Codes and Standards Enhancement (CASE) Initiative

2019 California Building Energy Efficiency Standards

Residential Indoor Air Quality – Draft Report

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

Residential IAQ

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EXECUTIVE SUMMARY

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

1. *Verification requirements for the compartmentalization requirement for high-rise buildings that use an exhaust-only ventilation strategy with passive vents for make-up air. Appendix B provides possible starting points for these verification requirements, and pros and cons of each.*
2. *Which compliance documents, residential or nonresidential, should be used to document sealing for compartmentalization in high-rise multifamily buildings?*
3. *Are Acceptance Test Technicians equipped to provide leakage testing of central ventilation shafts, and how should the results be documented?*
4. *The estimated incremental costs and if these reflect mature market trends.*
5. *The impact on product manufacturers.*
6. *The impact on the code compliance documentation process.*

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

Introduction

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

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

Measure Description

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. This version replaces the currently referenced 2010 version of ASHRAE 62.2. The 2016 version includes high-rise multifamily 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
- Decreases high-rise multifamily ventilation rates (which will be covered by 2019 Title 24, Part 6 Residential Standards)
- Provides for filtration of outside air in locations with high levels of fine particulate matter (PM2.5) concentrations
- Requires higher efficiency filters Minimum Efficiency Reporting Value (MERV) 13 for ducted recirculated air systems, compared with ASHRAE 62.2, to reduce PM2.5 concentrations indoors
- Requires verification that kitchen hoods in all unit types meet ASHRAE 62.2 requirements for external venting, air volume, and sound ratings
- Emphasizes and enhances existing language to ensure adequate ventilation and improved compartmentalization in high-rise multifamily(HRFM) units
- Provides for verification that central ventilation shafts or ducts in high-rise multifamily buildings are sealed to prevent leakage greater than six percent of total ventilation airflow

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: Scope of Code Change Proposal summarizes the scope of the proposed changes and lists which sections of the standards, reference appendices, and compliance documents will be modified as a consequence 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(o) and 150.0(m)	JA1, RA2, RA3	Yes - Change in mechanical ventilation rate for single family and high-rise multifamily	CF1R-PRF-01, CF3R-MCH-27

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

- Kitchen hoods will be Home Ventilating Institute (HVI) certified and verified to comply with ASHRAE 62.2 (externally vented, ≥100 cfm, ≤ 3 sones).
- The efficiency of filters in recirculating HVAC systems will be increased from MERV 6 to MERV 13.
- A dedicated makeup air source will be required for all high-rise multifamily units, with filtration requirements for units in high particulate matter in the 2.5-micron size range (PM 2.5) exposure areas.
- Where central ventilation 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 Public Resources Code 25402.8, which requires that the Energy Commission include the impact of indoor air pollution when considering energy conservation measures. Proposed measures also respond to Title 24, Part 11 (CALGreen) goals for reducing indoor pollutants. The energy impact of the increase in ventilation rate 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 recirculating HVAC systems will be costlier, 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 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, indoor air quality 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 much significant research on indoor air quality and its health effects over the past decade that supports the proposed changes.

Statewide Energy Impacts

The proposed code changes will increase single family residential ventilation rates, decrease high-rise multifamily (HRMF) ventilation rates, and will not affect low-rise multifamily buildings. 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 other CASE Reports by including the new proposed ventilation rates in the analysis used to evaluate the other proposed measures. For example, the CBECC prescriptive 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 is 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 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 have not changed, but will be HERS-verified 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 ventilation systems are employed. Depending on current practice, these requirements may affect construction costs.

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

1. INTRODUCTION

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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 proposal 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 the Title 24, Part 6 Building Energy Efficiency Standards.

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 use associated with the proposed code changes. This section also describes the methodology that the Statewide CASE Team used to estimate energy impacts.

Section 5 includes a discussion of additional materials and labor required to implement the measure and estimates the incremental cost.

Section 6 presents the statewide energy and non-energy impacts of the proposed code change for the first year after the 2019 Standards take effect. This includes impacts (increases or reductions) on material with emphasis placed on any materials that are considered toxic.

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

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 Standard 62.2-2016, which will replace the currently referenced 2010 version of ASHRAE Standard 62.2. The 2016 version has two primary impacts:

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

High-rise buildings that are included in this change are limited to full-time occupancy apartment buildings. Residential building types that have transient occupancy[1] will continue to be covered by ASHRAE 62.1. All Group R-3 occupancies (California Building Code Part 2, 310.5) and apartment houses (Part 2, 310.4) are covered by this proposal.

2.1.2 Proposed Change for Single Family Buildings

The provisions of ASHRAE Standard 62.2-2010 are currently mandatory for single family and low-rise residential buildings under Title 24, Part 6. The adoption of the 2016 ventilation standard will continue

[1] 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."

as a mandatory requirement. The primary impact will be a change in the way the mechanical ventilation rate is calculated. ASHRAE Standard 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 Pa.). The 62.2-2016 version requires blower door testing and uses the ACH50, height of the building, occupancy, and climate to calculate the infiltration rate (Q_{infil}). The impact of Q_{infil} reduces the required mechanical ventilation rate (Q_{fan}) as calculated using the following equations:

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

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

where CFA is the conditioned floor area and BR is the number of bedrooms

The Statewide CASE Team proposes to include an exception in Title 24, Part 6 to eliminate the need for the blower door test that is required in ASHRAE 62.2 by assuming a default leakage rate of 2 ACH50 for the determination of Q_{infil}. This 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}), and will be used by the compliance model for mechanical ventilation. As prescribed by ASHRAE 62.2-2016, the calculation of Q_{infil} includes a "weather and shielding factor" (wsf), which varies by climate zone. The calculated value of Q_{fan} will be listed in the CF-1R to facilitate selection of the correct size of the ventilation system.

This change effectively increases the mechanical ventilation rate for single family buildings by retaining the default 5 ACH50 leakage rate and increasing the mechanical ventilation rate (Qfan), which will vary by climate zone as shown in Figure 1 for the 2100 ft^2 and 2700 ft^2 Title 24, Part 6 prototype houses. The leakage rate used by the compliance model to compute the thermal impact of infiltration will be decoupled from the leakage rate used to calculate the required mechanical ventilation air volume.

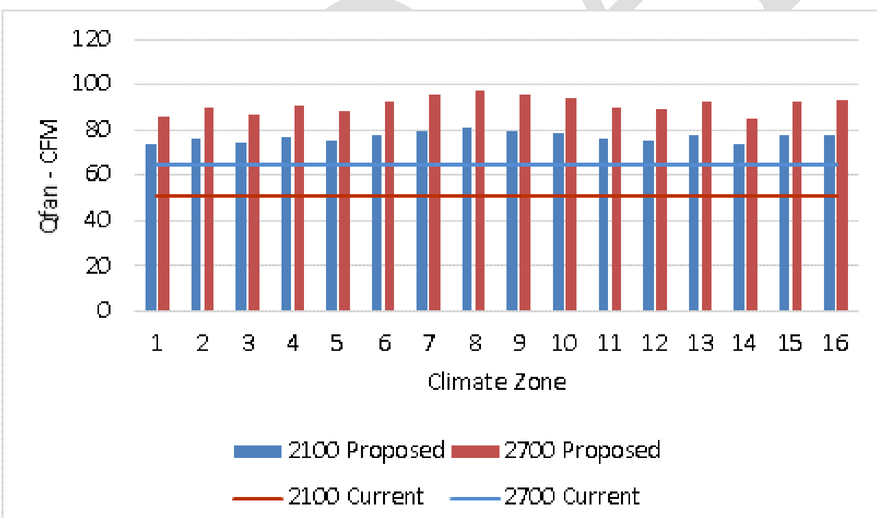

Figure 1: Change in mechanical ventilation rate resulting from the adoption of ASHRAE Standard 62.2-2016 for the Title 24, Part 6 prototype houses

To continue encouraging tight construction in single family buildings, the compliance model will apply the current five ACH50 in the standard design, and compliance credit will continue to be given for lower verified leakage rates based on the measured ACH50. For leakage rates below 2 ACH50 the measured leakage will be used to calculate a higher mechanical ventilation rate.

