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Codes and Standards Enhancement (CASE) Initiative

2019 California Building Energy Efficiency Standards

High Efficiency Fume Hoods in Laboratory Spaces – Final Report

Measure Number**:** 2019-NR-MECH4-F

Nonresidential Covered Processes

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EXECUTIVE SUMMARY

Introduction

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support California Energy Commission's (Energy Commission) efforts to update California's Building Energy Efficiency Standards (Title 24, Part 6) to include new requirements or to upgrade existing requirements for various technologies. The four California Investor Owned Utilities (IOUs) – Pacific Gas and Electric Company, San Diego Gas and Electric, Southern California Edison, and SoCalGas® – and several Publicly Owned Utilities (POUs) – Los Angeles Department of Water and Power, Sacramento Municipal Utility District, and Southern California Public Power Authority – 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 proposed measure is a prescriptive requirement for the installation of automatic sash closure systems for vertical sash laboratory fume hoods with variable air volume HVAC (heating, ventilation, and air conditioning) systems. This measure will apply to new construction as well as additions and alterations. The proposed measure is intended for variable air volume spaces where ventilation requirements are fume hood intensive. Title 24, Part 6 already prescriptively requires variable exhaust and make-up airflow for laboratory buildings meeting certain design criteria. These pre-existing conditions are an opportune context for the inclusion of additional controls that take advantage of variable air volume capabilities. The proposed sash closure controls are such a measure. The proposed measure does not modify existing requirements for variable exhaust and make-up airflow, but rather appends to it to ensure energy savings are achieved from the variable air system. The measure is prescriptive and thus can be displaced by alternative energy savings measures through a performance approach.

Automated sash closure systems detect the presence of laboratory technicians in front of the fume hood with an infrared occupancy sensor. When no occupancy is detected for a predefined period of time, the sash automatically lowers, thus reducing exhaust and make-up air using the capabilities inherent to the variable air volume system. The proposed measure aims to reduce the overall airflow through fume hoods that will result in energy savings associated with fans, cooling, and heating of the space. The proposed measure does not include revisions to minimum face velocity requirements; rather, it saves energy by reducing area of sash opening while maintaining constant face velocity defined by health and safety standards and facility protocols.

Scope of Code Change Proposal

Table 1 summarizes the scope of the proposed changes and which sections of the Standards, References Appendices, and compliance documents will be modified as a result of the proposed changes.

Table 1: Scope of Code Change Proposal

Measure Name	Type of Requirement	Modified Section(s) of Title 24, Part 6	Modified Title 24, Part 6 Appendices	Will Compliance Software Be Modified	Modified Compliance Document(s)
High Efficiency Fume Hoods in Laboratory Spaces	Prescriptive	140.9 – Prescriptive Requirements for Covered Processes	Nonresidential Appendix 7	Yes	A new compliance document will be added to certify measure meets the acceptance requirements specified in NA7 and several forms will be modified: • NRCC-PRC-09-E for Laboratory Exhaust • NRCC-PRC-01-E Compliance Certificate • NRCC-PRF-01-E will be modified to reflect the new measure requirements.

Market Analysis and Regulatory Impact Assessment

Automatic sash closing systems are offered by several manufacturers and distributors. The technology is well developed and its use is well documented in current laboratory ventilation systems and studies. However, despite safety and energy benefits, market penetration and adoption rates remain very low due to a variety of factors and market barriers. These barriers include low market awareness, few suppliers, end-user resistance, complexity of laboratory HVAC systems, and uncertainty around return on investment. This proposal attempts to address these barriers though discussion, exemptions that limit the measure to cost-effective situations, and by designating the measure as prescriptive.

The existing California fume hood base has been estimated to be 60,000 – 111,000 hoods of all types with roughly 50 percent of those being variable air volume. Using statewide laboratory survey data, the annual market size was estimated to be about 1,005,200 square feet and approximately 3,100 units installed in fume hood intensive spaces per year. "Fume hood intensive" designates spaces where laboratory fume hoods dominate ventilation requirements for enough hours of the year that the measure would be cost-effective. For the purposes of statewide estimates, this threshold is a fume hood density greater than 11 linear feet of hood width per 10,000 cubic feet of laboratory space (equivalent to 11 linear feet of hood width per 1,000 square feet of lab space with a ten-foot ceiling). This is also equivalent to about two percent of the laboratory area dedicated to hood work area. Laboratory space energy modeling and sensitivity to fume hood density and laboratory air change rates were used to inform measure exemptions based on cost-effectiveness.

Based on manufacturer interviews, the measure has an effective useful life (EUL) of 15 years. Manufacturers stated that the motors are tested to run up to 150,000 hours of continuous operation. Maintenance includes testing, lubrication, and calibration of the components used by the measure as well as periodic repairs that may arise. Manufacturers of the measure expect the closure systems to last at least the lifetime of the hood. As a result, energy savings will persist for the life of the measure since they are to be installed with any new hood in a hood intensive space.

The proposed changes to Title 24, Part 6 have a small impact on the complexity of the Standards and 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 methods and enforcement of this proposal.

Cost-Effectiveness

This proposed measure is cost-effective over the period of analysis for the covered spaces under prototypical conditions. Overall, it increases the wealth of the State of California and California businesses will save more money on energy than the amount for financing the efficiency measure. The proposed code change was found to be cost-effective in all instances that are not exempt. Exemptions were established that preclude applications that are not cost-effective by limiting covered spaces to those that are fume hood intensive and thus would realize cost-effective energy savings based on the energy modeling.

Benefit-to-cost (B/C) ratio compares the lifecycle cost benefits to the lifecycle costs. Measures that have a B/C ratio of 1.0 or greater are cost-effective. The larger the B/C ratio, the faster the measure pays for itself from energy cost savings. Depending on climate zone, the typical B/C ratio for this measure ranges from 3.3 to 4.5 for the prototypical lab. For each six-foot fume hood, the lifetime measure cost would be about 2020 present value (PV) $5,636 while avoiding energy costs of about 2020 PV $19,444 over the measure life. See Section 5 for a detailed description of the cost-effectiveness analysis.

Statewide Energy Impacts

The per-unit savings were combined with a California market analysis in order to estimate the total statewide impacts. Table 2 shows the estimated energy and water savings over the first year the proposed code change would be in effect. These statewide estimates include hospital occupancies, which accounts for about seven percent of the estimated market share and savings. If hospitals are not to be covered by Title 24, Part 6, then estimates can be proportionately decreased by seven percent to exclude that occupancy type. See Section 6 for more details.

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

Construction Type	First-Year Electricity Savings (GWh/year)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Water Savings (million gallons/year)	First-Year Natural Gas Savings (million therms/year)
New Construction	7.03	1.23	7.13	0.43
Additions and Alterations	10.52	1.83	10.68	0.65
Total	**17.55**	**3.06**	**17.82**	**1.08**

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

Compliance and Enforcement

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

The key issues related to compliance and enforcement are summarized below:

- Fume hood manufacturers and controls installers will need to ensure the systems offered or installed are compliant with the code change.
- Laboratory designers will need to ensure that systems designed and proposed are compliant with the code change. Supplemental information to demonstrate compliance will also need to be gathered and supplied.
- Modifications will be needed to forms NRCC-PRC-01-E Certificate of Compliance, NRCC-PRC-09-E Laboratory Exhaust, and NRCC-PRF-01-E to incorporate the new requirements.
- Laboratory Designer or Energy Consultant will have additional items to address in forms NRCC-PRC-01-E, NRCC-PRC-09-E, and NRCI-PRC-01-E (if prescriptive path is selected) or NRCC-PRF-01-E and NRCI-PRF-01-E (if performance path is selected).
- Plans examiners will have additional information within the Certificate of Compliance documents that will need to be verified to ensure system designs comply with code change.
- The proposed code change will require the addition of a new acceptance document NRCA-PRC-14-F Fume Hood Automatic Sash Closure System.
- NRCA-PRC-14-F will need to be filled out by the controls installer or field technician at the time of measure installation or commissioning. The field technician will act as the Acceptance Test Technician (ATT); a Certified ATT is not required for the proposed measure.
- Building inspectors will have to verify the additional compliance documents and code requirements to ensure fume hood controls comply with code change. These will include the modified NRCC, modified NRCI, and new NRCA forms listed above. No additional inspection beyond the ATT acceptance test at installation will be required.

Since the sash closure controls are often an aftermarket product and can include components external to the fume hood itself, upstream compliance at the fume hood manufacturer may be difficult. As such, field acceptance testing is recommended as part of this proposal unless efficient alternative compliance verification methods can be identified. The proposed compliance verification process can leverage the functional testing that is already performed during installation and commissioning as a matter of course.

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 Title 24, Part 6 Standards are adopted. The recommended compliance process and compliance documentation may also evolve with the code language. To effectively implement the adopted code requirements, a plan should be developed that identifies potential barriers to compliance when rolling out the code change and approaches to minimize barriers and overhead should be deployed.

1. 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® Company – and several Publicly Owned Utilities (POUs) – Los Angeles Department of Water and Power and Sacramento Municipal Utility District, and Southern California Public Power Authority – sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to energy efficiency in buildings. This report and the code change proposal presented herein 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/.

The overall goal of this CASE Report is to propose a code change proposal for high efficiency laboratory fume hood controls. The report contains pertinent information supporting the code change. When developing the code change proposal and associated technical information presented in this report, the Statewide CASE Team worked with industry stakeholders including building officials, manufacturers, builders, utility incentive program managers, Title 24 energy analysts, end-users, and others involved in the code compliance process. The proposal incorporates feedback received during public stakeholder workshops that the Statewide CASE Team held on December 13, 2016, March 7, 2017, and June 6, 2017 as well as comments received over the proposal development timeline.

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

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

Section 4 presents the per-unit energy, demand, and energy cost savings associated with the proposed code change. This section also describes the methodology that the Statewide CASE Team used to estimate energy, demand, and energy cost savings.

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

Section 6 presents estimates the statewide energy savings and environmental impacts of the proposed code change for the first-year after the 2019 Standards take effect. This includes the amount of energy that will be saved by California building owners and tenants, and impacts (increases or reductions) on material with emphasis placed on any materials that are considered toxic. Statewide water consumption impacts are also considered.

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

2. MEASURE DESCRIPTION

2.1 Measure Overview

The proposed measure seeks to support California's energy goals by targeting one of the larger energy users in laboratory facilities. The intent of this proposal is to establish a new prescriptive requirement that automatic sash closure systems be installed on laboratory fume hoods with variable exhaust systems. This measure will apply to new construction as well as additions or alterations. Further, the proposed measure will only be applied to spaces where ventilation requirements are fume hood intensive.

Laboratory fume hoods are defined by Title 8 (Industrial Regulations) of the California Code of Regulations (CCR) as "a device enclosed except for necessary exhaust purposes on three sides and top and bottom, designed to draw air inward by means of mechanical ventilation, operated with insertion of only the hands and arms of the user, and used to control exposure to hazardous substances." Fume hoods are used to contain airborne contaminants and fumes that are hazardous to human exposure. Laboratory air is drawn into the hood and exhausted through a stack that can be either isolated or connected to a common exhaust manifold.

Fume hoods have a moving sash that acts as a barrier between the occupied space and hood interior. In variable air volume (VAV) systems, the sash moves up and down (or left and right if horizontal) while maintaining a constant face velocity in order to ensure proper containment and safety controls. Thus, since airflow varies with sash position, HVAC (heating, ventilation, and air conditioning) energy use is impacted by sash positioning whenever the fume hood flowrates are greater than those required by cooling, pressurization, or laboratory ventilation setpoints. A space can be considered "fume hood intensive" when it is exhaust and supply airflows are often driven by fume hood demands. Typically, fume hood intensive spaces present an opportunity for energy savings through fume hood and sash position management.

The proposed prescriptive measure will apply to any space with a VAV HVAC system that is laboratory fume hood intensive. Although this is not necessarily limited to a single space type, scientific laboratories will comprise a majority of the covered applications. A scientific laboratory is defined by Title 24, Part 6, Section 100.1 as "a room or area where research, experiments, and measurement in medical and physical sciences are performed requiring examination of fine details. The area may include work benches, countertops, scientific instruments, and associated floor spaces. Scientific laboratory does not refer to film, computer, and other laboratories where scientific experiments are not performed."

Due to the complexities of laboratory design, a fume hood intensive space can be defined by a variety of building parameters. However, based on the analysis performed for this study, fume hood intensive spaces under representative assumptions can be defined by several parameters including fume hood density (total linear feet per laboratory area), laboratory ceiling height (feet), and minimum ventilation setpoints (Air Changes per Hour - ACH). It can also be shown that cost-effectiveness of the measure is correlated to fume hood density per 10,000 cubic feet of laboratory space enabling consolidation of the area and ceiling height parameters. See Section 4 for details on determining whether a space is fume hood intensive and therefore cost-effective under the proposed code change.

Fume hoods with automated sash closure systems are equipped with controls that detect the presence of laboratory technicians in front of the fume hood. The technology uses an infrared occupancy sensor (called a zone presence sensor) to detect technician proximity with response times under one second and adjustable detection ranges. This signal is used as a metric for whether the fume hood is in use and thus requires a raised sash.

When the technician moves away from the hood and outside the occupancy sensor range, the sash automatically lowers after a delay timer. Thus, exhaust air is reduced while maintaining face velocity and minimum hood ACH. Automatic sash closure systems employ a manual override option that enables the user to override the automatic controls. A built-in delay ensures that sash will not close after a false vacancy detection if the technician has briefly turned away or gone to get a tool or solution for their experimental work. Although the system is primarily used on hoods with vertical sashes, it can also be used for the vertical portion of a combination sash and providers are in the process of developing models for use with horizontal sashes as well.

Automatic sash closure systems can be installed on any hood with a vertical or combination sash and will increase user safety by ensuring a closed sash when not in use. However, energy will only be saved at any given time if the space air flow is fume hood driven at that moment. As described above, a space that has significant hours of the year that are fume hood driven can be called “fume hood intensive.” The measure does not modify face velocity requirements; it saves energy by reducing area of sash opening while maintaining velocity. Although face velocity settings can be a target for energy savings efforts, they are dictated by health and safety codes and facility practices and outside the scope of this proposed measure.

Due to the nature of the proposed measure and the unique building space to which it is applied, standard building prototypes do not apply. For this reason, the prototype laboratory space used to estimate energy savings impacts for the proposed measure will be clearly defined and justified. See Section 4 for detailed assumptions regarding energy savings analysis.

As energy savings associated with this measure depend on the controls being installed and calibrated correctly, an acceptance test will be required to verify the system is operating correctly. Compliance certification upstream of installation may not be possible due to the aftermarket nature and onsite integration of the measure.

Note that the proposed measure does not modify or replace existing code language but appends to it, most notably with a fume hood section in 140.9 “Prescriptive Requirements for Covered Processes”. The measure does not change which spaces are covered by existing VAV code requirements.

The proposed measure will not negatively impact laboratory health or safety, which are top priorities in any laboratory environment. In fact, automatic sash closure systems can improve laboratory safety by ensuring sashes are closed when not in use, enhancing the capture of any chemicals and hazardous substances being stored in the fume hood.

2.2 Measure History

Laboratory exhaust systems in California consume approximately 2,495 gigawatt-hours per year (GWh/yr) and 18 trillion British thermal units per year (Btu/yr) with a peak demand of about 574 megawatts (PG&E 2007). Fume hoods are one of the largest energy users in most laboratory facilities. This contributes to the fact that laboratories have an average energy use intensity (EUI) several times that of the average commercial building (Mills, Bell, et al. 1996). In 2006 Mills and Sartor reported that a typical six-foot fume hood consumes roughly three-and-a-half-times the energy of an average house in the United States (Mills and Sartor 2006). In California specifically, they reported that the average fume hood uses about 311 million Btu/yr while the average 1,583 square foot home used 62 million Btu/yr (U.S. Energy Information Administration 2009).

In laboratory facilities with high fume hood density, the fume hoods often dictate the airflow requirements for the entire laboratory space. As a result, fume hood intensive laboratory spaces often require more robust (i.e., larger) HVAC systems. For safety purposes, it is customary for hoods to maintain ventilation even when they are not in active use in order to exhaust any lingering contaminants or stored laboratory materials. In VAV systems, this ventilation rate varies with sash position to maintain a constant face velocity and minimum flowrate. Fume hoods typically operate 8,760 hours each year, even though the hoods are not utilized continuously. The proposed measure intends to reduce the overall airflow through the hoods thus resulting in HVAC energy savings and reduced facility energy costs.

There are no existing requirements in Title 24, Part 6 for laboratory fume hoods.

- Section 120.6 of 2016 Title 24, Part 6 does not currently address fume hoods.
- Section 140.9(c) of Title 24, Part 6 prescriptively requires variable exhaust and make-up airflow for laboratory buildings where the minimum circulation rate to comply with code or accreditation standards is 10 air changes per hour (ACH) or less.

Laboratory fume hoods are not covered by federal standards; there are no preemption concerns. There are no model codes that require sash closures.

Several studies have reported estimated energy savings for sash closure controls with a wide range of results and methods. Automatic sash control studies have estimated savings of 4,047 kWh/year and 552 therms/year (PG&E 2007), 17,145 kWh/year (SCE 2007), $3,412/year (Hilliard n.d.), 6,956 kWh/year and 134 therms/year (IES, Inc. 2012).

Additionally, several behavioral efforts using training and sash stickers have shown savings based on the same available savings opportunity. These studies have shown measured savings of $1,300 per year (Bell, Doyle and Getty 2012) and $1,181 per year (Gilly 2015), and about 300 kWh/year and 46 therms/year (Wesolowski, et al. 2010). One of these studies showed behavioral savings persistence almost two years after program initiation.

Another study estimated that savings of 14,663 kWh/year and 1,057 therm/year could be achieved with a variety of measures such as VAV controls and reducing a hood’s face open area (i.e., sash control) (Mills and Sartor 2006).

Table 3 summarizes estimated savings per hood reported in previous studies. Note that the analysis methods, baselines, assumptions, and conditions varied across these projects. However, they do give context for the estimated savings calculated for this report.

Table 3: Previous Reported Savings for Sash Closure Measures

Measure Type	Estimated Savings per Hood	Source
Auto closure controls	4,047 kWh/year 552 therms/year	(PG&E 2007)
Auto closure controls	17,145 kWh/year	(SCE 2007)
Auto closure controls	$3,412/year	(Hilliard n.d.)
Auto closure controls	6,956 kWh/year 134 therm/year	(IES, Inc. 2012)
Behavioral (training, sash stickers, etc.)	$1,300/year	(Bell, Doyle and Getty 2012)
Behavioral (training, sash stickers, etc.)	$1,181/year	(Gilly 2015)
Behavioral (training, sash stickers, etc.)	300 kWh/year 46 therms/year	(Wesolowski, et al. 2010)
Total hood potential (theoretical savings limit estimation)	14,663 kWh/year 1,057 therms/year	(Mills and Sartor 2006)

2.3 Summary of Proposed Changes to Code Documents

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

2.3.1 Standards Change Summary

This proposal will modify the following sections of the Building Energy Efficiency Standards as shown below. See Section 7.1 of this report for the detailed proposed revisions to the code language.

SECTION 140.9 – PRESCRIPTIVE REQUIREMENTS FOR COVERED PROCESSES

Subsection 140.9(c)2: The proposed code change adds a prescriptive requirement that automatic sash closure systems be installed on laboratory fume hoods with variable exhaust systems. The requirement applies if the fume hood is located in a fume hood intensive space in which ventilation requirements are largely driven by fume hood loads.

2.3.2 Reference Appendices Change Summary

This proposal will modify the Reference Appendices as shown below. See Section 7.2 of this report for the detailed proposed revisions to the text of the Reference Appendices.

NONRESIDENTIAL APPENDICES

NA7.16 – Fume Hood Automatic Sash Closure System: The proposed regulation adds an acceptance test that requires a construction inspection and functional testing to support the new prescriptive requirements for fume hoods. A new section of Reference Appendix NA7 will be added with proposed text provided below. The document should include fields to specify fume hood quantities being tested and inspected as part of the acceptance test. Multiple forms should not be needed when testing more than one hood.

2.3.3 Alternative Calculation Method (ACM) Reference Manual Change Summary

The proposed code change will require modifications to the ACM Reference Manual. See Section 7.3 of this report for more details on the revisions needed to the ACM Reference Manual and compliance software.

The California Building Energy Code Compliance for Commercial Buildings Software (CBECC-Com) includes modeling capability for lab fume hood exhaust systems but does not currently have features to model automatic sash closure controls. The proposed measure requires an adjustment to the compliance model that accounts for fume hood energy usage based on sash positioning. If the baseline compliance model includes calculations of VAV fume hood energy usage, an adjustment to the percentage of time the sash is open will be needed.

Since this is a prescriptive measure, compliance may be achieved through a performance approach by employing alternate energy efficiency measures. Although the alternate measures do not necessarily have to relate to fume hood and laboratory HVAC energy, some measures that could reduce fume hood energy usage include airside energy recovery, face velocity reductions, behavioral controls among others. These measures are not currently outlined by the ACM Reference Manual but could be considered for future updates.

2.3.4 Compliance Manual Change Summary

The proposed code change will add new sections to the Title 24, Part 6 Compliance Manual:

- 10.7.3 – Prescriptive Measures for Laboratory Exhaust
- 13.38 NA7.16 – Fume Hood Automatic Sash Closure System

2.3.5 Compliance Documents Change Summary

The proposed code change will require the creation of a new compliance documents in addition to the modification of existing forms, as listed below. Discussion of the new forms are presented in Section 7.2 and 7.5.

