Codes and Standards Enhancement (CASE) Initiative

2019 California Building Energy Efficiency Standards

Residential Indoor Air Quality – Final Report

Measure Number**:** 2019-RES-IAQ-F

Residential IAQ

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Table of Contents

List of Tables

List of Figures

EXECUTIVE SUMMARY

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 & Electric, Southern California Edison, and SoCalGas® and two Publicly Owned Utilities (POUs) – Los Angeles Department of Water and Power and Sacramento Municipal Utility District – sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to improve energy efficiency and energy performance in California buildings. This report and the code change proposal presented herein are a part of the effort to develop technical and cost-effectiveness information for proposed requirements on building energy efficient design practices and technologies.

The Statewide CASE Team submits code change proposals to the Energy Commission, the state agency that has authority to adopt revisions to Title 24, Part 6. The Energy Commission will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The Energy Commission may revise or reject proposals. See the Energy Commission's 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

The most significant proposed change to the 2016 Title 24, Part 6 Residential Standards is the adoption of the 2016 version of ASHRAE Standard 62.2, Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings. The 2016 ASHRAE Standard 62.2 version replaces the California version of ASHRAE Standard 62.2-2010 (which includes Addenda b, c, e, g, h, i, j, l, and n) that was adopted by the 2016 Title 24 Building Energy Efficiency Standards (BEES). The 2016 version includes high-rise multifamily (HRMF) buildings, which were formerly covered by the commercial ventilation standard, ASHRAE 62.1. The following impacts result from the adoption of ASHRAE 62.2-2016, as well as other proposed measures that are designed to enforce and complement the provisions of the ASHRAE ventilation standard:

- Increases single family residential ventilation rates by an average of 51 percent for the 2,100 square foot prototype and 41 percent for the 2,700 square foot prototype (see Figure 1)

- Moves coverage of high-rise residential from ASHRAE 62.1 to ASHRAE 62.2, which decreases HRMF building ventilation rates by approximately 30 percent, depending on unit configuration
- Provides for fine particulate matter (PM2.5) filtration of outside air in locations with high levels of fine particulate matter (PM2.5) concentrations
- Requires an increase to the filter efficiency requirement listed in Section 6.7 of ASHRAE 62.2-2016 of from MERV[1] 6 to MERV 13 to reduce indoor levels of PM2.5[2]
- Requires HERS verification that kitchen hoods in all dwelling unit types are Home Ventilating Institute (HVI) certified to meet ASHRAE 62.2 requirements for air volume, and sound ratings, and that they are externally vented
- Requires sealing of multifamily units to improve compartmentalization and verification of leakage rates
- For HRMF, requires a make-up air source for all units, and prohibits the use of passive vents in areas of high ambient PM2.5
- Provides for verification that central exhaust shafts and ducts in HRMF buildings are sealed to limit air leakage.
- Limits the use of indoor air being used as combustion air for space thermal conditioning, water heating and pool heating equipment.

These measures are intended to protect public health by providing a high level of indoor air quality (IAQ) while other Title 24, Part 6 requirements call for homes to be built with improved insulation and lower air leakage.

Scope of Code Change Proposal

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

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 Document(s)
Adoption of ASHRAE Standard 62.2-2016	Mandatory	150.0(m) and 150.0(o)	JA1, RA2, RA3	Yes - Change in mechanical ventilation rate for single family and high-rise multifamily	CF2R-MCH-27 CF3R-MCH-27

In accordance with Title 24 Part 6 Section 150.2(a), the proposed code change will apply to additions and alterations greater than 1,000 square feet. This requirement includes compliance with ASHRAE Standard 62.2-2016 and adopted modifications thereto.

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[1] MERV is Minimum Efficiency Reporting Value

[2] Pertains to Mechanical systems that supply air to an occupiable space through ductwork exceeding 10 feet in length and through a thermal conditioning component, except evaporative coolers. It is also referenced in Title 24 Part 6 Section 150(m)12.

This proposal also impacts other requirements in Title 24, Part 6 including:

- A dedicated makeup air source will be required for all HRMF units located in areas with high exposure to particulate matter in the 2.5 micron size range (PM2.5).
- Where central exhaust systems are included in the design of multifamily dwellings, they will be required to be tightly sealed and properly balanced.

Market Analysis and Regulatory Impact Assessment

Taken alone, the proposed measures do not reduce energy use, but they mitigate potential IAQ and moisture problems resulting from inadequate ventilation that can occur with more tightly constructed, better insulated buildings. In particular, the proposed changes meet the regulatory requirement of California Public Resources Code Section 25402.8, which requires that the Energy Commission include the impact of indoor air pollution when considering energy conservation measures. The proposed measures also respond to Title 24, Part 11 (CALGreen) goals for reducing indoor pollutants. The energy impact of the increase in ventilation rates associated with this proposal is accounted for in the benefit-to-cost analyses completed for other 2019 CASE proposals sponsored by the Statewide CASE Team, including the following measures: high performance walls, high performance attics, quality insulation installation, and high performance windows and doors.

The change in ventilation rate will have little or no impact on outdoor air ventilation products currently required and in widespread use. Use of vented (instead of recirculating) kitchen hoods will reduce the need for frequent cleaning of filters while removing cooking odors and moisture. The proposed requirement for MERV 13 filters in ducted thermal conditioning systems will increase costs, will require larger return air grilles to minimize pressure drop, and may require more frequent replacement, but these impacts can be minimized by using thicker pleated filters that have greater surface area.

Overall this proposal, in combination with others, increases the wealth of the state of California. California consumers and businesses save more money on energy than they do for financing the efficiency measure. The proposed changes to Title 24, Part 6 Standards 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 interviewed building officials, Title 24 energy analysts and others involved in the code compliance process to simplify and streamline the compliance and enforcement of this proposal.

Cost-Effectiveness

No cost-effectiveness calculations are provided in this report. In general, IAQ measures are intended to protect public health, and if they reduce energy use, it is coincidental. Public Resources Code section 25402.8 states: "When assessing new building standards for residential and nonresidential buildings related to the conservation of energy, the commission shall include in its deliberations the impact that these standards would have on indoor air pollution problems." There has been significant research over the past decade on IAQ and its health effects that supports the proposed changes.

Statewide Energy Impacts

The proposed code changes will increase single family residential ventilation rates, decrease HRMF ventilation rates, and not affect low-rise multifamily rates. The net energy impact of this code change may be close to neutral. The effect of the modified ventilation rates on other energy saving measures is captured in the other 2019 envelope related CASE Reports by including the new proposed ventilation rates in the analysis used to evaluate those measures. For example, the CBECC-Res simulation model used to evaluate high performance walls in residential buildings includes the higher ventilation rates required by 62.2-2016 in both the baseline simulations (2016 prescriptive package) and the improved case.

Compliance and Enforcement

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

- Title 24, Part 6 consultants, designers, and builders must be made aware of the change in the method of determining the required mechanical ventilation rate (to be calculated by the Alternative Calculation Method (ACM) model and reported on the CF-1R).
- Designers, builders, and Home Energy Rating System (HERS) Raters must be informed of the requirements for kitchen ventilation hoods, which although unchanged, will require HERS-verification under the new standard.
- Designers, builders, and inspectors of multifamily buildings must follow new requirements for providing ventilation makeup air, and sealing and balancing airflow where central exhaust systems are employed. Depending on current practice, these requirements may affect construction costs.

Although a needs analysis was conducted with the affected market actors while developing the code change proposal, the code requirements may change between the time the final CASE Report is submitted and the time the 2019 Title 24, Part 6 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 both potential barriers to compliance when rolling-out the code change and approaches that should be deployed to minimize the barriers.

1. INTRODUCTION

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

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

The overall goal of this CASE Report is to propose a code change for residential indoor air quality (IAQ) measures. This report contains pertinent information that supports adoption of the code change.

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

Section 2 of this CASE Report provides a description of the measure and its background. This section also presents a detailed description of how this change is accomplished in the various sections and documents that make up 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, demand, and energy cost savings associated with the proposed code change. This section also describes the methodology that the Statewide CASE Team used to estimate energy, demand, and energy cost savings.

Section 5 presents the lifecycle cost and cost-effectiveness analysis. This includes a discussion of additional materials and labor required to implement the measure and a quantification of the incremental cost. It also includes estimates of incremental maintenance costs. That is, equipment lifetime and various periodic costs associated with replacement and maintenance during the period of analysis.

Section 6 presents the statewide energy savings 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 would be saved by California building owners and tenants, and impacts (increases or reductions) on material with emphasis placed on any materials that are considered toxic. Statewide water consumption impacts are also considered.

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

2. MEASURE DESCRIPTION

2.1 Measure Overview

2.1.1 Change in Ventilation Rate and Scope

This group of measures includes the adoption of ASHRAE 62.2-2016, which will replace the currently referenced 2010 California version of ASHRAE 62.2.[3] The 2016 version has two primary impacts:

- Changes the calculation method of required mechanical ventilation for single family dwellings which includes raising the conditioned floor area multiplier from 0.01 to 0.03.
- Expands the scope of ASHRAE 62.2 to include HRMF units that were previously covered by ASHRAE 62.1 and the California Mechanical Code, Title 24 Part 4, and applies the same method for calculating ventilation rate as is used for low-rise multifamily units.

In accordance with Title 24 Part 6 Section 150.2(a), the proposed code change will apply to additions and alterations greater than 1,000 square feet. This requirement includes compliance with ASHRAE 62.2-2016 and adopted modifications thereto.

High-rise buildings included in this change are limited to full-time occupancy apartment buildings. All Group R-3 occupancies (California Building Code Part 2, 310.5) and apartment houses (Part 2, 310.4) are covered by this proposal. Residential building types that have transient occupancy[4] will continue to be covered by ASHRAE 62.1.

2.1.2 Proposed Change for Single Family Dwellings

The provisions of ASHRAE 62.2-2010 are currently mandatory for single family and low-rise residential buildings under Title 24, Part 6. The 2016 version of the ventilation standard will replace the current 2010 version. The primary impact will be a change in the way the mechanical ventilation rate is calculated for single family, horizontally attached, and high-rise dwelling units. ASHRAE 62.2-2010 allows an infiltration credit of 0.02 cubic feet per minute (cfm) per square foot of conditioned floor area (approximately equivalent to 5 ACH50 where ACH50 is the number of air changes per hour when the building is depressurized to 50 Pascals). ASHRAE 62.2-2016 requires blower door testing and uses the ACH50 from blower door tests, height of the building, occupancy, and climate to calculate the infiltration rate (Q_{infil}). The Q_{infil} calculated value reduces the required mechanical ventilation rate (Q_{fan}) as shown using the following equations:

Equation 1: $Q_{total} = 0.03 \text{ x } (CFA) + 7.5 \text{ x } (BR + 1)$

Equation 2: $Q_{fan} = Q_{total} - Q_{infil}$

where,

[3] Hereafter, references to ASHRAE Standard 62.2-2010 in this report pertain to the California version that includes Addenda b, c, e, g, h, i, j, l, and n.

[4] Title 24, Part 2 defines transient lodging as “hotels, motels, hostels, and other facilities providing accommodations of a short-term nature of not more than thirty days duration.”

CFA is the conditioned floor area,

BR is the number of bedrooms, and

Q is airflow in cubic feet per minute

For horizontally attached single family units, ASHRAE Standard 62.2-2016 allows an infiltration credit, but it is factored by the ratio of exterior envelope surface area that is not attached to garages or other dwelling units to the total envelope surface area.

The Statewide CASE Team proposes to include an exception in Title 24, Part 6 to eliminate the requirement for the blower door test specified in ASHRAE 62.2-2016 by assuming a default leakage rate of 2 ACH50 for the determination of Q_{infil}. This default leakage rate (or a lower value if the proposed building envelope leakage rate is less than 2 ACH50) will then be used to calculate the required mechanical ventilation airflow rate (Q_{fan}) as described in Equation 2. Figure 1 shows the impact of this change on mechanical ventilation rates for the 2,100 square-foot and 2,700 square-foot prototype houses commonly used in standards development activities. The horizontal lines indicate current mechanical ventilation requirements for the two prototypes, and the bars represent the mechanical ventilation rates that would be required under ASHRAE 62.2-2016.

As prescribed by ASHRAE 62.2-2016, the calculation of Q_{infil} includes a "weather and shielding factor" (wsf), which varies by climate zone, as well as house characteristics (ACH50 and building height). The equation for determining Q_{infi} is found in ASHRAE 62.2-2016 (Equation 4.3). To facilitate selection of the correct size of ventilation system, the calculated value of Q_{fan} is proposed to be listed on the Certificate of Compliance.

This change effectively increases the mechanical ventilation rate (Q_{fan}) in the compliance software model for single family dwellings while retaining the default 5 ACH50 leakage rate. The result will be a modest increase in energy use due to both higher fan electrical energy and the thermal impact of increased ventilation. Energy impacts are listed in Section 4 of the CASE report. The leakage rate used by the compliance model (default 5 ACH50 or as measured) to compute the thermal impact of envelope infiltration will be decoupled from the 2 ACH50 leakage rate assumption used to calculate the required mechanical ventilation air volume.

The current 5 ACH50 assumption used in the standard design will continue to be used so as to continue encouraging tight construction. Compliance credit will continue to be given for lower verified leakage rates based on the measured ACH50, if the builder pursues a building envelope leakage credit. For leakage rates below 2 ACH50 the measured leakage will be used to calculate a higher mechanical ventilation rate. Table 2 summarizes this compliance approach.

Table 2: Proposed Methods of Determining Mechanical Ventilation System Capacity and Ventilation Modeling for Single Family Dwellings

Blower Door Test (ACH50)	Required Fan Size	Modeled Q_{infil}	Modeled Q_{fan}
Not measured	Based on 2 ACH50	Based on 5 ACH50	Based on 2 ACH50
Less than 5, greater than 2	Based on 2 ACH50	Based on measured ACH50	Based on 2 ACH50
Less than 2	Based on measured ACH50	Based on measured ACH50	Based on measured ACH50

For single family horizontally attached[5] dwelling units ASHRAE 62.2-2016 requires the use of the following equation to calculate Q_{fan}:

Equation 3: $Q_{fan} = Q_{total} – (Q_{infil} \times A_{ext})$

where,

A_{ext} = the ratio of exterior envelope surface area that is not attached to garages or other dwelling units to the total envelope surface area.

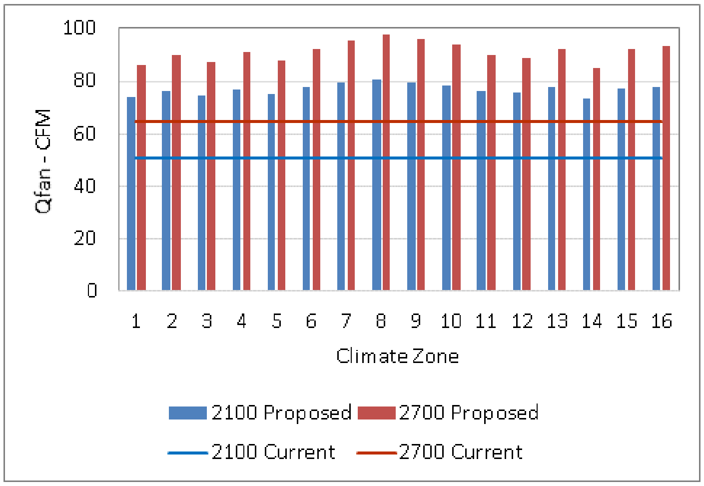

Figure 1: Change in mechanical ventilation rate resulting from the adoption of ASHRAE 62.2-2016 for the Title 24, Part 6 single family prototypes.

In accordance with Title 24 Part 6, Section 150.2(a), dwellings with additions greater than 1,000 square feet must comply with ASHRAE 62.2. For dwellings that have gas space heaters or water heaters that utilize indoor air as a source of combustion air, modifications must be made to these appliances so that combustion air is provided from outside. This is needed to prevent back-drafting of these appliances and associated risk of carbon monoxide exposure that could result from the proposed increased exhaust ventilation rates.

2.1.3 Proposed Changes Specific to Multifamily Units

2.1.3.1 Compartmentalization Requirement

The Statewide CASE Team proposes that the dwelling unit envelope enclosure area (comprised of all walls, ceilings, and floors that enclose the dwelling unit) of new construction multifamily units be air sealed. Multifamily dwelling units shall demonstrate compliance through a HERS verified blower door test with maximum allowable leakage of 0.3 cfm50 per square foot of dwelling unit envelope enclosure area. The HERS Rater must conduct this test on the individual unit. Sampling may be used to meet this requirement, in accordance with Residential Appendices RA2.6.3 and 2.6.4.

The primary goal of this requirement is to reduce pollutant transfer with adjacent units which is reported to be a common compliant by tenants.

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[5] Defined in this document as dwelling units constructed in a group of two or more attached units in which each unit extends from the foundation to roof and with open space on at least two sides. Includes duplexes, triplexes, and townhouses.

2.1.3.2 Proposed Changes for Low-Rise Multifamily Units

Neither ASHRAE 62.2-2010 nor ASHRAE 62.2-2016 allow an infiltration credit for low-rise multifamily buildings, so there would be no change in the ventilation rate for these building types[6]. Where balanced ventilation systems are used including Heat Recovery Ventilators (HRVs) or Energy Recovery Ventilators (ERVs), a reduction of the required ventilation rate to 85 percent of the calculated value is proposed.

The Statewide CASE Team proposes a reduction in the ventilation rate for balanced systems, because data indicate that balanced systems should reduce air transfer between multifamily units compared with exhaust-only strategies (Consortium for Advanced Residential Buildings 2014). Appendix B of this report provides the rationale for the development of the 0.85 factor for balanced ventilation systems.

2.1.3.3 Proposed Changes for High-Rise Multifamily Buildings

HRMF Ventilation Rates and Strategies

Currently, HRMF units must meet the following ventilation rates in the California Mechanical Code (CMC), Section 403.2.1, which are based on rates in ASHRAE Standard 62.1-2007:

Equation 4: $$Q_{total} = 5 \text{ cfm} \times (\text{Number of Bedrooms} + 1) + 0.06 \text{ cfm/ft}^2 \times A$$

where,

A = conditioned floor area (ft^2)

The proposal to change the ventilation rate reference to ASHRAE 62.2-2016 would increase the per-person ventilation and decrease floor area ventilation with the net impact being a decrease in the ventilation rate as shown in Equation 5, which is the same as Equation 1 but written in the same form as Equation 4.

Equation 5: $$Q_{total} = 7.5 \text{ cfm} \times (\text{Number of Bedrooms} + 1) + 0.03 \text{ cfm/ft}^2 \times A$$

The difference in ventilation rate under the current and proposed rate varies based on unit configuration (number of bedrooms and area). Table 3 presents ventilation rates for sample HRMF units. As shown, the proposed ventilation rate reduction ranges from 28 to 38 percent.

Table 3: Current and Proposed Ventilation Rates for Example HRMF Units

Bedrooms	Floor Area (ft^2)	Current Ventilation Rate, cfm (62.1-2007)	Proposed Ventilation Rate, cfm (62.2-2016)	Percent Reduction (2016 vs. 2007)
1	800	58	39	33%
1	1,000	70	45	36%
1	1,200	82	51	38%
2	1,000	75	53	30%
2	1,200	87	59	33%
2	1,500	105	68	36%
3	1,200	92	66	28%
3	1,500	110	75	32%

The current requirement is typically met by continuous (or scheduled intermittent) mechanical exhaust in bathrooms with either no dedicated make-up air (i.e., with infiltration providing all supply air), or

[6] Though it is specified in the Residential Compliance Manual, some HERS Raters that were interviewed were not aware of the ventilation rate change from one percent to three percent of floor area for low rise multiple family.

with passive vents, which rely on a pressure differential created by an exhaust system to allow outdoor air to enter the living space. According to interviewees contacted during the CASE proposal development process, the most common passive vent system in California HRMF units is a z-duct, which is shaped like a “z” with the outdoor intake separated from the indoor outlet by a vertical shaft that includes acoustic dampening. Other passive vent options include trickle vents, which are small openings in a window or other building envelope component, and air inlets such as Fresh 80 systems[7] installed in exterior walls. Interviewees reported it also somewhat common for designs to use packaged terminal air conditioners, which have an air inlet that remains open when they are not operating (i.e., not tempering air), thereby acting as a passive vent.

Although the current code (CBC Section 402.2) allows HRMF units to use operable windows (without continuous or scheduled intermittent mechanical exhaust) to meet the ventilation requirement, interviewees reported that almost no new HRMF projects use this approach. Under the current CASE proposal, which moves HRMF ventilation requirements to the residential sections of Title 24, HRMF units will not be allowed to use operable windows to meet the ventilation requirement. Title 24-2016 Section 150.0(o) prohibits use of operable windows for meeting the whole dwelling unit ventilation requirement, to align with the California version of ASHRAE 62.2-2010 Section 4.1, which requires “a mechanical exhaust system, supply system, or combination thereof”.

The Statewide CASE Team interviewed twenty HRMF mechanical engineers and energy analyst/ HERS Raters, five air quality specialists and public health officials, and three ASHRAE 62.2 committee members regarding whether reducing the ventilation rate will affect ventilation practices. Interviewees responded differently. Some reported that the industry will continue to use similar practices (i.e., exhaust-only strategies, sometimes with passive vents), but simply adjust fan flow rates. Others reported that reducing the ventilation rate will make the following strategies easier to implement, because of feasibility or cost reasons. Although interviewees were not able to quantify the cost reduction for reduced ventilation rates, they commented that:

- Lower ventilation flowrates (compared with 62.2-2016 rates) increases the feasibility of HRVs or ERVs, because some models of HRV or ERVs only accommodate low flows (e.g., maximum of 22 cfm). This comment was supported by the Statewide CASE Team’s product review of HRVs and ERVs, shown in Table 6 in Section 4.2.
- Lower ventilation flowrates reduce the costs of dedicated outdoor air systems (DOAS) that provide filtered, tempered air to each unit (e.g., central ducted ventilation systems) because the fans are smaller and ducts can be downsized.

Based on interviews and a literature review, the Statewide CASE Team identified four make-up air strategies used in HRMF new construction. Table 4 summarizes these strategies.

[7] http://www.positive-energy.com/product/fresh-80-air-inlet/

Table 4: Comparison of HRMF Ventilation Strategies

Method	Frequency of Use	Pros	Cons
1. Continuous exhaust with no dedicated make-up air: All make-up air comes from infiltration.	Common HRMF ventilation approach in California.	Inexpensive, simple.	Reliability concerns for providing outdoor air. Likely to result in negative pressures and bring in air from adjacent spaces.
2. Continuous exhaust with passive vents – typically z-ducts	Most common HRMF ventilation approach used, as indicated by interviewees.	Inexpensive, simple, provides somewhat more ventilation air than method 1.	Reliability concerns for providing outdoor air, occupants dislike drafts and often tape up openings. Likely to result in negative pressures and bring in air from adjacent spaces.
3. Central ducted supply air, such as dedicated outdoor air.	Occasionally used, such as when filtered air is required.	Greatest reliability and control for providing ventilation air; Capability to filter and temper incoming air.	High installation costs, potential for higher energy use.
4. HRV or ERV, usually serving individual dwelling units.	Occasionally used.	Can filter and temper incoming air. Most interviewees reported this can be less expensive than ducted supply air (method 3) due to less ductwork.	More expensive than passive vents, less control than ducted supply air, more wall penetrations. Not cost-justified for many California climates but can become cost competitive with methods 1 and 2, from downsizing of heating and cooling equipment and improved IAQ and comfort can increase marketability.

A common ventilation strategy in HRMF new construction is continuous bathroom exhaust with no dedicated make-up air. This was reported by interviewees and corroborated in the literature as a common strategy both in California and nationally. Interviewees reported they do not like this strategy – and generally do not design buildings using this approach – because of concerns regarding its reliability for providing outdoor air (note that almost all interviewees work on high performance buildings). Interviewees reported this strategy is likely to result in negative pressures and bring in air from adjacent spaces, including air from adjacent units that may have secondhand smoke or pollutants from cooking.

Interviewees reported that the other common strategy in HRMF units is continuous exhaust coupled with passive vents –typically z-ducts, as described above. None of the interviewees favored the passive vent strategy, because they questioned its reliability for providing outdoor air. However, they believed it provides somewhat more supply air than no dedicated make-up air, and it is relatively inexpensive (approximately $100 to $300 more expensive than no dedicated make-up air), compared with mechanically driven supply air strategies such as balanced systems (costs discussed below). Two studies conducted in the Northeast U.S. by the Consortium for Advanced Residential Buildings (CARB) supported the findings that both of these strategies (no dedicated supply air, and passive inlets) are inexpensive, but do not reliably provide the designed level of ventilation. (CARB 2014), (CARB 2016b). One of these studies found airflow from the passive vents was 13 to 36 percent of the air volume removed by the exhaust system (CARB 2016), about the same airflow as when no make-up air is provided (i.e., from infiltration).

HRMF units are occasionally served by central ducted supply air, such as dedicated outdoor air supply.

Figure **2** provides an example schematic of a central supply system. This figure shows duct branches to units on one floor of the building, but it would normally be extended to serve units on all floors.

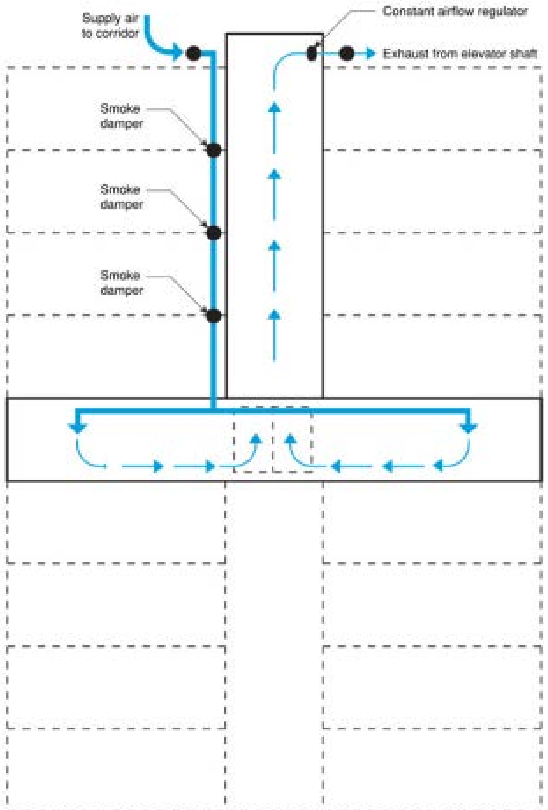

Figure 2: Example of central supply system in HRMF buildings.