Increasing the mechanical ventilation rate in existing buildings that have gas appliances that use indoor air for combustion may be a safety risk. Consequently, application of the ASHRAE 62.2-2016 ventilation rates to existing single family residences will only apply to additions greater than 1000 ft^2. Enforcement of kitchen hood requirements will apply to alterations involving replacement of hoods.

2.1.3 Proposed Changes for Low-Rise Multifamily Buildings

Neither ASHRAE 62.2-2010 (through Addendum j) or 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[2]. 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. This 15 percent reduction is qualitatively consistent with an ASHRAE 62.2-2016 ventilation rate reduction for single family homes when balanced systems are used[3], and it assigns greater value to balanced systems to account for reduced air transfer between units compared with exhaust-only or supply-only ventilation strategies.

2.1.4 Proposed Changes for High-Rise Multifamily (HRMF)Buildings

2.1.4.1 HRMF Ventilation Rates and Strategies

Currently, HRMF units must meet the ventilation rates specific in ASHRAE Standard 62.1-2007:

Equation 3: $Q_{total} = 5\text{ cfm} \times (\text{Number of Bedrooms} + 1) + 0.06\text{ cfm/ft}^2 \times A$

where A = conditioned floor area (ft^2)

The proposal to change the ventilation rate reference to ASHRAE 62.2 would decrease the ventilation rate:

Equation 4: $Q_{total} = 7.5\text{ cfm} \times (\text{Number of Bedrooms} + 1) + 0.03\text{ cfm/ft}^2 \times A$

The difference in ventilation rate under the current and proposed rate varies based on unit configuration (number of bedrooms and area). Table 2 presents ventilation rates for example HRMF units. As shown, the proposed ventilation rate reduction ranges from 28 to 38 percent.

Table 2: Current and Proposed Ventilation Rates for Example HRMF Units

Bedrooms	Area (ft^2)	Current Ventilation Rate, cfm (62.1-2007)	Proposed Ventilation Rate, cfm (62.2-2013)	Percent Reduction
1	800	58	39	33%
1	1000	70	45	36%
1	1200	82	51	38%
2	1000	75	53	30%
2	1200	87	59	33%
2	1500	105	68	36%
3	1200	92	66	28%
3	1500	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

[2] Though it is called out 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.

[3] The 62.2-2016 equation for adjusting the ventilation rate for single family with balanced ventilation could not be applied to multifamily units because this adjustment is based on the infiltration rate, which is assumed to be zero in multifamily units.

with passive vents, which rely on a pressure differential created by an exhaust system to provide outdoor air to the living space. According to interviewees, 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 dampering. 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 installed in exterior walls. Interviewees reported it also somewhat common for designs to use Packaged Terminal Air Conditioners (PTACs), 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 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 proposal, HRMF units cannot use operable windows to meet the ventilation requirement, because it is prohibited in ASHRAE 62.2-2013. Because this strategy is rarely used, this aspect of the proposal should not alter current industry practices.

The Statewide CASE Team conducted interviews with 12 HRMF mechanical engineers and energy analyst/ HERS Raters, five air quality specialists and public health officials, and three ASHRAE 62.2 committee members. Interviewees provided different responses regarding whether reducing the ventilation rate will affect ventilation practices. Some reported that the industry will continue to use similar practices, 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:

- HRVs or ERVs that serve individual units are lower cost and more feasible for lower ventilation rates, because some models only accommodate lower flows.
- Dedicated outdoor air strategies such as central ducted ventilation systems that provide filtered, tempered air to each unit become less costly 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 3 summarizes these strategies. The primary 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.

Table 3: Comparison of HRMF Ventilation Strategies

Method	Frequency	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.	Interviewees had strong concerns regarding reliability 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 by interviewees.	Inexpensive, simple, provides somewhat more ventilation air than method 1.	Interviewees questioned reliability for providing outdoor air, and reported occupants dislike drafts and often tape up openings. Studies conducted in the Northeast United States (U.S.) found that about the same air volume entered through trickle vents as when no make-up air is provided[4]. Still likely to result in negative pressures and bring in air from adjacent spaces.
3. Central ducted supply air, such as dedicated outdoor air.	Occasionally, such as when filtered air is required.	Greatest reliability and control for providing ventilation air, ability to filter and temper incoming air.	High installation costs, higher energy use.
4. HRV or ERV, usually serving individual dwelling units.	Occasionally.	Can filter and temper incoming air. Most interviewees reported this can be less expensive than ducted supply air (method 3) because less ductwork.	More expensive than passive vents, less control than ducted supply air, more wall penetrations. Interviewees reported they are not cost justified for many California climates, but can become cost competitive with methods 1 and 2, because they allow downsizing of heating and cooling equipment and can serve as bath fans, and that the improved IAQ and comfort can increase marketability.

Interviewees reported the next most common strategy 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).

[4] http://www.nrel.gov/docs/fy14osti/62313.pdf

HRMF units are occasionally served by central ducted supply air, such as dedicated outdoor air supply. Interviewees reported this is a much more reliable strategy for providing ventilation air than the passive strategies described above, but is rarely done because it is significantly more expensive. 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 estimate 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 has higher energy use (CARB 2014).

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), the ERV/HRV provides reliable outdoor air and 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/HRV is expensive, it requires much less ductwork than the ducted outdoor air. It may also enable designers to reduce the size of heating and cooling equipment, which reduce cost. For ERVs or HRVs installed in bathrooms, these units 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.

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 current fire code, so is not allowed in new construction. As noted above, all interviewees reported that operable windows are rarely used as the primary ventilation strategy in new construction HRMF.

2.1.4.2 Central Ventilation Duct/Shaft Sealing and Air Balancing

Field studies have shown that air leakage, stack effect, and lack of or improper balancing can prevent individual units from receiving their proper quota of ventilation air (Building Science Corporation 2012) (Center for Energy and Environment 2016). This proposed change will require that shafts (where they are used) are sealed to limit leakage to six percent of total ventilation airflow, and that constant air regulation devices or orifice plates be used in conjunction with VFD-controlled central fans to ensure that each unit receives the volume of air required by ASHRAE Standard 62.2-2016.

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

Because it is uncommon to test ventilation shaft leakage, many interviewees were hesitant to provide estimates of current leakage in new construction HRMF central ventilation shafts. Those who provided a response estimated a 10 to 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 5 percent, to be consistent with supply air duct leakage requirements. Some reported that 5 percent would be too stringent for a new requirement, while others reported this was attainable.

Testing and balancing central exhaust shafts is important, particularly in buildings with a large stack effect, such as tall (over eight story) 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, but Title 24, Part 6 does not require that results are verified, such as by a Home Energy Rating System rater (HERS Rater) or Acceptance Testing 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[5]. While these 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 should still perform well. Strategies such as balancing once with fixed edge orifice plates have the advantages (compared with self-balancing dampers) of requiring less maintenance and lower first cost.
- Older versions of self-balancing dampers[6] 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 of the technology have the same issue. However, many HRMF mechanical engineers reported concerns with maintenance 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 may vary depending on its 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.

2.1.4.3 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 supply as well as exhaust air and to reduce exchange of air between units (improved compartmentalization). This will compensate for the reduction in ventilation rate dictated by the new ASHRAE standards. In addition to meeting ASHRAE 62.2-2016 ventilation rate requirements, the following two alternate methods of compliance are proposed:

a. Where exhaust-only ventilation is used, partition walls shall be sealed and 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).

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[5] 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 pdf p. 106 of the Center for Energy and Environment, Multifamily Ventilation Assessment and Retrofit Guide, 2016.

[6] 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 pdf p. 15 of the Center for Energy and Environment, Multifamily Ventilation Assessment and Retrofit Guide, 2016.

Sealing of interior partition walls will follow the same method described in Residential Appendix RA3 for sealing exterior walls. Method (b) would be required within 500 feet of busy roadways, defined as a roadway with annual average daily traffic (AADT) greater than 100,000.

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

Note: The use of supply-only ventilation to pressurize units is prevented by the building code, which specifies that smoke shall be controlled by maintaining pressure differences across smoke barriers (Title 24, Part 2: 403.3.7.1 and 909.6). The reasoning behind this code is that interior corridors should be pressurized with respect to the dwelling units to prevent smoke and flame from a fire that originates in one unit from spreading into corridors.

