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CALIFORNIA ENERGY CODES & STANDARDS
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MEMO

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Subject: **Market Analysis in Support of Single-family and Updated Multifamily Range-Hood Requirements**

Introduction

Cooking-related pollution carries various health risks. Cooking over any type of cooktop (natural gas or electric) releases fine particles such as particulate matter 2.5 micrometers or smaller (PM2.5), as well as other irritants and potentially harmful gases including formaldehyde and polycyclic aromatic hydrocarbons (Singer and Chan 2018). The use of natural gas burners and ovens also releases nitrogen dioxide (NO_2) and carbon monoxide (CO).

Range hoods provide important protection from this cooking-related pollution, because – when operated – they remove a fraction of these pollutants. The percent of the pollution they remove is measured by the “capture efficiency”. In general, as the airflow of the kitchen range hood decreases, capture efficiency also decreases.

The current 2019-Title 24, Part 6 requirements include a minimum airflow of 100 cfm for range hoods and a maximum sound rating of 3 sones or less at working speed[1]. As documented in the

[1] As defined in HVI Standard 916: working speed is defined as the speed that produces 100 cfm, or the lowest speed above 100 cfm that a hood can produce, when working on the same duct system as the maximum speed test.

Multifamily Indoor Air Quality (MF IAQ) CASE Report, the MF IAQ Statewide CASE Team determined through our research that 100 cfm is too low to maintain IAQ at acceptable levels in multifamily dwelling units, so recommended that the Energy Commission increase the minimum required airflow for those units.

The scope of the Multifamily IAQ CASE Report was limited to multifamily units, but data indicates that the current range hood requirement of 100 cfm is too low for other dwelling units as well, as this memo discusses. In addition, the MF IAQ CASE Report used simulation results from Lawrence Berkeley National Laboratory (LBNL) and laboratory results from Texas A&M to correlate airflow to capture efficiency that have both since been updated.

The overall objective of this memo is to support the Energy Commission's proposed requirements for residential range hoods. This memo:

1. Presents updated results of IAQ simulations conducted by Lawrence Berkeley National Laboratory (LBNL) and updated results of the correlation between airflow and capture efficiency based on Texas A&M laboratory testing. These revised results were available after the Final Multifamily IAQ CASE Report was published.
2. Provides the Statewide CASE Team's recommended kitchen ventilation requirements. These have been updated since the Final Multifamily IAQ CASE Report, to align with the more recent LBNL's simulations and laboratory testing data, as well as with the Energy Commission's proposals (presented at the November 3, 2020 IAQ workshop). In addition, this memo proposes that the kitchen ventilation requirements be applied to single-family, as well as multifamily dwelling units.
3. Provides market analysis single family homes, and updated market analysis for multifamily units, based on the updated simulations and airflow to capture efficiency correlation.
4. Identified research opportunities that could inform utility programs or future code requirements to address this important pollution source.

Minimum Capture Efficiency and Airflow Needs for Acceptable IAQ

This section provides updated simulation results from LBNL and revised test results that correlated airflow with capture efficiency. Based on these results, this section provides updated proposed requirements for kitchen ventilation compared to those in the Multifamily IAQ Final CASE Report. The updated proposed requirements align with the proposals presented by the Energy Commission at the November 3, 2020 IAQ Workshop.

1.1 Simulation Results of Required Capture Efficiency or Airflow

The below table shows the minimum ASTM capture efficiencies and range hood airflows needed to meet health-based air pollutant guidelines:

- NO_2: 1-hour maximum of 100 ppb (California Air Resources Board 2016)
- $PM_{2.5}$: 24-hour average of 25 ug/m^3 (World Health Organization 2006) and 35 ug/m^3 (US Environmental Protection Agency 2012)

The table shows updated results from a report published by Chan et al. in March 2020: "Simulation of short-term exposure to NO_2 and $PM_{2.5}$ to inform capture efficiency standards" (Chan, Sangeetha, et al. 2020). The results are based on Monte Carlo simulations of pollutant levels during cooking, taking into account emissions from cooking, pollutants from outdoor air, removal of emissions and pollutants by kitchen ventilation, continuous dwelling unit ventilation, and deposition to surfaces. Compared to the originally published results, the updated results differ in that the new simulations tested different capture efficiency and exhaust airflow combinations, and included a proximity factor to account for higher exposures to pollutants for the person in the kitchen cooking (Chan, Walker and Singer, Technical Memo on Updated Analysis from NO2 and PM2.5 Cooking Simulations to Inform Capture Efficiency Standards 2020).

Table 3. Summary of ASTM capture efficiency or range hood airflows needed to meet 24-h $PM_{2.5}$ and 1-h NO_2 threshold value.

Threshold Value	Floor Area (ft^2)	ASTM Capture Efficiency	Airflow as installed (cfm)
24-h $PM_{2.5}$ 25 ug/m^3	>1500 ft^2	0.50	110
	1000 - 1500 ft^2	0.50	110
	750 - 1000 ft^2	0.55	130
	<750 ft^2	0.65	160
1-h NO_2 100 ppb	>1500 ft^2	0.70	180
	1000 - 1500 ft^2	0.80	250
	750 - 1000 ft^2	0.85	280
	<750 ft^2	0.85	280

Figure 1. Summary of airflows needed to meet ASTM capture efficiency requirements.