Source: (Building Science Corporation 2017)

Interviewees reported this is a much more reliable strategy for providing ventilation air than the passive strategies described above, but is rarely done because of its cost. This strategy is used when filtered supply air is required, such as along freeway corridors in San Francisco under Article 38 of the San Francisco Health Code because of PM 2.5 concerns. All interviewees reported this strategy is significantly more expensive than the base case (no make-up air), although few would provide estimates of costs. Two interviewees reported the incremental cost is roughly twice that of the base case, because it requires twice the ductwork. A study done in the Northeast supported that this strategy is significantly more expensive, and found that it also results in higher energy use (Consortium for Advanced Residential Buildings 2014).

One active designer of HRMF systems that was interviewed contributed the diagram shown in Figure 3 as their preferred ventilation design. The variable speed fan coil is operated continuously at a low speed to provide a constant supply of outside air. The air supplied can be balanced by exhaust fans, and by a roof-mounted “scavenger fan” that maintains a constant flow through the central exhaust shaft. Compared to the strategies listed in Table 4, this strategy both filters and tempers outdoor air using the coil, but it is in conflict with Title 24 Part 6, Section 150.0, which states: “Continuous operation of central forced air system air handlers used in central fan integrated ventilation systems is not a permissible method of providing the whole-building ventilation airflow…” Interviewees reported this is a lower cost strategy than central ventilation supply. The Statewide CASE Team estimated the cost of providing stand-alone ventilation using this strategy is $500, as described in Section 5.2. This does not include cost for the exhaust, since all units meet local exhaust requirements. Consequently, this analysis recommends that high-rise multifamily units be allowed to use continuous operation of central forced air system air handlers used in central fan integrated ventilation systems, if they use variable speed fans (i.e., be granted an exemption).

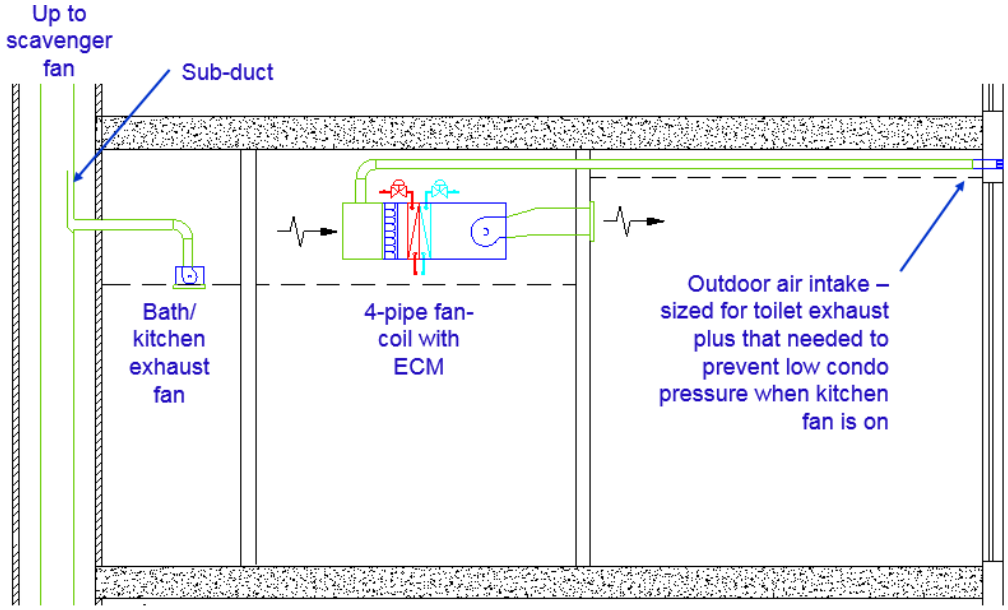

Figure 3: Example of a HRMF ventilation system using a combination of exhaust and supply air.

(Source: Taylor Engineering)

ERVs or HRVs are occasionally used, particularly small, through-wall ERVs and HRVs serving individual dwelling units. Compared to the base case (no dedicated make-up air), an ERV or HRV provides reliable outdoor air and also tempers air before it enters the dwelling unit, improving occupant comfort. Several interviewees reported this strategy is intermediate in cost between the base case and central ducted supply air. Although the ERV/HRVs are expensive, they require much less ductwork than the ducted outdoor air. It may also enable designers to reduce the capacity of heating and cooling equipment, which reduces cost. ERVs or HRVs installed in bathrooms can also replace bathroom fans. However, interviewees noted that ERVs and HRVs result in additional wall penetrations, which can cause challenges with design of the façade. In addition, ERVs and HRVs provide less control than central supply air. The literature review confirmed that ERVs and HRVs are used in multifamily construction when efficiency is a high priority and as permitted by the construction budget (Building Science Corporation 2017).

Almost all interviewees reported that new HRMF buildings do not use a corridor-based strategy for supplying air to units. Existing HRMF buildings often use a strategy whereby air is supplied to the corridors, and undercut doors provide air transfer to each unit. However, this strategy violates Title 24 Part 9 (California Fire Code) Sections 420 and 710.5, which limit air transfer through smoke partitions, so it is no longer allowed. As noted above, all interviewees reported that in their experiences, operable windows are rarely used as the primary ventilation strategy in new construction HRMF.

Exemption for Continuous Operation of Central Fan

Title 24-2016 Section 150.0(o) includes the following language: “Continuous operation of central forced air system air handlers used in central fan integrated ventilation systems is not a permissible method of providing the whole-building ventilation airflow required in Section 4 of ASHRAE Standard 62.2.” The Statewide CASE Team proposes an exemption to this language for central forced air system air handlers serving HRMF units with variable speed fans (based on requirements in Title 24 part 6

Section 140.9.a.5 for nonresidential buildings), to accommodate effective strategies currently used for HRMF buildings.

Central Exhaust Shaft Sealing, Testing, and Air Balancing

Field studies have shown that air leakage, stack effect, and lack of, or improper, balancing can prevent individual units from properly removing exhaust air (Center for Energy and Environment 2016) and increase energy use (WCEC 2014). This proposed Title 24, Part 6 code change will require that central exhaust shafts (where they are used) are sealed to limit leakage to ten percent of total airflow of the power rooftop ventilator. In addition, where central exhaust shafts are used, flowrates of the exhaust fans serving each unit must be balanced and verified, to ensure actual airflow is within ten percent of design airflow.

Interviewees reported that the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) has shaft sealing guidelines (primarily for supply air – not exhaust air), but it is uncommon to test central exhaust shaft leakage in HRMF units. Interviewees were generally supportive of this measure, because it reduces energy consumption – primarily through reduced total fan flow – and helps ensure that the exhaust shaft performs as designed. In addition, without sealing, measures such as self-balancing dampers do not function properly.

Because it is uncommon to test exhaust shaft leakage in HRMF buildings, many interviewees were hesitant to provide estimates of current shaft leakage. Those who responded estimated a 10-30 percent leakage rate. The literature supported estimates of around 25 percent (Harrington 2014).

Interviewees had different perspectives on what leakage target should be required. The originally proposed leakage rate that the Statewide CASE Team investigated was five percent, to be consistent with supply air duct leakage testing requirements. Some reported that five percent would be too stringent for a new requirement, while others reported this was attainable.

The Statewide CASE Team proposes ten percent leakage, because:

- Ten percent is stringent enough to catch major leakage issues – such as disconnected ducts in the exhaust shaft system.
- The exhaust ducts do not carry air for space conditioning. The energy penalty associated with central exhaust duct leakage comes from increased fan energy, so the proposed maximum leakage rate is less stringent than the permissible leakage for ducts carrying conditioned air (5% in residential and 6% in nonresidential buildings).
- There is currently no requirement for central exhaust shaft leakage, since limited data exists for typical leakage rates. Based on interviews and literature review, ten percent leakage represents the lower end of the range of estimates reported for shaft tightness without sealing. In the view of the Statewide CASE Team this represents a feasible goal.

The proposal leverages an existing testing protocol in Title 24: Nonresidential Appendix (NA) 2.1.4.2: Diagnostic Duct Leakage. The Statewide CASE Team also considered a testing procedure in a SMACNA manual (HVAC Air Duct Leakage Test Manual – SMACNA 016-2012), but referenced the Title 24 procedure because project teams are already familiar with the Title 24 procedure; it clearly specifies a methodology such as the test pressure (25 Pa), set-up protocols, and analysis methods; and the procedure can be applicable to central exhaust duct leakage testing.

Testing and balancing local exhaust fans in central exhaust shafts is important, particularly in buildings with a large stack effect, such as tall (over eight stories) multifamily buildings in climates with high heating or cooling loads (Markley 2014). Interviewees reported that testing and balancing is done as part of industry standard practice. However, Title 24, Part 6 does not require results to be independently verified, such as by a Home Energy Rating System rater (HERS Rater) or Acceptance Test Technician (ATT). As described below, based on findings from interviews and the literature review, the Statewide

CASE Team's findings indicate that the code proposal should require balancing but allow flexibility in how this requirement is met.

- Interviewees reported that HRMF buildings can achieve good results with other methods, including balancing with fixed edge orifice plates[8]. While these orifice plates do not adjust based on conditions in the building or weather, the pressure differences compared to the original conditions should be small enough that the systems are expected to perform well. Strategies such as balancing once with fixed edge orifice plates have the advantages (compared with self-balancing dampers) of requiring less ongoing maintenance and lower first costs.
- Older versions of self-balancing dampers[9] have demonstrated problems with clogging, based on interview findings and the literature (Center for Energy and Environment 2016), although it is unclear if newer versions have the same issue. However, many HRMF design engineers reported maintenance concerns for any type of self-balancing dampers because they are a moving part and (since they are installed within the unit) may not be accessible by maintenance staff.

The optimal strategy for a high-rise residential building will vary depending on building height, climate, and other factors. For example, in a building with a large stack effect (such as a building over eight stories in a more severe climate), or a building that will have a dedicated maintenance crew, self-balancing dampers may be a good solution. In a mid-rise (four to six story) building in a moderate climate a good strategy could be to balance the systems once using fixed edge orifice plates.

Testing and balancing exhaust rates: For HRMF buildings that use central exhaust shafts, testing and balancing local exhaust fan airflows helps ensure that each unit has adequate exhaust and also reduces fan energy of the power rooftop ventilator (WCEC 2014). The Statewide CASE Team's proposal for balancing to within ten percent of design flow aligns with industry practice for testing and balancing, which typically allows a maximum deviation of ten percent compared to the design rate. Although flow rates should ideally be no lower than design rates, only allowing ten percent above the design rate could be too narrow of a range to be feasible – e.g., 50 to 55 cfm for a bath fan with a design flow of 50 cfm. The Statewide CASE Team proposes that the requirement allow ten percent above and below the design rate, to reduce compliance challenges– between 45 and 55 cfm in the above example.

This proposal requires that exhaust airflows be compared with the design airflow. Note that the Statewide CASE Team considered requiring that exhaust airflows be compared with ASHRAE 62.2 airflow rates. However, Title 24 150.0(o) specifies that all requirements in ASHRAE 62.2 must be met, and 62.2 specifies minimum local exhaust requirements (e.g., 50 cfm for intermittent bathroom, 100 cfm for intermittent kitchen exhaust). Thus, Title 24, Part 6 already requires that the design meet ASHRAE 62.2 rates at a minimum. In some cases, designers may need to specify exhaust rates higher than the minimum values in ASHRAE 62.2 to ensure adequate removal of exhaust air. Consequently, the proposal would compare the tested flowrate with the design flowrate, which must be at least equal to the 62.2-2016 exhaust flowrate.

Proposed Ventilation Requirements for HRMF Buildings

The objective of the proposed changes for high-rise buildings is to ensure that there is a source of both supply and exhaust air. This will compensate for the reduction in ventilation rate dictated by the new

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[8] Orifice plates are metal insertions in the duct that are positioned to regulate airflow. They are adjusted during balancing, but are not readjusted continuously. See Figure 6 on p. 106 (PDF) of the Center for Energy and Environment, Multifamily Ventilation Assessment and Retrofit Guide, 2016.

[9] Self-balancing dampers are installed in a duct to regulate airflow, and continuously adjust as airflow varies. Older versions used a bladder that inflated or deflated to regulate airflow, while newer versions include dampers that lift in response to increasing static pressure. For the older self-balancing damper, see figure 3a on p. 15 (PDF) of the Center for Energy and Environment, Multifamily Ventilation Assessment and Retrofit Guide, 2016.

ASHRAE standards. In addition to meeting ASHRAE 62.2-2016 ventilation rate requirements, the following two discrete alternate methods of compliance are proposed:

a. Where exhaust-only ventilation is used, a source of outside makeup air (passive vents) will be provided to balance exhaust air.
b. Alternatively, the design must provide mechanically driven, filtered supply air. If a balanced ventilation system (e.g., HRV or ERV) is provided, the ventilation rate may be reduced to 85 percent of the calculated value (as for low-rise buildings).

   Method (b) would be required within 500 feet of busy roadways, defined as a roadway with annual average daily traffic (AADT) equal to or greater than 100,000.

c. Where central exhaust shafts are used, they shall be sealed to allow leakage of not more than ten percent of total exhaust airflow, and airflow at each unit shall be balanced to within ten percent of the required ventilation rate.

2.1.4 Kitchen Hood Verification

Both the 2010 and 2016 versions of ASHRAE 62.2 require that kitchen hoods have the capability to exhaust at least 100 cfm, that they not exceed a noise level of 3 sones, and that they be externally vented (not recirculating). To date, there has been no HERS verification process for kitchen range hoods. The Statewide CASE Team proposes that HERS Raters verify that installed range hoods are listed in the HVI Certified Products Directory[10] and that they meet the airflow and noise requirements of ASHRAE 62.2. This requirement would apply to all residential building types covered by Title 24, Part 6. The ASHRAE standard exempts range hoods that have a minimum airflow setting of greater than 400 cfm from the 3 sone at 100 cfm requirement.

2.1.5 Change in Filter Efficiency Requirement

A second proposed exception to ASHRAE 62.2-2016 increases the filter efficiency requirements for ducted forced air thermal conditioning systems from the currently required MERV 6 to MERV 13 (as determined using ASHRAE 52.2) or from the current 35 percent in the 3.0 – 10.0 micron (μm) range to 85 percent in the 1.0 – 3.0 μm range (as determined using AHRI 680). The purpose of this change is to reduce the concentration of particles in the 2.5 μm size range (PM 2.5), which are a known carcinogen.

See Appendix E[11] for a discussion of how pressure drop (resistance to air flow) is impacted by higher MERV filters. Tests were performed on a set of 24-inch by 24-inch filters to provide third-party verification data on the performance of filters with various MERV ratings in one and two-inch depths over a range of velocities for use by the Statewide CASE Team, the Energy Commission and stakeholders. The results show that acceptable pressure drops of less than 0.20 inch w.c. can be achieved by either one- or two-inch deep MERV 13 filters. No correlation was found between filter MERV ratings and pressure drop. One-inch and two-inch deep filters can have the same pressure drop at the same MERV rating, allowing either to be used. All filters have increasing pressure drop with increasing airflow. Four filters had printed labels giving their performance as will be required by the California Appliance Efficiency Regulations (Title 20). Test results were found to yield very similar values as indicated by the labels.

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[10] Available from http://hvi.org/proddirectory/index.cfm. Testing for loudness is based on HVI 915 and flow is based on HVI 916.

[11] Appendix E was added for the February 2018 version of this report.

2.1.6 Elimination of the Use of Indoor Air for Gas Appliance Combustion

Chapter 7 of the California Mechanical Code (Title 24, Part 4) allows several methods for providing air for combustion, ventilation, and dilution of flue gases for gas appliances that are installed within buildings. One method (701.4.1) allows the use of indoor combustion air provided there are at least 50 cubic feet of interior volume per 1000 Btu per hour of appliance capacity. There are several reasons why this method should no longer be applied in new homes. Homes are much more tightly constructed than when the mechanical code was written decades ago. The increase in the mechanical ventilation rate that will occur with the adoption of ASHRAE 62.2-2016, improved compliance of kitchen hood ventilation, and prescriptive requirements for whole house fans in single family homes (Climate Zones 8 through 14) will result in periods of high negative pressurization inside the dwelling. Under these conditions, indoor gas appliances, particularly furnaces and water heaters that rely on indoor combustion air, will be more likely to backdraft, that is combustion gases containing carbon monoxide and particulates will flow backward down the flue and into the house. The downward draft on the burner could also potentially create a fire hazard. Fortunately, the practice of installing atmospherically vented gas appliances inside houses has declined with the advent of direct vent, induced draft, and power exhaust appliances. The purpose of this code change proposal is to ensure the health and safety of homeowners by prohibiting indoor combustion air. Two options are available for furnaces, water heaters, and pool heaters that are located indoors: either requiring that they be sealed, direct vent type systems, which bring in combustion air for outside and exhaust flue gases, or requiring that they be enclosed in a closet that is isolated and sealed from the thermal envelope and provided with openings to outside air as required by California Mechanical Code Section 701.6. Additional background information on this can be found in Appendix D.

2.1.7 Affected Code Sections

Revisions to Title 24, Part 6 Standards Section 120.1 will be made to shift HRMF ventilation requirements from the nonresidential (Section 120.1) to the residential section (Section 150.0). Provisions for sealing of exhaust shafts and balancing airflow will also be added to Section 120.1. Language in Sections 120.5 and 150.0(m) will be edited to increase filter efficiency for ducted thermal conditioning systems[12] from MERV 6 to MERV 13 (or AHRI 680-2009 particle size efficiency of greater than 80 percent in the 1.0- 3.0 μm range), and to reference ASHRAE 62.2-2016. Subsections will be added to Section 150 to describe the proposed exceptions to 62.2-2016, including the default 2 ACH50 leakage assumption for Q_{infil} calculations, and the increase in filter efficiency. In the case of HRMF and LRMF compartmentalization is required. For HRMF, a mechanically driven outdoor ventilation supply air with MERV 13 filtration is required in areas with high ambient (outdoor) PM 2.5. Section 150 will also define requirements for kitchen hood verification.

The change in the ventilation standard for high-rise multifamily will also affect other parts of Title 24, including Part 2, the California Building Code and Part 4, the California Mechanical Code. Details of the code change language are provided in Section 7.1. These changes will help correct conflicting or confusing references in Parts 2, 4, and 6.

2.2 Measure History

2.2.1 Why These Measures are Being Proposed

2.2.1.1 Changes Pertaining to All Unit Types

[12] Consistent with the definition provided in Part 6, Section 150.0(m)12

California Public Resources Code 25402.8 (new building standards for residential/nonresidential buildings) specifies that the impact of energy conservation measures on indoor air pollution be considered. This was a prescient idea to have been included in the Warren-Alquist Act. The significant improvements in building science and efficiency that have been implemented over the past several code cycles and that are proposed for the 2019 Title 24, Part 6 Standards stem from decreased building envelope leakage, improved insulation and window thermal performance, and improvements in the quality of construction, including duct sealing. As has been well documented in building science literature, tighter buildings with thicker insulation can have unintended air quality consequences. Infiltration can no longer be relied upon to maintain IAQ, and the reduced air exchange can result in higher indoor relative humidity that can cause mold growth and damage to the building structure. Thicker wall insulation means the interior surfaces of exterior cladding can become cold enough to condense moisture. In California climates, adequate ventilation can prevent these kinds of moisture problems.

The benefits of ventilation and other practices required by the ASHRAE 62.2 standard were demonstrated in a study of 81 weatherized homes (Francisco, et al. 2016). That study found higher ventilation rates, lower concentrations of volatile organic compounds (VOCs), formaldehyde and carbon dioxide, and improvements in health (e.g., children had fewer headaches, eczema, and skin allergies; and adults had improvements in psychological distress) after the homes met the 62.2 standard. Approximately half the homes were improved to meet the 62.2-1989 standard, and half to meet the 62.2-2010. Furthermore, there were greater reductions of some pollutants for homes that met the 62.2-2010 standard compared with the 62.2-1989 standard.

Changes in ventilation rates: The proposed adoption of ASHRAE Standard 62.2-2016 (to replace the 2010 California version) into Title 24, Part 6 is the primary driver for this code change proposal. Because the ASHRAE 62.2-2016 standard was only recently adopted, there are no published field studies that investigate differences in IAQ or health impacts resulting from requirements in ASHRAE 62.2-2016 compared to ASHRAE 62.2-2010. However, data suggest that ASHRAE 62.2-2016, along with the other change proposals described here, will promote improved IAQ and health. There has been extensive debate over what constitutes sufficient ventilation on the ASHRAE 62.2 Standing Standard Project Committee, with some advocating that the current 0.03 cfm/ft^2 basis is too high, particularly in humid climates where it introduces excessive moisture from outdoors. In California, higher ventilation rates will improve the dilution of contaminants, such as formaldehyde and PM 2.5, as well as remove excess moisture. For these reasons the Energy Commission, the Statewide CASE Team, and the California Air Resources Board are advocating adoption of the ASHRAE 62.2-2016 requirements.

- For single family houses, the mechanical ventilation rates will <u>increase</u> from those determined using ASHRAE 62.2-2010 as shown in Figure 1. Whereas the infiltration rate is assumed to be a fixed value under 2016 Title 24, under the proposed adoption of ASHRAE 62.2-2016 in the 2019 Title 24, it will be calculated for each climate zone and house configuration, with tighter houses requiring more mechanical ventilation.
- For horizontally attached units such as triplexes and townhomes, the assumed infiltration rate will be reduced based on the envelope surface area, resulting in higher mechanical ventilation rates than for single family dwellings of similar floor area.
- For low-rise multifamily units, 2016 Title 24, Part 6 adopted the California version of ASHRAE 62.2-2010, which included Addendum j. This Addendum requires that multifamily units provide ventilation in accordance with Equation 1, and prohibits multifamily units from using infiltration to meet this rate. The proposed code change to ASHRAE 62.2-2016 will also apply to low-rise units, but since it uses the same equation as the 2010 version, there will be no change in required ventilation rates.
- For HRMF units, ventilation rates will <u>decrease</u> because of the shift from ASHRAE 62.1 to ASHRAE 62.2. However, as described below, this code change proposal includes requirements

that improve HRMF indoor air quality, including compartmentalization of all multifamily units to reduce pollutant transfer among units, and requirements for filtration of outside ventilation air for HRMF units in areas of high ambient PM2.5.

Improved filtration: Recent and ongoing studies of IAQ show that particulate matter in the PM 2.5 range is becoming a dominant health concern (Fisk 2017, Zhao 2015). Cooking with either gas or electricity has been shown to be a predominant source of PM 2.5, as well as oxides of nitrogen (Fabian 2012, Dacunto 2013) making indoor air filtration an important health concern.

Filtration of outside air is critical in areas with high levels of PM 2.5 which cover much of California. For exhaust-only ventilation systems, current research suggests that for single family residences, the building envelope can provide a similar level of filtration of particulates as a MERV 13 filter (Singer 2016). Based on the Statewide CASE Team's industry experience[13], low-rise multifamily units typically use a ventilation strategy of exhaust-only with infiltration. Low-rise multifamily units may not use passive vents as standard industry practice because, while there is still the potential for pollutant transfer among units, it is lower than in HRMF units, because:

- Stack effect increases pollutant transfer, and the risk therefore increases in taller buildings,
- Many low-rise multifamily buildings are garden-style with two or more walls exposed to the exterior, while many high-rise buildings have central corridors with one or at most two exposed walls. Corridors provide another pathway for pollutant transfer among units.
- Many units in low-rise multifamily buildings – including those in two-story buildings – have fewer surfaces adjacent to other units compared with HRMF units.

Consequently, low-rise multifamily units that use an exhaust-only strategy should have some removal of PM2.5, particularly after complying with the proposed requirement for compartmentalization. HRMF units – which (based on interviews) typically use passive vents for make-up air in an exhaust-only strategy – should use MERV 13 filters in locations with high outdoor levels of PM 2.5 (proposed to be defined as within 500 feet of a busy roadway; see Section 7.1.3).

The Statewide CASE Team considered proposing a requirement for MERV 13 for all outside air filtration. However, the Team did not propose this, because of concerns that it would discourage the use of balanced ventilation strategies, and encourage exhaust-only strategies. As shown in Table 12 and Table 13, balanced ventilation strategies are significantly more expensive than exhaust-only strategies, and the cost increases when MERV 13 filtration is added to the balanced system: an estimated $322 for exhaust-only using distributed exhaust, $1,313 for balanced with MERV 8, and $1,968 for balanced with MERV 13. (Exhaust-only ventilation strategies do not have supply air, so are not affected by filtration requirements.) As described in this report, the Statewide CASE Team believes that balanced ventilation is preferable, at least in multifamily units, because it reduces the risk of pollutant transfer between dwelling units. In other words, builders could circumvent a requirement for MERV 13 on outside air filtration by choosing exhaust-only ventilation. The result is a trade-off: MERV 13 reduces PM2.5 compared with MERV 8 for projects that use balanced ventilation, but there will be fewer balanced ventilation (and more exhaust-only) projects if MERV 13 is required compared with MERV 8. Consequently, the Statewide CASE Team limited the requirement for MERV 13 for outside air filtration only to areas that have high ambient PM2.5: near busy roadways. For the remainder of the state, the Statewide CASE Team proposes MERV 8 filtration on outside air.

Kitchen range hood verification: Ineffective kitchen range hoods – those that do not exhaust sufficient air, are not operated because they are too noisy, or have poor capture efficiency – contribute to the IAQ

[13] The scope of work for the Statewide CASE Team included interviews to investigate HRMF practices, because of the transition of these units into the residential portion of Title 24. Due to time limitations in interviews, low-rise multifamily practices were not investigated.

problem. The 2010 ASHRAE 62.2 ventilation standard previously adopted by Title 24, Part 6 requires that kitchen hoods meet venting, airflow, and noise standards. Performance data published by HVI can be used for verification. The proposal to increase air filter efficiency in ducted thermal conditioning systems to MERV 13 also addresses the concern about indoor sources of PM 2.5.

2.2.1.2 Changes Specific to Multifamily Dwelling Unit Types

Ventilation Rates and Strategies

There are additional concerns for HRMF dwelling units, which led the Statewide CASE Team to develop specific HRMF proposals. Besides exhaust-only with infiltration, another common ventilation strategy for HRMF buildings is exhaust-only ventilation coupled with passive vents installed on the exterior wall. While there is little data available on passive vent performance, the few studies conducted have found that the flowrate through passive vents is approximately one-third or less of the design rate: 15 to 40 percent (Consortium for Advanced Residential Buildings 2014) and 13 to 36 percent (Consortium for Advanced Residential Buildings 2016a). Furthermore, almost all mechanical engineers and HERS Raters interviewed by the Statewide CASE Team reported that occupants frequently cover these vents (using cardboard or tape) due to drafts, further reducing outdoor airflow. The remaining make-up air can still come from adjacent units. Pollutant transfer from adjacent units can be further exacerbated in HRMF units because of stack effect[14]. In addition, whereas the building envelope provides some level of particle filtration, passive vents provide almost no PM 2.5 filtration, because a filter with a high MERV rating will create a pressure drop that cannot be overcome passively. Because of the lack of filtration (Singer 2016, Fisk 2017), HRMF buildings constructed in areas with high levels of outdoor PM 2.5 (as described in Section 3.3.1) that use exhaust-only with passive vents could have high levels of indoor PM 2.5.