- A new compliance document will be required as the Statewide CASE Team is adding a new acceptance test for the proposed measure. NRCA-PRC-14-F Fume Hood Automatic Sash Closure System Acceptance document will need to be added to the compliance documents. This new document will be submitted to the enforcement agency that certifies the equipment and systems meet the acceptance requirements specified in NA7.16. The acceptance requirements will include both a construction inspection and functional testing and will assure that installed equipment complies with the new standard.
- Certificate of Compliance document NRCC-PRC-01-E will need to be modified to reflect the new measure requirements. Specifically, Test Description PRC-09-A will need to be added to the existing form. The Certificate of Compliance documents are submitted to and approved by the appropriate enforcement agency.
- Certificate of Compliance document NRCC-PRC-09-E for Laboratory Exhaust will need to be modified to reflect the new prescriptive measure requirements. The Certificate of Compliance and construction documents are submitted to and approved by the appropriate enforcement agency.
- NRCC-PRF-01-E Certificate of Compliance – Nonresidential Performance Compliance Method and NRCI-PRF-01-E Certificate of Installation – Nonresidential Performance Compliance Method forms will also require modification.

2.4 Regulatory Context

2.4.1 Existing Title 24, Part 6 Standards

Title 24, Part 6 does not include standards that address automatic sash closure systems. However, Section 140.9(c) outlines the prescriptive requirements for laboratory exhaust systems. The proposed measure builds upon Section 140.9(c) by adding a prescriptive requirement for automatic sash closure systems to be installed on VAV laboratory fume hoods.

Title 24, Part 6, Section 140.9(c) requires all laboratory exhaust systems with minimum circulation rates of ten ACH or lower to be designed with variable volume controls capable of reducing supply, fume exhaust, and general exhaust while still maintaining minimum circulation rates and pressurization requirements. An exception applies to laboratories that must maintain constant velocity controls or other measures for health, safety, and operations reasons or new zones being added to an existing constant air volume (CAV) system.

The Statewide CASE Team investigated local ordinances; however, none were found to be in conflict with the proposed measure.

2.4.2 Relationship to Other Title 24 Requirements

The California Mechanical Code (CMC) Title 24, Part 4 includes a non-mandatory appendix titled Sustainable Practices which recommends technical provisions to encourage sustainable building designs. Section E 503.5.11.3 includes recommended provisions for laboratory exhaust systems in buildings with total fume hood exhaust rates greater than 5,000 cfm. This is akin to the exhaust through four or more six-foot fume hoods. Section E 503.5.11.3 of Title 24, Part 4 suggests that at least one of three measures be applied in labs meeting the cfm criteria: (1) VAV systems incorporate a heat recovery system to precondition makeup air, (2) VAV labs with minimum ventilation rates have the capability to reduce airflow to the minimum rate or minimum pressurization requirements, or (3) regardless of airflow control, direct makeup air equal to or greater than 75 percent of the exhaust rate be heated to no more than two degrees below setpoint, cooled to no less than three degrees above setpoint, and no simultaneous heating and cooling is used for dehumidification. These recommendations for laboratory exhaust systems are consistent with ASHRAE 90.1-2013 6.5.7.2 standards and do not conflict with the proposed code measure.

CMC Title 24, Part 4, Section 410.1 and 410.3 provide requirements for laboratory ventilating systems and hoods in buildings with OSHPD occupancies. Section 410.1 requires laboratory ventilation systems to comply with the National Fire Protection Agency (NFPA) 99 standard. See Section 2.4.4 for details relating to NFPA 99. Section 410.3 specifies that the average face velocity for laboratory fume hoods shall be at least 75 feet per minute. If the fume hood is used with infectious or radioactive materials, the fume hood shall instead have a minimum face velocity of 90 to 110 feet per minute.

CMC Title 24, Part 4, Section 1.1.4 and Appendix E Sustainable Practices do not conflict with the proposed measure. Per the Appendix E matrix adoption table, the appendix has not been adopted by a state agency or local enforcing agency and would not preclude the measure even if it was. The 2019 Title 24, Part 6 CASE initiative for variable exhaust flow control[1] does not conflict with this proposed measure.

2.4.3 Relationship to State or Federal Laws

he Occupational Safety and Health Administration (OSHA), an agency of the U.S. Department of Labor, regulations specify requirements regarding fume hood operation in the Code of Federal Regulations, Volume 29, Part 1950.1450. OSHA requires employers to actively manage safety in the laboratories by means of ensuring permissible exposure limits to OSHA regulated substances via monitoring, developing and executing a chemical hygiene plan, and designating a chemical hygiene officer. The proposed measure is not duplicative or in conflict with the applicable OSHA regulations. The monitoring and maintenance of the automatic sash closure system will need to be incorporated into the employers' chemical hygiene plan.

Sections of the California Code of Regulations (CCR) include requirements for design exhaust airflow for laboratory fume hoods. Title 8 of the CCR, which California's Division of Occupational Safety and Health (Cal/OSHA) maintains, includes ventilation requirements for laboratory-type hood operations that explicitly allow ventilation rates to be reduced if no occupants are in the immediate area of the hood opening (Department of Industrial Relations n.d.).

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[1] http://title24stakeholders.com/induction-exhaust-fan-control/

Even though the proposed code change is not recommending modifications to the current ventilation health and safety requirements, it also will not prevent people from modifying ventilation rates if they want to apply for a variance from Cal/OSHA, as some laboratory stakeholders have already done. This variance allows for reduced face velocity settings with proven safety testing.

2.4.4 Relationship to Industry Standards

The American National Standards for Laboratory Ventilation (ANSI/AIHA Z9.5-2012, Section 3.1.1.4) specifies that the following conditions shall be met before using automatic sash closing devices:

- Automatic sash control systems shall have obstruction sensing capable of stopping travel during sash closing operations without breaking glassware, etc.
- Automatic sash controls shall allow manual override of positioning with forces of no more than 10 lbs (45 N) mechanical both when powered and during fault modes during power failures.

The ANSI/AIHA standard also includes guidelines for proper laboratory ventilation management programs (LVMP), which are designed to ensure safety and energy consumption minimization. The proposed measure incorporates ANSI/AIHA Z9.5-2012 sash closure conditions into the change recommendations for Title 24, Part 6.

NFPA 45 is a standard for fire protection in laboratories using chemicals that provides basic requirements to protect life and property through prevention and control of fires and explosions in chemical laboratories. NFPA 45 includes the following standards that must be met regarding fume/chemical exhaust hoods.

- NFPA 45-6.8.3* - Laboratory Hood Sash Closure. Laboratory hood sashes shall be kept closed whenever possible. When a fume hood is unattended, its sash shall remain fully closed.
- NFPA 45-A.6.8.3 - Users should be instructed and periodically reminded not to open sashes rapidly and to allow hood sashes to be open only when needed and only as much as necessary.

The asterisk for NFPA 45-6.8.3 signifies that there is explanatory material in Annex A (NFPA-A.6.8.3) of the standard. Annex A is considered informational and therefore its statements are not requirements. NFPA does not require automatic sash closures but sash closures can be used to comply with the NFPA standards.

Many NFPA standards have been adopted in Title 24, Part 9 California Fire Code which is enforced by the State Fire Marshall, the chief of a city or county fire department, or the chief of a fire protection district. However, NFPA 45 is not referenced in Title 24, Part 9.

NFPA 99 establishes codes for health care facilities mostly relating to air change and pressurization for health and safety in hospitals. NFPA 99-6.4.3.4 requires that fume hood ventilating controls be arranged to ensure proper balance between exhaust and supply for all hoods connected to the same system. Fume hoods should be designed to prevent backflow of contaminants into the room. Furthermore, NFPA 99 requires fume hood ventilating controls be tested annually by a qualified person who should certify the results of the test. Title 24, Part 4, California Mechanical Code, Section 410.1 requires compliance with NFPA 99.

ANSI/ASHRAE 110-2016 Method of Testing Performance of Laboratory Fume Hoods specifies quantitative and qualitative test methods for evaluating fume containment of laboratory fume hoods. Tracer gas testing is a method of testing fume hoods where the amount of gas particles escaping from fume hood chambers is precisely measured. This performance test is already required by Title 8 for fume hoods that reduce the ventilation rate from a minimum average face velocity of at least 100 fpm to a minimum average face velocity of 60 fpm. As the proposed measure is not recommending reductions in existing ventilation requirements, no additional performance testing as specified by ANSI/ASHRAE 110-2016 will be required as a result of this proposed Title 24, Part 6 measure.

2.5 Compliance and Enforcement

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

This code change proposal will primarily affect buildings that use the prescriptive approach to compliance. Changes to the compliance process are summarized below:

- **Design Phase**: The controls requirement will not change the design procedures for VAV laboratory HVAC systems except perhaps for the specification of fume hoods with automatic sash closure controls. Since VAV laboratory systems are inherently required to respond to varying sash heights, no changes to the design procedures, sizing, controls, or components are required. Current VAV design practices already enable flow control based on manual sash positioning; thus, they will respond to the automatic controls in the same manner. Furthermore, the occupant sensing and closing mechanism are built into the closure system controls and do not need to be integrated into HVAC controls for the measure to function. Although the designer should probably be aware of the measure, the automatic sash closure controls could be specified by any of the designers, laboratory consultants, architects, or owners and the VAV design would still function without complication.
- **Permit Application Phase**: The proposed measure does not offer a means for exceptions to the existing fume hood and laboratory standards. Currently, regulation of fume hood operation is handled by Title 24 Section 140.9(c) and Title 8 §5154.1. With the introduction of the proposed measure, these requirements will still need to be met. However, the NRCC-PRC-01-E Certificate of Compliance, NRCC-PRC-09-E Certificate of Compliance for Laboratory Exhaust, and NRCC-PRF-01-E Certificate of Compliance - Nonresidential Performance Compliance Method should be updated to reflect the new prescriptive requirement. The Certificate of Compliance documents will need to be provided to the plans examiner during the permit application phase. The plans examiner will need to be aware of the code requirements and compliance document changes. The plans examiner will also need to understand how the code requirements should be integrated into the design, while ensuring that all existing codes and standards for laboratories relating to health and safety are being properly addressed as they would have been regardless of the new measure.
- **Construction Phase**: Functional testing will be performed by the measure installer or primary manufacturer who will act at the ATT. No additional inspections will be required. Additional coordination will be required with the installer/manufacturer ATT to ensure that the appropriate NRCA-PRC-14-F forms are completed at the time of commissioning. Since functional testing of the fume hood sash controls would be performed during installation as a matter of course, the acceptance test and NRCA-PRC-14-F will leverage this opportunity to verify compliance through the installer ATT.
- **Inspection Phase**: The proposed code change will require a new Certificate of Acceptance document NRCA-PRC-14-F, which will need to be filled out by the field technician/installer who will act as the ATT. The Certificate of Acceptance document should be filled out and signed by the ATT and then provided to the building inspector to verify compliance and prevent delays in obtaining final occupancy permit.

Additional acceptance documents will be required during the inspection phase but increased burden on building officials is expected to be minimal. Upstream compliance at the fume hood manufacturer level may not be possible since the controls are often an aftermarket product with components external to the hood. However, the burden will be minimized by leveraging testing that would already be performed by the installer who will act as the ATT. As such, no additional inspection beyond the installation acceptance test would be required except for review of the proper compliance forms.

If this code change proposal is adopted, the Statewide CASE Team recommends that information presented in this section, Section 3, and Appendix B be used to develop compliance documentation and a plan for minimizing barriers to compliance. Additionally, guidance and training of field technicians and ATTs will be required so that compliance data and testing is performed and reported properly.

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 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 range of industry players who were invited to participate in utility-sponsored stakeholder meetings held December 13, 2016, March 7, 2017, and June 6, 2017.

3.1 Market Structure

The fume hood provider market comprises manufacturers and installers that work with fume hoods with and without automatic sash closing systems. The Statewide CASE Team had discussions with Supply & Equipment Foodservice Alliance (SEFA) who represents more than 40 fume hood manufacturers to ensure their concerns are addressed. Additionally, the Statewide CASE Team contacted fume hood manufacturers and installers, controls manufacturers, end-users, designers, and building energy consultants to obtain their perspectives for incorporation into the market and technical information of this study.

The following is an incomplete list of vendors that either manufacture fume hoods with automatic sash closing system applicability or automatic sash closing kits to retrofit VAV fume hoods:

- **Fume Hood Manufacturers:** Erlab, Green Energy Hoods, Iroquois Hoods, Lab Conco, Mott Manufacturing, Newtech, Waldner
- **Fume Hood Controls Integrators:** Acco, Aircuity, Air Master Systems, Phoenix Controls

Fume hoods equipped with automatic sash closure systems are readily available from multiple manufacturers and distributors and are offered in standard sizes (e.g., four-foot, six-foot, eight-foot). Additionally, the automatic sash controls themselves can be implemented by a wide range of controls manufacturers and distributors as an aftermarket solution. The retrofit of standard VAV fume hoods with automatic sash closure controls are not restricted to particular manufacturers or distributors (i.e., VAV fume hoods can be purchased from Manufacturer A and a compatible aftermarket kit to retrofit the system with automatic sash closure controls can be purchased from Manufacturer B).

3.2 Technical Feasibility, Market Availability, and Current Practices

Based on research and stakeholder discussions, many California academic and life science laboratories piloted automatic sash closure systems in the mid-to-late 2000’s with mixed opinions. The most common complaint about earlier designs of automatic sash closing systems involved the frequent misalignment of sensors, which would cause issues with sash closure and require the end user to manually override the controls. However, discussions with stakeholders who implemented more recent designs seem to suggest that manufacturers have overcome these barriers. If the controls are properly calibrated; the technology can be well-received by end users.

Due to the availability of automatic sash closure systems from multiple vendors, it is expected that the market can provide adequate supply in response to a code change. A production ramp-up is not anticipated as the measure components are not expected to have a significant lead time. Manufacturers interviewed indicated lead times ranging from one day to a maximum of six weeks.

Additional technical training should not be needed for field technicians or installers during the acceptance test process since the installer already possesses the necessary skills to understand and properly operate the proposed measure. However, familiarity with the acceptance test procedures and compliance documentation will be needed and may require some compliance training. Construction inspection and functional testing details are discussed in Section 7.2.

End-user comfort and ease of use may be moderately and temporarily affected as users become accustomed to the technology. While it is considered good practice to bring the sash to a minimum position when the fume hood is not in use, studies suggest that fume hood sashes are often left open (DOE 2012b). Behavioral sash closing campaigns have been shown to be effective but there is little reporting on whether these effects are sustained over time or become engrained in laboratory culture (Gilly 2015, DOE 2012a). Indeed, these shut the sash behavioral campaigns have shown that energy can be saved using sash management techniques, bolstering the case for using sash closure controls as a technological solution as an alternative to reliance on behavioral measures.

The Statewide CASE Team has identified two products that offer similar functionality to the proposed measure in that they reduce the exhaust air flow based on occupancy or usage. Zone presence sensors and high performance low flow fume hoods both offer a different means to reduce exhaust flow air volume without adjusting the sash position. The technologies typically lower face velocities below the Cal/OSHA required average of at least 100 feet per minute during active use. While the proposed measure is not recommending modifications to the current ventilation requirements, it also will not prevent people from modifying ventilation rates with zone presence sensors (with passing tracer gas tests) or reducing face velocities with a high performance low flow hood and a variance from Cal/OSHA. The Statewide CASE Team is proposing the installation of automatic sash closure systems as a prescriptive requirement to allow building owners the option of installing alternate technologies with equivalent or greater energy savings through the performance compliance pathway.

3.3 Market Impacts and Economic Assessments

3.3.1 Impact on Builders

It is expected that builders will not be impacted significantly by any one proposed code change or the collective effect of all proposed changes to Title 24, Part 6. Generally speaking, builders could be impacted by changes 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 incremental costs of construction. The cost of complying with Title 24, Part 6 requirements represents a 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.

The proposed code change will not impact builders considerably; however, additional coordination with installers will be required to be successful. Market actors will need to invest in training and education to ensure the construction trade workforce knows 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. Furthermore, responsibility for the controls implementation will likely primarily lie with the service providers employed or affiliated with fume hood manufacturer and controls companies. That workforce will require little additional training to be familiar with the measure, if any.

3.3.2 Impact on Building Designers and Energy Consultants

Adjusting design practices to comply with changing building codes practices is within the normal practices of building designers. Building codes (including the California building code and those published by the International Code Council, the International Association of Plumbing and Mechanical Officials, and ASHRAE) are typically updated on 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. 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 how requirements can be met. An update to forms NRCC-PRC-01-E, NRCC-PRC-09-E, and NRCC-PRF-01-E will be required during the permitting process. The additional requirements for this code will need to be incorporated into the design and referenced appropriately for the plans examiner during the permitting phase.

Energy consultants will likely be responsible for documenting and ensuring Title 24, Part 6 compliance. For that reason, they will have to become familiar with the new measure and how compliance is certified. In many cases, it may be their responsibility to ensure that automatic sash closure controls are specified during the design phase unless exemptions or performance-based alternatives apply. Building designers of new fume hood intensive labs should familiarize themselves with the code change and ensure that the designed mechanical systems include specification of the measure or alternatives. See Appendix B for details on how the compliance process will impact various market actors including designers and 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 Cal/OSHA. All existing health and safety rules will remain in place. Compliance 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.

Facility and organization environmental health and safety (EH&S) departments do often develop operations and maintenance protocols that cover fume hoods. For instance, it is common practice for EH&S to establish operating parameters, safety procedures, and an LVMP per ANSI/AIHA Z9.5 guidelines that overlap with fume hood use. These EH&S protocols can include sash management best practices, training, and sticker campaigns at facilities that are particularly proactive. The proposed measure will interact with these protocols and would displace any behavioral sash management practices in new construction or if a new fume hood were to be installed. However, the measure would objectively improve sash management adherence including health and safety concerns.

3.3.4 Impact on Building Owners and Occupants

The proposed code change is expected to increase incremental first costs for building owners as well as introduce additional maintenance costs over the EUL of the measure (although these may be slightly offset by decreased wear on other HVAC system components). Fume hood end users may experience a brief adjustment period while becoming accustomed to the new controls.

This measure is expected to result in energy use reductions for the building owner or tenant at an increased upfront cost. Since the measure is an entirely new control technology separate from typical fume hood purchasing and function, the entire measure cost is considered incremental. For each hood, this amounts to around a ten to thirty percent cost increase in materials cost but is a much smaller fraction when considering the ductwork, HVAC controls, design work, and other costs that are associated with standard laboratory installations regardless of sash controls. One concern voiced by some stakeholders was that the additional upfront cost burden would encourage building owners to request CAV designs instead of VAV in order to avoid the incremental costs associated with the sash controls. However, VAV systems already cost significantly more than CAV systems. Thus, the small additional cost associated with the proposed measure is unlikely to increase the already existing incentive to avoid first-costs associated with VAV systems. Indeed, the proposed measure will actually improve the cost-effectiveness of VAV systems, thereby making VAV designs more attractive over the lifetime of the system if it is properly designed, maintained, and operated.

As energy efficiency standards become more stringent, occupants of nonresidential buildings will benefit from energy cost savings. As this proposal is designed, the measure is deemed to be cost-effective under representative conditions and will provide benefits to building owners that well outweigh the additional incremental costs during construction. As discussed in Section 3.4.1, when building owners or tenants save on energy bills, they tend to spend it elsewhere in the economy, thereby creating jobs and economic growth for California.

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

The proposed code change will increase sales for the manufacturers and distributors of automatic sash closing systems. Depending on the price point, sales for manufacturers that do not offer built-in sash closing controls may be adversely affected. However, standard manual closing VAV fume hoods can be modified with an automatic sash closure retrofit kits thereby mitigating negative effects on providers of fume hoods without the controls as a standard option. This would require collaboration between manufactures and distributors of standard VAV fume hoods and suppliers of the automatic sash closing controls.

An NRCA document is proposed to indicate compliance. One option the Statewide CASE Team considered was to have compliance checks performed by the measures' manufacturers. If the systems shipped and installed were self-certified and code compliant, the need for an additional acceptance document would be eliminated thereby reducing compliance process overhead. However, there are significant issues with this approach and is not recommended at this time. Based on manufacturers' commissioning guidelines and installation documentation, sensor placement and sensitivity varies between fume hoods due to laboratory equipment, furniture arrangements, and site specific operating procedures. Furthermore, per discussions with installers, this measure is installed on site rather than shipped as an assembled package. These realities dictate that compliance be based on an onsite acceptance test and verification unless future fume hood product updates can integrate the controls in a self-contained, certifiable package. As such, the Statewide CASE Team concluded that an NRCA document is needed for the proposed measure to verify compliance.

3.3.6 Impact on Building Inspectors

While the proposed measure will involve the addition of one Certificate of Acceptance document, it will add to the list of compliance checks and forms for building inspectors and plans examiners. The inclusion of the new acceptance test will require a field technician to perform functional testing and complete and sign the corresponding compliance documents to ensure the measure meets the acceptance requirements specified in NA7.16. The addition of the Certificate of Acceptance document may require additional inspection time to verify compliance. While alternative methods for compliance checks could still be investigated, a new acceptance document is being proposed at this time. See Appendix B for how this code change will affect building inspectors, plan examiners, and field technicians or installers acting as the ATT.