Source: Chan, Walker and Singer, 2020.

NO_2 is the primary pollutant from natural gas ranges and $PM_{2.5}$ for electric ranges. Therefore, the results show that a higher capture efficiency and airflow is required for smaller units since there is less dilution, and particularly for kitchens with natural gas ranges.

1.2 Relationship between Airflow and Capture Efficiency

The below figure shows the relationship between airflow and capture efficiencies derived from three studies using the ATSM test method E3087. The ASTM test method uses heated emitters which inject carbon dioxide from both the middle of the range and outer circumference to represent gas or electric burner emissions. Range hood and emitter placements varied slightly between each study, which may explain why the "T24 CASE Data" had lower capture efficiencies than the other two studies. The black curve shows the capture efficiency and airflow relationship fitted from the data points.

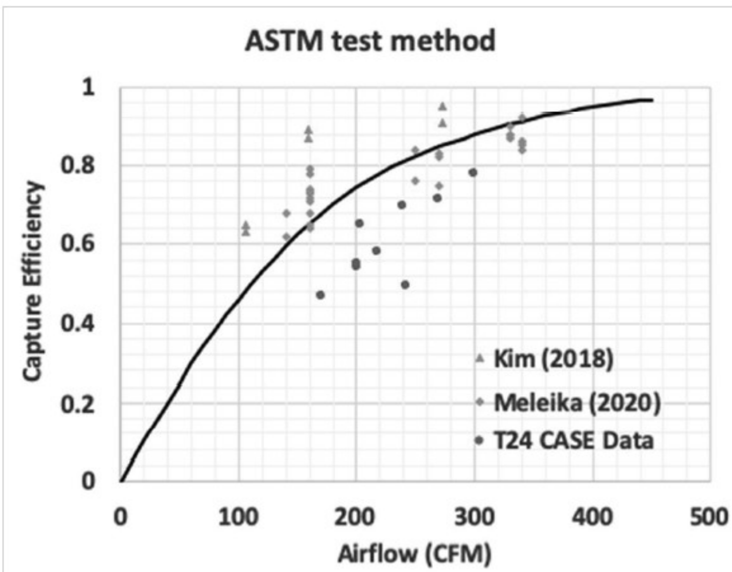

Figure 2. Capture efficiency and range hood airflow determined following the ASTM test method

Source: Chan, Walker and Singer, 2020.

The "T24 CASE Data" is from testing done as part of the Title 24 CASE 2022 cycle[2]. Figure 3 shows updated results for the "T24 CASE Data" that were updated in November 2020. Five undercabinet range hoods representative of what would be installed in multifamily buildings were selected from HVI listings, two of which were microwave range hood combinations (OTRs). All were 18 inches deep and were from five different manufacturers. Undercounter

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[2] Because capture efficiency results are not available from manufacturers at this time, the Statewide CASE Team contracted with a certified range hood testing laboratory—the Texas A&M RELLIS Energy Efficiency Laboratory (REEL)—to measure capture efficiency for a sample of range hood products.

range hoods were tested at a height of 24 inches above the cooktop surface, and microwave combination hoods were tested at a height of 18 inches, which is typical for those product types.

Compared to the T24 CASE Data in the MF IAQ Final CASE Report, Texas A&M made the following changes to generate the revised November 2020 results:

- Raised the emitter height relative to the range top (not the range hood) by almost 2 inches
- Closed a gap that had existed around the emitters which had allowed some heat to escape
- Changed the range material from thicker aluminum plate to a thinner, stainless steel plate to mitigate thermal issues
- Improved the sealing for the front of the bench that the range is built into.

These changes increased capture efficiency results by 10 to 30% for different range hoods.

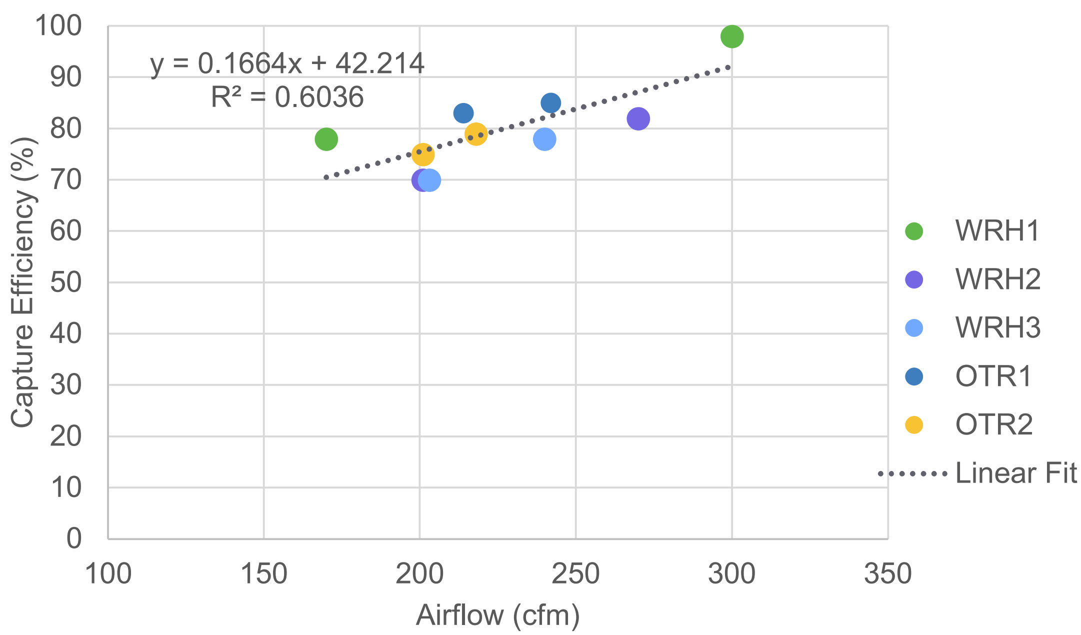

Figure 3. Relationship between capture efficiency and airflow from testing at Texas A&M Laboratory – Revised November 2020