For these reasons, the proposal includes the following:

<u>HRMF units within 500 feet of a busy roadway (with at least 100,000 annual average daily traffic [AADT]) are required to provide mechanically-driven supply air with MERV 13 filtration.</u> The requirement for mechanically-driven supply air (i.e., supply-only or balanced) will ensure that ventilation air comes from the outdoors, rather than neighboring units, and the MERV 13 requirement will significantly reduce outdoor PM 2.5. Because of the higher cost for balanced ventilation compared with exhaust-only in HRMF units (approximately $1,000 per unit, and $1,600 per unit with MERV 13, described in section 5.2), the low availability of HRVs with MERV 13, and since balanced ventilation is not predicted to generate cost-effective energy savings in mild climate zones (see section 4.3), the Statewide CASE Team proposes to only require this strategy where outdoor PM 2.5 risk is greatest. As described in section 3.3.1, studies have found strong correlations between health problems and residences in homes within 500 feet of a roadway. Furthermore, a requirement for MERV 13 filtration in the forced air space conditioning system without an accompanying MERV 13 requirement for mechanically provided supply air will further encourage HRMF units to use an exhaust-only approach with passive vents. Of most concern, a requirement for MERV 13 filtration that allows exhaust-only strategies would enable HRMF units constructed close to freeways to use exhaust-only ventilation with passive vents, thereby allowing large amounts of unfiltered air to enter the units.

<u>All multifamily units that use balanced ventilation may reduce the ASHRAE 62.2-2016 mechanical ventilation rate by 15 percent.</u> The Statewide CASE Team proposes to encourage balanced ventilation for all multifamily buildings by allowing multifamily units that use balanced ventilation to use a

[14]Stack effect is a natural force that generates pressure and drives vertical airflow in buildings in response to indoor-outdoor temperature differences. The stack effect increases in taller buildings.

reduced ventilation rate: 0.85 x Qtotal, where Qtotal is calculated as shown in Equation 1. This rate reduction will enable through-wall ERV systems in small multifamily units, based on ERV and HRV flowrates in Table 6 and the ventilation rate requirements in Table 15. As described in Section 2.1.2, ASHRAE 62.2-2016 does not allow for vertically attached[15] multifamily units to take credit for infiltration (Qinfil = 0), so Qfan is the same as Qtotal. (For horizontally attached dwelling units, ASHRAE 62.2-2016 allows partial credit based on the ratio of party walls to exterior walls – see Equation 3.) The rationale for the balanced ventilation rate reduction includes:

- Based on a study comparing ventilation strategies in multifamily units, only one-third of the design ventilation rate is delivered through passive vents, while the balanced system delivered 70 percent of design flowrate (Consortium for Advanced Residential Buildings 2014). Consequently, even at 85 percent of the ASHRAE 62.2-2016 ventilation rate, a balanced system should deliver more ventilation air from the outside (since the source of ventilation air is known) than an exhaust-only system with passive vents. The Statewide CASE Team developed the 0.85 factor by reviewing a variety of current and proposed ventilation rates. The rationale for the 0.85 factor is described in Appendix B.
- Several interviewees reported it is easier to provide a balanced system in HRMF units with the 15% lower ventilation rates, because some ERVs and HRVs that serve individual units have low maximum flowrates. A review of products confirmed these reports: For example, representative through-wall HRVs have a maximum flowrate ranging between 22 and 38 cfm, which is lower than the minimum ventilation rate for most HRMF unit configurations (see Table 6), without the 0.85 factor.
- Stakeholder comments indicate that builders prefer lower ventilation rates, so reducing the ventilation rate for balanced systems will encourage builders to use this strategy

HRMF units in areas of low outdoor PM 2.5 can use an exhaust-only strategy, but they must provide passive vents for make-up air and meet prescriptive compartmentalization requirements that must be verified by a HERS Rater. Although most interviewees report that passive vents may not provide a reliable ventilation rate, almost all interviewees believe that passive vents perform better than no dedicated makeup air system at all (i.e., solely relying on infiltration). The requirement for compartmentalization should reduce pollutant transfer and increase the performance of passive vents, according to a passive vent study which found that increased compartmentalization increases airflow through these vents (Consortium for Advanced Residential Buildings 2016a). The Statewide CASE Team proposes that the Residential Compliance Manual provide design guidelines for proper passive vent installation, including right-sizing these vents to increase airflow as recommended in the "Measure Guideline: Passive Vents" report (Consortium for Advanced Residential Buildings 2016b).

The requirement for mechanically driven supply air and MERV 13 filtration of outside air in high PM 2.5 areas is only for HRMF units, because low-rise units do not have as great a potential for pollutant transfer due to their reduced stack effect. In addition, low-rise units using an exhaust-only ventilation strategy generally use infiltration (as opposed to passive vents) for makeup air, so will typically have more filtration by the building envelope than HRMF units, which typically use passive vents. Particularly because few HRVs or ERVs products offer MERV 13 filtration (see Table 4), requiring MERV 13 on outside air for low-rise residential units could dissuade builders from installing a balanced ventilation system. Consequently, no MERV 13 filtration of outside ventilation air is proposed for low-rise units in areas of high PM 2.5 levels.

Through interviews, the Statewide CASE Team learned that one approach for providing mechanically driven supply air to HRMF units relies on continuous operation of forced air system air handlers. This

[15] Defined in this document as multifamily buildings that are vertically stacked and for which a majority of units have open space on fewer than two sides.

approach uses variable speed fans to efficiently provide ventilation, and can be an effective strategy for providing balanced ventilation. Consequently, this code change proposal includes an exemption for forced air system air handlers serving HRMF units from the following requirement in Section 150.0(o), now that HRMF units will shift to following the residential requirements in Title 24, Part 6: "Continuous operation of central forced air system air handlers used in central fan integrated ventilation systems is not a permissible method of providing the whole-building ventilation airflow required in Section 4 of ASHRAE Standard 62.2."

Compartmentalization in Multifamily Units

Compartmentalization reduces pollutant transfer between adjacent units, thereby improving IAQ and reducing odor and noise transfer. For multifamily units using an exhaust-only approach, compartmentalization increases the amount of ventilation drawn from the outside. Without a requirement for blower door testing, multifamily project teams may not seal between units. Studies supporting the need for compartmentalization include the following:

- In a field study of six existing multifamily buildings in Minnesota that underwent compartmentalization and ventilation upgrades (Center for Energy and Environment 2004), before the retrofit, all six buildings had at least one unit for which more than 10 percent of the air entering the unit came from another unit. The study found that the effective contaminant transfer (ECT, which models Environmental Tobacco Smoke [ETS] transfer), was reduced by an average of 41 percent after air sealing.
- In a study that included field measurements and modeling of multifamily buildings in New York (Center for Energy and Environment and WCEC 2016), researchers found significant sound attenuation improvement for frequencies above 500 Hz due to compartmentalization via aerosol sealing. Figure 4 presents the noise reduction results. This study also included EnergyPlus airflow modeling, which considered three different leakage levels (9.5, 3 and 0.6 ACH50 or 0.50, 0.16, and 0.03 cfm50/ft^2) and reported the annual average air flow rate between units for a six-story building. The study found, "for the leakiest units (9.5 ACH50), the average inter-unit airflow rate for all four ventilation strategies was 22.3 cfm, and all four values were within 4 % of the average. For the units with mechanical ventilation, the inter-unit air flow was about 25 % of the ventilation flow. This indicates that there is significant air and contaminant transfer between units with about 20% of the air that enters the units is coming from neighboring units" (p. 82). Furthermore, the 65 percent leakage reduction from 9.5 to 3.0 ACH50 resulted in an average reduction in inter-unit airflow of 86 percent. As described in Section 4.3, the proposed compartmentalization requirement of 0.3 cfm50/ft^2 enclosure area translates into roughly 6 to 7 ACH50. The inter-unit airflow reduction from the proposed requirement would likely be lower than what was found in the study, since final leakage was 3 ACH50. But the study results still demonstrate how air sealing between units reduces air transfer.
- A field study of a 13-story building in Canada built in 1986 that was not compartmentalized (Rickets and Straube 2014) found that pressures created by stack effect were of similar magnitude (10 to 15 Pa) as mechanical pressures. The study concluded, "there is significant potential for overwhelming of the mechanically induced pressures and consequently for alteration of airflow rates and direction." This study illustrates the need for compartmentalization, particularly in HRMF buildings, to reduce stack effect and enable ventilation systems to operate as designed.

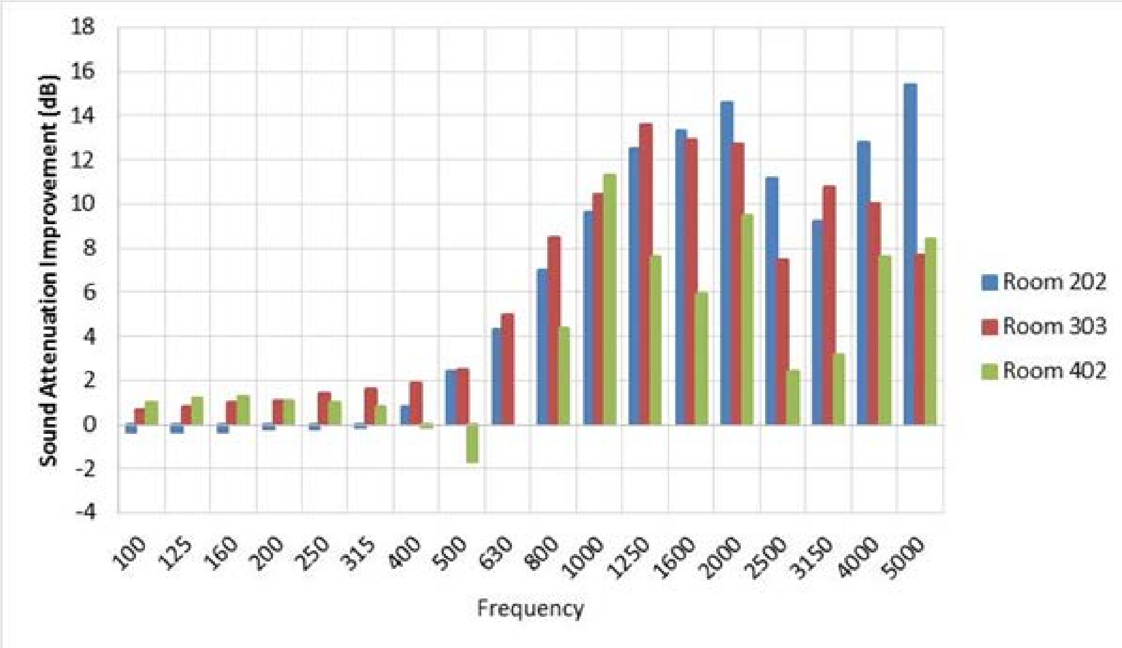

Figure 4: Sound attenuation results for three New York apartments that underwent air sealing.

(Source: CEE 2016, p. 8)

The Statewide CASE Team proposes that sampling be allowed to meet the compartmentalization requirement, because data indicate that leakage varies little among units in the same multifamily building. The Statewide CASE Team analyzed blower door test results from ten buildings in the ENERGY STAR® Multifamily High-Rise program, presented in Table 5. Based on this analysis, there was little variation in results among units in the same building. Consequently, sampling can reduce the cost of compliance with little sacrifice to rigor.

Table 5: Intra-building Blower Door Test Results, based on ENERGY STAR HRMF Program Data

Building	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
State (if available)		MD	MD	MD	CT			NY		
Floors in Building	4	4	4	4	5	6	11	11	37	9
No. of units tested	22	13	19	22	12	16	19	36	90	17
Average blower door result (cfm50/ft^2)	0.23	0.20	0.23	0.23	0.28	0.27	0.28	0.21	0.13	0.24
Minimum (cfm50/ft^2)	0.16	0.17	0.19	0.14	0.22	0.17	0.23	0.13	0.07	0.16
Maximum (cfm50/ft^2)	0.30	0.24	0.26	0.30	0.30	0.31	0.31	0.28	0.30	0.30
Standard deviation (cfm50/ft^2)	**0.04**	**0.02**	**0.02**	**0.04**	**0.03**	**0.04**	**0.02**	**0.03**	**0.04**	**0.04**

Central Exhaust Shaft Measures in HRMF Buildings

Field studies have also demonstrated that air leakage, stack effect, and lack of, or improper, balancing can prevent individual units from properly removing exhaust air (Center for Energy and Environment 2016) and increased energy use (WCEC 2014). Consequently, this code change proposal includes two separate measure for HRMF buildings that use central exhaust shafts:

- The shafts must be sealed to ten percent of the power rooftop ventilator's fan flowrate,
- The exhaust fans that discharge air into the central shaft must be balanced to within ten percent of design airflow.

For further information, refer to the description of model codes located in Section 2.4. There are no preemption concerns with this measure.

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.

Revisions to Title 24, Part 6 Section 120.1 will be made to shift ventilation requirements for HRMF from the nonresidential to the residential standards. Alternate means of meeting HRMF ventilation requirements and requirements for sealing of exhaust shafts and balancing airflow will also be added to Section 120.1. Language in Sections 120.5 and 150 will be edited to increase filter efficiency from MERV 6 to MERV 13 (or AHRI 680-2009 particle size efficiency of 85 percent or greater in the 1.0 – 3.0 μm range), and to reference ASHRAE 62.2-2016. Subsections will be added to Section 150 to describe the proposed exceptions to 62.2-2016, including the default 2 ACH50 leakage assumption, the increase in filter efficiency, and a requirement that multifamily occupancies using exhaust fans for outdoor air ventilation must provide a source of outside air (either passive or mechanically supplied). Section 150 will also define requirements for kitchen hood verification.

The change in the ventilation standard for HRMF buildings will also affect other parts of Title 24, including Part 2 of the California Building Code and Part 4 of the California Mechanical Code. Details of the code change language are provided in Section 7.1. These changes will help correct conflicting or confusing references in Parts 2, 4, and 6.

2.3.1 Standards Change Summary

This proposal would modify the following sections of the Building Energy Efficiency Standards as shown below. See Section 7 of this report for detailed proposed revisions to code language.

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

100.1(b) Definitions: The reference to ASHRAE Standard 62.2 is updated from 62.2-2010 to 62.2-2016.

SECTION 120 – REQUIREMENTS FOR VENTILATION

Subsection 120.1: Simplifies references to other codes.

Subsection 120.1(a)1: Exception 2 will be added to indicate that all occupancies classified as R-3 and non-transient residential occupancies classified as R-2 will be covered by Section 150.0.

Subsection 120.1(b)3: Provides for sealing of central exhaust shafts and ducts to ten percent maximum of total ventilation air and to require balancing within ten percent of design airflow.

Table 120.1-A: Changes the reference for high-rise residential from the California Building Code to Section 150.0(o).

Subsection 120.4(g): Requires sealing of exhaust shafts and ducts in HRMF buildings to within ten percent of the measured airflow of the powered roof ventilator (added).

Subsection 120.5(a)18: Adds requirement specifying that filters for ducted thermal conditioning systems in HRMF buildings shall comply with 150.0(m)12B.

SECTION 150 – MANDATORY FEATURES AND DEVICES

Exception to Subsection 150.0(e)1B: Removes exception for outdoor combustion air for fireplaces and decorative gas appliances if located on a slab and not near a wall.

Subsection 150.0(h)5: Requires alternatives to indoor combustion air for open combustion space conditioning equipment similar to the requirements in IECC Section R402.4.4.

Subsection 150.0(m)12B: Updates MERV and AHRI 680 Particle Size Efficiency (PSE) values to match the proposed filter efficiency requirement (from MERV 6 to MERV 13), and adds language requiring that filter media be labelled by the manufacturer with efficiency and static pressure information and verified.

Subsection 150.0(m)12B: Inserts MERV requirements for outdoor air ventilation systems based on high-rise or low rise construction, proximity to busy roadway and type of ventilation system.

Subsection 150.0(n)5: Requires alternatives to indoor combustion air for open combustion water heating equipment similar to the requirements in IECC Section R402.4.4.

Subsection 150.0(o): Adopts the version of ASHRAE Standard 62.2 that is referenced in Section 100.1(b).

Subsection 150.0(o)1: Requirement that mechanical ventilation system airflow is calculated on the basis of 2 ACH50 if no blower door test is completed. Requires higher mechanical ventilation flowrates if tested infiltration is lower than 2 ACH50 but does not reduce mechanical ventilation rate if tested infiltration rates are higher than 2 ACH50.

Subsection 150.0(o)2: When central fan integrated ventilation systems in HRMF units use continuous operation of central forced air system air handlers for meeting the whole-unit ventilation requirement, variable speed fans that change flowrates in response to loads are required.

Subsection 150.0(o)4A: Prescribes methods of meeting ventilation requirements in low-rise and high-rise multifamily buildings, and allows a reduction in ventilation air if balanced systems are installed.

Subsection 150.0(o)4B: New section titled Kitchen Exhaust Ventilation that requires field verification of the HVI certification information for the installed kitchen range hood and references a new field verification protocol for the range hood which will be added to RA3.7.4.3.

Subsection 150.0(o)4C: Requires sealing of multifamily units and HERS verification of maximum total leakage of 0.3 cfm at 50 Pa per square foot of dwelling unit enclosure area (sampling allowed in accordance with RA2.6.3).

Subsection 150.0(p)5: Requires alternatives to indoor combustion air for open combustion pool heaters similar to the requirements in IECC Section R402.4.4.

SECTION 150.2 – ENERGY EFFICIENCY STANDARDS FOR ADDITIONS AND ALTERATIONS TO EXISTING LOW-RISE RESIDENTIAL BUILDINGS

Exception 4 to Section 150.2(b): Indicates that the limitation on using indoor air for combustion air in Section150.0(h)5 (space conditioning equipment), 150.0(n)5 (water heaters), and 150.0(p)5 (pool heaters) do not apply to alterations.

2.3.2 *Reference Appendices Change Summary*

This proposal would modify the following sections of the standards appendices as shown below. See Sections 7.1.1 and 7.2.4 of this report for the detailed proposed revisions to the text of the reference appendices.

JOINT APPENDICES

JA1 - Glossary: The proposed regulations would update the existing ASHRAE Standard 62.2 definition to reference the 2016 version and adds definitions related to HVI labeling of kitchen hoods.

RESIDENTIAL APPENDICES

Table RA2-1 – Summary of Measures Requiring Field Verification and Diagnostic Testing: Adds field verifications for kitchen hood airflow and sone ratings, and blower door tests for compliance with compartmentalization of multifamily units.

RA 2.3.1.1 Whole-Building Compliance Approach for Multifamily Buildings: Clarify that the blower door test referenced in "(e) Building Envelope Sealing credit (blower door test)" is to determine infiltration, not for compartmentalization.

RA2.3.1.2: Documentation registration: Edited as follows: "For all low-rise <u>and high-rise</u> residential buildings…".

Table RA3.7-1 – Summary of Verification and Diagnostic Procedures: Change verification procedure references and add a reference to kitchen hood verification procedures as detailed in Section 7.

RA3.7.4 - Procedures: Change this section to **Procedures – All Building Types**

RA3.7.4.3 – Kitchen exhaust verification: New section describing the procedure.

RA3.7.4.4 – Procedures Specific to High-Rise Multifamily Buildings: This new section describes procedures related to IAQ ventilation airflow verification for the various types of systems used in high-rise multifamily buildings, such as exhaust with passive vents, central exhaust systems, and balanced ventilation.

The proposed regulations will be required to be updated to the acceptance test protocols in the nonresidential appendices to accommodate the following measures for high-rise residential buildings:

- Path 1: Air sealing for compartmentalization and makeup air for exhaust ventilation
- Path 2: Balanced ventilation and filtration (required for non-attainment areas)
- Buildings with central-exhaust: air sealing and balancing

RA3.8: Field Verification and Diagnostic Testing of Building Air Leakage: Add changes to this section to describe how to alter the blower door test to assess multifamily unit compartmentalization.

NONRESIDENTIAL APPENDICES

Although the common areas of HRMF buildings will continue to follow the nonresidential requirements of Title 24, Part 6, these areas affect the scope of this code change proposal – i.e., IAQ within the HRMF units. Consequently, this code change proposal includes the following revision:

NA2.1.4.1: Diagnostic Duct Leakage: Add a description that, for central exhaust shafts serving HRMF buildings, HERS Rater verification for 10% leakage should follow Procedure NA2.1.4.2.1.

2.3.3 *Alternative Calculation Method (ACM) Reference Manual Change Summary*

This proposal would modify the following sections of the Residential ACM Reference Manual. See Section 7.3 for the detailed proposed revisions to the text of the ACM Reference Manual.

SECTION 2 – The Proposed Design and Standard Design

Subsection 2.4.9: The proposed regulations will substantially change the algorithms applied for calculating the minimum required ventilation airflow rates. This section will be revised to include the calculation method for Q_{total}, Q_{inf}, and Q_{fan}.

2.3.4 Compliance Manual Change Summary

The proposed code change will modify the following sections of the Title 24, Part 6 Residential Compliance Manual (see Section 7 for details):

- Section 1.5 – Scope and Application
- Section 2.2.8 – Field Verification and Diagnostic Testing
- Section 3.5.8.9 – Natural Ventilation Through Fenestration
- Section 3.6.1.17 – Ventilation for Indoor Air Quality
- Section 4.1.2 – What's New for the 2019 Energy Standards
- Section 4.6 – Indoor Air Quality and Mechanical Ventilation
- Section 9 – Additions, Alterations, and Repairs

In addition, Chapter 4.3 of the Nonresidential Compliance Manual– Ventilation Requirements, will be modified.

2.3.5 Compliance Documents Change Summary

The proposed code change will modify CF2R-MCH and CF3R-MCH to accommodate verification of HRMF ventilation and kitchen hood verification for all residential unit types. Revisions to nonresidential documents will be required to verify sealing of HRMF partition walls and air tightness of central exhaust shafts.

2.4 Regulatory Context

2.4.1 Existing Title 24, Part 6 Standards

The current Title 24, Part 6 requirements reference ASHRAE 62.1-2010.

2.4.2 Relationship to Other Title 24 Requirements

Title 24, Part 2 (California Building Code) and Title 24, Part 4 (California Mechanical Code) include relevant requirements. Edits to Part 2 and Part 4 are needed to make it clear that single family residential and HRMF dwellings are covered by Part 6. Updates would also clarify which R-2 occupancies are covered by 62.1 versus 62.2.

Title 24, Part 2

Sections 310.4 and 310.5: These sections define Group R-2 and R-3 residential occupancy types. The interpretation by the Statewide CASE Team is that the only R-2 occupancy type that would use the residential ventilation standard (ASHRAE 62.2) is apartment houses with non-transient occupancy. All other listed R-2 occupancies would use the Nonresidential Standard (ASHRAE 62.1).

Section 1203.1: This section states that "mechanical ventilation shall be provided in accordance with the California Mechanical Code (Title 24, Part 4).

Title 24, Part 4

Section 402.1 Occupiable Spaces: Quoting from this section: “Ventilation air supply requirements for occupancies regulated by the California Energy Commission are found in the California Energy Code.”

Section 402.1.2. Dwelling: This section specifies “Requirements for ventilation air rate for single family dwellings shall be in accordance with this chapter or ASHRAE 62.2.”

Section 402.3: Mechanical Ventilation: States “Where natural ventilation is not permitted by this section or the building code, mechanical ventilation systems shall be designed, constructed, and installed to provide a method of supply air and exhaust air.”

Table 402.1. Minimum Ventilation Rates in Breathing Zone: Designates the ventilation rate for dwelling units as 5 cfm per person plus 0.06 cfm per square foot. Footnote “g” to the table states: “Air from one residential dwelling shall not be recirculated or transferred to other spaces outside of that dwelling.”

2.4.3 Relationship to Federal Laws

Changes in federal standards for furnace fan efficacy that take effect in 2019 are used as the basis for revisions to Title 24, Part 6; as proposed, they would lower the current 0.58 watt/cfm efficacy to 0.4 w/cfm. A requirement for higher efficiency filters may increase the difficulty of attaining a lower fan efficacy. No other current or proposed federal regulatory changes are known to be inconsistent with or duplicative of proposed changes to Title 24, Part 6, and there are no federal regulatory requirements that address the same topic as this proposed change

2.4.4 Relationship to Industry Standards

This proposal includes the adoption of ASHRAE Standard 62.2-2016. To date this version has not been adopted by the International Energy Conservation Code (IECC) or local ordinances. The IECC requires similar ventilation rates as calculated using the 2010 and 2013 versions of ASHRAE 62.2, which provide for an automatic infiltration credit.

Except for ASHRAE Standard 62.2, there are no industry standards that address the same topic as this proposed change.

2.5 Compliance and Enforcement

The Statewide CASE Team collected input during the stakeholder outreach process on what compliance and enforcement issues may be associated with these measures. This section summarizes how the proposed code change would modify the code compliance process. Appendix C 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 negative impacts on market actors who are involved in the process could be mitigated or reduced.

The key steps and changes to the compliance process are summarized below:

- **Design Phase**: This measure minimally impacts the design phase process for single family dwellings. Single family home designers will need to specify slightly larger mechanical ventilation systems that meet the increased ASHRAE 62.2-2016 ventilation rates as well as kitchen hoods that are HVI certified as meeting the ventilation/sound requirements. Improved compliance with ASHRAE 62.2-2016 will eliminate recirculating kitchen hoods and combination microwave exhaust hoods that cannot meet the 100 cfm, three sone requirement[16]. For HRMF buildings, designers will need to be aware of the following:

  - Title 24, Part 6 – not Part 4 – will prescribe required ventilation rates, which will be lower than previously required.
  - Externally vented kitchen hoods meeting ASHRAE 62.2-2016 for air volume and sound will be verified.
  - Central exhaust systems will need to meet requirements for balanced air delivery and shaft sealing.
  - Provisions must be made for makeup air or balanced ventilation.

  Single family and multifamily mechanical designers will also need to account for the pressure drop of higher efficiency filters in duct sizing calculations and ensure that either the prescriptive return grille, filter, and duct sizes are followed; or that the revised fan efficacy requirement can be met.

- **Permit Application Phase**: This measure will not have an impact on the existing permit application phase process other than minor changes to CF1R documents.
- **Construction Phase**: Provisions must be made to accommodate the new requirements for ventilation rates, kitchen hoods, and for multifamily units, makeup air and duct/shaft sealing and air balancing. The impact of changes for single family and low-rise occupancies will be very minor. The impact of changes for high-rise multifamily units will be significant in regions that are required to provide mechanically driven ventilation with MERV 13 filtration, but will be minor in all other areas of the state.
- **Inspection Phase**: For single family and low-rise multifamily units, this measure will have minimal impact on the existing building inspection phase process. There will be additional work for verifiers to inspect kitchen hoods. For high-rise buildings, inspection and verification will be required for the following:

  - Mandatory compartmentalization requirements required for all multifamily units with HERS verification
  - Central exhaust shaft sealing to ten percent of total fan flow
  - Central exhaust system balancing to within ten percent of design flow

  Inspections may be completed by a HERS Rater or an ATT inspector. Verifiers will be required to have new roles where they have typically not been involved in the past, and some training will be required.