3.3.7 Impact on Statewide Employment

Section 3.4.1 discusses statewide job creation from the energy efficiency sector in general, including updates to Title 24, Part 6. The proposed code change is expected to have minimal impact on job creation or shifting of employment in applicable sectors.

3.4 Economic Impacts

The Statewide CASE Team predicts no significant economic impacts on job markets, business operations, state government, or code enforcement. The capital outlay for the measure cost is a small portion of construction budgets and the technology will not cause any lasting competitive advantages across the construction and supply chains. Since there are other options for reducing energy consumption, the measure could potentially stifle competing sash and fume hood air control technology development, but only those which have less per-unit energy savings impact. Any innovation towards technologies which further improve the efficiency of VAV fume hoods beyond the proposed measure will not be negatively impacted due to alternate measures' abilities to improve efficiency beyond automatic sash closing systems.

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 on activities related to building efficiency. Employment in the building energy efficiency industry grew six percent between 2014 and 2015 while the overall statewide employment grew three percent (BW Research Partnership 2016). Lawrence Berkeley National Laboratory's report titled *Energy Efficiency Services Sector: Workforce Size and Expectations for Growth* (2010) provides details on the types of jobs in the energy efficiency sector that are likely to be supported by revisions to building codes.

Building codes that reduce energy consumption provide jobs through direct employment, indirect employment, and induced employment.[2] Title 24, Part 6 creates jobs in all three categories with a significant amount attributed to induced employment, which accounts for the expenditure-induced effects in the general economy due to the economic activity and spending of direct and indirect employees (e.g., non-industry jobs created such as teachers, grocery store clerks, and postal workers). A large portion of the induced jobs from energy efficiency are the jobs created by the energy cost savings due to the energy efficiency measures. Wei, Patadia, and Kammen (2010) estimate that energy efficiency creates 0.17 to 0.59 net job-years[3] per GWh saved. By comparison, they estimate that the coal and natural gas industries create 0.11 net job-years per GWh produced. Using the mid-point for the energy efficiency range (0.38 net job-years per GWh saved) and estimates that this proposed code change will result in a statewide first-year energy savings of 17.5 GWh, this measure will result in approximately six jobs created in the first year. See Section 6.1 for statewide energy savings estimates.

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[2] 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."

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

Additional labor for both construction and commissioning will be required by this measure. Installation and commissioning are estimated at six hours for installation and two hours for commissioning.

The proposed measure is not expected to create or eliminate any jobs within California. The technology comprises several add-on control hardware components to a common type of HVAC equipment. The measure is largely off-the-shelf and is installed without having to significantly alter, replace, or excise any other piece of equipment that is part of a typical VAV laboratory design. As such, it easily integrates with the existing labor resources dedicated to laboratory design, hardware sourcing, construction, operation, and maintenance. No new jobs are needed to implement the measure and conversely, no jobs are placed in jeopardy by its use. Furthermore, the technology is matured and has a manufacturing supply chain that is well-established although will likely need some adjustment to accommodate providers that do not currently have the controls as part of their offerings. Any new construction projects can tap into the existing supply chain, thus having little to no job creation within California.

The cost savings that the complying businesses will realize could potentially contribute towards increased capital available for business or workforce investment, but are unlikely to have a significant impact.

3.4.2 Creation or Elimination of Businesses in California

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

Table 4 lists industries that will likely benefit from the proposed code change classified by their North American Industry Classification System (NAICS) Code.

Table 4: Industries Receiving Energy Efficiency Related Investment, by North American Industry Classification System (NAICS) Code

Industry	NAICS Code
Nonresidential Building Construction	2362
Electrical Contractors	23821
Plumbing, Heating, and Air-Conditioning Contractors	23822
Manufacturing	32412
Other Nonmetallic Mineral Product Manufacturing	3279
Industrial Machinery Manufacturing	3332
Ventilation, Heating, Air-Conditioning, & Commercial Refrigeration Equip. Manf.	3334
Computer and Peripheral Equipment Manufacturing	3341
Communications Equipment Manufacturing	3342
Engineering Services	541330
Building Inspection Services	541350
Environmental Consulting Services	541620
Other Scientific and Technical Consulting Services	541690
Commercial & Industrial Machinery & Equip. (exc. Auto. & Electronic) Repair & Maint.	811310

There is little likelihood that the proposed code change will contribute to the creation or elimination of any businesses within California. Costs per fume hood installation are relatively small compared to typical business operations and construction costs. For smaller businesses with relatively large investments in fume hood intensive lab space growth, the capital outlays could potentially be a burden on facilities management and construction budgets. However, given that growth rates are expected to be distributed across many companies, which are typically large, it is reasonable to expect that the additional capital cost burdens will not impact business' balance sheets in a substantial manner. Furthermore, the return on investment on automatic sash closure systems suggests that even these negative upfront cost impacts will likely be short-lived and quickly reversed.

Since the costs and installation procedures will be absorbed into the laboratory design, sourcing, and construction processes without much disruption or additional efforts, no new businesses will need to be established, and existing ones will not be affected beyond a small change in equipment specification or hardware installation.

While the automatic sash closure systems will increase the cost of a VAV fume hood replacement by approximately ten to thirty percent, the Statewide CASE Team does not believe the proposed code change will make common existing building retrofits too expensive or burdensome, leading to a reduction in retrofits. Given the cost-effectiveness of the measure, the increased incremental first cost will quickly be paid back in energy cost savings. Additionally, since this is a prescriptive measure, combinations of other technologies can be used for compliance through a performance approach if the costs are found to be preventative or other options are deemed more effective or beneficial.

3.4.3 Competitive Advantages or Disadvantages for Businesses in California

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

Competitive advantages or disadvantages in comparison with other states could potentially impact businesses' decisions to expand or relocate in or outside of California. The perception of the costs associated with the implementation of codes and standards can affect business decisions, which could impact their ability to compete with businesses outside of California. However, no impact on competitive advantage is expected for this measure as the upfront measure cost is such a small portion of overall construction costs and utility cost returns are attractive and cancel out capital costs in a short period of time. Furthermore, anecdotes suggest that user acceptance of the measure can be positive after a brief acceptance period and the measure does not alter a laboratory's ability to conduct research or perform experiments. Investigation into additional end-user training and maintenance associated with the proposed measure yielded no measurable costs beyond a typical new VAV fume hood installation. A laboratory with an automatic sash closure system can function just as effectively as one without. This implies that laboratories within California that implement the proposed measure will not have any operational disadvantage to those that do not.

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.

Based on the same arguments presented in Sections 3.4.1 through 3.4.3, the proposed code change will not have any impact on investment in the State of California. The proposed code measure will add some construction costs for new facilities and some additional maintenance costs. These small increases in costs are not enough to impact investment and will be quickly offset through energy cost savings returns. Over the life of the measure, the total returns are expected to contribute to a business' bottom line or operations budget, but not enough to affect investment in the state.

3.4.5 Effects on Innovation in Products, Materials, or Processes

Alternative fume hood airflow control measures include behavioral controls (e.g., sash stickers), training, low velocity hoods, reduced face velocity under certain conditions (e.g., ZPS – zone presence sensors), high performance and alternative air intake design hoods (e.g., vertical sash air curtain intakes), and stack velocity reductions based on wind tunnel variables.

The proposed measure is effectively the same as behavioral controls and proper training, albeit using a technological, automated approach. In that sense, the proposed code change is in conflict with behavioral measures and asking for end-users to take responsibility for their fume hood usage. However, the proposed measure can provide increased reliability and assurance that fume hood sashes will be positioned properly. From discussions with stakeholders, users have expressed both appreciation for the convenience over behavioral controls as well as some frustration. This could be compared to other similar debates such as those for automatic light controls or other technological solutions that have improved efficiency by displacing behavioral training.

Automatic sash closure systems interact with the alternate energy efficiency measures relating to reduced face velocity control, air intake design, and other designs aimed at fume hood energy and demand reduction. Although designs such as vertical air curtain intakes, zone presence sensors for reduced face velocity, and other measures can be implemented in concert with automatic sash closure systems, the measures will have interactive effects on each other. Although each measure will increase overall efficiency, the stacking effect of measures will decrease the efficiency gains achieved by each measure. In this sense, the cost-effectiveness of measures enacted in addition to automatic sash closure controls will be reduced, even though they can still improve upon overall hood efficiency.

While this could be taken as an impediment to fume hood control innovation, automatic sash closure system technology is a proven, effective design that can be layered on top of available fume hood products with little alteration and complication and should be considered as a step towards optimized fume hood energy use. To encourage the development and implementation of alternate fume hood energy efficiency measures, the Statewide CASE Team is proposing this measure as prescriptive rather than mandatory so that building owners have the option of other VAV hood controls that provide energy benefits in excess of automatic sash closure systems using the performance compliance approach.

The proposed measure is complementary to typical VAV laboratory designs and thus will not have any impact on innovation outside of the fume hood sash control itself.

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

Since some of the new construction is likely to be state-owned or funded (such as university labs), there may be some peripheral interaction with state government spending. However, given the small measure cost and absorption of both costs and resultant benefits by facility operations and maintenance budgets, measure implementation is not expected to have an appreciable impact on state or local government spending.

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 are expected to increase discretionary income when holistically considering Title 24, Part 6 and the downstream economic impacts.

State and local sales tax revenues may increase if building owners 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 increase construction costs. As discussed in Section 3.3.1, however, there is no statistical evidence that Title 24, Part 6 drives construction costs or that incremental construction costs have a significant impact on building price. Since compliance with Title 24, Part 6 does not have a clear impact on purchase price, it can follow that Title 24, Part 6 cannot be shown to impact revenues from property taxes.

3.4.6.1 Cost of Enforcement

Cost to the State

State government already has budget for code development, education, and compliance enforcement. While state government will be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, these activities are already covered by existing state budgets. The costs to state government are small when compared to the overall cost savings and policy benefits associated with the code change proposals. Since the measure requires only minor changes to permitting and functional testing and no changes to safety testing, the proposed code measure should have little effect on state regulatory spending.

This measure only recommends relatively minor changes. The cumulative effect of all 2019 Title 24, Part 6 code changes must be considered when assessing the additional cost of enforcement to the State. Enforcement will require additional work by plans examiners and building inspectors. This will involve review of quantity of hoods or hood workspace per lab area, confirming exemptions, and confirmation of the automatic sash closure system installation or compliance documentation. This additional code enforcement will require additional documentation and training of compliance reviewers that will likely incur some additional annual costs.

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. This is not a new cost associated with the 2019 code change cycle. The building code is updated on a triennial basis and local governments plan and budget for retraining every time the code is updated. There are numerous resources available to local governments to support compliance training that can help mitigate the cost of retraining, including tools, training, and resources provided by the IOU codes and standards program (such as Energy Code Ace). As noted in Section 2.5 and Appendix B, the Statewide CASE Team considered how the proposed code change might impact various market actors involved in the compliance and enforcement process and aimed to minimize negative impacts on local governments.

Permitting delays are not likely unless the lab designers or construction contractors did not adhere to the code requirements. The Certificate of Acceptance document will be populated and signed by the ATT, who is often the fume hood manufacturer or installer already equipped with the necessary skills to evaluate the operation of the proposed measure. Functional testing and the associated paperwork should be completed by the ATT at the time of fume hood installation to avoid unnecessary additional travel costs. Note that the proposed measure does not require the use of a Certified ATT. As such, the impact to local governments will be the additional time needed for the plans examiner and building inspector to verify compliance for the proposed measure during the permit application and inspection phase.

3.4.7 Impacts on Specific Persons

The proposed measure will impact the automatic sash closure system or the fume hood installer if the automatic sash closure system is included as a feature on a new VAV fume hood. The installer will act as the field technician responsible for conducting the construction inspection and functional testing as required by NA7.16, as well as for completing and signing the Certificate of Acceptance. There will be some training and acceptance required for the end-users and facility management staff of the impacted buildings; however, training for the automatic sash closure systems should coincide with training on the newly installed VAV fume hood, resulting in minimal incremental impact.

The proposed changes to Title 24, Part 6 are not expected to have a differential impact on any groups relative to the state population as a whole including migrant workers, commuters, or persons by age, race, or religion.

4. Energy Savings

4.1 Key Assumptions for Energy Savings Analysis

To calculate unit energy savings and statewide potential average conditions for fume hood intensive laboratories were modeled across all California climate zones. Since there is no formally established laboratory prototype, one was created for the CASE study based on a variety of references and typical compliance calculation assumptions. Although the model has dependence on a variety of influential model parameters, a literature survey and modeling analysis was performed to justify the necessary assumptions. Wherever possible, equipment performance and building parameters were defined using ASHRAE or ACM guidelines and definitions (California Energy Commission 2016). Additionally, there are a variety of sources that outline suggested modeling practices and standard conditions for laboratory energy systems and controls such as Labs21 and the International Institute for Sustainable Laboratories (EPA 2007, Rumsey Engineers 2010).

Individual lab conditions will result in varying energy usage and savings, but the analysis presents average energy savings for a prototype lab under fume hood intensive conditions. For the sake of the CASE Report discussion, a lab that is fume hood intensive is one which has airflow rates that are dictated by fume hood needs for enough hours of the year to make the measure cost-effective. Due to the complex and varying nature of laboratory design and operation, a sensitivity analysis of building parameters variables was performed to develop a knowledge base and the code language. The dependence on several building variables led to a definition of fume hood intensive labs that is used to identify conditions that warrant a code exemption, based on cost-effectiveness.

The two parameters that primarily define the cost-effective conditions are:

- Minimum ventilation rate setpoints (in ACH)
- Fume hood density (in total linear feet of hood width per 10,000 cubic feet of lab space)

There are other influential parameters that define the prototype building and modeling. These include, but are not limited to:

- Fume hood face velocity and minimum hood ACH
- Average sash position and diversity of fume hood use
- HVAC equipment, control definitions, and setpoints
- Weather conditions
- Occupancy patterns

Building parameters can vary significantly across laboratories depending upon type of business, research, occupancy, controls, commissioning, design, and other factors. Generally, EH&S departments perform assessments of each individual lab to define operating conditions and settings based on the risks and needs of each space. In regards to HVAC, these individual lab protocols often result in a laboratory ventilation management plan as recommended by ANSI/AIHA Z9.5. This makes it difficult to establish representative operating conditions and building parameters. However, laboratory design guidelines, modeling guidelines, and literature studies suggest that there are common and representative situations that can be used to define the typical fume hood intensive lab.

Based on the available literature, the following key assumptions are factored into the energy savings and demand reduction analysis:

- 100 percent outside air and exhaust operation with negative pressure for containment.
- Two HVAC system types defined by the ACM Reference Manual (California Energy Commission 2016):
    - Packaged VAV with DX cooling, gas furnace, and boiler HW reheat (Type 1).
    - Single duct VAV with water-cooled chiller, boiler hot water, and hot water reheat (Type 2).
- Airflow constrained by minimum requirements of fume hood exhaust, ventilation, pressurization, and conditioning with a general exhaust valve for maintaining minimum lab airflow.
- Safety requirements and standards define minimum hood operating airflow and lab ventilation (ANSI/AIHA 2012, Cal/OSHA n.d.).
- Fume hood usage, average sash position, and exhaust diversity defined by average lab usage patterns (see Appendix C).
- Other building conditions presented in Section 4.2.

These assumptions and a variety of other parameters define the modeled operating conditions that were used to determine the unit energy savings, cost-effectiveness, and statewide potential.

4.2 Energy Savings Methodology

To assess the energy, demand, and energy cost impacts, the Statewide CASE Team compared current design practices to design practices that will comply with the proposed requirements. There are no existing Title 24 requirements that regulate fume hood sash closures. The Statewide CASE Team used current design practices and a literature survey to define the existing conditions without automatic sash closure controls.

The proposed measure conditions are defined as baseline design conditions with additional sash controls that comply with the proposed code change. Specifically, the proposed code change will reduce the number of hours per year the fume hood sashes are left partially or fully open when they are not in use. In conjunction with the baseline VAV system, this will reduce energy use and demand by increasing the annual time spent at part load and reduced air volume conditions.

Due to the nature of the proposed measure and the unique building space to which it is applied, standard building prototypes do not apply (Rumsey Engineers 2010). Furthermore, since laboratory airflow is typically isolated from the rest of the building and fume hood airflow is isolated from the rest of the lab, the model calculations should consider only the airflow through the hood and lab. For these reasons, a custom calculation method specific to the lab space is justified (as opposed to whole building modeling).

An earlier version of the modeling tool was developed by Statewide CASE Team members prior to the CASE Report analysis for purposes of evaluating energy efficiency benefits associated with a Demonstration of Energy-Efficient Developments (DEED) Program grant. In part, that work studied the installation of automatic sash control systems in site-specific retrofit applications. Statewide CASE Team members have also utilized the earlier tool version to validate energy savings and demand reduction associated with fume hood measures submitted under IOU and POU custom incentive programs. The custom spreadsheet tool was adapted and modified for use specifically for the CASE Report analysis. A more detailed description of the tool can be found in Appendix C.

The model executes hourly calculations of HVAC energy use to determine energy usage and peak demand for the representative climate zone year. Along with a variety of other references, ACM Reference Manual guidelines and Title 24, Part 6 requirements were used for defining baseline equipment performance.

Minimum ventilation ACH setpoints for the prototype labs were defined by assumed standard design and commissioning practices. However, ventilation ACH setpoints do vary above and below the assumed parameters. The sensitivity analysis and exemption table captures this dependence on ACH setpoints. Evidence suggests that ACH rates in existing labs have been recently reduced to best practice and safety minimums in many stakeholder buildings once the excess airflow was identified (CEEL 2015). The prototype lab used for developing statewide estimated included the ACH setpoints listed in Table 5. However, the code language and exemption definitions considered typical ACH ranges, such that cost-effectiveness was ensured within the range given other building parameter assumptions. Ceiling height is also critical parameter coupled to the ACH minimum setpoint since along with the lab area, it helps define the minimum exhaust cfm for any given lab square footage.

Fume hood density is a defining parameter in the modeling of a fume hood intensive laboratory. The density can be defined as total nominal linear feet of hood width per laboratory space. For instance, a 1,000 square foot lab with a ten-foot ceiling and two six-foot hoods has a fume hood density of 12 linear feet per 10,000 cubic feet of lab space. Higher fume hood densities correspond to more hours of fume hood driven operation in the year, thus increasing cost-effectiveness of the measure.

Average fume hood sash position and use diversity also drive the exhaust flow rate since the VAV system responds to the sash position automatically. Average sash position is a very influential variable that can influence energy usage and savings and whether the measure is cost-effective. This sash position metric is defined as 0.0 when hoods are effectively closed (six-inch position or lower) and 1.0 when open to their fullest extent. Labs that follow best practices and manually close sashes on a regular basis will see less return from the measure. However, a literature survey suggested that it is common for sashes to be left open when not in use. Even the practices of a lab that currently has a behavioral culture of closing sashes may change with staff turnover. Thus, a literature survey of sash monitoring case studies was used to define the average sash position during occupied times, unoccupied times, and active use times. This comes with an understanding that sash closing behavior is variable with some labs will save less or more energy than predicted. Occupied times refers to normal business hours regardless of whether hoods are being used whereas active use times refers to how often the hoods are actually in use.

To estimate savings, energy consumption of the baseline conditions and with the proposed code measure were modeled using the custom tool described above. Two different laboratory prototypes were developed based on the two HVAC system types prescribed by the ACM Reference Manual.

Table 5 lists the details of the prototype laboratories used in the analysis.

Table 5: Prototype Building used for Energy, Demand, Cost, and Environmental Impacts Analysis (New Construction and Alterations)

	Lab Prototype Type 1	Lab Prototype Type 2
Occupancy Type	Science research and testing	
Existing Statewide Area	9.04 million square feet	
HVAC System	VAV DX packaged unit with gas furnace and hot water reheat from central boiler	VAV single duct with chilled and hot water coils and hot water reheat from central water-cooled chiller and boiler
Cooling Efficiency	10 EER (packaged DX)	0.68 kW/ton (water-cooled chiller)
Heating Source Efficiency	83% (gas furnace)	83% (gas furnace)
Reheat Source Efficiency	82% (hot water boiler)	82% (hot water boiler)
Supply Air Temperature	55 °F	
Heating/Cooling Setpoint	70/75 °F	
Outside Air Fraction	100% (TSI, Inc. 2014) (Evan Mills 2006) (California Energy Commission 2016)	
Fan Position	Draw-through	
Hood Face Velocity	100 fpm (Cal/OSHA n.d.)	
Effective Closed Sash Position	6 inches	
Closed Flowrate	25 cfm per ft^2 of hood workspace or 100 fpm at 6-inch sash height (ANSI/AIHA 2012) (Cal/OSHA n.d.)	
Ceiling Height	10 feet	
Static Pressure	3.5 inches supply 4.0 inches exhaust (California Energy Commission 2016)	
Minimum Ventilation Setpoint	10 ACH occupied 6 ACH unoccupied (CEEL 2015) (TSI, Inc n.d.) (Gilly 2015) (DOE, Fume Hood Sash Stickers Increases Laboratory Safety and Efficiency at Minimal Cost 2012b) (California Energy Commission 2016) (EPA 2007)	
Fume Hood Density	95 feet total nominal hood width per 1,000 ft^2 of lab area (3.3% of total area)	
Average Sash Position (0.0 = closed, 1.0 = wide open)	0.42 occupied hours baseline 0.37 unoccupied hours baseline 0.12 occupied hours active use measure case 0.00 unoccupied hours measure case (IES, Inc. 2012) (D. T. Hitchings 1993) (SCE 2007) (Hilliard n.d.) (Vargas and Cheng 2016) (Phoenix Controls Corporation n.d.) (TSI, Inc. 2014)	
Occupancy Schedule	M-F 8:00 – 18:00 S-Su 10:00 – 14:00 (California Energy Commission 2016)	

Additionally, the modeling accounts for:

- California climate zone hourly weather conditions.
- Airflow rates are defined by the minimum lab requirements of hood exhaust, ventilation, pressurization, or conditioning needs at any given time. A general exhaust valve is used to maintain ventilation rates if hood exhaust falls below the minimum ACH or cooling needs (TSI, Inc. 2014).
- Fume hoods maintain minimum face velocities and air changes through 24/7 ventilation for safety controls even if they are closed (Lawrence Berkeley Laboratory n.d.).
- Internal heat gains and loads defined by the ACM Reference Manual and CBECC-Com methods (California Energy Commission 2015).
- Equipment sized based on the ACM Reference Manual guidelines and fan airflow is reduced to no less than 50 percent of capacity (California Energy Commission 2016).
- Negative pressurization for secondary containment (ten percent difference between exhaust and supply airflow on average) (ANSI/AIHA 2012) (University of California 2016).
- HVAC equipment efficiencies and performance curves defined by Title 24, Part 6 code minimums and the ACM Reference Manual guidelines (California Energy Commission 2016).

