Codes and Standards Enhancement (CASE) Initiative

2019 California Building Energy Efficiency Standards

Variable Exhaust Flow Control – Final Report

Measure Number: 2019-NR-MECH3-F

Nonresidential Covered Processes

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Authors: Jared Landsman (Integral Group)

Project Management: California Utilities Statewide Codes and Standards Team: Pacific Gas and Electric Company, Southern California Edison, SoCalGas®, San Diego Gas & Electric Company, Los Angeles Department of Water and Power, and Sacramento Municipal Utility District

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

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

Measure Description

Laboratories and process facilities require specially designed exhaust systems that allow for safe release and dispersion of harmful chemicals into the ambient outdoor environment. The performance of laboratory and process facility exhaust is highly dependent on exhaust stack design and fan specification. The type of exhaust system will impact how well the "re-entrainment into the building air intakes and contamination of building entrances, exits, and adjacent buildings" are avoided (McIntosh, Dorgan, & Dorgan, 2001). Presently, there are no requirements for performing dispersion analysis during the design of lab exhaust systems. This raises concerns for the safety of lab occupants and occupants of nearby buildings. There are numerous existing standards that address this concern, which gives the opportunity for the state of California to incorporate one of these standards, in order to ensure occupant safety.

Currently there are no requirements for the power demand of laboratory and process facility discharge exhaust systems in California. Furthermore, there is no existing baseline for laboratory or process facility exhaust power because they are currently listed as exempt process loads. Because there are no existing requirements, some laboratory exhaust systems currently being specified and built in the state of California are consuming more energy than necessary. Adding requirements for exhaust power will result in these systems being more efficient than they would have been otherwise, therefore creating significant savings opportunities for laboratory and process facility exhaust systems.

This measure is proposed to ensure that laboratories meet the discharge requirements in ANSI Z9.5 and to limit the power consumption of laboratory and process facility exhaust systems. The measure will revise the existing prescriptive fan power equation requirements to include a limited allowance for process discharge exhaust fan power. If the prescriptive fan power limit cannot be met, numerous pathways towards compliance will be provided including control by a rooftop anemometer or control by a contaminant sensor. This code change will affect prescriptive requirements for covered processes for new construction, additions and alterations. In practice, the proposed measure will impact the selection and implementation of laboratory exhaust systems.

Scope of Code Change Proposal

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

Table 1: Scope of Code Change Proposal

Measure Name	Type of Requirement	Modified Section(s) of Title 24, Part 6	Modified Title 24, Part 6 Appendices	Will Compliance Software Be Modified	Modified Compliance Document(s)
Variable Exhaust Flow Control	Prescriptive	140.9, 141.1	Nonresidential Appendix (NA) 7	Yes	New document created for acceptance testing, NRCC-PRC-01-E revised, NRCC-PRC-09-E revised

Market Analysis and Regulatory Impact Assessment

The market for induction exhaust fans (IEFs), which are the largest energy consumers of all lab exhaust systems specified today, is very well established. This industry has an annual market size of approximately $5-6 million in California. Fans are available from at least five major manufacturers: Greenheck, Cook, Strobic, Twin City, and MK Plastics. Roughly one-third of all lab exhaust systems specified in the state of California are IEFs. California consists of about 7.5 percent of nationwide lab fan market.

This proposal is cost-effective over the period of analysis. Overall this proposal increases the wealth of the State of California. California consumers and businesses save more money on energy than they do for financing the efficiency measure.

The proposed changes to Title 24, Part 6 have a negligible impact on the complexity of the standards or the cost of enforcement. When developing this code change proposal, the Statewide CASE Team interviewed building officials, energy analysts and others involved in the code compliance process to simplify and streamline the compliance and enforcement of this proposal.

Cost-Effectiveness

The proposed code change was found to be cost-effective for all climate zones where it is proposed to be required. The benefit-to-cost (B/C) ratio compares the lifecycle benefits (cost savings) 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 savings. The B/C ratio for this measure for conventional exhaust fans ranges between 4.8 in Climate Zone 3 and 5.5 in Climate Zone 11. The B/C ratio for this measure for induction exhaust fans ranges between 0.1 in Climate Zone 14 and 4.3 in Climate Zone 8. See Section 5 for a detailed description of the cost-effectiveness analysis.

Statewide Energy Impacts

Table 2 shows the estimated energy savings over the first twelve months of implementation of the proposed code change. See Section 6 for more details.

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

Measure	First-Year Electricity Savings (GWh/yr)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Water Savings (million gallons/yr)	First-Year Natural Gas Savings (million therms/yr)
New Construction	3.26	0.333	N/A	N/A
Alterations	6.05	0.611	N/A	N/A
Total	**9.32**	**0.945**	**N/A**	**N/A**

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 a compliance and enforcement process and to identify the impacts this process will have on various market actors. The compliance process is described in Section 2.5. The impacts the proposed measure will have on various market actors is described in Section 3.3 and Appendix B. The key issues related to compliance and enforcement are summarized below:

- Certifying effective dilution of pollutants with wind-speed control or contaminant sensors;
- Requesting manufacturers to ensure that all models are capable of wind speed/direction and contaminant sensor control; and
- Bringing designers, contractors, plan checkers, and inspectors up to speed on proper system design and control methods.

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

1. INTRODUCTION

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

The overall goal of this CASE Report is to propose a code change proposal for Variable Exhaust Flow Control. The report contains pertinent information supporting the code change.

When developing the code change proposal and associated technical information presented in this report, the Statewide CASE Team worked with a number of industry stakeholders including building officials, manufacturers, builders, utility incentive program managers, Title 24 energy analysts, and others involved in the code compliance process. The proposal incorporates feedback received during a public stakeholder workshop that the Statewide CASE Team held on December 13, 2016 and March 21, 2017.

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

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

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

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

Section 6 presents 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

With the knowledge that exhaust systems can be an extremely large component of laboratory energy consumption (Neuman, 2012), and the fact that there are numerous methods and technologies to reduce this energy, the following measure was developed.

Laboratories and process facilities often deal with pollutants that can be harmful to occupants. Therefore, they require high volume exhaust systems that allow for safe release and dispersion of harmful chemicals into the ambient outdoor environment. The performance of laboratory and process facility exhaust is highly dependent on exhaust stack design and fan specification. The type of exhaust system will impact how well the "re-entrainment into the building air intakes and contamination of building entrances, exits, and adjacent buildings" are avoided (McIntosh et al., 2001). The ASHRAE Laboratory Design Guide provides guidance on how to design exhaust systems to meet safety requirements. It is industry standard practice to follow this design guideline.

The proposed code changes presented in this report will impact the selection, design and construction of exhaust systems in laboratories and process facilities across California. For the purposes of this code change, "laboratories" and "process facilities" do not refer to buildings of type L (Laboratory Group L) occupancy, as these are not covered under Title 24, Part 6. "Laboratories" and "process facilities" contain nonhazardous testing and research labs, or spaces for assembling, disassembling, fabricating, finishing, manufacturing, packaging, repair, processing operations, or spaces that generate or store materials that constitute a physical or health hazard in quantities in excess of those allowed in control areas. Each of these spaces types fall within occupancy type B (Business Group B), type F (Factory Industrial Group F), or type H (High Hazard Group H). Therefore, this measure will impact buildings of type B, F, and H occupancy, which are all covered by Title 24, Part 6, and will not impact buildings of type L occupancy. A process facility is defined as any facility containing occupancy type F. Laboratories and process facilities will be referred to as labs/lab for the remainder of this report.

To fully understand the implications of this measure, it is important to first denote the factors that impact lab exhaust performance. To avoid re-entrainment of contaminated air, the discharge air must exit the facility at a height far enough away from the air intakes and with momentum high enough such that the contaminated air cannot reenter the facility. To ensure adequate plume elevation and momentum, the exhaust system must release the air through a stack of specified height, windband diameter, and exit velocity. The windband diameter is the diameter at the point in which the plume exits the stack. In addition to these controllable parameters, there are also certain variables that cannot be controlled, mainly the wind speed and wind direction, which affect the effective plume height. "Knowledge of the airflow around and over buildings is necessary" to design a successful lab exhaust system (McIntosh et al., 2001). This is typically provided by a certified wind consultant or engineer.

It is also necessary to denote the characteristics of a conventional lab exhaust system versus alternative exhaust systems. A conventional lab exhaust system comprises of a tall exhaust stack, which allows for the safe release of discharge air at a relatively low discharge velocity. A conventional exhaust system is diagrammed in Figure 1A. The requirement of a large stack height in a conventional system "for proper expulsion and dilution of the contaminate air often makes the stack very visible. This visibility is normally unwanted," especially by architects and local government planners.

Sometimes exhaust systems are equipped with a bypass damper on the mixing plenum box to add bypass air to the exhaust air stream, maintaining a fairly constant discharge volume from the stack. Bypass dampers are conventionally only used during partial flow conditions. Typically, when the system is at peak exhaust airflow rates – the bypass damper is closed. When the system is at partial exhaust airflow conditions – the bypass damper opens. Essentially the bypass damper opening state is a consequence of a varying exhaust load. A bypass damper is not required, and concerns can be addressed with other design features.

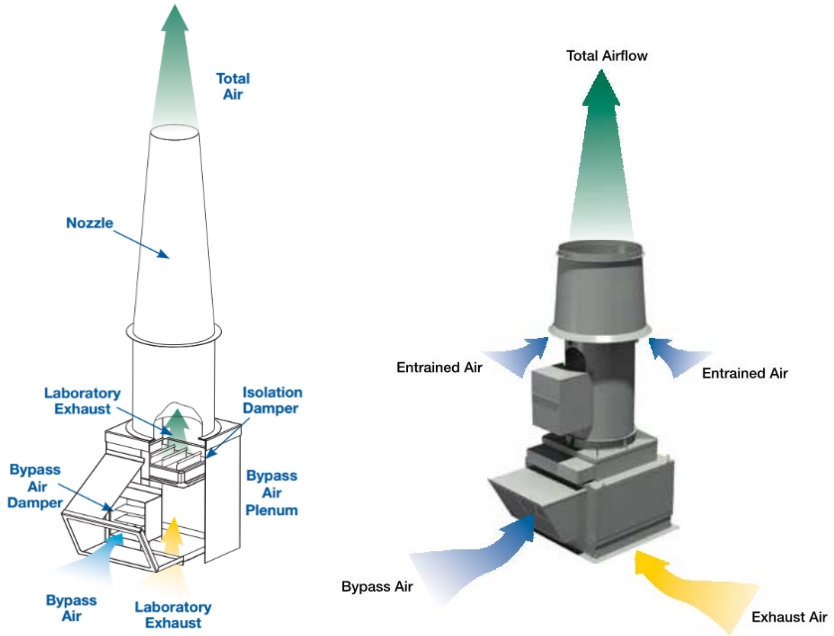

Figure 1: A) Conventional stack diagram, B) Induction exhaust fan diagram

Source: Greenheck Fan Corporation

To reduce the stack height, an alternative to the conventional system is an inducted, or entrained, exhaust system. An induction exhaust fan (IEF) entrains outdoor air and combines it with discharge air and bypass air to achieve larger momentum. This in turn creates an equivalent effective plume height while simultaneously allowing for a shorter exhaust stack. Because the exhaust stack is shorter, it can be hidden from the line of sight at the base of the facility, therefore becoming more aesthetically pleasing. An IEF is diagrammed in Figure 1B.

There are two types of IEFs, bifurcated nozzle and concentric nozzle. The bifurcated nozzle type, manufactured by Strobic and MK Plastics, splits the discharge exhaust into two air streams. The concentric nozzle type, manufactured by Greenheck and Loren Cook, uses only one air stream for the discharge air. Currently, there is no data provided from manufacturers on plume velocity characteristics. However, research has shown that the bifurcated nozzle creates a widely varying velocity profile across the air stream and leads to high turbulence within the plume. In addition, the plume produced by a bifurcated nozzle has a wide divergence angle and rapidly loses plume cohesiveness (Wisner & Meats, 2016). Within a couple of diameters above the exit plane, the bifurcated nozzle exhaust fan loses about 90 percent of the vertical exit velocity, and therefore these systems could not reach the plume rise from a conventional exhaust system ("Interview with Chet Wisner, Ambient Air Technologies, LLC," 2017). Conversely, research has shown that the concentric nozzle creates a uniform velocity profile across the air stream, generates low turbulence within the plume, and maintains a cohesive exhaust stream (Wisner & Meats, 2016). Figure 2 shows the velocity profile for both the bifurcated nozzle and the concentric nozzle.

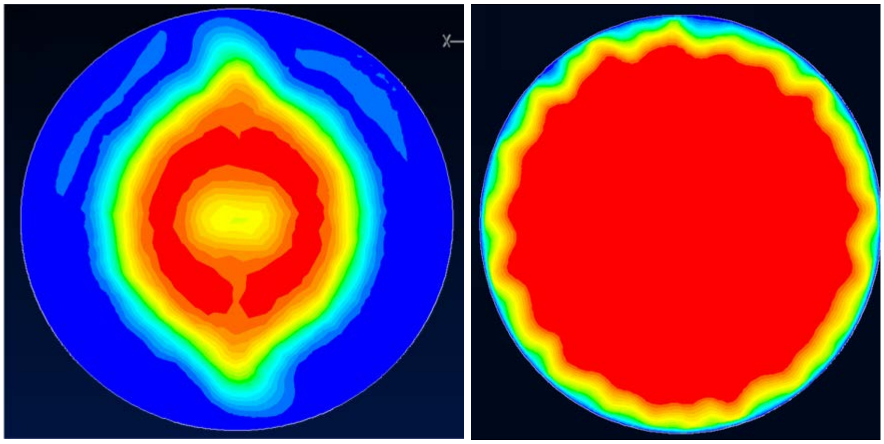

Figure 2: A) Bifurcated nozzle velocity profile, B) Concentric nozzle velocity profile

Source: Wisner & Meats, 2016

Although most designers feel as though the two systems provide an equivalent level of safety to building occupants, IEFs require significantly higher fan power than that of the conventional exhaust system to achieve higher momentum. Figure 3 shows the fan power necessary for five different exhaust systems at varying exhaust airflow rates. It is clear that the induced air exhaust systems require higher fan power than the conventional exhaust systems, especially at higher exhaust airflow rates.