  For all buildings, an additional field verification document will be needed to demonstrate kitchen exhaust hood verification. For high-rise buildings using exhaust shafts, additional testing will be required to verify proper distribution of ventilation air.

- **Compliance**: Compliance enforcement changes for new measures include the following:
  - MERV 13 filters, kitchen hoods, and proposed high-rise measure changes will increase the enforcement burden.
  - Verification of ventilation measures in high-rise projects where verification is typically not required is a significant change. Verification will include compartmentalization in HRMF units that use an exhaust-only with passive vents ventilation strategy, and verification of mechanically driven, filtered air in state regions where this is required.

[16] Currently addressed in Residential Compliance Manual section 4.6.5.1B.

- The measures are intended to close some loopholes to compliance (for example non-compliance of kitchen hoods with ASHRAE Standard 62.2.).

No added burden on building officials will be imposed by the proposed measures for low-rise residential units. For high-rise residential buildings, building officials will need to be familiar with changes to ventilation requirements as they will no longer be responsible for verifying related mechanical code requirements, and they will need to verify the ventilation strategy.

If this code change proposal is adopted, the Statewide CASE Team recommends that information presented in this section, Section 3, and Appendix C 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 Energy Commission staff, utility program 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

All products related to ventilation, including fans, kitchen hoods, heat exchange ventilators, passive vents, air control devices, and filters are commonly available from multiple suppliers. These products are manufactured both in the United States and abroad and are distributed through HVAC supply houses (e.g., Slakey Brothers and Ferguson) and by online vendors (e.g., Build.com and HVACquick.com). Large production builders may purchase commonly used products directly from manufacturers.

3.2 Technical Feasibility, Market Availability, and Current Practices

3.2.1 Ability of the Market to Accommodate the Measure

The construction industry is skilled in all methods used to implement the proposed measures, including; providing and installing appropriately sized and qualifying ventilation systems, kitchen range hoods, air conditioning filters, passive vents, and ventilation ducts and shafts. Training and support may be needed in some areas, for example, regarding sizing of filters and filter grilles that allow airflow and watt draw requirements to be met.

For the requirement for compartmentalizing multifamily units, no new products or strategies are needed, but education may be needed to make project teams aware that they must air seal interior partition walls as well as exterior walls to meet the requirement.

Because most HRMF units use exhaust-only strategies for supplying ventilation air, training and compliance manual guidance may be needed for designing systems that meet the requirement for mechanically driven supply air (e.g., balanced systems) and MERV 13 filtration in areas of high PM 2.5.

Builders who are accustomed to installing combination microwave exhaust fan units and recirculating range hoods will need to be educated on what products meet ASHRAE 62.2 Standards.

3.2.2 Product Availability and Related Issues

Ventilation Fans. There are numerous ventilation products capable of supplying ventilation in accordance with ASHRAE 62.2-2016. Most bathroom exhaust fans have the capacity to meet new ventilation requirements for any home size when used either individually (for smaller homes) or when used in combination (for larger homes). The HVI directory (HVI Publication 911) lists 4,107 different models from 46 manufacturers, with airflow ratings ranging from 14 to 620 cfm. Of these, 3,022 are ENERGY STAR® certified. HRVs, ERVs, and other available balanced exhaust systems incorporate variable speed fans with a wide range of capacities. There is also a large variety of inline fans that can be used for central ventilation systems.

Kitchen Range Hoods. Of the HVI listing of range hoods that meet ASHRAE 62.2 air volume and noise level requirements (100 cfm or greater and three sones or lower), there are 1,692 individual products listed by 22 manufacturers. Of these, 234 are ENERGY STAR certified. It is unknown whether there are any combination microwave-range hoods that meet the 100 cfm, three sone requirements since HVI listings for kitchen hoods do not specify whether microwaves are included.

Filters for Ducted Thermal Conditioning Systems. Stakeholders have expressed concern about the size and cost of MERV 13 filters relative to MERV 6 or MERV 8 filters, since the higher MERV rating is expected to require larger filter sizes to maintain equivalent pressure drop. Limited ceiling area may require additional return air grilles to be installed. In stakeholder meetings, a few HERS raters reported that they frequently see ventilation systems with inadequate airflow, because the system was not designed to overcome the pressure drop of the filter. These raters identified a training need for engineers and design-build HVAC contractors to properly design systems to increase the surface area when using higher MERV filters, and recommended that they provide more details in building plans (e.g., filter make and model).

Unfortunately, the cost impact of high MERV filters is difficult to assess because of the scarcity of filter performance data. A Title 20 Appliance Standards action was put in place that required labeling, but in an emergency rulemaking the Energy Commission extended the required date for labeling from July 1, 2016 to April 1, 2019[17]. As a result, Title 20 includes a category for filters, but none are listed to date. The AHRI Directory of Certified Performance does not include filters. A survey of products from big box stores and online sources show there are offerings from multiple manufacturers that provide MERV 13 or equivalent products, with the most popular brands including 3M Filtrete, American Air Filter, Honeywell, Ace, WEB, Lennox, and AprilAire. Only a few manufacturers have anticipated the Title 20 requirement by providing labeling.

Most high efficiency filters are pleated and range from one inch to four inches in thickness. Sizes up to 20 inch by 30 inch are commonly available. Larger thicknesses than 1 inch are not commonly seen in major retail stores but can be obtained from internet sources and wholesalers. The April 2019 filter labeling date will ensure that filter pressure drop data will be available for the January 1, 2020 initiation of the 2019 Standards.

The Statewide CASE Team analyzed the impact of MERV 13 filters on filter and grille sizing using data obtained from prior laboratory testing (Springer 2009), data from filter labels in stores, and information from manufacturers. Prior testing generally showed a large pressure drop penalty for MERV 13 filters relative to less efficient (MERV 7-8) filters, however the limited performance data that is currently available from manufacturers suggests there is not a clear correlation between filter

[17] Docket Number 17-AAER-02

pressure drop and MERV rating. For example, a 3M Filtrete MERV 7 has a higher pressure drop than a Filtrete MERV 13 (MacTavish 2017), but a 2” thick Aeolus MERV 13 filter has a 50% higher pressure drop a 2” Aeolus MERV 8 filter. Also, some 2” MERV 13 filters were found to have higher pressure drop than 1” MERV 13 filters. For costing purposes, an Aeolus SMP80 two-inch-thick MERV 13 filter was compared to a Flanders PP 40 1” MERV 8 filter[18], and the relative sizes were based on maintaining a 0.15 IWC pressure drop. For these products, the 2” MERV 13 filter would have to be ten percent larger than the 1” MERV 8 to achieve comparable pressure drop.

The air velocities that underlie Title 24, Part 6 Table 150.0-B and C filter and grille sizing range from 151 to 176 feet per minute (fpm). Applying these velocities to typical filter performance curves yields pressure drops that are well below the 0.15 IWC on which the incremental filter cost estimates are based.

Compartmentalization for Multifamily Units: Programs for above-code new construction that target multifamily buildings include a compartmentalization requirement that is at least as stringent as this proposal: The ENERGY STAR Multifamily Highrise program requires 0.3 cfm50 / ft^2 enclosure area[19], and the LEED for Homes Midrise program requires 0.23 cfm50/ft^2 enclosure area[20]. Consequently, project teams that have participated in these programs have met the proposed requirement. Based on the Statewide CASE Team’s industry knowledge and the literature (Building Science 2015), sealing interior partitions can be achieved with the same products as are commonly used for sealing the exterior, such as caulk, foam, and gaskets, but project team must pay attention to sealing interior partitions, not just the exterior, for the unit to comply with the maximum leakage rate of 0.3 cfm50/ft^2 enclosure area.

Multifamily Makeup Air Vents. Makeup air vents that replace air removed by exhaust fans may be fabricated using sheet metal louvers and ducts, but several manufactured products are available. Some, such as Munters Z-Duct, include passive air-to-air heat exchange. There are also several manufacturers (e.g., Panasonic, Therma-Stor, and Houzz) of low cost, passive through-the-wall vents which may include interior and exterior louvers and filters or insect screens.

Central Shaft Air Balancing: Most HRMF buildings with central exhaust shafts receive some type of testing and balancing for individual unit exhaust fans. Interviewees reported that this can be done through manually balancing fixed orifices, installing constant air regulation (CAR) devices, or using other methods. The manual balancing can be less expensive, and devices that provide automatically balanced ventilation are mostly used with high-rise multifamily buildings (as well as hotels). Manufacturers of the automatically balancing devices include American Aldes, Systemair, Mandik, Atlas Copco, and Smay. Title 24, Part 6 currently does not set an allowed maximum balancing result, nor does it require third party verification of central shaft balancing. However, interviewees reported that typical practice is balancing to within ten percent of the design flowrate, which is the proposed Title 24, Part 6 requirement.

Shaft Sealing. Exhaust shafts are typically sealed using standard drywall techniques (for gypboard shafts) and mastic and tape (for sheet metal ducts). An aerosol-based sealing method is also commercially available and has been demonstrated as being effective where there are no large openings. However, there is currently no widespread testing of exhaust shaft leakage, and consequently there is little data indicating typical leakage levels in exhaust shafts in new construction buildings. Interviewees

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[18] MERV 6 filters are required by ASHRAE 62.2, but performance data for them is more difficult to find.

[19] https://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_mfhr_guidance

[20] https://www.usgbc.org/sites/default/files/LEED%20v4%20Homes_10.17.16_current.pdf

indicated that, without attention to sealing, leakage can range from 10 to 30 percent; the literature supported an estimate of approximately 25 percent (WCEC 2014).

Table 6 provides HRV and ERV product information, based on the Statewide CASE Team web-based product review. The findings indicate that most residential HRVs and ERVs are not sold with an option for MERV 13 filtration. A few manufacturers offer products with MERV 13, including the Zehnder ComfoAir[21] and Fantech VHR200R[22]. The Zehnder product can be installed in an exterior wall and is advertised as applicable for apartment units. Several interviewees mentioned Lunos HRVs for HRMF units, because they can be installed in a through-wall design, but Lunos products also do not currently offer MERV 13 filtration. To comply with a MERV 13 requirement manufacturers will need to provide it as an option to existing products.

[21] Zehnder ComfoAir: http://zehnderamerica.com/wp-content/uploads/2014/11/CA350-2015.03.25.pdf

[22] Fantech VHR200R-EC Fresh Air Appliance: http://www.fantech.net/products/residential-fresh-air-systems/fresh-air-appliances/vertical-appliances/vhr-r/vhr200r-ec-fresh-air-appliance/

Table 6: HRV and ERV Product Cost, Flow Rates, and MERV Ratings

Manufacturer	Product Name	ERV/HRV	Cost	Flow Rate (cfm)	MERV Rating Options
Panasonic	WhisperComfort™ Spot ERV Ceiling Insert Ventilator (FV-04VE1)	ERV	$350	40/20/10 @ 0.1 static pressure	MERV 6
Fantech	VHR200R-EC Fresh Air Appliance	HRV	$2,163/ $1,987	80-200	MERV 13
Broan	Broan HRV70SE Heat Recovery Ventilator, 120V Side Ports for 4" Ducts - 73 CFM	HRV	$1,194	73	MERV 6
Broan	HRV70TE	HRV		35-70	MERV 6
Broan	HRV150TE	HRV	$1,299	40-157	MERV 9
Broan	ERV140TE	ERV		40-140	MERV 7
Broan	ERV70T	ERV		35-70	MERV 6
Solar Palau	TR90/TR90G	ERV		40-110	MERV 8
Solar Palau	TR130	ERV	$800	50-140	MERV 8
Solar Palau	TR200	ERV	$1,150	100-200	MERV 8
Mitsubishi	Lossnay LGH-F300RX5-E1	ERV	$1,687	300	MERV 6
Lennox	Healthy Climate® Heat Recovery Ventilator (HRV5-150, MERV3-300)	HRV	$1,588	150/300	MERV 4
Zehnder	ComfoAir 70	HRV	$1,195	up to 38	MERV 8, Optional MERV 13
Carrier	EV450IN	ERV		200-540	MERV 8
Lunos	Lunos e2	HRV	$1,055	up to 22	MERV 5, Optional MERV 10

Filtration Standards: Because of the proposal to increase filtration efficiency requirements for both ducted thermal conditioning systems and outside air ventilation systems, the Statewide CASE Team developed Table 7 to compare MERV requirements. This table shows filtration requirements in buildings standards (ASHRAE 62.1-2016 and 62.2-2016), above code programs (WELL Building Standard, LEED, and EPA Indoor AirPLUS), and in two city ordinances that require filtration above Title 24, Part 6 Standards (San Francisco and Los Angeles). As shown, there is precedence for requiring higher filtration, particularly for outside air in areas with high PM 2.5 concentrations (e.g., PM 2.5 nonattainment areas, and areas close to freeways). The CEC has expressed a strong preference for MERV 13 as a statewide standard. This will equal protection to all residential occupants and will address the PM 2.5 from cooking.

Table 7: Filtration Requirements in Building Standards, Above Code Programs, and City Ordinances

Standard / Ordinance	Scope	Ducted Thermal Conditioning Systems	Outside Air Filtration
ASHRAE 62.1-2016	Nonresidential		MERV 11 in PM 2.5 nonattainment areas
ASHRAE 62.2-2013	Residential	MERV 6	MERV 6
WELL Building Standard	Nonresidential	Not specified	MERV 13, or demonstrate outdoor PM 2.5 and PM10 levels below WELL Air Quality Standard for 95 percent of year
LEED v. 4 and LEED for Homes	Nonresidential (v.4) and Low-rise Residential (Homes)	MERV 8	Credit (not prerequisite) for MERV 13
EPA Indoor AirPLUS	Residential	MERV 8 on "HVAC filters" does not specify if for thermal conditioning systems or outside air ventilation	
City of San Francisco (Article 38)	Residential	Ventilation systems with MERV 13 ≤ 500 ft of freeways and other sensitive areas. Not specified if for ducted thermal conditioning systems or outside air ventilation	
City of Los Angeles (Ordinance 184245)	Nonresidential and Residential	MERV 13 ≤ 1000 ft from freeways, otherwise MERV 8	MERV 13 ≤ 1000 ft from freeways, otherwise MERV 8

3.2.3 Inspection Challenges

Current Title 24, Part 6 methods and documents cover the inspection and verification process for whole house ventilation systems. New procedures that would be put in place with the proposed measures include: verification of range hoods and filters for ducted thermal conditioning systems for all occupancies, makeup air vents, air regulation and balancing, and shaft sealing for multifamily occupancies. Range hoods and filters can be verified by HERS inspectors when HVAC systems are verified for airflow and fan efficacy for single family and low-rise buildings, but a separate inspection would be required for HRMF. For multifamily buildings, verification and acceptance tests for makeup air vents as well as exhaust shaft sealing and balancing may be completed either by HERS Raters or ATTs, and HERS Raters would conduct blower door testing for the compartmentalization requirement.

3.2.4 Building/System Longevity, Occupant Health and Comfort, and Other Considerations

The intent of these proposed measures is to balance energy efficiency improvements proposed by other CASE Reports with the need to maintain occupant comfort and health as well as building durability. By meeting the level of ventilation recommended by the national ASHRAE Standard, indoor pollutants will be reduced by dilution and filtration, and in the dry California climate indoor humidity will be maintained at a level that will not cause damage from moisture accumulation in construction materials. None of the proposed measures are expected to add to maintenance requirements. For example, pleated higher-rated air filters have more surface area than flat filters and should require no more frequent replacement. Kitchen hoods that are more effective at venting smoke and grease to the exterior reduce the amount of grease accumulation on walls and other surfaces.

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. Even as shown in Figure 5, California home prices have increased by about $300,000 in the last 20 years. In the six years between the peak of the market bubble in 2006 and the bottom of the crashing in 2012, the median home price dropped by $250,000. The current median price is about $500,000 per single family home. The combination of all single family measures for the 2016 Title 24, Part 6 Standards was around $2,700 (California Energy Commission 2015). This is a cost impact of approximately half of one percent of the home value. The cost impact is negligible as compared to other variables that impact the home value.

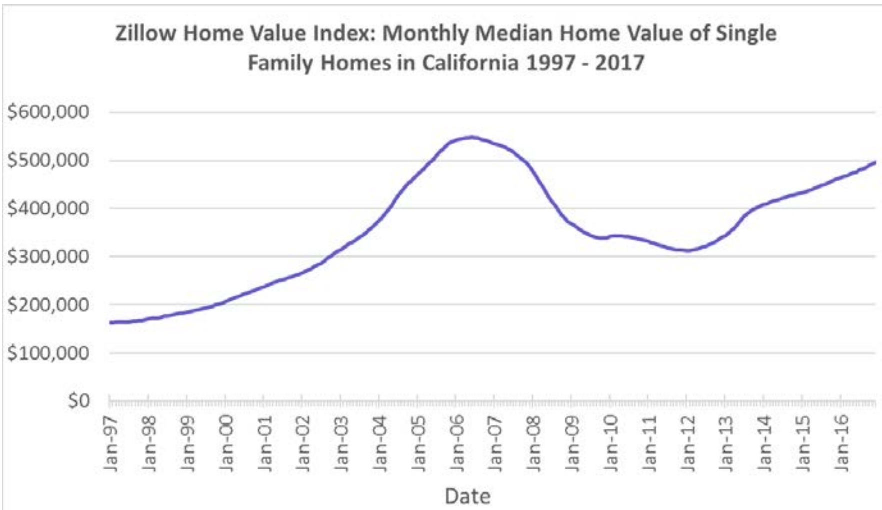

Figure 5: California median home values 1997 to 2017

Source: (Zilllow 2017)

Market actors will need to invest in training and education to ensure the workforce, including designers and those working in construction trades, know how to comply with the proposed requirements. Workforce training is not unique to the building industry, and is common in many fields associated with the production of goods and services. Costs associated with workforce training are typically accounted for in long-term financial planning and spread out across the unit price of many units as to avoid price spikes when changes in designs and/or processes are implemented.

Review of current builder practice relative to proposed changes for single family and low-rise multifamily buildings indicates that most builders meet ventilation requirements by providing continuously operating exhaust fans. Higher-capacity fans may need to be selected for single family homes. Air sealing (and blower door testing) is rarely used to earn additional compliance credit, and tighter buildings will require larger fans.

The requirement for compartmentalization is estimated to result in an increase of approximately $270 for air sealing, and approximately $20 per tested unit for the HERS Rater to conduct a blower door test (assuming sampling), for a total cost of approximately $290 per unit.

Combination microwave range hoods are in fairly common use in production homes, and the need to create space for stand-alone or combination oven-microwaves may be viewed by some builders as a marketing hardship. Research for this report was unable to identify any complying combination appliances, though one model tested by Lawrence Berkeley National Laboratory came close. HVI listings do not identify which range hoods include a microwave oven. Verification of range hoods may increase HERS fees slightly. As indicated in ASHRAE 62.2-2016 Addendum p, products that have a minimum speed setting greater than 400 cfm are exempt from the airflow/sone requirement and therefore from HERS verification.

The requirement for mechanically driven supply air with MERV 13 filtration of outside air in HRMF units will increase costs by approximately $1,600 per unit (Section 5.2). If MERV 13 is required statewide compliance will be simplified. At the risk of more complicated compliance, this proposal would delineate a "high ambient PM 2.5" area if it is located within 500 feet of a "busy roadway", defined as a roadway with annual average daily traffic (AADT) equal to or greater than 100,000 vehicles per day. There is strong evidence that people living within 500 feet of a freeway are at greater risk for health problems, such as asthma, bronchitis symptoms, and lung cancer (see Appendix B for citations and further information). The definition of a "busy roadway" is based San Francisco Health Code Article 38, which requires MERV 13 filtration in urban locations within 500 feet of a roadway with 100,000 vehicles per day. The Statewide CASE Team estimates that roughly five percent of the population will be affected, based on an article that estimated the population within 500 feet of freeways in Southern California (Barboza 2017).

Note that the Statewide CASE Team also considered proposing MERV 13 in PM 2.5 nonattainment areas. However, this would significantly increase the scope of this requirement. The U.S. EPA Greenbook (EPA 2017) shows that approximately three-fourths of the California population currently live in an area that is listed for nonattainment with either the annual PM 2.5 standard (South Coast Air Quality Management District [SCAQMD] and San Joaquin Valley), or the 24-hour PM 2.5 standard (SCAQMD, San Joaquin Valley, Bay Area, and Sacramento). The Bay Area and Sacramento appear to have reached attainment, and need to submit re-designation requests to the EPA to be delisted for nonattainment.[23] PM 2.5 levels in the SCAQMD region have been declining; the region is predicted to reach attainment with the annual standard by 2023 and no later than 2025, and with the 24-hour standard by 2019 (SCAQMD 2016). PM 2.5 levels have also been declining in the San Joaquin Valley (Air Resources Board 2016), with an attainment date of 2025 for the annual PM 2.5 standard (Air Resources Board 2016). Given the trends of improving PM 2.5 in the nonattainment areas and the longevity of buildings (50-100 years[24]); the incremental cost for mechanically driven supply air with MERV 13 filtration; and the training that would be needed for proper design and installation of these systems, the Statewide CASE Team recommends that a minimum MERV 8 (rather than MERV 13) be required in PM 2.5 nonattainment areas. Section Appendix B provides further detail on the rationale for the scope of this requirement.

Requirements for sealing central exhaust shafts will place an added burden on designers and builders who choose this method of ventilation for high-rise buildings as well as verifiers, but this measure, along with proper balancing and providing a source of outside air, will provide the level of IAQ and healthy environment that is intended by the ASHRAE 62.2 Standard.

The builder is responsible for understanding the design requirements, ensuring that all subcontractors are aware of these requirements, and ultimately ensuring that all requirements are implemented per the design intent. Additional time may be required for these processes but it's not expected to have a significant impact on project schedule.

Refer to Appendix C for additional information on how the compliance process would impact builders.

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[23] For the Bay Area see footnote 10: http://www.baaqmd.gov/research-and-data/air-quality-standards-and-attainment-status, and for Sacramento see: https://www3.epa.gov/region9/air/actions/sacto/index.html

[24] USGBC 2007: "On Green Buildings: Benefits to Health, the Environment, and the Bottom Line". https://www.epw.senate.gov/public/_cache/files/5/c/5c03f15d-1731-478a-9bfb-fe2fbbab6ab0/01AFD79733D77F24A71FEF9DAFCCB056.templeton.pdf

3.3.2 Impact on Building Designers and Energy Consultants

Adjusting design practices to comply with changing building code practices is within the normal practices of building designers. Building codes (including the California Building Code and model national building codes published by the International Code Council, the International Association of Plumbing and Mechanical Officials and ASHRAE 90.1) are typically updated on a three-year revision 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 adjust design practices to accommodate compliance with new building codes. As a whole, the measures the Statewide CASE Team is proposing for the 2019 Title 24, Part 6 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.

Energy consultants are responsible for identifying what measures are needed to obtain compliance, both for mandatory requirements and to meet prescriptive or performance requirements, and conveying this information to architects and builders (the design-build team). For single family dwellings, energy consultants will need to convey to the design-build team the required size of whole house ventilation fans (to be listed in the CF1R forms), and new requirements for kitchen hoods and filters for ducted thermal conditioning systems, so that these items can be properly specified. For multifamily buildings, energy consultants must also inform the design-build team (including mechanical engineers) of requirements for compartmentalization, and (where used) makeup air and design of central exhaust shafts. On high-rise projects, energy consultants can also assist mechanical engineers with identifying the relevant codes given the change in ventilation standards from 62.1 to 62.2.

Architects and engineers are responsible for developing building plans and specifications that detail mechanical equipment requirements and locations, and that comply with codes. For low-rise buildings, mechanical contractors typically have the responsibility for equipment sizing, duct design, and other installation requirements, whereas for larger multifamily projects this responsibility falls on the mechanical engineer. All design-build team participants will need to be informed of these code changes. Energy Code Ace (energycodeace.com) will be useful in providing the needed guidance.

Refer to Appendix C for additional information on how the compliance process would impact building designers and energy consultants.

3.3.3 Impact on Occupational Safety and Health

The proposed code change does not alter any existing federal, state, or local regulations pertaining to safety and health, including rules enforced by the California Division of Occupational Safety and Health. All existing health and safety rules will remain in place. Complying with the proposed code change is anticipated to improve the health of occupants (see Section 6.4), and is not anticipated to have adverse impacts on the safety or health of those involved with the construction, commissioning, and maintenance of the building.

3.3.4 Impact on Building Owners and Occupants (Including Homeowners and Potential First-Time Homeowners)

Building owners and occupants will benefit from lower energy bills. For example, the Energy Commission estimates that on average the 2016 Title 24, Part 6 Standards will increase the construction cost by $2,700 per single family home; however, the standards will also result in a savings of $7,400 in energy and maintenance cost savings over 30 years. This is roughly equivalent to an $11 per month increase in payments for a 30-year mortgage and a monthly energy cost savings of $31 per month. Overall, the 2016 Title 24, Part 6 Standards are expected to save homeowners about $240 per year relative to homeowners whose single family homes are minimally compliant with the 2013 Title 24, Part 6 requirements (California Energy Commission 2015). As discussed in Section 3.4.1, when homeowners or 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. Energy cost savings can be particularly beneficial to low income homeowners who typically spend a higher portion of their income on energy bills, often have trouble paying energy bills, and sometimes go without food or medical care to save money for energy bills (Association, National Energy Assistance Directors 2011).

This group of measures will ensure that health advantages afforded by improved ventilation and air filtration will be preserved and enhanced. Benefits include reduced exposure to volatile organic compounds (such as formaldehyde) and particulate matter, which has been linked to higher incidences of lung cancer; and for multifamily tenants, reduction of pollutants and odors from adjacent units. Section 6.4 provides further discussion of health benefits from the proposed measures, including benefits from increased filtration, and Sections 2.1.2 and 7.4 describe the need for these changes from an IAQ and health perspective.

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

The proposed measure may increase demand for certain ventilation and filtration products, including whole house ventilation systems, MERV 13 filters, and may create market demand for an HVI compliant microwave-hood combinations. The measure will not impact the way products are distributed or sold. See also Section 3.4.2.

3.3.6 Impact on Building Inspectors

Building inspectors will not be significantly impacted by this measure. Where they have been responsible for inspecting HRMF ventilation systems under the California Mechanical Code (Title 24, Part 4), this burden will be shared and absorbed by HERS or ATT inspectors. See also Appendix C.

3.3.7 Impact on Plans Examiners

Plans examiners will be responsible for verifying that CF1Rs and other compliance documents match information provided on the plans.

3.3.8 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. No increase in statewide job creation is likely to occur as a result of this measure.

