Codes and Standards Enhancement (CASE) Initiative

2028 California Energy Code

Air Distribution

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Executive Summary

This proposal presents updates to heating, ventilation and air conditioning (HVAC) system requirements for consideration in the 2028 California Energy Code (Title 24, Part 6). The measures were developed by the Statewide Codes and Standards Enhancement (CASE) Team to improve HVAC system performance, enhance design flexibility, strengthen compliance, and support California's long-term energy efficiency and greenhouse gas (GHG) reduction goals. The Statewide CASE Team is proposing two measures applicable to nonresidential buildings: Packaged Variable Air Volume (PVAV) Turndown and Modulating Dedicated Outdoor Air Systems (DOAS).

The proposed measures were developed for submission to the California Energy Commission (CEC) and must be technically feasible and cost effective in order to be considered for adoption. The proposals focus on reducing unnecessary airflow and improving HVAC system efficiency under low-load or low-occupancy conditions, while maintaining indoor air quality and occupant comfort.

Stakeholder engagement informed the development of these measures. The Statewide CASE Team collaborated with manufacturers, design engineers, energy analysts, and other stakeholders through stakeholder meetings held in September 2025 and April 2026. Additionally, several letters docketed through the CEC were reviewed and authors of those comments were contacted to understand their concerns. Feedback highlighted equipment limitations, market readiness, and compliance challenges, leading to refinements to the measures.

The Statewide CASE Team also considered environmental and social justice impacts, evaluating cost, health, resiliency, and comfort. The measures are not expected to negatively impact disadvantaged communities and may improve indoor air quality, efficiency, and resilience.

Measure 1: Packaged Variable Air Volume (PVAV) Turndown

Proposed Code Change

The proposal would require multi-zone (MZ) PVAV systems to either reduce airflow to low levels while maintaining mechanical cooling capability or incorporate a bypass method to redirect excess airflow back to the system. The requirement would apply to nonresidential buildings with MZ systems, including new construction, additions, and certain alterations.

Benefits of Proposed Change

The measure would reduce unnecessary cooling, reheating, and fan energy use during low-load or low-occupancy conditions. It addresses a disconnect between existing Energy Code requirements focused on reducing airflow at the zone level and the potential for the central plant equipment to not be able to match the overall low airflow that may result if enough zones associated with the system do not demand significant amounts of air. Currently, if a system is designed to Energy Code specifications at the zone level but the central equipment cannot turn down airflow to a sufficient degree, then zones are overcooled and reheat energy is needed to keep the spaces from getting too cold during warm weather. Overall, this measure seeks to overcome equipment limitations and supports compliance with existing ventilation and occupancy-based control requirements, improving energy performance and occupant comfort.

Compliance and Enforcement

Compliance would require designers to specify either turndown-capable equipment or a bypass system. Verification would occur through acceptance testing and updated compliance forms. Education for designers, contractors, and inspectors is recommended to support successful implementation.

Market Assessment

PVAV systems are widely available, though not all currently support deep airflow turndown. The Statewide CASE Team performed manufacturer outreach to determine the current availability of PVAV equipment that would be capable of complying with the level of turndown required by the measure. These results indicated that product availability would be limited in the near term. This caused the Statewide CASE Team to incorporate a bypass duct compliance pathway into the measure. The inclusion of a bypass compliance pathway ensures technical feasibility and supports market readiness. Manufacturers are expected to adapt as U.S. Department of Energy appliance standards take effect in 2029 and as more states adopt ASHRAE 90.1-2025, which includes the version of this measure without the bypass duct option.

Cost Effectiveness

The measure was found to be cost effective based on lifecycle savings from reduced energy use, though specific benefit-cost ratios[1] vary by building type and climate

[1] The benefit-to-cost ratio (BCR) compares benefits or cost savings to costs over the 30-year period of analysis. Proposed code changes with a BCR of 1.0 or greater are cost effective.

zone. The incremental first cost was based on the bypass duct compliance pathway, as was the savings methodology.

First-Year Statewide Impacts

The proposal is expected to reduce electricity use, peak demand, and GHG emissions, while generating long-term system cost savings. Detailed quantitative values are provided in the main report tables.

Table 1: Summary of Key Statewide Impacts - PVAV Turndown

Metric	Total Statewide Impacts [a]
Annual Electricity Savings (GWh)	12.5
Peak Demand Reduction (MW)	-0.7
Annual Natural Gas Savings (Million Therms)	0.8
Annual Source Energy Savings (Million kBtu)	19.1
30-Year Long-term System Cost Savings (Million 2029 PV$)	114
Reduced GHG Emissions (Metric Ton CO2e)	1,015

a. Impacts from Construction During First Year 2028 Code is Effective

Measure 2: Modulating Dedicated Outdoor Air Systems (DOAS)

Proposed Code Change

This proposal includes five submeasures. The primary submeasure (submeasure a) would be a requirement for modulating dampers on DOAS systems in buildings with greater than 3,000 cubic feet per minute (cfm) of outdoor air. This requirement would enable DOAS systems to comply with demand-controlled ventilation (DCV) and occupied standby measures, thus saving energy. Other submeasures include an occupied standby cleanup (submeasure b), a new prescriptive supply air delivery option (submeasure c), adjustments to mechanical DOAS supply air temperatures (submeasure d), and the final submeasure (submeasure e) would introduce a prescriptive limit to the amount of outdoor air being delivered to spaces.

Benefits of Proposed Change

This measure would reduce energy consumption while maintaining or even potentially enhancing indoor air quality (via better real time sensing with the new requirements) by aligning ventilation with actual occupancy. It supports broader energy and carbon reduction goals and improves system performance under variable conditions.

Compliance and Enforcement

Implementation would build on existing ventilation and control requirements, with updated compliance documentation and acceptance testing procedures. Stakeholder feedback was incorporated to clarify requirements and address concerns.

Market Assessment

DOAS technology is established in the market, and the modulating capabilities proposed in submeasure a are already required for mixed-air systems. Adapting the technology to DOAS is straightforward for market actors. DOAS equipment is generally shipped with variable speed supply fans even when used in constant air volume (CAV) applications due to the need for system balancing. Other submeasures focus on adjusting control settings and are achievable by the market. The measure is considered technically feasible.

Cost Effectiveness

The measure is expected to be cost effective due to energy savings and improved system performance over time. A robust cost effectiveness analysis was conducted for submeasure a, where detailed upfront costs were gathered by a Bay Area mechanical contractor to support the analysis. The remaining submeasures do not incur incremental first costs and were therefore excluded from a detailed analysis, however, cost effectiveness for submeasure c is described in general terms.

First-Year Statewide Impacts

The measure would contribute to statewide energy savings, demand reduction, and GHG emissions reductions, with detailed quantitative results documented in the report.

Table 2: Summary of Key Statewide Impacts – Modulating DOAS

Metric	Total Statewide Impacts[a]
Annual Electricity Savings (GWh)	4.33
Peak Demand Reduction (MW)	0.58
Annual Natural Gas Savings (Million Therms)	0
Annual Source Energy Savings (Million kBtu)	5.81
30-Year Long-term System Cost Savings (Million 2029 PV$)	36.47
Reduced GHG Emissions (Metric Ton CO2e)	308

a. Impacts from Construction During First Year 2028 Code is Effective

Acronyms

Table 3 presents a list of acronyms used in this report. Title24stakeholders.com also maintains a glossary of terms.