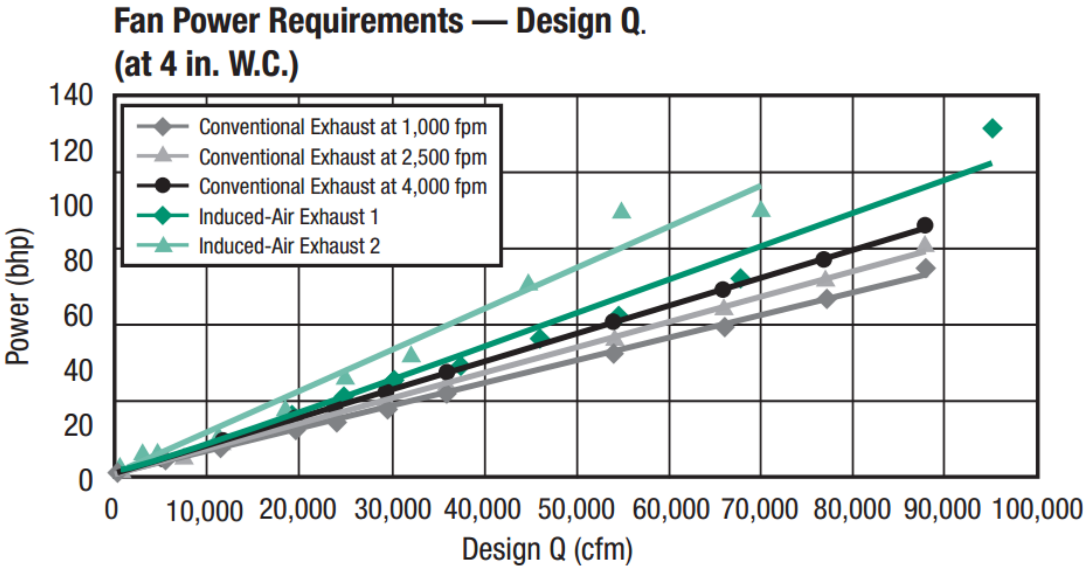

Figure 3: Exhaust airflow rate vs fan power for different exhaust fan types

Source: Petersen, Amon, & Lintner, 2005

Numerous technologies and strategies have been developed to reduce the energy consumption from lab exhaust. These strategies are described below.

1. **Fan Staging**: The simplest strategy is to use multiple exhaust fans and then stage the fan operation based on the exhaust demand. When one fan reach its maximum capacity, the next fan is turned on. Conversely, when one fan reaches its minimum capacity, the next fan is turned off.

As soon as a fan is turned on, the system adjusts to split the airflow between each fan. Because of the fan laws, it is often more energy efficient to split large exhaust loads equally amongst multiple fans, rather than pushing all of the air through a single fan. When demand is low, using fewer fans makes sense to avoid the unnecessary bypass air needed to achieve target exit velocities.

2. **Wind-Responsive Exhaust Control**: The plume rise is highly dependent on the wind speed. When wind speeds are low, the plume has a larger rise and when wind speeds are high, the plume has a smaller plume rise. By installing a rooftop anemometer that measures real-time wind speed, the fan speed can be adjusted in real time depending on the wind speed. Therefore, during low wind speed conditions, the fans can be ramped down, which in turns reduces exhaust system energy use. This strategy is most applicable to lab exhaust systems that are safe at full flow, but unsafe at minimum flow during high wind speeds.
3. **Contaminant Exhaust Control**: By installing a contaminant sensor in the exhaust stack, measurements from the contaminant sensor can then be compared to predetermined contaminant thresholds. When the contaminant levels are low and the exhaust stream is considered clean, the fans can be ramped down to create a lower dilution level that is still sufficient for contaminants that might be exhausted from the lab.
4. **Variable Geometry Stack**: One last strategy is the use of variable geometry stacks. The exit velocity for an exhaust stack is determined by the airflow exiting the stack, in addition to the area of the stack at the exit point, also known as the windband area. Typically, the windband area is held constant. However, an alternative option is to use a variable geometry stack, which allows for a changeable windband area. This strategy utilizes nozzle blades that adjust to maintain constant discharge velocity while the fan operates at varying rotations per minute, volume and power. During periods of low exhaust demand, a variable geometry stack allows for a reduced exhaust airflow while maintaining the necessary discharge velocity.

The proposed code change will establish a new prescriptive requirement for power consumption of fan systems serving lab exhaust systems over 10,000 cubic feet per minute (cfm). The power consumption requirements apply to the fan system, which includes power use from all fans required to operate at design conditions to exhaust polluted air from the conditioned space to the outdoors. This includes all exhaust air from fume hoods, hazardous exhaust flows, or other manifolded exhaust streams, and excludes bypass air and entrained air. The primary prescriptive requirement specifies that fan system power must be 0.65 watts per cfm of exhaust air. For existing buildings, the new code requirement will only be triggered if there is a new exhaust system being installed that is over 10,000 cfm. There are two alternate prescriptive requirements that builders can elect instead of the primary option:

- Fan speed controls with contaminant sensors
- Fan speed controls with wind sensors

If electing to use one of the alternate pathways, dispersion analysis will be necessary to successfully design the exhaust system. However, the primary prescriptive pathway will not require any dispersion analysis. In addition, the alternate pathways will require failsafe contingencies for system failure and calibration expiration.

The proposed code change will affect Section 140.9: Prescriptive Requirements for Covered Processes, Section 141.1: Requirements for Covered Processes in Additions, Alterations, to Existing Buildings and Section 5.7 of the Nonresidential ACM Reference Manual: HVAC Secondary Systems. Currently, there are no requirements for laboratory and process facility discharge exhaust power demand. This requirement will lead to major energy savings further detailed in this report.

The proposed code change creates a new prescriptive requirement for covered processes. Because this change will be applied to covered processes as opposed to space conditioning systems, this requirement will not allow for tradeoffs between exhaust systems and other HVAC fan systems if using the prescriptive approach. However, it will allow for tradeoffs if using the performance approach. It will also provide multiple pathways for compliance.

The proposed code change will require a revision to the current laboratory exhaust certificate of compliance, NRCC-PRC-09-E, and the NRCC-PRC-01-E Compliance Certificate. It will also require the creation of a new acceptance test form to ensure exhaust fan systems are installed and controlled correctly, to comply with the new prescriptive measure, specifically meeting ANSI Z9.5 requirements.

Regarding the compliance pathway of measuring wind speed/direction taken from a calibrated "local station", it must still be decided if this will be a rooftop anemometer or a nearby meteorological station. To conduct wind analysis or wind tunnel testing, historical data is collected from the closest meteorological station, which is typically located at an airport at a height of ten meters. Because wind analysis uses historical data to dictate the required stack height and exit velocity, there is an argument to be made that a rooftop anemometer will not accurately match the wind profile used for design. However, there is also an argument to be made that the rooftop anemometer will more accurately capture the wind speed/direction directly at the site of the exhaust stream. It is our recommendation that the code require an anemometer be installed on the rooftop.

2.2 Measure History

In the 2013 code cycle, the Statewide CASE Team recommended two code change proposals to reduce energy use from laboratory exhaust systems. The first measure was for section 140.9 Prescriptive Requirements for Covered Processes. This measure was a new prescriptive requirement that all laboratory exhaust systems where the minimum circulation rate to comply with code is 10 air changes per hour (ACH) or less, be designed for variable volume control on the supply, fume exhaust and general exhaust. In other words, if using the prescriptive path, a laboratory must be capable of reducing its zone exhaust to the specified minimum circulation rate. This measure was approved by the Energy Commission and incorporated into Title 24, Part 6 for the 2013 code cycle.

The second code change proposal from the 2013 code cycle, also for section 140.9 Prescriptive Requirements for Covered Processes, recommended a new prescriptive requirement for all buildings with laboratory exhaust systems having a total exhaust rate greater than a specified value to incorporate a heat recovery system to precondition makeup air from laboratory exhaust. The Energy Commission did not accept the second proposal, so there is no current requirement for heat recovery in lab exhaust systems. These two measures are the only related measures that have been proposed in former rulemakings (Taylor Engineering, 2011).

In 2016 Title 24, Part 6, there are requirements that laboratory exhaust systems be designed for variable volume control. However, the following items do not currently exist in Title 24, Part 6:

1. Requirements for variable volume control for process facilities
2. Regulations of laboratory and process facility discharge exhaust power demand
3. Baseline for laboratory and process facility exhaust power, as these are currently listed as exempt process loads
4. Requirements that restrict fan power by wind speed/direction or contaminant concentration

2.3 Summary of Proposed Changes to Code Documents

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

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 standards language. The proposed code change creates a new prescriptive requirement for covered processes. Because this change will be applied to covered processes as opposed to space conditioning systems, this requirement will not allow for tradeoffs between exhaust systems and other HVAC fan systems if using the prescriptive approach. That being said, it will provide multiple pathways for compliance. If using the performance approach, tradeoffs between exhaust systems and other HVAC fan systems are allowed.

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

The proposed code change adds a definition of ANSI Z9.5 and Process Facility.

SECTION 140.9 – PRESCRIPTIVE REQUIREMENTS FOR COVERED PROCESSES

Subsection 140.9(c): The proposed code change requires that lab exhaust fans meet the discharge requirements of ANSI Z9.5. The proposed code change also adds a power consumption requirements for fan system power (max power use of 0.45 watts per cfm exhaust air). The proposed language allows the prescriptive compliance using one of three options: 1) meet watt per cfm requirement, 2) fan speed controls a rooftop anemometer, or 3) fan speed controls with a contaminant sensor. The proposed code change would include acceptability criteria for the design parameters to assure the exhaust airflow is appropriate to the facility.

SECTION 141.1 –PRESCRIPTIVE REQUIREMENTS FOR COVERED PROCESSES IN ADDITIONS, ALTERATIONS, TO EXISTING BUILDINGS

Subsection 141.1(f): The proposed code change requires that retrofits of labs and process facilities follow the requirements in section 140.9(c).

2.3.2 Reference Appendices Change Summary

This proposal modifies the following sections of 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.

APPENDIX JA1 – GLOSSARY: The proposed requirements add the definition of process facility.

APPENDIX NA7 – INSTALLATION AND ACCEPTANCE REQUIREMENTS FOR NONRESIDENTIAL BUILDINGS AND COVERED PROCESSES

Appendix NA7.5 Mechanical Systems Acceptance Tests: The proposed requirements add an acceptance test for fan-speed control and contaminant control of exhaust fans by a trained inspector.

2.3.3 Alternative Calculation Method (ACM) Reference Manual Change Summary

This proposal modifies the following sections of the Alternative Calculation Method (ACM) Reference Manual as shown below. See Section 7.3 of this report for the detailed proposed revisions to the text of the ACM Reference Manual.

SECTION 5.7 HVAC SECONDARY SYSTEMS: The proposed code changes establish a primary prescriptive path to be used for the performance method baseline.

2.3.4 Compliance Manual Change Summary

The proposed code change will modify the following Section 10.7 Laboratory Exhaust of the Nonresidential Compliance Manual.

2.3.5 Compliance Documents Change Summary

The proposed code change will alter the compliance documents listed below to certify that exhaust fan systems are installed and controlled correctly to comply with code. Examples of the revised documents are presented in Section 7.5.

- NRCC-PRC-01-E Compliance Certificate
- NRCC-PRC-09-E for Laboratory Exhaust Systems Requirements
- NRCA-PRC-04-F-Lab Exhaust

2.4 Regulatory Context

2.4.1 Existing Title 24, Part 6 Standards

There are two existing requirements in Title 24, Part 6 relevant to this measure. The first of which is in section 140.4(c) Power Consumption of Fans. In this section, the total fan power demand does not include fan system power caused by exempt process loads. This means that section 140.1(c) currently does not apply to laboratory exhaust fans or fans used in other process exhaust systems.

The second relevant section is section 140.9(c) Prescriptive Requirements for Laboratory Exhaust Systems, which requires that variable exhaust and makeup airflow be coordinated to achieve varied levels of demand and fan system capacity, as previously discussed in Measure History. The Statewide CASE Team is not recommending revisions to this requirement.

Additionally, there is a measure being proposed this code cycle for automatic sash control for fume hoods. A CASE Report for this measure is currently being developed.

2.4.2 Relationship to Other Title 24 Requirements

Lab discharge air is addressed in Title 24, Part 4. This code mandates that a lab "exhaust system shall discharge at a point where it will not cause a nuisance" and "from which it cannot be readily drawn in by a ventilating system." The codes also specify that "exhaust ducts discharging other product (heat, odors, smoke, etc.) shall terminate 10 ft. from the property line, 3 ft. from exterior walls and roofs, 10 ft. from openings into the building, and 10 ft. above adjoining grade." When the exhaust stream contains explosive or flammable vapors, the exhaust duct "shall terminate 30 ft. from the property line, 10 ft. from openings into the building, 30 ft. from combustible walls and openings in the building, and 10 ft. above adjoining grade."

It should also be noted that California Title 8: Industrial Relations, Subchapter 7. General Industry Safety Orders includes ventilation requirements for lab hood operations. Section 5154.1 Ventilation Requirements for Laboratory-Type Hood Operations subsection e4 states, "exhaust stacks shall be located in such a manner with respect to air intakes as to preclude the recirculation of laboratory-type hood emissions within a building." To protect employees on the roof, this code suggests a list of potential methods, one of which is designing "exhaust stacks extending at least 7 feet above the roof and discharging vertically upward." There are no specific regulations of distance between discharge stacks and air intakes in Title 8.

In addition to state regulations, there are also local regulations that influence lab exhaust design. Each municipality in California has a specific line of sight requirement. For example, labs located in municipalities that have a coastal view must have no stack in view on the bayside or Pacific Ocean side. Strict line of sight requirements increase the frequency of IEF specified in those municipalities. When lab exhaust systems are being designed, they must accommodate the planning requirements of the city in which they reside.

2.4.3 Relationship to Federal Laws

There do not appear to be any federal regulation related to lab exhaust design.

2.4.4 Relationship to Industry Standards

There are two existing model codes related to laboratory exhaust design which offer recommendations for minimum stack heights and discharge velocities. The first is the American National Standards Institute / American Industrial Hygiene Association Standard Z9.5: Laboratory Ventilation (*ANSI Z9.5 - Laboratory Ventilation*, 2012). This code requires that "exhaust discharge from stacks shall be in vertical-up direction at minimum of ten feet above adjacent roof line and located with respect to openings and air intakes to avoid reentry." Wind speed/direction control is not addressed in ANSI Z9.5, but rather the code necessitates that "exhaust discharge shall have discharge velocity of at least 3,000 feet per minute (fpm) for stack with internal condensation." Many manufacturers and designers believe ANSI Z9.5 claims that one can assume 3,000 fpm is a safe exit velocity for all conditions, however this is a misinterpretation of the standard. In reality, the standard dictates that one must conduct dispersion modeling to determine the safe operating parameters, which usually requires the employment of a wind consultant.

