Codes and Standards Enhancement (CASE) Initiative

2019 California Building Energy Efficiency Standards

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

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

Nonresidential Mechanical

June 2017

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EXECUTIVE SUMMARY

This is a draft report. The Statewide CASE Team encourages readers to provide comments on the proposed code changes and the analyses presented in this version of the report. When possible, provide supporting data and justifications in addition to comments. Readers' suggested revisions will be considered when refining proposals and analyses. The final CASE Report will be submitted to the California Energy Commission in the third quarter of 2017. For this report, the Statewide CASE Team is requesting input on the following:

1. *The estimated incremental costs and if these reflect mature market trends;*
2. *The impact on product manufacturers; and*
3. *The impact on the code compliance documentation process.*

Email comments and suggestions to info@title24stakeholders.com. Comments will not be released for public review or will be anonymized if shared with stakeholders.

Introduction

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

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

Measure Description

This measure proposes revising Title 24, Part 6 requirements using a combination of the requirements in Title 24, Part 4, ASHRAE 62.1-2016: Ventilation for Acceptable Indoor Air Quality (ASHRAE 62.1), and leveraging current research on indoor air quality. The ventilation requirements in Title 24, Part 4 are based on or reference ASHRAE 62.1. 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. 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:

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, aligning with the rates found in ASHRAE 62.1 Table 6.2.2.1 *Minimum Ventilation Rates in Breathing Zone* multiplied by 130 percent.

b. Harmonize with the full ventilation rate procedure (VRP) found in Title 24, Part 4 (ASHRAE 62.1) including the requirements for multiple zone recirculating systems.
   - The proposed code change will adapt the full ventilation rate procedure found in Title 24, Part 4 (ASHRAE 62.1) for calculation of minimum ventilation air supply rates. The ventilation rate procedure calculates outdoor air intake rates based upon the contaminant sources and source emission rates that are typical for that occupancy category. The calculated outdoor air intake rate is intended to be sufficient to dilute and exhaust contaminants from occupants and off-gassing from building materials and furnishings in order to meet the sensory satisfaction of occupants. Hence, the ventilation rate procedure calculates rates that account for the control of both the people-related and building-related sources of contaminants. It is assumed that the people and building area-related source components are additive, and can be scaled proportionally to occupancy and to the space's floor area, respectively. In addition, the ASHRAE 62.1 Appendix A calculations for multiple-zone recirculating systems will be included.

c. Revise requirements for natural ventilation.
   - The proposed code change will align the Title 24, Part 6 natural ventilation requirements with those found in Title 24, Part 4 (ASHRAE 62.1). The ASHRAE 62.1 natural ventilation rate requirements include a calculation that establishes the floor area to be ventilated by natural ventilation based on the size and types of openings, and allows 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 provide ventilation 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.

d. Revise requirements for outdoor air treatment.
   - The proposed code change will add to Title 24, Part 6 the ASHRAE 62.1 requirements for outdoor air treatment of particulate matter (PM). The proposed code change requires that if the regional and/or local air quality where the building is located is in "non-attainment" (i.e., above threshold concentrations), then outdoor air treatment would be required for the building. For areas that exceed the PM standard, higher minimum efficiency reporting value (MERV) filters or other method of reducing PM in the air stream would be required (MERV 13 for areas exceeding the 2.5 micron (PM2.5) threshold).

e. Include requirements for exhaust ventilation from Title 24, Part 4 to Title 24, Part 6.
   - The proposed code change will incorporate the requirements for exhaust ventilation found in Title 24, Part 4 Section 403.7 (ASHRAE 62.1 Section 6.5.1) into Title 24, Part 6. This proposed change is primarily an effort to include all ventilation requirements in Title 24, Part 6 for all occupancies regulated by the Energy Commission. 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.

Scope of Code Change Proposal

Table 1 summarizes the scope of the proposed changes and which sections of the standards, nonresidential manual, references appendices, and compliance documents that will be modified as a result of the proposed change.

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Table 1: Scope of Code Change Proposal

Measure Name	Type of Requirement	Modified Section(s) of Title 24, Part 6	Modified Title 24, Part 6 Appendices	Will Compliance Software Be Modified	Modified Compliance Documents(s)
Nonresidential Indoor Air Quality (Proposal Based on ASHRAE 62.1-2016)	Mandatory	Section 120.1 – Requirements for Ventilation	None: NA7.5.1 is 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 buildings requiring a mechanically ventilated system, and by extension, all the components of an air system.

A literature review in Section 5.7 Health and Productivity Cost Impacts provides some estimates on the large productivity gains from improved indoor air quality. Although specific cost-benefit data does not currently exist, the potential productivity gains are orders of magnitude greater than the costs required to improve indoor air quality. In addition, the coastal areas of California have such a mild climate that additional outside air has little impact on energy consumption.

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 demonstrate 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.

Cost-Effectiveness

The primary drivers of this code change proposal are to improve indoor air quality by referencing Title 24, Part 4, ASHRAE 62.1-2016, and leverage current research on indoor air quality. ASHRAE 62.1 is a national ventilation standard that is widely accepted as industry standard practice throughout the country, and there is opportunity to further improve indoor air quality by leveraging the leading industry research on this topic. 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, as opposed to achieving energy savings. While developing this code change proposal, the Statewide CASE Team worked with the Energy Commission and other state agencies, such as the California Air Resources Board, and indoor air quality experts (such as those at Lawrence Berkeley National Labs) to evaluate the costs and benefits of the proposed changes. In some situations, ventilation air is reduced, and in others, 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 in areas where PM2.5 levels are in non-attainment, reduced indoor carbon dioxide (CO_2) levels throughout the state, and improved occupant health throughout the state. The use of 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 and Table 3 show potential energy savings using the Small School prototype building (which is a conservative estimate) and the Small Office prototype building over the first-year the proposed code changes would be in effect. See Section 6 for more details.

Table 2: Estimated Statewide First-Year[1] Energy and Water Savings (Using Small School Prototype Building)

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)
(65.1)	(89.6)	N/A	(6.8)

Table 3: Estimated Statewide First-Year[1] Energy and Water Savings (Using Small Office Prototype Building)

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)
(6.7)	8.2	N/A	2.3

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

Compliance and Enforcement

The Statewide CASE Team worked with stakeholders to develop a recommended compliance and enforcement process and to identify the impacts this process will have on various market actors. The compliance process is described in Section 2.5. The impacts the proposed measure will have on various market actors is described in Section 3.3 and 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 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.
- Building inspector will need to become familiar with the new ventilation rate requirements to verify code compliance and proper installation of building features.

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

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1. INTRODUCTION

This is a draft report. The Statewide CASE Team encourages readers to provide comments on the proposed code changes and the analyses presented in this version of the report. When possible, provide supporting data and justifications in addition to comments. Readers' suggested revisions will be considered when refining proposals and analyses. The final CASE Report will be submitted to the California Energy Commission in the third quarter of 2017. For this report, the Statewide CASE Team is requesting input on the following:

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The overall goal of this CASE Report is to propose a code change proposal for Nonresidential Indoor Air Quality and Ventilation. 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 a public stakeholder workshop that the Statewide CASE Team held on September 27, 2016.

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 public health and safety is maintained as building envelop requirements become more stringent. This measure will result in increased energy use in some buildings. This CASE Report discusses the likely energy impacts with the goal of providing data that the Energy Commission can consider to make informed decision 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 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. Although a cost-effectiveness analysis is not required, 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 estimates 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, statewide Greenhouse Gas (GHG) reductions associated with reduced energy consumption, and impacts (increases or reductions) on material with emphasis placed on any materials that are considered toxic. Statewide water consumption impacts are also considered.

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

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2. Measure Description

2.1 Measure Overview

The proposed code change aims to update the ventilation and indoor air quality requirements found in Title 24, Part 6: Section 120.1 Requirements for Ventilation with a combination of the requirements found in Title 24, Part 4, ASHRAE 62.1-2016: Ventilation for Acceptable Indoor Air Quality (ASHRAE 62.1), and leveraging current research on 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 found in ASHRAE 62.1 Table 6.2.2.1 *Minimum Ventilation Rates in Breathing Zone* multiplied by 130 percent.

b. Harmonize with the full ventilation rate procedure (VRP) found in Title 24, Part 4 (ASHRAE 62.1) including the requirements for multiple zone recirculating systems.
    - The proposed code change will adapt the full ventilation rate procedure found in Title 24, Part 4 (ASHRAE 62.1) for calculation of minimum ventilation air supply rates. The ventilation rate procedure calculates outdoor air intake rates based upon the contaminant sources and source emission rates that are typical for that occupancy category. The calculated outdoor air intake rate is intended to be sufficient to dilute and exhaust contaminants from occupants and off-gassing from building materials and furnishings in order to meet the sensory satisfaction of occupants. Hence, the ventilation rate procedure calculates rates that account for the control of both the people-related and building-related sources of contaminants. It is assumed that the people and building area-related source components are additive, and can be scaled proportionally to occupancy and to the space's floor area, respectively. In addition, the ASHRAE 62.1 Appendix A calculations for multiple-zone recirculating systems will be included.

c. Revise requirements for natural ventilation.
    - The proposed code change will align the Title 24, Part 6 natural ventilation requirements with those found in Title 24, Part 4 (ASHRAE 62.1). The ASHRAE 62.1 natural ventilation rate requirements include a calculation that establishes the floor area to be ventilated by natural ventilation based on the size and types of openings, and allows 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 provide ventilation 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.

d. Revise requirements for outdoor air treatment.
    - The proposed code change will add to Title 24, Part 6 the ASHRAE 62.1 requirements for outdoor air treatment of particulate matter (PM). The proposed code change requires that if the regional and/or local air quality where the building is located is in "non-attainment" (i.e., above threshold concentrations), then outdoor air treatment would be required for the building. For areas that exceed the PM standard, higher minimum efficiency reporting value (MERV) filters or other method of reducing PM in the air stream would be required (MERV 13 for areas exceeding the 2.5 micron (PM2.5)

threshold). In other words, areas with high PM2.5 will trigger the MERV 13 filtration requirement. The CASE team was also considering, but ultimately abandoned, removing the trigger for MERV 13 filtration and having the requirement be mandatory for all ducted systems; this idea was rejected due to lack of evidence that the benefits would outweigh the costs in regions with low outdoor particle concentrations and in buildings with low indoor particle emission rates (such as offices without cooking facilities).

e. 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 in Title 24, Part 4 Section 403.7 (ASHRAE 62.1 Section 6.5.1) into Title 24, Part 6. This proposed change is primarily an effort to include all ventilation requirements in Title 24, Part 6 for all occupancies regulated by the Energy Commission. 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.

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.