Refer to Appendix C for further details on modeling methods and additional results.

The energy savings from this measure varies by climate zone. Thus, the energy impacts and cost-effectiveness were evaluated by climate zone. Energy savings, cost savings, and peak demand reductions were calculated using a TDV (time dependent valuation) methodology using the 2019 nonresidential 15-year factors. Figure 1 and Figure 3 show the energy savings results for the representative fume hood intensive lab prototypes across the 16 California climate zones. These results were translated to per-unit energy impacts for use in statewide impact estimation.

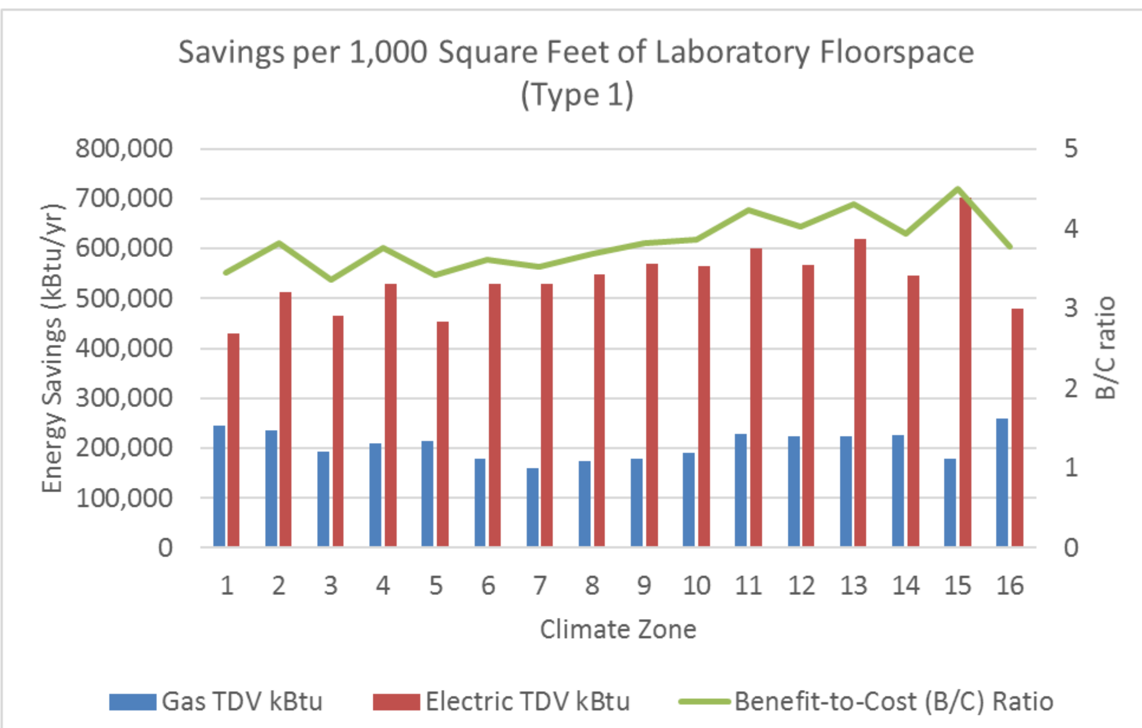

Figure 1: TDV energy savings per prototype laboratory (type 1)

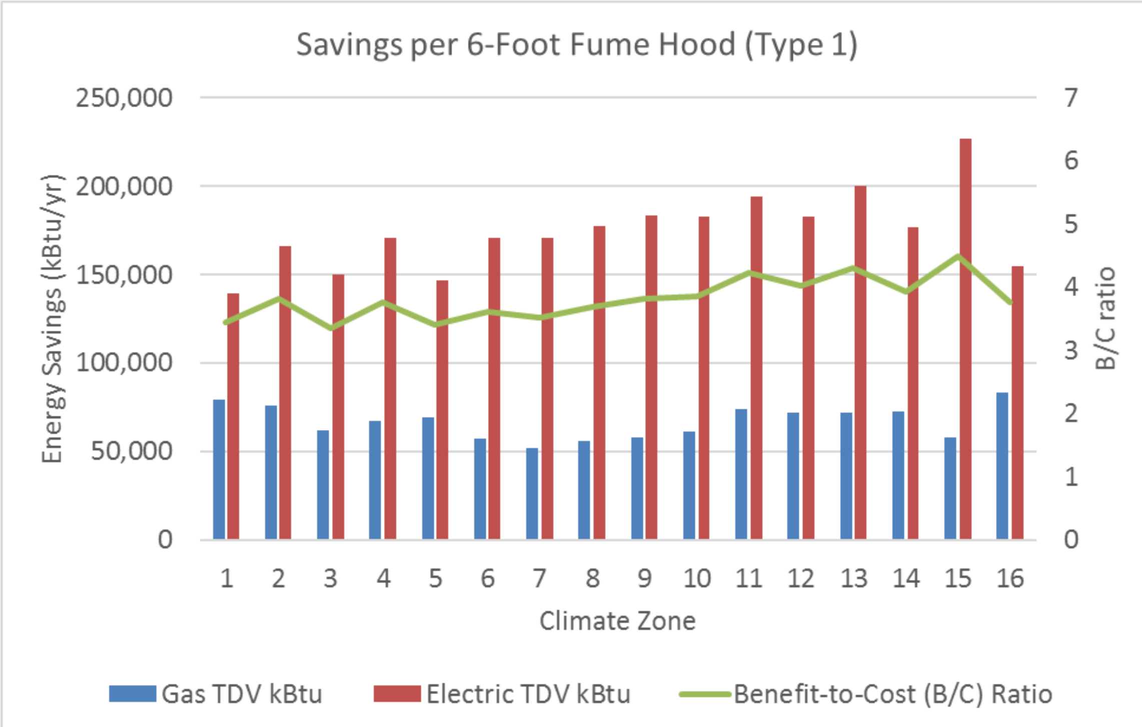

Figure 2: TDV energy savings per fume hood in lab type 1

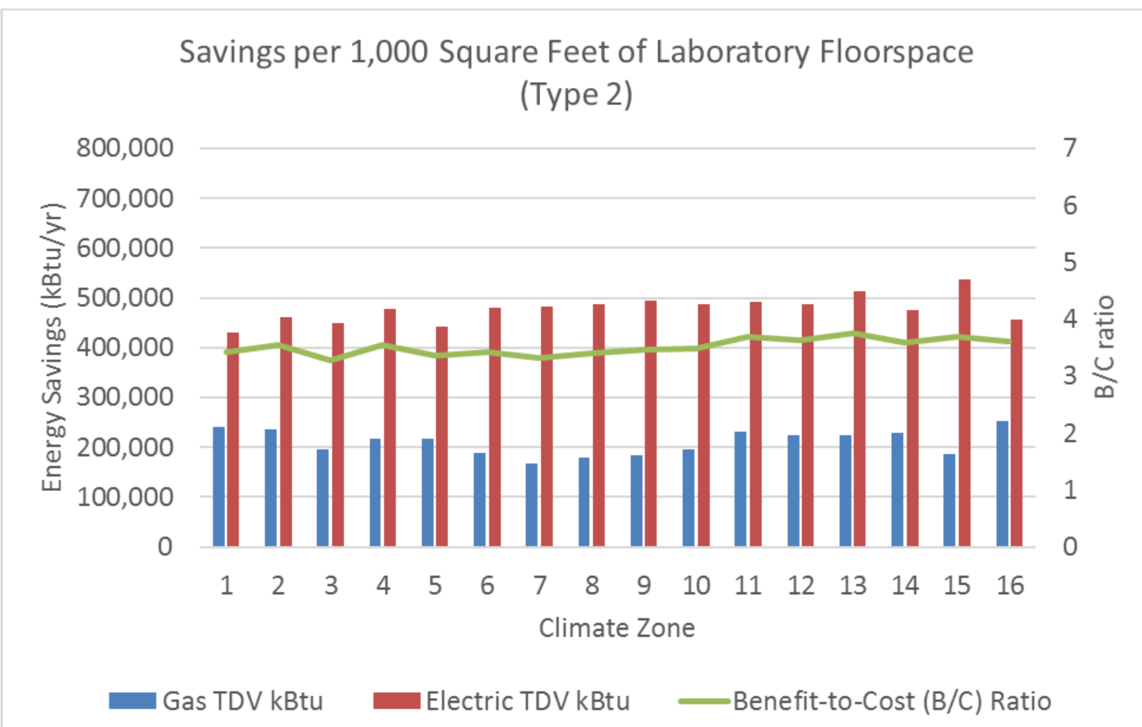

Figure 3: TDV energy savings per prototype laboratory (type 2)

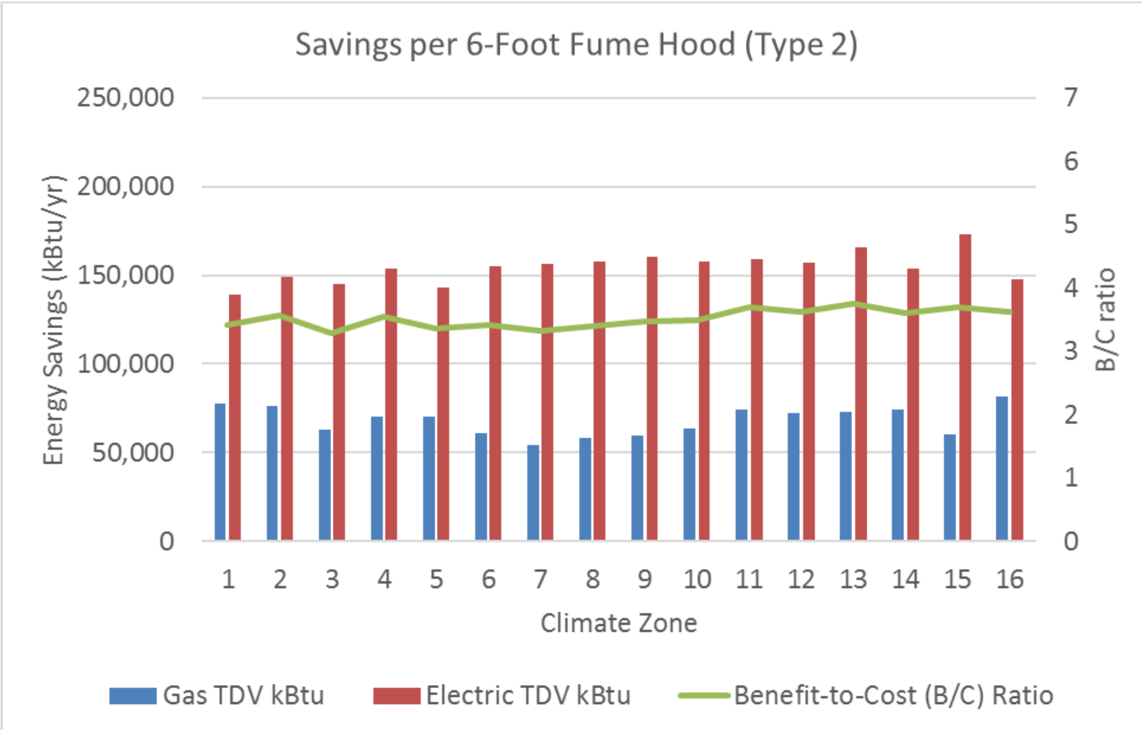

Figure 4: TDV energy savings per fume hood in lab type 2

For the purposes of the CASE Report, the results from lab types 1 and 2 were combined into single estimates for per-unit and statewide savings figures and are presented thusly. No information on market breakdowns of each type in statewide laboratories was available.

As previously noted, since laboratory design and usage is highly variable, care must be taken to define what parameters determine a fume hood intensive lab which ensures in measure cost-effectiveness. Assuming a certain average sash position, the dominance of fume hood exhaust on HVAC energy consumption depends on several parameters, such as ceiling height, minimum ventilation setpoint, and fume hood density. A sensitivity analysis of the building parameters was performed to explore influence on energy savings and cost-effectiveness as detailed in Appendix C. Using a set of modeling runs, the exemption summarized in Table 6 were developed based on cost-effectiveness of the measure which was consistent across climate zones near the cost-effectiveness threshold. Covered laboratory fume hood intensive spaces are presented in Table 7.

Table 6: Exempt Laboratory Spaces

Occupied Minimum ACH	4	6	8	10	12	14
Exempt fume hood density (nominal linear feet per 10,000 cubic feet of lab space)	<6	<8	<10	<12	<14	<16

Table 7: Covered Laboratory Fume Hood Intensive Spaces

Occupied Minimum ACH	4	6	8	10	12	14
Exempt fume hood density (nominal linear feet per 10,000 cubic feet of lab space)	≥6	≥8	≥10	≥12	≥14	≥16

4.3 Per-Unit Energy Impacts Results

Using a per-hood basis requires an assumption of the average fume hood size, which could reasonably be a six-foot hood (Evan Mills 2006). Fume hood workspace is defined as the internal area from the sash to the back wall and is equivalent to about 10.7 square feet of work area for a six-foot hood. Thus, the presented results are analogous to energy savings on a per 10.7 square feet of hood work area basis. Similarly, energy savings could be thought of on a per six linear feet of nominal hood length basis. Savings are also presented per 1,000 ft^2 of lab area and per 10,000 ft^3 of lab space in Appendix C, using the prototype lab fume hood density. Note that energy savings are presented for cost-effective fume hood intensive laboratories only. Labs that are not predominantly fume hood driven will realize less energy savings and are not included based on the code requirement language and cost-effectiveness thresholds determined by modeling.

The California Public Utilities Commission's (CPUC) Database for Energy Efficiency Resources (DEER) defines peak demand as the average grid level impact for a measure between 2:00 p.m. and 5:00 p.m. during the three consecutive weekday periods containing the weekday temperature with the hottest temperature of the year. The DEER Peak periods are defined by individual climate zones. Demand reductions were calculated for DEER on-peak hours. The demand reduction is comprised of both reduced fan power and electrical load for cooling. While fan demand reduction is largely weather-independent, cooling power demand reduction will vary with weather.

In some isolated instances, fume hood sashes have been included in pilot demand response (DR) projects, which relied on manual closing upon notice. Since the sash closure controls will ensure that the hoods use the minimum amount of energy at the required safety code face velocity, there is no DR potential in relation to the technology or at the sashes after measure installation.

Energy savings and peak demand reductions per hood for new construction and alterations are shown in Table 8. Energy savings per six-foot hood for the first year range between 5,000 and 6,720 kWh/year and between 293 and 440 therms/year depending upon climate zone. On-peak demand reductions range between 0.65 kW and 1.18 kW per hood depending on climate zone. Note that for the discussion of the CASE Report, results for the Type 1 and Type 2 prototype lab system types were averaged since each has significant market share and the savings were similar.

Per-unit results for alterations were determined to be the same as new construction since existing VAV labs can and should operate with all the same prototype building conditions as new construction. Even if some existing labs may operate with higher minimum ventilation ACH setpoints, VAV systems should be capable of reducing to minimums of four to six ACH and recent trends suggest that this is happening in the field. This would increase the cost-effectiveness of the proposed measure. Alterations consisting of new hood installations or replacements should therefore operate under the same conditions as assumed for new construction.

Table 8: First-Year Energy Impacts per Fume Hood (Six-Foot Equivalent) – New Construction and Alterations

Climate Zone	Electricity Savings (kWh/year)	Peak Electricity Demand Reduction (kW)	Natural Gas Savings (therms/year)	TDV Energy Savings (TDV kBtu/year)
1	5,002.0	0.65	429.8	217,703.1
2	5,386.9	0.99	415.6	233,627.3
3	5,193.8	0.85	341.0	210,221.7
4	5,480.8	0.99	376.3	231,476.4
5	5,171.5	0.75	380.8	214,465.6
6	5,677.9	0.94	325.6	222,357.3
7	5,679.8	0.91	293.0	216,539.8
8	5,791.2	0.92	314.5	224,547.4
9	5,754.3	1.18	321.3	230,496.0
10	5,790.2	1.09	341.5	232,623.3
11	5,870.9	1.03	403.8	250,900.4
12	5,635.3	1.00	392.2	242,293.6
13	5,939.9	1.01	393.3	255,242.7
14	5,653.3	0.92	394.8	238,550.1
15	6,722.0	1.16	327.7	259,205.5
16	5,298.1	0.79	439.6	233,786.7

5. Lifecycle Cost and Cost-Effectiveness

5.1 Energy Cost Savings Methodology

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

5.2 Energy Cost Savings Results

Per-unit energy cost savings over the 15-year period of analysis are presented in Table 9 for new construction and alterations. It is estimated that the first-year TDV energy savings is between 210,221.7 and 259,205.5 TDV kBtu per hood depending on climate zone. The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. Depending on climate zone, electric TDV savings during on-peak periods account for ten to twenty-five percent of the total electric TDV savings.

Table 9: TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Fume Hood (Six-foot Equivalent) – New Construction and Alterations

Climate Zone	15-Year TDV Electricity Cost Savings (2020 PV $)	15-Year TDV Natural Gas Cost Savings (2020 PV $)	Total 15-Year TDV Energy Cost Savings (2020 PV $)
1	$12,374	$7,002	$19,376
2	$14,022	$6,770	$20,793
3	$13,138	$5,572	$18,710
4	$14,464	$6,138	$20,601
5	$12,885	$6,202	$19,087
6	$14,504	$5,286	$19,790
7	$14,559	$4,713	$19,272
8	$14,905	$5,080	$19,985
9	$15,300	$5,215	$20,514
10	$15,140	$5,564	$20,703
11	$15,727	$6,603	$22,330
12	$15,145	$6,419	$21,564
13	$16,283	$6,433	$22,717
14	$14,686	$6,545	$21,231
15	$17,812	$5,258	$23,069
16	$13,467	$7,340	$20,807

5.3 Incremental First Cost

The Statewide CASE Team estimated the current incremental construction costs, which represents the incremental cost of the measure if a building meeting the proposed standard were built today, using feedback from manufacturers, distributors, and stakeholder feedback. Per Energy Commission direction, design costs are not included in the incremental first cost.

The Statewide CASE Team contacted stakeholders including fume hood end-users and controls manufacturers dealing specifically with automatic sash closing systems. Stakeholders were solicited for input regarding the market average current incremental construction costs associated with implementing this measure as well as potential maintenance costs. See Appendix D for a list of the targeted outreach questions. The average incremental installed first cost was determined to be $3,250, with a maximum and minimum cost of $3,500 and $3,000, respectively. Only costs obtained from manufacturers that offer new fume hoods with automatic sash closure systems as an option were used in establishing this value. Costs obtained from fume hood controls integrators that offer aftermarket sash closure systems were not averaged into the first incremental cost as the proposed measure is primarily focused on new construction applications.

Additional costs may be incurred depending on the type of system and level of controls integration the customer requires. Some sash positioners can integrate into building automation systems (BAS) to provide feedback and remote control to facility managers. Specific costs will vary and data logging integration is not required for the measure to be effective. Testing of the BAS integration is not required as part of the acceptance testing process although proper VAV commissioning should couple airflow controls to sash positions regardless of the proposed measure.

The incremental construction cost may see a minor reduction due to the new standard. Cost decreases could result from new competitors entering market since barriers for entering market are minimal. However, it is unlikely that manufacturers will increase production substantially due to the small market size. Therefore, manufacturing costs are not expected to decrease significantly. Labor costs associated with the measure installation will not decrease based on increased production.

5.4 Lifetime Incremental Maintenance Costs

Incremental maintenance cost is the incremental cost of replacing the equipment or parts of the equipment as well as periodic maintenance required to keep the equipment operating as designed. The present value of equipment and maintenance costs was calculated using a three percent real inflation adjusted discount rate (d), which is consistent with the discount rate used when developing the 2019 TDV factors. The present value of maintenance costs that occurs in the n^{th} year is calculated as follows:

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

The Statewide CASE Team solicited maintenance costs as part of the interviews conducted with the stakeholders and determined the average lifetime replacement parts cost to be $200. The EUL of the measure was determined to be 15 years. Annual functional testing, tuning, and lubrication of the pulley system was cited as a common maintenance procedure with associated labor costs. Failure of the sash sensors was cited as the most common replacement item with an associated cost of $100 with an average of 2 replacements per lifetime.