The second model code is the National Fire Protection Association (NFPA) Standard 45: Standard on Fire Protection for Laboratories Using Chemicals (*NFPA 45 Standard on Fire Protection for Laboratories Using Chemicals*, n.d.). NFPA 45 demands that "air exhausted from laboratory hoods shall be discharged above roof at a location, height, and velocity sufficient to prevent re-entry of chemicals" and that "exhaust stacks should extend at least ten feet above highest point on roof to protect personnel on roof."

In addition to ANSI Z9.5, NFPA 45, and Title 8, there is a relevant fan power limitation pressure drop adjustment in the most recent version of ASHRAE 90.1 for laboratory systems. Table 6.5.3.1-2 suggests that laboratory systems get a fan power limitation pressure drop adjustment of 2.15 in. of water.

In addition, there are numerous design guides and reference books that are commonly used in industry to aid in the design of lab exhaust systems. These design guides and reference books are not a regulation or requirement, but provide best practices for the design.

The ASHRAE Fundamentals Handbook 2013 is the most important reference, specifically chapter 24: Airflow Around Buildings. This chapter uses specific equations and methods from two chapters in the ASHRAE HVAC Application Handbook 2011. The first is Chapter 16: Laboratories, which has some high-level recommendations on stack heights and air intakes in Section 3.5. The second is chapter 45: Building Air Intake and Exhaust Design. This chapter explains that the "exhaust velocity should be maintained above 2000 fpm to provide adequate plume rise and dilution, but above 3000 to 4000 fpm, noise, vibration, and energy costs can become an important concern." It is also explained that at low exhaust velocities, "a taller stack may be needed to counteract downwash." This handbook suggests that "when a detailed dispersion modeling analysis is conducted…an analysis can determine the minimum exit velocity needed to maintain acceptable dilution versus stack height. Generally, the taller the stack, the lower the required exit velocity and hence fan energy."

As an industry standard, the handbook suggests that the exit velocity "should be at least 1.5 times the design speed at roof height in the approach wind to avoid stack wake downwash," as seen in Figure 4.

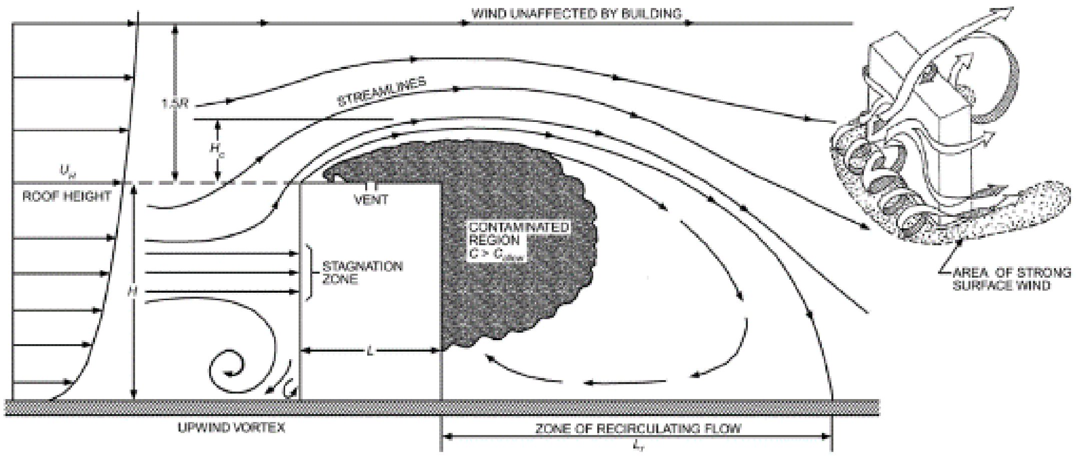

Figure 4: Diagram of air movement around a building

Source: 2011 ASHRAE Handbook - HVAC Applications, 2011

Another common practice suggested in the handbook is to use “a meteorological station design wind speed Umet that is exceeded less than one percent of the time” for the design wind speed. The handbook provides a geometric method for estimating stack height and a method for calculating the exhaust-to-intake dilution, which is discussed further in the Energy Savings section, and is diagrammed in Figure 5. Finally, the ASHRAE HVAC Applications Handbook indicates that “the plume rise…plus the physical stack height should not be considered equivalent to an effective stack height. A real stack of that height has better performance for two reasons: the effective height is achieved immediately instead of somewhere downstream, and the plume is higher than the effective height because of exhaust momentum. Stack height plus plume rise are additive in the geometric method as a simplification, but there are other conservatisms built into the geometric method to offset this approach.”

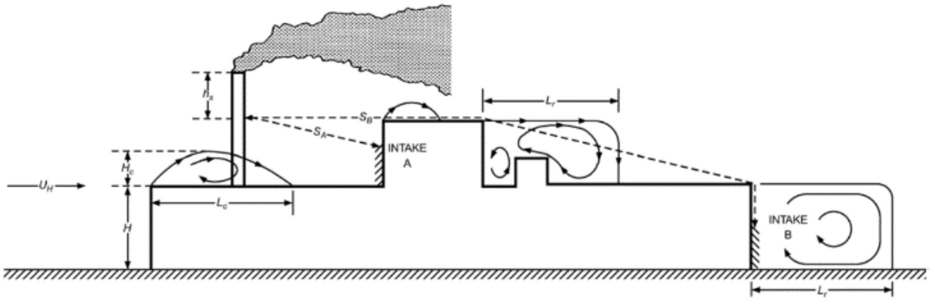

Figure 5: Diagram for establishing safe plume height

Source: 2011 ASHRAE Handbook - HVAC Applications, 2011

The next major design guide is the ASHRAE Laboratory Design Guide, specifically chapter 9: Exhaust Stack Design. This guide suggests that the “stack height must be sufficient to ensure that the exhaust plume is sufficiently diluted when it reaches sensitive areas or turbulent areas that include sensitive areas” and that “a counteractive force to the plume rise due to an increased exit velocity is a down-wash resulting from the exhaust air sticking to the leeward side of the stack relative to the wind direction.” The guide also recommends that “the stack exhaust velocity has to exceed 2,560 fpm to prevent rain from entering the stack and to prevent condensed moisture from draining into the stack. If the exhaust speed is lower than this during operation, stack designs with internal drains have to be installed to prevent water from entering the fan or pooling at low spots in the exhaust duct work." Different stack designs are laid out in Figure 6.

The Design Guide provides a series of equations (9-1 through 9-3) to calculate the effective plume height, where h_e is the effective plume height, h_s is the stack height, h_r is the plume rise, h_d is the down wash, V is the exit velocity, d is the windband diameter, and U is the design wind speed. These equations have been widely adopted by most exhaust fan manufacturers, and are used in the energy savings analysis.

$$h_e = h_s + h_r - h_d \qquad \text{(Equation 9-1)}$$

$$h_r = \frac{3Vd}{U} \qquad \text{(Equation 9-2)}$$

$$h_d = 2d\left(1.5 - \frac{V}{U}\right) \qquad \text{(Equation 9-3)}$$

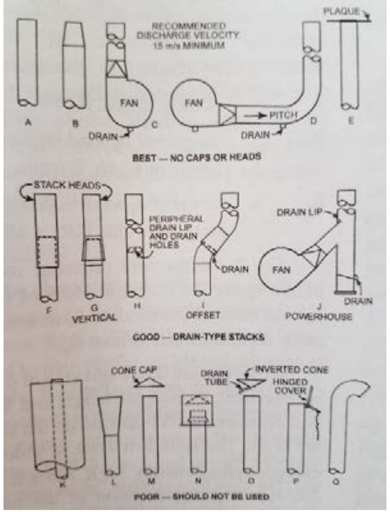

Figure 6: Stack designs

Source: McIntosh et al., 2001

Another relevant design guide is Industrial Ventilation: A Manual of Recommended Practice for Design, specifically section 5.12 Discharge Stacks. The manual explains that "the effect of wind on stack height varies with speed:

- At very low wind speeds, the exhaust jet from a vertical stack will rise above the roof level resulting in significant dilution at the air intakes.
- Increasing wind speed can decrease plume rise and consequently decrease dilution.
- Increasing wind speed can increase turbulence and consequently increase dilution."

Similar to the ASHRAE HVAC Applications Handbook, this manual recommends that "stack velocity should be at least 1.5 times the wind velocity to prevent downwash" and that "a good stack velocity is 3000 fpm, because it prevents downwash for winds up to 2000 fpm (22 mph). It also increases effective stack height and allows selection of a smaller centrifugal exhaust fan. It can also provide transport velocity if there is any particulate in the exhaust or if there is a failure of the air-cleaning device." The impacts of exit velocity and stack height are highlighted in Figure 7. Also, important to note for IEFs, the manual suggest that "high exit velocity is a poor substitute for stack height. For example, a stack located at roof elevation requires a velocity over 8000 fpm to penetrate the recirculation cavity boundary."

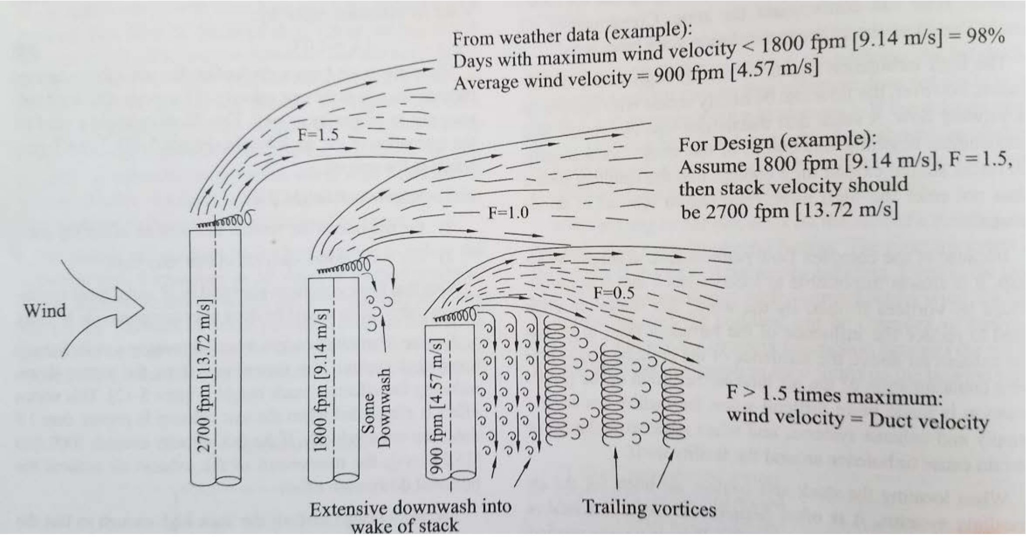

Figure 7: Impact of exit velocity and stack height

Source: Industrial Ventilation: A Manual of Recommended Practice for Design

Finally, the University of California (UC) has developed a guide to be followed for any new lab constructed on UC property titled the UC Lab Safety Design Manual, which can be found at: http://lsdm.ucop.edu/. This design guide, which is still undergoing modifications, requires that “fume hood exhaust should have vertical stacks that terminate at least 10 feet above the roof deck or two feet above the top of any parapet wall, whichever is greater.” This requirement is actually for the safety of maintenance workers on the roof, but is not necessarily sufficient for prevention of harmful contaminants entering the air intake. The design manual also requires a “minimum discharge velocity of 3,000 fpm” to meet “the dilution criteria necessary to reduce the concentration of hazardous materials in the exhaust to safe levels at all potential receptors.” The guide specifically mentions that “high-discharge velocity and temperature increase plume rise, but high velocity is generally less effective than increased stack height.” One major difference between the UC design manual and other design guides is that the UC manual explicitly declares that “considerations must be given to a wind-tunnel study to assure that re-entrainment of exhaust will not occur, and that potentially hazardous exhaust will not impact nearby buildings”, that “higher stacks may be found to be necessary…based on wind tunnel studies,” and that “actual height and placement shall be confirmed via 3-D modeling in a wind tunnel where building exhaust is likely to have significant ground level impact, or is likely to affect air intake for nearby buildings.”

2.5 Compliance and Enforcement

The Statewide CASE Team collected input during the stakeholder outreach process on what compliance and enforcement issues may be associated with these measures. This section summarizes how the proposed code change modifies 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 reduced.

This code change proposal will affect buildings that use the prescriptive approach and buildings that use the performance approach to compliance. The key steps changes to the compliance process are summarized below:

- **Design Phase**: Manufacturers will need to ensure that all exhaust fans, especially IEFs, are capable of wind-speed or contaminant control. In addition, mechanical designers will need to guarantee that the exhaust system they specify is designed to code. If the designer opts to use the performance approach, this translates to designers being required to find tradeoffs between exhaust fan energy and other building system energy. This will also likely require that mechanical designers collaborate more with controls engineers and wind consultants. Finally, controls engineers will be required to specify sensitivity and calibration of any sensor chosen for code compliance. If the performance approach is being used, energy consultants will need to coordinate the compliance options and complete the compliance documentation.
- **Permit Application Phase**: The permit office will be required to check that all equipment, including variable frequency drives and sensors, are specified correctly. The permit office will also be required to check that the designs meet all health and safety statutes, which will add some time and complexity to the review process.
- **Construction Phase**: For some pathways to compliance, rooftop anemometers or exhaust stack contaminant sensors will need to be installed. This will likely increase collaboration between installation teams.
- **Inspection Phase**: Inspections will be necessary to ensure that all sensors are installed properly, which will require the development of a new certificate of installation form. New acceptance test requirements will need to be established to certify that exhaust fans are being controlled correctly and that all sensors are calibrated. This will require inspectors to learn about the new acceptance test. These inspections will have to coordinate with all other agencies that currently conduct inspections related to lab pollution. The inspectors will also need to be trained to understand the system and controls, which would need to be integrated into the construction schedule and budget.

Compliance and enforcement of this measure is feasible. Enforcement should not add a large burden on building officials since lab exhaust is a health and safety issue that is already being addressed. The only major challenge in the performance compliance path will be adjusting CBECC-Com to set the baseline exhaust system power limit and to allow the energy modeler to incorporate one of the alternative compliance pathways. The software will have to provide an opportunity for the energy modeler to use wind-speed control or contaminant control of laboratory exhaust. Methods for modeling these strategies have not yet been developed fully. Those that will be responsible for updating the software must still be interviewed to understand the complexity of the software changes.

If this code change proposal is adopted, the Statewide CASE Team recommends that information presented in this section, Section 2.5 and Appendix B be used to develop a plan that identifies a process to develop compliance documentation and how to minimize barriers to compliance.