Table 3: List of Acronyms

Acronym	Definition
ACM	Alternative Calculation Method
ADA	Americans with Disabilities Act
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
ATT	Acceptance Test Technician
BCR	Benefit-to-cost Ratio
BEM	Building Energy Modeling
Btu	British Thermal Units
CALGreen	California Green Building Standards Code
Cal/OSHA	California Division of Occupational Safety and Health
CARB	California Air Resources Board
CASE	Codes and Standards Enhancement
CBSC	California Building Standards Commission
CBECC	California Building Energy Code Compliance Software
CEC	California Energy Commission
CEQA	California Environmental Quality Act
CBO	Community-Based Organization
CPUC	California Public Utilities Commission
CSE	California Simulation Engine
CTF	Conduction Transfer Functions
CZ	Climate Zone
DAC	Disadvantaged Community
DGS	California Department of General Services
DOAS	Dedicated Outdoor Air System
DOSH	Division of Occupational Safety and Health
ECC	Energy Code Compliance
EIR	Environmental Impact Report
EPIC	Electric Program Investment Charge
ESJ	Environmental and Social Justice
FSOR	Final Statement of Reasons
GHG	Greenhouse Gas

Acronym	Definition
GWh	Gigawatt-Hour
HVAC	Heating, Ventilation, and Air Conditioning
IDF	Input Data File
IECC	International Energy Conservation Code
IOU	Investor-Owned Utility
ISOR	Initial Statement of Reasons
Kg/s	Kilograms per Second
kWh	Kilowatt-Hour
kWh/year	Kilowatt-Hour Per Year
LSC	Long-term System Cost
MeasureSET	CASE Measure Savings Estimation Template
MG	Million Gallons of Water
MZ	Multi Zone
NAICS	North American Industry Classification System
NPDI	Net Private Domestic Investment
PEP	Public Engagement Plan
PV	Present Value
RTU	Rooftop Unit
SDD	Standards Data Dictionary
SOC	Standard Occupational Classification
SPMS	Saturation Pressure Measurement Sensors
SRIA	Standardized Regulatory Impact Assessment
TON	12,000 Btu/h of heating or cooling capacity
W	Watt

1. Introduction

1.1 Report Context

This proposal describes specific energy efficiency code changes (referred to as "measures") aimed at reducing wasteful, uneconomic, inefficient, or unnecessary consumption of energy in California. These measures are submitted to the California Energy Commission (CEC) for consideration and potential inclusion in California's Energy Code (Title 24, Part 6), which sets statewide energy efficiency requirements for newly constructed buildings and for additions and alterations to existing buildings. Measures may also be considered for inclusion in CALGreen (Title 24, Part 11) as voluntary energy efficiency standards, which would take effect only if adopted by a local jurisdiction seeking to exceed the minimum requirements of the Energy Code. Measures submitted to the CEC will be reviewed, may be modified, and may be incorporated into a broader regulatory package proposed and adopted by the CEC. To be included in the Energy Code, proposed measures must be both cost effective and technically feasible.

1.2 Proposal Sponsors

Three California Investor-Owned Utilities (IOUs), Pacific Gas & Electric Company, San Diego Gas & Electric, and Southern California Edison, jointly sponsored this effort. Where the term "Statewide CASE Team" is used in this report, it refers to the authors and State Building Codes Advocacy activities supported through the Codes and Standards program.

1.3 Stakeholder Engagement to Inform Proposal

When developing the code change proposal and associated technical information presented in this report, the Statewide CASE Team worked with many industry stakeholders including manufacturers, energy analysts, state agencies, 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 September 23, 2025 and April 21, 2026.

For the PVAV Turndown measure at the September 2025 meeting, manufacturers highlighted the potential need for equipment redesigns to meet the requirements. This feedback was incorporated into the measure's cost effectiveness analysis. At the April 2026 meeting, stakeholders expressed concern that though ASHRAE 90.1-2025 requires the same capability to reduce airflow, and that manufacturers are designing equipment to meet the requirement, as of today there are few models that can provide low airflow and maintain mechanical cooling. The Statewide CASE Team, in consultation with CEC, has taken this concern into consideration and proposes to add a second compliance path that would not require a level of fan turndown, but would require that excess air not needed in the zones be bypassed to the intake of the air handler without entering the conditioned spaces.

For the Modulating DOAS measure at the September 2025 meeting, stakeholder feedback focused on questions regarding the proposed supply air temperature limitations. In the second stakeholder meeting in April 2026, the webinar focused on incremental changes to the measures since the first meeting and generally got into additional details on the drivers of the measures, the research done to support the analysis and cost-effectiveness, as well as savings and cost-effectiveness results. Stakeholders provided valuable feedback in the meeting and afterwards.

Please see Appendix E for more comprehensive details on the Statewide CASE Team's stakeholder engagement.

1.4 Addressing Energy Equity and Environmental Justice

The Statewide CASE Team recognizes, acknowledges, and accounts for a history of prejudice and inequality in environmental and social justice (ESJ) communities.[2] These issues persist today. To minimize the risk of perpetuating inequity, code change proposals are being developed with intentional consideration of the unintended consequences on ESJ communities.

When analyzing impacts for nonresidential buildings, the Statewide CASE Team reviewed each nonresidential building type through the lens of the four criteria: cost, health, resiliency, and comfort. The Statewide CASE Team examined which building types are used by ESJ communities most frequently and evaluated the allocation of impacts related to the following areas among all populations. Some building types have unique environmental justice concerns due to their common uses, location, or other factors.

[2] The CPUC refers to ESJ communities as "low-income or communities of color that have been underrepresented in the policy setting or decision-making process, are subject to a disproportionate impact from one or more environmental hazards, and likely to experience disparate implementation of environmental regulations and socio-economic investments in their communities" (CPUC 2022). ESJ communities also include the CPUC definition for Disadvantaged Communities, which comprises "(1) Census tracts receiving the highest 25 percent of overall scores in CalEnviroScreen 4.0 (1,984 tracts); (2) Census tracts lacking overall scores in CalEnviroScreen 4.0 due to data gaps, but receiving the highest 5 percent of CalEnviroScreen 4.0 cumulative pollution burden scores (19 tracts); (3) Census tracts identified in the 2017 DAC designation as disadvantaged, regardless of their scores in CalEnviroScreen 4.0 (307 tracts); and (4) Lands under the control of federally recognized Tribes (OEHHA 2022).

The Statewide CASE Team will continue to build relationships with CBOs and other stakeholders to improve the identification of potential impacts for future code cycles and is open to additional resources that can contribute to this effort.

1.5 Relationship with the Indoor Lighting Controls CASE Report

There is a parallel CASE effort occurring in the 2028 code cycle titled *Indoor Lighting Controls*. This effort relates to the DOAS measure detailed in Section 3 of this report, particularly submeasure b, *Occupied Standby Cleanup*. The occupied standby cleanup submeasure is primarily seeking to clarify the spaces where ventilation occupied standby is required. The present Title 24 Part 6 layout is not clear, as it sends the reader to multiple other sections of the code to determine whether a given space type must comply with occupied standby for ventilation. More details regarding the challenges and proposed enhancements are included in Section 3 of this report. The 2028 Indoor Lighting Controls CASE study is expanding the list of space types that would be required to comply with lighting occupied standby. Some of these spaces are also permitted to include ventilation occupied standby, so in this measure's effort at clarifying ventilation occupied standby requirements, the Air Distribution Team has included in its list of required ventilation space types the proposed new lighting space types where ventilation is already allowed.

Additionally, the Indoor Lighting Controls CASE study proposes to decrease the lighting time delay from 20 to 15 minutes, aligning with industry standard practice and national model codes. This change would have the indirect impact of also reducing the ventilation occupied standby trigger from between 20-25 minutes to 15-20 minutes, since ventilation is allowed up to five additional minutes once lighting occupied standby is triggered.

2. Packaged Variable Air Volume (PVAV) Turndown

2.1 PVAV Turndown - Measure Description

2.1.1 Proposed Code Change

This proposed code change would modify prescriptive requirements for multi-zone variable air volume (VAV) HVAC systems in Section 401.3.14 *[Section 140.4(m)]*. There are two paths to compliance.

In light of the concern by stakeholders that even though manufacturers are designing equipment that will meet the airflow turndown requirement in the original proposal, there are few models on the market today that meet the requirement, the Statewide CASE Team propose a bypass path that will require a method to bypass excess supply airflow not needed in the zones from the supply directly to the return inlet without the excess supply air entering conditioned spaces.

The bypass path would be typically met in one of two ways: a bypass damper or by releasing excess air into the ceiling plenum. Bypass ducts were used on early multi-zone systems that had constant-speed fans but variable airflow to the zones. Bypass ducts can be anywhere in the system, but are typically installed near the air handler, where there is typically the least distance between the supply and return ducts. A bypass damper controls the flow through the duct. This method is shown in Figure 1.