Figure 3 shows capture efficiency and airflow results for each product under two static pressures: 0.1 inches w.c. and 0.25 inches w.c. The lower static pressure (0.1 inches w.c.) is used for high speed ratings, and the higher static pressure (0.25 inches w.c.) is a more accurate representation of installed conditions. The Statewide CASE Team fit a line (R-squared value of 0.60) to the capture efficiency and airflow results.

Table 1. Minimum Airflow Proposed by Energy Commission Compared to Correlated Airflow from Revised November 2020 Title 24 CASE Data

Capture Efficiency (Percent)	Minimum Airflow Proposed by Energy Commission (cfm)	Corresponding Airflow based on Revised T24 CASE Testing (cfm)
50	110	Below tested range
55	130	
65	160	134
70	180	163
80	250	222
85	280	252

As shown in Table 1, for a given capture efficiency, the airflow in the corresponding airflow based on Revised November 2020 T24 CASE Testing is similar to – although slightly lower than – the airflow proposed by the Energy Commission. While the corresponding airflow based on Revised T24 CASE Testing is lower, the Statewide CASE Team recommends that the Energy Commission maintain the airflow values that it proposed. This is because the laboratory-measured airflows are obtained under ideal conditions. Static pressures are likely to be higher in the field than those specified under the airflow path (proposed as 0.1” w.c.), which would reduce airflow and therefore reduce capture efficiency. Stated another way: HVI ratings performed at 0.1 inch w.c. will perform at a lower airflow (cfm) in the field, thus airflows in the field are likely to be more similar to the values shown in the Revised T24 CASE Testing column. In addition, the presence of the cook can disturb the plume, which would reduce capture efficiency.

1.3 2022-Title 24, Part 6 Proposed Kitchen Ventilation Requirements

The Statewide CASE Team had proposed kitchen ventilation requirements for multifamily dwelling units as part of the Multifamily IAQ CASE Report. Based on the updated simulations and laboratory testing results, the Statewide CASE Team is revising some of those proposed requirements through this memo. In addition, the Statewide CASE Team is proposing that those requirements apply to single-family dwelling units, not just multifamily.

The Statewide CASE Team proposes the following language for 2022-Title 24, Part 6 Section 150.0(o)1G for single-family dwelling units and Section 160.2(b)2BAviiB for multifamily dwelling units. Note that – as a separate effort within the 2022-Title 24, Part 6 development process – a new section was proposed for multifamily buildings: Section 160. Section 160.2(b)2BAviiB provide multifamily kitchen ventilation requirements within that section, which replaces the multifamily requirements that are currently (under 2019-Title 24, Part 6) in Section 120.1(b)2Avi for high-rise multifamily dwelling units and in Section 150.0(o)1G for low-rise multifamily dwelling units.

The Multifamily IAQ CASE Report proposed different capture efficiency and airflow requirements than those as shown below, and were limited to multifamily units. The Multifamily IAQ CASE Report used the 2019-Title 24, Part 6 numbering conventions – i.e., proposed requirements for 150.0(o) for low-rise multifamily and 120.1(b)2A for high-rise multifamily dwelling units. The proposed language below is intended to *be a substitute for* similar language in the Multifamily IAQ CASE Report – i.e., to replace the proposed requirements for Section 120.1(b)2Avi and 150.0(0)1G in that CASE report.

The Multifamily IAQ CASE Report proposed additional requirements, including a requirement to provide ventilation information to occupants and building owners in Section 10-103(b)4, combustion requirements in Section 120.1(b)2C (for high-rise) and Section 150.0(o)3 (for low-rise dwelling units), and requirements for additions and alterations. The Statewide CASE Team does not propose any changes to those other requirements through this memo.

Proposed language for Section 160.2(b)2BAviiB

Kitchen Ventilation. A local mechanical exhaust system shall be installed in each kitchen and comply with the following.

1. Exhaust systems in non-enclosed kitchens must meet a, b, or c below, and exhaust systems in enclosed kitchens must meet a, b, c, or d below:
    a. A vented range hood with at least one speed setting with a minimum capture efficiency shown in Table 4.506.2, measured in accordance with ASTM E3087 at nominal installed airflow described in HVI Publication 920; or
    b. A vented range hood with at least one speed setting with a minimum airflow shown in Table 4.506.2 at 25 Pa (0.1 inches w.c.) or higher; or
    c. A vented downdraft kitchen exhaust fan with at least one speed setting with a minimum airflow of 300 cfm at 25 Pa (0.1 inches w.c.) or higher; or
    d. Continuous exhaust system with a minimum airflow equal to five kitchen air changes per hour.