3. MARKET ANALYSIS

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. The Statewide CASE Team considered how the proposed standard may impact the market in general and individual market actors. The Statewide CASE Team gathered information about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, Energy Commission staff, and a wide range of industry players who were invited to participate in utility-sponsored stakeholder meetings held on December 13, 2016, and March 21, 2017.

3.1 Market Structure

Exhaust fans are considered life safety equipment and are therefore required for all labs and process facilities. Because of this requirement, the market for exhaust fans is extremely well established. California consists of about 7.5 percent of nationwide lab fan market. Roughly one-third of all lab exhaust systems specified in the state of California are IEFs (“Interview with Jim Meats, Loren Cook Company,” 2016). The market for these fan systems is dominated by five major manufacturers: Greenheck, Loren Cook, Strobic, Twin City, and MK Plastics. The IEF industry has an annual market size of approximately $5-6 million in California (“Interview with Jake Barker, Air Treatment Corporation,” 2016).

The anemometer market is also well established and dominated by two major suppliers: Vaisala and Lufft. Davis Instruments, headquartered in Hayward, California, is another anemometer manufacturer that has a smaller market penetration. Anemometers are also typically sold by any company that manufacturers or distributes weather stations. Another component that is necessary for anemometer control of an exhaust fan is a direct digital control (DDC) controller. The major manufactures in the DDC controller market include Johnson Controls, Siemens, and Honeywell, Reliable Controls Corporation, Delta Controls Inc., Distech Controls, Schneider Electric USA, Inc., Automated Logic Corporation, and Allerton. Although the anemometer market is established, there are not a lot of reported cases of anemometers being specified for exhaust fans.

The air contaminant sensor market is fairly small. This industry is led by Aircuity, Inc., which develops intelligent measurement sensors systems for demand control ventilation. They were founded in 2000 and are headquartered in Newton, Massachusetts. The leading manufacturer of Photo Ionization Detectors (PID), the actual sensors used to detect contaminants, is RAE Systems. RAE Systems, headquartered in San Jose, California, offers a full line of wirelessly enabled solutions including personal, hand-held, transportable, and fixed instruments designed for applications such as PID. Currently, Aircuity is the only company that provides a fully integrated suite of contaminant sensors and controls. However, PIDs can be setup and installed for contaminant exhaust control without the fully integrated package provided by Aircuity, for a significantly lower price. This simply requires more time and effort in the design process for establishing the control sequences that must be put in place with the PIDs.

The last industry relevant to this measure is the wind consulting and wind tunnel testing market. This is a very specialized market and is typically only engaged in specific design scenarios. This measure will likely increase the applicability of this market. The wind consulting market is dominated by the following companies: Cermak Peterka & Petersen (CPP) Wind Engineering Consultants; Ambient Air Technologies; Rowan Williams Davies & Irwin (RWDI) Inc.; and Arup.

3.2 Technical Feasibility, Market Availability, and Current Practices

The market is well equipped to supply the necessary products and services in response to this code change. Due to the fact that the primary pathway towards compliance can only be achieved with conventional exhaust stacks, this measure will likely increase the specification of conventional exhaust stacks. For cases in which conventional exhaust stacks are not an option, the measure will likely increase the specification of IEFs paired with anemometer control and IEFs paired with contaminant sensor control. Because the exhaust fan market is already so established, the increased demand for conventional stacks should not cause any stress on the market. Regarding IEFs, most manufacturers are already producing products that are capable of wind-speed control. Almost all IEFs already contain a variable frequency drive. Some companies even have products on the market that are specifically tailored to wind speed/direction control, such as Loren Cook. Loren Cook has a product on the market named the Powered Induction Fan. This product contains separate fans for the exhaust air and entrained air, and is specifically designed to modulate the entrained air fan speed by wind-speed control.

In the last few years, there have been several implementations of lab exhaust system design that are relevant to the proposed measure. One tactic that has been trending is the use of wind consultants to conduct wind tunnel testing and analysis in order to optimize the exhaust stack height and placement (Gudorf, n.d.). Another tendency amongst high performance labs is the act of weighing stack performance above stack aesthetic and choosing conventional exhaust systems (Gudorf, n.d.; “Interview with Justin Lewis, UC Davis,” 2016). For those high-performance labs that do choose to employ IEF, there is a trend toward utilizing wind-speed controlled exhaust (“Interview with Justin Lewis, UC Davis,” 2016; Neuman, 2012). Many labs in the California are employing wind-responsive exhaust systems, including Genentech, Novartis, University of California San Diego, University of California Davis, University of California Santa Barbara, University of California Berkeley, San Diego State University, and Cedars Sinai Hospital (“Interview with Brad Cochran, CPP Wind Engineering & Air Quality Consultants,” 2017). Some high performance labs are going in a different direction and staging their system with multiple exhaust fans and stacks, such as the J. Craig Venter Institute (Thomas et al., 2011). Finally, numerous labs in medical research and bio/life sciences have been employing the use of contaminant sensors in their exhaust plenum and have found that the contaminant threshold level is being exceeded much less frequently than anticipated during design, allowing for exhaust fan speed to be ramped down for low contaminant conditions (Sharp, 2010).

There are a number of concerns regarding feasibility, reliability, and safety of the proposed measure. The first concern is that manufacturers and designers might assume that IEFs are more effective at diluting pollutants without wind-speed control. This should not be a concern as long as the system is designed properly (i.e. the exhaust stream is not within reach of air intakes). On the contrary, wind-speed control has the capability of ensuring safer conditions for high wind-speed situations, in which typically specified IEFs, designed for a constant exit velocity of 3,000 fpm, might not be releasing the air with enough momentum to achieve an effective stack height above the air intakes.

It is also possible that there will be hesitancy from building owners to rely on wind sensors or contaminant sensors to ensure safe discharge of pollutant exhaust. Periodic calibration of the rooftop anemometer or contaminant sensor should be done to ensure persistence of safe discharge. Additionally, there could be push-back from building owners because this measure will likely necessitate the employment of wind consultants, which can be a costly addition to a project. While this may be the case, truly safe conditions for the building occupants cannot be met unless this type of wind analysis is conducted and therefore safety should be placed above additional first cost.

3.3 Market Impacts and Economic Assessments

3.3.1 Impact on Builders

It is expected that builders will not be impacted significantly by any one proposed code change or the collective effect of all of the proposed changes to Title 24, Part 6. Builders could be impacted for change in demand for new buildings and by construction costs. Demand for new buildings is driven more by factors, such as the overall health of the economy and population growth than the cost of construction. The cost of complying with Title 24, Part 6 requirements represents a very small portion of the total building value. Increasing the building cost by a fraction of a percent is not expected to have a significant impact on demand for new buildings or the builders’ profits.

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

The impact on builders will be:

- Increased time for installation of sensors
- Increased time for programming controls
- Increased time for acceptance testing and coordination to find qualified individuals to conduct the inspections
- Increased liability placed on the builder for performance of the system.

For more information, see Appendix B.

3.3.2 Impact on Building Designers and Energy Consultants

Adjusting design practices to comply with changing building codes practices is within the normal practices of building designers. Building codes (including the California Building code and model national building codes published by the International Code Council, the International Association of Plumbing and Mechanical Officials and ASHRAE 90.1) are typically updated on a three-year revision cycles. As discussed in Section 3.3.1, all market actors should (and do) plan for training and education that may be required to adjusting design practices to accommodate compliance with new building codes. As a whole, the measures the Statewide CASE Team is proposing for the 2019 code cycle aim to provide designers and energy consultants with opportunities to comply with code requirements in multiple ways, thereby providing flexibility in requirements can be met.

Because this measure presents multiple pathways towards compliance, building designers and energy consultants need to be prepared to deal with any of the pathways. Most building designers and energy consultants who deal with labs in the state of California are already familiar with the process of employing a conventional stack exhaust system and staging of multiple exhaust fans. Anemometer control and contaminant sensor control are not currently widely deployed strategies and therefore additional time will be necessary for designers and modelers to learn and understand the energy implications of these strategies. It is suggested that guidelines be developed to help designers determine which pathway towards compliance makes the most sense for their specific scenario. In addition, energy consultants will have an extra step in the modeling process to specify which type of exhaust system and lab exhaust system control is being used for the proposed model in CBECC-Com. For more information, see Appendix B.

3.3.3 Impact on Occupational Safety and Health

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

3.3.4 Impact on Building Owners and Occupants

Building owners and occupants will benefit from lower energy bills. As energy efficiency standards become more stringent, occupants of nonresidential buildings will benefit from energy cost savings. As discussed in Section 3.4.1, when building occupants save on energy bills, they tend to spend it elsewhere in the economy, thereby creating jobs and economic growth for the California economy.

For this specific measure, owners will need to weigh the pros and cons of having a low-energy aesthetically unappealing conventional stack exhaust system versus a high-energy induction exhaust system with additional sensor control. If the latter is chosen, owners will need to decide if the energy cost savings outweigh the first costs and maintenance costs of the sensor systems. Maintenance costs will include training and/or hiring of maintenance staff that are equipped to check sensors and make sure they stay calibrated. This will entail additional training for maintenance staff. Wind speed/direction control or contaminant control will ensure that plume rise is sufficient to avoid air inlets at all conditions, and therefore should improve the safety and health of all building occupants. For more information, see Appendix B.

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

Manufacturers will have to guarantee their exhaust systems are compatible with wind-speed control and contaminant control. It is likely that there will be a decrease in demand for IEFs in California and an increase in demand for conventional systems. Finally, this measure will probably boost sales in California for anemometers and contaminant sensors. For more information, see Appendix B.

3.3.6 Impact on Building Inspectors

This measure will dictate that inspectors conduct a new acceptance test for laboratory exhaust systems. Building departments will have to check plans, make sure all other codes are not affected, ensure that everything is within health and safety parameters, and review on site acceptance testing documentation before the final occupancy permit provided.

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. This measure likely will not have an impact on statewide employment.

3.4 Economic Impacts

As a whole, the energy consumption of the products being impacted by this code change in new construction is estimated to be 56 GWh/year. This value is based on the following assumptions:

- Labs and process facilities have an average energy use intensity of 250 kBtu/ft^2. This comes from the Laboratories for the 21st Century Benchmarking Database.
- Ventilation accounts for 45 percent of lab energy (Thomas et al., 2011).
- Exhaust accounts for 40 percent of facility ventilation energy, or 18 percent of total lab energy (Neuman, 2012).
- There are 4.3 million square feet of new lab & process facility construction (see details in Section 4.1).

At a cost of $0.17/kWh, there will be a total of about $9.6 million spent in the next year on lab and process facility exhaust electricity consumption. This measure has the opportunity to drastically reduce the amount of money spent on lab exhaust.

Looking at the first cost impact of the measure, there are a number of potential outcomes. If a lab were to choose a conventional stack rather than an induction exhaust fan, there would be a reduction in first cost. Induction exhaust systems are typically more expensive than conventional exhaust systems ("Interview with Chet Wisner, Ambient Air Technologies, LLC," 2017).

If a lab were to choose an IEF paired with a rooftop anemometer, there will be a slightly higher first cost. However, the additional cost of the rooftop anemometer is only about five percent of the cost of fan equipment, so the difference is nominal ("Interview with Brent Eubanks, Integral Group," 2016). If a lab were to choose an induction exhaust fan paired with contaminant sensors, this could add a sizeable amount to the first cost.

Looking at statewide economic effects, the measure likely will not have a noticeable impact. It is possible that the measure will increase the number of conventional stacks specified and decrease the number of IEFs specified. However, neither of these systems have manufacturers in California and both will likely remain prevalent in the state.

Although it is unlikely for the measure to change the exhaust fan market, the measure does have the ability to influence the sensor market and wind consulting market in California. It is likely that the number of anemometers and contaminant sensors specified by lab designers will increase if this measure is implemented. For the most part, these sensors are not manufactured in California, but there will be an increase in demand for sensor technology from the labs in California, and therefore this will lead to increased distribution of these products across the state. Regarding wind consulting, the execution of this code change will likely increase the request for services from wind consultants, which might help boost the wind consulting industry in California.

Finally, there is a possibility that this measure could impact the building retrofit market in California. The code change will require that any lab or process facility retrofit in the state must include a retrofit of its exhaust system, if not already designed to code. This could add additional costs to the retrofit budget if the lab owners were not originally intending to retrofit the exhaust system, which could change the economic viability of the lab retrofit.

The estimated impacts that the proposed code change will have on California's economy are discussed below.

3.4.1 Creation or Elimination of Jobs

In 2015, California's building energy efficiency industry employed more than 321,000 workers who worked at least part time or a fraction of their time on activities related to building efficiency. Employment in the building energy efficiency industry grew six percent between 2014 and 2015 while the overall statewide employment grew three percent (BW Research Partnership 2016). Lawrence Berkeley National Laboratory's report 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 (Goldman, et al. 2010).

Building codes that reduce energy consumption provide jobs through *direct employment*, *indirect employment*, and *induced employment*.[1] Title 24, Part 6 creates jobs in all three categories with a significant amount attributed to induced employment, which accounts for the expenditure-induced effects in the general economy due to the economic activity and spending of direct and indirect employees (e.g., non-industry jobs created, such as teachers, grocery store clerks, and postal workers). A large portion of the induced jobs from energy efficiency are the jobs created by the energy cost savings due to the energy efficiency measures. For example, as mentioned in Section 3.3.4, the 2016 Standards are expected to save single family homeowners about $240 per year. Money saved from hundreds of thousands of homeowners over the entire building life will be reinvested in local businesses. Wei, Patadia, and Kammen (2010) estimate that energy efficiency creates 0.17 to 0.59 net job-years[2] per GWh saved. By comparison, they estimate that the coal and natural gas industries create 0.11 net job-years per GWh produced. When utilizing a mid-point for the energy efficiency range (0.38 net job-years per GWh saved), the estimates that this proposed code change will result in 9.3 GWh of

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[1] 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."

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

savings statewide in the first year the 2019 standards are in effect; the resulting job creation will be a projected 3.5 jobs in the first year. See Section 6.1 for statewide savings estimates.