3.4 Economic Impacts

3.4.1 Creation or Elimination of Jobs

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

Building codes create jobs through *direct employment*, *indirect employment*, and *induced employment*.[25] Title 24, Part 6 creates jobs in all three categories with a significant amount attributed to induced employment, which accounts for the expenditure-induced effects in the general economy due to the economic activity and spending of direct and indirect employees (e.g., non-industry jobs created such as teachers, grocery store clerks, and postal workers). A large portion of the induced jobs from energy efficiency are the jobs created by the energy cost savings due to the energy efficiency measures. For example, as mentioned in Section 3.3.4, the 2016 Standards are expected to save single family homeowners about $240 per year. Money saved from hundreds of thousands of homeowners over the entire life of the building will be reinvested in local businesses. Wei, Patadia and Kammen (2010) estimate that energy efficiency creates 0.17 to 0.59 net job-years[26] per GWh saved. By comparison, they estimate that the coal and natural gas industries create 0.11 net job-years per GWh produced. See Section 6.1 for statewide savings estimates.

This report only addresses non-energy measures that ensure that other proposed energy-related measures do not negatively impact IAQ or building durability. Other CASE Reports describe the relationship between energy measures and job creation. Since the proposed measures herein primarily deal with substitution of one product for another and do not affect the level of effort required for procurement or installation, the impact on job creation will be very small. One exception is that sealing of exhaust shafts and provisions for makeup air in multifamily buildings will slightly increase labor needs.

3.4.2 Creation or Elimination of Businesses in California

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

The proposed code change would have very minor impact on the use of specific products, all of which are manufactured outside of California and the affected products would not alter the existing supply chains.

As proposed, implementation of the proposed measures would affect new single family and multifamily construction and additions greater than 1000 ft^2.

The proposed change introduces no new products but may have an impact on the volume of sales of certain products. Few, if any, of the affected products are manufactured in California, and there is not likely to be any change in market advantage for California distribution companies. Those in the supply chain that currently handle the more specialized ventilation products for multifamily buildings may see an increase in volume. Affected products would include:

- Exhaust fans used for whole house ventilation
- Heat or energy recovery ventilators

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[25] The definitions of direct, indirect, and induced jobs vary widely by study. Wei et al (2010) describes the definitions and usage of these categories as follows: "*Direct employment* includes those jobs created in the design, manufacturing, delivery, construction/installation, project management and operation and maintenance of the different components of the technology, or power plant, under consideration. *Indirect employment* refers to the ''supplier effect'' of upstream and downstream suppliers. For example, the task of installing wind turbines is a direct job, whereas manufacturing the steel that is used to build the wind turbine is an indirect job. *Induced employment* accounts for the expenditure-induced effects in the general economy due to the economic activity and spending of direct and indirect employees, e.g., non-industry jobs created such as teachers, grocery store clerks, and postal workers."

[26] One job-year (or ''full-time equivalent'' FTE job) is full time employment for one person for a duration of one year.

- Passive through-wall vents
- Constant airflow regulators
- Filters for ducted thermal conditioning systems and outside air systems
- Kitchen range hoods

Sales and distribution of larger exhaust fans may increase to meet higher single family residential ventilation rates, but this may be countered by the reduced ventilation rates that will be required for high-rise multifamily buildings. Some increase in sales of small HRVs or ERVs, passive vents, and constant airflow regulators may occur to serve ventilation needs in high-rise buildings. Sales volume of higher-efficiency HVAC filters will increase and volume of lower-efficiency filters will decline. The market for combination microwave range hoods for new buildings will disappear unless manufacturers begin producing ASHRAE 62.2-compliant products.

These changes are not anticipated to shift market share from one manufacturer or distributor to another. For example, the same manufacturers and distributors supply range hoods with and without microwave ovens. The market for specialized ventilation products would be expected to expand, particularly if there is growth in the construction of high-rise residential buildings.

The proposed codes and standards changes will have little or no impact on construction industry jobs. The same workforce that currently provides and installs ventilation products would shift to using products that meet ASHRAE 62.2 and related requirements.

Table 8 lists industries that may benefit from the proposed code change by North American Industry Classification System (NAICS) Code.

Table 8: Industries Receiving Energy Efficiency Related Investment, by North American Industry Classification System (NAICS) code

Industry	NAICS Code
Residential Building Construction	2361
Manufacturing	32412

3.4.3 Competitive Advantages or Disadvantages for Businesses in California

In 2014, California's electricity statewide costs were 1.7 percent of the state's gross domestic product (GPD) while electricity costs in the rest of the United States were 2.4 percent of GDP (Thornberg, Chong and Fowler 2016). As a result of spending a smaller portion of overall GDP on electricity relative to other states, Californians and California businesses save billions of dollars in energy costs per year relative to businesses located elsewhere. Improved IAQ should reduce healthcare costs and increase productivity, and is expected to contribute to the ability of California to compete globally.

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.

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 taxes most relevant to 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 is expected to increase discretionary income. State and local sales tax revenues may increase if homeowner spend their 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 have a negligible impact on construction costs. As discussed in Section 3.3.1 there is no statistical evidence that Title 24, Part 6 drives construction costs or that construction costs have a significant impact on home 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.

The proposed residential changes will not impact state buildings.

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, including tools, training and resources provided by the IOU codes and standards program (such as Energy Code Ace). As noted in Section 2.5 and Appendix C, 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 home prices, the proposed code changes are not expected to have an impact on financing costs for business or home-buyers. Some financial institutions have progressive policies that recognize the financial implications associated with occupants of energy efficient homes saving on energy bills and therefore have more discretionary income.[27]

Renters will typically benefit from lower energy bills if they pay energy bills directly. These savings should more than offset any capital costs passed-through from landlords. Renters who do not pay directly for energy costs may see some of the net savings depending on if and how landlords account for energy cost when determining rent prices.

[27] For example, see U.S. EPA's ENERGY STAR website for examples: http://www.energystar.gov/index.cfm?fuseaction=new_homes_partners.showStateResults&s_code=CA.

On average, low-income families spend less on energy than higher income families, however lower income families spend a much larger portion of their incomes on energy (Association, National Energy Assistance Directors 2011). Thus, low-income families are likely to benefit more from Title 24, Part 6 Standards that reduce residential energy costs.

4. ENERGY SAVINGS

4.1 Key Assumptions for Energy Savings Analysis

This group of measures is not projected to save energy. Changes in energy use resulting from increased ventilation rates in single family buildings and decreased ventilation rates in HRMF buildings are accounted for in the evaluation of energy saving measures described in other CASE Reports. For example, the analysis of energy savings for single family envelope measures used the ASHRAE 62.2-2016 ventilation rates in the modeling that evaluated those measures.

4.2 Energy Savings Methodology

There is an existing Title 24, Part 6 Standard that covers the building system in question. Existing conditions assume that a building minimally complies with the 2016 Title 24, Part 6 Standards.

As noted, proposed measures are not intended to reduce energy use, but will foster healthy environments in energy-efficient buildings. In theory, higher ventilation rates will increase energy use due to increased fan energy and the thermal impact of increased delivery of outdoor air that may be either warmer or cooler than the desired indoor temperature. The impact of increased ventilation rate on energy use in new single family homes was estimated using CBECC-Res with the proposed 2019 Time Dependent Valuation (TDV) schedules.

Table 9 lists the characteristics of the buildings that were used to evaluate energy savings and costs. Low-rise multifamily buildings were not evaluated, because the ventilation rates, and consequently their energy use, will not change.

For HRMF buildings, the proposals will decrease energy use in most cases, because of the decrease in required ventilation rate in moving from ASHRAE Standard 62.1-2007 to 62.2-2016. This was modeled using the low-rise multifamily prototype. The Statewide CASE Team used the low-rise multifamily building prototype and low-rise compliance software (CBECC-Res) to model the energy savings between the current (62.1-2007) and proposed (62.2-2016) ventilation rates, because the high-rise compliance software (CBECC-Com) is unable to allow ventilation rates below the current requirements. The central exhaust shaft sealing requirement will also decrease energy use through fan energy savings. For an HRV or ERV, energy savings will vary with climate zone. Many interviewees reported that in mild climates, such as the San Francisco Bay Area, the fan energy penalty of an HRV or ERV could counteract the energy cost savings. However, central systems with ducted outside air, and ERVs/HRVs, should improve IAQ through filtered, reliable ventilation.

The two single family prototype houses used for code development (2,100 square foot one-story and 2,700 square foot two-story) were used for this analysis. Construction characteristics were based on 2016 Title 24, Part 6 prescriptive requirements. Results were weighted 45 percent for the 2,100 square foot prototype and 55 percent for the 2,700 square foot prototype, resulting in blended 2,430 square foot prototype results. Refer to other CASE Reports for a detailed description of methodologies and the net impact of changes in ventilation rates combined with energy-saving measures.

The 2016 Title 24 Part 6 compliance model (CBECC) assumes that the infiltration rate corresponds to a 5 ACH50 blower door test result, and that an additional quantity of air is delivered mechanically, equivalent to 0.01 cfm/square foot plus 7.5 cfm per occupant. The CBECC-Res analysis for single family energy impacts also assumed an infiltration rate that corresponds to 5 ACH50, but used a mechanical ventilation rate that is calculated based on a leakage rate corresponding to 2 ACH50, such that the total ventilation rate will be approximately 0.03 cfm/square foot plus 7.5 cfm per occupant, consistent with ASHRAE 62.2-2016.

To determine the mechanical ventilation rate, it was necessary to apply the calculations in ASHRAE 62.2-2016 to estimate the infiltration rate. This was done using an open-access software tool.[28] Inputs to this tool included building floor area and height, number of occupants (or bedrooms + 1), and climate location. The results (i.e. required mechanical ventilation rates) were entered in CBECC-Res to develop energy use impacts for each climate zone and prototype house[29].

As noted in Title 24, Part 6, Section 150.2(a), ASHRAE Standard 62.2 will apply to additions greater than 1,000 square feet. However, increasing the mechanical ventilation rate in buildings that have gas appliances that use indoor air for combustion is a potential safety risk, and such appliances must be provided with combustion air from an external source. This proposed change aligns with the IECC but is in conflict with Chapter 7 of the CMC, which allows the use of indoor combustion air. See the proposed code language changes in Section 7.

Table 9: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype ID	Occupancy Type	Area (ft^2)	Number of Stories	Statewide Area (million ft^2)
New Construction Prototype 1	Residential single family	2,100	1	110.6
New Construction Prototype 2	Residential single family	2,700	2	173.8
New Construction Prototype 1	Residential multifamily	6,960	2	45.7

Energy savings, energy cost savings, and peak demand reductions were calculated using a TDV methodology. The latest 2019 TDV multipliers (updated February 2017) were applied in the analysis.

4.3 Per Unit Energy Impact Results

Energy use and peak demand impact per unit for new single family houses (using the blended 2,430 square foot home results) are presented in Table 10. Negative values indicate increases in energy use versus the current 2016 prescriptive base case. Electricity use is affected by increases in fan energy use due to larger ventilation rates, and in most climate zones by resulting increases in air conditioning loads. Furnace gas consumption is also increased as a result of higher ventilation rates during winter periods. Surprisingly, CBECC-Res shows gas energy savings in Climate Zone 14. The per unit energy impact estimates do not take naturally occurring market adoption or compliance rates into account.

[28] http://www.residentialenergydynamics.com/REDCalcFree/Tools/ASHRAE6222016

[29] Equation 4.3 in the version of ASHRAE Standard 62.2-2016 that includes Addenda k, l, q, and s and 11/4/2016 errata can also be used to calculate Q_{inf} from single point tests of ACH50 in accordance with ASTM E1827 or ANSI/RESNET/ICC Standard 380.

Table 10: First-Year Energy Impacts for Blended Single Family Prototype – New Construction

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	-59.3	-0.01	-12.01	-4,691
2	-67.1	-0.01	-9.09	-5,127
3	-58.4	-0.01	-9.29	-3,978
4	-67.0	-0.02	-6.88	-4,034
5	-58.8	-0.01	-7.64	-3,587
6	-68.0	-0.02	-7.15	-3,990
7	-70.4	-0.01	-6.45	-3,496
8	-47.8	0.05	-5.34	-1,271
9	-52.5	0.01	-5.68	-3.092
10	-38.2	0.02	-5.12	-2,345
11	-45.9	0.02	-3.91	-2,063
12	-39.0	0.05	-3.93	-1,763
13	-58.9	0.00	-5.81	-3,864
14	-23.0	0.05	2.10	825
15	-152.3	-0.04	-2.36	-5,403
16	-67.1	-0.01	-3.16	-3,113

Table 11 shows energy use impact estimates for new high-rise residential units for the proposed requirement to reduce ventilation rates from the 62.1-2007 to the 62.2-2016 rates. These estimates are based on modeling the current (62.1-2007) and proposed (62.2-2016) ventilation rates in low-rise compliance software (CBECC-Res) using the low-rise multifamily prototype shown in Table 9. The HRMF prototype was not used because the high-rise compliance software (CBECC-Com) does not allow ventilation rate reductions below the currently required levels. These proxy results show savings at an aggregated level representing the eight unit 6,960 ft^2 low rise multifamily prototype building (four one-bedroom, 780 square foot units and four two-bedroom 960 square foot units). Results show that this measure will result in positive energy savings, with greater savings in climate zones with higher cooling loads.

The Statewide CASE Team did not estimate the energy savings from the proposal for compartmentalization in multifamily units, but estimates that the requirement will have no effect or may slightly increase energy savings, depending on project teams' current sealing practices. The exact translation of the compartmentalization requirement of 0.3 cfm50/square foot enclosure area to air changes per hour depends on unit geometry (e.g., ceiling height, length to width ratio of the walls), but the Statewide CASE Team estimates that the requirement represents approximately 6 to 7 ACH50[30]. Compliance software assumes 7 ACH50 for all multifamily dwelling units, and assumes that all infiltration air originates from the exterior. This assumption is conservative from an energy standpoint, since some air leakage comes from adjacent units which may be conditioned. Based on interview results, multifamily air sealing practices vary by project team and jurisdiction. For some HRMF buildings in urban areas, interior partitions are sealed because of acoustical requirements. In other multifamily buildings, project teams air seal exterior surfaces because of energy concerns, but do not seal interior partitions. Under the proposed compartmentalization requirement, leakage from the exterior would likely stay the same or decrease under the proposed requirement, depending on a project team's current practices with air sealing. In either case, the 7 ACH50 assumption of air leakage from the

[30] Assuming 8 to 9 foot ceilings, and where units ranged from square (i.e., all walls the same length) to one set of parallel walls measuring almost twice the length of the other set of walls (e.g., 20 ft by 39 ft for the 780 sf HRMF unit prototype).

exterior is an upper estimate (i.e., conservative), since a fraction of air leakage could come from adjacent, conditioned spaces.

The Statewide CASE Team did not estimate energy savings for the requirement of mechanically driven supply air with MERV 13 filtration for high-rise residential buildings in high PM 2.5 areas because it is anticipated that most units will use an ERV or HRV to meet this requirement and the current compliance software does not allow modeling of these systems.

Table 11: First-Year Energy Impacts of Ventilation Rate Change for HRMF Building Type (8 units, 6,960 ft^2) – New Construction

Climate Zone	Electricity Savings (kWh/yr)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	59.0	24.9	6,960
2	62.1	16.6	6,265
3	46.9	12.0	4,176
4	51.3	13.4	4,872
5	39.6	11.2	3,480
6	41.0	6.3	2,088
7	36.4	2.0	1,392
8	35.0	3.6	2,088
9	54.4	6.3	4,177
10	55.6	7.4	4,176
11	91.6	15.6	6,960
12	63.9	15.9	6,264
13	93.1	14.6	6,950
14	82.8	14.6	6,264
15	169.0	1.8	6,976
16	58.5	24.2	6.960

5. Lifecycle Cost and Cost-Effectiveness

5.1 Energy Cost Savings Results

The proposed measures in general provide no energy savings for single family buildings, have no impact on low-rise multifamily buildings, and produce modest savings in high-rise multifamily buildings. As directed by the Energy Commission, since this is a health and safety measure, lifecycle cost and cost-effectiveness has not been analyzed.

5.2 Incremental First Cost

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

Per the Energy Commission's guidance, design costs are not included in the incremental first cost. Total costs are presented as costs to the builder. A 30 percent overhead and profit markup was applied to all material costs. Labor costs were based on a fully loaded labor rate from RSMeans of $44/hour after applying an average California regional labor multiplier of 1.1. Labor costs for adding a return grille and duct to accommodate MERV 13 filters was obtained from a contractor and weighted 45 percent one-story and 55 percent two-story.

Incremental costs for single family whole house ventilation fans are based on Panasonic model FV-##VQ5 bathroom fans. Moving from ASHRAE 62.2-2010 to 62.2-2016 ventilation rates for the two single family prototypes requires one step up in fan capacity (e.g., 50 to 80 cfm for the 2,100 square foot prototype and 80 to 110 cfm for the 2,700 square foot prototype). No change in labor cost was assumed, because there is little change in the physical size of the larger fans. Since multiple fans could be commissioned to meet whole house ventilation requirements, the costs presented in Table 12 are conservative.

No additional labor is required to install complying range hoods. The tradeoff between material and installation costs for range hoods with microwaves and oven-microwave combinations was assumed to be even.

For the upgrade from MERV 8 to MERV 13 filters, incremental costs for both larger grille sizes and larger filters were tabulated. MERV 8 filters were used as the base cost because cost data for currently required MERV 6 filters is scarce. For one-story houses, additional labor and materials costs were included to account for the installation of a second return grille, which would be required for higher pressure drop MERV 13 filters (based on the 2,100 square foot prototype and a 3-ton cooling system). The calculation of incremental costs for two-story houses assumed that two returns were already provided and only the cost of larger grilles and filters were accounted for (based on the 2,700 square foot prototype and a 4-ton cooling system). Incremental costs for the one and two-story prototype houses were blended 45 percent and 55 percent respectively.

The larger high efficiency filter and grille is the only added expense for low-rise multifamily, which due to the lower airflow requires a smaller filter and grille than for the single family cases.

Several industry practitioners were interviewed to determine current practice and to obtain ideas on optimal ventilation strategies for HRMF building ventilation (see Appendix B). Typically, they have utilized exhaust fans, sometimes in combination with passive vents, to meet code requirements. Air is supplied through leaks in interior and exterior walls and doorways, and through passive vents (if used). This represents the lowest cost ventilation approach.

For the cost of compartmentalization, the Statewide CASE Team used the NREL Measure Database (National Renewable Energy Laboratory 2013), and assumed a reduction from 7 ACH50 (the current assumption for air leakage in multifamily units under Title 24) to 6 ACH50 (the approximate conversion of 0.3 cfm50/ft^2 enclosure area). The NREL database estimates the cost ranges $0.13 -$0.49 per square foot of conditioned area, with an average cost of $0.31 per square foot of conditioned area. The average size of multifamily units in both the low-rise and high-rise prototypes is 870 square feet, so the average cost for sealing is estimated at $270.

Based on interviews with five HERS Raters, each blower door test can range from $65 to $150 per unit, with an average cost of $100 per tested unit. The Statewide CASE Team assumed that one in five units will be selected for blower door testing, for an average cost of $20 per unit (after sampling). Although the sampling procedures in RA2.6 allow one in seven units to be a sample group, this analysis conservatively assumed one in five because it is not uncommon for multifamily buildings to have less than seven units.

Those interviewed generally recognize the inadequacies of the low-cost ventilation approach and appreciate the need for improved delivery of outside air. Penetrations through exterior walls are undesirable from an aesthetic perspective, but central supply ventilation systems (see

Figure **2** in Section 2.1.3.3 for an example strategy) are costly. Adding filters to passive vents essentially eliminates their airflow, making balanced systems the preferred choice for high ambient PM 2.5 areas. The decision to select a particular ventilation strategy is affected by a multitude of factors besides cost. One interviewee estimated that the cost for balanced ventilation would lie somewhere between the baseline cost and the cost of central ventilation.

Table 12 lists estimated incremental costs for each measure. Table 13 summarizes costs for two baseline ventilation approaches: individual exhaust fans with no makeup air, and central supply ventilation (common exhaust ducts or shafts) with no makeup air. The cost for a third approach, balanced ventilation using an HRV, is also provided.

As another alternative for balanced ventilation, the Statewide CASE Team estimated the cost for stand-alone ventilation supplied to the individual unit (see Figure 3), using RS Means, as follows:

- $183 for ductwork, assuming 30 feet of 6-inch flex duct. This assumes for a 29-foot x 29-foot unit, with some bends in the ductwork,
- $152 for the soffit.
- $100 for a smoke damper,
- $65 for a balancing damper,

This totals to $500 for the ventilation component of a strategy that provides stand-alone ventilation at the individual dwelling unit level. The cost for the exhaust system in this strategy is not included in this estimate, since all multifamily units must have exhaust fans to meet the 62.2-2016 local exhaust requirements.

Table 12 uses the ERV cost for balanced ventilation, because interviews and the literature indicated that ERVs are currently a more common approach for providing balanced ventilation than stand-alone ventilation. In addition, an ERV could reduce costs for an exhaust system if used as part of a local exhaust strategy.

Table 12: Summary of Estimated Incremental Costs for High Rise Multiple Family

Product Type	Description	Material Cost / Unit	Additional Labor Cost / Unit[a]	Total Cost / Unit Including Markup	Unit
Whole house ventilation fan	Based on airflow calculated in accordance with ASHRAE 62.2-2016	$5.87 single family (blended)	$0	$7.63	Each single family unit
Kitchen range hoods required to meet ASHRAE 62.2-2016 requirements[a]	HVI listed, at least one speed setting of ≤ 400 cfm or less having a noise level of ≤ three sones[1]	Assume no incremental cost; Ample products available that meet requirement	$0	$0.00	Each single family or multifamily unit
MERV 13 return air filter & grille (single family, 400 cfm/ton)	MERV 13 or better rating per ASHRAE Standard 52.2 or having a particle size efficiency of ≥85% in the 1.0 to 3.0- µm range per AHRI Standard 680-2009	$70 single family blended	Additional return required in some houses $121(blended)	$191	Each single family unit
Makeup Air Vent[b]	Based on a generic passive through-wall outdoor air inlet (cost estimated by interviewee)	Included in total cost	Included in total cost	$200	Each HRMF unit

Product Type	Description	Material Cost / Unit	Additional Labor Cost / Unit[a]	Total Cost / Unit Including Markup	Unit
Constant airflow regulator[b]	Based on Aldes CAR 4" MR Modulo Adjustable Flow Regulator, 10-50 CFM	$41	One hour	$97	Each HRMF unit
Exhaust shaft sealing[b]	Sealing using typical means employed for gypboard or ducts	Nominal	Four hours more than standard practice for sealing, plus four hours for testing leakage	$306	Each exhaust shaft (assume one per building)
Sealing of unit enclosure[b]	Sealing exterior and partition walls using similar techniques used for exterior walls	$10	$0.31 per ft^2 of conditioned floor area	$270	Each multifamily unit
HERS verification of compartmentalization	Blower door test to confirm unit has been sealed to 0.3 cfm50/sf of enclosure area	Nominal	$20/unit	$20	Each multifamily unit
Compact HRV[b]	HRV for multifamily units where balanced ventilation is selected	$507	Two hours	$945	Each unit
Compact HRV with MERV 13 filter	HRV for HRMF units requiring balanced ventilation and MERV 13 filtration	$1,195	Three hours	$1,600	Each HRMF unit

a. Addendum p to ASHRAE 62.2-2013 listed in ASHRAE 62.2-2016 clarifies that occupants that have typical sized range hoods (i.e., those with at least one speed setting 400 cfm) will have at least one speed setting rated 3 sones.

b. Not required, but can be used as a ventilation strategy for single family homes, or for low-rise or multifamily units.

Table 13: Estimated Incremental Costs for Proposed Measures for Each New Construction Prototype

Measure	Single Family	Low-Rise Multifamily	High-Rise Multifamily (per unit[a])		
			Exhaust Ventilation, Distributed	Exhaust Ventilation, Central	Balanced Ventilation
Exhaust Fan	$8[b]				
MERV 13 Filter & Grille for 2" Filter	$191	$15	$78	$78	$78
Passive Makeup Air Vent			$200	$200	
Seal Partition Walls		$270	$270	$270	$270
HERS Verification of Compartmentalization		$20	$20	$20	$20
Constant Airflow Regulator				$97	
Central Exhaust Sealing[b]				$10	
Balanced with MERV 13					$1,600[c]
TOTAL	**$199**	**$305**	**$568**	**$675**	**$1,968**

a. Per unit cost for 30 units.

b. Incremental cost for larger fan that meets 62.2-2016 ventilation rate requirement.

c. For an ERV with lower filtration, the cost is lower. For example, for a compact ERV ($945), the total cost is $1,313.

5.3 Lifetime Incremental Maintenance Costs

The incremental cost of annual filter replacement is not included in the cost estimating tables. If the frequency of filter replacement is the same for MERV 6 or 8 and MERV 13 filters, then the incremental cost of replacement (blended for the two prototypes) is estimated to be $18.25 (not including labor or markups).

Because the proposed measures generally do not provide energy savings, lifecycle costs are not calculated and other maintenance costs are not reported. One advantage of central ventilation systems is that there are fewer fans to maintain, but as described above, there are many factors and cost tradeoffs involved in the decision of which system type to use.

5.4 Lifecycle Cost-Effectiveness

Individually, the proposed measures are not cost-effective, because they do not save energy; therefore, lifecycle cost-effectiveness is not reported. However, they are necessary for the maintenance of IAQ.

6. First-Year Statewide Impacts

6.1 Statewide Energy Savings and Lifecycle Energy Cost Savings

Statewide energy savings are not reported for this group of measures. Refer to other CASE Reports, which report on the net savings from energy-saving measures and energy costs related to increased ventilation rates.

6.2 Statewide Water Use Impacts

The proposed code change will not result in water savings.

6.3 Statewide Material Impacts

The proposed code change will not result in impacts to toxic materials or materials.