There is a net increase in the maintenance costs, relative to existing conditions. Annual functional testing, tuning, and lubrication costs are expected to cost one hour of routine maintenance that should be performed for fume hoods each year. This was estimated from stakeholder input on maintenance requirements with estimates that varied from zero hours to three hours per year with an average of 1 hour per year. Additionally, replacement of common failure items is expected to be $100 in materials every six years along with three additional hours of labor. Most stakeholders said that maintenance and repairs were primarily handled by internal labor but was outsourced on occasion if issues exceeded their capacities. Internal labor was estimated at the average cost of $106.29 per hour starting in 2020 for one hour per year of regular maintenance plus 3 hours for each replacement sensor (Gordian n.d.).

Thus, the recurring maintenance and repair costs are:

- Annual functional testing and lubrication: 1 hour x $106.29/h r = $106.29
- Two replacements of motion sensor: $100 + 3 hours x $106.29/hr = $418.87
- Total 2020PV lifetime costs = $2,385.89

Using this method, the total lifetime incremental maintenance costs are estimated to be $2,385.89 2020PV.

Energy and cost savings associated with the measure should persist for the life of the measure and performance verification of the fume hoods is not required if the automatic closers are functional. However, ongoing commissioning and maintenance of VAV systems is necessary for proper function and savings attributable to the sash closure controls. This ongoing commissioning and maintenance of VAV system components and controls should be performed regardless of the proposed measure and would be included in any LVMP as recommended by ANSI/AIHA Z9.5.

5.5 Lifecycle Cost-Effectiveness

This measure proposes a prescriptive requirement and a lifecycle cost analysis is required to demonstrate that the measure is cost-effective over the 15-year period of analysis. The Energy Commission establishes the procedures for calculating lifecycle cost-effectiveness. The Statewide CASE Team collaborated with Energy Commission staff to confirm that the methodology described in this report is consistent with their guidelines, including which costs were included in the analysis. In this case, incremental first cost and incremental maintenance costs over the 15-year period of analysis were included. The TDV energy cost savings from electricity and natural gas savings were also included in the evaluation. It should be noted that design costs, incremental costs of code compliance verification, and O&M costs associated with fume hood and VAV systems were not included (outside of sash control costs).

According to Energy Commission definitions, a measure is cost-effective if the benefit-to-cost (B/C) ratio is greater than 1.0. The B/C ratio is calculated by dividing the total present lifecycle cost benefits by the present value of the total incremental costs. Results of the per-unit lifecycle cost-effectiveness analyses are presented in Table 10 for new construction and alterations.

The proposed measure was found to reduce energy costs over the 15-year period of analysis, relative to existing conditions. After exclusion of labs that are not predominantly fume hood driven, the proposed code change is cost-effective in every climate zone, exceeding the required B/C ratio of 1.0. This cost-effectiveness ratio was calculated for the typical prototype conditions although the exemption table includes lab conditions with B/C ratios below those presented in Table 10. Within the fume hood intensive laboratory space defined by Table 7, some labs will have varying B/C ratios across climate zones, fume hood density, and ACH setpoints, but will still be well above 1.0 given the lab conditions in Table 5. The cost-effectiveness is identical for both new construction and alterations as cost and savings are similar for both scenarios.

Table 10: Lifecycle Cost-effectiveness Summary Per Fume Hood (Six-foot Equivalent) – New Construction and Alterations

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2020 PV $)	Costs Total Incremental PV Costs[b] (2020 PV $)	Benefit-to-Cost Ratio
1	$19,376	$5,636	3.4
2	$20,793	$5,636	3.7
3	$18,710	$5,636	3.3
4	$20,601	$5,636	3.7
5	$19,087	$5,636	3.4
6	$19,790	$5,636	3.5
7	$19,272	$5,636	3.4
8	$19,985	$5,636	3.5
9	$20,514	$5,636	3.6
10	$20,703	$5,636	3.7
11	$22,330	$5,636	4.0
12	$21,564	$5,636	3.8
13	$22,717	$5,636	4.0
14	$21,231	$5,636	3.8
15	$23,069	$5,636	4.1
16	$20,807	$5,636	3.7

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis ((Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first cost savings if proposed first cost is less than current first cost. Includes present value maintenance cost savings if PV of proposed maintenance costs is less than the PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement and maintenance costs over the period of analysis. Costs are discounted at a real (inflation adjusted) three percent rate. Includes incremental first cost if proposed first cost is greater than current first cost. Includes present value of maintenance incremental cost if PV of proposed maintenance costs is greater than the PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

6. FIRST-YEAR STATEWIDE IMPACTS

6.1 Statewide Energy Savings and Lifecycle Energy Cost Savings

There are approximately 60,000-111,000 fume hoods in California, about 50 percent of which are in VAV laboratories (Mills and Sartor 2006, CEEL 2015). As shown in Table 6 and Table 7, the average fume hood density threshold for cost-effectiveness is about two percent of lab floor space (corresponding to about 11 linear feet of hood length per 1,000 square feet of lab space).

As detailed in Appendix A, survey data collected for a recent California laboratory study (CEEL 2015), showed that approximately 13.8 percent of statewide laboratory floor space meets this cost-effective fume hood density threshold such that code requirements would be triggered. The CEEL survey data suggested that these covered labs have an average fume hood density of about 3.3 percent (corresponding to about 18 linear feet of hood length per 1,000 square feet of lab space).

From manufacturer estimates the typical lifespan of a fume hood is about 15 years. As a result, one out of fifteen hoods or 6.7 percent the existing hood population is replaced each year. Additionally, fume hood providers estimate that vertical or combination sash hoods comprise about 95 percent of the market. On a statewide basis, this means about 1,865 fume hoods for additions and alterations replaced each year covering about 602,436 square feet of lab space. See Appendix A for more details on the market size estimations.

For the covered building types in I and L occupancies the new construction, there are roughly 1,247 new vertical sash fume hoods installed per year in fume hood intensive laboratories across 402,778 square feet of floor space. Combining the annual statewide additions, alterations, and new construction, about 3,112 new vertical sash VAV fume hoods would be installed in fume hood intensive laboratories in California each year across 1,005,212 square feet of floor space.

Approximately seven percent of the qualifying fume hoods are in hospital occupancies. If the fume hood measure is not applied to hospitals the statewide savings would decrease proportionately. The percentage of hospital contributions to the measure savings is small but should be acknowledged since that occupancy type may not be covered by Title 24, Part 6 requirements. The impact of hospital occupancies on the statewide estimates for the measure is relatively small but should be considered during decision making on future code coverage of hospital institutions. For more details of this calculation and market analysis, see Appendix A.

The Statewide CASE Team calculated the first-year statewide energy savings by multiplying the per-unit energy savings, which are presented in Section 4.3, by the statewide new construction forecast for 2020 or expected alterations in 2020, which is presented in more detail in Appendix A. The first-year energy impacts represent the first-year annual energy savings from all buildings that will be completed in 2020. The lifecycle energy cost savings represents the energy cost savings over the entire 15-year analysis period for those installations. Results are presented in Table 11 and Table 12 for new construction and alterations, respectively. The statewide savings estimates do not take naturally-occurring market adoption or compliance rates into account.

Using available data for new construction forecasts and expected alterations in 2020, the Statewide CASE Team estimates that the proposed code change will reduce annual statewide electricity use by 17.55 GWh, with an associated demand reduction of 3.06 MW. Natural gas use is expected to be reduced by 1.08 million therms. The energy savings for fume hoods installed in new construction and in alterations in 2020 are associated with a present valued energy cost savings of approximately 2020 PV $63 million in discounted energy costs over the 15-year period of analysis.

Table 11: Statewide Energy and Energy Cost Impacts – New Construction

Climate Zone	Statewide New Construction in 2020 (fume hood intensive lab square feet)	First-Year[a] Electricity Savings (GWh)	First-Year[a] Peak Electrical Demand Reduction (MW)	First-Year[a] Natural Gas Savings (million therms)	Lifecycle[b] Present Valued Energy Cost Savings (PV$ million)
1	1,609	0.0	0.00	0.00	$0.10
2	10,511	0.2	0.03	0.01	$0.68
3	50,626	0.8	0.13	0.05	$2.93
4	23,666	0.4	0.07	0.03	$1.51
5	4,595	0.1	0.01	0.01	$0.27
6	34,582	0.6	0.10	0.03	$2.12
7	28,774	0.5	0.08	0.03	$1.72
8	49,526	0.9	0.14	0.05	$3.06
9	60,226	1.1	0.22	0.06	$3.82
10	34,533	0.6	0.12	0.04	$2.21
11	8,829	0.2	0.03	0.01	$0.61
12	53,364	0.9	0.17	0.06	$3.56
13	18,320	0.3	0.06	0.02	$1.29
14	6,503	0.1	0.02	0.01	$0.43
15	5,765	0.1	0.02	0.01	$0.41
16	11,347	0.2	0.03	0.02	$0.73
TOTAL	**402,777**	**7.0**	**1.23**	**0.43**	**$25.44**

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

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

Table 12: Statewide Energy and Energy Cost Impacts – Alterations

Climate Zone	Statewide Construction in 2020 (fume hood intensive lab square feet)	First-Year[a] Electricity Savings (GWh)	First-Year[a] Peak Electrical Demand Reduction (MW)	First-Year[a] Natural Gas Savings (million therms)	Lifecycle[b] Present Valued Energy Cost Savings (PV$ million)
1	2,491	0.0	0.01	0.00	$0.15
2	15,824	0.3	0.05	0.02	$1.02
3	68,727	1.1	0.18	0.07	$3.98
4	36,542	0.6	0.11	0.04	$2.33
5	7,095	0.1	0.02	0.01	$0.42
6	56,783	1.0	0.16	0.06	$3.48
7	43,528	0.8	0.12	0.04	$2.60
8	80,068	1.4	0.23	0.08	$4.95
9	86,459	1.5	0.32	0.09	$5.49
10	54,660	1.0	0.18	0.06	$3.50
11	13,193	0.2	0.04	0.02	$0.91
12	74,890	1.3	0.23	0.09	$5.00
13	27,406	0.5	0.09	0.03	$1.93
14	10,066	0.2	0.03	0.01	$0.66
15	8,447	0.2	0.03	0.01	$0.60
16	16,256	0.3	0.04	0.02	$1.05
TOTAL	**602,436**	**10.5**	**1.83**	**0.65**	**$38.05**

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

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

6.2 Statewide Water Use Impacts

The Statewide CASE Team investigated the potential water savings associated with evaporation losses due to reduction in heat rejection. These evaporative losses occur at end-user central plants and at thermoelectric power generation facilities supplying the electrical grid. For example, the proposed measure could result in water savings associated with decreased loads on cooling towers at customer sites. However, water savings at customer sites will be far less than power plant savings as the majority of electrical savings associated with the measure occur on the airside of the HVAC system rather than the water side. Thus, water savings are largely attributable to evaporation reductions at power generation stations.

The California Energy Almanac reported that statewide energy consumption came from the sources listed in Table 13 (CEC 2015). Additionally, factors for water consumption by generation source by state have been reported by NREL (Torcellini, Long and Judkoff 2003).

Table 13: Statewide Electricity Consumption Sources and Water Consumption Factor

Electricity Generation Source	Total 2015 Consumption (GWh)	Percent of Total Consumption	Generation Station Water Use (gall/kWh)
Hydroelectric	13,993	5%	20.87
Thermoelectric	157,422	53%	0.05
Wind	12,180	4%	n/a
Solar PV	12,600	4%	n/a
Out-of-state Imports	99,211	34%	0.47

Combining these figures suggests that the average in-state power plant water consumption is roughly 1.53 gallons per kWh for the 66 percent of electrical energy consumption that comes from in-state sources. Thus, the statewide electrical energy savings presented in Table 11 and Table 12 would result in an estimated 17,816,000 gallons of avoided water usage per year. Additionally, reductions in imported energy would save an additional 2,770,000 gallons of water in neighboring states.

This water savings estimate assumes that energy savings from the measure would be evenly distributed across the electrical energy supply stream, thus having savings distribution consistent with the distribution of grid energy supplies. While this is likely not completely true, it is a necessary assumption for a water savings estimate given the available information. Additionally, the water factor used per kWh reported by NREL is from 2003 but no more recent, equivalent factors were found in the literature.

6.3 Statewide Material Impacts

The proposed measure is not expected to have any impacts on material use.

6.4 Other Non-Energy Impacts

The main non-energy benefit of the measure is increased user safety. Closing the fume hood sash provides increased safety by improving the capture of any chemicals being stored in the fume hood. All safety standards state that sashes shall be kept closed to the maximum extent allowed by working conditions including OSHA, ANSI/AIHA Z9.5, and NFPA 45. The proposed measure will help maintain those recommended safety guidelines through automatic closure when the hood is not in use.

7. PROPOSED REVISIONS TO CODE LANGUAGE

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

7.1 Standards

SECTION 140.9 – PRESCRIPTIVE REQUIREMENTS FOR COVERED PROCESSES

(c) Prescriptive Requirements for Laboratory ~~exhaust systems~~ Exhaust Systems and Fume Hoods.

1. Laboratory Variable Exhaust and Makeup Air. For buildings with laboratory exhaust systems where the minimum circulation rate to comply with code or accreditation standards is 10 ACH or less, the design exhaust airflow shall be capable of reducing zone exhaust and makeup airflow rates to the regulated minimum circulation rate, or the minimum required to maintain pressurization requirements, whichever is larger. Variable exhaust and makeup airflow shall be coordinated to achieve the required space pressurization at varied levels of demand and fan system capacity.

EXCEPTION 1 to Section 140.9(c)1: Laboratory exhaust systems serving zones where constant volume is required by the Authority Having Jurisdiction, facility Environmental Health & Safety department or other applicable code.

EXCEPTION 2 to Section 140.9(c)1: New zones on an existing constant volume exhaust system.

2. Fume Hood Automatic Sash Closure. Variable air volume laboratory fume hoods with vertical sashes shall have an automatic sash closure system that complies with the following:

A. Has a dedicated zone presence sensor that detects people in the area near the fume hood sash and automatically closes the sash within 5 minutes of no detection if the sash is not blocked by obstructions.

B. Sash closing mechanism is overridden by a force on the sash of no more than 10 lbs.

C. Sash has an obstruction sensor that prevents the sash from automatic closing with obstructions in the sash opening. Obstruction sensor shall be capable of sensing transparent materials such laboratory glassware.

EXCEPTION to Section 140.9(c)2: Enclosed spaces determined to be exempt per TABLE 140.9-B.

TABLE 140.9-B FUME HOOD DENSITY TABLE FOR EXCEPTION to SECTION 140.9(c)2

Occupied Minimum Ventilation ACH	≤4	>4 and ≤6	>6 and ≤ 8	>8 and ≤10	>10 and ≤12	>12 and ≤14
Exempt hood density (linear feet per 10,000 ft^3 of space)	≤6	≤8	≤10	≤12	≤14	≤16

3. **Fume Hood Automatic Sash Closure Acceptance**. Before an occupancy permit is granted for fume hoods subject to 140.9(c)2, the equipment and systems shall be certified as meeting the Acceptance Requirement for Code Compliance as specified by the Reference Nonresidential Appendix NA7. A Certificate of Acceptance shall be submitted to the enforcement agency that certifies that the equipment and systems meet the acceptance requirements specified in NA7.16.

7.2 Reference Appendices

Joint Appendix JA1

Appendix JA1 – Glossary

SASH ZONE PRESENCE SENSOR is an occupancy sensor that detects people in the area near the fume hood sash for automatic closure controls.

FUME HOOD SASH OBSTRUCTION SENSOR detects obstructions in the sash opening and prevents automatic closing when obstructions are present.

Nonresidential Appendix 7

NA7.16 – Fume Hood Automatic Sash Closure System Controls

NA7.16.1 General Requirements

In accordance with §120.6, §110.9(b)4 and Title 24, Part 8 §5154.1. These requirements cannot supersede ANSI/AIHA Z9.5-2003-3.1.1.4, OSHA or other safety requirements. If equipped, verify that all indicators and annunciators are working per the manufactures instructions.

NA7.16.1 Construction Inspection

Verify and document the following prior to functional testing:

(a) The fume hood sash zone presence sensor has a valid factory calibration certificate.
(b) Each fume hood sash obstruction sensor has a valid factory calibration certificate.
(c) Presence sensor has been located and adjusted to minimize false signals.
(d) Presence sensor pattern does not enter adjacent zones.
(e) Sash obstruction sensor has been installed per manufacturer instructions.
(f) Presence sensor has been installed per manufacturer instructions.

NA7.16.2 Functional Testing

For projects with up to five fume hoods with automatic sash closing controls, all fume hoods shall be tested. For projects with more than five fume hoods with automatic sash closing controls, sampling may be done with similar sensors and fume hoods beyond the first five. Sampling shall include a minimum of one fume hood for each group of up to five additional fume hoods. If the first fume hood in the sample group passes the acceptance test, the remaining building spaces in the sample group also pass. If the first fume hood in the sample group fails the acceptance test, the rest of the fume hoods in that group must be tested. If any tested fume hood fails it shall be repaired, replaced, or adjusted until it passes.

For each sash closure control system to be tested perform the following:

(a) Simulate an unoccupied condition. Verify and document the following:
    a. Sash controlled by the presence sensor closes within a maximum of five minutes from the start of an unoccupied condition.
    b. The presence sensor does not trigger a false ON from movement in an area adjacent to the space containing the controlled sash.
    c. Signal sensitivity is adequate to achieve desired control.
    d. Sash closes to the minimum position.

(b) Confirm that the sash obstruction sensor correctly acknowledges when:
    a. An obstruction is detected between the sensor transmitter and receiver.

b. While the sash is closing, trigger the sash obstruction sensor by inserted an obstruction into the sash opening. Verify the sash stops immediately when the light curtain sensor is activated.
c. Ensure that the sash returns to its original condition or once the reset has been activated.

(c) Confirm that the manual controls are operational. Set the sash to the middle of the sash opening position. Verify and document the following:

Open Test

a. Press the button that opens the sash and ensure the sash opens to the appropriate maximum height.
b. If equipped, while the sash is opening, trigger the stop button, verify the sash stops immediately when the stop button is activated.
c. Ensure that the sash returns to its original condition once the reset has been activated.

Closed Test

a. Press the button that closes the sash and ensure the sash closes to the appropriate minimum height.
b. If equipped, while the sash is closing, trigger the stop button, verify the sash stops immediately when the stop button is activated.
c. Ensure that the sash returns to its original condition once the reset has been activated.

(d) Confirm that the sash object detection controls are operational. Set the sash to the maximum height. Place a transparent object (such as a clear plastic flask) in the pathway of the sash. Verify and document the following:

a. Verify that the sash operates per the manufactures instructions.
b. Verify the sash stops before contacting the transparent object.
c. Ensure that the sash returns to its original condition automatically or once the reset has been activated.

7.3 ACM Reference Manual

Modifications will be required to the ACM Reference Manual, including potential reference to the new NRCA document. Currently the ACM Reference Manual does not explicitly describe how fume hood ventilation is treated in compliance calculations. However, CBECC-Com does have a designation for minimum laboratory ventilation setpoints and a fume hood usage schedule. Collaboration and discussion with compliance software developers and the ACM Reference Manual authors will be needed to clarify how fume hood intensive laboratories are modeled and what modifications are necessary to properly handle the proposed measure.

To model the prescriptive code measure and alternatives, compliance software will need to calculate laboratory airflow requirements on an hourly basis with and without sash closure controls installed. At a minimum, this will require an adjustment to the fume hood usage schedule. Current fume hood usage schedules are shown in Figure 5. These will have to be modified to account for the expected sash position schedules with and without the proposed measure. If behavioral sash management practices are to be modeled, a third schedule (hard coded or custom user input) could be a potential option but there would likely be no way to confirm the schedule in many cases especially before construction.

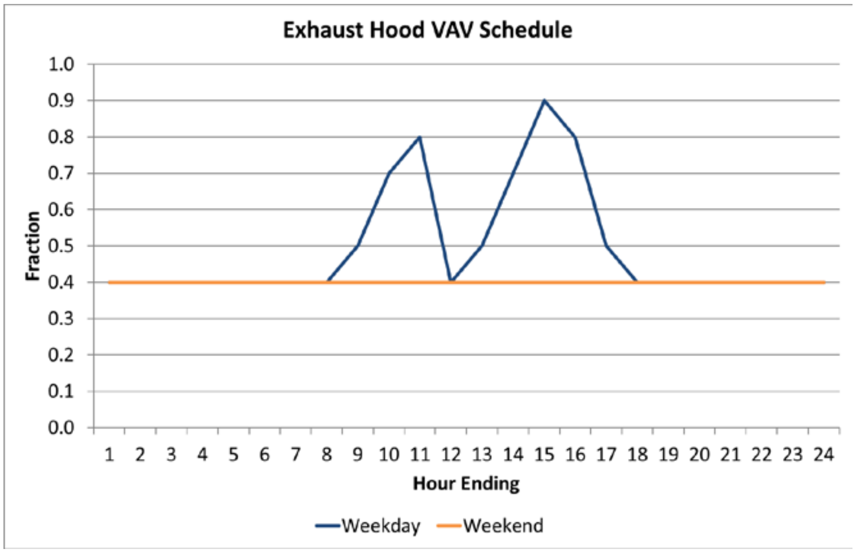

Figure 5: Current CBECC-Com lab hood exhaust schedule

Alternative methods of achieving savings through fume hood efficiency include low-flow, high-performance hoods, and face velocity reductions. Beyond measures controlled at the fume hoods themselves, laboratory HVAC energy efficiency can be improved through the exhaust and supply air heat exchange (such as a runaround loop), static pressure reduction, ventilation ACH reductions or setbacks, and typical HVAC control measures such as SAT reset and setpoint setbacks with scheduling. Although these may not necessarily be alternatives to fume hood sash controls, they are interactive with the proposed measure and thus energy savings from these measures may overlap with those achieved through sash controls. Since the proposed measure is prescriptive, these measures or others unrelated to fume hood and laboratory air controls would be potential trade-off measures integrated into compliance modeling.