TABLE 4.506.2 Minimum Capture Efficiency (CE) or Airflow (cfm) for demand-controlled range hoods

<table>
<tr><th>Dwelling unit floor area (ft2)</th><th>Hood over electric range[a]</th><th>Hood over gas range[a]</th></tr>
<tr><td>≤ 750</td><td>65% CE or 160 cfm</td><td rowspan="2">85% CE or 280 cfm</td></tr>
<tr><td>750 – 999</td><td>55% CE or 130 cfm</td></tr>
<tr><td>1,000 – 1,500</td><td rowspan="2">50% CE or 110 cfm</td><td>80% CE or 250 cfm</td></tr>
<tr><td>>1,500</td><td>70% CE or 180 cfm</td></tr>
<tr><td colspan="3">[a]If a range is plumbed for both electricity and gas, the minimum CE or airflow must meet the requirements for gas.</td></tr>
</table>

Market Analysis of Compliant Equipment

1.4 Product Availability in HVI Database

The following tables show results based on analysis using the HVI database (Home Ventilating Institute 2020). The Statewide CASE Team filtered the HVI database for products that were rated at a static pressure of at least 0.1 inches w.c., were either a microwave, undercabinet, island or chimney range hood, and had ducting sizes of either 3-inch by 10-inch, 3.25-inch by 10-inch, 6-inch diameter (round or square ducting) or 7-inch diameter (round or square ducting). In addition, when analyzing the HVI database, the Statewide CASE Team attempted to combine models with nearly identical model numbers and performance characteristics (but which differed by only aesthetic characteristics, such as color) based on unique sets of model number/letters. Range hood products which were not explicitly categorized with a subcategory (e.g., microwave range hood, undercabinet range hood) in the HVI database were excluded from the analysis. Note that the MF IAQ Final CASE Report presented analysis for the microwave and undercabinet range hoods only, since these are commonly installed in multifamily units.

The Statewide CASE Team found the proposed requirements are feasible for all or most island and chimney range hood products, and for the majority of undercabinet range hoods. There are some microwave range hood products that would comply with the 250 and 280 cfm proposed requirements for smaller units with natural gas ranges. For microwave range hood, all products could meet the minimum airflow requirement up to 160 cfm. Most microwave range hoods (92%) could meet the minimum airflow requirement of 180 cfm. About half of the products could meet the minimum airflow requirement of 250 cfm with horizontal configuration, and some products (17%) could meet the minimum airflow requirement of 280 cfm.

Table 2. Count of Microwave Range Hoods Meeting Proposed Requirements

Rated CFM	Proportion of Compliant Products		Number of Brands with Compliant Products	
	Horizontal (n=66)	Vertical (n=66)	Horizontal (n=20)	Vertical (n=20)
>=110	100%	100%	20	20
>=130	100%	100%	20	20
>=160	100%	100%	20	20
>=180	92%	92%	20	20
>=250	48%	79%	16	19
>=280	17%	30%	6	7

Table 3. Count of Undercabinet Range Hoods Meeting Proposed Requirements

Rated CFM	Proportion of Compliant Products		Number of Brands with Compliant Products	
	Horizontal (n=30)	Vertical (n=43)	Horizontal (n=8)	Vertical (n=9)
>=110	100%	100%	8	9
>=130	100%	100%	8	9
>=160	100%	100%	8	9
>=180	100%	98%	8	9
>=250	77%	91%	8	9
>=280	63%	72%	5	9

Table 4. Count of Chimney Range Hoods Meeting Proposed Requirements

Rated CFM	Proportion of Compliant Products		Number of Brands with Compliant Products	
	Horizontal (n=3)	Vertical (n=64)	Horizontal (n=1)	Vertical (n=11)
>=110	100%	100%	1	11
>=130	100%	100%	1	11
>=160	100%	100%	1	11
>=180	100%	100%	1	11
>=250	100%	100%	1	11
>=280	100%	94%	1	11

Table 5. Count of Island Range Hoods Meeting Proposed Requirements

Rated CFM	Proportion of Compliant Products		Number of Brands with Compliant Products	
	Horizontal (n=0)	Vertical (n=9)	Horizontal (n=0)	Vertical (n=4)
>=110	N/A	100%	0	4
>=130	N/A	100%	0	4
>=160	N/A	100%	0	4
>=180	N/A	100%	0	4
>=250	N/A	100%	0	4
>=280	N/A	100%	0	4

1.5 Cost Analysis of Compliant and Non-Compliant Products

To understand the cost impacts of the proposed requirements, the Statewide CASE Team compared prices for compliant with non-compliant products. Since all or most island and chimney range hoods would meet all proposed minimum airflow requirements, the Statewide CASE Team did not analyze cost differences, but focused on cost differences within the microwave and undercabinet range hood product groups. Table 6 shows the proposed requirements for which the Statewide Case Team compared costs.