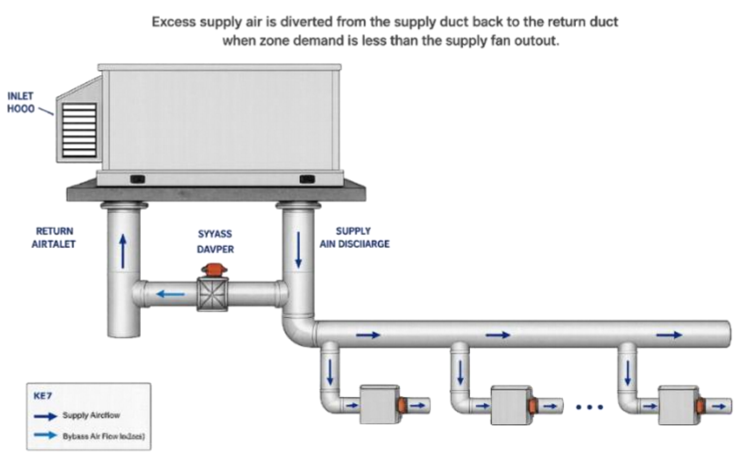

Figure 1: Bypass method of compliance using a bypass and return duct.

Where there is a ceiling plenum that is used for return air, a simple method to return excess air without entering the conditioned space is to discharge directly from the supply duct into the plenum. This can be accomplished in many cases by using a cooling-only VAV box. This method is often referred to as a "dump damper." A schematic of this method is shown in Figure 2.

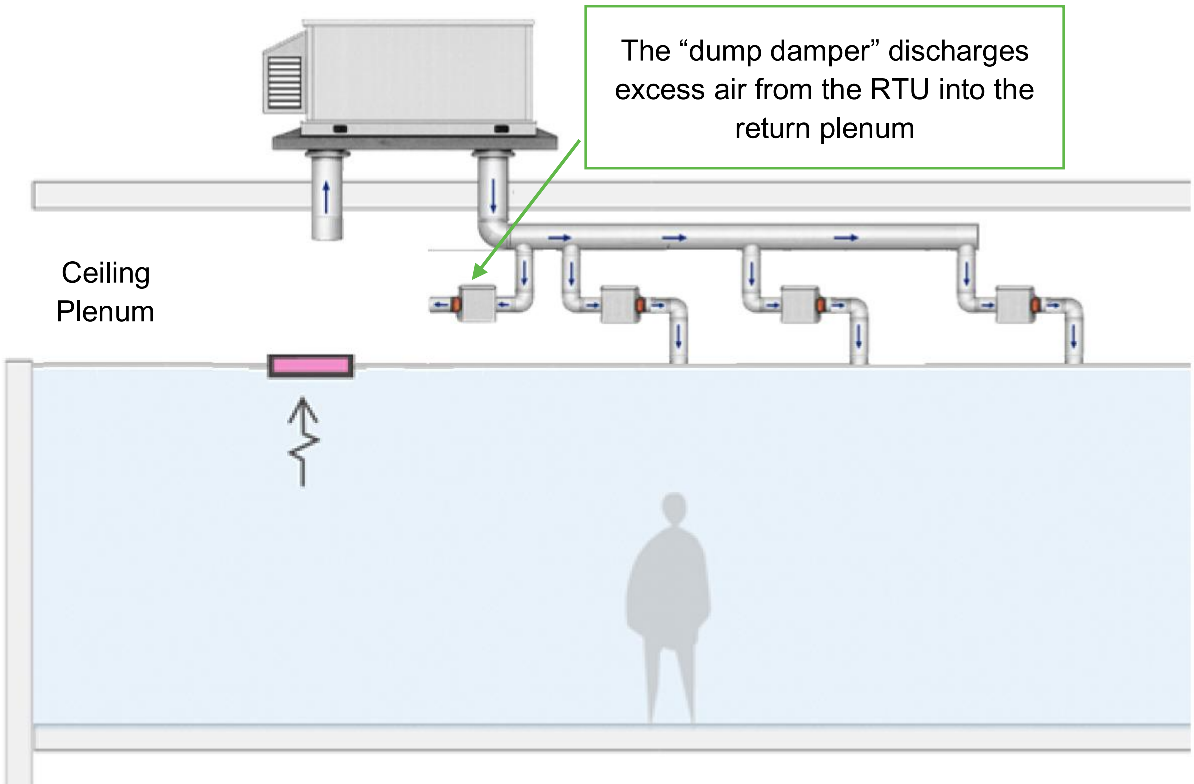

Figure 2: Bypass method of compliance using a dump damper and return plenum

The second path would require the central supply fan to be capable of and configured to turn down to the larger of 15 percent of design airflow or the sum of the minimum outdoor air required by Section 401.2.1.1.3 *[Section 120.1(c)3]*. The equipment must be able to provide mechanical cooling at that airflow.

Multi-zone systems controlled by pneumatic systems would be exempted.

Table 4 summarizes the scope of the proposed code change.

Table 4: Scope of Proposed Code Change

A ☑ indicates the proposed code change is relevant.

Building Type(s)	Construction Type(s)	Type of Change
☐ Single Family	☑ New Construction	☐ Mandatory
☐ Multifamily	☑ Additions	☑ Prescriptive
☑ Nonresidential (not Group R uses)	☑ Alterations	☐ Performance

Application Climate Zones	Energy Code Sections	Compliance Forms	Sections of ACM Reference Manuals
Climate Zones 1-16	• Part 6, Section 401.3.14 *[Section 140.4(m)];* Section 401.5.2.21 *[Section 141.0(b)2C]* • Nonresidential Reference Appendix Section 7.5.6	NRCC-MCH-E and NRCA-MCH-07-A	Section 5.1.3, 5.6.7

Third Party Verification	Updates to Compliance Software
☐ No changes to third-party verification	☐ No updates
☑ Update existing verification requirements	☑ Update existing feature
☐ Add new verification requirements	☐ Add new feature

2.1.2 Benefits of Proposed Change

Multi-zone VAV systems control space temperature by modulating airflow to the space. The systems also provide a minimum flow of outdoor air to the space, in accordance with the outdoor airflow requirements specified in Section 401.2.1.1.3 *[Section 120.1(c)3]*. Section 401.3.6.2 *[Section 140.4(d)(2)(A)(ii) and 140.4(d)(2)(B)(ii)]* requires terminal units in the individual zones for these systems to be capable of turning down airflow to no greater than the minimum required outdoor airflow during deadband operation, where there is no demand for heating or cooling. In many applications, this would be 15 percent or less of the air handler's design airflow. However, there is no requirement that the central air handler be able to turn down flow to any level and have mechanical cooling enabled.

The measure would also help ensure that systems can comply with the mandatory demand control ventilation (DCV) requirements in Section 401.2.1.3 *[Section 120.1(e)]* and the occupied standby requirements in Section 401.2.1.4 *[Section 120.1(f)]*. Even in buildings that have relatively high outdoor air requirements, DCV and occupied standby reduce outdoor airflow, so those buildings would benefit.

Additionally, there is currently no limitation on multi-zone VAV direct expansion (DX) compressors from locking out at low airflow levels, a challenge that has been encountered in the field. That is, even if the unit can turn down its airflow below 50 percent of design airflow, the compressor is often locked out by the unit, preventing it from providing mechanical cooling if some zones require it. This is typically encountered during times when the integrated economizer is used to satisfy space conditioning requirements.

Current workarounds to deal with DX PVAV units that do not turn down below 50 percent of design airflow or lock out their compressors at a relatively high part-load airflow lead to significantly more energy consumption than is needed. The excess airflow increases the cooling load, and where the air is reheated at the VAV box to prevent overcooling the excess airflow causes more heating energy to be used. If the unit cannot operate mechanical cooling at the ventilation airflow, the fan consumes more energy.

Designers have two ways to handle the mismatch: (1) they can set the minimum zone airflow to match the higher airflow if they use a modeling compliance path, or (2) they can specify a bypass duct that returns the excess airflow directly to the unit. The first method leads to higher cooling, heating, and fan energy described above. Using a bypass duct or a dump damper would be permitted by this proposal, so the fan energy savings would not be realized, but the cooling and heating savings would be, which is about 2/3 of the savings that would be realized if the fan can turn down.

This proposed code change would apply to new construction, additions served by a new DX or hydronic unit, and alterations in which a new DX or hydronic air handler unit is installed, or 50 percent of the VAV boxes are replaced. For alterations of VAV boxes, users are already required to set the minimum airflow settings of the associated VAV boxes to realize the savings. This can be accomplished through the BMS system in most cases. The proposed code change would apply to all climate zones and to all building and space types with multi-zone VAV systems. This does not apply to single-zone VAV systems that control mechanical cooling capacity directly based on space temperature.