7.4 Compliance Manuals

Chapters 10 and 13 of the 2016 Nonresidential Compliance Manual will need to be revised.

7.5 Compliance Document

Document NRCA-PRC-14-F Fume Hood Automatic Sash Closure System Acceptance will need to be added to the compliance documents in Appendix A of the 2016 Nonresidential Compliance Manual. This new document certifies that the automatic sash closure equipment and systems meet the acceptance requirements specified in NA7.16. Certificate of Compliance documents NRCC-PRC-01-E and NRCC-PRC-09-E in Appendix A will need to be modified to reflect the new measure requirements. These forms certify that the system design plans comply with the Energy Standards. NRCC-PRF-01-E and NRCI-PRF-01-E will need to be modified to account for the proposed measure if the performance path is selected over the prescriptive path.

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Appendix A: STATEWIDE SAVINGS METHODOLOGY

The projected nonresidential new construction forecast that will be impacted by the proposed code change in 2020 is presented in Table 19. The projected nonresidential existing statewide building stock that will be impacted by the propose code change as a result of additions and alterations in 2020 is presented in Table 20.

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

1. Translated data from FCZ data into building climate zones (BCZ). This was completed using the FCZ to BCZ conversion factors provided by the Energy Commission (see). Translated data from FCZ data into building standards climate zones (BSCZ). Since Title 24, Part 6 uses BSCZ, the Statewide CASE Team converted the construction forecast from FCZ to BSCZ using conversion factors supplied by the Energy Commission. The conversion factors, which are presented in Table 21 represent the percentage of building square footage in FCZ that is also in BSCZ. For example, looking at the first column of conversion factors in Table 21, 22.5 percent of the building square footage in FCZ 1 is also in BSCZ 1 and 0.1 percent of building square footage in FCZ 4 is in BSCZ 1. To convert from FCZ to BSCZ, the total forecasted construction for a specific building type in each FCZ was multiplied by the conversion factors for BSCZ 1, then all square footage from all FCZs that are found to be in BSCZ 1 are summed to arrive at the total construction for that building type in BSCZ 1. This process was repeated for every climate zone and every building type. See Table 23 for an example calculation to convert from FCZ to BSCZ. In this example, construction BSCZ 1 is made up of building floorspace from FCZs 1, 4, and 14.
2. Redistributed square footage allocated to the "Miscellaneous" building type. The building types included in the Energy Commissions' forecast are summarized in Table 22. The Energy Commission's forecast allocated 18.5 percent of the total square footage from nonresidential new construction in 2020 and the nonresidential existing building stock in 2020 to the miscellaneous building type, which is a category for all space types that do not fit well into another building category. It is likely that the Title 24, Part 6 requirements apply to the miscellaneous building types, and energy savings will be realized from this floor space. The new construction forecast does not provide sufficient information to distribute the miscellaneous square footage into the most likely building type, so the Statewide CASE Team redistributed the miscellaneous square footage into the remaining building types in such a way that the percentage of building floor space in each climate zone, net of the miscellaneous square footage, will remain constant. See Table 24 for an example calculation.
3. Made assumptions about the percentage of nonresidential new construction in 2020 that will be impacted by proposed code change by building type and climate zone. The Statewide CASE Team's assumptions are presented in Table 25 and Table 26 and discussed further below.
4. Made assumptions about the percentage of the total nonresidential building stock in 2020 that will be impacted by the proposed code change (additions and alterations) by building type and

climate zone. The Statewide CASE Team's assumptions are presented in Table 25 and Table 26 and discussed further below.

5. Calculated nonresidential floor space that will be impacted by the proposed code change in 2020 by building type and climate zone for both new construction and alterations. Results are presented in Table 19 and Table 20.

The percentages of each building type that are dedicated to fume hood intensive lab space were estimated by combined data from the existing building stock and the results of a recent California statewide laboratory survey (CEEL 2015). The data in the report included an estimation of total lab space in California non-profit, hospital, academia, and life science research businesses. Comparing this to the existing building stock enabled an estimation of the percentage of each standard building type that is lab space, as shown in Table 14 and Table 15.

Table 14: Existing Statewide Laboratory Space

Laboratory Type	Existing Laboratory Space, 2015 (Lab area in square feet)	Building Type Analog
Academia Research	24,700,000	College
Academia Teaching	12,600,000	College
Life Sciences Research	68,300,000	½ Small Office and ½ Large Offices
Hospitals	7,700,000	Hospital
Non-profits	3,100,000	25% College, 25% Hospital, 30% Large Office, 20% Small Office

The mapping allows for estimation of the percentage of existing building stock that is lab space.

Table 15: Laboratory Percentage of Statewide Building Stock

Building Type	Existing Statewide Floor Space, 2015 (square feet)	Estimated Laboratory Space, 2015 (square feet)	Laboratory % of Floor Space
College	296,788,100	38,075,000	12.8%
Large Office	1,264,338,700	35,080,000	2.8%
Hospital	365,041,200	8,475,000	2.3%
Small Office	373,665,900	34,770,000	9.3%

The fraction of laboratories that are fume hood intensive was determined by examining the statewide survey data for laboratories with fume hoods. From the CASE analysis and density thresholds in Table 6, labs that have fume hood density greater than 2.0 percent of total lab square footage are considered fume hood intensive. As shown in Figure 6, about 13.8 percent of all lab space with fume hoods exceeds this threshold and is thus covered by the code measure since it is fume hood intensive and cost-effective.

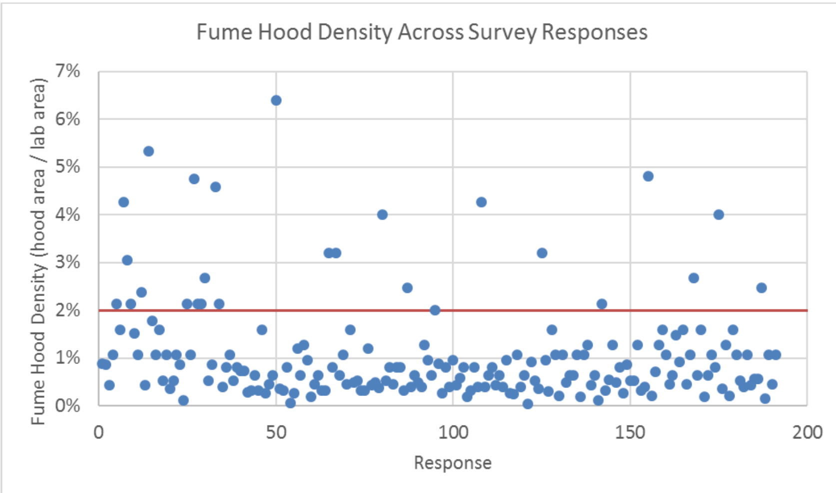

Figure 6: Estimated fume hood density of responses to statewide laboratory survey (CEEL 2015)

Additionally, the survey found about 6.8 percent of laboratories did not have any fume hoods and about 50 percent of existing laboratories were VAV. Finally, fume hood and sash control providers estimated that about five percent of the market comprises horizontal sashes.

Thus, the forecasted percentage of covered new construction fume hood intensive laboratories can be estimated with the factors in Table 16.

Table 16 - New Construction Floor Space Percentage Dedicated to Fume Hood Intensive Laboratories by Building Type

Building Type	Laboratory % of Floor Space	Laboratory Space with Fume Hoods	Fume Hood Intensive Floor Space Factor	Vertical Sash Market Share Factor	Fume Hood Intensive % of New Construction Floor Space
College	12.8%	93.2%	13.8%	95%	1.57%
Large Office	2.8%				0.34%
Hospital	2.3%				0.28%
Small Office	9.3%				1.14%

Applying the same factors and accounting for a fume hood EUL of 15 years, the 2020 building floor space impacted by alterations is shown in Table 17.

Table 17: Existing Fume Hood Intensive Laboratory Floor Space Percentage Impacted by Alterations by Building Type

Building Type	Laboratory % of Floor Space	Vertical Sash Fume Hood Intensive Market Share Factor	VAV Market Share Factor	Annual Fume Hood Replacement Rate (1/EUL)	Fume Hood Intensive Alteration % of Existing Floor Space
College	12.8%	93.2% x 13.8% x 95%	50%	6.7%	0.05%
Large Office	2.8%				0.01%
Hospital	2.3%				0.01%
Small Office	9.3%				0.04%

These factors were used to estimate the annually covered statewide floor space as shown in Table 19 through Table 26. These tables are directly drawn from the approved CASE study new construction and additions and alterations floor space calculator. The total covered floor space per year and associated quantity of fume hoods is summarized in Table 18. Total code coverage is estimated at 478,383 square feet of lab space and 2,603 fume hoods per year (6-foot equivalent). Hospitals account for about seven percent of the impacted annual market and are included for the purposes of this report. If hospital occupancies are not covered by the Title 24, Part 6 measure, then the statewide impacts can be proportionately decreased by seven percent.

Table 18: Estimated Annual Covered Market Size

Building Type	New Construction Annual Floor Space (square feet)	New Construction Annually Covered Fume Hoods	Additions and Alterations Annual Covered Floor Space (square feet)	Additions and Alterations Annual Covered Fume Hoods
College	109,394	298	190,971	520
Large Office	144,019	392	169,500	461
Hospital	25,558	70	48,179	131
Small Office	123,806	337	193,786	527

Table 19: Estimated New Nonresidential Construction Impacted by Proposed Code Change in 2020, by Climate Zone and Building Type (Million Square Feet)

Climate Zone	New Construction in 2020 (Million Square Feet)											
	Small Office	**Restaurant**	**Retail**	**Food**	**Non-Refrigerated Warehouse**	**Refrigerated Warehouse**	**School**	**College**	**Hospital**	**Hotel**	**Large Office**	**TOTAL**
1	0.0007	0	0	0	0	0	0	0.0006	0.0001	0	0.0002	**0.0016091**
2	0.0030	0	0	0	0	0	0	0.0032	0.0007	0	0.0035	**0.0105112**
3	0.0098	0	0	0	0	0	0	0.0143	0.0029	0	0.0236	**0.0506260**
4	0.0067	0	0	0	0	0	0	0.0072	0.0018	0	0.0080	**0.0236663**
5	0.0013	0	0	0	0	0	0	0.0014	0.0003	0	0.0015	**0.0045951**
6	0.0090	0	0	0	0	0	0	0.0090	0.0018	0	0.0148	**0.0345825**
7	0.0120	0	0	0	0	0	0	0.0074	0.0019	0	0.0075	**0.0287736**
8	0.0125	0	0	0	0	0	0	0.0126	0.0027	0	0.0217	**0.0495259**
9	0.0123	0	0	0	0	0	0	0.0148	0.0038	0	0.0293	**0.0602263**
10	0.0141	0	0	0	0	0	0	0.0108	0.0023	0	0.0074	**0.0345334**
11	0.0040	0	0	0	0	0	0	0.0027	0.0007	0	0.0014	**0.0088294**
12	0.0213	0	0	0	0	0	0	0.0133	0.0035	0	0.0153	**0.0533636**
13	0.0086	0	0	0	0	0	0	0.0054	0.0016	0	0.0027	**0.0183200**
14	0.0023	0	0	0	0	0	0	0.0019	0.0005	0	0.0018	**0.0065033**
15	0.0031	0	0	0	0	0	0	0.0014	0.0003	0	0.0009	**0.0057647**
16	0.0032	0	0	0	0	0	0	0.0033	0.0007	0	0.0042	**0.0113466**
TOTAL	**0.1238**	**0**	**0**	**0**	**0**	**0**	**0**	**0.1094**	**0.0256**	**0**	**0.1440**	**0.402777**

Table 20: Estimated Existing Nonresidential Floor Space Impacted by Proposed Code Change in 2020 (Alterations), by Climate Zone and Building Type (Million Square Feet)

Climate Zone	Alterations in 2020 (Million Square Feet)											
	Small Office	Restaurant	Retail	Food	Non-Refrigerated Warehouse	Refrigerated Warehouse	School	College	Hospital	Hotel	Large Office	TOTAL
1	0.0011	0	0	0	0	0	0	0.0009	0.0002	0	0.0003	**0.002218**
2	0.0049	0	0	0	0	0	0	0.0054	0.0013	0	0.0042	**0.014607**
3	0.0155	0	0	0	0	0	0	0.0226	0.0053	0	0.0254	**0.064864**
4	0.0111	0	0	0	0	0	0	0.0124	0.0032	0	0.0099	**0.033774**
5	0.0022	0	0	0	0	0	0	0.0024	0.0006	0	0.0019	**0.006558**
6	0.0154	0	0	0	0	0	0	0.0188	0.0040	0	0.0186	**0.052927**
7	0.0182	0	0	0	0	0	0	0.0120	0.0033	0	0.0101	**0.038986**
8	0.0213	0	0	0	0	0	0	0.0259	0.0059	0	0.0270	**0.074736**
9	0.0193	0	0	0	0	0	0	0.0275	0.0071	0	0.0325	**0.081643**
10	0.0229	0	0	0	0	0	0	0.0178	0.0042	0	0.0097	**0.048944**
11	0.0059	0	0	0	0	0	0	0.0045	0.0013	0	0.0016	**0.011721**
12	0.0300	0	0	0	0	0	0	0.0211	0.0063	0	0.0176	**0.067399**
13	0.0128	0	0	0	0	0	0	0.0091	0.0027	0	0.0028	**0.024208**
14	0.0038	0	0	0	0	0	0	0.0032	0.0008	0	0.0023	**0.009123**
15	0.0048	0	0	0	0	0	0	0.0020	0.0006	0	0.0011	**0.007255**
16	0.0049	0	0	0	0	0	0	0.0054	0.0012	0	0.0047	**0.015026**
TOTAL	**0.1938**	**0**	**0**	**0**	**0**	**0**	**0**	**0.1910**	**0.0482**	**0**	**0.1695**	**0.553989**

Table 21: Translation from Forecast Climate Zone (FCZ) to Building Standards Climate Zone (BSCZ)

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

Table 22: Description of Building Types and Sub-types (Prototypes) in Statewide Construction Forecast

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

Table 23: Converting from Forecast Climate Zone (FCZ) to Building Standards Climate Zone (BSCZ) – Example Calculation

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

Table 24: Example of Redistribution of Miscellaneous Category - 2020 New Construction in Climate Zone 1

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

Table 25: Percent of Floor Space Impacted by Proposed Measure, by Building Type

Building Type *Building sub-type*	**Composition of Building Type by Sub-types**[1]	**Percent of Square Footage Impacted**[2]	
		New Construction	**Existing Building Stock (Alterations)**[3]
Small office		*1.14%*	*0.04%*
Restaurant			
Retail			
Stand-Alone Retail	*10%*		
Large Retail	*75%*		
Strip Mall	*5%*		
Mixed-Use Retail	*10%*		
Food			
Non-refrigerated warehouse			
Refrigerated warehouse			
Schools			
Small School	*60%*		
Large School	*40%*		
College		*1.57%*	*0.05%*
Small Office	*5%*		
Medium Office	*15%*		
Medium Office/Lab	*20%*	*7.85%*	*0.25%*
Public Assembly	*5%*		
Large School	*30%*		
High Rise Apartment	*25%*		
Hospital		*0.28%*	*0.01%*
Hotel/motel			
Large offices		*0.34%*	*0.01%*
Medium Office	*50%*	*0.34%*	*0.01%*
Large Office	*50%*	*0.38%*	*0.01%*

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

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

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

Table 26: Percent of Floor Space Impacted by Proposed Measure, by Climate Zone

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

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

Table 26 defines the percentage of floor space associated with fume hood intensive laboratories in each climate zone that is impacted by the proposed measure. Each value is 100 percent, since the fraction of lab space that is fume hood intensive was already accounted for in Table 25.

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

This section discusses how the recommended compliance process, which is described in Section 2.5, could impact various market actors. Discussions with manufacturers and fume hood installers specifically addressed the current commissioning process used for VAV fume hoods and automatic sash closure systems, allowing the Statewide CASE Team an opportunity to integrate items already addressed in the commissioning process into the proposed acceptance test form. The key results from feedback received during stakeholder meetings and other outreach efforts are detailed below.

Table 27 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.

The proposed compliance process should easily fit into the existing workflow of the key market actors involved. The measure primarily will affect the fume hood manufacturers, installers, and acceptance test technicians (i.e., field technicians), which are typically one and the same. Based on outreach to these market actors, fume hoods currently undergo a commissioning schedule which provides an ideal point to integrate the proposed functional testing requirements that will be required as part of the compliance process.

Additional coordination between parties that do not already communicate is not expected. HVAC design of the laboratories that will be affected by this measure are typically designed for maximum exhaust flow conditions of the fume hoods. This measure should not impact design requirements for exhaust or supply fans.

Document NRCA-PRC-14-F Fume Hood Automatic Sash Closure System Acceptance will need to be added to Appendix A of the 2016 Nonresidential Compliance Manual. No specialized training or equipment is expected to be required since the ATT is already equipped with the necessary skills to evaluate the operation of the proposed measure; however, a modest increase in time may be needed for the ATT to perform the functional testing.

Table 27: 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
Fume Hood Manufacturer/ Controls Installer	• Identify requirements for compliance with proposed measure • Coordinate with commissioning agent/ATT as necessary	• Quickly and easily determine requirements based on scope • Demonstrate compliance with calculations required for other design tasks • Clearly communicate system requirements to constructors	• Will need to ensure fume hood system controls comply with code change	• Create a detailed commissioning process and report to ensure that equipment will meet requirements to be checked by ATT • Investigate opportunities to bring testing in house.
Laboratory HVAC Designer	• Identify relevant requirements • Specify fume hood controls that satisfy code requirements • Provide correction comments if necessary	• Quickly and easily determine requirements based on scope • Quickly and easily provide correction comments that will resolve issue	• Will need to ensure systems affected by this measure are compliant	• Could auto-specify fume hood sash controls measure under certain conditions
Energy Consultant	• Identify relevant requirements • Confirm data on forms is compliant • Complete updated NRCC-PRC-09-E Laboratory Exhaust compliance document • Confirm plans/specifications match data on forms • Provide correction comments if necessary	• Quickly and easily determine if data in forms meets requirements • Quickly and easily determine if plans/specs match forms • Quickly and easily provide correction comments that will resolve issue	• Will need to ensure specified systems comply with the code measure • Will need to ensure proper compliance documentation	• Compliance document could auto-verify data is compliant with Standards

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Acceptance Test Technician (ATT)	• Complete NRCA-PRC-14-F Fume Hood Automatic Sash Closure System Acceptance form	• Quickly complete compliance documents • Coordinate with installer to address any compliance issues determined when completing the acceptance form • Minimize coordination during construction	• Will need to document functional testing with acceptance test, not currently documented • Will need to obtain and document construction inspection, not currently documented	• Integrate acceptance functional testing with commissioning schedule to reduce time and impact • Many of tests may already be part of the existing commissioning process
Plans Examiner	• Checks that updated NRCC-PRC-09-E for Laboratory exhaust is submitted and completed appropriately • Checks building plans, equipment specifications, and controls sequence are in accordance with compliance documents	• Quickly and easily determine if proposed system is in compliance • Quickly and easily provide correction comments to resolve issues	• Additional compliance requirements to verify • Additional specifications and controls sequences to review	• Provide education on new requirements to familiarize party with new code change. • Specify that this code change would only apply to a small subset of laboratory buildings. Specifically fume hood intensive laboratories only.
Building Inspector	• Checks completed NRCA document for compliance	• Quickly and easily determine if acceptance document has been properly completed • Quickly and easily provide correction comments to ATT to resolve issues	• Additional acceptance test to verify	• Provide education on new requirements to familiarize party with additional acceptance forms • Specify that this code change would only apply to a small subset of laboratory buildings. Specifically fume hood intensive laboratories only.

Appendix C: Calculation Methods and Additional Results

Annual HVAC energy savings and demand reduction for the laboratory space were calculated by subtracting the post measure results from the baseline conditions without sash closure controls on an hourly basis.

$$\Delta E = E_{base} - E_{post}$$

$$\Delta P = P_{base} - P_{post}$$

where *E* is the annual energy consumption (electrical kWh or natural gas therms), *P* is total kW demand during on-peak periods, *base* designates baseline, and *post* designates the proposed measure case.

The HVAC energy of the lab can be represented by

$$E = \sum_{i=1}^{8,760} \left(E_{fi} + E_{ci} + E_{hi}\right)$$

where *f*, *c*, and *h* designate energy consumed by the fans (supply and exhaust), cooling, and heating. Hourly values are designated by *i*.