The proposed measure is anticipated to be a mandatory requirement for the building types listed above. 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, then the proposed measure is also triggered.

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

2.1.1 Ozone Outdoor Air Treatment

Although ozone outdoor air treatment is an important issue, it will not be included into this cycle's code change. The ASHRAE 62.1 ozone outdoor air treatment requirements (Section 6.2.1.3) require a 40 percent removal efficiency. However, compliance for ozone filtration systems is difficult compared to compliance for particulate matter filtration. Compliance for particulate matter filtration simply requires the design engineer to identify a filter with the required MERV rating and then determining an appropriate size that will result in an acceptable pressure drop at the design airflow. This contrasts to compliance for ozone filtration, because there is currently no method to look at a manufacturer's catalog and select an ozone filter with the required 40 percent removal efficiency; the design engineer would need to contact an activated carbon filter manufacturer to determine the requisite carbon characteristics along with the face area and depth of the filter. Further, the code official will not easily be able to verify compliance, because the activated carbon filter will not have a label that states the required performance.

Furthermore, there are very few research studies that indicate how well, and for how long, activated carbon systems remove ozone. It will be difficult to prove the performance of activated carbon filters at this current time and for this code change cycle.

Additionally, activated carbon filters are expensive and pressure drops can be very high. There is oftentimes not enough space for this new hardware in ducts, and trays of granular activated carbon may even require fire protection. Incoming particulate matter often needs to be pre-filtered because it would affect the performance of the activated carbon filter. Together, the increased first cost and operating costs are high.

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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 requires the Energy Commission to consider the impacts of any new building standards on indoor air quality (§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. According to the Health and Safety Code Section 105400:

> "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."

According to Health and Safety Code Section 105410:

> "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, 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.

2.2.2 Title 24, Part 6 Ventilation Standard – Measure History

The minimum ventilation rates have not been updated since the 1992 Title 24, Part 6 Standards. This suggests an opportunity to make code revisions to align with the latest science and consensus on 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 commercial buildings ventilation standards that is required in most other states. Aligning California's ventilation standards with parts of ASHRAE 62.1-2016 would provide the auxiliary benefit of aligning California with national standards, which allows designers to leverage resources that are available throughout the country.

Finally, by adopting the ASHRAE 62.1 ventilation rate procedure, minimum ventilation rates are more accurately calculated for most occupancy categories.

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In 1990, the Energy Commission was directed 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 their 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 efficiency requirements. After much debate and public hearings, the result was the adoption of Section 121- Requirements for Ventilation for the 1992 Standards. This section has remained largely unchanged since the 1992 Standards.

At about the same time, ASHRAE began the process of 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 represents the latest research in establishing ventilation rates. The ventilation rate procedure was expressly developed for use in building codes and aims to produce 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 the ventilation rates in ASHRAE 62.1.

See the Appendix 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 provide a summary of how each Title 24, Part 6 documents 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. See Section 7 of this report for the detailed proposed revisions to the code language.

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)1A: This proposed code changes will align the Title 24, Part 6 natural ventilation requirements with those found in Title 24, Part 4 (ASHRAE 62.1). The section describes how to calculate the floor area to be ventilated by natural ventilation based on the size and types of openings that exist.

Subsection 120.1(b)2: This proposed code changes define the procedure for calculating minimum quantities of outdoor air for mechanical ventilation in alignment with the full VRP found in Title 24, Part 4 (ASHRAE 62.1).

Subsection 120.1(f): The proposed code change adds requirements for the treatment of outdoor air for particulate matter and ozone from a ventilation system, in alignment with ASHRAE 62.1 requirements.

Subsection 120.1(g): The proposed code change adds requirements for exhaust ventilation in alignment with Title 24, Part 4 (ASHRAE 62.1) requirements.

2.3.1.1 Proposed Addendum b to Standard 62.1-2016, Ventilation for Acceptable Indoor Air Quality

During the second Utility-Sponsored Stakeholder meeting where this proposed code change was presented, there was feedback that the ASHRAE 62.1 ventilation rate procedure in its current form is a complicated process, especially for multiple zone recirculating systems. Some stakeholders stated that due to the complexity of the ventilation rate procedure, some engineers will use it in a very conservative manner that can double or triple minimum ventilation rates, resulting in an increase in energy use.

The ASHRAE Standing Standard Project Committee 62.1 (SSPC 62.1) has created "Proposed Addendum b to Standard 62.1-2016", which provides a simplified method for calculating ventilation rates that provide similar ventilation rates for test buildings. The proposed Addendum b has been in public review since 2014.

Addendum b will likely provide lower minimum outdoor air rates than might result from using the existing ventilation rate procedure with poor assumptions.

However, it would be prudent to have changes to the standard occur through ASHRAE, and not at a local level, and the proposed Addendum b warrants a more thorough review for the next code cycle.

2.3.2 Reference Appendices Change Summary

This code change proposal is not expected to modify the reference appendices. The Mechanical Acceptance Test 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 Alternative Calculation Method (ACM) Reference Manual as summarized below. See Section 7.3 of this report for the detailed proposed revisions to the text of the ACM Reference Manual.

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 Title 24, Part 6 Compliance Manual

- 4.3 Ventilation Requirements

2.3.5 Compliance Documents Change Summary

The proposed code change will modify the compliance documents listed below. Examples of the revised documents are presented in Section 7.5.

- Document NRCA-MCH-02-A

- Document NRCC-MCH-03-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. 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:

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

In Table 120.1-A, a list of ten “Types of Use” and corresponding minimum cfm per square foot of conditioned floor area are listed. If a Type of Use is not captured by the ten listed in the table, there is an “All others” option that specifies 0.15 CFM per square foot of conditioned floor area.

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

Title 24, Part 6 currently does not have requirements for outdoor air treatment or exhaust ventilation. There are other parts of Title 24 that do have requirements for these, described in Section 2.4.2 below.

2.4.2 Relationship to Other Title 24 Requirements

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.

The full ASHRAE 62.1 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. There are also other natural ventilation requirements found in Title 24, Part 2 (California Building Code).

Requirements for air treatment can be found in CALGreen mandatory measure 5.504.5.3, requiring filters with a MERV rating of 8. Voluntary CALGreen measures A5.504.5.3.1 and 5.504.5.3.1.1 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.

Section 402.1 in Title 24, Part 4 currently contains language that leads to confusion on 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 <u>air supply, exhaust, and makeup air</u> requirements for occupancies regulated by the California Energy Commission are found in the California Energy Code, <u>and those occupancies do not need to follow the provisions of this chapter.</u>"*

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 standard into Title 24, Part 6, concurrently 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 Standard 62.1's ventilation rate procedure

For those new construction projects pursuing Leadership in Energy and Environmental Design (LEED) certification, one of the mandatory prerequisites is a mechanical ventilation system that is designed using the ventilation rate procedure defined in ASHRAE 62.1. Further, one of the LEED voluntary ventilation credits 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 Title 24, Part 6 2019. The key steps 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.
- **Permit Application Phase**: Since the calculations are more complicated, it may take plans examiners more time to confirm the calculations were completed 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, manages installers and subcontractors. The Installer/Specialty Subcontractor coordinates with the General Contractor to properly install the ventilation system.
- **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 determined minimum required ventilation air supply rates is more difficult for mechanical designers and enforcement officials. This may require building officials 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 (VRP)

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 in order to calculate ventilation rates.

Some relevant entities that have identified the risks associated with inadequate indoor air quality, and therefore ventilation rates and calculation methodologies, include federal agencies (such as the US Environmental Protection Agency and US Department of Energy) and state agencies (such as the California Air Resources Board, the California Department of Public Health, and Cal/OSHA).

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. Principle manufacturers of particulate matter filters include Camfil, AAF Flanders and Purafil. Filters are a well-established technology and readily available from multiple manufacturers.

3.2 Technical Feasibility, Market Availability and Current Practices

3.2.1 Modified Minimum Ventilation Rates and Ventilation Rate Procedure (VRP)

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

For systems that are not 100 percent outside air, the system's peak airflow rate is dependent on heating and cooling loads, and not on the minimum ventilation rates that are being modified in the proposed code change. Therefore, the system sizing and cost should not change with the proposed code change.

Furthermore, in Section 402.1 of Title 24, Part 4, there is currently language that leads to confusion on whether or not ventilation requirements should follow Title 24, Part 4 or Title 24, Part 6. The following is a suggested revision that makes it clearer that mechanical ventilation rates for occupancies that the the Energy Commission regulates should be found in Title 24, Part 6.

> *"Ventilation air supply, exhaust, and makeup air requirements for occupancies regulated by the California Energy Commission are found in the California Energy Code, and those occupancies do not need to follow the provisions of this chapter."*

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 in order 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 heading.

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

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The proposed code change impacts all new construction nonresidential buildings requiring a mechanically ventilated system. For buildings that are constructed in an area where the national standard for particulate matter smaller than 2.5 micrometers is exceeded, particle filters with a MERV rating of 13 or greater must be installed. Therefore, there will be an increase in MERV 13 particle filters that will be specified as a result of this code change. However, 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.

There are some concerns related to space constraints for requiring MERV 13 filters in all ducted systems, including in smaller off-the-shelf package units (<10 tons). However, after speaking with vendors, there are widely available two inch MERV 13 filter options 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, improved air filtration will improve indoor air quality and economic productivity in workers. Furthermore, the green building industry has experienced a trend to improving indoor air quality; for example, in the WELL building standard, MERV 13 filters are required in the ventilation system to filter outdoor air, and this would be at the expense of increased energy use.

The energy impacts are addressed in Section 4.3.3 Outdoor Air Treatment.

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 for change in demand for new buildings and by construction costs. Demand for new buildings is driven more by factors such as the overall health of the economy and population growth than the cost of construction. The cost of complying with Title 24, Part 6 requirements represents a very small portion of the total building value. Increasing the building cost by a fraction of a percent is not expected to have a significant impact on demand for new buildings or the builders' profits.

See Appendix C 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.) are typically updated on a three-year revision cycles. As discussed in Section 3.3.1, all market actors, including building designers and energy consultants, should (and do) plan for training and education that may be required to adjusting design practices to accommodate compliance with new building codes. 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 requirements can be met.

See Appendix C 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 Department of Occupational Safety and Health (Cal/OSHA). All existing health and safety rules will remain in place. Complying with the

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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 (SBS) 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

Building owners and occupants will benefit from lower energy bills. As discussed in Section 3.4.1 when building occupants save on energy bills, they tend to spend it elsewhere in the economy thereby creating jobs and economic growth for the California economy.

The primary first cost associated with this measure is for those buildings located in regions with high levels of particulates. In these regions MERV filters are required to reduce particulates. However, these costs are offset by less illness and 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 this may not involve enough subjects to be considered conclusive. (Kajtar, L., L. Herczeg, et al. 2006) (Satish, U., Mendell, M.J., et al. 2012) (Maddalena, R., M. J. Mendell, 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.