2.1.5 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 and that they not exceed a noise level of three sones. Previously there has been no verification process, and the Statewide CASE Team proposes that compliance with these requirements be verified for all residential building types covered by Title 24, Part 6. These two performance parameters are listed in the Home Ventilating Institute (HVI) Certified Products Directory[7] for a large number of tested hoods.

2.1.6 Change in Filter Efficiency Requirement

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

2.1.7 Affected Code Sections

Revisions to Title 24, Part 6 Section 120.1 will be made to shift ventilation requirements for high-rise multifamily from the nonresidential (Section 120.1) to the residential section (Section 150.0). Provisions for sealing of ventilation 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 recirculating HVAC systems from MERV 6 to MERV 13 (or AHRI 680-2009 particle size efficiency of greater than 80 percent in the 1.0 to 3.0 μm range), and to reference ASHRAE Standard 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, the increase in filter efficiency, the requirement for an outside air source for multifamily occupancies using exhaust fans for outdoor air ventilation, and the requirement for mechanically driven outdoor ventilation supply air with MERV 13 filtration in areas with high 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 (CBC) and Part 4, the California Mechanical Code (CMC). 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.

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

2.2 Measure History

2.2.1 Why These Measures are Being Proposed

Changes Pertaining to All Unit Types

Public Resources Code 25402.8 (New Building Standards for Residential, etc.) 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 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 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 proposed adoption of ASHRAE Standard 62.2-2016 (to replace the 2010 version) into Title 24, Part 6 is the primary driver for this code change proposal. There has been extensive debate over what constitutes sufficient ventilation on the ASHRAE SSPC 62.2 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. 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 Statewide CASE Team, the Energy Commission, and the California Air Resources Board (CARB) are advocating the adoption of the requirements in the 2016 version of ASHRAE 62.2.

Recent and ongoing studies of IAQ show that particulate matter in the 2.5 μm size range (PM 2.5) 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).

Filtration of outside air is critical in areas with high levels of PM 2.5. For exhaust only 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). A similar assumption can be made for low-rise multifamily buildings, but properly compartmentalized HRMF units 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, as defined in Section 7.1.3).

Ineffective range hoods that either do not exhaust sufficient air, are not operated because they are too noisy, or have poor capture efficiency contribute to the IAQ problem. The ASHRAE ventilation standard adopted by Title 24, Part 6 requires that kitchen hoods meet venting, airflow, and noise standards. Performance data is published by HVI and can be used for verification. The proposal to increase recirculating air filter efficiency to MERV 13 also addresses the concern about indoor sources of PM 2.5.

As noted in Section 3, it is standard practice in most new dwelling units, including low and high-rise multifamily buildings to rely on envelope leakage as a source of outdoor air. In multifamily buildings, much of the “fresh” outdoor air is drawn from adjacent units. The requirement for makeup air in multifamily occupancies is proposed to ensure that adequate outdoor air is provided for more tightly constructed buildings, and that the air is free from pollutants, including cigarette smoke and cooking odors from adjacent units.

Changes Pertaining to HRMF and Balanced Ventilation in All Multifamily Dwelling Types

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 is exhaust-only coupled with passive vents installed on the exterior wall. While there is little data 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 (CARB 2014) and 13 to 36 percent (CARB 2016). 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, which would further reduce 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[8]. In addition, whereas infiltration through 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 outdoor PM 2.5 (as described in Section 3.3.1) that use exhaust-only with passive vents could have high levels of outdoor PM 2.5.

For these reasons, the proposal includes the following:

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. 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.

All stacked multifamily units that use balanced ventilation may reduce the ASHRAE 62.2-2016 mechanical ventilation rate by 15 percent. The Statewide CASE Team proposes to encourage balanced ventilation for all multifamily buildings (low-rise and high-rise), by allowing stacked multifamily units that use balanced ventilation to use a reduced ventilation rate: 0.85 x Qtotal, where Qtotal is calculated in Section 2.1.2, Equation 1: Qtotal = 0.03 x (CFA) + 7.5 x (BR + 1). As described in that section, ASHRAE 62.2-2016 does not allow for stacked multifamily units to take credit for infiltration (Qinfil = 0), so Qfan is the same as Qtotal. (For horizontally attached multifamily units, ASHRAE Standard 62.2-2016 allows some infiltration credit.) Rationale for the ventilation rate reduction for balanced ventilation include:

- 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, where only one-third (up to 40 percent) of the design ventilation rate is delivered through passive vents. The Statewide CASE Team developed the 0.85 factor by reviewing a variety of current and proposed ventilation rates, as described in Appendix B.

[8]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.

- Several interviewees reported it is easier to provide a balanced system in HRMF units with lower ventilation rates, because some ERVs and HRVs that serve individual units have low maximum flowrates. A review of products confirmed the interviewees' 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 4), without the 0.85 factor (see Section 8.2).
- 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 the literature indicates, and almost all interviewees reported, that passive vents may not provide a reliable ventilation rate, almost all interviewees believe that passive vents perform better than no dedicated make-up 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, since a passive vent study (CARB 2016) found that increased compartmentalization increases airflow through these vents. 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, such as recommendations from the "Measure Guideline: Passive Vents" report (CARB 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, because low-rise units do not have as great a potential for pollutant transfer due to their reduced stack effect, and because low-rise units using an exhaust-only ventilation strategy generally use infiltration (as opposed to passive vents) for make-up air. Particularly because there are few HRVs or ERVs products that 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, low-rise units in areas of high PM 2.5 do not have a MERV 13 requirement for outside air.

Field studies have also demonstrated that central ventilation systems using fire-rated shafts to convey air to multifamily units may leak excessively, and that dampers and/or central fans are either not provided or are improperly adjusted to ensure that airflow is balanced and that the right quantity is delivered to each unit (Building Science Corporation 2012) (Center for Energy and Environment 2016). Leakage in shafts can also distribute air from one unit to another instead of delivering 100 percent outside air.

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 ventilation 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 to 3.0 µm range), and to reference ASHRAE Standard 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 the requirement for an outside air source for multifamily occupancies using exhaust fans for outdoor air ventilation. Section 150 will also define requirements for kitchen hood verification.

The change in the ventilation standard for HRMF will also affect other Parts of Title 24, including Part 2 of the California Building Code (CBC) and Part 4 of the California Mechanical Code (CMC). 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.

SECTION 120 – REQUIREMENTS FOR VENTILATION

Subsection 120.1: References to other codes will be simplified.

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)1A: Exception that allows natural ventilation in high-rise buildings will be deleted.

Subsection 120.1(b)3A & B: These sections will be added to limit leakage from ventilation shafts and ducts to six percent of total ventilation air and to require balancing within ten percent of design airflow.

Table 120.1-A: Change the reference for high-rise residential from the CBC to Section 150.0(o).

Subsection 120.4: Add exception to provide for the use of drywall ducts to convey ventilation air if sealed in accordance with Subsection 120.1(b)3A.

Subsection 120.5(a): Add a line (18) to specify that filters for recirculating HVAC systems in HRMF buildings will comply with 150.0(m)12B.

SECTION 150 – MANDATORY FEATURES AND DEVICES

Subsection 150.0(m)12B: Update MERV and AHRI 680 PSE values to match the proposed filter efficiency requirement, and add language requiring that filter media be labelled by the manufacturer with efficiency and static pressure information and verified. Add an exception that filter verification is not required for heat pumps with less than ten feet of duct.

Subsection 150.0(o): Change the reference to the *current* version of ASHRAE Standard 62.2.

Subsection 150.0(o): Revise language to reference 2016 version of ASHRAE Standard 62.2 and include relevant California exceptions.

Subsection 150.0(o)1B: New section titled Kitchen Exhaust Ventilation that specifies HVI certification and compliance with Sections 5 and 7 of Standard 62.2, and that requires field verification as provided for in RA3.7.4.3.

Subsection 150.0 Exception 1: Requires that air filter media shall meet the requirements of Section 150.0(m)12B (MERV 13 instead of MERV 6).

Subsection 150.0 Exception 2: Clarifies that if a blower door test is not completed, then the capacity of the mechanical ventilation system will be based on 2 ACH50.