6.4 Other Non-Energy Impacts

Implementation of the proposed measures will result in significant improvements to IAQ for all dwelling units. In particular, indoor PM 2.5 will be reduced because of increased filtration requirements. While the Energy Commission has stated that indoor IAQ measures do not have to be cost-effective, various studies have found that reduced PM 2.5 leads to an increase in health outcomes (reduced mortality), and the resulting economic benefit of these health improvements outweigh the cost of the measures. For example, one study used modeling to estimate health benefits of different levels of filtration (including MERV 12 and MERV 14) on recirculation filters in single family homes for various U.S. cities (Zhao 2015). After accounting for the fractional runtime, for MERV 12 recirculation filters compared with MERV 5, the study estimated annual per-person benefits of $10-$200 for San Francisco and $15-$300 for Los Angeles. Recirculation filters in homes with exhaust-only systems produced lower benefits ($10-$25 for San Francisco, $15-$40 for Los Angeles), than homes with supply-only and central fan integrated systems ($50-$200 for San Francisco, $75-$300 for Los Angeles), because an exhaust-only strategy removes much of the PM 2.5 entering the home (thereby reducing PM 2.5 removal from recirculation filters). For an exhaust-only system, assuming 2.5 people per household based on census data, this translates into approximately $25-$63 per home for San Francisco and $38-$100 per home for Los Angeles. Another study (Fisk 2017) modeled the impact of using high efficiency particulate air (HEPA) filters in homes and found reduced mortality of 0.25 to 2.4 per 10,000 population, and that the economic benefits always exceeded costs (benefit to cost ratios ranging from 3.9 to 133). While this study assumed HEPA filters (essentially 100 percent efficient) and assumed a higher rate of operation (30 to 40 percent of the time) than may be found for air passing through recirculation filters in California homes, the results indicate that health outcomes could outweigh, or at least significantly offset, the additional costs of increased filtration. PM 2.5 reductions would also be seen in HRMF units that use MERV 13 filtration for outside air.

Reduction of indoor humidity due to increased ventilation will also lower the potential for mold accumulation and moisture damage to walls, and will reduce dust mite populations, which are known to cause allergic reactions.

For multifamily units, the requirement for compartmentalization will improve IAQ through reduced pollutant transfer. See section 2.2.1.2 for results of studies showing reduction of pollutant transfer after air sealing multifamily units.

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).

7.1 Standards

7.1.1 Title 24, Part 2 (California Building Code)

SECTION 1203 – INTERIOR ENVIRONMENT

1203.1: Buildings shall be provided with natural ventilation in accordance with Section 1203.4, or mechanical ventilation in accordance with the California Mechanical Code. <u>All occupancies defined as Group R-2 and R-3 under Sections 310.4 and 310.5 shall meet the ventilation requirements of Title 24, Part 6.</u>

7.1.2 Title 24, Part 4 (California Mechanical Code)

SECTION 402 – VENTILATION AIR

402.1.2 Dwelling. Requirements for ventilation air rate for single family <u>and multifamily</u> dwellings, <u>including high-rise,</u> shall be in accordance with ~~this chapter or~~ the version of ASHRAE 62.2 <u>that is referenced by Title 24, Part 6. Other provisions of Chapter 4 do not apply to these occupancy types.</u>

CHAPTER 7 – COMBUSTION AIR

701.4 Indoor Combustion Air. The required volume of indoor air shall be determined in accordance with the method in Section 701.4.1 or Section 701.4.2, except that where the air infiltration rate is known to be less than 0.40 ACH (air change per hour), the method in Section 701.4.2 shall be used. The total required volume shall be the sum of the required volume calculated for appliances located within the space. Rooms communicating directly with the space in which the appliances are installed through openings not furnished with doors, and through combustion air openings sized and located in accordance with Section 701.5, are considered a part of the required volume. [NFPA 54:9 .3 .2] <u>In new residential buildings or residential additions, the use of indoor air is prohibited for open combustion space conditioning, water heating and pool heating appliances.</u>

701.6 Outdoor Combustion Air. Outdoor combustion air shall be provided through opening(s) to the outdoors in accordance with the methods in Section 701.6.1 or Section 701.6.2. . <u>Open combustion space conditioning, water heating and pool heating appliances in new construction residential buildings or residential additions</u> <u>shall be installed in accordance with the method in Section 701.6.3.</u> The dimension of air openings shall be not less than 3 inches (76 mm). [NFPA 54:9.3.3]

…

> <u>**701.6.3 Residential New Construction and Additions – Combustion Air Separation from Conditioned Space.** Open combustion space conditioning, water heating and pool heating appliances in residential new construction and residential additions, shall be located outside the building envelope or in an enclosure that is isolated from conditioned space inside the building envelope. Such enclosures shall be sealed and insulated in accordance with the exterior envelope requirements of Title 24, Part 6. All access openings to the enclosure shall be fully gasketed. All openings to the enclosure shall be fully sealed and insulated in accordance with the requirements of Title 24, Part 6, appropriate for the building type. Combustion air ducts passing through conditioned spaces shall be insulated to a minimum of R-8.</u>
>
> <u>**Exception to 701.6.3:**</u> <u>Direct vent appliances with both intakes and exhausts installed continuous to the outside.</u>

APPENDIX E – SUSTAINABLE PRACTICES

E 605.0 Indoor Air Quality for Residential Buildings.

E 605.1 General. Rooms or occupied spaces within single family homes, ~~and~~ low-rise multifamily structures of three stories or less above grade, and high-rise multifamily structures shall be designed to have ventilation (outdoor) air for occupants in accordance with ~~Section E 605.1.1 through Section E 605.1.3.2, or the applicable local code.~~ Title 24 Part 6, Section 150.0(o).

[Strike all other subsections under E 605]

7.1.3 Title 24, Part 6

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

(b) Definitions.

ASHRAE STANDARD 62.2 is the American Society of Heating, Refrigerating and Air-Conditioning Engineers document titled "Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings," 2016~~0~~ (ANSI/ASHRAE Standard 62.2-2016~~0~~ with Addenda k, l, q, and s ~~including ANSI/ASHRAE Addenda b, c, e, g, h, i and l to ANSI/ASHRAE 62.2-2010 published in the 2011 supplement, and ANSI/ASHRAE Addendum j to ANSI/ASHRAE Standard 62.2-2010 published in March, 2012, and ANSI/ASHRAE Addendum n to ANSI/ASHRAE Standard 62.2-2010~~ published in ~~February, 2012~~ November, 2016).

SECTION 120.1 – REQUIREMENTS FOR VENTILATION

Nonresidential~~, high-rise residential,~~ and hotel/motel buildings shall comply with the requirements of ~~Section 120.1(a) through 120.1(e)~~ this section and the California Building Code.

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

EXCEPTION 2 to Section 120.1(a)1: Mechanical ventilation for all residential buildings, including those defined as Group R-2 and R-3 occupancies under California Building Code Part 2, Volume 1, Sections 310.4 and 310.5 will be provided as specified by Section 150.0(o).

~~**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.~~

120.1(b)3: Central exhaust shafts and ducts. Central exhaust shafts and ducts in high-rise multifamily buildings shall meet the following requirements, which shall be confirmed by field verification:

A. Shaft and/or ducts and branches shall be sealed to ten percent or less of the measured fan airflow of the powered rooftop ventilator.

B. Airflow exhausted from individual units shall be balanced to within ten percent of design airflow.

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~~Section 150.0(o)
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

SECTION 120.4 – REQUIREMENTS FOR AIR DISTRIBUTION SYSTEM DUCTS AND PLENUMS

EXCEPTION to 120.4: Central exhaust shafts in high-rise multifamily buildings shall comply with the applicable requirements of Section 120.4, except that they must be sealed to ten percent or less leakage of measured fan airflow of the powered roof ventilator, as measured in accordance with NA2.1.4.2.

SECTION 120.5 – REQUIRED NONRESIDENTIAL MECHANICAL SYSTEM ACCEPTANCE

120.5(a): 18. Filters for high-rise multifamily mechanical systems shall meet the requirements of 150.0(m)12B.

SECTION 150.0 – MANDATORY FEATURES AND DEVICES

(e) **Installation of Fireplaces, Decorative Gas Appliances and Gas Logs**

1. If a masonry or factory-built fireplace is installed, it shall have the following:
   A. Closeable metal or glass doors covering the entire opening of the firebox; and
   B. A combustion air intake to draw air from the outside of the building, which is at least 6 square inches in area and is equipped with a readily accessible, operable, and tight-fitting damper or combustion-air control device; and

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

(h) **Space-Conditioning Equipment.**

…

5. Combustion air. Open combustion fuel burning equipment shall be located outside of the conditioned building envelope, or enclosed in an unconditioned room isolated from conditioned spaces by an envelope that meets the exterior envelope requirements of Section 150.1(c). The door into the isolated room shall be fully gasketed. The combustion air ducts shall meet the combustion air requirements of the CMC and combustion air ducts passing through conditioned spaces shall be insulated to a minimum of R-8.

EXCEPTION to Section 150.0(h)5: Direct vent appliances with both intakes and exhausts installed continuous to the outside.

(m) **Air-Distribution and Ventilation System Ducts, Plenums, and Fans.**

…

12. **Air Filtration.** Mechanical systems that supply air to an occupiable space through ductwork exceeding 10 ft (3 m) in length and through a thermal conditioning component, except evaporative coolers, shall be provided with air filter devices in accordance with the following:

…

B. Air Filter Media Efficiency. The system shall be provided with air filter media having a designated efficiency equal to or greater than MERV ~~6~~ 13 when tested in accordance with ASHRAE Standard 52.2, or a particle size efficiency rating equal to or greater than 85 percent in the ~~3.0-10~~ 1.0-3.0 μm range when tested in accordance with AHRI Standard 680-2009. (Note: This is a modification of ASHRAE 62.2-2016 which requires MERV 6 or greater.)

…

150.0(m)14: Air Filter Media Efficiency for Outdoor Air. Air filter media used with outdoor air ventilation systems shall comply with the MERV ratings listed in Table 150.0-A. The AHRI Standard 680 equivalent to MERV 8 is 70 percent in the 3.0 to 10.0 μm range. [Note that tables following Table 150.0-A must be re-numbered].

TABLE 150.0-A FILTER MEDIA REQUIREMENTS FOR OUTDOOR AIR VENTILATION SYSTEMS

Unit Type and Ventilation Strategy	>500 ft of Busy Roadway (AADT≥100,000)	≤ 500 ft of Busy Roadway (AADT<100,000)
Single Family and Low-rise Multifamily		
Exhaust-only	NR	NR
Supply only	8	13
Balanced	8	8
High-rise Multifamily		
Exhaust-only with passive vents	NR	NR
Supply only with relieve vent	8	13
Balanced	8	13

Note: AADT is annual average daily traffic

(n) **Water Heating System**.

…

5. Combustion air. Open combustion fuel burning equipment shall be located outside of the conditioned building envelope, or enclosed in an unconditioned room isolated from conditioned spaces by an envelope that meets the exterior envelope requirements of Section 150.1(c). The door into the isolated room shall be fully gasketed. The combustion air ducts shall meet the combustion air requirements of the CMC and combustion air ducts passing through conditioned spaces shall be insulated to a minimum of R-8.

EXCEPTION to Section 150.0(n)5: Direct vent appliances with both intakes and exhausts installed continuous to the outside.

150.0(o): Ventilation for Indoor Air Quality. All dwelling units shall meet the requirements of the currently referenced version of ASHRAE Standard 62.2, with the following modifications and additional requirements specified in this section. ~~Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings~~.

150.0(o) 1. Infiltration Rate Adjustment to Ventilation Rates. For single family dwellings, if no blower door measurement is available the required mechanical ventilation rate shall be determined by applying the ASHRAE Standard 62.2 calculation using an infiltration rate based on 2 ACH50. If a blower door measurement is completed and leakage is less than 2 ACH50, the measured leakage shall be used to determine the mechanical ventilation rate. If a blower door measurement is completed and exceeds 2 ACH50, than the 2 ACH50 assumption will be used to calculate the mechanical ventilation rate.

150.0(o) 2. Central Fan System Ventilation.: High rise multifamily units may use continuous operation of central forced air system air handlers in central fan integrated ventilation systems for meeting the whole-unit ventilation requirement, if they have variable speed fans and controls that vary the airflow rate as a function of load. These systems can be central to the dwelling unit or to the building.

150.0(o)3. Ventilation Air Rates: In meeting the dwelling unit ventilation rate,

Qtotal = 0.03 x A + 7.5 x (number of bedrooms + 1),

where A = conditioned floor area (square feet).

For all multifamily units (low-rise and high-rise) except townhouses, infiltration cannot be used to meet Qtotal, and units must follow Section A or B for meeting the whole dwelling ventilation rate. High-rise multifamily dwelling units within 500 feet of a busy roadway - defined as having annual average daily traffic (AADT) greater than 100,000 must follow B:

A. Passively provided supply air.

i. For units following this pathway, the total mechanical ventilation rate equals the total ventilation rate: Qfan = Qtotal.

ii. High-rise multifamily units must meet the following additional requirements:

a. Supply air must be delivered through a dedicated inlet and coupled with mechanical exhaust - such as continuous or scheduled intermittent exhaust.
b. Airflow to individual units served by central exhaust shafts shall be balanced to within 10 percent of design airflow using either constant air regulation devices, manual dampers, or orifice plates.
c. Units must meet prescriptive compartmentalization requirements

OR

B. Provide mechanically driven, filtered supply air.

i. For balanced systems, the total mechanical ventilation rate must be at least 85 percent of the total ventilation rate: Qfan = 0.85 x Qtotal from Equation 1.

ii. For supply-only systems, the total mechanical ventilation rate shall be Qtotal from Equation 1.

iii. Supply air shall be passed through a filter meeting the requirements of Table 150.0-A.

~~1.~~ 4. Field Verification and Diagnostic Testing.

A. Airflow Performance: The Whole-Building Ventilation airflow required by Section 4 of ASHRAE Standard 62.2-2016 shall be confirmed through field verification and diagnostic testing in accordance with the applicable procedures specified in Reference Residential Appendix RA3.7

B. Kitchen Exhaust Ventilation. An HVI-Certified kitchen hood or fan with a valid HVI label shall be installed in each kitchen to provide local mechanical exhaust ventilation to meet the requirements of Sections 5 and 7 of ASHRAE Standard 62.2-2016 and shall directly exhaust to the exterior of the building, which shall be confirmed by HERS verification.

C. Compartmentalization in Multifamily Dwelling Units: All new construction multifamily dwelling units must air seal the dwelling unit envelope, including partitions with interior and exterior areas, to a maximum leakage of 0.3 cfm per square foot of dwelling unit enclosure area, as confirmed through field verification and diagnostic testing in accordance with Reference Residential Appendix RA3.8.

(p) **Pool Systems and Equipment Installation.** Any residential pool system or equipment installed shall comply with the applicable requirements of Section 110.4, as well as the requirements listed in this section.

…

5. Combustion air. Open combustion fuel burning appliances shall be located outside of the conditioned building envelope, or enclosed in an unconditioned room isolated from conditioned spaces by an envelope that meets the exterior envelope requirements of Section 150.1(c). The door into the isolated room shall be fully gasketed. The combustion air ducts shall meet the combustion air requirements of the CMC and combustion air ducts passing through conditioned spaces shall be insulated to a minimum of R-8.

EXCEPTION to Section 150.0(p)5: Direct vent appliances with both intakes and exhausts installed continuous to the outside.

SECTION 150.2 – ENERGY EFFICIENCY STANDARDS FOR ADDITIONS AND ALTERATIONS TO EXISTING LOW-RISE RESIDENTIAL BUILDINGS

(a) **Additions.** Additions to existing low-rise residential buildings shall meet the requirements of Sections 110.0 through 110.9, Sections 150.0(a) through (q), and either Section 150.2(a)1 or 2.

…

(b) **Alterations.** Alterations to existing low-rise residential buildings or alterations in conjunction with a change in building occupancy to a low-rise residential occupancy shall meet either Item 1 or 2 below.

1. **Prescriptive approach.** The altered component and any newly installed equipment serving the alteration shall meet the applicable requirements of Sections 110.0 through 110.9 and all applicable requirements of Section 150.0(a) through (m), Section 150.0(o) through (q); and…

2. **Performance approach.** This performance approach shall only be used for projects that include tradeoffs between two or more altered components that are listed in TABLE 150.2-C.

NOTE: The altered components may be components of the same type, such as a tradeoff between two windows, or components of differing types, such as a tradeoff between a window and an amount of attic insulation.

A. The altered components shall meet the applicable requirements of Sections 110.0 through 110.9 and Section 150.0(a) through (q); and …

…

EXCEPTION 4 to Section 150.2(b): Combustion Air. The requirements of Section150.0(h)5, 150.0(n)5, and 150.0(p)5 are not applicable to Section 150.2(b).

7.2 Reference Appendices

7.2.1 JOINT APPENDIX 1 – GLOSSARY

ASHRAE STANDARD 62.2 is the American Society of Heating, Refrigerating and Air-Conditioning Engineers document titled "Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings," 2016~~0~~ (ANSI/ASHRAE Standard 62.2-2016~~0~~ with Addenda k, l, q, and s ~~including ANSI/ASHRAE Addenda b, c, e, g, h, i and l to ANSI/ASHRAE 62.2-2010 published in the 2011 supplement, and ANSI/ASHRAE Addendum j to ANSI/ASHRAE Standard 62.2-2010 published in March, 2012, and ANSI/ASHRAE Addendum n to ANSI/ASHRAE Standard 62.2-2010~~ published in ~~February, 2012~~ November, 2016).

HVI is the Home Ventilating Institute.

HVI-Certified product is a home ventilation product, which has been tested and certified by HVI in accordance with HVI Publication 920, is labelled in accordance with HVI Publication 925, and is listed in HVI Publication 911.

HVI Publication 911 is the HVI document titled “Certified Home Ventilating Products Directory”, which is a directory of residential ventilation products updated monthly by HVI. All models listed in HVI Publication 911 have been tested according to HVI procedures and have been found to qualify based on the requirements of HVI Publication 920.

HVI Publication 920 is the HVI document titled “Product Performance Certification Procedure Including Verification and Challenge,” which provides product testing, certification, and challenge procedures and the use of labels for HCI-Certified home ventilating products.

HVI Publication 925 is the HVI document titled “Label and Logo Requirements,” which identifies labels and specifies appropriate uses and placements of labels for HVI-Certified home ventilating products.

7.2.2 RESIDENTIAL APPENDIX 2 – RESIDENTIAL HERS VERIFICATION, TESTING, AND DOCUMENTATION PROCEDURES

Table RA2-1 - Summary of Measures Requiring Field Verification and Diagnostic Testing

Measure Title	Description	Procedure(s)
Continuous Whole-Building Mechanical Ventilation Airflow	Measurement of whole-building mechanical ventilation is mandatory for newly constructed buildings.	RA3.7.4.1
Intermittent Whole-Building Mechanical Ventilation Airflow	Measurement of whole-building mechanical ventilation is mandatory for newly constructed buildings.	RA3.7.4.2
Kitchen Exhaust Verification	Verifying compliance of kitchen exhaust hoods and fans with the local exhaust requirements of ASHRAE Standard 62.2.	RA3.7.4.3
Blower Door Test in Multifamily Units	Verifying compliance with compartmentalization requirement in multifamily dwelling units	RA3.8 for procedure, RA2.6.3 for sampling

RA2.3.1.2 Documentation Registration: For all low-rise and high-rise residential buildings for which compliance requires HERS field verification, all compliance documentation (Certificate of Compliance,

Certificate of Installation, and Certificate of Verification) required for the dwelling unit shall be submitted for registration and retention to a HERS Provider data registry.

7.2.3 RESIDENTIAL APPENDIX 3 – RESIDENTIAL FIELD VERIFICATION AND DIAGNOSTIC TEST PROTOCOLS

Table RA3.7-1 - Summary of Verification and Diagnostic Procedures

Diagnostic	Description	Procedure
Whole-Building Mechanical Ventilation Airflow – Continuous Operation	Verify that whole-building ventilation system complies with the airflow rate required by ASHRAE Standard 62.2.	RA3.7.4.1 ~~Continuous Operation~~
Whole-Building Mechanical Ventilation Airflow – Intermittent Operation	Verify that whole-building ventilation system complies with the airflow rate required by ASHRAE Standard 62.2.	RA3.7.4.2. ~~Intermittent Operation~~
Blower Door Test Procedure in Multifamily	Procedure for conducting blower door test in multifamily units to demonstrate compliance with compartmentalization requirement	RA3.8 for procedure, RA2.6.3 for sampling
Kitchen Exhaust Verification	Verify that kitchen exhaust complies with the requirements of ASHRAE Standard 62.2.	RA3.7.4.3

RA3.7.4.3 Kitchen Exhaust Fan Verification:

Visual inspection of the kitchen exhaust hood or fan used to meet the local exhaust requirements of 100 cfm shall verify the presence of a label on the exhaust hood or fan indicating that it is an HVI-Certified product. The manufacturer name and model number from the label will be used to look up the unit in HVI Publication 911. Data from this listing will be used to determine whether the fan or hood meets the minimum airflow rate of 100 cfm and maximum sound level of three (3) sones. If the listed airflow is less than required, the kitchen exhaust does not comply, and corrective action shall be taken. If the listed noise level rate is equal to or less than the value required by Section 7 of ASHRAE Standard 62.2, the kitchen exhaust ventilation complies with the requirement for kitchen exhaust ventilation airflow. If the listed noise level is greater than required, the kitchen exhaust does not comply, and corrective action shall be taken.

RA3.7.4.4 Procedures for Verifying Ventilation Airflow Rates in High-rise Multifamily Buildings

The Executive Director may approve exhaust, supply, and balanced mechanical ventilation systems, devices, or controls for use for compliance with the HERS Rater field verification and diagnostic testing requirement for mechanical ventilation airflow in high-rise multifamily buildings, subject to a manufacturer providing sufficient evidence to the Executive Director that the installed mechanical ventilation systems, devices, or controls will provide at least the minimum whole-building ventilation airflow required by ASHRAE Standard 62.2, and subject to consideration of the manufacturer's proposed field verification and diagnostic test protocol for these ventilation system(s).

Approved systems, devices, or controls, and field verification and diagnostic test protocols for all exhaust ventilation Systems Supply Ventilation Systems shall be listed in directories published by the Energy Commission.

7.2.4 NONRESIDENTIAL APPENDIX 2

NA2.2.1 Purpose and Scope

1. NA2.1 contains procedures for field verification and diagnostic testing for air leakage in single zone, constant volume, nonresidential air distribution systems serving zones with 5000 ft² of conditioned floor area or less as required by Standards section 140.4(l), as well as central exhaust shaft and duct systems that exhaust air from more than one unit in high-rise multifamily buildings.

NA2.1.4.2.1 Diagnostic Duct Leakage from Fan Pressurization of Ducts

(a) 4. When testing central exhaust shafts in multifamily buildings ensure that the shaft and ducts are sealed to allow leakage of not more than ten percent of the powered rooftop ventilator airflow.

7.3 ACM Reference Manual

7.3.1 Residential ACM Reference Manual

Subsection 2.4.9: The proposed regulations will substantially change the algorithms applied for calculation requirement minimum ventilation airflow rates. This section will be revised to include the calculation method for Q_{total}, Q_{infil}, and Q_{fan} as described in Section 2.1 of this report.

7.3.2 Nonresidential ACM Reference Manual

The proposed regulations will substantially change the algorithms applied for calculation requirement minimum ventilation airflow rates for HRMF buildings. Section 2.7 of the Nonresidential ACM Reference Manual will refer to the requirements of Section 150.0(o) the BEES.

7.4 Compliance Manuals

Revisions will be made to Chapters 1, 2, 3, 4, and 9 of the Residential Compliance Manual as follows:

Section 1.5: Add high-rise multifamily buildings to the list of building types covered by ventilation standards.

Section 2.2.8: Add kitchen hoods and HRMF central exhaust shafts to the list of measures requiring field verification.

Section 2.5.1: Add kitchen hoods and multifamily IAQ measures (central exhaust shaft pressure test, exhaust balancing test, and makeup air vents) to the measures list for field verification.

Section 3.5.8.9: Clarify operable windows cannot be used to meet whole house ventilation requirements.

Section 3.6.1.17: Add paragraph describing method of determining mechanical ventilation rate.

Section 4.1.2: Add changes to 62.2 requirements to “What’s New” section.

Section 4.6: Update requirement for high efficiency filters from MERV 6 to MERV 13 where required (introduction and 4.6.6.8), revise reference to ASHRAE 62.2 and discuss high-rise residential applications, describe method for selecting mechanical ventilation rate (4.6.3.1), update section on intermittent ventilation (4.6.3.2), describe verification process for kitchen hoods (4.6.5), describe requirements for makeup air and shaft sealing (4.6.6, 4.6.6.9), add to requirements for ventilation fans, including ENERGY STAR and humidity control requirements currently in Title 24, Part 11.

Section 9: Describe what triggers requirement for kitchen hood verification (9.4.2, 9.4.3).

Section 4.3 of the Nonresidential Manual will be modified to clarify that ventilation for indoor air quality for R-2 and R-3 occupancies is covered by the Residential Manual. Documents Forms.

7.5 Compliance Documents

The following documents will require revisions as follows:

- CF2R & CF3R-MCH-27 – Checklist items will be added for verification of ventilation in HRMF unit types, and a new section will be added for kitchen hood verification.
- Revisions to Nonresidential forms will be required for sealing of HRMF partition walls, and sealing and testing air tightness of central exhaust shafts.

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Appendix A: Statewide Savings Methodology

The IAQ measures are not intended to save energy, therefore, the Statewide CASE Team did not estimate statewide impacts. However, the Statewide CASE Team did evaluate first year energy impacts for new single family and multifamily buildings that comply with the proposed 2019 Title 24, Part 6 Standards.

Appendix B: SUPPORTING INFORMATION FOR MULTIFAMILY VENTILATION MEASURES

Rationale for Areas Requiring HRMF Balanced Ventilation and MERV 13 Filtration

In identifying areas with high ambient PM 2.5, the Statewide CASE Team considered proximity to busy roadways, and PM 2.5 nonattainment zones, as classified by the Environmental Protection Agency (EPA). This section describes the rationale for the final recommendations for mechanically driven supply air and MERV 13 filtration for high-rise residential buildings within 500 feet of roadways with at least 100,000 annual average daily traffic (AADT), and in identifying areas with high ambient PM 2.5, the Statewide CASE Team considered proximity to busy roadways, and PM 2.5 nonattainment zones, as classified by the Environmental Protection Agency (EPA). This section describes the rationale for the final recommendations for mechanically driven supply air and MERV 13 filtration for high-rise residential buildings within 500 feet of roadways with at least 100,000 AADT.

High-rise residential buildings within 500 feet of a busy roadway (≥ 100,000 AADT)

Various studies show health effects in occupants living close to freeways. The San Francisco Indicator Project reported, "Epidemiologic studies have consistently found that proximity to high traffic density or flow results in reduced lung function and increased asthma hospitalizations, asthma symptoms, bronchitis symptoms, and medical visits. Children appear to be most sensitive to adverse effects. California freeway studies show exposure levels are strongest within 300 feet, and that there is a 70 percent drop off in particulate pollution levels after 500 feet."[31] A 2017 Los Angeles Times article reported that people living within 500 feet of a freeway suffer higher rates of asthma, heart attacks, strokes, lung cancer, and pre-term births, citing long-terms studies to support these health claims (Barboza 2017). Air quality researchers interviewed reported that the Air Resources Board recommends no residential development within 500 feet of a freeway. Several cities (including San Francisco and Los Angeles) have a requirement for MERV 13 filtration near freeways.