The installation of MERV filters may require additional maintenance and replacements. Generally, MERV filters are replaced every three months.

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 document NRCA-MCH-02-A. Care will be taken to ensure the updates to this form 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 6 percent between 2014 and 2015 while the overall statewide employment grew 3 percent (BW Research Partnership 2016). Lawrence Berkeley National Laboratory's 2010 *Characterizing the Energy Efficiency Services Sector* report provides a detail on the types of jobs in the energy efficiency sector that are likely to be supported by revisions to building codes.

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3.4.2 Creation or Elimination of Businesses within 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 4 lists industries that will likely benefit from the proposed code change classified by their North American Industry Classification System (NAICS) Code.

Table 4: 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 within 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 otherwise be invested, which provides California businesses with an advantage that will only be strengthened by the adoption of the proposed codes 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. As discussed in Section 3.3.1,

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however, 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 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. There are numerous resources available to local governments to support compliance training that can help mitigate the cost of retraining. 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 business.

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, Small Office.
- Zone Air Distribution Effectiveness (E_z): 0.8, representing a typical variable air volume (VAV) system with ceiling supply of cool air.
- Occupant densities: Title 24, Part 6 occupant densities.
- Small School prototype building has air-side economizer operation; Small Office prototype building does not have economizer control.
- The OpenStudio interface to the EnergyPlus whole building simulation program was used in order to quantify energy savings and peak electricity demand reductions resulting from the proposed measure. Enhancements will need to be made to the Energy Commission approved simulation program (CBECC-Com) in order to perform the ASHRAE 62.1 ventilation rate procedure calculations.

- The Small Office prototype building did not have space types in the model. A space type breakdown for offices, listed in the National Commercial Construction Characteristics (NC^3), was used. The NC^3 dataset is comprised of 343 buildings that were constructed or designed from 2001-2007. A blended ventilation rate weighted by the space type breakdown was used for both the Baseline and Proposed models. The space type breakdown was as follows:

Table 5: National Commercial Construction Characteristics Space Type Breakdown for Offices

Title 24 Occupancy Category	Percent of Floor Space
Office (250 square feet in floor area or less)	22.3%
Corridors, Restrooms, Stairs, and Support Areas	16.5%
Office (Greater than 250 square feet in floor area)	14.1%
Commercial and Industrial Storage Areas (conditioned or unconditioned)	13.2%
Assembly (non-Concentrated) - Convention, Conference, Multipurpose and Meeting Center Areas	10.2%
Assembly (Concentrated) - Lobby, Main Entry	5.9%
Assembly (non-Concentrated) - Lounge, Recreation	3.6%
Electrical, Mechanical, Telephone Rooms	2.8%
Housing, Public and Common Areas: Multi-family, Dormitory	2.3%
General Commercial and Industrial Work Areas, High Bay	1.9%
Kitchen, Commercial Food Preparation	1.6%
Assembly (non-Concentrated) - Dining Area	1.5%
Classrooms, Lecture, Training, Vocational Areas	0.77%
Garage, Parking - Parking Garage Area Dedicated Ramps	0.72%
Assembly (non-Concentrated) - Gymnasium/Sports Arena	0.63%
Medical and Clinical Care	0.61%
Library - Library, Reading Areas	0.44%
Transportation Function, Ticketing	0.42%
Financial Transaction Area	0.14%
Laundry	0.14%
Laboratory, Scientific	0.11%
Locker/Dressing Room (**assume restroom)	0.04%

4.2 Energy Savings Methodology

4.2.1 Modified Minimum Ventilation Rates and Ventilation Rate Procedure (VRP)

To assess the energy, demand, and energy cost impacts, the Statewide CASE Team compared current design practices to design practices that would comply with the proposed requirements. There are existing Title 24, Part 6 standards that covers the building system in question, so the existing conditions assume the building is minimally complaint with the 2016 Title 24, Part 6 Standards.

The proposed conditions are defined as the design conditions that will comply with the proposed code change. Specifically, the proposed code change will use the minimum ventilation rates of ASHRAE 62.1 multiplied by 130 percent and the full ventilation rate procedure to calculate ventilation supply rates and its associated energy use. This will be compared with the energy use associated with ventilation supply calculated using the existing 2016 Title 24, Part 6 Standards.

Energy Commission staff provided guidance on the type of prototype buildings that must be modeled. Specifically, the Small School and Small Office prototype building will be used to determine energy savings.

The models will be run in climate zones with diverse characteristics. For example, energy use results will differ greatly for models run in warm or cold climate zones, or in climate zones with vastly different economizer hours.

Table 6 presents the details of the prototype building used in the analysis. Table 7 and Table 8 present details on various space types contained within the Small School and Small Office prototype buildings.

Table 6: 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	x
Prototype 2	Small Office	5,502	1	x

Table 7: Small School Floor Area and Occupancy Assumptions

Thermal Zone	Zone Floor Area (ft^2)	Zone Population (people)	Breathing Zone Outdoor Airflow (cfm)
Cafeteria	1,226	6.13	135.51
Corridor	911	4.55	71.02
Lobby	775	3.87	85.63
Mechanical Room	729	0.73	61.59
Office	561	18.70	165.27
Restroom	326	10.87	96.08
Corridor	200	6.67	111.84
Classroom, Wing 1, Side 1	155	0.23	13.58
Classroom, Wing 1, Side 2	127	1.27	9.89
Corridor	102	0.51	14.57
Classroom, Wing 2, Side 1	87	0.22	15.73
Classroom, Wing 2, Side 2	82	2.75	46.04

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Table 8: Small Office Floor Area and Occupancy Assumptions

Thermal Zone	Zone Floor Area (ft^2)	Zone Population (people)	Breathing Zone Outdoor Airflow (cfm)
Office (250 square feet in floor area or less)	1,226	6.13	135.51
Corridors, Restrooms, Stairs, and Support Areas	911	4.55	71.02
Office (Greater than 250 square feet in floor area)	775	3.87	85.63
Commercial and Industrial Storage Areas (conditioned or unconditioned)	729	0.73	61.59
Assembly (non-Concentrated) - Convention, Conference, Multipurpose and Meeting Center Areas	561	18.70	165.27
Assembly (Concentrated) - Lobby, Main Entry	326	10.87	96.08
Assembly (non-Concentrated) - Lounge, Recreation	200	6.67	111.84
Electrical, Mechanical, Telephone Rooms	155	0.23	13.58
Housing, Public and Common Areas: Multi-family, Dormitory	127	1.27	9.89
General Commercial and Industrial Work Areas, High Bay	102	0.51	14.57
Kitchen, Commercial Food Preparation	87	0.22	15.73
Assembly (non-Concentrated) - Dining Area	82	2.75	46.04
Classrooms, Lecture, Training, Vocational Areas	42	1.06	20.40
Garage, Parking - Parking Garage Area Dedicated Ramps	40	0.10	10.29
Assembly (non-Concentrated) - Gymnasium/Sports Arena	34	1.15	13.42
Medical and Clinical Care	34	0.17	3.73
Library - Library, Reading Areas	24	0.24	5.31
Transportation Function, Ticketing	23	0.38	5.49
Financial Transaction Area	8	0.04	1.01
Laundry	8	0.04	1.41
Laboratory, Scientific	6	0.03	1.79
Locker/Dressing Room	2	0.02	0.16

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

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

4.2.2 Natural Ventilation Procedure

An analysis comparing the natural ventilation requirements of Title 24, Part 6 2016 (the baseline) and ASHRAE 62.1-2016 (the proposed change) was completed using the Small School prototype model. The analysis will determine if the proposed code change would increase the number of spaces that are allowed to be naturally ventilated, which in turn reduces the load for mechanical ventilation. A more detailed energy savings analysis will not be completed for this sub-measure.

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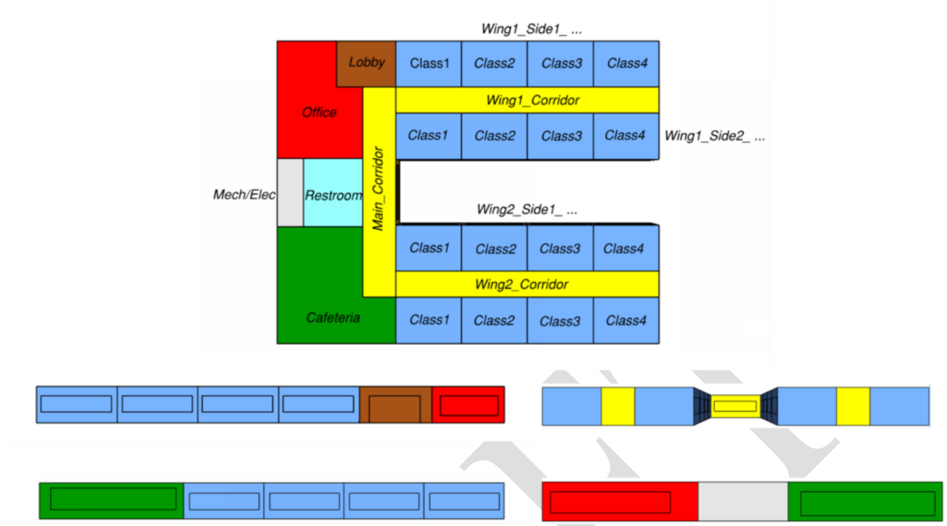

Figure 1: Floor Plan and Elevation Views of Small School Prototype

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 2H.
  - Double Side Opening: The maximum distance from the operable openings cannot be more than 5H.
  - Corner Opening: The maximum distance from the operable openings cannot be more than 5H 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 opening 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:

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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)		Allowable Maximum Distance from Opening (ft)		Natural Ventilation Allowed?
							Title 24, Part 6	ASHRAE 62.1	Title 24, Part 6	ASHRAE 62.1	
	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 *	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

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

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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 the load for mechanical ventilation.

4.2.3 Outdoor Air Treatment

The incremental energy use associated with outdoor air treatment through the use of high efficiency filters is calculated by the following equation:

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

where,

BHP = brake horsepower (hp)
cfm = supply air flow rate (cfm)
TSP = total static pressure (inWG)
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):

Table 10: Filtration Incremental Fan Electrical Demand Compared to No 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

An engineering standard practice is that a clean filter's initial resistance should have a pressure drop between 0.27 and 0.41 inches water gauge (inWG) depending on filtration efficiency, and a dirty filter's final resistance be 1.0 inWG, at which point the filter should be replaced. However, the reality is that there is significant variation in pressure drop even amongst filters of different manufacturers with the same MERV rating, and so the results shown above are rough estimations.