A modern, code-compliant building with a multi-zone VAV system is likely to experience significant periods where the airflow to the zones is much lower than the design rate. This is due to both social factors and other code requirements. Commercial building occupancy densities can vary widely, resulting in reduced cooling demand on building HVAC systems during scheduled occupied periods. Other code requirements, such as demand-controlled ventilation and occupied standby (OS) (both located in Section 401.2.1.2 *[Section 120.1(d)]*), place mandatory zone airflow turndown requirements on the air distribution system when appropriate.

Section 401.3.6.2 *[Section 140.4(d)2ii]* requires that the terminal units in the individual zones turn down airflow to no greater than the design outdoor airflow during deadband operation when there is no demand for heating or cooling. In many applications, this would be equivalent to 15 percent or less of the air handler's design airflow. However, there is no requirement that the central air handler be able to turn down flow to any level. Furthermore, at low airflow levels, multi-zone VAV DX equipment will automatically lock out mechanical cooling, which poses significant challenges to occupant comfort and system energy performance at low loads. This measure would address these issues.

This measure is expected to improve occupant comfort and system efficiency performance for buildings that use this equipment type. Currently, the main workaround for buildings using multi-zone VAV DX systems, using higher airflow at the zones that violate the prescriptive zone turndown rules, leading to unacceptably high amounts of overcooling and reheating at the zone terminal units.

2.1.3 Background Information

The Energy Code, ASHRAE 90.1, and the International Energy Conservation Code all have requirements to be able to turn down or even turn off the zone airflow when spaces are unoccupied. Mandatory measures such as occupied standby and demand-controlled ventilation (DCV) permit airflow rates to dip below mandatory minimum values. Further, the Energy Code has a prescriptive requirement in Section 401.3.6.2 [Section 140.4(d)2] that supply airflows to the zone during deadband operation not exceed the design outdoor airflow. This last value is typically less than the value to which designers set minimum zone airflows, based on a review of more than twenty plan sets from California projects.

There are many more hours where DCV or occupied standby mode should be in effect than many realize. Our research shows that office buildings are much more lightly occupied daily than is often assumed. Research released by one commercial real estate organization said that current office utilization in North America is 52 percent, and that even pre-COVID, the average was 57 percent.[3] For occupancies where DCV is required, such as schools, the occupied mode often extends well past the time when students are expected to be in class.

While hydronic MZ VAV systems can easily provide mechanical cooling at low airflows, packaged VAV (PVAV) systems typically have a minimum airflow of 200 cfm per nominal ton of cooling, or just a bit less. Therefore, when many of the zones are unoccupied but some zones require mechanical cooling, the system airflow must be

[3] https://www.jll.com/en-us/insights/occupancy-benchmark-report Utilization of the percentage of the work week where office employees are in the office. It does not include vacant spaces.

increased significantly above the required minimums. This leads to overcooling of the zones, which must be addressed with extra reheating by the zone coils. Essentially, the equipment must provide more cooling than is needed, which is addressed by creating a false load by reheating excess air.

ASHRAE 90.1 addressed this in the 2025 edition by creating a prescriptive requirement than equipment in MZ VAV systems be able to provide mechanical cooling to an airflow no greater than the larger of 15 percent of design airflow or the sum of the design outdoor airflows through addendum u.[4] Further, a limitation was placed on the design outdoor airflow in addendum p.[5] Both addenda were incorporated into IECC 2027.

Neither ASHRAE 90.1 nor IECC provide an alternative path that allows the use of a bypass method, and the proposal in the Draft CASE Report did the same. However, stakeholder feedback noted that though manufacturers have said they will be ready to meet the turndown requirement when it goes into effect, few can meet it today. Therefore, the Statewide CASE Team added the bypass path to address those concerns. Bypass systems have long been used in MZ VAV systems, especially in the 1990s and 2000s, so they are not new technology and do not depend on manufacturers to update their designs.

2.1.4 Modifications to Energy Code Documents

This section provides descriptions of how the proposed code change would affect each Energy Code document. See 02.5.6 of this report for detailed revisions to code language.

2.1.4.1 Energy Code Change Summary

SECTION 401.3 *[SECTION 140.4]* – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

Subsection 401.3.14 *[Subsection 140.4(m)]:* This is a new requirement that requires building owners to provide a method either, 1) Provide a method to bypass excess supply airflow greater than that mandated by the Energy Code, or, 2) provide equipment that can provide mechanical cooling at the greater of 15 percent of the design supply airflow or the sum of the outdoor airflow requirements found in 401.2.1.1.3 [Section 120.1(c)3].

4

https://www.ashrae.org/file%20library/technical%20resources/standards%20and%20guidelines/standards%20addenda/90_1_2022_u_20241231.pdf

5

https://www.ashrae.org/file%20library/technical%20resources/standards%20and%20guidelines/standards%20addenda/90_1_2022_p_20240531.pdf

Federal pre-emption is not anticipated to be an issue. The measure is directly based on Addendum u to ASHRAE 90.1 2022, which, as the Statewide CASE Team notes, does not include the bypass option. Because the bypass option does not affect federally regulated equipment, it is also not a pre-emption concern.

401.5 [Section 141.0] Additions and alterations to existing buildings.

Subsection 401.5.2.2.1.3 [New section]: The proposed regulation would require compliance with the new requirements being added to Section 401.3.14.4 when more than 50 percent of the indoor air-terminal units or the central air handler or direct-expansion air conditioner of a multiple-zone system is being replaced. This proposed change would save energy by reducing the amount of reheat energy experienced by the multizone HVAC system.

2.1.4.2 Reference Appendices Change Summary

Nonresidential Appendix (NA) 7 – Installation and Acceptance Requirements for Nonresidential Buildings and Covered Processes: For systems that are required to comply with the measure, the proposed changes update the acceptance testing for multizone VAV equipment to demonstrate that the system can reduce zone supply airflow to the prescribed minimum zone airflows and that mechanical cooling is available. Testers would use the BMS system to fully close the outside air dampers and set all the VAV boxes to their minimum airflow.

For systems that use the performance method to comply, the sum of the VAV box airflows would be set to the minimum airflow for mechanical cooling entered by the designer plus five percent.

The setpoint in the zones would be reduced to prove that mechanical cooling engages. The entire test is performed at the central controller. Technicians would not need to manually adjust VAV boxes or climb to the roof.

2.1.4.3 Compliance Manuals Change Summary

The “Prescriptive Requirements” subsection of “HVAC System Control Requirements” in Chapter 4 of the 2025 Nonresidential Compliance Manual would need to be modified to describe the changes being proposed in this measure. Designers would need to calculate the required minimum airflow for mechanical cooling and include it in their schedules. Manufacturer submittals would need to include confirmation that mechanical cooling is or can be enabled to that level. In cases where the equipment controls are not set at the factory to meet the requirements, designers would need to instruct technicians to adjust the minimum airflow.

2.1.4.4 Alternative Calculation Method Reference Manual Change Summary

The Alternative Calculation Method (ACM) Reference Manual would be modified to better describe more capable PVAV equipment features that would result from the inclusion of this measure. The ACM would be modified to provide user input on the supply airflow turndown percentage while still supplying mechanical cooling capability of the central station air handler or PVAV equipment. The user shall also be able to indicate in a supply air bypass method will be provided.

The software will take the minimum supply airflow at which mechanical cooling can be provided into account and set the supply airflow to at least that value whenever there is a call for mechanical cooling.

The standard design will use a PVAV unit that can provide mechanical cooling at 200 cfm per ton of rated cooling capacity and include a bypass duct to allow zone airflows to be unaffected by calls for mechanical cooling.

We also recommend that occupancy and lighting schedules be modified to reflect the requirements in the Energy Code to provide demand control ventilation and occupied standby capabilities.

2.1.4.5 Compliance Forms Change Summary

The compliance forms would change by adding fields to NRCC-MCH-E that describe how the zone supply air turndown requirements will be met: either using the bypass provisions or certifying that the equipment can turn down to the greater of 15 percent of the design supply airflow or the minimum outdoor air requirement in Section 401.2.1.1.3 [Section 120.1(c)3] and be able to provide mechanical cooling at all airflows. In addition, where the bypass method is used, the form shall show that mechanical cooling can be provided at 200 cfm per nominal ton of cooling capacity.

There must be a clarification existing space on NRCC-MCH-E that is intended to show the minimum deadband airflow is based on Section 401.2.1.1.3 [Section 120.1(c)3] and is not value selected by the designer.

For systems that use the performance path, the compliance form will show the minimum cooling enabled airflow that was modeled and whether a bypass method was included.