Table 6. Proposed Requirements with Cost Comparisons

Applicable Households	"Compliant" Products	"Noncompliant" Products	Rationale for Cost Analysis
Natural gas kitchen; household between 1,000 and 1,500 square feet	Minimum airflow of 250 cfm at 0.1'' w.c. static pressure	Minimum airflow ≥100 cfm and < 250 cfm at 0.1'' w.c. static pressure	About half of microwave and one-quarter of undercabinet are "noncompliant"
Natural gas kitchen; household less than 1,000 square feet	Minimum airflow of 280 cfm at 0.1'' w.c. static pressure	Minimum airflow ≥100 cfm and < 280 cfm at 0.1'' w.c. static pressure	About 80% of microwave and 40% of undercabinet are "noncompliant"

The Statewide CASE Team used the HVI database to take a random sample of products compliant under the minimum range hood airflow pathway ("compliant" products: - i.e., vented range hood with a minimum airflow of 250 cfm at 0.1'' w.c. static pressure or greater for a natural gas fueled kitchen for household between 1,000 and 1,500 square feet), with those that comply with the current requirement but not proposed requirement (“noncompliant” products: vented range hood with a minimum airflow between 100 and 250 cfm at 0.1’’ w.c. static pressure or greater for a natural gas fueled kitchen for household between 1,000 and 1,500 square feet).

The prices of products were found online (i.e. Home Depot, Amazon, Best Buy, Appliances Connection, and others for a few products). To provide an equitable comparison between compliant and noncompliant products, the Statewide CASE Team would start by looking for the product in the Home Depot website; if not available, the Statewide CASE Team would move to Amazon, then Best Buy, then Appliances Connection, then other websites in that order. To sample products that would most likely be used in smaller dwelling units, the Statewide CASE Team filtered out products with an airflow rating of greater than 400 cfm[3]. Some products had model numbers with similar numbers and characters (usually constituting of the same product but with different colors) and were grouped as one product. Since prices differed by color, the price of the black product was used if available. When black was not available, the next commonly available color was stainless steel. Due to scope constraints and the hundreds of products in the HVI database, the Statewide CASE Team did not check whether all listed products in the HVI database were available and offered for sale. However, in reviewing the sample of products for this cost analysis, the Statewide CASE Team was unable to find some listed products for sale online. In this case, the Statewide CASE Team chose a different product as a replacement but did not adjust the total count of products because this would result in removing only sampled products. Additionally, the Statewide CASE Team could not confirm that a product not found online was not for sale in brick-and-mortar stores.

For undercabinet and microwave range hoods, there were fewer compliant products for the 250 and 280 cfm proposed minimum airflow requirements, so the Statewide CASE Team reviewed cost differences between compliant and non-compliant products. For both microwave and undercabinet range hoods, compliant products were more expensive than non-compliant products with statistical significance at the 1% significance level for both the 250 and 280 cfm requirements. Undercabinet range hoods had a higher incremental cost between non-compliant and compliant products, increasing from 114% to 117% compared to microwave range hoods which had an incremental cost increase of 60% to 69%.

[3] The Statewide CASE Team assumed most designers would not install kitchen range hoods greater than 400 cfm in small dwelling units. The international mechanical code requires make-up air for range hoods with an airflow greater than 400 cfm.

Table 7. Sampled Costs of Microwave Range Hood Products – 250 cfm Requirement

	Average Price	Standard Error	Precision	Products Sampled	Total Products	p-value (one-tailed)
Microwave Range Hood Compliant: 250-400 cfm	$546	$40	16%	15	32	<0.01
Microwave Range Hood Non-Compliant: 100-250 cfm	$340	$28	18%	11	34	
Incremental Cost Increase	$206					
Incremental Cost Increase (%)	60%					

Table 8. Sampled Costs of Undercabinet Range Hood Products – 250 cfm Requirement

	Average Price	Standard Error	Precision	Products Sampled	Total Products	p-value (one-tailed)
Undercabinet Range Hood Compliant: 250-400 cfm	$658	$40	13%	13	23	<0.01
Undercabinet Range Hood Non-Compliant: 100-250 cfm	$243	$92	25%	5[4]	7	
Incremental Cost Increase	$415					
Incremental Cost Increase (%)	171%					

[4] The Statewide CASE Team tried to sample all products in this category to improve precision, but were unable to find two of the products online. Low precision indicates that there is more uncertainty in the estimate due to fewer products sampled, more variation in results among products in each sample, or both.

Table 9. Sampled Costs of Microwave Range Hood Products – 280 cfm Requirement

	Average Price	Standard Error	Precision	Products Sampled	Total Products	p-value (one-tailed)
Microwave Range Hood Compliant: 280-400 cfm	$652	$43	16%	7	11	0.01
Microwave Range Hood Non-Compliant: 100-280 cfm	$385	$33	18%	19	55	
Incremental Cost Increase	$267					
Incremental Cost Increase (%)	69%					

Table 10. Sampled Costs of Undercabinet Range Hood Products – 280 cfm Requirement

	Average Price	Standard Error	Precision	Products Sampled	Total Products	p-value (one-tailed)
Undercabinet Range Hood Compliant: 280-400 cfm	$712	$46	15%	10	19	<0.01
Undercabinet Range Hood Non-Compliant: 100-280 cfm	$334	$22	15%	9	11	
Incremental Cost Increase	$379					

Incremental Cost Increase (%)	114%

Incremental Cost Compared to Health Care Costs

The proposed measure would help reduce pollutants that carries various health risks. For example, a study found that asthmatic children are at higher risk for more severe asthma symptoms at low levels of NO_2 and that the risk rises as levels of NO2 rise (Belanger 2013).