The annual hours of occupancy for Title 24, Part 6 Schools from Appendix 5.4B of the Nonresidential Alternative Compliance Manual (NR ACM) is 1,808 hours during which fans will be operated.

4.3 Per Unit Energy Impacts Results

4.3.1 Modified Minimum Ventilation Rates and Ventilation Rate Procedure (VRP)

Energy savings and peak demand reductions per Small School and Small Office prototype building are presented in Table 11. The predicted annual energy use and peak kW demand vary widely by climate zone.

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Table 11: First-Year Energy Impacts per Prototype School 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)
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)
SMALL OFFICE				
1	(292)	0.00	213	32,796
2	(242)	0.29	128	23,862
3	(408)	0.10	105	10,814
4	(283)	0.23	87	15,787
5	(417)	0.12	112	10,760
6	(381)	0.40	46	2,747
7	(500)	0.18	24	(6,029)
8	(286)	0.38	38	5,587
9	(200)	0.34	47	13,138
10	(125)	0.40	52	15,979
11	78	0.21	117	36,130
12	(97)	0.21	117	29,735
13	58	0.22	109	33,677
14	44	0.33	106	30,557
15	489	0.15	20	27,942
16	(203)	0.14	214	37,876

The Small Office had natural gas savings but overall electricity use increased. This is because with the proposed code change, in some climates, cooling energy will increase due to less free cooling.

The per unit TDV energy cost savings over the 15-year period of analysis are presented in Table 14 These are presented as the discounted present value of the energy cost savings over the analysis period.

4.3.2 Natural Ventilation Procedure

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 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
Mech/Elec	N/A
Office	Neither
Restroom	N/A
Wing1_Corridor	N/A
Wing1_Side1_Class1 *	ASHRAE 62.1
Wing2_Corridor	N/A

4.3.3 Outdoor Air Treatment

The annual energy savings associated with installing outdoor air filtration (MERV 13) compared to having either no filter or a MERV 8 filter are presented in Table 13. While this measure will increase the energy use of fans by increasing the system static pressure, it relates closely to the Fan System Power measure in the Proposals Based on ASHRAE 90.1-2106 CASE Report, which allows systems that include increased pressure drops to claim adjustment factor credits to raise the minimum allowable fan power.

Table 13: Filtration Annual Energy Savings Compared to No Filters

Total Static Pressure (in. WG)	Annual Energy Savings (kWh)
MERV 13 compared to No Filter	
0.41 (clean filter, MERV 13)	(3,809)
1 (dirty filter)	(9,291)
MERV 13 compared to MERV 8 Filter	
0.41 (clean filter, MERV 13)	(1,301)
1 (dirty filter)	0

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. Although a cost-effectiveness analysis is not required, 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.

5.2 Energy Cost Savings Methodology

Time Dependent Value (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 (Energy Commission 2016).

5.3 Energy Cost Savings Results

Per unit energy cost savings over the 15-year period of analysis are presented in Table 14 for new construction. For the Small School prototype building, it is estimated that total energy costs will increase in all 16 climate zones. For the Small Office prototype building, it is estimated that there will be total energy cost savings in all climate zones except Climate Zone 7. However, 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. Some of the cooling energy increase occurred during the peak periods.

Table 14 only includes energy impacts from the updated minimum ventilation rates and ventilation rate procedure sub-measure for the Small School and Small Office prototype buildings, respectively. The remaining sub-measures do not require a cost-effectiveness analysis.

Table 14: TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Small School and Small Office Prototype Building

Climate Zone	15-Year TDV Electricity Cost Savings (2020 PV $)	15-Year TDV Natural Gas Cost Savings (2020PV $)	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)
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

5.4 Incremental First Cost

The Statewide CASE Team estimated the Current Incremental Construction Costs and Post-Adoption Incremental Construction Costs. The Current Incremental Construction Cost represents the incremental cost of the measure if a building meeting the proposed standard were built today. The Post-Adoption Incremental Construction Cost represents the anticipated cost assuming full market penetration of the measure as a result of the new Standards, resulting in possible reduction in unit costs as manufacturing practices improve over time and with increased production volume of qualifying products the year the Standard becomes effective.

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

Implementation of the ASHRAE 62.1 ventilation rates and VRP should not alter the first costs between the baseline and proposed code change, because the system's peak airflow rate, for multiple zone recirculating systems, is dependent on heating and cooling loads, and not on the minimum ventilation rates that are being changed in this measure. However, for dedicated outside air systems (DOAS), the peak system air flow rate would increase.

The remaining sub-measures do not require a cost-effectiveness analysis.

5.5 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 (where d is the discount rate of three percent):

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

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; this is because all that is being altered is the outside air minimum air flow rate damper position

Hence, there would be no significant increase or decrease in lifecycle maintenance costs when comparing both the proposed measure and the baseline.

The remaining sub-measures do not require a cost-effectiveness analysis.

5.6 Lifecycle Cost-Effectiveness

The Statewide CASE Team did not perform a lifecycle cost-effectiveness analysis for the proposed code changes that are recommended for the primary purpose of protecting public health and safety. See Section 2.2.1 for an explanation of why a cost-effectiveness analysis is not required for this measure.

5.7 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, headaches. The report remarks that increased ventilation, source removal and control, air cleaning and purification are important components for reducing the health hazards of inadequate indoor air quality.

A recent Harvard study (MacNaughton et al, 2015) concluded that the health benefits associated with higher ventilation rates far exceeds the increased energy costs. 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 develops estimates of the magnitude of productivity gains from improved indoor air quality. Some of the estimates cited by the study 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 the average salary of an employee is $40,000, increased ventilation reduces sick building symptoms by 25 percent, and 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 the average salary of an employee is $40,000, and improved filtration reduces allergic symptoms experienced by 20 percent of the work force, and 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.

Although specific cost-benefit data does not currently exist, these two studies demonstrate that the potential productivity gains are orders of magnitude greater than the costs of improved indoor air quality.

Another study (Maddalena et al, 2014) shows the importance of avoiding low ventilation rates per person and low ventilation rates per floor area in order to minimize decrements 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.

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 attention declines (Kajtar, Herczeg, 2011). A different study shows that at 2,500 ppm, large and statistically significant reductions occurred in decision making performance (Satish, 2012). The mechanism for why decision making ability decreases a function of CO_2 levels in the space is not well understood. Nevertheless, the decrease in performance can be economically significant for employers.

Although the mechanism is not well understood, compared to natural ventilation, mechanical ventilation showed an increase of approximately 30-200 percent in the incidence of sick building syndrome symptoms (Seppanen, Fisk, 2002).

As a result of the above findings, protection of human health and productivity is prioritized over energy savings. This proposal attempts to maintain the 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. To further improve indoor air quality, the proposed code change will also include requirements for outdoor air treatment when outdoor levels of particulate matter are high.

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, 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.

For further information, Section 2.2 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 represents the energy cost savings over the entire 15-year analysis period. Results are presented in in Table 15.

Both the Small School and Small Office prototype buildings were modeled, and both of their statewide energy savings are presented in Table 15. The results from the Small School model have negative energy and cost savings owing to the fact that classrooms have a higher ventilation rate in ASHRAE

62.1 compared to Title 24, Part 6. The results from the Small Office model have positive energy and cost savings.

Using the results from the Small School prototype model, and given data regarding the new construction forecast for 2020, the Statewide CASE Team estimates that the proposed code change will increase annual statewide electricity use by 65.1 GWh with an associated demand increase of 89.6 MW. Natural gas use is expected to be increased by 6.8 million therms. The energy savings for buildings constructed in 2020 are associated with a present valued energy cost increase of approximately PV $4,375 million in (discounted) energy costs over the 15-year period of analysis.

Using the results from the Small Office prototype model, and given data regarding the new construction forecast for 2020, the Statewide CASE Team estimates that the proposed code change will increase annual statewide electricity use by 6.7 GWh with an associated demand reduction of 8.2 MW. Natural gas use is expected to decrease by 2.3 million therms. The energy savings for buildings constructed in 2020 are associated with a present valued energy cost savings of approximately PV $460 million in (discounted) energy costs over the 15- year period of analysis.

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Table 15: Statewide Energy and Energy Cost Impacts for the Small School and Small Office Prototype Models

Climate Zone	Statewide Construction in 2020 (million ft^2)	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (million therms)	Lifecycle[2] Present Valued Energy Cost Savings (PV$ million)
SMALL SCHOOL					
1	0.5	0.05	(0.02)	(0.04)	(5.6)
2	4.1	(1.3)	(2.2)	(0.2)	(103.7)
3	20.9	(4.8)	(4.2)	(1.2)	(417.9)
4	9.3	(3.2)	(3.9)	(0.4)	(231.6)
5	1.8	(0.4)	(0.4)	(0.1)	(35.8)
6	14.9	(5.7)	(6.1)	(0.6)	(360.5)
7	9.5	(3.3)	(2.1)	(0.3)	(201.3)
8	21.5	(9.1)	(13.8)	(0.7)	(554.6)
9	24.7	(11.8)	(18.2)	(0.8)	(798.4)
10	15.8	(6.8)	(9.7)	(0.5)	(426.7)
11	3.7	(1.9)	(3.1)	(0.2)	(135.1)
12	20.5	(8.4)	(14.9)	(0.9)	(593.8)
13	7.8	(3.7)	(4.4)	(0.3)	(212.8)
14	3.1	(1.5)	(3.1)	(0.1)	(96.0)
15	2.9	(2.8)	(2.9)	(0.1)	(124.6)
16	4.4	(0.6)	(0.5)	(0.3)	(77.2)
TOTAL	**165.4**	**(65.1)**	**(89.6)**	**(6.8)**	**(4,375.5)**
SMALL OFFICE					
1	0.5	(0.03)	0.00	0.02	2.9
2	4.1	(0.2)	0.2	0.1	17.6
3	20.9	(1.5)	0.4	0.4	41.0
4	9.3	(0.5)	0.4	0.1	26.7
5	1.8	(0.1)	0.0	0.0	3.5
6	14.9	(1.0)	1.1	0.1	7.5
7	9.5	(0.9)	0.3	0.0	(10.4)
8	21.5	(1.1)	1.5	0.1	21.9
9	24.7	(0.9)	1.5	0.2	58.9
10	15.8	(0.4)	1.1	0.1	46.0
11	3.7	0.1	0.1	0.1	24.3
12	20.5	(0.4)	0.8	0.4	110.7
13	7.8	0.1	0.3	0.2	48.0
14	3.1	0.0	0.2	0.1	17.4
15	2.9	0.3	0.1	0.0	14.7
16	4.4	(0.2)	0.1	0.2	30.2
TOTAL	**165.4**	**(6.7)**	**8.2**	**2.3**	**460.8**

1. First-year savings from all buildings completed statewide in 2020.
2. 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 5.7 of this report.

