25
Classrooms - Elementary Classrooms	50	25
Classrooms - Other Classrooms, Lecture, Training, Vocational Areas	50	25
Commercial and Industrial Storage Areas (conditioned or unconditioned)	2	1
Commercial and Industrial Storage Areas (refrigerated)	0	0
Computer Room (Data Center)	3	2
Corridors, Stairs, and Support Areas	10	5
Dry Cleaning (Coin Operated)	10	5
Dry Cleaning (Full Service Commercial)	10	5
Electrical, Mechanical, Telephone Rooms	3	2
Exercise Room	20	10
Financial Transaction Area	10	5
Garage, Parking	5	3
General Commercial and Industrial Work Areas, High Bay	10	5
General Commercial and Industrial Work Areas, Low Bay	10	5
General Commercial and Industrial Work Areas, Precision	10	5
Hotels and Apartments - Hotel Function Area	143	71
Hotels and Apartments - Hotel/Motel Guest Room	5	3
Hotels and Apartments - Lobby, Hotel	10	5
Housing, Public and Common Areas: Multi-family, Dormitory	20	10
Housing, Public and Common Areas: Senior Housing	10	5
Kitchen, Commercial Food Preparation	5	3
Kitchenette or Residential Kitchen	5	3
Laboratory - Equipment Room	5	3
Laboratory - Educational, Scientific	10	5
Laundry	10	5
Library - Library, Reading Areas	20	10
Library - Library, Stacks	10	5
Locker/Dressing Room	20	10
Medical and Clinical Care	10	5
Nurseries for Children - Day Care	29	14
Office (250 square feet in floor area or less)	10	5

TYPE OF USE	CA Building Code Max Occupancy for Egress Table 1004.1.2 (person/1,000sf)	Estimated Average Occupancy at 1/2 of Max
Office (Greater than 250 square feet in floor area)	10	5
Police Station and Fire Station	10	5
Restrooms – private	10	5
Restrooms – public	10	5
Retail - Grocery Sales Areas	33	17
Retail - Malls and Atria	33	17
Retail - Merchandise Sales, Wholesale Showroom	33	17
Retail - Pet shops (animal areas)	33	17
Transportation Function	33	17
Transportation Function, Concourse & Baggage	33	17
Transportation Function, Ticketing	33	17
Unleased Tenant Area	10	5
Unoccupied-Exclude from Gross Floor Area	0	0
Unoccupied-Include in Gross Floor Area	0	0
Videoconferencing Studio	10	5

To calculate the steady state CO_2 increase in a space due to occupants is given by the following:

$$C_s - C_o = \frac{N}{V_o} \times CF$$

Solving for C_s the total steady state CO2 concentration, Cs, is as follows:

$$C_s = \frac{N}{V_o} \times CF + C_o$$

Where:

C_s = total CO_2 concentration, ppm

C_o = CO_2 concentration in outdoor air, 400 ppm

CF = conversion factor, 1x 10^6, ppm

N = CO_2 generation rate per person, CO2 cfm/person

V_o = outdoor airflow rate per person, cfm/person

The table below shows the effective outdoor air flow rate for both the baseline (Title 24, 2016) and proposed (ASHRAE 62.1 rates multiplied by 130 percent). In addition, CO_2 concentrations for spaces using the proposed ventilation rates are shown. The 130 percent multiplier is necessary to keep CO_2 concentrations below levels that can cause adverse health effects. Furthermore, this table provides further substantiation that there should not be an exception for the 130 percent multiplier in systems with demand control ventilation; this is because the spaces where DCV is required are also the spaces with the highest occupancy and therefore CO_2 concentrations. The spaces that are required to have DCV are also the spaces where the 130 percemt multiplier is needed most.

Total CO_2 concentration is given below with the assumption that the ambient CO_2 concentration is 400 ppm.