A paper in American Thoracic Society 2018 estimated annual asthma costs to be $3,266, where $1,830 was for prescriptions, $640 for office visits, $529 for hospitalizations, $176 for hospital outpatient visits and $105 for emergency room care (American Thoracic Society 2018). This translates to an average annual cost of $280 per person for the general population in California based on the incidence of asthma in the California population: 8.5% (Centers for Disease Control and Prevention 2020).

Impact on Single Family Homes

1.6 Estimated Impact on All Single Family Homes

The Statewide CASE Team reviewed the proportion of single and multifamily homes that would be impacted by each of the proposed requirements. Figure 4 shows floor area distributions of detached and attached single family[5] and multifamily homes from the 2017 American Housing Survey (AHS), which looked at new California homes built since 2010. The floor area distributions from the AHS are used to estimate the proportion of homes that will need to meet

[5] From the AHS Definitions: Single-family structures include fully detached, semi-detached (semi-attached, side-by-side), row houses, duplexes, quadruplexes, townhouses. Each unit must be separated by a ground-to roof wall, have a separate heating system, have individual meters for public utilities and have no units located above or below. If each unit within the building does not meet the conditions above, the building is considered multifamily. https://www.census.gov/construction/chars/definitions/

each of the proposed requirements based on home size.

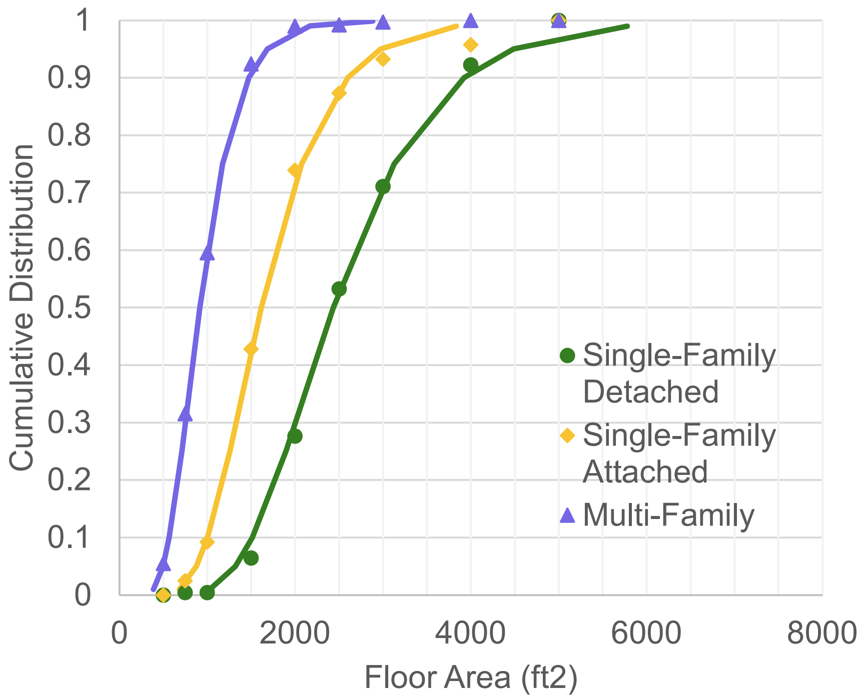

Figure 4. Distribution of floor area with datapoints from American Housing Survey (2017) and trend lines indicating approximate lognormal distribution.

Source: Chan, Kumar and Singer, 2020.

AHS also reported the proportion of homes built since 2010 using natural gas as the cooking fuel. Among newly constructed homes built between 2010 and 2017, about 84% of single-family detached homes, 60% of single-family attached homes, and 41% of multifamily units used natural gas as the cooking fuel (Chan, Sangeetha, et al. 2020). These values were used in this analysis because they were the most recent data available, although the fraction of homes with natural gas cooking may decrease as electrification becomes more common. Figure 5 through Figure 7 below combine the floor area distribution and cooking fuel data to produce estimates of proportions of new construction that would have to follow each of the proposed requirements based on floor area and cooking fuel type. The Statewide CASE Team found that about 5.4% of single-family detached homes and 26% of single-family attached homes would be affected by the more stringent minimum airflow requirements, which would potentially have less product availability or higher incremental costs (estimated to be an incremental cost increase of 60% to 69% for microwave range hoods and between 114% to 117% for undercabinet range hoods in Section 1.5). As trends of increasing electrification continue however, it is likely that the proportion of electric ranges will increase in the future, which would reduce the proportion of homes needing to comply with more stringent range hood requirements.

For single-family detached homes, most of the homes (94%) were larger than 1,500 square feet and would have to meet the minimum airflow requirement of 110 cfm for electric and 170 cfm for natural gas cooking fuel. Only about 5% of single-family detached homes would have to follow the more stringent minimum airflow requirement of 250 cfm, which would be required for homes with natural gas cooking fuel and floor area between 1,000 and 1,500 square feet. A very small amount of homes (about 0.4%) would have to follow the minimum airflow requirement of 280 cfm, required for homes with natural gas cooking fuel and floor area less than 1,000 square feet. In Figure 5 below, some categories in the legend do not show in the pie chart because it is only a small proportion (less than 1%).