7. PROPOSED REVISIONS TO CODE LANGUAGE

The proposed changes to the Standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2016 documents are marked with underlining (new language) and ~~strikethroughs~~ (deletions). Changes to the 2016 documents marked with green underlining indicate that similar language can be found and referenced in Title 24, Part 4.

7.1 Standards

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

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

AIR, EXHAUST air removed from a space and discharged to out- side 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 sup- ply 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 in. (75 and 1800 mm) above the floor and more than 2 ft (600 mm) from the walls or fixed air-conditioning equipment.

CONCENTRATION is the quantity of one constituent dispersed in 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

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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.

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 cate- gory, 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

Spaces intended for human occupancy within nonresidential, high-rise residential, and hotel/motel buildings shall comply with the requirements of Section 120.1(a) through 120.1(g).

EXCEPTION to Section 120.1: Spaces within dwelling units in residential occupancies in which occupants are nontransient shall comply with Section 150.0(o).

(a) General Requirements.

1. All enclosed spaces in a building shall be ventilated in accordance with the requirements of this section and the California Building Code.

   EXCEPTION to Section 120.1(a)1: Refrigerated warehouses and other spaces or buildings that are not normally used for human occupancy and work.

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

(b) **Outdoor air quality** shall be investigated in accordance with 120.1(b)1-2 prior to completion of ventilation system design. The results of this investigation shall be documented in accordance with 120.1(b)3

1. **Regional Air Quality.** The status of compliance with national ambient air quality standards shall be determined for the geographic area of the building site. Compliance status shall be either in "attainment" or "nonattainment" with the National Ambient Air Quality Standards. Areas with no U.S. Environmental Protection Agency (USEPA) compliance status designation shall be considered "attainment" areas.

2. **Local Air Quality.** An observational survey of the building site and its immediate surroundings shall be conducted during hours the building is expected to be normally occupied to identify local contaminants from surrounding facilities that will be of concern if allowed to enter the building.

3. **Documentation.** Documentation of the outdoor air quality investigation shall be reviewed with building owners or their representative and shall include the following as a minimum:

   A. Regional air quality compliance status

   B. Local survey information (Date of observations, Time of observations, Site description, Description of facilities on site and on adjoining properties, Observation of odors or irritants, Observation of visible plumes or visible air contaminants, Description of sources of vehicle exhaust on site and on adjoining properties, Identification of potential contaminant sources on the site and from adjoining properties, including any that operate only seasonally)

   C. Conclusion regarding the acceptability of outdoor air quality and the information supporting the conclusion

(c) **Outdoor Air Treatment**. In addition to meeting Title 24, Part 11 MERV 8 filter requirements listed in Section 5.504.5.3, each ventilation system that provides outdoor air through a supply fan shall comply with the following:

EXCEPTION to Section 120.1(c): Systems supplying air for enclosed parking garages, warehouses, storage rooms, janitor's closets, trash rooms, recycling areas, shipping/receiving/distribution areas.

1. **Particulate Matter Smaller than 2.5 Micrometers (PM2.5).** In buildings located in an area where the national standard or guideline for PM2.5 is exceeded, particle filters or air-cleaning devices shall be provided to clean the outdoor air at any location prior to its introduction to occupied spaces. Particulate matter filters or air cleaners shall have an efficiency reporting value (MERV) of not less than 13.

(d) **Design Requirements for Minimum Quantities of Outdoor Air.** Every space in a building shall be designed to have outdoor air ventilation according to Item (e) or (f) below:

(e) **Natural ventilation.** Natural ventilation systems shall be designed in accordance with this section and shall include mechanical ventilation systems designed in accordance with Section 120.1(f).

EXCEPTION 1 to Section 120.1(e): The mechanical ventilation systems shall not be required where natural ventilation openings that comply with the requirements of Section 120.1(e) are permanently open or have controls that prevent the openings from being closed during periods of expected occupancy

EXCEPTION 2 to Section 120.1(e): The mechanical ventilation systems shall not be required where the zone is not served by heating or cooling equipment.

1. **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 determined by Sections 120.1(e)1A-C, from operable wall openings that meet the requirements of Section 120.1(e)2. For spaces with ceilings that are not parallel to the floor, the ceiling height shall be determined in accordance with Section 120.1(e)1D.

   A. **Single Side Opening.** For spaces with operable openings on one side of the space, the maximum distance from the operable openings shall be not more than $2H$, where H is the ceiling height.

   B. **Double Side Opening**. For spaces with operable openings on two opposite sides of the space, the maximum distance from the operable openings shall be not more than $5H$, where H is the ceiling height.

   C. **Corner Openings.** 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 farthest apart. Floor area outside that line shall comply with Section 120.1(e)1D.

   D. **Ceiling Height.** The ceiling height (H) to be used in Sections 120.1(e)1A-C shall be the minimum ceiling height in the space.

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EXCEPTION to 120.1(e)1D: For ceilings that are increasing in height as distance from the openings is increased, the ceiling height shall be determined as the average height of the ceiling within 20 ft from the operable openings.

2. **Location and Size of Openings.** Spaces or portions of spaces to be naturally ventilated shall be permanently open to operable wall openings directly to the outdoors. The open- able area shall be not less than 4% of the net occupiable floor area. Where openings are covered with louvers or otherwise obstructed, 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% of the area of the interior room or less than 25 ft^2.
3. **Control and Accessibility.** The means to open required operable openings 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.

(f) **Mechanical ventilation**. Each space that is not naturally ventilated under 120.1(e) above shall be ventilated with a mechanical system capable of providing an outdoor air intake flow (Vot) ~~rate~~ in accordance with the following sections: ~~no less than the larger of:~~

1. **Zone Calculations.** Ventilation zone parameters shall be determined in accordance with Sections 120.1(f) for ventilation zones served by the ventilation system.
2. **Breathing Zone Outdoor Airflow.** The outdoor airflow required in the breathing zone (V_{bz}) of the occupiable space or spaces in a ventilation zone shall be not less than the value determined in accordance with EQUATION 120.1-A.

$V_{bz} = 1.3 \times (R_p \times P_z + R_a \times A_z)$ (EQUATION 120.1-A)

WHERE:

V_{bz}	=	volume of ventilation air required to be delivered to the breathing zone
R_p	=	outdoor airflow rate required per person as determined from Table 120.1-A
P_z	=	design zone population, the peak number of people in the ventilation zone during typical use. 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.
R_a	=	outdoor airflow rate required per unit area as determined from Table 120.1-A
A_z	=	zone floor area, the net occupiable floor area of the ventilation zone, ft^2

A. **Zone Air Distribution Effectiveness.** The zone air distribution effectiveness (E_z) shall be not greater than the default value determined using Table 120.1-B

B. **Zone Outdoor Airflow.** The zone outdoor air- flow (V_{oz}) provided to the ventilation zone by the supply air distribution system shall be determined in accordance with Equation 120.1-B.

$V_{oz} = V_{bz}/E_z$ (EQUATION 120.1-B)

3. **Single-Zone Systems.** For ventilation systems wherein one or more air handlers supply a mixture of out-door 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)

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4. **100% Outdoor Air Systems.** For ventilation systems wherein one or more air handlers supply only outdoor air to one or more ventilation zones, the outdoor air intake flow (V_{ot}) shall be determined in accordance with EQUATION 120.1-D.

   $V_{ot} = \Sigma_{all\ zones} V_{oz}$ (EQUATION 120.1-D)

5. **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 determined in accordance with Sections 120.1(f)5A-D

   A. **Primary Outdoor Air Fraction.** Primary out- door air fraction (Z_{pz}) shall be determined for ventilation zones in accordance with EQUATION 120.1-E.

   $Z_{pz} = V_{oz}/V_{pz}$ (EQUATION 120.1-E)

   where

   V_{pz} is the zone primary airflow to the ventilation zone, including outdoor air and recirculated air.

   For VAV-system design purposes, V_{pz} is the lowest zone primary airflow value expected at the design condition analyzed

   B. **System Ventilation Efficiency.** The system ventilation efficiency (E_v) shall be determined in accordance with TABLE 120.1-C .

   C. **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)

   The occupant diversity ratio (D) shall be determined in accordance with Equation 120.1-G to account for variations in population within the ventilation zones served by the system.

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

   WHERE

   Ps = design system population, the largest (peak) number of people expected to occupy all ventilation zones served by the ventilation system during use.

   D. **Outdoor Air Intake.** The design outdoor air intake flow (Vot) shall be determined in accordance with EQUATION 120.1-H.

   Vot = Vou/Ev (EQUATION 120.1-H)

6. **Multiple-Zone Systems.** This section presents an alternative procedure for calculating the system ventilation efficiency (E_v) where values in TABLE 120.1-C are not used. Ev is equal to the lowest calculated value of the zone ventilation efficiency Evz, as shown below:

   $E_v = \text{minimum}(E_{vz})$ (EQUATION 120.1-I)

   A. **Average Outdoor Air Fraction.** The average outdoor air fraction (Xs) for the ventilation system shall be calculated using EQUATION 120.1-J

   $X_s = V_{ou} / V_{ps}$ EQUATION 120.1-J

   The uncorrected outdoor air intake (Vou) shall be determine in accordance with Section 120.1(c)5D, and the system primary airflow (Vps) shall be determined at the condition analyzed.

   B. **Zone Ventilation Efficiency.** The zone ventilation efficiency shall be calculated using section 120.1(f)6Bi or 120.1(f)6Bii

      i. **Single Supply Systems.** EQUATION 120.1-K shall be used for "single supply" systems, where all the ventilation air is a mixture of outdoor air and recirculated air from a single location (e.g, reheat, single-duct VAV, single-fan dual-duct, and multizone).

$E_{vz} = 1 + X_s – Z_{pz}$ (EQUATION 120.1-K)

ii. **Secondary Recirculation Systems.** EQUATION 120.1-L shall be used for systems that provide all or part of their ventilation by recirculating air from other zones without directly mixing it with outdoor air (e.g., dual-fan dual-duct, fan-powered mixing box, and transfer fans for conference rooms).