Finally, the NRCA-MCH-07-A “Supply Fan Variable Flow Controls” form would be modified to reflect the proposed changes to the acceptance test.

2.1.5 Measure Context

2.1.5.1 Comparable Model Codes or Standards

As noted above, this measure was originally based on Addendum u to ASHRAE 90.1-2022, which was officially approved on December 31, 2024, and appears in the 2025 edition of ASHRAE 90.1. Further, the measure will be included in the 2027 edition of the International Energy Conservation Code (IECC). Additionally, the United States Department of Energy finalized new appliance standard requirements for unitary equipment that is expected to impact multizone VAV DX products that are expected to take effect on January 1, 2029. This measure does not violate pre-emption because it is based on ASHRAE 90.1-2022 Addendum u and, further, provides a compliance path that does not place any requirement on the regulated equipment.

2.1.5.2 Interactions with Other Regulations

The proposed measures do not conflict with other state or federal laws and regulations. This measure is not expected to be federally preempted, because the path to not lock out mechanical cooling above 15 percent of design airflow or the sum of design minimum airflows is in ASHRAE 90.1-2025. The Energy Policy and Conservation Act allows states to adopt higher equipment efficiency and design requirements for commercial unitary air conditioners and heat pumps if those requirements are identical to or less stringent than those in ASHRAE 90.1.

2.2 PVAV Turndown - Compliance and Enforcement

2.2.1 Compliance Considerations

First, it is important to understand that this measure enables compliance with the established requirement that the minimum airflow for individual zones when in deadband does not exceed the minimum required outdoor airflow, along with DCV and occupied standby. When equipment cannot provide mechanical cooling at that airflow rate, building operators are forced to violate those requirements to maintain occupant comfort.

Though the Statewide CASE Team expects that most manufacturers will be able to comply with the turndown path, as the requirement is in ASHRAE 2025 and is in the published draft of IECC 2027, the addition of the bypass path should address any lingering concerns.

Section 2.1.4 outlines the new considerations for designers, installers, acceptance-testing technicians, and code officials. Designers must ensure they specify a bypass method or equipment capable of reducing airflow to the greater of 15 percent of the design airflow or the sum of the design zone outdoor-airflows without locking out mechanical cooling. Installers or control technicians must ensure the equipment controls are configured correctly.

Acceptance-testing technicians would need to understand the expanded test in Section NA7.5.6.2 and captured by the NRCA-MCH-07-A form. Where the bypass path is employed, they would need to understand that they need to ensure that mechanical cooling is available when the VAV boxes are set at the design minimums. We need to ensure that those design minimums must be communicated to them. The technician must confirm that mechanical cooling is enabled by recording the temperature drop between the return and supply air.

Education must be provided to code officials, so they understand the requirements. More importantly, the code official must understand that if the central air handler or air conditioner cannot provide mechanical cooling at the design zone minimum supply airflows, it is likely that the minimum airflows would be reset upwards to provide necessary cooling.

The Statewide CASE Team is recommending changes to the acceptance test for multizone VAV units to ensure compliance with this measure. The new testing requirements would confirm that the installed equipment can provide mechanical cooling turn down to the minimum zone outdoor airflow requirements in accordance with 401.2.1.1.3 [Section 120.1(c)3].

2.2.2 Impact on Market Actors

Table 5 summarizes impacts on market actors and suggests outreach and education that might be helpful to support market actors as they prepare for the effective date of the requirements.

Table 5: Impacts on Market Actors and Suggested Training and Education Opportunities

Market Actor	Impact(s)	Suggested Outreach and Education
Owner/Developer [a]	Equipment or bypass systems that meets this requirement would likely be more expensive than non-compliant equipment.	Make sure owners/developers are aware of the large energy savings and that compliance with Sections 401.3.5 and 401.3.6 *[Sections 140.4(c) and 140.4(d)]* is difficult without meeting this requirement.
Design Professional [b]	Designers must specify the minimum airflow at which mechanical cooling is enabled and add a bypass method when the equipment cannot meet the turndown path.	Use local ASHRAE chapters and CI team trainings to raise awareness and ensure capabilities are reflected in designs.
Construction Team [c]	Mechanical and controls contractors need to understand the requirement for zone airflow reduction and the paths and be prepared to install the bypass duct or set the equipment controls to meet the requirement.	Outreach through Energy Code Ace and manufacturer training.
Building Department [d]	Plan reviewers must be cognizant of the proposed updates to the compliance forms described earlier and understand how to check that DCV and occupied standby are called out in controls sequences. Building inspectors should ensure that bypass systems are installed when specified in the plans and ensure the test described in NA7.5.6.2 is completed.	Inform officials about new requirements through newsletters and training sessions.
Verification Tester [e]	Modification to the PVAV acceptance test to ensure new measure requirements are met.	The proposed acceptance test modifications are very straightforward and should be easily understood by testers once they are made aware.
Manufacturers and Distributors	Manufacturers may choose to redesign their in-scope equipment to allow for lower achievable airflow rates and eliminate compressor lockout. An enhanced description of	Manufacturers are aware of this upcoming requirement due to the ASHRAE 90.1-2022 Addendum u measure passing in 2024. Additional outreach by the CI team could underscore the need to

Market Actor	Impact(s)	Suggested Outreach and Education
	these equipment capabilities in the product literature would also benefit the industry. Distributors should be aware of these new features but otherwise should not experience much of a change.	have compliant equipment in time for the 2028 code cycle's enforcement period which begins on 1/1/2029.

a. Owner/Developer is funding the project and is the primary decision-maker.

b. Design professionals include architects, engineers (mechanical, electrical, plumbing, structural), specification writers, cost estimators, commissioning agents, lighting designers, and energy consultants.

c. Construction team includes general contractors, home builders, design-build contractors, installation contractors (e.g., HVAC, plumbing, electrical), commissioning agents, and tradespeople.

d. Building departments include plans reviewers, building inspectors, specialty inspectors, permit counter technicians and third-party plan review and inspection.

e. Verification testers include commissioning agents, ECC Raters, and Acceptance Test Technicians.

The 2028 CASE Methodology Report presents a quantitative assessment of how changes to the California building code impact builders, building designers and energy consultants, and building owners and occupants. The analysis in the methodology report is not specific to the code change presented in this report. The following provides a qualitative description of how this specific code change affects various market actors and additional quantitative analyses of its potential impacts on building industry subsectors.

Builders. The proposed change would likely affect commercial builders; however, it would likely not impact firms focused on the construction or retrofitting of industrial buildings, utility systems, public infrastructure, or other heavy construction. The proposed change would not affect all firms and workers in the residential and commercial building industries equally; instead, it would primarily affect specific subsectors within the industry. Table 4 shows the commercial building subsectors that the Statewide CASE Team expects to be impacted by the changes proposed in this report. The commercial building industry may experience very minor impacts by this measure due to the presence of the bypass duct option for compliance.

Table 6: Specific Subsectors of the California Commercial Building Industry Impacted by Proposed Change to Code/Standard by Subsector in 2025 (Estimated)

Construction Subsector	Establishments	Employment	Annual Payroll (Billions $)
Commercial Building Construction	4,919	83,028	9.0
Nonresidential Plumbing & HVAC Contractors	2,346	55,572	5.5
Other Nonresidential Equipment Contractors	556	9,594	1.0

Source: (State of California, n.d.)

Manufacturers. As noted elsewhere, this measure may result in certain PVAV equipment manufacturers choosing to perform a one-time product redesign to meet the proposed requirements. Though, with the added bypass path, a redesign will no longer be required to comply with the California Energy Code. Manufacturers may also choose to add the capability to control bypass dampers to their firmware.

Another driver for manufacturers is the new federal test procedure for commercial unitary air conditioners and heat pumps that encourages manufacturers to provide equipment that can mechanically cool at low airflows. Interested readers can review the test procedure documented in AHRI 1340.[6]

The current metric, Integrated Energy Efficiency Ratio will be replaced with Integrated Ventilation, Economizing, and Cooling Efficiency (IVEC), which is designed to emphasize performance at low part load conditions. While the new test procedure and new energy conservation standards that also take effect on January 1, 2029, do not directly require any level of fan turndown, equipment ratings would be significantly penalized if mechanical cooling would not operate at 25 percent of the rated airflow. The IVEC test procedure was finalized in 2023, and manufacturers have been working since then to redesign equipment.