2.3.2 Reference Appendices Change Summary

This proposal would modify the following sections of the standards appendices as shown below. See Section 7.1.1 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 filter labeling.[9]

RA2.3.1.2: Documentation registration: Edited as follows: "For all low-rise and high-rise 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.

RA3.7.5 – Procedures Specific to High-Rise Multifamily Buildings: This new section describes procedures related to 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 ventilation: air sealing and balancing

2.3.3 Alternative Calculation Method (ACM) Reference Manual Change Summary

This proposal would modify the following sections of the Residential Alternative Calculation Method (ACM) Reference Manual as shown below. See Section 7.3 of this report 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 would substantially change the algorithms applied for calculation requirement minimum ventilation airflow rates. This section would 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 section of the Title 24, Part 6 Compliance Manual:

- Residential Compliance Manual Section 4.6 – Indoor Air Quality and Mechanical Ventilation
- Nonresidential Compliance Manual Chapter 4.3 – Ventilation Requirements

2.3.5 Compliance Documents Change Summary

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

- CF2R & 3R-MCH-22a & b – Add checklist item to verify filter labeling (e.g., MERV 13 or AHRI 680-2009 particle size efficiency of 85 percent in the 1.0 to 3.0 µm range)

[9] Not required for mini-split heat pumps or ducted variable speed heat pumps with less than 10' of duct connected.

- CF2R & CF3R-MCH-27a-d – Add checklist item for makeup air verification, applicable to multifamily only.
- CF2R & CF3R-MCH-31 – Add new form for kitchen hood verification.

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. Improvements would also provide clarity as to which R-2 occupancies are covered by 62.1 vs. 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 apply the Residential Ventilation Standard (ASHRAE 62.2) is apartment buildings with non-transient occupancy. All other listed R-2 occupancies would apply the Nonresidential Standard (ASHRAE 62.1). Some gray areas may remain, for example with condominium buildings that are occupied both intermittently and full time.

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 "Dwelling. Requirements for ventilation air rate for single family dwellings shall be in accordance with this chapter or ASHRAE 62.2."

Section 402.3: 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 ft^2. 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 planned to be accommodated in revisions to Title 24, Part 6 and, as proposed, would lower the current 0.58 W/cfm efficacy to 0.4 w/cfm. A requirement for higher efficiency filters may increase the difficulty of attaining a lower 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. IECC requires similar ventilation rates as calculated using the 2010 and 2013 versions of 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 on what compliance and enforcement issues may be associated with this measure during the stakeholder outreach process. This section summarizes how the proposed code change 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.

This code change proposal will affect buildings that use either the prescriptive or performance approach to compliance. 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[10] and combination microwave exhaust hoods that cannot meet the 100 cfm, 3 sone requirement. 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 ventilation systems will need to meet requirements for balanced air delivery and shaft sealing.
    - Provisions must be made for makeup air or balanced ventilation.

  Single 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 forms.
- **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 areas 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, low-rise multifamily units this measure will have minimal impact on the existing building inspection phase process. There will be additional work for

[10] Currently addressed in Residential Compliance Manual section 4.6.5B.

verifiers to inspect kitchen hoods. For high-rise buildings, inspection and verification will be required for the following:

  - Prescriptive compartmentalization requirements – required for all HRMF units, and with verification required for HRMF units using exhaust-only with passive vents as the strategy for complying with the whole dwelling unit ventilation rate
  - Central ventilation shaft sealing to six percent of total fan flow
  - Central ventilation 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 form will be needed to document kitchen exhaust hood verification. For high-rise buildings using ventilation shafts, additional testing will be required to verify air tightness and proper distribution of ventilation air.

- **Compliance**: Compliance enforcement changes for new measures include:
  - MERV 13 filters, kitchen hoods, and proposed high-rise measure changes will increase the enforcement burden.
  - Verification of high-rise projects where verification is typically not required is a significant change, and includes compartmentalization in high-rise multifamily units that use an exhaust-only with passive vents ventilation strategy, and verification of mechanically driven, filtered air in areas where this is required.
  - 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 utility program staff, Energy Commission staff, and a wide range of industry players who were invited to participate in Utility-Sponsored Stakeholder Meetings held on September 27, 2016 and March 16, 2017.

3.1 Market Structure

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). 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 Supply the Measure

The construction industry is skilled in all of the 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; sizing of filters and filter grilles that allow airflow and watt draw requirements to be met.

Because most HRMF units use exhaust-only strategies for supplying ventilation air, some training or 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 ample 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 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 balanced exhaust systems are available that incorporate variable speed fans that have a wide range of capacities. There are 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 sone s 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, 3 zone requirements since HVI listings for kitchen hoods do not specify whether microwaves are included.

Filters for Recirculating HVAC Systems. In an emergency rulemaking, the Energy Commission extended the required date for filter labeling from July 1, 2016 to April 1, 2019[11]. As a result, the California Appliance Efficiency Standards (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. Some manufacturers have complied with the Title 20 labeling requirement, notably 3M Filtrete. Most high efficiency filters are pleated and range from 1-inch to 4-inches thickness. Sizes up to 20 x 30-inch are commonly available and larger sizes can be obtained from internet sources and wholesalers. The April 2019 filter labeling date will ensure that data concerning filters will be available for the January 1, 2020 start of the 2019 Standards.

[11] Docket Number 17-AAER-02

In general, higher MERV ratings correlate to increased pressure drop. A few 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 that use higher MERV filters to ensure they have sufficient surface area, and recommended that engineers provide more details in building plans (e.g., filter make and model) to ensure adequate airflow.

The Statewide CASE Team analyzed the impact of MERV 13 filters on filter grille size using data from prior testing (Springer 2009) and obtained from labeled filters. Based on an assumed maximum filter pressure drop of 0.15", the analysis showed that a 1" Filtrete 1900 MERV 13 filter would require 3 times the surface area of a MERV 8 filter (Filtrete 600) and a 2" Aeolis Mini-Pleat MERV 13 filter would require 1.5 times the surface area of the MERV 8 filter (In testing, the Filtrete 600 filter had a lower pressure drop than a MERV 6 filter.). Consequently, larger filters and filter grilles will be required to accommodate this code change, which will increase installed and filter replacement costs. However, sizing filter grilles to accommodate high MERV filters will minimize future system problems that can occur when homeowners replace filters with ones that are more restrictive.

The air velocities that underlie the existing filter grille sizing in Tables 150.0-B and C range from 151 to 176 feet per minute (fpm). Applying these velocities to a pressure drop curve for a 1" MERV 13 filter (Filtrete 1900) results in pressure drops ranging from 0.08 to 0.10 inches water column (w.c.). For this specific filter, if the velocity is limited to 200 fpm, the pressure drop would not exceed 0.11 inches w.c., which is a reasonable pressure drop to use for duct design purposes given the available static pressure of typical furnaces.

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 of low cost, passive through-the-wall vents, including Panasonic, Therma-Stor, and Houzz. These may include interior and exterior louvers and filters or insect screens.

Central Shaft Air Balancing: Most high-rise multifamily buildings with central ventilation shafts receive some type of testing and balancing (TAB) for individual unit exhaust fans. Interviewees reported that this can be done through manually balancing fixed orifices, installing constant air regulation (CAR) devices, or 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 require a 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. Ventilation shafts are typically sealed using typical 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 typically no test of ventilation shaft leakage, and (consequently) there is little data indicating typical leakage in ventilation shafts in new construction buildings. Interviewees indicated that, without attention to sealing, leakage can range from 10 to 30 percent, and the literature supported an estimate of approximately 25 percent (WCEC 2014).

Table 4 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 manufactures offer products with MERV 13, including the Zehnder

ComfoAir[12] and Fantech VHR200R[13]. 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 do not currently offer MERV 13 filtration.

Table 4: HRV and ERV Product Cost, Flowrates, and MERV Ratings

Manufacturer	Product Name	ERV/HRV	Cost	Flowrate (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	$2163/ $1987	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, 13 option
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 requirements for both the recirculating air filter and the outside air filter, the Statewide CASE Team developed Table 5 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).