Evz = (Fa + Xs*Fb – Zpz*Ep*Fc)/Fa (EQUATION 120.1-L)

WHERE

E_p	=	Primary air fraction to the zone: $E_p = V_{pz}/V_{dz}$ (E_p = 1.0 for single-duct and single-zone systems).
E_r	=	In systems with secondary recirculation of return air, fraction of secondary recirculated air to the zone that is representative of average system return air rather than air directly recirculated from the zone.
F_a	=	Fraction of supply air to the zone from sources outside the zone: $F_a = E_p + (1 – E_p)*E_r$
F_b	=	Fraction of supply air to the zone from fully mixed primary air: $F_b = E_p$
F_c	=	Fraction of outdoor air to the zone from sources outside the zone: $F_c = 1-(1-E_z)*(1-E_r)*(1-E_p)$.
V_{dz}	=	Zone Discharge Airflow: The expected discharge (supply) airflow to the zone that includes primary airflow and locally recirculated airflow.
V_{ps}	=	System Primary Airflow: The total primary airflow supplied to all zones served by the system from the air handling unit at which the outdoor air intake is located: $V_{ps} = \sum V_{pz}$
X_s	=	Average outdoor Air Fraction: At the primary air handler, the fraction of outdoor air intake flow in the system primary airflow: $X_s = V_{ou}/V_{ps}$.
Z_{pz}	=	Primary Outdoor Air Fraction required in the primary air supplied to the ventilation zone prior to the introduction of a secondary recirculation air: $Z_{pz} = V_{oz}/V_{pz}$.

iii. **EXCEPTION to Section 120.1(f):** 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:

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

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

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

~~(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 dwelling units and hotel/motel 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:~~

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

~~ii. 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)~~ (h) **Operation and Control Requirements for Minimum Quantities of Outdoor Air.**

This code section is unchanged and omitted for brevity.

~~(d)~~ (i) **Ducting for Zonal Heating and Cooling Units.**

This code section is unchanged and omitted for brevity.

~~(e)~~ (j) **Design and Control Requirements for Quantities of Outdoor Air**

This code section is unchanged and omitted for brevity.

~~*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~~

TABLE 120.1-A MINIMUM VENTILATION RATES

TYPE OF USE	**People Outdoor Air Rate, Rp (cfm/person)**	**Area Outdoor Air Rate, Ra (cfm/ft2)**	**Occupied Standby Controls**
All Others (including unleased tenant space in multi-tenant facilities)	5	0.06	

Commented [RS1]: See the CASE report entitled "Proposals Based on ASHRAE 90.1-2016 – Draft Report" for details on the proposed code change for Occupant Sensor Ventilation Requirements. The column "Occupied Standby Controls" is only included for clarity in this CASE report.

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Assembly (Concentrated) - Auditorium Area	5	0.06	Y
Assembly (Concentrated) - Lobby, Main Entry	5	0.06	Y
Assembly (Concentrated) - Religious Worship Area	5	0.06	Y
Assembly (Concentrated) - Theater, Motion Picture	10	0.06	Y
Assembly (Concentrated) - Theater, Performance	10	0.06	Y
Assembly (Concentrated) - Waiting Area	7.5	0.06	
Assembly (non-Concentrated) - Bar, Cocktail Lounge and Casino Areas	7.5	0.18	
Assembly (non-Concentrated) - Convention, Conference, Multipurpose and Meeting Center Areas	5	0.06	Y
Assembly (non-Concentrated) - Dining Area	7.5	0.18	
Assembly (non-Concentrated) - Exhibit, Museum Areas	7.5	0.06	Y
Assembly (non-Concentrated) - Gymnasium/Sports Arena	20	0.18	
Assembly (non-Concentrated) - Lounge, Recreation	7.5	0.18	
Auto Repair Area	10	0.18	
Beauty Salon Area	20	0.12	
Civic Meeting Place Area	5	0.06	Y
Classrooms, Lecture, Training, Vocational Areas	10	0.12	
Commercial and Industrial Storage Areas (conditioned or unconditioned)	5	0.06	
Commercial and Industrial Storage Areas (refrigerated)	10	0	
Computer Room (Data Center)	5	0.06	Y
Corridors, Restrooms, Stairs, and Support Areas	0	0.06	Y
Dry Cleaning (Coin Operated)	7.5	0.12	
Dry Cleaning (Full Service Commercial)	7.5	0.12	
Electrical, Mechanical, Telephone Rooms	5	0.06	
Exercise Room	20	0.06	
Financial Transaction Area	7.5	0.06	Y
Garage, Parking - Parking Garage Area Daylight Adaptation Zones	7.5	0.18	
Garage, Parking - Parking Garage Area Dedicated Ramps	7.5	0.18	
Garage, Parking - Parking Garage Building, Parking Area	7.5	0.18	
General Commercial and Industrial Work Areas, High Bay	10	0.06	
General Commercial and Industrial Work Areas, Low Bay	10	0.06	
General Commercial and Industrial Work Areas, Precision	10	0.06	
Hotels and Apartments - Hotel Function Area	5	0.06	
Hotels and Apartments - Hotel/Motel Guest Room	5	0.06	Y
Hotels and Apartments - Lobby, Hotel	7.5	0.06	Y
Housing, Public and Common Areas: Multi-family, Dormitory	0	0.06	Y
Housing, Public and Common Areas: Senior Housing	0	0.06	Y
Kitchen, Commercial Food Preparation	7.5	0.12	
Kitchenette or Residential Kitchen	5	0.12	
Laboratory, Equipment Room	5	0.06	

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Laboratory, Scientific	10	0.18	
Laundry	5	0.12	
Library - Library, Reading Areas	5	0.12	
Library - Library, Stacks	5	0.12	
Locker/Dressing Room	7.5	0.12	
Medical and Clinical Care	5	0.06	
Nurseries for Children - Day Care	10	0.18	
Office (250 square feet in floor area or less)	5	0.06	Y
Office (Greater than 250 square feet in floor area)	5	0.06	Y
Police Station and Fire Station	7.5	0.12	
Retail - Grocery Sales Areas	7.5	0.06	Y
Retail - Malls and Atria	7.5	0.06	Y
Retail - Merchandise Sales, Wholesale Showroom	7.5	0.12	
Transportation Function	7.5	0.06	Y
Transportation Function, Concourse & Baggage	7.5	0.06	Y
Transportation Function, Ticketing	7.5	0.06	Y
Unleased Tenant Area	5	0.06	Y
Unoccupied-Exclude from Gross Floor Area	0	0	
Unoccupied-Include in Gross Floor Area	0	0	
Videoconferencing Studio	5	0.06	

NOTES: Ventilation air for occupancy categories noted with a Y in the column "Occupied Standby Controls" are permitted to be reduced to zero when the space is in occupied-standby mode.

TABLE 120.1-B ZONE AIR DISTRIBUTION EFFECTIVENESS

AIR DISTRIBUTION CONFIGURATION	*Ez*
Ceiling supply of cool air	1
Ceiling supply of warm air and floor return	1
Ceiling supply of warm air 15°F (8°C) or more above space temperature and ceiling return	0.8
Ceiling supply of warm air less than 15°F (8°C) above pace temperature and ceiling return provided that the 150 fpm (0.8 m/s) supply air jet reaches to within 4.5 ft (1.4 m) of floor level	1
Floor supply of cool air and ceiling return, provided that the vertical throw is greater than 50 fpm (0.25 m/s) at a height of 4.5 ft (1.4 m) or more above the floor	1
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 (0.25 m/s) at a height of 4.5 ft (1.4 m) above the floor	1.2
Floor supply of warm air and floor return	1
Floor supply of warm air and ceiling return	0.7
Makeup supply drawn in on 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: "Cool air" is air cooler than space temperature. "Warm air" is air warmer than space temperature. "Ceiling supply" includes any point above the breathing zone. "Floor supply" includes any point below the breathing zone. For lower velocity supply air, $E_z = 0.8$

TABLE 120.1-C SYSTEM VENTILATION EFFICIENCY

Max (*Zpz*)	**Ev**
≤0.15	1
≤0.25	0.9
≤0.35	0.8
≤0.45	0.7
≤0.55	0.6

TABLE 120.1-D MINIMUM EXHAUST RATES

OCCUPANCY CATEGORY	**CFM PER SQUARE FOOT**
Arenas	0.5
Art classrooms	0.7
Auto repair rooms	1.5
Barber shops	0.5
Beauty and nail salons	0.6
Cells with toilet	1
Copy, printing rooms	0.5
Darkrooms	1
Educational science laboratories	1
Janitor closets, trash rooms, recycling	1
Kitchenettes	0.3
Kitchens—commercial	0.7
Locker rooms for athletic, industrial, and health care facilities	0.5
All other locker rooms	0.25
Shower rooms	20/50 cfm/unit
Paint spray booths	—
Parking garages	0.75
Pet shops (animal areas)	0.9
Refrigerating machinery rooms	—
Residential kitchens	50/100 cfm/unit
Soiled laundry storage rooms	1
Storage rooms, chemical	1.5
Toilets—private	25/50 cfm/unit
Toilets—public	50/70 cfm/unit
Woodwork shop/classrooms	0.5

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7.2 Reference Appendices

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

7.3 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.

7.4 Compliance Manuals

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

7.5 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.

8. References

ASHRAE Standing Standard Project Committee 62.1. (2016). "Ventilation for Acceptable Indoor Air Quality."

Apte, M.G. et al. "Associations Between Indoor CO2 Concentrations and Sick Building Syndrome Symptoms in US Office Buildings" Indoor Air

Bluyssen, P.M. and H.J.M. Cornelissen "Addition of Sensory Pollutant Loads—Simple or Not, That is the Question" ASHRAE Design, Construction, and Operation of Healthy Buildings (1998) 161–168

Bluyssen, P.M. et al. European Audit Project to Optimize Indoor Air Quality and Energy Consumption in Office Buildings (1995)

Berg-Munch, B. et al. "Ventilation Requirements For The Control Of Body Odor In Spaces Occupied By Women" Environ. Int. 12 (1986): 195–200.

CA DOF (California Department of Finance). "Economic and Fiscal Impact Statement." 2009. http://www.documents.dgs.ca.gov/bsc/proc_rsltn/2009/STD-399-EconomicandFiscalImpactStatement.pdf.

CA DWR (California Department of Water Resources). 2016. "California Counties by Hydrologic Regions." Accessed April 3, 2016. http://www.water.ca.gov/landwateruse/images/maps/California-County.pdf.

CPUC (California Public Utilities Commission). 2015a. "Water/Energy Cost-Effectiveness Analysis: Revised Final Report." Prepared by Navigant Consulting, Inc. http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=5360.

DRAFT

———. 2015b. “Water/Energy Cost-Effectiveness Analysis: Errata to the Revised Final Report.” Prepared by Navigant Consulting, Inc. http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=5350.

Cain, W.S., et al. “Ventilation Requirements In Buildings” Atmospheric Environment 17 no. 6 (1983): 1183–1197.