2.2.3 Compliance Software Updates

The Alternative Calculation Method (ACM) Reference Manual would be modified to better describe more capable PVAV equipment features that would result from the inclusion of this measure. The ACM Reference Manual would be modified to provide user input on the supply airflow turndown percentage while still supplying mechanical

[6] AHRI 1340 (I-P): Performance Rating of Commercial and Industrial Unitary Air-conditioning and Heat Pump Equipment is the test procedure referenced by the federal test procedure. https://www.ahrinet.org/search-standards/ahri-1340-i-p-performance-rating-commercial-and-industrial-unitary-air-conditioning-and-heat-pump

cooling capability of the central station air handler or PVAV equipment. The user shall also be able to indicate whether a supply air bypass method would be provided.

The software would take the minimum supply airflow at which mechanical cooling can be provided into account and set the supply airflow to at least that value whenever there is a call for mechanical cooling.

We also recommend that occupancy and lighting schedules be modified to reflect the requirements in the Energy Code to provide demand control ventilation and occupied standby capabilities.

2.2.4 Cost of Enforcement

The Statewide CASE Team acknowledges that changes to the code could impact enforcement costs. This report is an evaluation of specific measures, and the collective impact of all proposed changes for the California Energy Code may represent an increase in training and/or workload for enforcement personnel.

The increase in the cost of enforcement will be small. Plan reviewers must be cognizant of the proposed updates to the compliance forms described earlier and understand how to check that DCV and occupied standby are called out in controls sequences. Building inspectors will need to ensure that bypass systems are installed when specified in the plans and ensure the test described in NA7.5.6.2 is completed.

The compliance forms would change by adding fields to NRCC-MCH-E that describe how the zone supply air turndown requirements will be met: either using the bypass provisions or certifying that the equipment can turn down to the greater of 15 percent of the design supply airflow or the minimum outdoor air requirement in Section 401.2.1.1.3 *[Section 120.1(c)3]* and be able to provide mechanical cooling at all airflows. In addition, where the bypass method is used, the form shall show that mechanical cooling can be provided at 200 cfm per nominal ton of cooling capacity.

In addition, the existing space on NRCC-MCH-E that is intended to show the minimum deadband airflow is based on Section 401.2.1.1.3 *[Section 120.1(c)3]* and is not value selected by the designer.

Finally, the NRCA-MCH-07-A “Supply Fan Variable Flow Controls” form would be modified to reflect the proposed changes to the acceptance test.

2.3 PVAV Turndown - Market and Economic Analysis

2.3.1 Market Structure and Availability

2.3.1.1 Current Market Structure and Availability

PVAV equipment has been on the market for decades and is a mature product. All major HVAC manufacturers produce a version of this product. A review of the AHRI Directory [7] indicates 34 brands, though some of these brands are subsidiaries of a parent brand, listed for unitary large equipment at capacities greater than 240,000 Btu/h, which serves as a proxy for PVAV systems. There are 9,587 active listings in the AHRI database for sale in the United States as of August 2025. Since the proposed code change allows two paths to compliance, both will be discussed here.

We expect that many users will choose the bypass path, as it may be a significantly lower first cost. Although bypass ducts and dump dampers are not necessarily the preferred approach for many new multizone VAV systems today, they are not unusual or experimental components. Changeover-bypass VAV and VVT-type systems were widely applied in light-commercial packaged rooftop-unit systems during the 1990s and 2000s, particularly where a single constant-volume or limited-turndown RTU served multiple zones. These systems provided a practical way to add zone-level temperature control without requiring a fully variable-air-volume air handler, pressure-independent terminal units, or more complex central plant controls.

The bypass function was commonly implemented using a supply-to-return bypass duct, a modulating bypass damper, or a dump/relief arrangement that allowed excess supply air to return to the unit or return plenum when zone dampers closed. While modern designs often avoid this approach in favor of variable-speed fans, improved compressor turndown, and more advanced controls, bypass components remain commercially available and are still used in some current zoning products and retrofit applications. As a result, the use of a bypass duct or dump damper should be understood as a well-established HVAC practice, even if it is less common as a first-choice strategy in new high-performance construction.

The proposed bypass method does require that the PVAV be able to provide mechanical cooling down to 200 cfm per ton of nominal airflow (e.g., 10,000 cfm for a 50-ton system). The Statewide CASE Team reviewed manufacturer literature for 25-ton to 150-ton units to ensure that such equipment is readily available on the market today. As noted previously, not all manufacturers make this information available. The

[7] https://www.ahridirectory.org/https://www.ahridirectory.org/

Statewide CASE Team would appreciate comments from manufacturers about this requirement. The results of the research are as follows:

- Carrier WeatherMaker and WeatherMaster can turn down to 100 cfm/ton[8,9]
- York Sun Premier can turn down to 200 cfm/ton and in some cases a bit less.[10,11]
- Trane:
  - Intellipak 1, 2, and 3 can turn down to 200 cfm/ton in most cases. The literature for the Intellipak 1 includes a note to contact a Trane sales office if airflow outside the published range is needed.[12]
  - Voyager literature indicates that it cannot provide cooling at 200 cfm/ton.[13]
- AAON and Daikin do not publish minimum airflows but communicated to the Statewide CASE Team that 200 cfm/ton is not a barrier.

As noted above, the new federal test procedure for commercial packaged air conditioners and heat pumps that goes into effect on January 1, 2029, will severely penalize equipment that cannot provide mechanical cooling at low part loads. Therefore, the Statewide CASE Team believes that it is likely that all manufacturers will be able to provide equipment that allows mechanical cooling at 200 cfm per nominal ton of cooling by the time the 2028 Building Energy Code goes into effect.

Regarding the equipment airflow reduction path that does not require a bypass duct, the Statewide CASE Team readily admits that most manufacturers do not have equipment that meets the requirement currently. However, at least one manufacturer has asserted that their equipment already complies with this path's requirements and that they would not incur product redesigns. Another has told us that because of the same requirement in ASHRAE 90.1 2025 they will be able to comply before the 2028 Energy Code goes into effect. During the ASHRAE 90.1 proceeding, two manufacturers expressed concern about requiring turndown to 15 percent, but in the end agreed that they could do it. The same proposal is included in the draft of IECC 2027, and no manufacturer submitted a public comment. One of the manufacturers that submitted a comment to ASHRAE 90.1 was a member of the IECC committee and voted in favor of the proposal.

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[8] https://www.shareddocs.com/hvac/docs/1005/Public/0F/48-50K-2PD.pdf

[9] https://www.shareddocs.com/hvac/docs/1005/Public/01/48-50V-05PD.pdf

[10] https://docs.johnsoncontrols.com/ductedsystems/r/YORK/en-US/YORK-Sun-Premier-Rooftop-Units-25-Ton-to-80-Ton-Technical-Guide-R-454B/2024-08-14/Physical-data

[11] https://files.hvacnavigator.com/p/6481114-ytg-b-0125.pdf

[12] https://www.trane.com/commercial/north-america/us/en/products-systems/packaged-units-and-split-systems/rooftop-units/intellipak.html

[13] https://elibrary.tranetechnologies.com/public/commercial-hvac/Literature/Product%20Catalog/RT-PRC123C-EN_04172026.pdf

2.3.1.2 Market Challenges and Solutions

The market challenges for this system type include a lack of clarity around how low the equipment can deliver airflow without cycling and at what part load airflow rate the compressor is locked out. This lack of clarity impacts designers, installers, and building owners. Designers may have difficulty specifying the correct products for the job due to a lack of information from manufacturers.

This measure is expected to result in some product redesigns for units that are currently unable to reduce airflow to 15 percent of design capacity or lock out compressor operation at low airflow rates. Without redesigns, some equipment could encounter issues with oil return or coil freezing. However, it is worth noting that, since the requirement will be in ASHRAE 90.1-2025, manufacturers must meet these design requirements regardless of whether they are adopted in Title 24.

While manufacturers do not have to redesign their equipment to meet this measure due to the addition of the bypass path, the Statewide CASE Team expect many will to meet the requirements of ASHRAE 90.1, IECC 2027, and designers who want the most efficient systems. There are several options available to manufacturers to modify their equipment to meet this measure's requirements: adding a reheat coil (already a standard option), hot gas bypass to allow mechanical cooling at low airflow, smart control logic for intelligent cycling control of compressor stages in the unit, adding baffles, redesigning coil circuiting, and adding additional stages of mechanical cooling (including introducing variable speed, variable capacity, digital, two-stage, or multiple compressors in the unit). It is important to reiterate that with Addendum u to ASHRAE 90.1-2022, manufacturers must undertake this work regardless of the outcome of this Title 24, Part 6 code change proposal.