The on-peak demand is defined as

$$P = \frac{\sum P_i}{PeakHours}, \forall\ h \in DEER\ Peak\ Periods$$

where P_i is the hourly demand in kW during peak hours and *Peak Hours* is the total number of on-peak hours in the year. Peak hours were defined to be between 14:00 and 17:00 on weekdays from May to September. The hourly demand P_i is

$$P_i = P_f + P_c + P_h$$

Fan energy E_f is defined by sizing supply and exhaust fans, and using VFD fan performance curves as defined by the ACM Reference Manual (California Energy Commission 2016). It should be noted that this approach yielded results similar to those using an average fan power of 0.8 W/cfm supply and 0.3 W/cfm exhaust. This approach has been taken in some past studies on hood energy use.

The airflow rate is defined as the maximum needed to satisfy cooling, ventilation, or fume hood exhaust requirements at any given time.

$$\dot{V}_e = maximum \begin{cases} \dot{V}_{vent}\ necessary\ to\ maintain\ minimum\ ventilation\ ACH \\ \dot{V}_{hood}\ necessary\ to\ maintain\ fume\ hood\ exhaust\ rates \\ \dot{V}_{cool}\ defined\ by\ supply\ air\ necessary\ to\ satisfy\ conditioning\ loads \end{cases}$$

If the airflow rate is primarily determined by fume hood exhaust requirements at any given time, the laboratory is considered fume hood driven at that moment.

Unless the airflow is being driven by cooling needs, the supply airflow rate tends to follow the necessary exhaust rate. It is reasonable to assume that the supply flow rate is about 90 percent of the exhaust flowrate to maintain a negative lab pressure as a secondary containment control barrier.

$$\dot{V}_s = 0.9 * \dot{V}_e\ (unless\ driven\ by\ cooling\ load)$$

In fume hood intensive laboratories, cooling loads are rarely unsatisfied by the minimum airflow requirements for ventilation ACH or fume hood exhaust. The minimum ventilation rate is set by the ACH set point and thus

$$\dot{V}_{vent} = \begin{cases} A_{Lab} * H_C * ACH_{occc}\text{ , } during\ occupied\ hours \\ A_{Lab} * H_C * ACH_{unocc}\text{ , } during\ unoccupied\ hours \end{cases}$$

where A_{Lab} is the net lab area and H_c is the ceiling height. ACH set points were taken to be ten and six for occupied and unoccupied hours based on the ACM and best recommended laboratory ventilation practices in most situations.

Assuming an equal probability of use for any given hood and a balanced hood to user ratio, expected hood airflow is at any given time is thus governed by a binomial probability distribution (TSI, Inc. 2014). Since the fume hood exhaust rate will greatly depend on the number of hoods open simultaneously and the sash height, a Monte Carlo simulation of hood user behavior would be ideal. The probability of hood opening during the baseline period could be defined amount of time the hoods are left open and at what height. The probability for the post case would be defined by the amount of active use. However, assuming an average hood opening based on case studies provides a reasonable representation of hood airflow. A literature survey was performed to determine the average sash position during occupied hours, unoccupied hours, and under active use.

Table 28 lists the average, diversified sash position values available from case studies and public literature on hood usage. They are averages across all hoods in the case studies by use hours wherever possible, thus accounting for diversity of use. The weighted occupied and unoccupied sash positions represent usage patterns without any sash closure controls while the active use position represents occupied use with closure controls in place. Unoccupied diversified sash position with closure controls installed is 0.0, as confirmed by the case studies.

Table 28: Average Effective Sash Position Research and Definitions

Group	N	Occupied sash position	Unoccupied sash position	Active use sash position
Group 1 (SCE 2007)	7	0.25	0.24	
Group 2 (SCE 2007)	5			0.07
Group 3 (Hilliard n.d.)	15	0.55		0.12
Group 4 (D. T. Hitchings 1993)	16	0.25	0.20	
Group 5 (D. T. Hitchings 1993)	21	0.19	0.14	
Group 6 (D. T. Hitchings 1993)	110	0.48	0.45	
Group 7 (Phoenix Controls Corporation n.d.)	68			0.08
Group 8 (Phoenix Controls Corporation n.d.)	31			0.14
Group 9 (Phoenix Controls Corporation n.d.)	9			0.21
Group 10 (Phoenix Controls Corporation n.d.)	6			0.10
Group 11 (Phoenix Controls Corporation n.d.)	114			0.12
Group 12 (Vargas and Cheng 2016)	40	0.43	0.36	0.13
Group 13 (Vargas and Cheng 2016)	14	0.44	0.44	
Weighted Average		**0.42**	**0.37**	**0.12**

The total airflow in cfm through the laboratory fume hoods is dependent upon the number of hoods, face velocity, and fume hood sash position.

$$\dot{V}_{hood} = \dot{V}_{hood,min} * A_{hood} + SashPosition * (\dot{V}_{hood,max} - \dot{V}_{hood,min} * A_{hood})$$

where $V_{hood,min}$ is defined as 25 cfm per square feet of workspace (or 100 fpm at a six-inch effective closed sash position) (Cal/OSHA n.d.) (ANSI/AIHA 2012), A_{hood} is the total hood workspace, *SashPosition* is the effective sash position between 0.0 and 1.0, and $V_{hood,max}$ is the airflow through the hood at the fully open sash position. Note that the sash is effectively closed when it is positioned at six inches or less.

The required airflow for conditioned air at peak cooling loads is defined as

$$\dot{V}_{cool} = \frac{Q_{net}}{1.08\ (T_{RA} - T_{SA})}$$

where Q_{net} is the net cooling load of the lab space based on internal heat gains and envelope loads.

Finally, heating and cooling energy is calculated by accounting for both sensible and latent loads. Heating and cooling is assumed to be carried out sensibly when latent loads are not significant. The following equation[4] is used to calculate the sensible heat load of the supply air (ASHRAE 2009).

$$q_{tot} = q_s = 60 * \frac{1}{v} * \dot{V} * (0.24 + 0.45W) * |T_{OA} - T_{SA}|$$

where q_s is the sensible heat gain of the supply air in Btu/hr, v is the air specific volume in ft^3/lb_{da}, $\dot{V}$ is the airflow in cfm, W is the humidity ratio in lb_w/lb_{da}, T_{OA} is the outside air dry bulb temperature in °F, and T_{SA} is the supply air dry bulb temperature in °F.

When latent loads become significant (when supply air temperatures fall below the dew point temperature of the outside air), the latent load is accounted by the following (ASHRAE 2009).

$$q_{tot} = q_s + q_l = 60 * \frac{1}{v} * Q * [(h_{OA} - h_{SA}) + h_w(W_{OA} - W_{SA})]$$

If needed, sensible reheat energy is calculated to bring the supply air to the required discharge air temperature to satisfy loads at a reasonable temperature given the flowrate. Site electrical demand in kW, cooling energy in kWh, and heating energy in therms for any given hour is calculated as

$$P_c = \frac{q_{tot,cool}}{\eta_c * 12{,}000}$$

$$E_c = P_c$$

$$E_h = \frac{q_{tot,heat}}{\eta_h * 99{,}976}$$

where η is the cooling or heating system efficiency as defined by ACM equipment performance curves and equipment efficiencies.

TDV energy usage and savings was then calculated by applying the standard hourly factors to the hourly energy calculations:

$$\Delta TDV = TDV_{base} - TDV_{post}$$

$$TDV = \sum_{i=1}^{8{,}760} TDV_i * \left(E_{fi} + E_{ci} + E_{hi}\right)$$

Table 29 shows some of the inputs of the modeling tool, with values that defined the representative lab as determined by literature survey, modeling guidelines, and standards.

[4] ASHRAE Handbook Fundamentals

Table 29: Example Model Conditions

Building Characteristics

Lab Area	5,100	Square Feet
Ceiling Height	10	Feet
Occ ACH Vent Setpoint	10	ACH
Unocc ACH Vent Setpoint	6	ACH
Occ ACH CFM Vent Setpoint	8,220	CFM
Unocc ACH CFM Vent Setpoint	4,932	CFM
Fume Hood Density	**3.30%**	Hood workspace to lab area
Climate Zone	**CZ16**	Using CZ2010 weather data
Hood Area	168	Square Feet
Num Hoods	15.8	Hoods
Total Hood Length (outer dim)	95	Feet
Peri Area	0.3	% perimeter on exterior wall

HVAC system

Water-cooled chiller	0.68	kW/ton
Hot Water Coils	80	%
DX	10	EER
Furnace	0.83	thermal eff
Hot Water Boiler	0.82	thermal eff
Cooling Setpoint	75	F
Heating Setpoint	70	F
SAT Reset?	No	Yes or No
Setpoint Setback?	No	Yes or No
Setpoint Setback Amount	3	F
Fan Position	DT	BT blow-through; DT draw-through
Setpoint Setback OAT Changepoint	65	F

Hood Characteristics

Face Velocity		100	fpm
Hood Length		6	feet
Hood Workspace Depth		24	inches
Hood Workspace Width		5.33	Feet
Closed Height		6	Inches
Sash Stop Height		18	inches
Sash Height		29	inches
Closed Flowrate (Cal/OSHA)		257.8	CFM
Min Hood Flow (Z9.5)		266.7	CFM
Open Hood Flow		800	CFM
Fully Open Flowrate		1,289	cfm
Present Value Lifetime Cost	$	4,140	per hood
Base Occ Sash Position Avg		0.42	
Post Occ Sash Position Avg		0.12	
Base Unocc Sash Position Avg		0.37	
Z9.5 Min	25		CFM/hood area

Energy consumption was modeled for the two system types across all climate zones for the prototype lab conditions. The modeled energy consumption, on-peak demand, and savings are shown in Figure 7 through Figure 12 on a per 1,000 ft^2 of lab area basis. Note that this is consistent to a per 10,000 ft^3 basis since the prototype ceiling height is 10 feet.

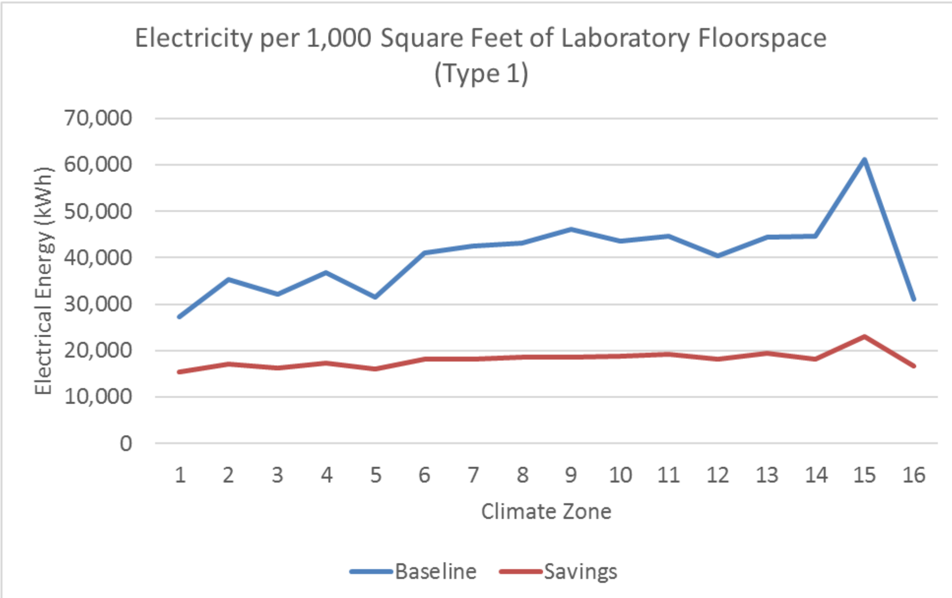

Figure 7: Electrical energy model results for lab (type 1) per 1,000 ft^2

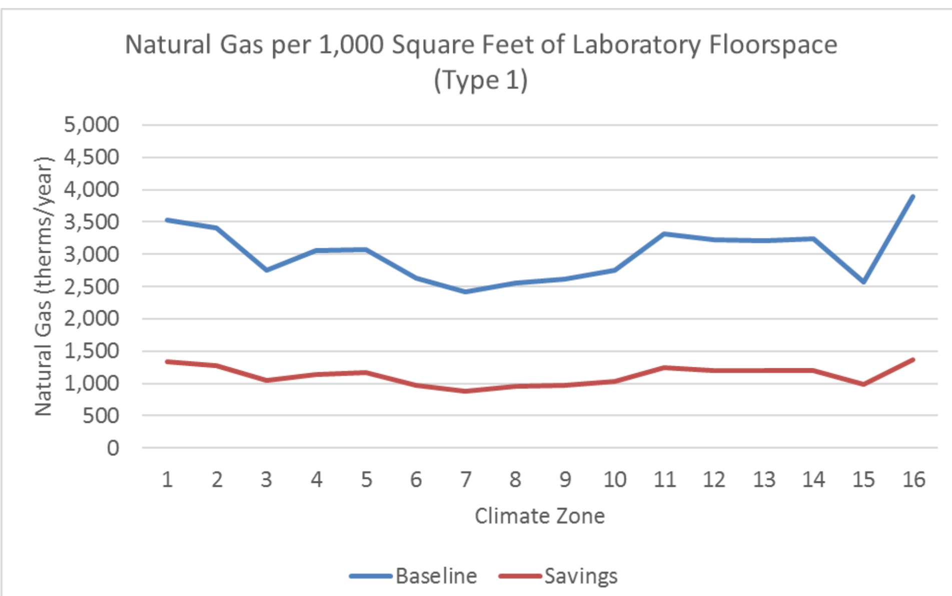

Figure 8: Natural gas model results for lab (type 1) per 1,000 ft^2

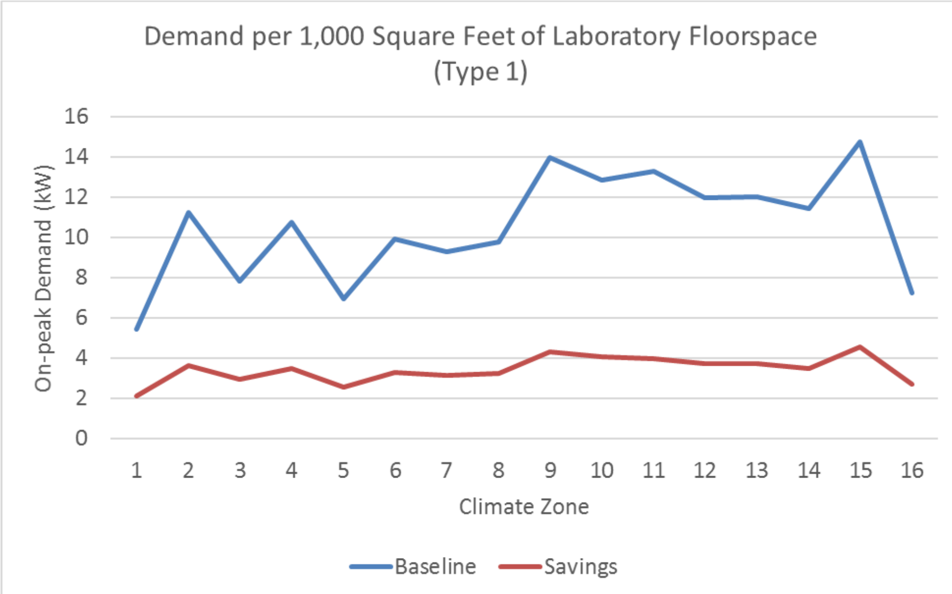

Figure 9: Electrical demand modeling results for lab (type 1) per 1,000 ft^2

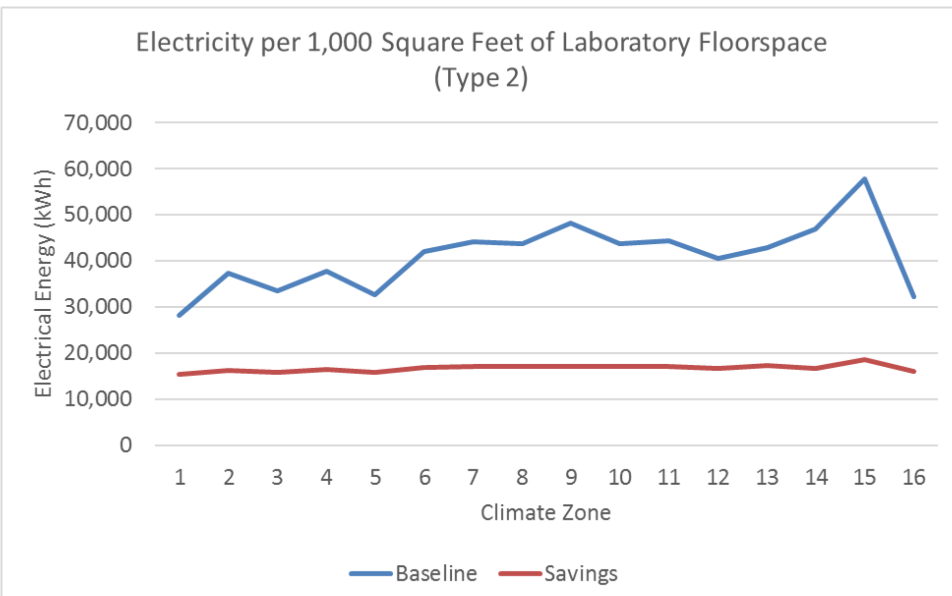

Figure 10: Electrical energy modeling results for lab (type 2) per 1,000 ft^2

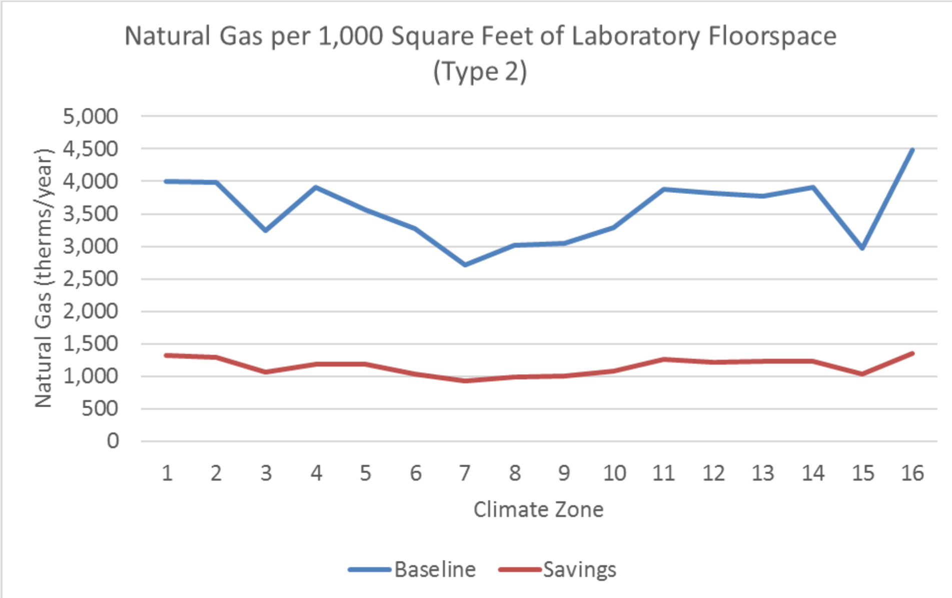

Figure 11: Natural has modeling results for lab (type 2) per 1,000 ft²

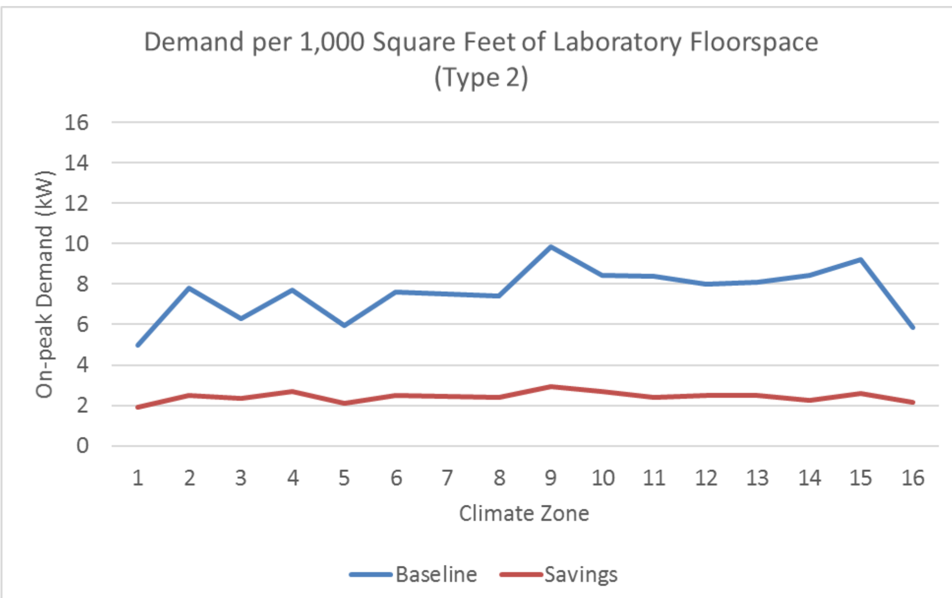

Figure 12: Electrical demand modeling results for lab (type 2) per 1,000 ft²

Results are also shown on a per six-foot hood unit basis in Figure 13 through Figure 18.