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

[13] 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 5: Filtration Requirements in Building Standards, Above Code Programs, and City Ordinances

Standard / Ordinance	Scope	Recirculating Air Filter	Outside Air Filter
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 recirculating or outside air	
City of San Francisco (Article 38)	Residential	Ventilation systems with MERV 13 <= 500 ft of freeways and other sensitive areas. Not specified if recirculating or outside air	
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

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 of low cost, passive through-the-wall vents, including Panasonic, Therma-Stor, and Houzz. These may include interior and exterior louvers and filters or insect screens.

Central Shaft Balancing: Most high-rise multifamily buildings with central ventilation shafts receive some type of testing and balancing (TAB) for individual unit exhaust fans. Interviewees reported that this can be done through manually balancing fixed orifices, installing constant air regulation (CAR) devices, or 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 require a 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. Ventilation shafts are typically sealed using typical 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 typically no test of ventilation shaft leakage, and (consequently) there is little data indicating typical leakage in ventilation shafts in new construction buildings. Interviewees indicated that, without attention to sealing, leakage can range from 10 to 30 percent, and the literature supported an estimate of approximately 25 percent (WCEC 2014).

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 recirculating HVAC filters 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, and ventilation shaft sealing and balancing may be completed either by HERS inspectors or ATTs.

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

The intention of the proposed measures is to balance energy efficiency improvements that are proposed by other CASE Reports with the need to maintain occupant comfort, health, and building durability. By providing the level of ventilation recommended by the national ASHRAE Standard, indoor pollutants will be reduced by dilution and filtration, and 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, the pleated surface of higher rated air filters has 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 regarding compliance with any one proposed code change or the collective effect of all 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 2, 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.

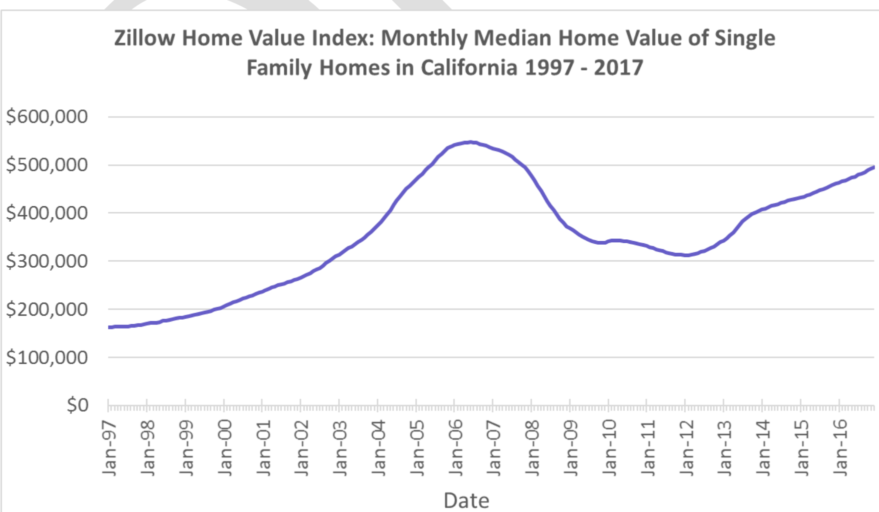

Figure 2: California median home values 1997 to 2017

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.

Reviewing current builder practice relative to proposed changes for single family and low-rise multifamily buildings, 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.

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 completed for this report was unable to identify any complying combination appliances, though one model that was tested by Lawrence Berkeley National Laboratory came close. HVI listings do not identify which range hoods include a microwave oven. Verification of hoods and recirculating HVAC filters may increase HERS fees slightly.

The requirement for mechanically driven supply air with MERV 13 filtration of outside air in HRMF units in areas of high ambient PM 2.5 will increase costs in those areas by approximately $1,600 per unit (section 5.2). 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) 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 Article 38, which requires MERV 13 filtration in urban locations within 500 feet of a roadway with 100,000 vehicles per day. The CASE Team provides an estimate 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 considered proposing this requirement 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 lives 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.[14] PM 2.5 levels in the SCAQMD have been declining, and the SCAQMD 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), and has 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; 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 does not recommend requiring this measure in PM 2.5 nonattainment areas. Section Appendix B provides further detail on the rationale for the scope of this requirement.

[14] 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

Requirements for sealing central ventilation 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 will impact builders.

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.) 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 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, they will have the responsibility to convey to the design-build team the required size of whole house ventilation fans (to be listed in CF1R forms), and new requirements for kitchen hoods and recirculating HVAC filters, so these items can be properly specified. For multifamily buildings, energy consultants must also inform the design-build team (including mechanical engineers) of requirements for makeup air and design of central ventilation shafts, where used. 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 will be useful in providing the needed guidance.

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

3.3.3 Impact on Occupational Safety and Health

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

3.3.4 Impact on Building Owners and Occupants (including homeowners and potential first-time homeowners)

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, but 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 a $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 that has been linked to higher incidences of lung cancer; and for multifamily tenants, elimination of odors from adjacent units.

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 and MERV 13 filters, and may create market demand for 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 are 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 2010 *Characterizing the Energy Efficiency Services Sector* report provides a detail on the types of jobs in the energy efficiency sector that are likely to be supported by revisions to building codes.

Building codes jobs through *direct employment*, *indirect employment*, and *induced employment*.[15] Title 24, Part 6 creates jobs in all three categories with a significant amount created from 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 (Wei, Patadia and Kammen 2010). Wei et al. (2010) estimates that energy efficiency creates 0.17 to 0.59 net job-years[16] per GWh saved. By comparison, they estimate that the coal and natural gas industries create 0.11 net job-years per GWh produced.

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 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 ventilation shafts and provisions for makeup air in multifamily buildings will increase labor needs slightly.

3.4.2 Creation or Elimination of Businesses within California

There are approximately 43,000 businesses that play a role in California's advanced energy economy (BW Research Partnership 2016). California's clean economy grew ten times more than the total state economy between 2002 and 2012 (twenty 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 only affect new single family and multifamily construction. Application to alterations or additions may be considered in future code cycles.

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

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:

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[15] 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."

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

- Exhaust fans used for whole house ventilation
- Heat or energy recovery ventilators
- Passive through-wall vents
- Constant airflow regulators
- Filters for recirculating 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 6: 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 within California

Improved IAQ should reduce healthcare costs and increase productivity, and is expected to have a measurable impact on the ability of California to compete.

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 the California's General Fund, any state special funds, or local government funds. Revenue to these funds comes from taxes levied. The most relevant taxes to consider for this proposed code change are: personal income taxes, corporation taxes, sales and use taxes, and property taxes. The proposed changes for the 2019 Title 24, Part 6 Standards are not expected to result in noteworthy changes to personal or corporate income, so the revenue from personal income taxes or corporate taxes is not expected to change. As discussed, reductions in energy expenditures 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 standards, 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. 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 will have a greater benefit to tenants of multifamily buildings, where IAQ is sub-par, because of inadequately designed or installed ventilation systems, and where buildings are located in low outdoor air quality attainment areas. Groups affected are likely to be more economically disadvantaged than the general population.

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.[17]

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

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

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 utilized the ASHRAE 62.2-2016 ventilation rates in the models used to evaluate 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 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 TDV schedules.

Table 7 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 high-rise multifamily buildings, the proposals will decrease energy use in most cases, because of the decrease in ventilation rate moving from the 62.1 to 62.2-2016 rates. This was modeled using the multifamily proto-type shown in Table 7. The Statewide CASE Team used the low-rise multifamily 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 software (CBECC-Com) would not 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 2100 ft^2 prototype and 55 percent for the 2700 ft^2 prototype, resulting in blended 2,430 ft^2 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 current (2016) compliance approach to ventilation 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/ft^2 plus 7.5 cfm per occupant. The analysis completed to estimate single family energy impacts assumed an infiltration rate corresponding to 2 ACH50 and a mechanical ventilation rate that would yield a total ventilation rate of 0.03 cfm/ft^2 plus 7.5 cfm/occupant, in accordance 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.[18] Inputs to this tool include building floor area and height, number of occupants (or bedrooms + 1), and climate

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

location. The results (required mechanical ventilation rates) were entered in CBECC-Res to develop energy use impacts for each climate zone and prototype house.