In comparison, single-family attached homes were smaller on average than single-family detached homes. About 20% of single-family attached homes would have to follow the more stringent minimum airflow requirement of 250 cfm, which would be required for homes with natural gas cooking fuel and floor area between 1,000 and 1,500 square feet and about 6% would have to follow the minimum airflow requirement of 280 cfm, required for homes with natural gas cooking fuel and floor area less than 1,000 square feet.

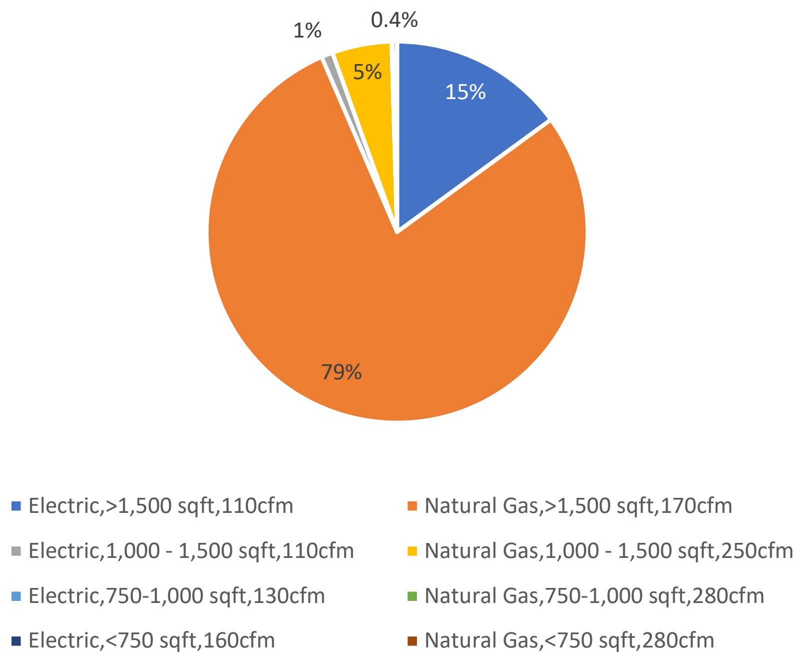

Figure 5. Proportion of detached single-family homes under each proposed requirement

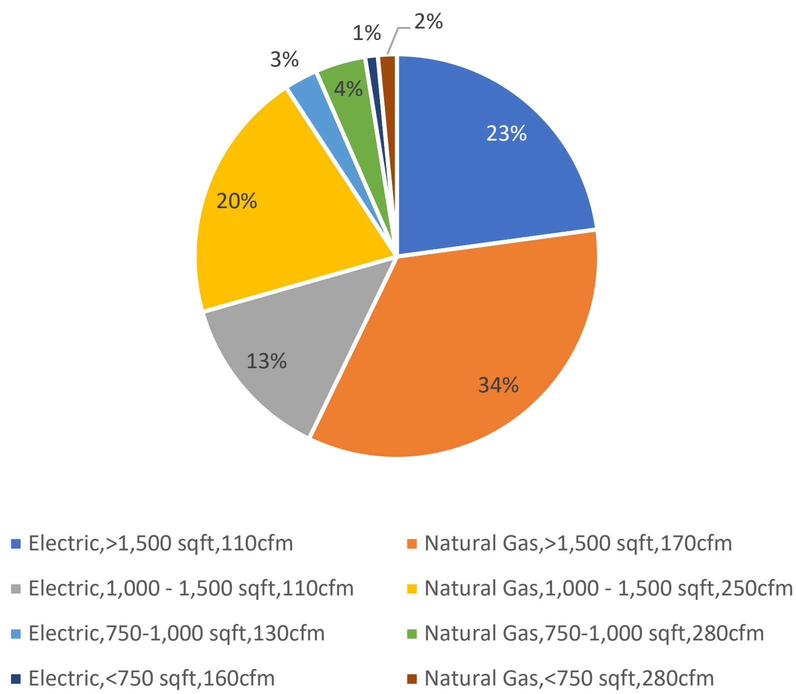

Figure 6. Proportion of attached single family homes under each proposed requirement

For multifamily units, there was more variation in categorization. Some would trigger the least stringent requirement (at least 110 cfm), others the most stringent requirement (at least 280 cfm), while others fell in between those extremes. About one-quarter (24 percent) would trigger the most stringent requirement (at least 280 cfm) and another 13 percent are estimated to trigger the next most stringent requirement (at least 250 cfm). Thus, just over one-third are estimated to trigger requirements that would lead to higher incremental costs.