CARB (California Air Resources Board). 2010. “Proposed Regulation for a California Renewable Electricity Standard Staff Report: Initial Statement of Reasons Appendix D.” Accessed November

CEC 2016. Chief Counsel of the California Energy Commission, Warren-Alquist State Energy Resources Conservation and Development Act of 2016, P.R.C. § 25000 et seq. 2016. http://www.energy.ca.gov/2016publications/CEC-140-2016-002/CEC-140-2016-002.pdf. E3 (Energy + Environmental Economics) 2016. “Time Dependent Valuation of Energy for Developing Building Efficiency Standards: 2019 Time Dependent Valuation (TDV) Data Sources and Inputs.” July 2016. Prepared for the California Energy Commission. http://docketpublic.energy.ca.gov/PublicDocuments/16-BSTD-06/TN212524_20160801T120224_2019_TDV_Methodology_Report_7222016.pdf

Fanger, P.O. and B. Berg- Munch “Ventilation And Body Odor” Proceedings of An Engineering Foundation Conference on Management of Atmospheres in Tightly Enclosed Spaces (ASHRAE 1983): 45–50.

Fanger, P.O. et al. “Air Pollution Sources in Offices and Assembly Halls” Energy and Buildings 12 (1988): 7–19.

Fisk, W., A. Rosenfeld. 1997. “*Estimates of Improved Productivity and Health for Better Indoor Environments.”* Lawrence Berkeley National Library and U.S. Department of Energy. http://www.healthyheating.com/Productivity/Downloads/LBNL-42123.pdf

Gunnarsen, L. and P. O. Fanger “Adaptation to Indoor Air Pollution” Healthy Buildings 3 (Stockholm, Sweden 1988): 157–167.

Gunnarsen, L.“Adaptation and Ventilation Requirements” Fifth International Conference on Indoor Air Quality and Climate 1 (Toronto, Canada 1990): 599–604.

Iwashita, G. et al. “Indoor Air Quality Assessment Based on Human Olfactory Sensation” Journal of Architectural Planning and Environmental Engineering 410 (1990): 9–19.

Iwashita, G. and K. Kimura “Addition of Olfs from Common Air Pollution Sources Measured with Japanese Subjects” CIB Working Group WG77: Indoor Climate (1995).

Kajtar, L., L. Herczeg, et al. (2006) Influence of carbon dioxide pollutant on human well being and work intensity, Healthy Buildings 2006 Vol. 1, Lisbon, Portugal, 85–90.

Kajtar, L.& L. Herczeg. (2012) *Influence of carbon dioxide pollutant on human well-being and intensity of mental work.* Idojaras: Quarterly Journal of the Hungarian Meteorological Service. Vol. 116, No. 2, April-June 2012, pp 145-169.

Lauridsen, J. et al. “Addition of Olfs for Common Indoor Pollution Sources” Healthy Buildings 3 (1988): 189–195

DRAFT

MacNaughton, P., Pegues, J., Satish, U., Santanam, S., Spengler, J., Allen, J. "Economic, Environmental and Health Implications of Enhanced Ventilation in Office Buildings". International Journal of Environmental Research and Public Health. 12 (2015): 14709-14722.

Maddalena, R., M. J. Mendell, et. al. (2014) *Effects of ventilation rate per person and per floor area on perceived air quality, sick building syndrome symptoms, and decision-making.* Indoor Air. doi:10.1111/ina.12149

Mendell, M.J. "Non-Specific Symptoms in Office Workers" Indoor Air 3 no. 4 (1993): 227–236.

Pejtersen, J. et al. "A Simple Method to determine the Olf Load in a Building" The Fifth International Conference on Indoor Air Quality and Climate, Indoor Air 1 (1990): 537–542.

Pejtersen, J. et al. "Air Pollution Sources in Kindergartens" IAQ 91 Healthy Buildings (1991): 221–224.

Persily, A.K. and Gorfain, J. Analysis of Ventilation Data from the U.S. Environmental Protection Agency Building Assessment Survey and Evaluation (BASE) Study, NISTIR 7145 (NIST December 2004)

Satish, U., Mendell, M.J., et al. (2012) *Is CO2 an indoor pollutant? Direct effects of low-to moderate CO2 concentrations on human decision-making performance*. Environ. Health Perspect., 2012, 20.

Seppanen, O.A. et al. "Association of Ventilation Rates and CO2 Concentrations with Health and Other Responses in Commercial and Institutional Buildings" Indoor Air 9 no. 4 (1999): 226–252.

Taylor, Steve. "July 13th, 2006 Workshop Report – Non-Residential Ventilation Requirements" (2006).

Taylor, S.T. *LEED and Standard 62.1* ASHRAE Journal September 2005. pp.54-57. http://www.taylor-engineering.com/Websites/taylorengineering/articles/ASHRAE_Journal_-_LEED_and_Standard_62.1.pdf

Thorstensen, E. et al. "Air Pollution Sources and Indoor Air Quality in Schools" The Fifth International Conference on Indoor Air Quality and Climate Indoor Air 1 (1990): 531–536.

U.S. Census Bureau. 2014. Population Division. "Annual Estimates of the Resident Population: April 1, 2010 to July 1, 2014." http://factfinder2.census.gov/bkmk/table/1.0/en/PEP/2014/PEPANNRES/0400000US06.05000.

U.S. EPA (United States Environmental Protection Agency). 2011. "Emission Factors for Greenhouse Gas Inventories." Accessed December 2, 2013. http://www.epa.gov/climateleadership/documents/emission-factors.pdf.

Wargocki, P. et al. "Field Study of Addition of Indoor Air Sensory Pollution Sources" Indoor Air 4 (1996): 307–312

Wargocki, P. et al. "Perceived Air Quality and Sensory Pollution Loads in Six Danish Office Buildings" Indoor Air (2002)

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

The Energy Commission Demand Analysis Office provided the Statewide CASE Team with the nonresidential new construction forecast for 2020, broken out by building type and forecast climate zones (FCZ). The raw data from the Energy Commission is not provided in this report, but can be available upon request.

The Statewide CASE Team completed the following steps to refine the data and develop estimates of statewide floorspace that will be impacted by the proposed code changes:

1. Translated data from FCZ data into building climate zones (BCZ). This was completed using the FCZ to BCZ conversion factors provided by the Energy Commission (see Table 18).
2. Redistributed square footage allocated to the "Miscellaneous" building type. The Energy Commission's forecast allocated 18.5 percent of the total square footage from nonresidential new construction in 2020 and the nonresidential 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 floorspace. The new construction forecast does not provide sufficient information to distribute the miscellaneous square footage into the most likely building type, so the Statewide CASE Team redistributed the miscellaneous square footage into the remaining building types in such a way that the percentage of building floorspace 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 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 total 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 and discussed further below.
5. Calculated nonresidential floorspace 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 16 and Table 17.

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Table 16: 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	0.0624	0.0206	0.1078	0.0363	0.0465	0.0030	0.0829	0.0283	0.0000	0.0318	0.0690	**0.4886**
2	0.2634	0.1159	0.8896	0.2335	0.5955	0.0477	0.4123	0.1639	0.0000	0.2961	1.0438	**4.0619**
3	0.8593	0.4853	3.9510	0.9175	3.5733	0.2309	1.5130	0.7308	0.0000	1.6641	6.9282	**20.8533**
4	0.5865	0.2639	2.1380	0.5551	1.3529	0.1190	0.9313	0.3686	0.0000	0.6610	2.3426	**9.3189**
5	0.1139	0.0512	0.4151	0.1078	0.2627	0.0231	0.1808	0.0716	0.0000	0.1283	0.4549	**1.8094**
6	0.7882	0.5772	3.3114	0.8283	2.7167	0.1184	0.9998	0.4577	0.0000	0.7713	4.3662	**14.9352**
7	1.0552	0.3173	2.0421	0.6279	1.1428	0.0112	1.0756	0.3767	0.0000	0.6743	2.2004	**9.5235**
8	1.0965	0.8296	4.7789	1.1887	3.8598	0.1642	1.4590	0.6419	0.0000	1.1082	6.3919	**21.5188**
9	1.0763	0.9179	5.0481	1.2250	4.1325	0.1377	1.4796	0.7545	0.0000	1.2751	8.6231	**24.6697**
10	1.2326	0.8023	3.8314	1.0753	3.2834	0.0746	2.0664	0.5515	0.0000	0.7384	2.1700	**15.8260**
11	0.3489	0.1079	0.8068	0.2750	0.8004	0.0947	0.5383	0.1387	0.0000	0.1786	0.4119	**3.7013**
12	1.8705	0.5377	4.3939	1.1580	3.7594	0.2787	2.1966	0.6757	0.0000	1.1038	4.5040	**20.4783**
13	0.7571	0.2495	1.7891	0.6025	1.5334	0.2459	1.1913	0.2765	0.0000	0.4021	0.7897	**7.8371**
14	0.2010	0.1534	0.7569	0.2039	0.6413	0.0235	0.3759	0.0975	0.0000	0.1386	0.5436	**3.1354**
15	0.2704	0.1062	0.6649	0.2263	0.7179	0.0208	0.3797	0.0734	0.0000	0.1667	0.2721	**2.8984**
16	0.2779	0.1700	0.9567	0.2578	0.6697	0.0416	0.4056	0.1669	0.0000	0.1890	1.2472	**4.3825**
TOTAL	**10.8602**	**5.7059**	**35.8816**	**9.5191**	**29.0882**	**1.6350**	**15.2881**	**5.5742**	**0.0000**	**9.5274**	**42.3586**	**165.4384**

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Table 17: Estimated Existing Nonresidential Floorspace 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	2.7271	0.8806	4.7761	1.6197	2.3786	0.1347	3.5259	1.4541	2.0743	1.6713	2.8387	**24.0811**
2	12.1697	4.5369	36.3004	9.5968	25.3928	2.0088	19.7766	8.6200	13.4907	12.7763	42.1975	**186.8664**
3	38.6306	18.1710	151.0360	35.1344	131.9462	9.1224	76.7849	36.1359	53.1588	60.5967	253.7392	**864.4561**
4	27.6830	10.2182	87.7391	22.8171	59.8603	5.0827	45.3074	19.8329	32.0477	29.4404	98.6842	**438.7131**
5	5.3750	1.9840	17.0357	4.4302	11.6227	0.9869	8.7970	3.8508	6.2225	5.7162	19.1608	**85.1819**
6	38.5602	25.6635	151.5080	37.9306	141.0001	5.7181	67.0611	30.0659	39.9703	42.0909	185.7045	**765.2733**
7	45.4244	13.1861	91.6718	27.8039	61.3083	0.5632	44.0334	19.1882	32.8659	39.0235	100.7949	**475.8635**
8	53.3243	36.6793	216.4327	53.9610	198.4139	7.9116	94.3329	41.3876	58.9530	59.7116	269.7610	**1090.8688**
9	48.1556	38.6253	208.8644	51.0978	187.6288	6.3786	83.6812	44.0754	71.1196	58.6977	325.3763	**1123.7008**
10	57.1621	36.8672	181.3325	50.3472	193.9207	3.7158	86.5794	28.5217	42.4086	41.2900	97.2855	**819.4306**
11	14.7131	4.2629	32.2700	11.0238	35.0108	4.0709	21.7259	7.1293	12.9648	7.2447	15.5507	**165.9669**
12	74.9078	21.4145	178.6854	47.1829	159.7953	12.3380	92.4670	33.7061	62.7380	46.5710	175.8677	**905.6737**
13	31.9871	9.6246	69.4604	23.3737	59.4087	10.1352	49.0815	14.5402	27.3750	15.1517	27.8628	**338.0009**
14	9.4250	6.9753	34.7848	9.3429	36.1847	1.0955	16.2987	5.1027	8.4363	7.2423	22.6280	**157.5161**
15	11.9267	4.6478	28.3720	9.4307	34.9671	0.9122	13.8235	3.2499	5.6342	7.1085	10.8208	**130.8936**
16	12.2941	7.1591	41.5829	11.1792	32.6699	1.8121	17.7269	8.6928	12.3284	8.8212	46.7222	**200.9887**
TOTAL	**484.4658**	**240.8964**	**1531.8522**	**406.2720**	**1371.5088**	**71.9866**	**741.0033**	**305.5535**	**481.7881**	**443.1541**	**1694.9949**	**7773.4755**

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

Forecast Climate Zone (FCZ)	Building Climate Zone (BCZ) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
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%

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Table 19: 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.