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

Table 3: Industries Receiving Energy Efficiency Related Investment, by North American Industry Classification System (NAICS) Code

Industry	NAICS Code
Electrical Contractors	23821
Manufacturing	32412
Industrial Machinery Manufacturing	3332
Ventilation, Heating, Air-Conditioning, & Commercial Refrigeration Equip. Manf.	3334
Communications Equipment Manufacturing	3342
Engineering Services	541330
Building Inspection Services	541350
Other Scientific and Technical Consulting Services	541690
Commercial & Industrial Machinery & Equip. (exc. Auto. & Electronic) Repair & Maint.	811310

Because this measure will provide pathways toward compliance through the use of different sensor technologies, there will likely be increased demand for this equipment in the state of California. Therefore, it is possible that new businesses will be created in the state of California for the manufacturing, distribution, and installation of rooftop anemometer stations and contaminant sensors. Currently, these industries are dominated by companies in other states, but this is an opportunity for small businesses to develop in California.

In addition, the necessity to meet discharge requirements in ANSI Z9.5 will likely increase the demand for services of wind consultants. Most existing wind consultants are located outside of the state of California. This increase in demand presents an opportunity for the creation of new wind consulting firms in California.

3.4.3 Competitive Advantages or Disadvantages for Businesses in California

In 2014, California's electricity statewide costs were 1.7 percent of the state's gross domestic product (GPD) while electricity costs in the rest of the United States were 2.4 percent of GDP (Thornberg, Chong and Fowler 2016). As a result of spending a smaller portion of overall GDP on electricity relative to other states, Californians and California businesses save billions of dollars in energy costs per year relative to businesses located elsewhere. 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 that impact nonresidential buildings.

By limiting exhaust power for labs, institutions managing labs can save money on their annual energy bill and use this money for alternative purposes. In addition, dispersion analysis will allow these institutions to support occupant safety, giving them better health security. This measure will therefore provide a competitive advantage to institutions who are assembling, manufacturing, or conducting testing and research (with nonhazardous materials) in California over those undergoing these activities in other states.

3.4.4 *Increase or Decrease of Investments in the State of California*

The proposed changes to the building code are not expected to impact investments in California on a macroeconomic scale, nor are they expected to affect investments by individual firms. The allocation of resources for the production of goods in California is not expected to change as a result of this code change proposal.

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

The proposed code changes are not expected to have a significant impact on the California's General Fund, any state special funds, or local government funds. Revenue to these funds comes from taxes levied. The most relevant taxes to consider for this proposed code change are: personal income taxes, corporation taxes, sales and use taxes, property taxes, and business taxes. The proposed changes for the 2019 Title 24, Part 6 standards are not expected to result in noteworthy changes to personal or corporate income, so the revenue from personal income taxes or corporate taxes is not expected to change. As discussed, reductions in energy expenditures are expected to increase discretionary income. State and local sales tax revenues may increase if building 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. There is no statistical evidence that Title 24, Part 6 drives construction costs or that construction costs have a significant impact on building price. Since compliance with Title 24, Part 6 does not have a clear impact on purchase price, it can follow that Title 24, Part 6 cannot be shown to impact revenues from property taxes.

3.4.5.1 Cost of Enforcement

Cost to the State

State government already has budget for code development, education, and compliance enforcement. While state government will be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised standards, these activities are already covered by existing state budgets. The costs to state government are small when compared to the overall costs savings and policy benefits associated with the code change proposals. These costs will include adjusting CBECC-Com to provide options for laboratory exhaust control, developing a new acceptance test form, and revising existing certificates of compliance documents.

Cost to Local Governments

All revisions to Title 24, Part 6 will result in changes to compliance determinations. Local governments will need to train building department staff on the revised Title 24, Part 6 Standards. While this re-training is an expense to local governments, it is not a new cost associated with the 2019 code change cycle. The building code is updated on a triennial basis, and local governments plan and budget for retraining every time the code is updated. There are numerous resources available to local governments to support compliance training that can help mitigate the cost of retraining, including tools, training and resources provided by the IOU codes and standards program (such as Energy Code Ace). As noted in Section 2.5 and Appendix C, the Statewide CASE Team considered how the proposed code change might impact various market actors involved in the compliance and enforcement process and aimed to minimize negative impacts on local governments.

3.4.6 Impacts on Specific Persons

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

4. ENERGY SAVINGS

4.1 Key Assumptions for Energy Savings Analysis

The assumptions used to conduct energy savings analysis are as follows for both baseline and proposed conditions:

- Laboratory operating hours are from 9 AM – 5 PM Monday through Friday. These operating hours reflect the typical working hours in the United States
- Laboratories have an exhaust airflow rate of 10 ACH during occupied hours. This value is a conservative exhaust airflow rate used by professional mechanical designers. The 2016 Title-24 ACM Reference manual uses 15 ACH for “hood-dominated labs” and 6 ACH for “load-dominated labs”.
- There is 40 percent turn down on exhaust airflow rates during unoccupied hours. This assumption is based on reduced occupancy ventilation and reduced equipment usage while unoccupied.
- The desired effective plume height for the exhaust plume is at least 20 feet above roof level.
- The total static pressure of the exhaust system is 4 inches. Baseline laboratory exhaust static pressure for comparison was compared to the prescriptive allowance for laboratory spaces in ASHRAE 90.1, 2013. The baseline static is based on a variable air volume system. 1 inch is attributed to exhaust baseline fan, pressure credits for a laboratory (2.15 inches), exhaust controls (0.5 inches) and laboratories serving fume hoods (0.35 inches). This resulted in a total baseline fan static pressure of 4.0 inches.
- Laboratory air intakes are located on the roof approximately 30 feet from the exhaust stack.
- Laboratories exist in primarily urban environments.
- Laboratories have a maximum contaminant concentration criterion of 400 (µg/m3)/(g/s). This value is found in ASHRAE Fundamental Chapter 45.
- Laboratories in California fall in one of five buckets of square footage: 1,000 ft^2, 2,000 ft^2, 5,000 ft^2, 10,000 ft^2 or 20,000 ft^2. These laboratory sizes were used for the analysis conducted in the Market Assessment of Energy Efficiency Opportunities in Laboratories, a study conducted by the Center for Energy Efficient Laboratories (http://www.etcc-ca.com/sites/default/files/reports/ceel_market_assessment_et14pge7591.pdf).
- Laboratories in California fall in one of four categories: hospital labs, nonprofit labs, academic labs, and private research labs. These laboratory categories were used for the analysis conducted in the Market Assessment of Energy Efficiency Opportunities in Laboratories. The existing California laboratory building stock consists of 8 million square feet of hospital labs, 3 million square feet of nonprofit labs, 24.5 million square feet of academic labs, and 68 million square feet of private research labs.
- It is assumed that the fraction of each building type that is occupied by laboratory space in the existing building stocks remains the same for new construction. The breakdown of existing buildings square footage, by building type, was obtained from the Commercial Buildings Energy Consumption Survey (CBECS).

- Approximately 33 percent of new laboratories in California specify IEFs. This value is based on manufacturer estimates, along with restrictions on stack height along the California coast ("Interview with Jim Meats, Loren Cook Company," 2016). The other 67 percent of new laboratories in California specify conventional exhaust systems.

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, specifically the use of rooftop anemometer control. There are no existing Title 24, Part 6 requirements that cover the building system in question, so the Statewide CASE Team used current design practices as the existing conditions.

The Statewide CASE Team decided not to use prototype models to calculate energy impacts because the energy savings from this measure all coming from reduced fan power, and it was more appropriate to perform spreadsheet modeling that specifically isolated savings from fan energy. In addition, since there is no existing baseline for laboratory exhaust in Title 24, Part 6, and there are no existing rulesets in CBECC-Com, it would not be possible to determine the savings from this measure using CBECC-Com models. Since CBECC-Com was not used to calculate savings, the analysis does not account for the secondary savings associated with space heating and cooling; the energy savings estimates are conservative as a result.

Because the market consists of both induction exhaust fans and conventional exhaust fans, two different analyses were conducted. The first analysis, for conventional exhaust fans, used a baseline system run at a constant fan efficiency of 60 percent, which equated to 0.78 W/cfm. The proposed conditions are defined as the design conditions that will comply with the proposed code change. Specifically, the proposed code change will ensure that the system achieves 0.65 W/cfm. The energy savings from this measure varies by climate zone. As a result, the energy impacts and cost-effectiveness were evaluated by climate zone. To evaluate energy impacts, exhaust fans were sized and priced using the Loren Cook fan sizing tool. Fan laws were then used to determine the hourly fan power at varying airflow rates. The baseline fan power was compared to the code compliant fan power to see the energy savings from this measure. This process was repeated for five size laboratories (as discussed in the key assumptions).

The second analysis, for induction exhaust fans, used the wind-responsive pathway toward compliance. The baseline system used induction exhaust systems designed to have a minimum exit velocity of 3,000 fpm. This value reflects that specified in ANSI/AIHA Z9.5-2012. The proposed system used induction exhaust fans designed to fluctuate exit velocity depending on wind conditions. The proposed conditions are defined as the design conditions that will comply with the proposed code change. Specifically, the proposed code change will ensure that the fan power for IEFs is reduced when there are favorable wind conditions. The energy savings from this measure varies by climate zone. As a result, the energy impacts and cost-effectiveness were evaluated by climate zone. To evaluate energy impacts for each climate zone, the following approach was taken. First, hourly wind speed data was collected from the Typical Meteorological Year weather file (TMY3) of each climate zone. Next, IEF parameters were obtained for different exhaust airflow rates, including maximum motor power, entrained airflow rate, number of exhaust stacks, stack height, and windband diameter. These parameters were provided from the Loren Cook fan sizing tool. The fans were sized using ASHRAE one percent extreme wind speeds for each climate zone. Although there are a number of assumptions in this analysis that are not reflective of every possible case in California, it was confirmed by experts in the wind consulting industry that this methodology is acceptable for making estimates of energy savings from wind responsive exhaust systems.

Using the above-mentioned data, the necessary IEF exit velocity was calculated for each hour to achieve the desired effective plume height. This was calculated using equation 9-1 from the ASHRAE

Laboratory Design Guide. The hourly exit velocity was then adjusted to attain the maximum allowable pollutant concentration. This was calculated using ASHRAE plume dispersion equations. Finally, the hourly exit velocity was adjusted to ensure minimum exhaust airflow rates were being reached. Using the final hourly exit velocities, the hourly fan power with wind-speed control was calculated. As a first round of analysis, the fan power was estimated using a methodology from the article Saving Energy in Lab Exhaust Systems, ASHRAE Journal, June 2011. As a second round of analysis, fan laws were used to determine the fan power. The wind speed-controlled fan power was compared to the typically designed induction fan power to see the energy savings from this measure. This process was repeated for five size laboratories (as discussed in the key assumptions) and for three different pollutant concentration limits at rooftop level: 100, 1,000, and 10,000 (µg/m3)/(g/s).

Once both analyses were completed, two-thirds of the savings attributed to conventional systems and one-third of the savings attributed to induction exhaust fans were tabulated, representative of the total savings across California. Energy savings, energy cost savings, and peak demand reductions were calculated using a TDV (Time Dependent Valuation) methodology.

4.3 Per-Unit Energy Impacts Results

Energy savings and peak demand reductions per-unit for conventional exhaust systems are presented in Table 5. Per-unit savings for the first-year are expected to equal 0.98 kilowatt-hours per square foot per year (kWh/sf-yr) in every climate zone. Labs range from 1,000 to 20,000 square feet in size. Peak demand reductions are not expected because design conditions for exhaust systems are the same for the baseline and proposed models. This measure will not have potential for demand response because the measure impacts life safety equipment and wind is unpredictable. This measure will not have any natural gas savings because all the energy savings analyzed comes from reduced fan power, rather than space conditioning.

Table 4: First-Year Energy Impacts per Square Foot for Conventional Exhaust Systems

Climate Zone	Electricity Savings (kWh/ft^2/yr)	Peak Electricity Demand Reductions (kW/ft^2)	Natural Gas Savings (therms/ft^2-yr)	TDV Energy Savings (TDV kBtu/ft^2/yr)
1	0.98	2.2×10^{-4}	N/A	26
2	0.98	2.2×10^{-4}	N/A	27
3	0.98	2.2×10^{-4}	N/A	26
4	0.98	2.2×10^{-4}	N/A	28
5	0.98	2.2×10^{-4}	N/A	26
6	0.98	2.2×10^{-4}	N/A	28
7	0.98	2.2×10^{-4}	N/A	28
8	0.98	2.2×10^{-4}	N/A	28
9	0.98	2.2×10^{-4}	N/A	28
10	0.98	2.2×10^{-4}	N/A	28
11	0.98	2.2×10^{-4}	N/A	28
12	0.98	2.2×10^{-4}	N/A	28
13	0.98	2.2×10^{-4}	N/A	28
14	0.98	2.2×10^{-4}	N/A	28
15	0.98	2.2×10^{-4}	N/A	28
16	0.98	2.2×10^{-4}	N/A	26

Energy savings and peak demand reductions per-unit for induction exhaust systems are presented in Table 5. Per-unit savings for the first-year are expected to range from a high of 6.2 kilowatt-hours per square foot per year (kWh/sf-yr) in Climate Zone 2 to a low of 0.2 kWh/yr in Climate Zone 14. Labs range from 1,000 to 20,000 square feet in size. Peak demand reductions are not expected because design conditions for exhaust systems are the same for the baseline and proposed models. This measure will not have potential for demand response because the measure impacts life safety equipment and wind is unpredictable. This measure also will not have any natural gas savings because all the energy savings analyzed comes from reduced fan power, rather than space conditioning.

Table 5: First-Year Energy Impacts per Square Foot for Induction Exhaust Systems[3]

Climate Zone	Electricity Savings (kWh/ft^2/yr)	Peak Electricity Demand Reductions (kW/ft^2)	Natural Gas Savings (therms/ft^2-yr)	TDV Energy Savings (TDV kBtu/ft^2/yr)
1	4.6	0	N/A	139
2	6.2	0	N/A	173
3	2.7	0	N/A	75
4	4.5	0	N/A	127
5	3.8	0	N/A	120
6	4.9	0	N/A	125
7	5.5	0	N/A	157
8	5.9	0	N/A	162
9	5.5	0	N/A	152
10	5.7	0	N/A	159
11	1.1	0	N/A	48
12	2.9	0	N/A	84
13	5.7	0	N/A	160
14	0.1	0	N/A	8
15	2.2	0	N/A	58
16	4.2	0	N/A	135

The per-unit TDV energy cost savings over the 15-year period of analysis are presented in

Table 7 These are presented as the discounted present value of the energy cost savings over the analysis period.

5. LIFECYCLE COST AND COST-EFFECTIVENESS

5.1 Energy Cost Savings Methodology

Time Dependent Valuation (TDV) energy is a normalized format for comparing electricity and natural gas cost savings that takes into account the cost of electricity and natural gas consumed during each hour of the year. The TDV values are based on long term discounted costs (30 years for all residential measures and nonresidential envelope measures and 15 years for all other nonresidential measures). In this case, the period of analysis used is 15 years. The TDV cost impacts are presented in 2020 present 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 (kW). The Energy Commission derived the 2020 TDV values that were used in the analyses for this report (Energy Commission 2016).