Based on these findings, the Statewide CASE Team recommends that mechanically driven supply air with MERV 13 filtration be required within 500 feet of a busy roadway. To define "busy roadway", the Statewide CASE Team used the definition from San Francisco Article 38, which requires MERV 13 for residential buildings within 500 feet of roadways with at least 100,000 AADT for urban areas, and at least 50,000 AADT in rural areas. Because the Statewide CASE Team anticipates that almost all high-rise residential buildings will be developed in urban areas, we used the urban area minimum of 100,000 AADT. The Statewide CASE Team recommends that the Residential Compliance Manual provide a link to California Department of Transportation (CalDOT) websites showing AADT data.

High-rise residential buildings in PM 2.5 nonattainment areas

The EPA designates areas as in attainment or nonattainment with its ambient air quality standards. There are two PM 2.5 standards in effect:

1. An annual PM 2.5 standard implemented in 2012: 12 ug/m^3
2. A 24-hour PM 2.5 standard implemented in 2006: 35 ug/m^3

[31] http://www.sfindicatorproject.org/objectives/standards/55

The SCAQMD Air Quality Management Plan predicts that the SCAQMD will be in attainment with the 24-hour standard in 2019, and with the annual standard by approximately 2023 (and no later than 2025) (SCAQMD 2016). One of the air quality specialists interviewed reported that attainment is not always reached as projected in the air quality management plans. However, as shown in Figure 6 SCAQMD measurements indicate that PM 2.5 levels are generally declining and are only slightly higher (~15-20 percent) than the PM 2.5 standards. The SCAQMD predicts that no actions will need to be taken to meet the PM 2.5 standards by the attainment years identified. The SCAQMD will need to take action to meet the ozone standards, and several of the ozone mitigation measures will also reduce PM 2.5 (SCAQMD 2016).

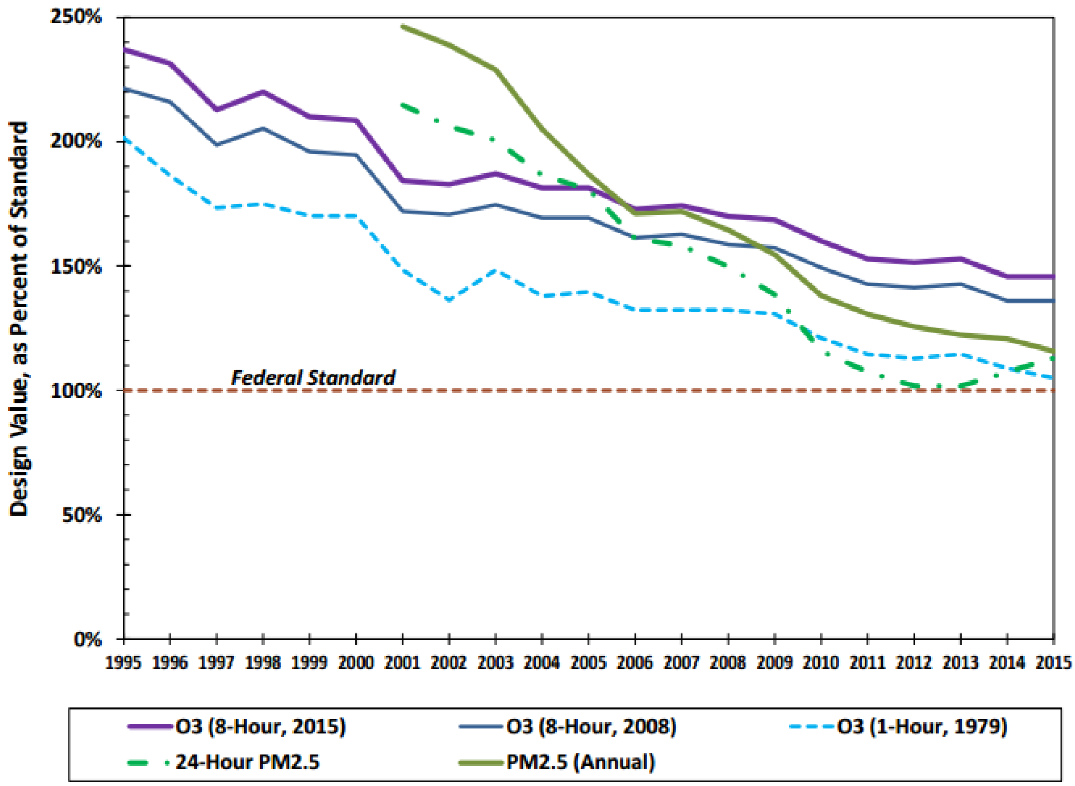


Figure 6: SCAQMD Ozone design values in percentages of the federal standards.

Source: SCAQMD 2016

Table 14 shows areas of California in nonattainment with one or both of annual and 24-hour standards. This table also includes the EPA's population estimate for the nonattainment area, which the EPA provides based on 2010 populations. As shown in the table, half of the state is nonattainment with the annual standard, and approximately three-fourths of the state is listed as in nonattainment with the 24-hour standard. However, monitoring data for the Bay Area shows that it is in attainment, but the BAAQD musts submit a redesignation request and maintenance plan to the EPA to be removed from the nonattainment list.[32] Similarly, although the EPA Greenbook lists Sacramento as a nonattainment area, Sacramento was determined in attainment with the 24-hour standard in 2013. [33]

[32] From footnote 10, on http://www.baaqmd.gov/research-and-data/air-quality-standards-and-attainment-status

[33] https://www3.epa.gov/region9/air/actions/sacto/index.html

PM 2.5 levels in the San Joaquin Valley have also been declining. Although the California Statewide Implementation Plan (SIP) calls out the San Joaquin Valley PM 2.5 exceedances as one of the greatest challenges for the State in meeting its EPA standards (Air Resources Board 2017), this region also has an attainment date of 2025 for the annual PM 2.5 standard. In summary, the results of Table 14, as well as the literature review indicate that PM 2.5 levels are generally in attainment for the Bay Area and Sacramento, and in nonattainment, but improving in the SCAQMD and the San Joaquin Valley.

It is important to note that requiring MERV 13 filtration on balanced and supply-only systems, while allowing exhaust-only ventilation, would likely further encourage the use of exhaust-only strategies. As shown in Table 6, there is a significant cost increase for ERVs with MERV 13 filtration ($1,588) compared with ERVs with lower MERV (e.g., $1,055 for Lunos, with MERV 10). The Statewide CASE Team believes that a requirement for MERV 13 filtration on outside air, without a prohibition of exhaust-only systems, will further encourage the use of exhaust-only ventilation strategies, because it is the much cheaper option. This could cause worse IAQ, because of reduced outdoor air delivery and increased pollutant transfer between units. In units with passive vents, such as many HRMF units, this could lead to significant introduction of PM2.5 in areas of high ambient PM2.5.

Table 14: PM 2.5 Standards Attainment Status for California Regions

	Annual (2012) PM 2.5 Std		24-hour (2006) PM 2.5 Std		
Area Description	**Attainment Status**	**Population in Nonattainment Area (Millions)**	**Attainment Status**	**Population in Nonattainment Area (Millions)**	**Comment**
Bay Area Air Quality Management District (BAAQMD)	Attainment	N/A	Nonattainment listing	7.0	Listed as nonattainment, but measurements show attainment.
Sacramento	Attainment	N/A	Nonattainment listing	2.2	Listed as nonattainment, but EPA determined in attainment in 2013.
South Coast Air Quality District (SCAQMD)	Nonattainment	15.7	Nonattainment	15.7	Projected to be in attainment with 24-hr std in 2019, and with annual std in 2025.
San Joaquin Valley	Nonattainment	2.9	Nonattainment	3.8	More counties in nonattainment with the 24-hour than annual standard. No attainment year found in literature reviewed.
Other Areas of CA	Generally Attainment	0.006	Generally Attainment	0.4	Part of Plumas County in nonattainment with Annual std, and parts of Chico and Imperial Counties in nonattainment with 24-hour std.
Total Population in Nonattainment Area		**18.6 (50% of CA total)**		**29.1 (78% of CA total)**	**Assumes 37 Million people in CA, based on U.S. Census data for 2010.**

Due to the challenges of providing mechanically driven supply air and MERV 13 filtration, including a high incremental cost, training of the building industry for proper design and construction, and the low availability of HRV products with MERV 13 filtration, the Statewide CASE Team proposes limiting the scope of this requirement to where outdoor PM 2.5 levels are most egregious.

- As described above, there is strong evidence that outdoor PM2.5 levels near busy roadways pose the greatest risk for ambient PM2.5, particularly beginning in the mid 2020's.
- While there is concern about PM2.5 penetration in low-rise multifamily units, the risk is lower for these units because the predominant ventilation strategy is exhaust-only with infiltration used as make-up air, rather than passive vents.

Consequently, the Statewide CASE Team proposes applying this requirement only to high-rise residential buildings of California within 500 feet of a busy roadway (defined above).

Development of 0.85 Factor for Balanced Multifamily Ventilation Rate

This section describes the rates that were considered for developing the 0.85 factor for balanced ventilation for multifamily units.

Table 15 lists ventilation rates that are currently in use and have been proposed, as well as estimates of airflow through passive vents using an exhaust-only + passive vent strategy.

The Statewide CASE Team developed ventilation rates under different HRMF configurations (different areas and numbers of bedrooms) to develop, which compares the proposed rate for balanced ventilation systems with other rates. The 0.85 factor was designed to be significantly higher than the current and proposed rates with passive vents, and higher than the 62.2-2010 rates. Table 16 presents rates for example HRMF units under the current and proposed rates, with and without the 0.85 factor.

Table 15: Description of Ventilation Rates in Past, Current, and Proposed Standards for High-Rise Multifamily Units

Description of Rate	Rate Calculation
Proposed for balanced: 62.2-2016 x 0.85	Rate that is being proposed for HRMF units with balanced ventilation. This rate is higher than the estimated airflow rate through passive vents (36% of design) and higher than the previous rate for low-rise (62.2-2010), but lower than proposed rates for unbalanced systems (from 62-2016). The proposed rate for balanced of 0.85 x [7.5 x (BR+1)+0.03 cfm/ft^2 x A] also results in similar rates in a proposed amendment to 62.2-2016, to change the ventilation rate for all dwelling units to 7.5 cfm x (BR + 1) + 0.022 cfm/ft^2 x A. The proposed amendment was supported by a majority of 62.2 members, but not the supermajority needed for publication and public review.
Current (from 62.1-2007)	Rate that HRMF units currently follow, based on 62.1-2007: 5 cfm *(BR + 1) + 0.06cfm/ft2 x A.
Proposed (62.2-2016)	Rate that is being proposed for HRMF units, to align with low-rise ventilation requirement: 62.2-2016: 7.5 cfm x (BR + 1) + 0.03 cfm/ft^2 *A.
Estimate of current (62.1-2007) rate through passive vents	Estimate of how much air actually enters passive vents under current rates (62.1-2007). Assumes 36% of design flowrate, based on the CARB finding that 13-36% of exhaust rates entered through the passive vents in well compartmentalized units.
Estimate of proposed (62.2-2016) rate through passive vents	Estimate of how much air actually enters passive vents under proposed rates (62.2-2016). Assumes 36% of design flowrate, based on the CARB finding that 13-36% of exhaust rates entered through the passive vents in well compartmentalized units.
62.2-2010 (previous rate for low-rise)	The old rate for low-rise multifamily units. 62.2-2010: 7.5 cfm x (BR + 1) + 0.01 cfm/ft^2 x A.

Table 16: Ventilation Rates under Different Standards for Example HRMF Unit Configurations (cfm)

Bedrooms	Floor Area (ft^2)	Proposed for Balanced: 62.2-2016 x 0.85	Current (from 62.1-2007)	Proposed for unbalanced (62.2-2016)	Estimate of Current (62.1-2007) Rate through Passive Vents	Estimate of Proposed (62.2-2016) Rate through Passive Vents	62.2-2010 (previous rate for low-rise)
1	500	26	40	30	14	11	20
1	800	33	58	39	21	14	23
2	800	40	63	47	23	17	31
1	1,000	38	70	45	25	16	25
1	1,200	43	82	51	30	18	27
2	1,000	45	75	53	27	19	33
2	1,200	50	87	59	31	21	35
2	1,500	57	105	68	38	24	38
3	1,200	56	92	66	33	24	42
3	1,500	64	110	75	40	27	45

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

This section discusses how the recommended compliance process, which is described in Section 2.5, could impact various market actors. The Statewide CASE Team asked stakeholders for feedback on how the measure would impact various market actors during public stakeholder meetings that were held on September 27, 2016 and March 16, 2017. Notes from these meetings are provided at: http://title24stakeholders.com/res-indoor-air-quality/.

Key takeaways and questions from stakeholder meetings are detailed below. The CASE Report responds to the key issues raised.

First Stakeholder Meeting

- Circular references in the California Mechanical Code and Title 24 need to be resolved to eliminate confusion.
- Fans designed to be used for whole house ventilation are turned off and switch labels are missing or easily removed.
- Concern about the impact of higher MERV filters on pressure drop, airflow, energy, cost, homeowner failure to replace, and minimal improvement of indoor air quality.

Second Stakeholder Meeting

There was considerable discussion about increasing the filter MERV requirement for ducted thermal conditioning systems from 6 to 13, and strong opposition, primarily from HVAC contractors and the building industry, with comments such as:

- Filter grille sizes are already problematic with current standards. The standards must consider the cost of larger or additional return air grilles, and the cost of higher efficiency blowers, which may drive the cost beyond "cost-effective."
- The HVAC industry is still struggling with current airflow/watt draw requirements with MERV 6 filters. What fan efficacy changes must be made to compensate for the higher static pressure of MERV 13 filters?
- People do not remember to change filters, the consequences of which will be aggravated by high MERV filters.
- Most people do not have health issues with current filtration. Allergy/asthma sufferers can use individual solutions that cost less.
- Thought the building shell was filtering outdoor air to the equivalent of MERV 13.
- If HVAC fan run time is only 6-15 percent of the year, how is filtration provided for the remainder of the time?
- Cannot MERV 6 filters be used on returns if outside air is separately filtered, and will not MERV 13 filters require more frequent replacement? Should adhere to 62.2 standards without revisions.
- If roadways are the problem let us address them, not all homes.
- Are there any studies that demonstrate the current impact 62.2-2010 has had on IAQ in residential new construction?

Representatives from the California Air Resources Board and Lawrence Berkeley National Laboratory responded with the following perspectives:

- Health impacts seen along busy roadways are cardiovascular and respiratory, leading to hospital admissions and death. Allergy problems are secondary.
- CARB does not consider the building shell to provide adequate removal of very fine particulates that are responsible for health impacts.
- Savings in health costs will likely exceed costs for better filters.
- The ongoing HENGH study led by Lawrence Berkeley National Laboratory will provide data on IAQ in newer homes.

Comments pertaining to HRMF buildings were as follows:

- How is compartmentalization verified or enforced?
- Providing a credit for balanced systems is appreciated.
- How do we know what the PM 2.5 levels are in outside air?
- Studies show that a small amount of air is admitted by passive vents. More research is needed.
- Passive air inlets have acoustic problems. Can they be used in buildings close to freeways?
- Do PM 2.5 levels change depending on the height of the building?
- Is there a method for verifying six percent leakage in large exhaust systems?
- Who tests the façade for leakage in HRMF buildings?
- For HRMF renovations, venting to the exterior is not always possible. What exceptions are there?

Comments relating to kitchen exhaust were fewer:

- At what fan speed does a kitchen exhaust fan need to meet the airflow and noise specifications (low, medium, high)?
- What about microwave exhaust hoods that do not meet the HVI sound certification?

In addition, telephone interviews were conducted with twenty-two subject matter experts including mechanical engineers, architects, energy analysts, modelers, raters, researchers, and manufacturers. A list is provided in Section 8. The results from feedback are interwoven into the report and referenced in Section 2.1.3.3.

Table 17 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. To summarize, the proposed compliance process will affect the current compliance and enforcement process as follows:

- Assuming that there has been 100 percent compliance under current standards, the compliance process for the proposed measures will generally fit within the current work flow of market actors and, apart from new kitchen hood verification requirements and testing of exhaust shaft leakage for HRMF buildings, will not require additional tasks, but will require more attention to detail and additional time and materials for existing tasks.
- To ensure that MERV 13 filters do not result in lower HVAC performance, closer coordination between system designers and HVAC contractors will be necessary to ensure the designs are properly implemented and that “standard practice” is improved upon. Builders must also communicate to homebuyers the importance of filter maintenance.
- Depending on who is given the responsibility of HRMF verifications, (HERS Rater, ATT, or both) coordination will be required.
- Builders and subcontractors will require specialized training to acquaint them with procedures for sealing MFHR units to provide compartmentalization.
- All of the proposed measures will require additional resources, including labor and materials, to meet both existing requirements (as for kitchen hood performance) and newly proposed

measures, such as increased mechanical ventilation rates (larger fans) and higher efficiency filters.

- A new compliance document will be required to document verification of exhaust shaft sealing. Other proposed measures can probably be accommodated by changes to existing documentation.

Table 17: 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
Manufacturers & Distributors	• Make available products that meet code requirements	• Balance cost objectives and customer needs with code requirements	• Provides opportunities for expanding product offerings	• N/A
Architect / Designer	• Product specification (e.g., qualifying kitchen hoods) • Ensure design can accommodate new requirements (e.g., passive vents)	• Balances form/function to satisfy owner desires • Documentation prepared for permit submittal with minimal clarifications • Meet project budgets	• Increased detail and inclusion of code provisions in drawings	• Provide resources to designers on sizing of filter grilles, and for HRMF buildings methods for meeting makeup air requirements and information on PM 2.5 areas
Title 24 Consultant	• Provide feedback on the impact of energy measures on compliance • Ensure builder is aware of code requirements • Complete compliance documents & upload to HERS registry	• Project team is aware of requirements with no surprises • IAQ goals are met • Minimal plan check comments	• No change to work flow	• Create awareness of ASHRAE 62.2-2016 impacts and leakage testing options
Owner	• Develop project goals including programming, schedules, & budget • Little direct involvement	• Project completed to expected standards and within budget & schedule	• No change to work flow	• Permanent labeling of whole house ventilation fan switches • Written instructions on filter maintenance
Builder	• Coordinate with design team & trades • Ensure trades are aware of all requirements • Ensure proper product installation • Schedule inspections & post forms onsite	• Owner satisfied and no warranty issues • Meet project budgets & schedule • Minimal inspection failures • Minimal paperwork required • Owner satisfied and no warranty issues	• May require additional coordination time, especially for HRMF buildings	• Training for builders on proper installation and sealing techniques • Training on HRMF ventilation system requirements

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Subcontractors (HVAC, drywall contractor, electrician)	• Install products to meet requirements • Properly sized return air grilles • Properly sealed HRMF units & shafts	• Meet builder's schedule • Finish within budget • Minimal inspection failures • Minimal paperwork required	• Account for extra time to install larger filter grilles • Account for time to seal for compartmentalization, and seal exhaust shafts	• Training on filter grille sizing • Training on sealing (HRMF)
HERS/ATT Verifier	• Review CF1R compliance documents for methods of complying with ventilation requirements • Complete verifications & registry entries	• Verifications completed as required	• Additional time required to verify kitchen hoods • Additional time required to inspect sealing and test shafts (HRMF only)	• Online directory of complying kitchen hoods • Shaft leakage testing protocol and training
Plans Examiner	• Verify that CF-1R is consistent with building plans and meets compliance criteria for local jurisdiction	• Minimize amount of paperwork needed to review	• No change to work flow	• N/A
Building Inspector	• Verify code requirements are met • Verify that paperwork is complete & CF documents are signed and certified • Sign occupancy permit	• Issue permit with minimal re-inspections • Minimal paperwork	• No change to work flow	• N/A

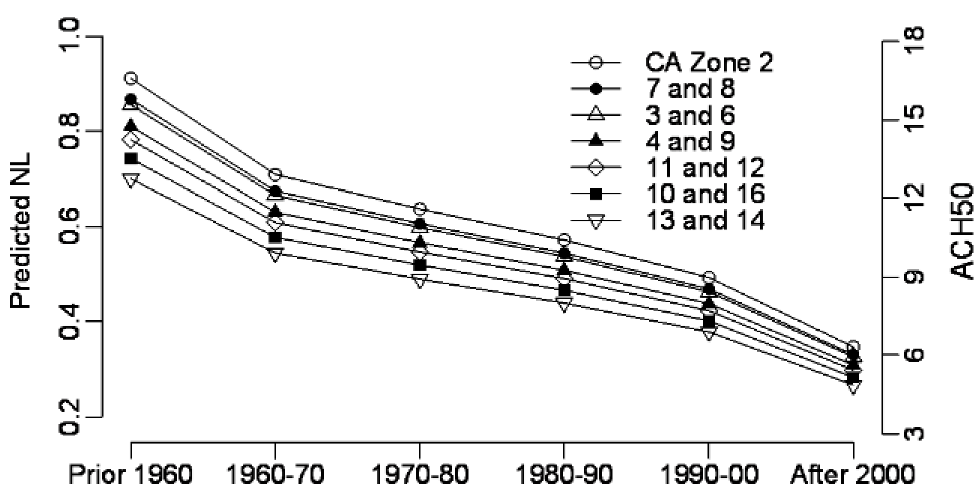
Appendix D: SUPPORTING INFORMATION FOR COMBUSTION AIR PROPOSAL

Proposed code changes to Title 24 Part 6 for 2019 require significant increases to residential mechanical ventilation for the purposes of indoor air quality, including:

- Increase in mechanical ventilation by an average of 40%.
- Verification that kitchen hoods vent to outside and capable of exhausting at least 100 cfm.
- Under the 2016 Title 24, Part 6 cycle whole house fans became a prescriptive requirement in climate zones 8-14 – this is 69% of all projected new single family and 59% of new multifamily dwelling construction in 2020.

In addition, over time windows and doors are more airtight and with stucco being the most common form of wall construction, walls are also more airtight. Since 2005, ICAT (insulated ceiling air tight) recessed luminaires have been required when the luminaire projects into the ceiling cavity. All of these air tightening measures have resulted in more energy efficient homes. The figure below from the PIER/LBNL RESAVE study illustrates the reduced effective leakage areas in California homes over time. In comparison, the current rules for use of conditioned air for atmospheric combustion devices have been around for years and do not reflect current construction practice.

Figure 2.1.1: Normalized Leakage (NL) of California Homes in Different Climate Zones, and as a Function of Year Built, Predicted Using the Regression Model.



Thus, with tighter envelopes and increased ventilation, new homes have a greater potential for negative pressurization. Negative pressurization can lead to back-drafting of atmospheric combustion appliances installed within the building envelope. If back-drafting were to occur, this could pose significant risk to the health and safety of the occupants, potentially including:

- Introducing carbon monoxide and PM2.5, into the occupied space.
- Flame rollout from open combustion appliances, a fire risk.

These risks will exist so long as combustion air may be drawn from within the building envelope.

In addition to these safety considerations, having a hole in the building thermal envelope for combustion air and burning partially conditioned air (not all combustion air will come from outside, some of the air will be drawn from the conditioned space) results in an energy penalty. The 2015 version of the IECC addressed this issue by prohibiting conditioned air from being used for combustion air as follows:

Residential Provisions

R402.4.4 Rooms containing fuel-burning appliances. In Climate Zones 3 through 8, where open combustion air ducts provide combustion air to open combustion fuel burning appliances, the appliances and combustion air opening shall be located outside the building thermal envelope or enclosed in a room, isolated from inside the thermal envelope. Such rooms shall be sealed and insulated in accordance with the envelope requirements of Table R402.1.2, where the walls, floors and ceilings shall meet not less than the basement wall *R*-value requirement. The door into the room shall be fully gasketed and any water lines and ducts in the room insulated in accordance with Section R403. The combustion air duct shall be insulated where it passes through conditioned space to a minimum of R-8.

Exceptions:

1. Direct vent appliances with both intake and exhaust pipes installed continuous to the outside.

2. Fireplaces and stoves complying with Section R402.4.2 and Section R1006 of the *International Residential Code*.

Commercial Provisions

C402.5.3 Rooms containing fuel-burning appliances. In *Climate Zones* 3 through 8, where open combustion air ducts provide combustion air to open combustion space conditioning fuel-burning appliances, the appliances and combustion air openings shall be located outside of the *building thermal envelope* or enclosed in a room isolated from inside the thermal envelope. Such rooms shall be sealed and insulated in accordance with the envelope requirements of Table C402.1.3 or C402.1.4, where the walls, floors and ceilings shall meet the minimum of the below-grade wall *R*-value requirement. The door into the room shall be fully gasketed, and any water lines and ducts in the room insulated in accordance with Section C403. The combustion air duct shall be insulated, where it passes through conditioned space, to a minimum of R-8.

Exceptions:

1. Direct vent appliances with both intake and exhaust pipes installed continuous to the outside.

2. Fireplaces and stoves complying with Sections 901 through 905 of the *International Mechanical Code*, and Section 2111.13 of the *International Building Code*.

A review of these requirements indicate that there are multiple configurations that make use of the full range of both direct vent and atmospheric combustion equipment while mitigating the energy and safety issues associated with using indoor air for combustion air. They include:

- Using atmospheric combustion devices outside of the conditioned envelope. This can be outdoors, in ventilated attics, or in garages.
- Using direct vented devices where outdoor air is vented directly into the sealed combustion device.
- Building a sealed and insulated "mechanical room" for atmospheric combustion devices inside conditioned space

Thus, the Statewide CASE Team has recommended aligning the new construction combustion air requirements with the IECC, the national residential model energy code that is the metric of interest when states provide a determination to DOE of their progress on their energy code. This approach allows for the full range of combustion appliances being applied in a manner that is suitable for their handling of combustion air.

Appendix E: HVAC System Filter Testing for Pressure Loss[34]

Executive Summary

The 45-Day Language includes the mandatory requirement of MERV 13 filters. Stakeholders have expressed concerns about the pressure drop (resistance to air flow) of higher MERV filters. Tests were performed on a set of 24-inch by 24-inch filters to provide third-party verification data on the performance of filters with various MERV ratings in one and two-inch depths over a range of velocities for use by the Statewide CASE Team, the Energy Commission and stakeholders. The results show that acceptable pressure drops of less than 0.20 inch w.c. can be achieved by either one- or two-inch deep MERV 13 filters. No correlation was found between filter MERV ratings and pressure drop. One-inch and two-inch deep filters can have the same pressure drop at the same MERV rating, allowing either to be used. All filters have increasing pressure drop with increasing airflow. Four filters had printed labels giving their performance as will be required by the California Appliance Efficiency Regulations (Title 20). Test results were found to yield very similar values as indicated by the labels.

Recommendations

The following modifications to the 45-Day Language are proposed:

1. Eliminate all mandatory requirements related to filter pressure drop and size, and rely on the verification of fan efficacy to ensure that all system components, not just filters, are properly designed and installed.
2. In Section 150.0(m)12Bii, prescribe a design maximum filter pressure drop of 0.15 inch w.c. and a maximum velocity of 225 feet per minute (fpm) instead of 150 fpm.
3. Reference the CALGreen mandatory measure for ACCA Manual D sizing in Part 6 section 150(m)12 to reinforce the requirement.