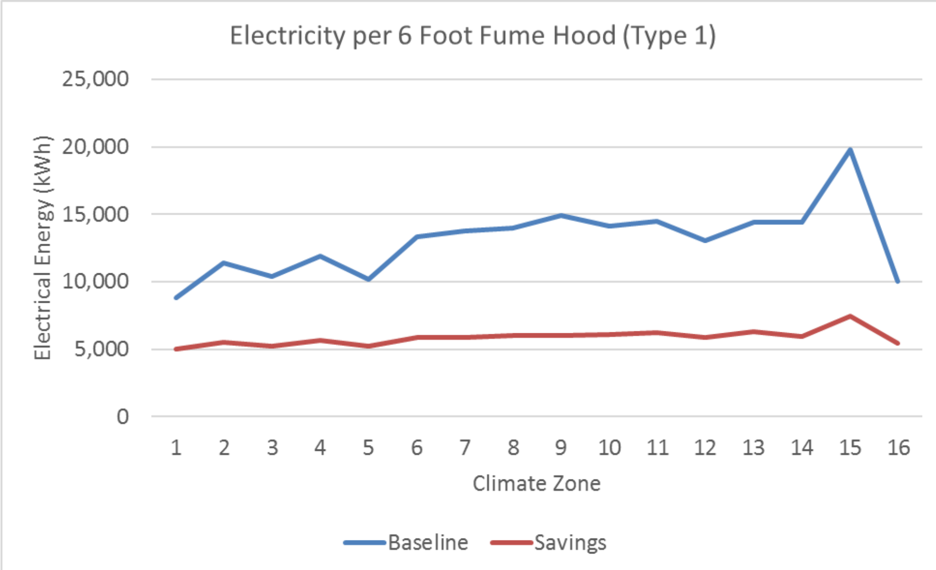

Figure 13: Electrical energy model results for lab (type 1) per fume hood

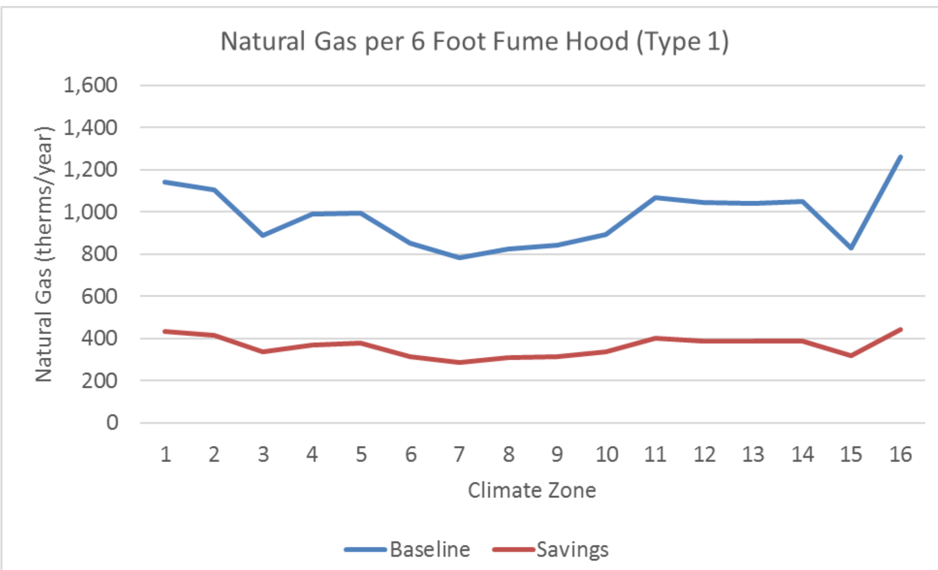

Figure 14: Natural gas model results for lab (type 1) per fume hood

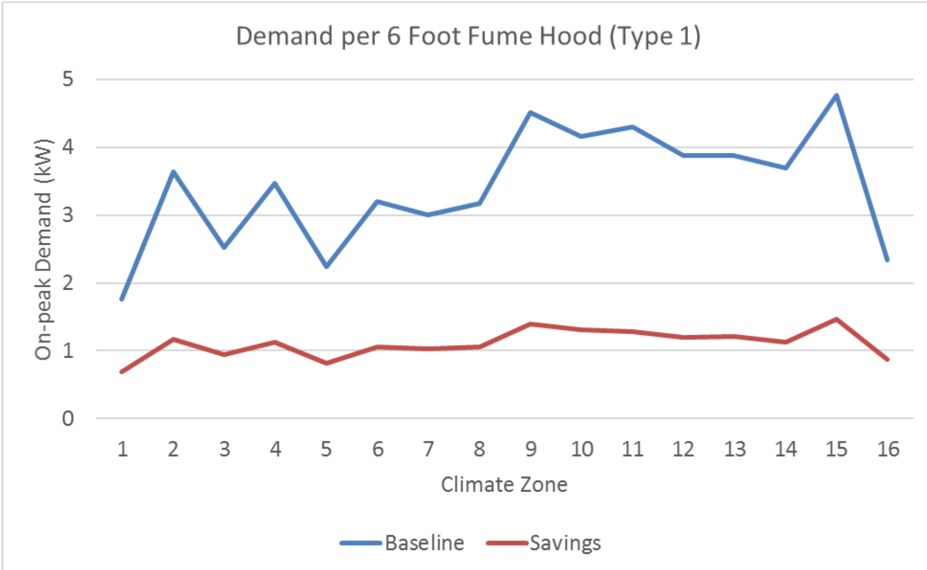

Figure 15: Electrical demand modeling results for lab (type 1) per fume hood

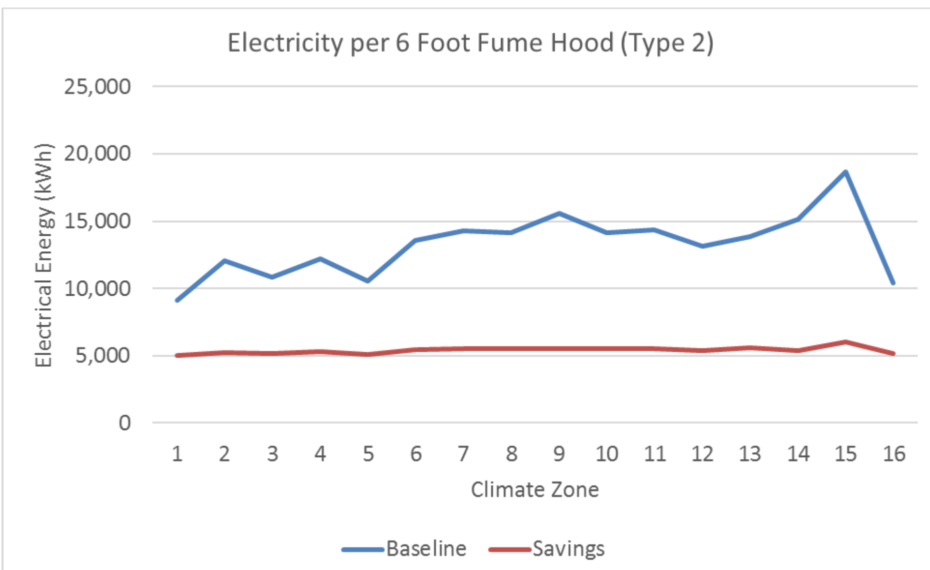

Figure 16: Electrical energy modeling results for lab (type 2) per fume hood

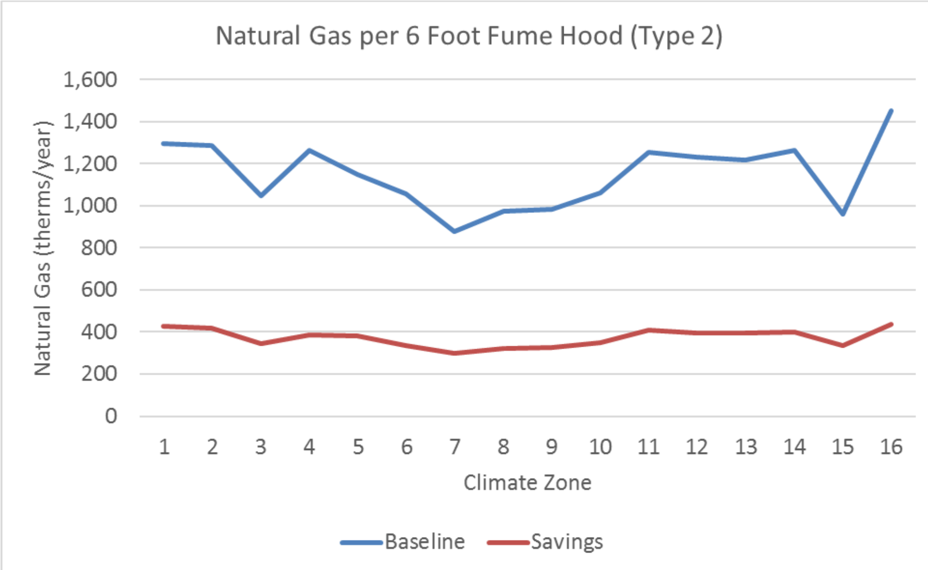

Figure 17: Natural gas model results for lab (type 1) per fume hood

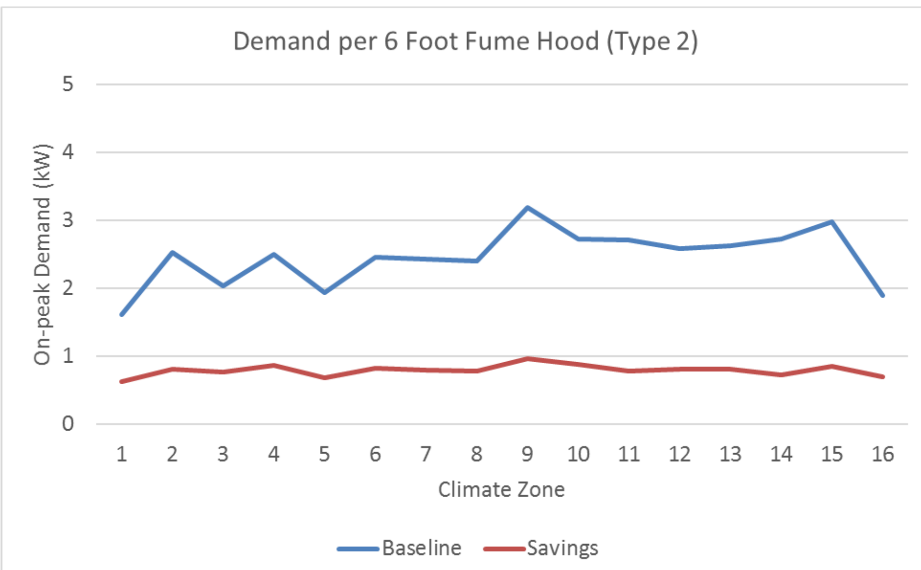

Figure 18: Electrical demand modeling results for lab (type 2) per fume hood

A sensitivity analysis to the driving model parameters was performed to define the impacted, cost-effective labs as designated in **Table 6**. Figure 19 shows the impact of minimum occupied ventilation ACH setpoints and fume hood density on energy savings for the representative laboratory. As minimum ventilation setpoints increase, fewer hours throughout the year are fume hood dominated, thus reducing the cost-effectiveness. Note that this analysis assumed the prototype lab unoccupied minimum ACH setpoint of six and consolidated lab area and ceiling height into a single basis for fume hood density.

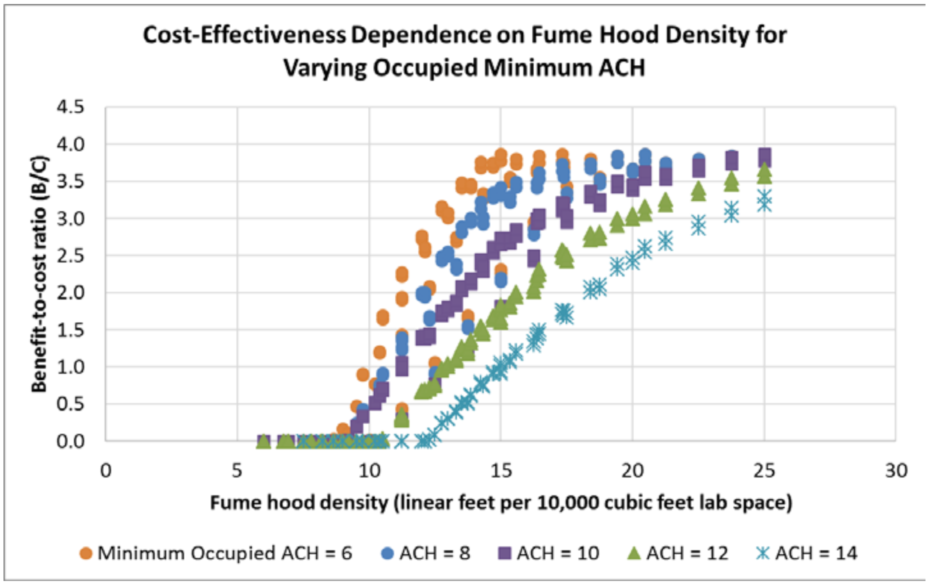

Figure 19: Benefit-to-cost dependence on minimum occupied ventilation setpoint and hood density

However, minimum ventilation rates can vary significantly. Standard laboratory conditions according to Labs21 are ACH greater than six for standard conditions (EPA 2007). As a conservative estimate, the prototype lab used ten ACH for occupied times and six for unoccupied times. This implies that many labs might achieve greater cost-effectiveness than the prototype lab under conditions with lower minimum ventilation rates. A collection of model runs with varying ACH was gathered as presented in Figure 20.

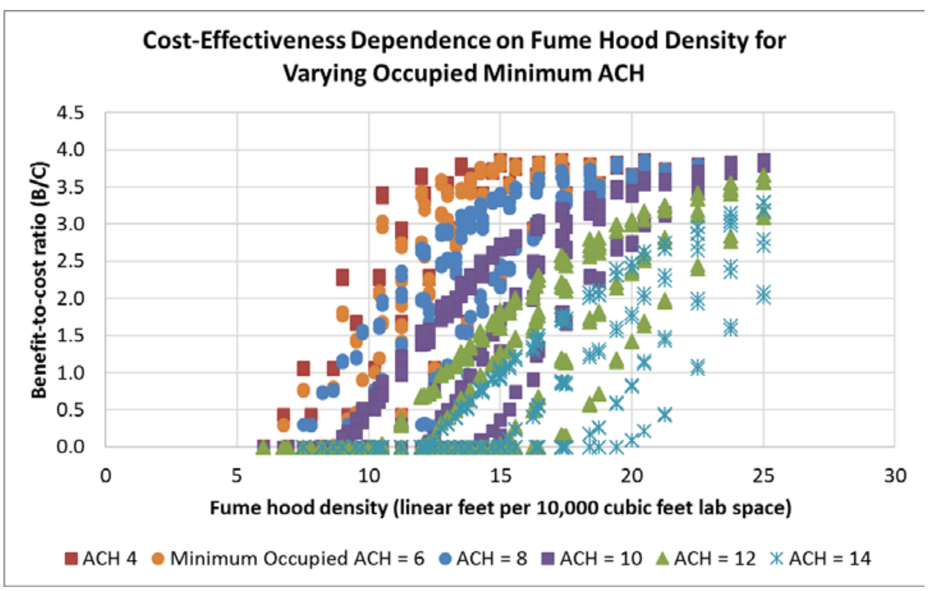

Figure 20: Benefit-to-cost dependence on minimum ventilation setpoint and hood density

Using these model runs, a regression for the B/C ratio was derived.

$$B/_{C} = 0.44848 + 0.23846 * FHD - 0.2354 * ACH_{\min occ}$$

where *FHD* is fume hood density in nominal linear feet per 10,000 cubic feet of lab space. This regression has an adjusted R^2 of 0.764, *FHD* has a t-stat of 68.8, and $ACH_{min\ occ}$ has a t-stat of 44.9.

For a B/C of 1.0, the minimum fume hood density can thus be derived as

$$If\ B/_{C} \geq 1.0, \qquad FHD \geq -1.8804 + 0.9872 * ACH_{\min occ}$$

This relationship was used to develop the exemption space defined in Table 6.

Aside from these variables that are the primary determinants of energy savings in the modeling approach, occupied hours, unoccupied ACH setpoint, supply air temperatures, ceiling height, sash height assumptions, and other parameters impact the energy savings and cost-effectiveness of the measure. However, aside from the average sash position parameter, all other variables are far less significant than occupied minimum ACH and fume hood density, especially when fume hood density uses a metric that includes ceiling height.

Appendix D: Targeted Outreach Questions - Manufacturers

Survey Questions:

1. If offered, what is the cost of a new 6-foot variable air volume (VAV) hood **without** automatic sash closing controls?
2. If offered, what is the cost of a new 6-foot VAV hood **with** automatic sash closing controls?
   a. What is the typical lead time for ordering this equipment?
3. If offered, what is the cost for an aftermarket retrofit kit for a 6-foot variable air volume (VAV) hood to modify a manual sash to an automatic closing sash?
   a. What is the lead time for ordering this equipment?
4. What type of maintenance should be performed to ensure the continued proper operation of automatic sash closure systems?
   a. What is the average annual cost of maintenance?
   b. At what frequency should maintenance be performed?
5. What is the expected useful life for automatic sash closing controls (years)?
   a. If known, what component(s) are the most common source of failure and in need of replacement?
   b. What is the cost of these individual components?
6. What percentage of fume hood sales/installations are in variable air volume (VAV) systems?
7. What percentage of hood sales/installations are 4-foot hoods? 6-foot? 8-foot? Other?
8. What percentage of hood sales/installations use horizontal sashes?
9. What is the typical air change rate (ACH) of the average lab during occupied and unoccupied hours? Are most designed and controlled to the 6 ACH recommended by best practices guidelines?
10. What is the typical air change rate (ACH) of the average fume hood when fully open and fully closed?
11. Can you provide any energy savings substantiation (e.g., calculations, marketing materials, case studies, etc.) for high-performance, low-flow hoods? For our purposes, this is defined as hoods that reduce face velocity below the California minimum of 100 fpm under certain conditions or employ alternative air intakes such as vertical air curtain intake (e.g., Berkeley hood).
12. Can you provide manufacturer's specifications for the individual components of the automatic sash closure system (e.g., infrared occupancy sensor, sash drive unit, etc.)?
13. Is compressed air required for the automatic sash closer to function?
14. The proposed regulations would add an acceptance test that requires a construction inspection and functional testing to Title 24 Nonresidential Appendix, NA7 to support the new prescriptive requirements for fume hoods. Would you be willing to provide input and/or existing functional testing procedures (i.e., commissioning checklist) to assist in developing the proposed acceptance test requirements?

Appendix E: Fume Hood General Outreach Survey

Survey Questions:

1. What is your role in the laboratory fume hood industry?
   a. Building official
   b. Fume hood/controls manufacturer
   c. Fume hood/controls distributor
   d. Facility manager
   e. Fume hood end-user
   f. Laboratory HVAC Designer
   g. Other
2. Please provide your contact information.
   a. Name:
   b. Organization/Affiliation:
   c. City/Town:
   d. State/Province:
   e. Email Address:
3. Please provide feedback on the following definition for a fume hood driven laboratory: combined area of laboratory spaces in a building sharing a common exhaust system with a fume hood density greater than 1 square foot of hood work surface per 25 gross square feet of laboratory.
4. What are the typical air change rates of scientific laboratories during occupied and unoccupied periods?
   Note, Scientific laboratory is defined by Title 24, Part 6 as "a room or area where research, experiments, and measurement in medical and physical sciences are performed requiring examination of fine details...Scientific laboratory does not refer to film, computer, and other laboratories where scientific experiments are not performed."
5. What percentage of new fume hood purchases/installations are variable air volume (VAV) systems?
6. Based on your experience, what is the average expected useful life of a VAV fume hood (i.e. how often are VAV fume hoods replaced)?
7. In your experience, what percentage of time (or how many hours per day) are fume hood sashes left open during laboratory **occupied** periods?
8. How many hours per day is a typical fume hood utilized?
9. In your experience, what percentage of time (or how many hours per day) are fume hood sashes left open during laboratory **unoccupied** periods?
10. What percentage of time during laboratory **unoccupied** periods are VAV fume hoods turned off completely (using a switch, for instance)?
11. When open, what percentage of the time are fume hood sashes left in the following positions:
    a. Fully open, ~29 inches (if sash stops are not installed):
    b. 18-24 inches (typical sash stop position):
    c. 7-18 inches:
    d. 6 inches or less:
12. When a fume hood is fully open or is open to the sash stop position, what is the typical design point air flow rate?
13. What is the typical minimum air flow rate when the fume hood sash is closed (e.g., percent of design flow rate)?

14. What percentage of VAV fume hoods have widths of the following dimensions:
    a. 4 feet:
    b. 5 feet:
    c. 6 feet:
    d. 8 feet:
15. Describe your experience with automatic sash closure systems for VAV laboratory exhaust systems.
16. Describe your observations about the end-user acceptance of automatic sash closure systems.
17. What do you perceive as the biggest market barriers for the automatic sash closure system technology?
18. In your opinion, what type of maintenance should be performed to ensure the continued proper operation of automatic sash closure systems?
    a. If known, what is the average annual cost of this maintenance?
    b. At what frequency should this maintenance be performed?
19. Based on your experience, what other energy efficiency measures are being implemented for laboratory fume hoods in lieu of or in addition to automatic sash closure systems?