Table 29: Comparison of Effective Outdoor Air Flow rates and Total CO_2 2016 T-24 vs. Proposal

	Baseline (Title 24, Part 6 (2016)		Proposed 2019 Title 24, Part 6		ASHRAE 62.1-2016
Type of Use	Effective Outdoor Air Flow Rate Per ft^2 (cfm/sf)	CO_2 total concentration Cs (Title 24, Part 6 (2016)) (ppm)	Effective Outdoor Air Flow Rate Per ft^2 130% of ASHRAE 62.1 (cfm/sf)	CO_2 total concentration, Cs (130% ASHRAE 62.1) (ppm)	CO_2 total concentration, Cs (100% ASHRAE 62.1) (ppm)
All Others (including unleased tenant space in multi-tenant facilities)	0.15	765	0.111	895	1,044
Assembly (Concentrated) - Auditorium Area	1.07	1,130	0.542	1,842	2,275
Assembly (Concentrated) - Lobby, Main Entry	0.5	1,130	0.295	1,638	2,010
Assembly (Concentrated) - Religious Worship Area	1.07	1,130	0.542	1,842	2,275
Assembly (Concentrated) - Theater, Motion Picture	1.07	1,130	1.007	1,177	1,410
Assembly (Concentrated) - Theater, Performance	1.07	1,130	1.007	1,177	1,410
Assembly (Concentrated) - Waiting Area	0.5	1,130	0.403	1,306	1,577
Assembly (non-Concentrated) - Bar, Cocktail Lounge and Casino Areas	0.5	1,130	0.559	1,053	1,249
Assembly (non-Concentrated) - Convention, Conference, Multipurpose and Meeting Center Areas	0.5	1,130	0.295	1,638	2,010
Assembly (non-Concentrated) - Dining Area	0.5	1,130	0.559	1,053	1,249
Assembly (non-Concentrated) - Exhibit, Museum Areas	0.5	1,130	0.403	1,306	1,577
Assembly (non-Concentrated) - Gymnasium/Sports Arena	0.5	1,130	1.101	732	831
Assembly (non-Concentrated) - Lounge, Recreation	0.5	1,130	0.559	1,053	1,249
Auto Repair Area	1.5	436	0	400	400
Barber Shop	0.4	537	0.286	591	649
Beauty or Nail Salon Area	0.4	537	0.286	591	649
Civic Meeting Place Area	0.5	1,130	0.295	1,638	2,010

Type of Use	Baseline (Title 24, Part 6 (2016)		Proposed 2019 Title 24, Part 6		ASHRAE 62.1-2016
	Effective Outdoor Air Flow Rate Per ft^2 (cfm/sf)	CO_2 total concentration Cs (Title 24, Part 6 (2016)) (ppm)	Effective Outdoor Air Flow Rate Per ft^2 130% of ASHRAE 62.1 (cfm/sf)	CO_2 total concentration, Cs (130% ASHRAE 62.1) (ppm)	CO_2 total concentration, Cs (100% ASHRAE 62.1) (ppm)
Classrooms - Art, Science and Wood/Metal	0.38	1,130	0.559	890	1,036
Classrooms - Elementary Classrooms	0.38	1,130	0.481	969	1,140
Classrooms - Other Classrooms, Lecture, Training, Vocational Areas	0.38	1,130	0.481	969	1,140
Commercial and Industrial Storage Areas (conditioned or unconditioned)	0.15	473	0.085	530	568
Commercial and Industrial Storage Areas (refrigerated)	0.15	N/A	0	N/A	N/A
Computer Room (Data Center)	0.15	509	0.088	587	643
Corridors, Stairs, and Support Areas	0.15	765	0.078	1,102	1,312
Dry Cleaning (Coin Operated)	0.3	582	0.205	667	748
Dry Cleaning (Full Service Commercial)	0.45	522	0.205	667	748
Electrical, Mechanical, Telephone Rooms	0.15	509	0	400	400
Exercise Room	0.15	1,130	0.338	724	821
Financial Transaction Area	0.15	765	0.127	832	961
Garage, Parking	0.15	582	0	400	400
General Commercial and Industrial Work Areas, High Bay	0.15	765	0.143	783	898
General Commercial and Industrial Work Areas, Low Bay	0.15	765	0.143	783	898
General Commercial and Industrial Work Areas, Precision	0.15	765	0.143	783	898
Hotels and Apartments - Hotel Function Area	1.07	1,130	0.542	1,842	2,275
Hotels and Apartments - Hotel/Motel Guest Room	0.15	582	0.094	690	778
Hotels and Apartments - Lobby, Hotel	0.15	765	0.127	832	961