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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**	---	-	---
Large offices	0.055	13%	0.014	0.069
Total	0.534	100%	**0.111**	0.534

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

Building Type *Building sub-type*	**Composition of Building Type by Sub-types** [1]	**Percent of Square Footage Impacted** [2]	
		New Construction	**Existing Building Stock (Alterations)** [3]
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%*

1. 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.
2. When the building type is comprised of multiple sub-types, the overall percentage for the main building category was calculated by weighing the contribution of each sub-type.
3. Percent of existing floorspace that will be altered during the first-year the 2019 Standards are in effect.

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

Climate Zone	Percent of Square Footage Impacted	
	New Construction	Existing Building Stock (Alterations) [1]
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%

1. Percent of existing floorspace that will be altered during the first-year the 2019 standards are in effect.

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Table 23: Projected New Residential Construction in 2017 by Climate Zone[1]

Building Climate Zone	Single Family Starts	Multifamily Starts[2]
Climate Zone 1	695	47
Climate Zone 2	2,602	507
Climate Zone 3	5,217	3,420
Climate Zone 4	5,992	1,053
Climate Zone 5	1,164	205
Climate Zone 6	4,142	2,151
Climate Zone 7	6,527	2,687
Climate Zone 8	7,110	3,903
Climate Zone 9	8,259	8,023
Climate Zone 10	16,620	1,868
Climate Zone 11	5,970	217
Climate Zone 12	19,465	1,498
Climate Zone 13	13,912	770
Climate Zone 14	3,338	492
Climate Zone 15	3,885	433
Climate Zone 16	3,135	508
Total	**108,032**	**27,784**

Source: Energy Commission Demand Analysis Office

1. The Energy Commission provided a low, middle, and high forecast. The Statewide CASE Team used the middle forecast for the statewide savings estimates. Statewide savings estimates do not include savings from mobile homes.

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

Table 24: Energy Commission Residential New Construction Forecast Households Mid Case

Building Climate Zone	Single Family Starts	Multifamily Starts[2]
Climate Zone 1	695	47
Climate Zone 2	2,602	507
Climate Zone 3	5,217	3,420
Climate Zone 4	5,992	1,053
Climate Zone 5	1,164	205
Climate Zone 6	4,142	2,151
Climate Zone 7	6,527	2,687
Climate Zone 8	7,110	3,903
Climate Zone 9	8,259	8,023
Climate Zone 10	16,620	1,868
Climate Zone 11	5,970	217
Climate Zone 12	19,465	1,498
Climate Zone 13	13,912	770
Climate Zone 14	3,338	492
Climate Zone 15	3,885	433
Climate Zone 16	3,135	508
Total	**108,032**	**27,784**

Source: Energy Commission Demand Analysis Office

1. The Energy Commission provided a low, middle, and high forecast. The Statewide CASE Team used the middle forecast for the statewide savings estimates. Statewide savings estimates do not include savings from mobile homes.

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

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

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Table 25: 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: ○ Energy consultant: to complete documents and to interpret Part 6 language ○ Plans examiner: to address questions and comments raised by the plans examiner. ○ Builder/General Contractor: Ensure ventilation product selection is in alignment with specifications • Success is designing a ventilation system that meets the minimum code requirements • Design passes 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 compliance 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

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Energy Consultant	• 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: ○ 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

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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: ○ Mechanical Designer: to attain clarification regarding mechanical drawings ○ Subcontractors/Installers: ensure work is properly installed ○ Plans examiner: May obtain building permit on behalf of owner by submitting drawings. ○ Building Inspector: Coordinates inspections with the Building Department. • Success is 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 (i.e. ventilation system).	• Installation of the ventilation system. Signs and uploads documents to HERS registry. Present for verification and inspection with building department. • Coordination with: ○ General Contractor: coordinate to ensure that what is being installed is what is required from the design ○ 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 satisfied 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, and documents, issuance of construction permit.	• Confirm that mechanical schedule is in compliance with the Energy Efficiency Standards • Coordination with: ○ Mechanical Designer: to 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, 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.

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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: General contractor to verify code compliance and proper installation of ventilation system • Success is issuing the Certificate of Occupancy with as few re-inspections 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 documents.
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: architect and designers to 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.

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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
Acceptance Testers	• One or more site visits to outside air controls and flow via acceptance tests, signing certificate of acceptance	• Work is conducting ventilation acceptance tests according to Title 24, Part 6 procedures • Coordinate with the installer primarily, possibly the mechanical designer • Success is verifying minimum ventilation rates, and issuing a certificate of acceptance with as few re-inspections as possible	• Acceptance Tester must ensure that outside air controls and flow meet updated acceptance tests and documenting them with the certificate of acceptance documents to be verified by the building inspector and provided to the building owner.	• Ensure that acceptance test documents and testing procedures are clear and understandable.

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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 in 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 sources associated with occupants and their activities 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 the predominant form of interaction (impact on people) is additivity. 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 we assume 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

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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 source strengths of the individual sources. In general, the agreement was good, 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 occupant activities and occupants themselves) 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 of the amount of ventilation air required to dilute occupant-generated odors and irritants (Berg-Munch et al 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 et al. 1986, 195-200), but less to building materials (Gunnarsen and Fanger. 1988, 157-167) (Gunnarsen 1990, 599-604). While the data for adapted occupants are less extensive, a 1983 study (Cain et al. 1983, 1183-1197) (Fanger and Berg-Munch 1983, 45-50) shows that about 5 cfm (2.5 L/s) will satisfy a substantial majority of adapted occupants.
- *Research on the Building Component:* There have been several studies of the source strengths associated with sensory pollutants from the building itself, rather than from the occupants. The results of these studies indicate 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 the most common subject of field studies was office buildings. 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 et al. 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 Standard when outdoor air rates were a 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 Standard 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 3000 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, to a very large extent ventilation rates were 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 even 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 five cubic feet per minute (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 some 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 26: 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 referenced above.

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Table 27: 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 VRP 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" to a space, not to the adapted occupants within the 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/ft^2. 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 of the space 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 ability of the system to deliver air from the supply air

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outlet to the breathing zone of the space. 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 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 (people, PCs) cause plumes of warm air that rise up 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 under-ventilated 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[1]. 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 121 (b) 2) are ignoring ventilation system efficiency. The use of transfer air effectively treating all systems as having a ventilation efficiency of 1.0. This makes Title 24, Part 6 easier to use and assures that on average there is sufficient outdoor air, but some zones have above the minimum outdoor air and others do not have enough outdoor air to meet the ventilation 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.

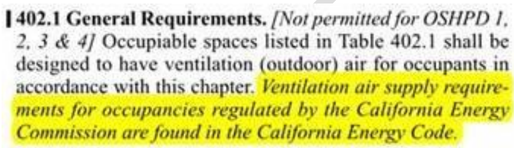
[1] ASHRAE Standard 62.1-2016 TABLE 6.2.5.2 System Ventilation Efficiency.

Appendix D: FEEDBACK SURVEY FOR CALIFORNIA VENTILATION RATE CALCULATIONS

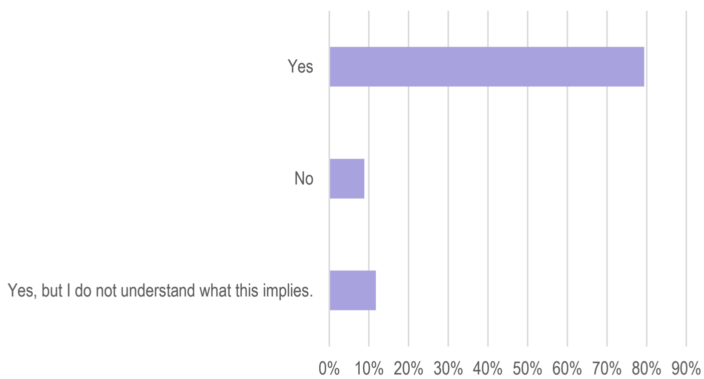
The CASE Team created a survey in order to gather information on current industry practices regarding the design of ventilation supply, exhaust, and make-up air in Title 24, Part 4 – California Mechanical Code (ASHRAE 62.1) and Title 24, Part 6 – California Energy Code. The CASE Team sought input from 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. The following is a summary of the survey results from the 34 respondents.

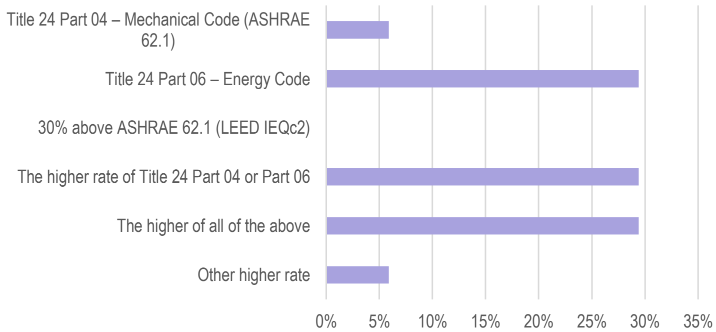
Question 1. *Are you familiar with the code section 402.1 from Title 24, Part 4 – Mechanical Code, which states that "ventilation air supply requirements for occupancies regulated by the California Energy Commission are found in the California Energy Code"?*



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"?*