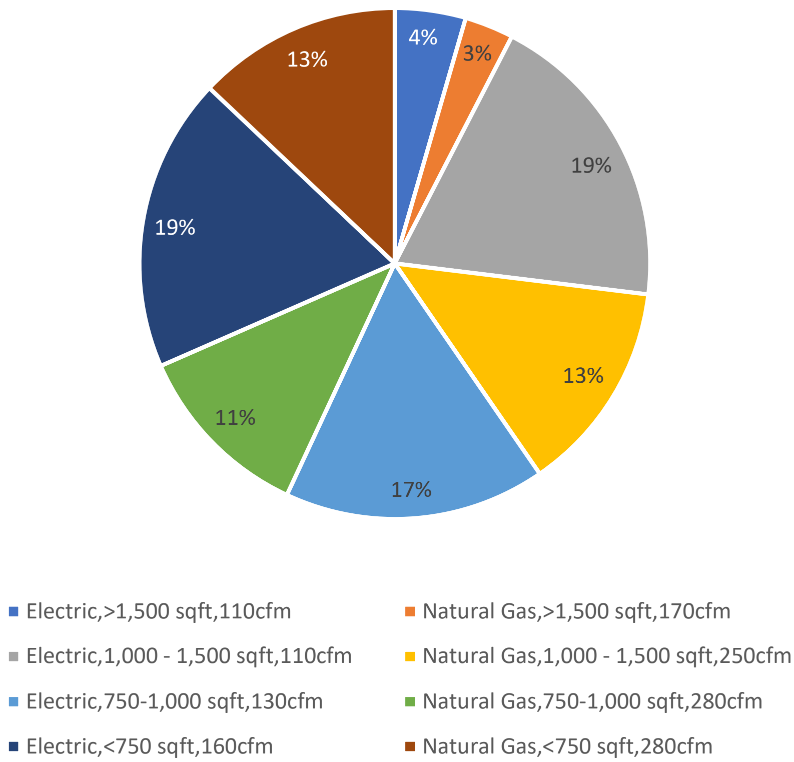

Figure 7. Proportion of multifamily units under each proposed requirement

1.7 Impacts on Accessory Dwelling Units

Imposing the same requirements for single family dwelling units would have the greatest impacts on small dwelling units (smaller than 1,000 sqft) and structures like Accessory Dwelling Units (ADUs) and Junior Accessory Dwelling Units (JADUs).

The permitting and construction of ADUs have increased over the years. From 2018 to 2019, the number of ADU permits increased from about 6,000 to 16,000 and the number of ADU completions has increased from about 2,000 to 7,000 (Chapple, et al. 2020). The 2020 CEC Residential Building Stock Forecast estimated 117,098 new construction single family starts in

2019. ADU permits were therefore about 14% of the number of new construction single family starts in 2019.

Homeowners may also create JADUs, which must be within the walls of the proposed single-family residence (i.e., a garage or carport) and less than 500 square feet. The JADU may share central systems and a bathroom, and contain a basic kitchen (California Department of Housing and Community Development n.d.).

Because these small units would have less dilution air to reduce pollutant levels (similar to multifamily units), they should also meet the same range hood requirements to ensure adequate indoor air quality levels.

Future Research

The following provides suggestions of future research that could inform utility programs or future code requirements.

1.8 Automated Range Hoods

During the standard development process, several stakeholders recommending requiring automated range hoods, since many consumers do not always operate their hoods when cooking. The concept of requiring the hood to turn on automatically whenever temperature sensors show that cooking is occurring, or when pollutant sensors indicate ventilation is needed, is an exciting idea that should be explored in future code cycles as a means of increasing the IAQ benefits to occupants. However, it was not proposed as an update for the 2022 Energy Code cycle, in part because there were almost no off-the-shelf products available with these automated features. In addition, energy impacts and user acceptability of automated kitchen ventilation should be investigated before an automatic function is required.

1.9 Commissioning requirements

To ensure that range hoods operate as intended and meet requirements as installed (not just as designed), the Statewide CASE Team recommends that commissioning requirements be added in a future cycle. These could include field airflow testing requirements of the range hood at the time of installation. Such requirements should consider costs for airflow testing, and provide guidance for reducing costs, such as potentially allowing sampling in multifamily units or single-family home developments.

1.10 Sound limits

Past studies that used consumer surveys found that some consumers do not regularly operate their range hood because they find it too noisy. Future investigations should consider requiring a sound requirement at a higher airflow than working speed (100 cfm). The new requirement may still not be stringent enough to encourage consumer range hood use during all cooking events, particularly because range hoods will have a higher sone rating at the higher airflow or capture efficiency required in this proposal. Since adding a sound rating requirement at a higher airflow would require product retesting, the Statewide CASE Team considered dropping the allowable sound requirement at 100 cfm from three sones to two sones. However, the Statewide CASE Team could not find a strong correlation showing that lower sound levels at lower airflow corresponded to sound levels at higher airflow. Future code cycles should consider a sound requirement at airflows corresponding to the minimum airflow required or at the minimum capture efficiency required for compliance.

1.11 Static pressure for Airflow Testing

The proposed requirements for the airflow path use a static pressure of 0.1" w.c., because most product databases (HVI and Association for Home Appliance Manufacturers) currently list range hoods at this static pressure. Because of the additional static pressure in the field, and the resulting decrease in capture efficiency and air flow, range hood products that comply with the proposed airflow requirements will likely provide lower results than the laboratory test. Consequently, it may not maintain PM2.5 and NO_2 concentrations at acceptable values.

Industry groups are currently discussing listing products at a higher static pressure or at a nominal installed airflow – calculated from the intersection of the product's airflow curve and a nominal system curve. Future code proposals should consider adjusting the proposed requirement to address the higher static pressure of installed conditions, preferably in alignment with the direction of industry. For example, the California Energy Commission should adopt the new rating metrics if ASHRAE Standard 62.2 is revised to require compliance with the HVI procedures for nominal installed flow.

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