Type of Use	Baseline (Title 24, Part 6 (2016)		Proposed 2019 Title 24, Part 6		ASHRAE 62.1-2016
	Effective Outdoor Air Flow Rate Per ft^2 (cfm/sf)	CO_2 total concentration Cs (Title 24, Part 6 (2016)) (ppm)	Effective Outdoor Air Flow Rate Per ft^2 130% of ASHRAE 62.1 (cfm/sf)	CO_2 total concentration, Cs (130% ASHRAE 62.1) (ppm)	CO_2 total concentration, Cs (100% ASHRAE 62.1) (ppm)
Housing, Public and Common Areas: Multi-family, Dormitory	0.15	1,130	0.156	1,102	1,312
Housing, Public and Common Areas: Senior Housing	0.15	765	0.078	1,102	1,312
Kitchen, Commercial Food Preparation	0.15	582	0.18	552	597
Kitchenette or Residential Kitchen	0.15	582	0.172	559	607
Laboratory - Equipment Room	0.15	582	0.094	690	778
Laboratory - Educational, Scientific	0.15	765	0.299	583	638
Laundry	0.15	765	0.189	690	778
Library - Library, Reading Areas	0.15	1,130	0.221	895	1,044
Library - Library, Stacks	0.15	765	0.189	690	778
Locker/Dressing Room	0.15	1,130	0.254	832	961
Medical and Clinical Care	0.15	765	0.111	895	1,044
Nurseries for Children - Day Care	0.21	1,130	0.42	773	884
Office (250 square feet in floor area or less)	0.15	765	0.111	895	1,044
Office (Greater than 250 square feet in floor area)	0.15	765	0.111	895	1,044
Police Station and Fire Station	0.15	765	0.205	667	748
Restrooms - private	0.15	765	0.078	1,102	1,312
Restrooms - public	0.15	765	0.078	1,102	1,312
Retail - Grocery Sales Areas	0.25	1,130	0.24	1,159	1,386
Retail - Malls and Atria	0.25	1,130	0.24	1,159	1,386
Retail - Merchandise Sales, Wholesale Showroom	0.25	1,130	0.318	973	1,145
Retail - Pet shops (animal areas)	0.25	1,130	0.318	973	1,145
Transportation Function	0.25	1,130	0.24	1,159	1,386
Transportation Function, Concourse & Baggage	0.25	1,130	0.24	1,159	1,386

Type of Use	Baseline (Title 24, Part 6 (2016)		Proposed 2019 Title 24, Part 6		ASHRAE 62.1-2016
	Effective Outdoor Air Flow Rate Per ft^2 (cfm/sf)	CO_2 total concentration Cs (Title 24, Part 6 (2016)) (ppm)	Effective Outdoor Air Flow Rate Per ft^2 130% of ASHRAE 62.1 (cfm/sf)	CO_2 total concentration, Cs (130% ASHRAE 62.1) (ppm)	CO_2 total concentration, Cs (100% ASHRAE 62.1) (ppm)
Transportation Function, Ticketing	0.25	1,130	0.24	1,159	1,386
Unleased Tenant Area	0.15	765	0.111	895	1,044
Unoccupied-Exclude from Gross Floor Area	0.15	N/A	0	400	N/A
Unoccupied-Include in Gross Floor Area	0.15	N/A	0	400	N/A
Videoconferencing Studio	0.15	765	0.111	895	1,044

Appendix G: Small School Lifecycle Costs for Outdoor Air Treatment of PM-2.5

Lifecycle costs for outdoor air treatment of PM-2.5 presented below are based on the small school prototype building, with a cooling capacity of 63 tons and air flow rate of 25,623 cfm.

A survey of filter costs was completed and results shown in Table 30.