Increasing the mechanical ventilation rate using an exhaust fan in existing buildings that have gas appliances that use indoor air for combustion is a safety risk. Consequently, the increase in ventilation rates resulting from the adoption of ASHRAE 62.2 are only proposed for new single family residences, not for alterations or additions.

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

Prototype ID	Occupancy Type (Residential, Retail, Office, etc.)	Area (ft^2)	Number of Stories	Statewide Area (million ft^2)
New Construction Prototype 1	Residential single family	2,100	1	70.1
New Construction Prototype 2	Residential single family	2,700	2	110.1
New Construction Prototype 1	Residential multifamily	6,960	2	36.8

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

4.3 Per Unit Energy Impact Results

Energy use and peak demand impact per unit for new single family houses (using the blended 2100 ft^2 and 2700 ft^2 prototypes) are presented in Table 8. Negative values indicate increases in energy use versus the current prescriptive cases. Electricity use is affected by increases in fan energy use due to larger ventilation rates, and in most climate zones by increases in air conditioning loads. Gas consumption is also increased as a result of higher ventilation rates during winter periods. Surprisingly, CBECC-Res shows gas energy savings in the coldest climate zone (16).

Table 8: First-Year Energy Impacts for Blended Single Family Prototype

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	-1.9
2	-67.1	-0.01	-9.09	-2.1
3	-58.4	-0.01	-9.29	-1.6
4	-67.0	-0.02	-6.88	-1.7
5	-58.8	-0.01	-7.64	-1.5
6	-68.0	-0.02	-7.15	-1.6
7	-70.4	-0.01	-6.45	-1.4
8	-47.8	0.05	-5.34	-0.5
9	-52.5	0.01	-5.68	-1.3
10	-38.2	0.02	-5.12	-1.0
11	-45.9	0.02	-3.91	-0.8
12	-39.0	0.05	-3.93	-0.7
13	-58.9	0.00	-5.81	-1.6
14	-23.0	0.05	2.10	0.3
15	-152.3	-0.04	-2.36	-2.2
16	-67.1	-0.01	-3.16	-1.3

Table 9 provides 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 7. The high-rise multifamily prototype was not used because the high-rise compliance software did not allow ventilation rate reductions below the currently required (62.1-2007) levels. Results show savings at the dwelling unit level, averaged between the four one-bedroom, 780 square foot units and the four two-bedroom 960 square foot units in the multifamily prototype building. 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 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 9: First-Year Energy Impacts of Ventilation Rate Change for High-Rise Residential Unit Prototypes (Averaged)

Climate Zone	Electricity Savings (kWh/yr)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	59.0	24.9	1.0
2	62.1	16.6	0.9
3	46.9	12.0	0.6
4	51.3	13.4	0.7
5	39.6	11.2	0.5
6	41.0	6.3	0.3
7	36.4	2.0	0.2
8	35.0	3.6	0.3
9	54.4	6.3	0.6
10	55.6	7.4	0.6
11	91.6	15.6	1.0
12	63.9	15.9	0.9
13	93.1	14.6	1.0
14	82.8	14.6	0.9
15	169.0	1.8	1.0
16	58.5	24.2	1.0

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, and produce modest savings in high-rise multifamily buildings. For this reason, lifecycle cost and cost-effectiveness are not presented in this report.

5.2 Incremental First Cost

The Statewide CASE Team estimated the Current Incremental Construction Costs and Post-Adoption Incremental Construction Costs. The Current Incremental Construction Cost represents the incremental cost of the measure if a building meeting the proposed standard were built today. The Post-Adoption Incremental Construction Cost represents the anticipated cost assuming full market penetration of the measure as a result of the new standards, resulting in possible reduction in unit costs as manufacturing practices improve over time and with increased production volume of qualifying products the year the standard becomes effective. Per the Energy Commission's guidance, design costs are not included in the incremental first cost. Total costs are presented as costs to the builder. A thirty 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.

Incremental costs for single family whole house ventilation fans are based on Panasonic model FV-##VQ5 bathroom fans. Moving from ASHRAE 2016-2010 to -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 ft^2 prototype and 80 to 110 cfm for the 2,700 ft^2 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 10 are conservative.

One hour of additional labor was included to account for the installation of a second return grille required for the upgrade from MERV 6 to MERV 13 filters. The 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 the single family case.

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.

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

Those interviewed generally recognize the inadequacies of the low-cost approach and appreciate the need for improved delivery of outside air. Adding penetrations through exterior walls is undesirable from an aesthetic perspective, but providing central ventilation (shafts or ducts) is costly. Adding filters to passive vents reduces 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 10 lists estimated incremental costs for each measure. Table 11 summarizes costs for two baseline ventilation approaches: exhaust fans with no makeup air, and central ventilation with no makeup air. The cost for a third approach, balanced ventilation using an HRV, is also provided.

Table 10: Summary of Incremental Costs

Product Type	Description	Material Cost / Unit	Additional Labor Cost / Unit[1]	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[1]	HVI listed, at least one speed setting of ≤ 400 cfm or less having a noise level of ≤ 3 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, 1200 cfm)	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-micron range per AHRI Standard 680-2009	Increase from 1-12x18 to 2-20x18 filters/grilles, total $56	1 hour for additional grille & ducting	$117	Each single family or multifamily unit
Makeup Air Vent [2]	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
Constant airflow regulator [2]	Based on Aldes CAR 4" MR Modulo Adjustable Flow Regulator, 10-50 CFM	$41	1 hour	$97	Each HRMF unit
Ventilation shaft sealing [2]	Sealing using typical means employed for gypboard or ducts	Nominal	4 hours more than standard practice for sealing, plus 4 hours for testing leakage	$306	Each ventilation shaft (assume one per building)
Sealing of interior partition walls [2]	Sealing partition walls using similar techniques as used for exterior walls	$10	1 hour more than standard practice	$57	Each multifamily unit
Compact HRV[19]	HRV for multifamily units where balanced ventilation is selected	$507	2 hours	$945	Each unit
Compact HRV with MERV 13	HRV for HRMF units requiring balanced ventilation and MERV 13 filtration	$1,195	3 hours	$1,600	Each HRMF unit

1. 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.

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

Table 11: Incremental Costs for Proposed Measures for Each New Construction Prototype

Measure	Single Family	Low-Rise Multifamily	High-Rise Multifamily (per unit[1])		
			Exhaust Ventilation, Distributed	Exhaust Ventilation, Central	Balanced Ventilation
Exhaust Fan	$8[2]				
MRV 13 Filter & Grille	$117	$78	$78	$78	$78
Passive Makeup Air Vent			$200	$200	
Seal Partition Walls			$44	$44	
Constant Airflow Regulator				$97	
Central Ventilation Sealing[2]				$10	
Balanced with MERV 13					$1,600
TOTAL	**$125**	**$78**	**$322**	**$429**	**$1,600**

1. Per unit cost for 30 units.
2. Incremental cost for larger fan that meets 62.2-2016 ventilation rate requirement.

5.3 Lifetime Incremental Maintenance Costs

Because the proposed measures generally do not provide energy savings, lifecycle costs are not calculated and 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, but are necessary for the maintenance of IAQ. Therefore, lifecycle cost-effectiveness is not reported.

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 Studies, 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, which require significant energy inputs.

6.4 Other Non-Energy Impacts

Implementation of the proposed measures will result in significant improvements to IAQ, particularly for single family and HRMF occupants. In particular, indoor PM 2.5 will be reduced because of increased filtration requirements. While the 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, Zhao 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.

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

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. 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.

7.1.2 Title 24, Part 4

SECTION 402 – VENTILATION AIR

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

APPENDIX E – SUSTAINABLE PRACTICES

E 605.0 Indoor Air Quality for Low-Rise Residential.

E 605.1 General. Rooms or occupied spaces within single family homes, ~~and~~ low-rise multifamiIy 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 120.1 – REQUIREMENTS FOR VENTILATION

120.1: 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.

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 ventilation shafts and ducts. Central ventilation 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 six percent or less of the measured fan airflow of the roof ventilator.

B. Airflow exhausted from individual units shall be balanced to within ten percent of design airflow using either constant air regulation devices, manual dampers, or orifice plates.