- Spreadsheet modeling (Microsoft Excel) used to quantify energy savings and peak electricity demand reductions resulting from proposed measure

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[3] Updated values in climate zones 11-16 in the December 2017 report revision.

- Benefits could not be quantified using the Standards reference methods (CBECC-Com) because there is no existing CBECC-Com module for this measure
- Enhancement in CBECC-Com needed to allow for wind-speed dependent or contaminant dependent exhaust fan power

5.2 Energy Cost Savings Results

The TDV energy cost savings for conventional exhaust systems presented in Table 6 are given per square foot of laboratory space in the given climate zone. The breakdown of laboratory spaces is explained in Section 4.1.

Table 6: TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot for Conventional Exhaust Systems[4]

Climate Zone	15-Year TDV Electricity Cost Savings (2020 PV $/ft^2)	15-Year TDV Natural Gas Cost Savings (2020 PV $/ft^2)	Total 15-Year TDV Energy Cost Savings (2020 PV $/ft^2)
1	$2.29	N/A	$2.29
2	$2.44	N/A	$2.44
3	$2.33	N/A	$2.33
4	$2.48	N/A	$2.48
5	$2.34	N/A	$2.34
6	$2.45	N/A	$2.45
7	$2.45	N/A	$2.45
8	$2.50	N/A	$2.50
9	$2.49	N/A	$2.49
10	$2.50	N/A	$2.50
11	$2.52	N/A	$2.52
12	$2.48	N/A	$2.48
13	$2.46	N/A	$2.46
14	$2.51	N/A	$2.51
15	$2.50	N/A	$2.50
16	$2.32	N/A	$2.32

The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. The savings from wind-responsive control likely will not be attributed to peak periods. Because wind speed is not correlated to peak heating or cooling conditions, and the savings from this measure are dependent upon wind speed, this suggests that the savings from wind-speed control also will not be correlated to peak heating or cooling conditions. Conversely, the savings will be most significant during low wind-speed conditions, in which the baseline exhaust fans are running at 3,000 fpm exit velocities, whereas wind-speed controlled exhaust fans are running at lower exit velocities.

The TDV energy cost savings for induction exhaust fans presented in Table 7 are given per square foot of laboratory space in the given climate zone.

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[4] Updated all values in the December 2017 report revision.

Table 7: TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot for Induction Exhaust Systems[5]

Climate Zone	15-Year TDV Electricity Cost Savings (2020 PV $/ft^2)	15-Year TDV Natural Gas Cost Savings (2020 PV $/ft^2)	Total 15-Year TDV Energy Cost Savings (2020 PV $/ft^2)
1	$12.34	N/A	$12.34
2	$15.44	N/A	$15.44
3	$6.66	N/A	$6.66
4	$11.33	N/A	$11.33
5	$10.69	N/A	$10.69
6	$11.13	N/A	$11.13
7	$13.99	N/A	$13.99
8	$14.46	N/A	$14.46
9	$13.57	N/A	$13.57
10	$14.15	N/A	$14.15
11	$4.23	N/A	$4.23
12	$7.51	N/A	$7.51
13	$14.25	N/A	$14.25
14	$0.69	N/A	$0.69
15	$5.12	N/A	$5.12
16	$12.02	N/A	$12.02

5.3 Incremental First Cost

To comply with the primary prescriptive pathway, the additional first costs associated with designing a system below 0.65 W/cfm have been calculated using the Loren Cook fan sizing tool. Fans were sized for each lab type and the price difference was calculated between the least expensive option and least expensive code-compliant option. The price difference ranged from $50, for the smallest fan, to $1,400, for the largest fan.

It is likely that many current induction exhaust fans on the market will use more than the 0.65 W/cfm limit, thereby forcing the designer to choose a conventional exhaust system, or chose an alternative pathway towards compliance. As shown in Figure 8, conventional exhaust systems are less expensive than induction exhaust systems, suggesting that this code change would save money rather than create an additional financial burden. In addition, the first cost savings for a conventional system increase as the building size increases. This data suggests that conventional stack systems are approximately $2.00/ft^2, whereas induction exhaust systems are about $3.70/ft^2.

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[5] Updated values in climate zones 11-16 in the December 2017 report revision.

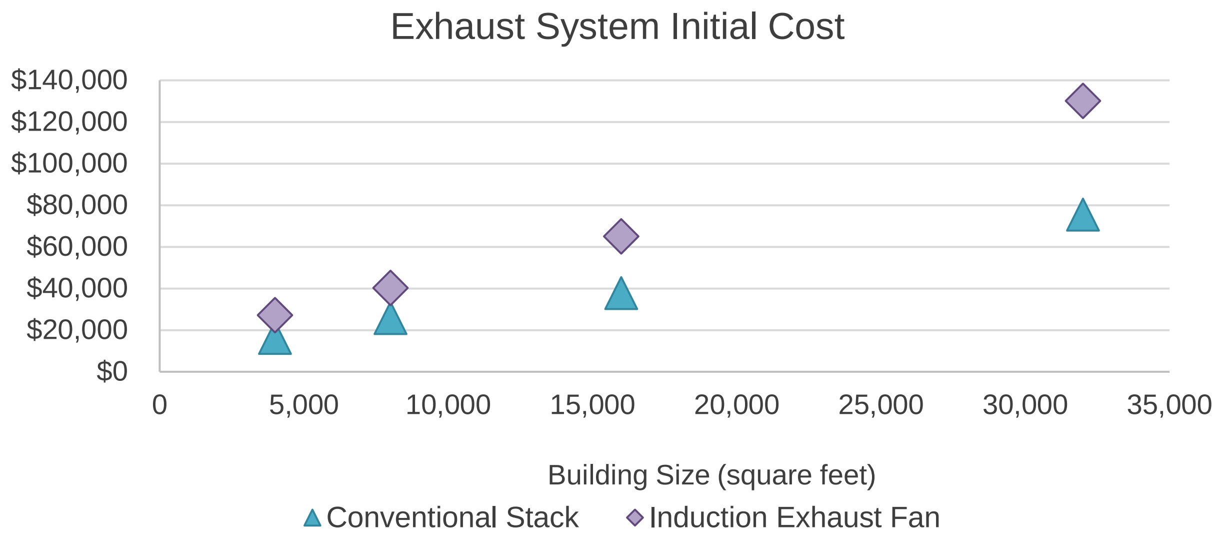

Figure 8: Exhaust airflow rate vs. initial cost (Loren Cook Sizing Tool)

The additional costs that result from implementing this measure are the costs associated with the purchase and installation of rooftop anemometers or contaminant sensor. If the designer chooses to use the rooftop anemometer approach, each laboratory facility would need only one rooftop anemometer regardless of square footage. From conversations held with professional controls engineers, the first cost of all equipment, supplies, and installation of a rooftop anemometer is approximately $2,500. This can be broken down into the following: $1,800 for a calibrated device with a low temperature range, $250 for cable, $200 for a mounting adapter, and $250 for a bird screen. The labor cost for installing a rooftop anemometer and connecting it to the energy management control system for controls integration is $2,500. There is typically no additional first cost associated with the actual exhaust fan that has wind speed/direction control capability because fans specified for California must already be installed with a variable frequency drive by code. The total incremental first cost for a wind-responsive system is $5,000.

In addition to hard costs and labor costs, there are also additional design costs associated with a wind-responsive system. One supplementary design cost is that associated with structural engineering services to design the anemometer mount, which equates to $5,000. To comply with ANSI Z9.5, the lab would also need to employ wind consultants to do dispersion modeling or wind tunnel testing. According to professionals in the field, a wind tunnel study can add an additional $10,000 to $30,000 to the budget. Finally, the additional services of evaluating the current operating conditions, developing a sequence of operations, and updating and reviewing code adds an additional $10,000 to $20,000 to the budget. These design costs have not been included in the lifecycle cost analysis because design costs are not considered for Title 24, Part 6 cost-effectiveness analyses, but are provided here for reference.

If the designer chose to use the contaminant sensor approach, the first cost of all equipment, supplies, and installation of the system is approximately $70,000. This can be broken down into the following: $31,000 for sensor suite, routers, probes, pumps, structured cable, and system integrator; $9,500 for services commitment; $1,500 for optimization; $12,000 for engineering and programming; $8,900 for installation; $4,500 for startup; and $2,600 for taxes. These values were obtained from a contaminant sensor vendor.

Per the Energy Commission’s guidance, design costs are not included in the incremental first cost. The cost effectiveness analysis only includes hard costs and labor costs.

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 relative to current practices over the period of analysis. The present value of equipment and maintenance costs (savings) was calculated using a three percent discount rate (d), which is consistent with the discount rate used when developing the 2019 TDV. The present value of maintenance costs that occurs in the nth year is calculated as follows:

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

Rooftop anemometer systems require very little maintenance after installation. One of the few maintenance requirements is the removal of obstructions, such as bird nests, which should be taken care of by a bird screen. The second maintenance requirement is replacement of the sensors at the end of the sensor lifespan. Rooftop anemometer manufacturers rate the anemometer sensor at a useful life of 100,000 hours, which is equivalent to approximately 11.4 years. Because the cost analysis is done over a period of 15 years, the sensor only needs to be replaced once during this period. The present value cost of sensor replacement, excluding labor, is equal to approximately $1,285. The present value cost of labor to replace a sensor is $1,785. The total incremental maintenance cost is equal to $3,070.

Energy savings related to this measure should continue as long as the rooftop anemometer is working properly. Although unlikely, it is possible that there will some maintenance required for recalibrating the sensor if it becomes uncalibrated for some reason over its lifetime. Persistence of energy savings is dependent on verification and commissioning of the anemometer sensor. Periodic calibration of the rooftop anemometer can ensure persistence of energy savings.

Contaminant sensor systems require approximately $7,000 in maintenance fees. This includes sensor swap-out, sensor calibration, and software updates. These values were obtained from Rich Yardley of Newmatic Engineering.

With regard to the fan unit itself, there should be very little incremental maintenance costs for the exhaust system enabled with wind-speed or contaminant controlled fans. Varying the fan speed more frequently could put additional stress on the shaft, and in theory this may affect the longevity of the equipment. That being said, the lifespan of IEFs exceeds the period of analysis and therefore this should not impact the incremental maintenance costs for this analysis.

5.5 Lifecycle Cost-Effectiveness

This measure proposes a prescriptive requirement. As such, 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 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 savings were also included in the evaluation.

Design costs were not included nor were the incremental cost of code compliance verification.

According to the Energy Commission's 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.

To calculate the total incremental cost for each climate zone, the present valued cost for a rooftop anemometer was multiplied by the number of labs in a given climate zone and then divided by the total square footage of labs in that climate zone. The number of labs in each climate zone was determined using the assumptions listed in Section 4.1 and data from the Market Assessment of Energy Efficiency Opportunities in Laboratories, a study conducted by the Center for Energy Efficient Laboratories and the Commercial Buildings Energy Consumption Survey.

To calculate the total TDV energy cost savings for each climate zone, the total TDV energy savings for each size lab in a given climate zone was summed up and divided by the total square footage of labs in that climate zone. The total climate zone TDV energy savings was then multiplied by the present valued cost of TDV energy.

The results of the per-unit lifecycle cost-effectiveness analyses for conventional exhaust systems and induction exhaust fans are presented in Table 8 and Table 9, respectively Table 9. The proposed code change for conventional exhaust systems is cost-effective in all sixteen climate zones. The proposed code change for induction exhaust fans is cost-effective in 13 of the 16 climate zones. The two climate zones in which the measure is not cost-effective experience more severe wind conditions, and therefore the fans have less opportunity to reduce airflow rates during low wind-speed conditions.

Table 8: Life Cycle Cost-Effectiveness Summary Per Square Foot for Conventional Exhaust Systems[6]

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2020 PV $/ft^2)	Costs Total Incremental Present Valued (PV) Costs[b] (2020 PV $/ft^2)	Benefit-to-Cost Ratio
1	$2.29	$0.12	18.66
2	$2.44	$0.12	20.51
3	$2.33	$0.12	19.90
4	$2.48	$0.12	20.79
5	$2.34	$0.12	19.64
6	$2.45	$0.12	20.93
7	$2.45	$0.12	20.62
8	$2.50	$0.12	21.32
9	$2.49	$0.12	21.29
10	$2.50	$0.12	20.73
11	$2.52	$0.12	20.52
12	$2.48	$0.12	20.88
13	$2.46	$0.12	19.94
14	$2.51	$0.12	21.00
15	$2.50	$0.12	20.84
16	$2.32	$0.12	19.62

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) 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 present valued costs, the B/C ratio is infinite.

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[6] Updated costs and benefit-to-cost ratios for all climate zones in the December 2017 report revision.

Table 9: Life Cycle Cost-Effectiveness Summary Per Square Foot for Induction Exhaust Systems[7]

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2020 PV $/ft^2)	Costs Total Incremental Present Valued (PV) Costs[b] (2020 PV $/ft^2)	Benefit-to-Cost Ratio
1	$12.34	$10.64	1.16
2	$15.44	$4.06	3.81
3	$6.66	$3.36	1.98
4	$11.33	$3.58	3.16
5	$10.69	$5.09	2.10
6	$11.13	$3.38	3.30
7	$13.99	$3.56	3.92
8	$14.46	$3.36	4.30
9	$13.57	$3.34	4.07
10	$14.15	$3.58	3.96
11	$4.23	$4.62	0.92
12	$7.51	$3.44	2.18
13	$14.25	$3.96	3.60
14	$0.69	$4.59	0.15
15	$5.12	$5.35	0.96
16	$12.02	$4.02	2.99

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 present valued costs, the B/C ratio is infinite.

6. FIRST-YEAR STATEWIDE IMPACTS

6.1 Statewide Energy Savings and Lifecycle Energy Cost Savings

It was determined that there will be 4.3 million square feet of new lab construction and lab space alterations in the state of California in the year of 2017. This new construction value is only reflective of the building types as defined in section 2.1. This value was calculated using a few different resources. First, a breakdown of the existing California laboratory building stock was found in the Market Assessment of Energy Efficiency Opportunities in Laboratories report. This indicated that there are currently eight million square feet of hospital labs, three million square feet of non-profit labs, 24.5 million square feet of academic labs, and 68 million square feet of private research labs. Next, a breakdown of existing buildings square footage, by building type, was obtained from the Commercial Buildings Energy Consumption Survey (CBECS). This revealed the fraction of each building type that is occupied by laboratory space. There is an assumption that this fraction will remain constant for future construction.