Table 30: Filter unit costs for MERV 8 and MERV 13

Nominal Height	Nominal Width	Nominal Depth	MERV 8	MERV 13	Incremental Cost
16"	20"	2"	$6.70 /Each	$16.06 /Each	$9.36
16"	25"	2"	$6.82 /Each	$16.76 /Each	$9.94
20"	20"	2"	$7.02 /Each	$16.73 /Each	$9.71
20"	24"	2"	$7.42 /Each	$16.90 /Each	$9.48
20"	25"	2"	$7.62 /Each	$17.24 /Each	$9.62

Based on similar 60-ton rooftop package units, six 20x20 and twelve 20x25 filters are required. The incremental cost for the small school prototype model is shown in Table 31.

Table 31: Incremental first costs for MERV 8 versus MERV 13

Filter Size	Quantity	MERV 8 to 13 Incremental unit cost	Incremental Cost
20x20	6	$9.71	$58.26
20x25	12	$9.62	$115.44
		Incremental First Costs	$173.70

It is assumed that filters are replaced quarterly. Therefore, the annual incremental cost is $694.80. The average increased total static pressure comparing MERV 8 to MERV 13 filters was calculated in Table 32.

The increased static pressure of MERV 13 filters compared to MERV 8 is higher at the beginning of the filter life and then drops until the filters are changed. It is common practice to change filters when they reach a total static pressure (TSP) of 1 inches water gage. Table 31 takes this practice and calculates the progress of filter clogging in nine steps. It is assumed that both filters will reach the 1 IWG replacement trigger within the three-month time period. The average incremental TSP is 0.085 IWG.

Table 32: Incremental Total Static Pressure

	Total Static Pressure (IWG)		
Time Step	**MERV 8**	**MERV 13**	**Incremental Total Static Pressure**
0	0.240	0.410	0.170
1	0.324	0.476	0.151
2	0.409	0.541	0.132
3	0.493	0.607	0.113
4	0.578	0.672	0.094
5	0.662	0.738	0.076
6	0.747	0.803	0.057
7	0.831	0.869	0.038
8	0.916	0.934	0.019
9	1.000	1.000	0.000
Average Incremental Total Static Pressure			**0.085**

This average increase in TSP causes an increase in the brake horse power required by the blower as shown in Table 33. The result is that average annual incremental energy use is 790 kWh, as shown in Table 33. Various scenarios can be analyzed which would raise the incremental increase in energy use but the impact on LCC would be low.

Table 33: Annual Incremental Energy Use

Incremental Total Static Pressure (in. WG)	Incremental Brake Horsepower (bhp)	Incremental Power (kW)	Annual Incremental Energy Use (kWh)
0.085	0.59	0.44	790

Table 34 presents the LCC of improving school filters from MERV 8 to 13. Total costs are the sum of incremental first cost, the present value of the annual increased maintenance cost, and the present value of the increased energy consumption. The total is $10,369. Since this change is for the benefit of the students and staff of the school over the 15-year period of the analysis it is correct to calculate how much per person year it costs. With 442 people in the small school prototype there will 6,630 person years during the 15-year LCC period. The cost per student year is $1.56 as found by dividing the total persons into the present value of the costs. To put this number in perspective the average cost for school facilities is $1000 per student and California spend about $10,000 per year on each student. While the results will vary for each project it is likely that the 2019 Title 24, Part 6 efficiency improvements will result in savings the exceed the cost incurred per student year. Even if electricity use doubled the cost per person year would only increase to $1.85.

Table 34: LCC per person per year

Cost per person of MERV 13 verse MERV 8		
	Analyzed Energy use 790 kWh/yr	**Double Energy Use 1580 kWh/yr**
Incremental First Costs	$174	$174
Incremental annual maintenance	$696	$696
Present worth factor - 15 years	$11.94	$11.94
PV 15-year maintenance costs	$8,309	$8,309
kWh/year per year at $0.20/kwh	$158	$316
PV energy costs 15 years	$1,886	$3,772
Total 15 year LCC	$10,369	$12,255
Total people small school prototype	442	442
Total persons over 15 years	6630	6630
Cost per person year	**$1.56**	**$1.85**