Background

Proposed Changes to Filter Requirements in Title 24, Part 6 for 2019

The 2019 Title 24 45-Day Language includes the following substantive changes related to filter requirements for all residential buildings:

150.0(m)12A. Air Filtration: Extends the requirement for filters to include outside air delivered by supply-only and balanced ventilation systems as well as thermal conditioning systems.

150.0(m)12B. System Design and Installation: Requires either a two-inch deep filter or a one-inch filter sized for a face velocity not to exceed 150 fpm.

150.0(m)12C. Air Filter Efficiency: Requires a minimum of MERV 13 (ASHRAE Standard 52.2) or particle size efficiency >50% in the 0.30-1.0 μm range (AHRI Standard 680). This is an increase from the MERV 6 required by ASHRAE Standard 62.2-2016.

150.0(m)12D. Air Filter Pressure Drop: Requires two-inch deep filters or a maximum pressure drop of 0.1 inch w.c., or filter sizing in accordance with Table 150.0-B and C.

[34] Appendix E was added to the CASE Report during the February 2018 update.

150.0(m)13B & C. Single & Zonally Controlled Forced Air Systems: Requires verification of furnace maximum fan efficacies of 0.45 W/cfm for furnaces and 0.58 W/cfm for heat pump air handlers.

Tables 150.0-B & C. Return Duct and Filter Grille Sizing: Effectively limits filter face velocity, depending on system tonnage, to 151 and 176 feet per minute at an airflow of 350 cfm/ton. In the 45-Day Language, the maximum allowable pressure drop is increased from 0.05 to 0.10 inch w.c. The current return duct size requirements allow velocities in the range of 376 to 439 fpm (also based on 350 cfm/ton), with resulting pressure drops of from about 0.024 to 0.046 inch w.c. per 100 feet of flex duct. ACCA Manual D indicates velocities of 500 fpm or less do not produce objectionable noise.

Summarizing the proposed 45-Day Language requirements, MERV 13 or equivalent filters must be used, and systems must include either:

- Two-inch deep filters per 150.0(m)12Biia
- One-inch deep filters with a verified face velocity of 150 fpm or less and a pressure drop less than 0.10 inch w.c. per 150.0(m)12Biib
- One-inch deep filters with a verified face velocity of not more than 151-176 fpm (depending on system size) and a pressure drop less than or equal to 0.10 inch w.c., and return ducts sized per Tables 150.0-B/C (resulting in 376 to 439 fpm duct velocity)

Other Relevant Standards

Section 1607(d)(12) of the California Appliance Efficiency Regulations (Title 20) require air filters to be labeled using the format below. The original effective date of July 1, 2016 was delayed until July 2019.

MERV	(µm) PSE (%)	0.30-1.0	1.0-3.0	3.0-10	Airflow Rate (CFM)	[val 1]	[val 2]	[val 3]	[val 4]	[val 5]	*Max Rated Airflow
[value]		[value]	[value]	[value]	Initial Resistance (IWC)	[value]	[value]	[value]	[value]	[value]	

Figure 7: Example of filter label in Title 20.

Source: (California Energy Commission 2016)

The mandatory requirements in the California Green Building Standards (Title 24, Part 11 or CALGreen) require that systems be sized in accordance with ACCA Manual D or equivalent methods (Division 4.5, 4.507.2). The Manual D process involves adding up the pressure losses from the cooling coil, filter, supply and return grilles, and other components, subtracting this sum from the manufacturer's listed external static pressure at the required airflow to obtain the available static pressure, and sizing the ducts so they do not exceed this available pressure. Unfortunately, this requirement is enforced by only a few building departments. A reasonably well-designed system might have the pressure drops shown in Table 18 below. As in this example, the total external pressure drop for the furnace or air handler is equal to the sum of the component pressure drops at the design airflow rate.

Table 18: Typical Residential System Pressure Losses

Component	Pressure Drop (inche w.c.)
Cooling Coil	0.25
Filter	0.15
Supply Grilles	0.03
Return Grilles	0.03
Ducts	0.24
Total PD	**0.70**
Design Furnace ESP	**0.70**

Stakeholder Issues

Through pre-rulemaking workshops and docket postings, stakeholders have expressed the following concerns:

- The ability of systems with MERV 13 filters to meet proposed lower efficacy requirements (Statewide Utility Codes and Standards Team 2016).
- The challenges of installing larger filter grilles needed for MERV 13 filters due to space limitations and higher cost (Statewide Utility Codes and Standards Team 2017).
- Filter size limitations with ceiling-mounted air handlers designed for multifamily systems, including the inability of air handlers to accommodate two-inch filters and filters with sufficient face area to meet the velocity limits (California Building Industry Association 2017).

The CASE team has also found that while there is an ample selection of one-inch MERV 13 filters available in retail stores, no walk-in stores currently offer two-inch filters and they must be ordered through the store, or purchased online, typically in full box quantities.

Goals of Testing

The Title 20 requirement for filter labeling will not become effective until July 2019. Currently, there is limited data available on filter pressure drop characteristics. The CASE Team identified only one manufacturer, 3M Filtrete, that provides labels that meet the forthcoming requirement. Testing was initiated to develop pressure drop data on un-labeled filters, and as a verification of data provided in filter labels. The results can be used to determine whether the difference in pressure drop between one and two-inch deep filters is significant enough to justify making two-inch deep filters mandatory, to verify manufacturer ratings, and to assess whether stakeholder concerns about filter pressure drop requirements are supported by test data.

Test Procedures

Filter Selection

The Statewide CASAE Team and PG&E’s Applied Technology Services (ATS) test lab staff developed a list of filters to test in Table 19 based on product availability and technical specifications. The list below is sorted by ∆P to highlight the correlation between MERV rating and pressure drop.

Table 19: List of Filters Tested

BRAND	MODEL DESCRIPTION	SIZE	MERV RATING	ΔP @ 295 fpm (IWC)*
FilterBuy	AFB Platinum MERV 13 24×24×2 (AFB24×24×2M13)	24×24×2	13	0.13
Flanders	Flanders Air Filter MERV 6 (81255-012525)	25×25×1	6	0.15
Flanders	Pre Pleat M13 (90013.022424)	24×24×2	13	0.17
3M	Filtrete HVAC Basic (3MHBR13.012424)	24×24×1	13	0.18
3M	Filtrete 300 HVAC Basic Dust	24×24×1	5	0.20
Nordic Pure	Pleated Air Filters MERV 7	24×24×1	7	0.20
FilterBuy	AFB Platinum MERV 13 24×24×1 (AFB24×24×1M13)	24×24×1	13	0.22
FilterBuy	AFB Bronze MERV 6 24×24×1 (AFB24×24×1M6)	24×24×1	6	0.22
3M	Filtrete 1085 MPR Micro Allergen Extra	24×24×1	11	0.23
3M	Filtrete 600 MPR Dust & Pollen	24×24×1	7	0.23
Nordic Pure	MERV 13 Pleated Air Filters	24×24×2	13	0.25
FilterBuy	AFB Gold MERV 11 24×24×1 (AFB24×24×1M11)	24×24×1	11	0.26
Flanders	Pre Pleat M13 (90013.012424)	24×24×1	13	0.30
Nordic Pure	Pleated Air Filters MERV 13	24×24×1	13	0.37

*Measured at airflow of 1180 cfm for all but the Flanders 25x25x1, which was measured at 1280 cfm

Laboratory Setup, Test Standards, and Procedures

All testing was completed at PG&E's ATS lab facility in San Ramon. Figure 8 diagrams how the ATS lab facility was configured for filter testing. One test chamber (on the left) was utilized, and its accompanying nozzle chamber and fan were used to measure and regulate airflow. Each filter was mounted and then the automated lab management software collected pressure drop at four air velocities: 50%, 75%, 100%, and 125% of the MERV rating test point.

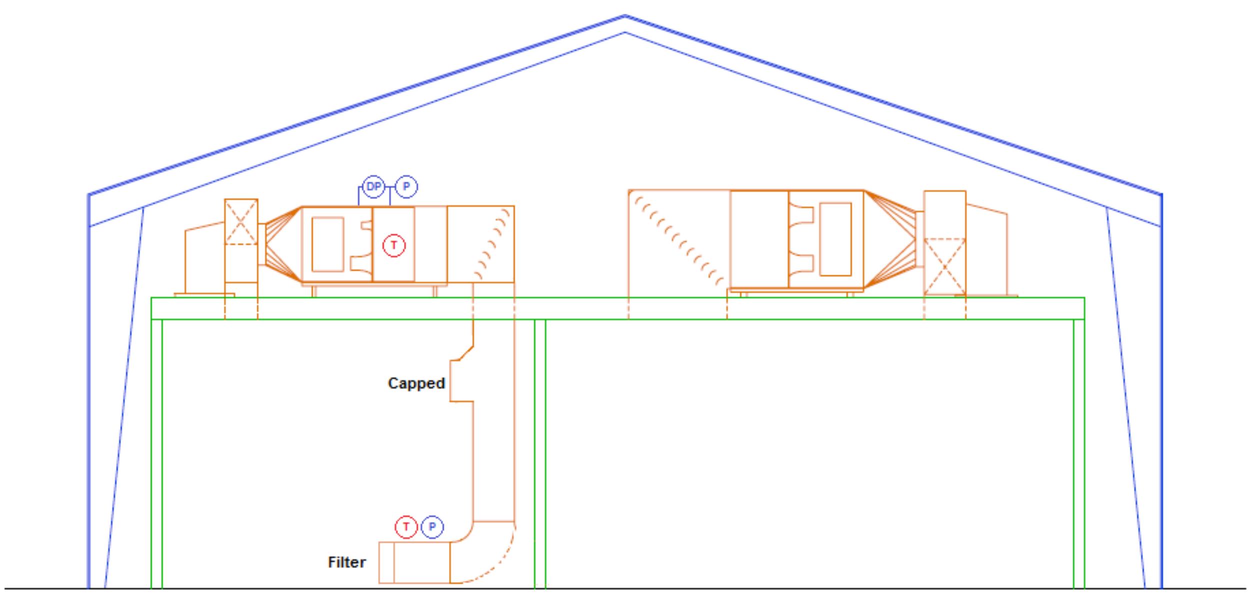


Figure 8: Diagram of laboratory testing equipment and positioning of filters for testing.

Standards referenced in the development of test procedures include:

1. Standard 37-2009 – Methods of Testing for Rating Electrically Drive Unitary Air-Conditioning and Heat Pump Equipment
2. Standard 41.2-1987 (RA 1992) – Standard Methods for Laboratory Airflow Measurement
3. Standard 41.3-2014 – Standard Methods for Pressure Measurement
4. Standard 52.2-2012 – Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size

Standard 37-2009 is the defining document for the design of the test facility and includes some of the same information for airflow and pressure measurements as the 41 series. Standard 52.2 was referenced for the test setup, but it is mostly concerned with particulate removal.

For expediency, the test setup adapted the existing airflow measurement configuration which achieved the intent of the relevant standards. The filters were all mounted at the entrance to a 24-inch long straight duct, with the pressure measurement taps at about 18 inches from the entrance; with taps in the center of all four walls and manifolded together to the pressure transmitter. A second static pressure measurement was located downstream at the entrance to the flow nozzle (see Figure 8).

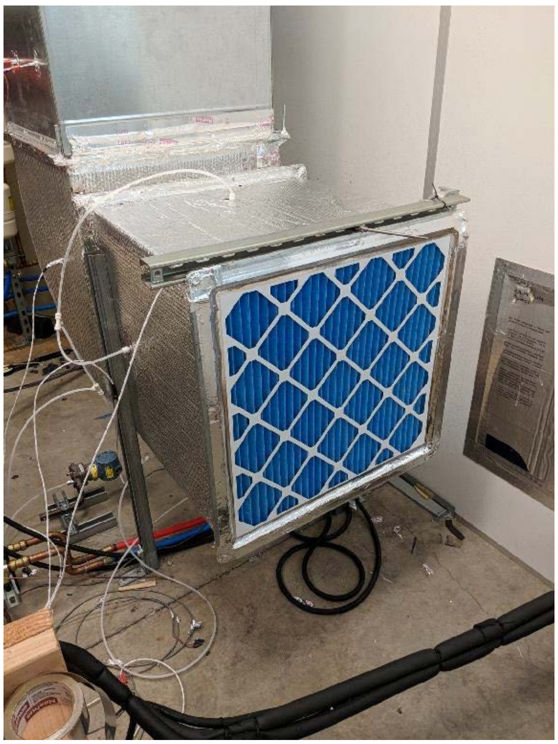


Figure 9: Testing of one 24-inch by 24-inch filter.

The flow measurement system was set to achieve and maintain a specified flow rate by adjusting the speed of the booster fan to draw air though the filters and the flow measuring nozzles. The "test airflow rate" of 1180 cfm was determined using a gross face velocity of 295 fpm, as recommended by ASHRAE Standard 52.2 Section 8.1.1. Pressure drops were measured at airflow rates corresponding to 50%, 75%, 100%, and 125% of the test airflow rate. For the 24 inch-square filters, the test airflows correspond to velocities of 148, 221, 295, and 369 fpm respectively. A single airflow measurement nozzle configuration was not sufficient to achieve the full range of airflows from 50% to 125% and keep the nozzle airflow within the standard ranges, so two or more data sets were generated for each filter representing the different nozzle sizes. When possible, data sets were overlapped with at least one flow rate being the same in each set to demonstrate that the nozzle selection had no discernable effect. The airflow set points were adjusted automatically using lab management software that made a change every

10 minutes. The stable operation data of the last five minutes was averaged and used as the test result. Table 20 lists the instrumentation already installed in the HVAC test lab used for these tests.

Table 20: Instrumentation List

Measurement	Instrument	Manufacturer/Model	Accuracy
Barometric Pressure	Multi-function weather station on roof of building	Vaisala WTX520	±0.007 PSIA (±50 Pa)
Dew-point temperature	Chilled mirror dew point sensor	General Electric Optica Burns Engineering	±0.36°F
Filter differential pressure	Pressure transmitter attached to manifolded pressure taps at center of each side of filter	Rosemount 3051C	±0.04% of span (-0.5 to 1.5 IW)
Supply airflow station dry bulb temperature	Single fast-response RTD upstream of nozzles	Burns Engineering	±0.2°F

Test Results

Pressure Drop vs. Airflow & Velocity

Figure 10 graphs the performance of all filters tested. The legend indicates the MERV rating and the filter depth (e.g., M13-2" is a two-inch deep MERV 13 filter).

The dotted lines are plots of manufacturer performance data and show reasonably good alignment with ATS lab test results. Tests of two Nordic Pure 13 MERV filter were completed with similar results. As with Table 19, the plot shows there is no direct correlation of MERV rating to pressure drop performance. For example, the MERV 7 Filtrete 700 curve is above the MERV 13 Filtrete Basic.

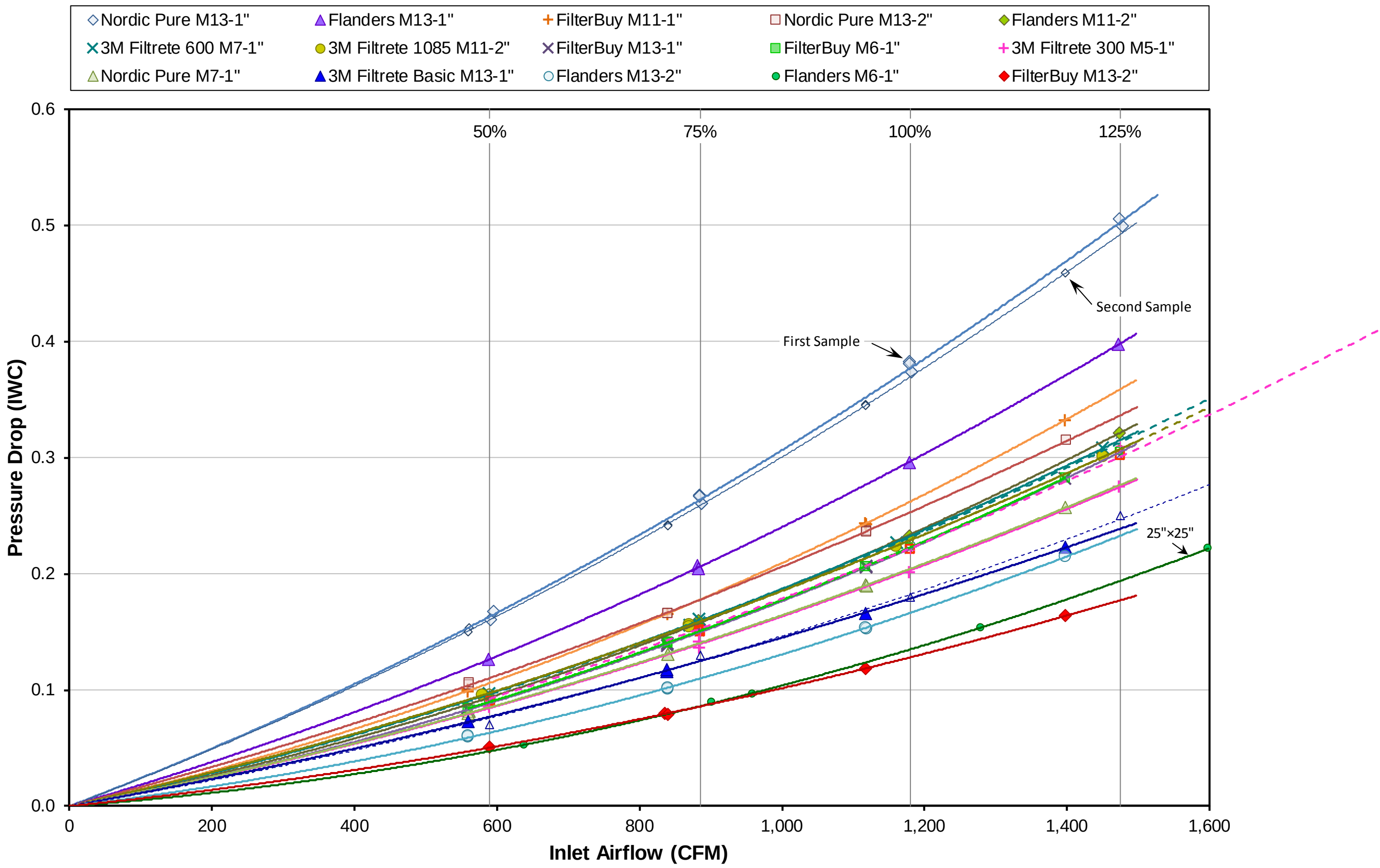


Figure 10: Pressure drop versus airflow for all filters tested

Figure 11 shows only the curves for MERV 13 filters. The MERV 13 Filtrete Basic filter tested is not one that was commonly available in retail stores during the procurement of the filters used in this project, but can be ordered. As purchased for this test, it had a lower price than the Filtrete 1900. For comparison, a curve fit of the label data from a Filtrete 1900 was included in the Figure 5 plot, which appears as the green dotted line. The curves in Figure 11 are also labeled to indicate the filter depth.

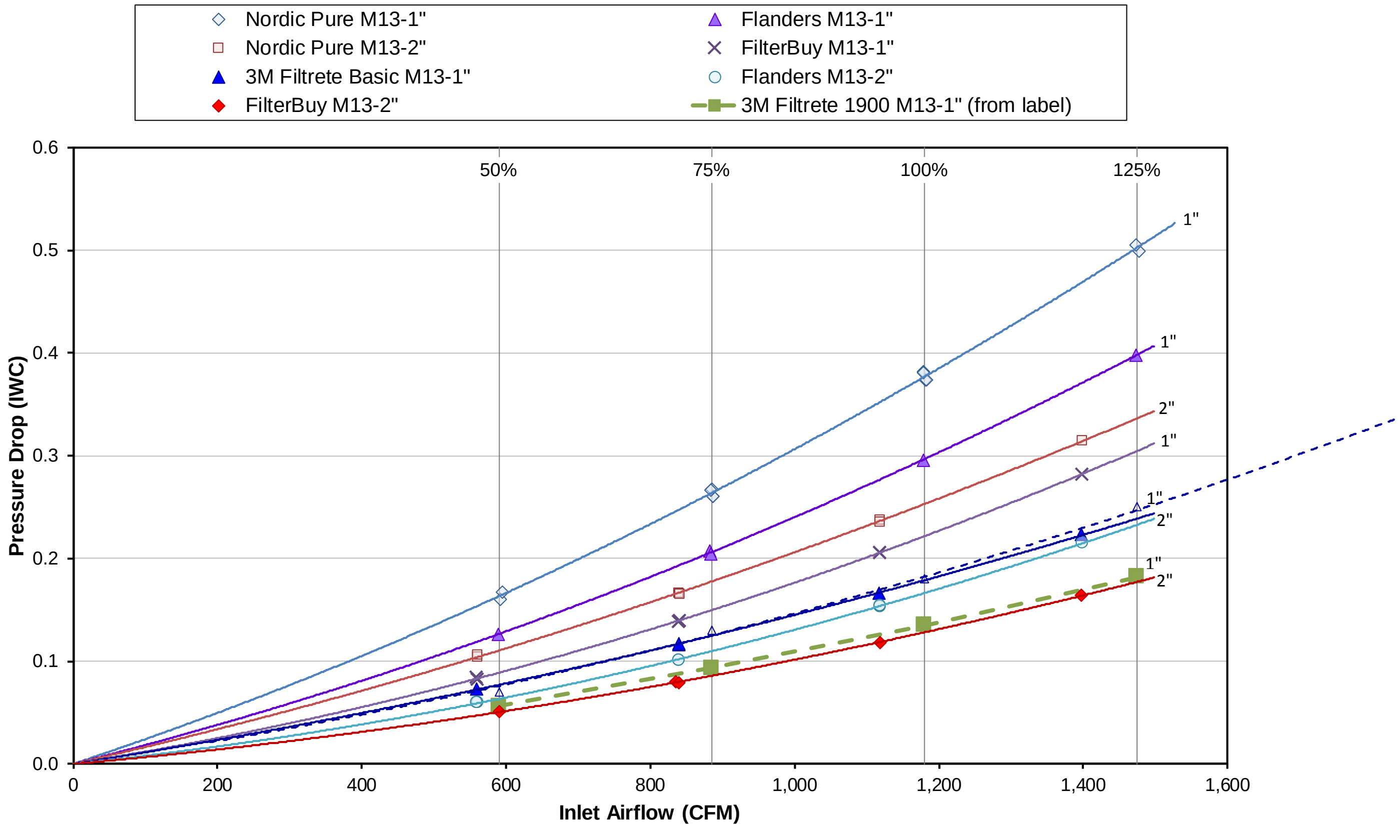


Figure 11: Pressure drop versus airflow for only the MERV 13 rated filters

Other Observations

It was noted that the CFM values reported in filter labels are based on the nominal face area rather than the face area of the filter media. Also, the total area of the 3M filters, at 23-13/16 inches^2, is slightly larger than the other filters which are 23-3/8 inches^2. Thus, the 100% point is at 1180 CFM (295 fpm × 4 ft^2). ATS staff worked through all of the test data to derive curve fits from which he calculated what the pressure drop would be at any flow rate, and calculated values for each at the four nominal flow rates. These results are available in the "Tests" tab of his results spreadsheet, and the values at 295 fpm (the 100% point) are included in Table 21.

It is notable that the printing of filter model numbers as well as performance information on the filters is very valuable. For example, the FilterBuy units only included the size and airflow direction, and when removed from their wrappings there was no way of identifying the part number or name, and since the media looked identical it was not possible to distinguish the MERV 6 from the MERV 13 filters.

Four of the filters had pressure drop information labeled on the frames. A photo of the label from one of the Filtrete filters (Figure 12) showed it is identical to the label required by the Title 20 standard shown in Figure 7. This information allowed test results to be compared with the filter labels.

Figure 12: Label printed on 3M Filtrete filter.

Table 21 compares labeled pressure drops to those obtained in testing. The closeness is demonstrated by noting that the biggest difference was 0.03. This supports the validity of the forthcoming Title 20 requirements for labeling.

Table 21. Labeled VersusTested Pressure Drop

Labeled Versus Tested Pressure Drop - inches water column					
		Velocity - fpm			
		50%	75%	100%	125%
MERV	Source	148	221	295	369
13	Label	0.07	0.13	0.18	0.25
13	Test	0.08	0.12	0.18	0.24
11	Label	0.08	0.14	0.20	0.28
11	Test	0.10	0.16	0.23	0.31
7	Label	0.09	0.16	0.23	0.32
7	Test	0.10	0.16	0.23	0.32
5	Label	0.09	0.15	0.22	0.31
5	Test	0.08	0.14	0.20	0.28

Relevance of Test Results to Proposed Title 24, Part 6 Standards

In response to stakeholder concerns regarding the difficulty complying with lower efficacy requirements, referring to Table 18, if filter pressure drop is kept at or below 0.15 inch w.c., then a total external static pressure of 0.7 inch w.c. should be easily achieved. Referring to Figure 11, five of the eight MERV 13 filters tested are at or below 0.15 inch w.c. at a velocity of about 225 fpm. From prior ATS testing of furnaces and heat pumps it was learned that they can comply with a 0.45 W/cfm standard at or below external static pressures of 0.7 inch w.c.[35] If designers and contractors comply with the mandatory requirement in CALGreen for system sizing using Manual D or other methods, then this concern can be dismissed.

Regarding the perception that larger filter grilles will be needed for MERV 13 filters, Figure 10 shows that filter pressure drop does not correlate to MERV rating. If filters are selected carefully using labelled pressure drop data, then implementers should not encounter this problem.

[35] See Appendix D of the Residential Quality HVAC Measures – Final Report; Revised December 2017, which is available here: http://title24stakeholders.com/wp-content/uploads/2017/12/2019-T24-CASE-Report_Res-Quality-HVAC_Final_December-2017.pdf

The 45-Day Language proposed requirements for either providing a two-inch deep filter or maintaining a filter velocity of 150 fpm or less is not necessary and could be a hardship on the HVAC industry, especially for ceiling-mounted air handlers used in multifamily installations. Filter slots for many of these ceiling units are not designed for filters deeper than one inch and many, to conserve space, incorporate return air grilles in the air handler box rather than using ducted returns. Again, referring to Figure 11, all but three of the MERV 13 filters would meet the requirement for a pressure drop not to exceed 0.15 inch w.c. at a velocity of 225 fpm (or 900 cfm for the 24x24 filter size), so if they can meet the velocity limits then they could also meet the 0.15 inch w.c. pressure drop requirement in 150.0(m)12Biib.

Of the five filters shown in Figure 11 that fall at or below 0.15 inch w.c. static pressure at 225 fpm, three are one inch deep. This result does not support the mandatory use of two-inch filters, or the more rigorous requirements proposed for one-inch deep filters.