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[7] Updated costs and benefit-to-cost ratios for climate zones 11-16 in the December 2017 report revision.

The Statewide CASE Team then calculated the first-year statewide savings by multiplying the per-unit savings, which are presented in Section 4.3, by the statewide new construction forecast for 2020, which is presented in more detail in Appendix A. The first-year energy impacts represent the first-year annual savings from all buildings that were completed in 2020. The lifecycle energy cost savings represents the energy cost savings over the entire 15-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account. Results are presented in in Table 10.

Given data regarding the new construction forecast for 2020, the Statewide CASE Team estimates that the proposed code change will reduce annual statewide electricity use by 9.3 GWh with no associated demand reduction or natural gas reduction. The energy savings for buildings constructed in 2020 are associated with a present valued energy cost savings of approximately PV $23 million in (discounted) energy costs over the 15-year period of analysis.

Table 10: Statewide Energy and Energy Cost Impacts – New Construction and Alterations[8]

Climate Zone	Statewide Construction in 2020 (million ft^2)	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	0.014	0.03	3.01x10^{-3}	N/A	$0.08
2	0.113	0.31	2.50 x10^{-2}	N/A	$0.77
3	0.584	0.90	1.29 x10^{-1}	N/A	$2.20
4	0.261	0.56	5.75x10^{-2}	N/A	$1.42
5	0.051	0.10	1.12 x10^{-2}	N/A	$0.26
6	0.421	0.96	9.26 x10^{-2}	N/A	$2.25
7	0.267	0.67	5.88 x10^{-2}	N/A	$1.68
8	0.603	1.58	1.33x10^{-1}	N/A	$3.91
9	0.723	1.80	1.59x10^{-1}	N/A	$4.47
10	0.320	0.82	7.06 x10^{-2}	N/A	$2.04
11	0.073	0.08	1.61 x10^{-2}	N/A	$0.23
12	0.485	0.79	1.07x10^{-1}	N/A	$2.02
13	0.147	0.37	3.23 x10^{-2}	N/A	$0.94
14	0.065	0.04	1.43 x10^{-2}	N/A	$0.12
15	0.041	0.06	8.96 x10^{-3}	N/A	$0.14
16	0.120	0.25	2.65 x10^{-2}	N/A	$0.67
TOTAL	**4.288**	**9.32**	9.45x10^{-1}	**N/A**	**$23.20**

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.

6.2 Statewide Water Use Impacts

The proposed code change will not result in water savings.

6.3 Statewide Material Impacts

The proposed code change will not result in material impacts.

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[8] Updated lifecycle PV energy cost savings for climate zones 11-16 in the December 2017 report revision.

6.4 Other Non-Energy Impacts

This measure has the ability to not only impact energy consumption, but also indoor air quality and the health and safety of building occupants. Firstly, it should be known that conventional stacks are considered safer and more effective than IEFs. This is because conventional stacks release the exhaust stream at a greater height above the air intake, whereas IEF release at a lower height, potentially below the air intake, and rely on the momentum to take the exhaust to a safe height. Induced-air fan manufacturers claim a specified effective stack height for their systems, but in reality, these heights occur “far downwind of the stack (on the order of 100 to 200 ft.),” and the difference in plume height for an induction fan versus a conventional stack is “only 1 to 2 ft. at 20 ft. downwind” (Petersen, Amon, & Lintner, 2005).

Secondly, comparing wind-controlled induction fans versus typical induction fans, there is a belief that when the fan speed ramps down for favorable wind conditions, the shorter plume rise can lead to adverse health effects. This should not be the case as long as the system is designed properly (i.e., the exhaust stream is not within reach of air intakes and the system is designed with reasonable reaction time). Wind-speed control has the capability of ensuring safer conditions for high wind-speed situations, in which typically specified IEFs, designed for a constant exit velocity of 3,000 fpm, might not be releasing the air with enough momentum to achieve an effective stack height above the air intakes.

7. PROPOSED REVISIONS TO CODE LANGUAGE

The proposed changes to the Standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2016 documents, which became effective in 2017, are marked with underlining (new language) and ~~strikethroughs~~ (deletions).

7.1 Standards

SECTION 100.1 - – DEFINITIONS AND RULES OF CONSTRUCTION

ANSI Z9.5 is the American National Standards Institute document titled “Laboratory Ventilation,” 2012 (ANSI/ASSE Z9.5-2012).

PROCESS FACILITY is any facility containing occupancy type F.

SECTION 140.9 – PRESCRIPTIVE REQUIREMENTS FOR COVERED PROCESSES

(c) **Prescriptive Requirements for Laboratory and Process Facility Exhaust Systems.**

1. **Fan System Power Consumption.** All newly installed fan systems for a laboratory or process facility exhaust system greater than 10,000 CFM, shall meet the following requirements:
    A. System shall meet all discharge requirements in ANSI Z9.5-2012; and
    B. The allowable exhaust fan system power demand shall not exceed 0.65 watts per cfm of exhaust air. Exhaust fan system power demand equals the sum of the power demand of all fans in the exhaust system that are required to operate at normal occupied design conditions in order to exhaust air from the conditioned space to the outdoors. Exhaust air does not include entrained air, but does include all exhaust air from fume hoods, hazardous exhaust flows, or other manifolded exhaust streams. The exhaust fan system, including fan, nozzle, stack and wind band shall be licensed to bear the AMCA ratings seal for air performance (AMCA 210) or AMCA ratings seal for induced flow fan high plume dilution blowers (AMCA 260).

EXCEPTION 1 to Section 140.9(c)1B: The volume flow rate at the stack shall vary based on the measured 5 minute averaged wind speed and wind direction obtained from a calibrated local anemometer installed in a location and at a height that is outside the wake region of nearby structures and experiences similar wind conditions to the free stream environment above the exhaust stacks. Look-up tables will be used to define the required volume flow rate as a function of at least eight wind speeds and eight wind directions, to maintain downwind concentrations below health and odor limits for all detectable chemicals. Wind speed/direction sensors shall be certified by the manufacturer to be accurate within plus or minus 40 fpm (0.2 m/s) and 5.0 degrees when measured at sea level and 25°C, factory calibrated, and certified by the manufacturer to require calibration no more frequently than once every 5 years. Upon detection of sensor and/or signal failure, the system shall provide a signal which resets to exhaust the quantity of air needed to achieve the aforementioned criteria at the worst-case wind conditions;

EXCEPTION 2 to Section 140.9(c)1B: The volume flow rate at the stack shall vary based on the measured contaminant concentration in the exhaust plenum from a calibrated contaminant sensor installed within each exhaust plenum. A contaminant-event threshold shall be established based on maintaining downwind concentrations below health and odor limits for all detectable chemicals at the worst-case wind conditions. Contaminant concentration sensors shall be Photo Ionization Detectors (PID) certified by the manufacturer to be accurate within plus or minus 5% when measured at sea level and 25°C, factory calibrated, and certified by the manufacturer to require calibration no more frequently than once every 6 months. Upon detection of sensor and/or signal failure, the system shall provide a signal which resets to exhaust the quantity of air needed to achieve the aforementioned criteria at the worst-case release of any contaminant at the worst-case wind conditions.

2. **Airflow Reduction Requirements.** 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.

SECTION 141.1 – PRESCRIPTVE REQUIREMENTS FOR COVERED PROCESSES IN ADDITIONS, ALTERATIONS, TO EXISTING BUILDINGS THAT WILL BE NONRESIDENTIAL, HIGH-RISE RESIDENTIAL

(f) **Lab and Process Facility Exhaust Systems.** All newly installed fan systems for a laboratory or process facility exhaust system greater than 10,000 CFM comply with this section if they comply with the applicable requirements of Sections 140.9(c).

7.2 Reference Appendices

NA7.16 LAB VENTILATION SYSYTEM ACCEPTANCE TEST

NA7.16.1 Construction Inspection for Wind Speed/Direction Control

Verify and document the following tests prior to the functional testing:

(a) Wind speed and direction sensor is factory-calibrated (with calibration certificate) or field calibrated, as specified by Section 140.9(c)1B.

(b) The sensor is located in a location and at a height that is outside the wake region of nearby structures and experiences similar wind conditions to the free stream environment above the exhaust stacks as specified by Section 140.9(c)1B.

(c) The sensor is installed in close proximity to the fan that it will control so that it captures a representative wind speed/direction reading.

(d) The sensor is wired correctly to the controls to ensure proper control of volume flow rate.

(e) Wind speed/direction look-up table has been established and matches dispersion analysis results.

(f) Verify the methodology to measure volume flow rate:

- i. Airflow sensor
- ii. Static pressure as proxy
- iii. Fan speed to volume flow rate curve
- iv. Other

NA7.16.2 Construction Inspection for Contaminant Control

Verify and document the following tests prior to the functional testing:

(a) Contaminant sensor is factory-calibrated (with calibration certificate) or field calibrated, as specified by Section 140.9(c)1B.

(b) The sensor is located within each exhaust plenum as specified by Section 140.9(c)1B.

(c) The sensor is wired correctly to the controls to ensure proper control of volume flow rate.

(d) Contaminant concentration threshold has been established and matches dispersion analysis results.

(e) Verify the methodology to measure volume flow rate:

- i. Airflow sensor
- ii. Static pressure as proxy
- iii. Fan speed to volume flow rate curve
- iv. Other

(f) If multiple sensors are present, ensure fan is controlled based on the maximum reading.

NA7.16.3 Functional Testing for Wind Speed/Direction Control

Step 1: Simulate the minimum look-up table wind speed by either covering the sensor or overriding the curve points so the current wind speed is below the speed correlating to minimum volume flow rate at the stack.

(a) With all sensors active and all sensors reading below the minimum wind speed, observe minimum volume flow rate at the stack.
(b) Restore all curve points.

Step 2: Simulate a mid-range wind speed from the look-up table by either inducing a wind current, with an air speed accuracy of +/- 2%, or overriding the curve points so the current wind speed correlates to a mid-range volume flow rate at the stack.

(a) With all sensors active and all sensors reading a mid-range wind speed, observe corresponding mid-range volume flow rate at the stack.
(b) Restore all curve points.

Step 3: Simulate the maximum look-up table wind speed by either inducing a wind current, with an air speed accuracy of +/- 2%, or overriding the curve points so the current wind speed correlates to the maximum volume flow rate at the stack.

(a) With all sensors active and all sensors reading above the maximum wind speed, observe maximum volume flow rate at the stack.
(b) Restore all curve points.

Step 4: Temporarily override the programmed sensor calibration/replacement period to 5 minutes. Wait 5 minutes and observe that minimum volume flow rate at the stack is that at worst-case wind conditions and an alarm is received by the facility operators. Restore calibration/replacement period.

Step 5: Simulate sensor failure by disconnecting the sensor. Observe that minimum volume flow rate at the stack is that at worst-case wind conditions and an alarm is received by the facility operators. Reconnect sensor.

NA7.16.4 Functional Testing for Contaminant Control

Step 1: Ensure no contaminant event is present. Simulate minimum exhaust air demand in all lab spaces.

(a) Verify that the volume flow rate at the stack is at or above the minimum non-event value.

Step 2: Increase exhaust air demand at the lab spaces.

(a) Verify that the volume flow rate at the stack is at or above the minimum non-event value.

Step 3: Simulate minimum exhaust air demand in all lab spaces. Simulate a contaminant event.

(a) Verify that the volume flow rate at the stack is at or above the minimum event value.

Step 4: Increase exhaust air demand at the lab spaces.

(a) Verify that the volume flow rate at the stack is at or above the minimum event value.

Step 5: Temporarily override the programmed sensor calibration/replacement period to 5 minutes. Wait 5 minutes and observe that minimum volume flow rate at the stack is that of a contaminant event and an alarm is received by the facility operators. Restore calibration/replacement period.

Step 6: Simulate sensor failure by disconnecting the sensor. Observe that minimum volume flow rate at the stack is that of a contaminant event and an alarm is received by the facility operators. Reconnect sensor.

7.3 ACM Reference Manual

Section 5.6.5.3 Zone Exhaust and Section 5.7.3.4 Exhaust Fan Systems of the ACM Reference Manual will need to be updated to establish a primary prescriptive path to be used as the performance method baseline for this measure and provide control options for a wind-responsive system and contaminant-responsive system. Within Section 5.6.5.3, the subsections that will need revisions include Laboratory Exhaust Rate Type, Exhaust Air Flow Rate, Exhaust Minimum Air Flow Rate, and Exhaust Fan Schedule. Within Section 5.7.3.4, the subsections that will need revisions include Exhaust Fan Design Airflow, Exhaust Fan Control Method, and Exhaust Fan Schedule.

7.4 Compliance Manuals

10.7.3 Prescriptive Measures

§140.9(c)1 requires that all laboratory exhaust systems greater than 10,000 cfm shall comply with discharge requirements in ANSI Z9.5-2012 and shall not exceed a fan system power demand of 0.6 watts per cfm of exhaust air.

An exception is provided for systems that are controlled with a rooftop anemometer.

A second exception is provided for systems that are controlled with a contaminant concentration sensor.

§140.9(c)2 requires that all laboratory exhaust with minimum circulation rates of 10 ACH or lower shall be designed for variable volume control on the supply, fume exhaust and general exhaust.

An exception is provided for laboratory exhaust systems where constant volume is required by code, the Authority Having Jurisdiction (AHJ), or the facility Environmental Health and Safety (EH&S) division (Exception 1 to §140.9(c)). Examples include: hoods using perchloric acid; hoods with radio isotopes; and exhaust systems conveying dust or vapors that need a minimum velocity for containment.

A second exception is provided for new zones added to an existing constant volume exhaust system (Exception 2 to §140.9(c)).

7.5 Compliance Documents

The NRCC-PRC-09-E for Laboratory Exhaust Systems Requirements document will need to be updated with language that ensures exhaust fan systems are installed and controlled correctly to comply with the new prescriptive measure, specifically meeting ANSI Z9.5 requirements. The proposed revisions are presented below.