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 ventilation shafts in high-rise multifamily buildings shall comply with the applicable requirements of Section 120.4, except that they may use drywall ducts to convey ventilation air if the shaft and branches are sealed to six percent or less leakage of measured fan airflow of the roof ventilator when pressurized to 25 Pa.

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

150.0(m)12B: Air Filter Media Efficiency for Recirculated Air. 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. Installed air filter media shall be labelled with the efficiency and static pressure ratings by the manufacturer, which shall be confirmed by field verification.

EXCEPTION to 150.0(m)12B: Air filter media labeling is not required for mini-split heat pumps or ducted variable speed heat pumps with less than ten feet of connected duct.

150.0(m)12B.ii: Air Filter Media Efficiency for Outdoor Air. Air filter media used with 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

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~~, Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings~~. For multifamily units, this includes the 62.2 Section 6.1 requirement for compartmentalization: Measures shall be taken to minimize air movement across envelope components to dwelling units from adjacent spaces, such as garages unconditioned crawlspaces, unconditioned attics, and other dwelling units. Pressure boundary wall, ceiling, and floor penetrations shall be sealed, as shall any vertical chases adjacent to dwelling units. Doors between dwelling units and common hallways shall be gasketed or made substantially airtight."

150.0(o)1A: 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 (ft^2), for all multifamily units (low-rise and high-rise except horizontally attached), 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. A HERS Rater or ATT inspector must verify that the dwelling unit has been compartmentalized using the visual verification procedures specified in Reference Residential Appendix RA3. [to be developed]
c. Airflow to individual units served by central ventilation shafts shall be balanced to within 10 percent of design airflow using either constant air regulation devices, manual dampers, or orifice plates.

Units following this pathway 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.

150.0(o)1~~A~~B: Airflow Performance: The Whole-Building Ventilation airflow required by Section 4 of ASHRAE Standard 62.2 shall be confirmed through field verification and diagnostic testing in accordance with the applicable procedures specified in Reference Residential Appendix RA3.7

150.0(o)1C: 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 and shall directly exhaust to the exterior of the building, which shall be confirmed by field verification.

EXCEPTION 1 to 150.0(o): Air filter media shall meet the requirements of Section 150.0(m)12B.

EXCEPTION 2 to 150.0(o): 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.

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 (ASHRAE) document titled "Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings," 201~~0~~6 ('ANSI/'ASHRAE Standard 62.2-201~~0~~6 ~~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~~).

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

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 HERS VERIFICATION, TESTING, AND DOCUMENTATION PROCEDURES

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~~
High-rise Multifamily Unit Compartmental-ization for Exhaust-only Strategy	For HRMF units using a ventilation strategy of exhaust-only with passive vents, visually verify that the unit has met the prescriptive compartmentalization requirements described in RA3. [specify section]	[To be developed]
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 Verification:

Visual inspection of the kitchen exhaust hood or fan used to meet the local exhaust requirements in Section 5 of ASHRAE Standard 62.2 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 and maximum sound level requirements in Sections 5 and 7, respectively, of ASHRAE Standard 62.2. If the listed airflow rate is equal to or greater than the value required by Section 5 of ASHRAE Standard 62.2, the kitchen exhaust ventilation complies with the requirement for kitchen exhaust ventilation airflow. 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.

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 ventilation shafts or ducts for providing outdoor air in high-rise multifamily buildings.

NA2.1.4.2.1 Diagnostic Duct Leakage from Fan Pressurization of Ducts

(a) 4. When testing central ventilation shafts in multifamily buildings ensure that exhaust or supply grilles in all units are tightly sealed to allow leakage of not more than 6 percent of total ventilation fan 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 Qtotal, Qinf, and Qfan as described in Section X 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. This section will be revised to include the calculation method for Qtotal, Qinf, and Qfan.

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 buildings to the list of building types covered by ventilation standards.

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

Section 2.5.1: Add kitchen hoods and multifamily IAQ measures (ventilation shaft pressure test, central ventilation balance dampers, air sealing checklist, 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 forms will require revisions as follows:

- CF2R-MCH-27 – This Certificate of Installation will be revised to add a section for kitchen hood verification.
- CF3R-MCH-27 – This Certificate of Field Verification will be revised to add a section 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 ventilation shafts

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Appendix A: Statewide Savings Methodology

The projected new residential construction forecast that will be impacted by the proposed code change in 2020 is presented in Table 12.

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

The California Energy Commission Demand Analysis Office provided the projected annual residential dwelling starts for the single family and multifamily sectors. The Energy Commission provided a single projection for residential construction broken out by forecast climate zones (FCZ). The Statewide CASE Team translated this data to building climate zones (BCZ) using revised weighting of FCZ to BCZ also provided by the Energy Commission, as presented in Table 13.

Table 12: Projected New Residential Construction Completed in 2020 by Climate Zone[1]

Building Climate Zone	Single Family Buildings					Multifamily Dwelling Units[2]				
	Total Buildings Completed in 2020	Percent of Total Construction in Climate Zone	Percent of New Buildings Impacted by Proposal	Buildings Impacted by Proposal	Percent of Total Impacted by Proposal in Climate Zone	Total Dwelling Units Completed in 2020	Percent of Total Construction in Climate Zone	Percent of New Dwelling Units Impacted by Proposal	Dwelling Units Impacted by Proposal	Percent of Total Impacted by Proposal in Climate Zone
1	441	0.6%	100%	441	0.0%	85	0.2%	100%	85	0.0%
2	1,754	2.4%	100%	1,754	2.5%	970	2.3%	100%	970	2.4%
3	4,229	5.7%	100%	4,229	5.9%	4,936	11.7%	100%	4,936	12.0%
4	4,019	5.4%	100%	4,019	5.6%	2,362	5.6%	100%	2,362	5.8%
5	780	1.1%	100%	780	1.1%	459	1.1%	100%	459	1.1%
6	3,026	4.1%	100%	3,026	4.2%	4,187	9.9%	100%	4,187	10.2%
7	4,067	5.5%	100%	4,067	5.7%	3,165	7.5%	100%	3,165	7.7%
8	4,549	6.1%	100%	4,549	6.4%	5,819	13.7%	100%	5,819	14.2%
9	3,986	5.4%	100%	3,986	5.6%	7,846	18.5%	100%	7,846	19.1%
10	12,734	17.2%	100%	12,734	17.8%	4,272	10.1%	100%	4,272	10.4%
11	4,338	5.9%	100%	4,338	6.1%	765	1.8%	100%	765	1.9%
12	14,300	19.3%	100%	14,300	20.0%	3,561	8.4%	100%	3,561	8.7%
13	8,892	12.0%	100%	8,892	12.4%	1,251	3.0%	100%	1,251	3.0%
14	2,311	3.1%	100%	2,311	3.2%	778	1.8%	100%	778	1.9%
15	2,588	3.5%	100%	2,588	3.6%	638	1.5%	100%	638	1.6%
16	2,137	2.9%	100%	2,137	0.0%	1,258	3.0%	100%	1,258	0.0%
Total	**74,151**	**100%**		**74,151**	**100%**	**42,352**	**100%**		**42,352**	**100%**

Source: Energy Commission Demand Analysis Office

1. Statewide savings estimates do not include savings from mobile homes.
2. Includes high-rise and low-rise multifamily construction.

Table 13: Translation from Forecast Climate Zone (FCZ) to Building Standards Climate Zone (BCZ)

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

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."[20] 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) requirement 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/m3

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

2. A 24-hour PM 2.5 standard implemented in 2006: 35 ug/m3

The SCAQMD Air Quality Management Plan predicts that the SCAQMD will be in attainment with the 24-hr 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 3, SCAQMD measurements indicate that PM 2.5 levels are generally declining and are only slightly higher (~15-20%) 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).