See Section 2.2 for a description of workforce training that may be needed to ensure effective design, installation, and commissioning.

2.3.2 Design and Construction Practices

2.3.2.1 Current Design and Construction Practices

The current best practice for dealing with the equipment's turndown limitation is to install a bypass duct in the air distribution system, one of the options in the measure. However, our review of VAV system plans only showed one design with a method of bypass. Based on our review of twenty recent California MV VAV plan sets in the Dodge

Pipeline database, most designers do not employ a bypass duct and set their VAV box minimum airflows above the requirements in the California Energy Code.[14]

The purpose of the bypass duct is to prevent conditioned air from being delivered to zones at excessive rates when demand for cooling is low. Without a bypass duct, and where the central station air handler or air conditioner cannot provide mechanical cooling below 200 cfm per ton of nominal cooling capacity, the zones are overcooled, which in turn causes excess reheating energy in the terminal units. Dump dampers, which release the excess air into a ceiling return damper, are also used on occasion.

As noted above, at least one manufacturer claims to produce products that can reduce airflow to meet the proposed requirement without bypass; however, it can be difficult to ascertain which ones comply due to insufficient labeling and advertising of these capabilities in product literature. This places a burden on designers and equipment procurers to conduct significant research prior to specifying and purchasing equipment.

Recent changes to code requirements and building occupancy patterns are increasing the need for more clarity around the technical capabilities of PVAV equipment. Code measures such as DCV and occupied standby are contributing to reduced airflow requirements for the system during part-load conditions. As noted above, the pandemic has led to lower commercial building occupancy patterns, further depressing the need for airflow delivered to the zones.

Unfortunately, most systems are designed without a bypass method or the capability to turn down to the zone minimums. There are no bypass ducts, and compliant products are not installed in the building; a ‘last resort’ workaround would be to elevate the zone terminal unit’s minimum airflow settings to ensure the system remains effective. As noted above, this would result in unnecessary reheat energy being used at the terminal unit, which may violate Title 24, Part 6 limitations on simultaneous cooling and heating.

2.3.2.2 Health and Safety Considerations

There are no health and safety considerations or impacts.

2.3.2.3 Design and Construction Challenges and Solutions

This measure is seen as a critical enhancement to the PVAV equipment so that it can continue to satisfy evolving building needs. As noted elsewhere in this report, measures that reduce airflow delivered to zones in low load and/or low occupancy periods are becoming increasingly widespread in recent years (both in California as well as nationally). Equipment must be able to turn down airflow to sufficiently low rates to

[14] The Dodge Pipeline database is a subscription service that contains nearly all construction projects in the USA and provides plans where they are publicly available. The plans are typically those released for the purpose of bidding.

efficiently provide conditioning in light of new code requirements. Additionally, as noted elsewhere, the lack of clarity around which specific PVAV options can deliver this capability is a major barrier to the design and construction community. This measure would level the playing field by providing assurance to the entire stakeholder community.

Due to the lack of advertised minimum airflow settings and compressor lockout controls for PVAV equipment, some designers and installers are not even aware of these limitations prior to installation and startup. This could result in the aforementioned challenges with energy efficiency and occupant comfort. This barrier would be overcome by this measure in the sense that stakeholders would gain confidence that all products on the market can meet low airflow conditions without locking out the compressor.

See Table 5 in Section 2.2.2 for a description of workforce training that could support effective design, installation, and commissioning.

2.3.3 Energy Equity and Environmental Justice

Each measure in this CASE Report was evaluated for ESJ impacts using 4 criteria: cost, health, resiliency, and comfort. The details of that evaluation can be found in Section 1.4 and the 2028 CASE Methodology Report.

Based on a preliminary review, the measures in this section are unlikely to have significant impacts on ESJ outside of any impacts mentioned in the 2028 CASE Methodology Report, therefore reducing the impacts of disparities on ESJ communities.

The proposed change has the potential to significantly improve occupant health and comfort by providing increased air ventilation. Additionally, the proposed change has the potential to improve the resiliency and efficiency of buildings, especially during periods of very warm temperatures. The Statewide CASE Team has determined the proposed change does not negatively impact the disaster readiness of ESJ communities.

2.3.4 Impacts on Jobs and Businesses

The Statewide CASE Team does not anticipate significant employment or financial impacts on any particular sector of the California economy. However, the proposed change may have modest impacts on employment in California. The Statewide CASE Team estimates the proposed change would affect statewide employment and economic output directly and indirectly through its impact on builders, designers, energy consultants, and building inspectors. Table 5, Table 8, and Table 9 outline the statewide implications for these job categories. For more information on the Statewide CASE Team's economic impacts methodology, see the 2028 CASE Methodology Report.

The Statewide CASE Team does not anticipate that the proposed changes would lead to the creation of new types of jobs or the elimination of existing types of jobs. In other words, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. Rather, it would lead to modest changes in the employment of existing jobs.

Table 7: Estimated Impact that Adoption of the Proposed Measure would have on the California Nonresidential Construction Sector

Type of Economic Impact	Employment (Jobs)	Labor Income (Million)	Total Value Added (Million)	Output (Million)
Direct Effects (Additional spending by Commercial Builders)	207	$16.4	$23.5	$48.9
Indirect Effect (Additional spending by firms supporting Commercial Builders)	106	$8.4	$14.3	$25.2
Total Economic Impacts	**313**	**$24.8**	**$37.8**	**$74.2**

Source: Statewide CASE Team analysis of data from the IMPLAN modeling software.[1]

Table 8: Estimated Impact that Adoption of the Proposed Measure would have on the California Building Designers and Energy Consultant Sectors

Type of Economic Impact	Employment (Jobs)	Labor Income	Total Value Added	Output
Direct Effects (Additional spending by building designers and energy consultants)	13	$1,475,988	$1,461,211	$2,309,581
Indirect Effect (Additional spending by firms supporting building designers and energy consultants)	5	$439,476	$610,784	$983,237
Total Economic Impacts	**19**	**$1,915,464**	**$2,071,995**	**$3,292,818**

Source: Statewide CASE Team analysis of data from the IMPLAN modeling software.

Table 9: Estimated Impact that Adoption of the Proposed Measure would have on California Building Inspectors

Type of Economic Impact	Employment (Jobs)	Labor Income	Total Value Added	Output
Direct Effects (Additional spending by building inspectors)	1	$160,292	$190,086	$230,993
Indirect Effect (Additional spending by firms supporting building inspectors)	0	$14,845	$23,121	$40,269
Total Economic Impacts	**2**	**$175,137**	**$213,207**	**$271,262**

Source: Statewide CASE Team analysis of data from the IMPLAN modeling software.

The proposed change represents a modest adjustment to multi-zone VAV HVAC systems to ensure systems can reduce airflow when not needed to save energy, which is not expected to excessively burden or competitively disadvantage California businesses, nor is it expected to lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not expect the proposed code changes to result in the creation of new businesses or the elimination of existing ones.

The proposed code changes would apply to all businesses operating in California, regardless of whether the business is incorporated inside or outside of the state.[2] Therefore, the Statewide CASE Team does not anticipate that the proposed changes would have an advantageous or an adverse effect on the competitiveness of California businesses.

The Statewide CASE Team derived a reasonable estimate of the change in investment by California businesses based on the estimated change in economic activity associated with the proposed measure and its expected effect on business income. The Statewide CASE Team's IMPLAN modeling resulted in an estimated $3,406,574 increase in California business income due to the proposed code change. The Statewide CASE Team assumed that net business investment is positively correlated with business income and that a portion of business income will be allocated to net business investment.

To estimate the portion of business income that would be allocated to net investment, the Statewide CASE Team analyzed national data on corporate profits and net capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI).[3] As Table 4 shows, between 2020 and 2024, NPDI as a percentage of corporate profits ranged from a low of 18 percent in 2020 due to the worldwide economic slowdowns associated with the COVID 19 pandemic to a high of 28 percent in 2022, with an average of 23 percent. While only an approximation of the proportion of business income used for net capital investment, it provides a reasonable estimate of the proportion of incremental income that business owners would reinvest into expanding their capital stock.