STATE OF CALIFORNIA LABORATORY EXHAUST CEC-NRCC-PRC-09-E (Revised 01/16)				
Certificate of Compliance				
System air flow as designed: _______________ ACH[1]				
System power demand: ________________ W/CFM				
Equipment Tags and System Description[2]				
PRESCRIPTIVE MEASURES	**T-24 Sections**	**Reference to the Requirements in the Contract Documents[3]**		
ANSI Z9.5-2012 requirements	140.9(c)1A			
Power demand below 0.6 watts per cfm	140.9(c)1B			
Power demand above 0.6 watts per cfm – Exc. 1c	140.9(c)1 Exception 1			
Power demand above 0.6 watts per cfm – Exc. 1c	140.9(c)1 Exception 2			
Power demand above 0.6 watts per cfm – Exc. 1c	140.9(c)1 Exception 3			
Exhaust control device requirements	140.9(c)2A			
Exhaust control device requirements	140.9(c)2B			
Exhaust control device requirements	140.9(c)2C			
Exhaust control device requirements	140.9(c)2D			
Exhaust system with VAV hood	140.9(c)3			
Exhaust system without VAV hood – Exc. 1c	140.9(c)3 Exception 1			
Exhaust system without VAV hood – Exc. 1c	140.9(c)3 Exception 2			
Notes: 1. Enter the designed system air flow rate in Air Changes per Hour (ACH) and the designed power demand in Watts per Cubic Foot per Minute (W/CFM) for all Laboratory systems under this permit. 2. Provide equipment tags (e.g. EF-1 to x and AHU 1 to y) for all systems that are covered by these requirements. This includes systems that are VAV flow hoods as well as system that are exempted as per sections 1 or 2 under section 140.9(c). 3. Provide references to plans (i.e. Drawing Sheet Numbers) and/or specifications (including Section name/number and relevant paragraphs) where each requirement is specified. Enter "N/A" if the requirement is not applicable to this system. Explicitly list which exception is used (if used).				

The NRCC-PRC-01-E Process Compliance Forms and Worksheets Table B will need to be updated with a new acceptance test for lab exhaust. The proposed revisions are presented below.

B. PROCESS ACCEPTANCE FORMS
(check box for required forms)

Designer:
This form is to be used by the designer and attached to the plans. Listed below are all the acceptance tests for process systems. The designer is required to check the applicable boxes for all acceptance tests that apply and list all equipment that requires an acceptance test. If all equipment of the same type requires a test, list the equipment description and the number of systems.

Installing Contractor:
The contractor who installed the equipment is responsible to either conduct the acceptance test them self or have a qualified entity run the test for them. If more than one person has responsibility for the acceptance testing, each person shall sign and submit the Certificate of Acceptance applicable to the portion of the construction or installation for which they are responsible.

Enforcement Agency:
Plancheck – The NRCC-PRC-01-E form is not considered a completed form and is not to be accepted by the building department unless the correct boxes are checked.
Inspector - Before occupancy permit is granted all newly installed process systems must be tested to ensure proper operations.

Test Description		**PRC-01A**	**PRC-02A**	**PRC-03A**	**PRC-04A**	**PRC-05A**	**PRC-06A**	**PRC-07A**	**PRC-08A**	**PRC-09A**
Equipment Requiring Testing or Verification	# of units	Compressed Air Systems	Garage Exhaust	Kitchen Exhaust	RHW Evap Fan Motor Controls	RHW Evap Condenser Controls	RHW Air-Cooled Condenser Controls	RHW Variable Speed Compressors	RHW Elect. Underslab Heating	Lab Exhaust
		o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o

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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 11. 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 12.

To calculate these values, the following steps were taken. First, a breakdown of the existing California laboratory building stock was found in the Market Assessment of Energy Efficiency Opportunities in Laboratories report. This indicated that there are currently eight million square feet of hospital labs, three million square feet of non-profit labs, 24.5 million square feet of academic labs, and 68 million square feet of private research labs. Next, a breakdown of existing buildings square footage, by building type, was obtained from the Commercial Buildings Energy Consumption Survey (CBECS). This revealed the fraction of each building type that is occupied by laboratory space (11.9 percent of colleges, 3.4 percent of hospitals, 10.3 percent of large offices, and 0.9 percent of small offices). There is an assumption that these fractions will remain constant for future construction. It was determined that the average life span of an exhaust fan is 25 years, so it is assumed that 1/25 of all existing labs will undergo retrofit and therefore will be required to comply with this code change.

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 floorspace that will be impacted by the proposed code changes:

1. 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 13 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 13, 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 15 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 14. The Energy Commission’s forecast allocated 18.5 percent of the total square footage from nonresidential new construction in 2020 and the nonresidential existing building stock in 2020 to the miscellaneous building type, which is a category for all space types that do not fit well into another building category. It is likely that the Title 24, Part 6 requirements apply to the miscellaneous building types, and savings will be realized from this floorspace. The new construction forecast does not provide sufficient information to distribute the miscellaneous square footage into the most likely building type, so the Statewide CASE Team redistributed the

miscellaneous square footage into the remaining building types in such a way that the percentage of building floorspace in each climate zone, net of the miscellaneous square footage, will remain constant. See Table 16 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 (see percentages above). The Statewide CASE Team’s assumptions are presented in Table 17 and Table 18 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 Table 17 and Table 18 and discussed further below.
5. Calculated nonresidential floorspace that will be impacted by the proposed code change in 2020 by building type and climate zone for both new construction and alterations. Results are presented in Table 11 and Table 12.

Table 11: 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	0.0004	0	0	0	0	0	0	0.0023	0.0006	0	0.0014	**0.0047**
2	0.0017	0	0	0	0	0	0	0.0131	0.0043	0	0.0209	**0.0400**
3	0.0055	0	0	0	0	0	0	0.0586	0.0170	0	0.1389	**0.2199**
4	0.0038	0	0	0	0	0	0	0.0295	0.0103	0	0.0470	**0.0906**
5	0.0007	0	0	0	0	0	0	0.0057	0.0020	0	0.0091	**0.0176**
6	0.0050	0	0	0	0	0	0	0.0367	0.0102	0	0.0875	**0.1395**
7	0.0068	0	0	0	0	0	0	0.0302	0.0108	0	0.0441	**0.0919**
8	0.0070	0	0	0	0	0	0	0.0514	0.0156	0	0.1282	**0.2022**
9	0.0069	0	0	0	0	0	0	0.0605	0.0222	0	0.1729	**0.2624**
10	0.0079	0	0	0	0	0	0	0.0442	0.0132	0	0.0435	**0.1088**
11	0.0022	0	0	0	0	0	0	0.0111	0.0042	0	0.0083	**0.0258**
12	0.0120	0	0	0	0	0	0	0.0541	0.0200	0	0.0903	**0.1765**
13	0.0048	0	0	0	0	0	0	0.0222	0.0091	0	0.0158	**0.0520**
14	0.0013	0	0	0	0	0	0	0.0078	0.0026	0	0.0109	**0.0226**
15	0.0017	0	0	0	0	0	0	0.0059	0.0018	0	0.0055	**0.0149**
16	0.0018	0	0	0	0	0	0	0.0134	0.0038	0	0.0250	**0.0440**
TOTAL	**0.0695**	**0**	**0**	**0**	**0**	**0**	**0**	**0.4466**	**0.1479**	**0**	**0.8493**	**1.5133**

Table 12: Estimated Existing Nonresidential Floorspace 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	0.0007	0	0	0	0	0	0	0.0047	0.0013	0	0.0023	**0.0090**
2	0.0031	0	0	0	0	0	0	0.0276	0.0087	0	0.0338	**0.0733**
3	0.0099	0	0	0	0	0	0	0.1158	0.0344	0	0.2035	**0.3637**
4	0.0071	0	0	0	0	0	0	0.0636	0.0208	0	0.0791	**0.1706**
5	0.0014	0	0	0	0	0	0	0.0123	0.0040	0	0.0154	**0.0331**
6	0.0099	0	0	0	0	0	0	0.0964	0.0259	0	0.1489	**0.2811**
7	0.0116	0	0	0	0	0	0	0.0615	0.0213	0	0.0808	**0.1753**
8	0.0137	0	0	0	0	0	0	0.1326	0.0382	0	0.2163	**0.4008**
9	0.0123	0	0	0	0	0	0	0.1413	0.0461	0	0.2610	**0.4606**
10	0.0146	0	0	0	0	0	0	0.0914	0.0275	0	0.0780	**0.2115**
11	0.0038	0	0	0	0	0	0	0.0228	0.0084	0	0.0125	**0.0475**
12	0.0192	0	0	0	0	0	0	0.1080	0.0407	0	0.1410	**0.3089**
13	0.0082	0	0	0	0	0	0	0.0466	0.0177	0	0.0223	**0.0949**
14	0.0024	0	0	0	0	0	0	0.0164	0.0055	0	0.0181	**0.0424**
15	0.0031	0	0	0	0	0	0	0.0104	0.0037	0	0.0087	**0.0258**
16	0.0031	0	0	0	0	0	0	0.0279	0.0080	0	0.0375	**0.0765**
TOTAL	**0.1240**	**0**	**0**	**0**	**0**	**0**	**0**	**0.9793**	**0.3122**	**0**	**1.3594**	**2.7749**

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

		Building Standards Climate Zone (BSCZ)																
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**Total**
Forecast Climate Zone (FCZ)	**1**	22.5%	20.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	9.8%	33.1%	0.2%	0.0%	0.0%	13.8%	**100%**
	2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	22.0%	75.7%	0.0%	0.0%	0.0%	2.3%	**100%**
	3	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	20.9%	22.8%	54.5%	0.0%	0.0%	1.8%	**100%**
	4	0.1%	13.7%	8.4%	46.0%	8.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	22.8%	0.0%	0.0%	0.0%	0.0%	**100%**
	5	0.0%	4.2%	89.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.6%	0.0%	0.0%	0.0%	0.0%	**100%**
	6	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100%	0.0%	0.0%	0.0%	0.0%	**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%	**100%**

Table 14: 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 ft^2	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 ft^2	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 15: 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 16: 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 17: Percent of Floorspace Impacted by Proposed Measure, by Building Type

Building Type *Building sub-type*	**Composition of Building Type by Sub-types** [a]	**Percent of Square Footage Impacted** [b]	
		New Construction	**Existing Building Stock (Alterations)** [c]
Small Office		0.64%	0.64%
Restaurant		0%	0%
Retail		0%	0%
Stand-Alone Retail	*10%*	*0%*	*0%*
Large Retail	*75%*	*0%*	*0%*
Strip Mall	*5%*	*0%*	*0%*
Mixed-Use Retail	*10%*	*0%*	*0%*
Food		0%	0%
Non-Refrigerated Warehouse		0%	0%
Refrigerated Warehouse		0%	0%
Schools		0%	0%
Small School	*60%*	*0%*	*0%*
Large School	*40%*	*0%*	*0%*
College		6.41%	6.41%
Small Office	*5%*	*0%*	*0%*
Medium Office	*15%*	*0%*	*0%*
Medium Office/Lab	*20%*	*32.05%*	*32.05%*
Public Assembly	*5%*	*0%*	*0%*
Large School	*30%*	*0%*	*0%*
High Rise Apartment	*25%*	*0%*	*0%*
Hospital		1.62%	1.62%
Hotel/Motel		0%	0%
Large Offices		2.01%	2.01%
Medium Office	*50%*	*0%*	*0%*
Large Office	*50%*	*4.01%*	*4.01%*

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 floorspace that will be altered during the first year the 2019 Standards are in effect.

Table 18: Percent of Floorspace Impacted by Proposed Measure, by Climate Zone

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

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

Appendix B: DISCUSSION OF IMPACTS OF COMPLIANCE PROCESS ON MARKET ACTORS

This section discusses how the recommended compliance process, which is described in Section 2.5, could impact various market actors. The Statewide CASE Team asked stakeholders for feedback on how the measure will impact various market actors during public stakeholder meetings that were held on December 13, 2016, and March 21, 2017 (Statewide CASE Team 2016 Induction Exhaust Fans).

The key results from feedback received during stakeholder meetings and other target outreach efforts are detailed below.

Table 19 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.

Table 19: 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
Induction Exhaust Fan Manufacturers	• Identify relevant requirements • Develop products and equipment that will meet exhaust design specifications and code regulations	• Products and equipment are code compliant • Products and equipment are specified by mechanical designers	• Must make sure IEF are equipped to meet all new requirements	• Manufacturers can be provided with detailed list of necessary changes to equipment
Mechanical Designers	• Identify relevant requirements • Coordinate design with other team members (HVAC & modeler) • Specify the products, performance requirements, and many sequences of operations • Review submittals during construction • Coordinate with commissioning agent/ ATT as necessary	• System meets owner's aesthetic requirements • Streamlined coordination with other team members • Clearly communicate system requirements to constructors • Quickly complete compliance documents • Minimize coordination during construction	• Will need to perform additional calculations to show compliance with proposed requirements • Will need to document compliance with new requirement, not currently being documented	• Revise compliance document to automate compliance calculations • Proposed documentation methodology uses materials already produced as part of the design/ construction process. No additional documentation necessary
Wind Consultants	• Identify relevant requirements • Perform wind modelling to guide mechanical designers in mechanical layout and product specification to ensure the design meets code and safety requirements	• Develops model that captures the specified mechanical system, meets project energy goals, and falls within code compliance	• Will need to advise mechanical designers on mechanical layout and product specification to meet new code requirements	• Wind consultants can be provided with a design decision form to be populated after wind modeling is complete
Energy Consultants	• Identify relevant requirements • Perform energy modeling, load calculations, and advise the design team on the compliant project approach	• Builds model that meets the compliance criteria and is accurate to the building to pass plan check	• Will need to include new information in energy model to comply via performance path	• Modeling software will need to be updated to include proposed values. Software training updates

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
Installers	• Identify relevant requirements • Select and install exhaust system • Conduct acceptance testing	• Completes installation and acceptance testing in a timely manner to the designers' specifications, falls within compliance, passes field inspection on first visit, and the owner is satisfied	• Will need to install new equipment required by Title 24 • Will need to conduct new acceptance tests	• Manufacturer can label equipment as registered with Title 24 and meets new requirement • Acceptance test document can be easily filled with information provided by manufacturers
Inspectors	• Identify relevant requirements • Must verify if equipment is registered as compliant with Title 24	• Complete inspection in a timely manner to avoid re-inspection	• Will need to verify equipment meets new code requirements • Will need to verify equipment is built and installed to new code requirements	• Manufacturer can label equipment as registered with Title 24 and meets new requirement • Document compliance on documents in a way easily compared to product specs
Plan Checkers	• Identify relevant requirements • Review the permit submittal for code compliance, issue construction permit, issue occupancy permit, installation review • Provide correction comments if necessary	• Quickly and easily determine if plans/ specs match documents • Quickly and easily provide correction comments that will resolve issue	• Will need to verify new calculations and designs are compliant • Will need to verify calculations match plans	• Compliance document could auto-verify data is compliant with Standards • Document compliance on documents in a way easily compared to plans