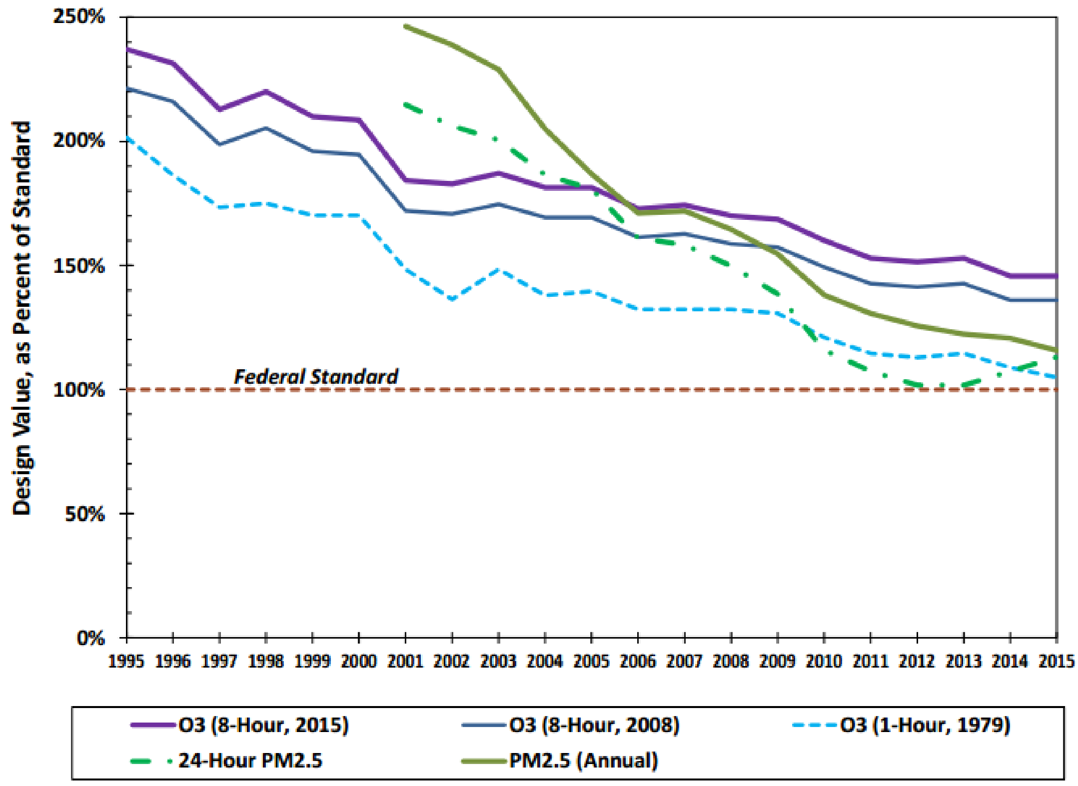

Figure 3: SCAQMD design values in percentages of the federal standards (source: SCAQMD 2016)

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.[21] Similarly, although the EPA Greenbook lists Sacramento as a nonattainment area, Sacramento was determined in attainment with the 24-hour standard in 2013. [22]

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

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

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 (BAAQD)	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 (SCAQD)	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.**

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: PM 2.5 Standards Attainment Status for California Regions 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.

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. 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 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 Table 16, 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, higher than the 62.2-2010 rates, and at least as high as the 62.2-2016 with 0.022 proposal.

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

Description of Rate	Rate Calculation
Current (from 62.1-2007)	Rate that HRMF units currently follow, based on 62.1-2007: 5 cfm/p*(BR + 1) + 0.06cfm/ft^2 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/p x (BR + 1) + 0.03 cfm/ft^2 *A.
Proposed for balanced: 62.2-2016 x 0.85	Rate that is being proposed for HRMF units with balanced ventilation.
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 lowrise)	The old rate for low-rise multifamily units. 62.2-2010: 7.5 cfm/p x (BR + 1) + **0.01** cfm/ft^2 x A.
62.2-2016, with proposal for 0.022 Area factor	Rate that was proposed to the 62.2 committee, to adjust the 62.2-2016 to 7.5 cfm/p x (BR + 1) + 0.022 cfm/ft^2 x A. The proposal was supported by the majority of 62.2 members, but not the supermajority needed to pass the proposal.

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

Bedrooms	Area	Current (from 62.1-2007)	Proposed (62.2-2016)	Proposed for balanced: 62.2-2016 x 0.85	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)	62.2-2016, with proposal for 0.022 Area factor
1	500	40	30	**26**	14	11	20	26
1	800	58	39	**33**	21	14	23	33
2	800	63	47	**40**	23	17	31	40
1	1000	70	45	**38**	25	16	25	37
1	1200	82	51	**43**	30	18	27	41
2	1000	75	53	**45**	27	19	33	45
2	1200	87	59	**50**	31	21	35	49
2	1500	105	68	**57**	38	24	38	56
3	1200	92	66	**56**	33	24	42	56
3	1500	110	75	**64**	40	27	45	63

HRMF Verification of Compartmentalization

For all multifamily units, project teams must seal each dwelling unit's air barrier to reduce pollutant transfer, as required in ASHRAE 62.2 Section 6.1. For HRMF units that use an exhaust-only with passive vent approach for ventilation, a HERS Raters must verify that this has been achieved. This is because passive vents only work when units are compartmentalized (CARB 2016).

The Statewide CASE Team will develop a verification form for this requirement, and is considering basing this form off one of the following. Both would need to be significantly modified for this purpose. The pros and cons of each document are described below.

Requirements based on CF3R: This is the verification form for Air Infiltration Sealing for Quality Installation Insulation (QII) credit.

Pros:

- The building industry is already used to this form.
- It is written as a verifiable checklist.

Cons:

- It is intended to check for sealing with the exterior, and much of the language would need to be revised for interior partitions. For example, from the CF3R: "All penetrations through the exterior wall air barrier are sealed to provide an air-tight envelope to unconditioned spaces, such as the outdoors, attic, garage, and crawl space."
- It is not specific to multifamily units.
- This form is long (6 pages), since it was developed for the building level. It would be onerous (i.e., expensive) to fill out this checklist for every unit in a HRMF building.

Requirements based on the ENERGY STAR High-rise Multifamily Verification Protocol

Pros:

- Specific to compartmentalization.
- Specific to HRMF units.

Con:

- Would need revisions to translate the requirements into a compliance checklist.
- Has stringent requirements that would be time-consuming for verifiers (i.e., expensive to implement), including a recommendation for 3-5 verification visits. The Protocols allow sampling to reduce costs.

An abbreviated list of the visual inspection requirements from the ENERGY STAR High-rise Testing and Verification worksheet is shown in Table 17.[23]

[23] From the "Testing and Verification Worksheets", tab "8.1-INF_COMPTZN VIS INSPECTION' from https://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_mfhr_guidance

Table 17: Example Compartmentalization Checklist

COMPARTMENTALIZATION - VISUAL INSPECTION CHECKLIST	
Compartmentalization - Notes for drawings and specifications	Heating pipe penetrations through interior partitions
Compartmentalization Visual Inspection – General	Plumbing/sprinkler pipe penetrations
Sample Unit - Visual inspection	Range gas line penetration
Inspect framing layout	Gap between take off duct and gypsum board
Gypsum board to concrete floor plank connection	Electrical panel
Gypsum board to concrete ceiling plank connection	HVAC access doors
Window to interior gypsum board	Thermostats
A/C Sleeve Cover (if A/Cs provided by building)	Intercoms
Air conditioner sleeve sealed to drywall	Lighting fixtures
Outlet/Electrical Box - Exterior and demising walls	Door latch hole
Heating pipe penetrations through exterior walls	Medicine cabinet

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 9, 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 most of the issues raised.

First Stakeholder Meeting

- Circular references in the CMC 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 recirculating HVAC filter MERV requirement 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 don't 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% of the year, how is filtration provided for the remainder of the time?
- Can't MERV 6 filters be used on returns if outside air is separately filtered, and won't MERV 13 filters require more frequent replacement? Should adhere to 62.2 standards without revisions.
- If roadways are the problem let's 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 LBNL 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 LBNL 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 6% 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 don't 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, References. The results from feedback are interwoven into the report and referenced in Table 3 and Section 2.1.4.1.

Table 18 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 ventilation 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 ventilation shaft sealing. Other proposed measures can probably be accommodated by changes to existing forms.

Table 18: 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 forms & 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 ventilation shafts	• Training on filter grille sizing • Training on sealing (HRMF)
HERS/ATT Verifier	• Review CF1R forms 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)	• On-line 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 forms are signed and certified • Sign occupancy permit	• Issue permit with minimal re-inspections • Minimal paperwork	• No change to work flow	• N/A