Table 10: Net Domestic Private Investment and Corporate Profits, U.S.

Year	Net Domestic Private Investment by Businesses, Billions of Dollars	Corporate Profits After Taxes, Billions of Dollars	Ratio of Net Private Investment to Corporate Profits (Percent)
2020	389	2,212	18
2021	545	2,888	19
2022	825	2,951	28
2023	836	3,069	27
2024	885	3,441	26
5-Year Average	Intentionally blank	Intentionally blank	23

Source: (Federal Reserve Economic Data (FRED) n.d.)

Given the estimated total increase in California business income and net business investment ratio described above, the Statewide CASE Team estimates the proposed code change would result in a $799,656 increase in net private investment by California businesses.

2.3.5 Economic and Fiscal Impacts

The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed measure would lead to a significant change (increase or decrease) in investment, directly or indirectly, in any affected sectors of California's economy. The proposed change would not result in economic disruption to any sector of the California economy. For more information on the Statewide CASE Team's economic and fiscal impacts methodology, see the 2028 CASE Methodology Report.

Adoption of this code change proposal would result in relatively modest economic impacts through the additional direct spending by those in the commercial building industry, architects, energy consultants, and building inspectors. The Statewide CASE Team does not anticipate that money saved by commercial building owners or other organizations affected by the proposed 2028 code cycle regulations would result in additional spending by those businesses.

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

The Statewide CASE Team does not expect the proposed code changes to have a measurable impact on California's General Fund, any state special funds, or local government funds.

Cost to State: The state government already has a budget for code development, education, and compliance enforcement. While the state government would be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, these activities are already covered by existing state budgets. The costs for the state government are small when compared to the overall cost savings and policy benefits associated with the code change proposals. State buildings would also be impacted by the proposed measure because they would be required to comply with the new requirement (new construction, additions, and alterations). However, the proposed measure has been found to be cost effective, so there is a net benefit in complying with the new requirements.

Cost to Local Governments: All proposed code changes to Title 24, Part 6 would result in changes to compliance determinations. Local governments would need to train building department staff on the revised Title 24, Part 6 Standards. While this retraining is an expense to local governments, it is not a new cost associated with the 2025 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 Statewide Utility Codes & Standards program (such as Energy Code Ace). As noted in Section 2.2.2, 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.

2.3.5.2 Mandates on Local Agencies or School Districts

There are no relevant mandates to local agencies or school districts because the requirements are widely applicable and not specific to local agencies or school districts.

2.3.5.3 Costs to Local Agencies or School Districts

There are no costs to local agencies or school districts because the requirements are widely applicable and not specific to local agencies or school districts. There are incremental costs associated with the proposed measure (as outlined in Section 2.4) but they are not specific to local agencies or school districts, and the proposal has been shown to be cost effective.

2.3.5.4 Costs or Savings to Any State Agency

There are no costs or savings to any state agencies beyond what is already described in Section 2.3.5.1. The proposed measure would not impose additional costs on state agencies because it does not have any requirements specific to any state agencies.

2.3.5.5 Other Non-Discretionary Cost or Savings Imposed on Local Agencies

There are no added non-discretionary costs or savings to local agencies as the proposed measure does not have any requirements specific to any local agencies.

2.3.5.6 Costs or Savings in Federal Funding to the State

There are no costs or savings to federal funding to the state. There proposed measure would not require federal funding to implement the proposed measure.

2.4 PVAV Turndown - Cost Effectiveness

2.4.1 Cost Effectiveness Methodology

The Statewide CASE Team collaborated with CEC staff to confirm that the cost-effectiveness methodology aligns with CEC guidelines, including cost inclusion parameters. The 2028 CASE Methodology Report and Appendix A provide reproducibility details.

Per California Law (Public Resources Code 25000), a measure is considered cost-effective if its benefit-to-cost ratio (BCR) is 1.0 or greater, amortized over the economic life of the structure. The Statewide CASE Team calculates BCR by dividing total dollar benefits by total dollar costs over a 30-year analysis period.

Benefits are based on Long-term System Cost (LSC), which assigns an hourly dollar value to energy use. LSC hourly factors weigh the long-term value of each hour differently, where times of peak demand are valued more than off-peak hours. These factors are not utility rates, forecasts, or bill estimates. The CEC develops and publishes LSC hourly conversion factors for each code cycle.

Costs include first costs and ongoing maintenance costs assessed over the 30-year period. Benefits and costs are evaluated incrementally, relative to the most recently adopted Energy Code. The analysis excludes design costs and incremental code compliance verification costs.

2.4.2 Energy and Energy Cost Savings Results

PVAV systems are commonly found in three types of buildings - Medium Offices, Schools, and Medium Laboratories. For this analysis, only the Medium Office was modeled. The savings in labs would be small, as their ventilation needs are such that there is no need for a bypass method. Schools were not modeled because the Statewide CASE Team could not determine the proportion of schools with PVAV systems, so savings are not claimed. Further, since CBECC does not model DCV well the savings shown would likely be small.

The Statewide CASE Team believes that most of the applications would be alterations in existing buildings. For new buildings and additions, 50 percent of the floor space is expected to be served by PVAV, which is 7.7 million square feet per CEC construction forecast. For existing Medium Office buildings, the Statewide CASE Team assumes 80 percent is served by PVAV systems that are replaced every 20 years. Per the CEC existing building stock, the measure would apply to 515.2 million square feet each year.

Modifications to the CBECC Medium Office Baseline

The original baseline IDF file was created using CBECC 2028 Research Version 1. It was subsequently modified to reflect realistic occupancy conditions in existing buildings and new buildings constructed to meet the prescriptive code. Unlike CBECC 2025, which uses a minimum airflow fraction of 30 percent, this version correctly reflects the requirement to have the VAV box minimum airflow equivalent to the outdoor airflow required in Table 401.2-A [Table 120.1-A]– Minimum Ventilation Rates. The input file from the research version was used as the measure and was modified to use a minimum flow fraction of 30 percent for the baseline.

The CBECC model uses an air-to-water heat pump (AWHP) with a supplemental electric boiler for heating. Based on the judgement of the Statewide CASE Team, it was assumed that alterations are heated with a 90 E_t boiler. The AWHP was removed and the supplemental boiler was converted to natural gas in both the measure and baseline models.

After considering feedback from stakeholders about the availability of equipment that could turn down to 15 percent of design airflow proposed in the Draft CASE report, a compliance path using a bypass has been added. Since using a bypass would not provide any fan power savings, the fan power savings in the measure case were zeroed out in post processing.

Updates to occupancy, lighting, and receptacle schedules

The occupancy, lighting, and plug loads schedules have been modified away from default values to reflect more realistic occupancy patterns in offices in the measure and baseline models. These changes are based on the professional judgment of an HVAC design engineer on the Statewide CASE Team and are supported by recently published data for North American office utilization.[15] The changes are further described in Appendix A.

New buildings are presumed to use an air-to water heat pump and a supplemental electric boiler for heating. Energy savings (electricity, natural gas, and source energy) and peak demand reductions per unit are presented in Table 11. Per-unit savings for the first year are expected to range from 0.22 to 0.86 kWh/yr, depending upon climate

[15] https://www.jll.com/en-uk/insights/market-outlook/top-global-cre-trends

zone. Demand reductions/increases are expected to range between -0.06 kW and 0.15 kW, depending on climate zone.

Table 11: Energy and Energy Cost Savings – Per Square Foot Medium Office

Climate Zone	First Year Electricity Savings (kWh)	First Year Peak Demand Reduction (kW)	First Year Natural Gas Savings (kBtu)	First Year Source Energy Savings (kBtu)	Total 30-Year LSC Savings (2029 PV$)
1	0.43	0.01	0	0.77	3.93
2	0.51	0.14	0	0.88	4.60
3	0.65	0.08	0	1.04	5.73
4	0.46	0.08	0	0.82	4.22
5	0.64	0.07	0	1.02	5.79
6	0.86	(0.02)	0	1.42	7.74
7	0.86	(0.01)	0	1.47	7.89
8	0.71	(0.03)	0	1.19	6.61
9	0.57	(0.03)	0	0.94	5.11
10	0.53	(0.03)	0	0.92	4.94
11	0.43	0.00	0	0.70	3.86
12	0.22	0.07	0	0.39	2.11
13	0.44	0.03	0	0.77	3.93
14	0.34	0.03	0	0.60	3.21
15	0.36	(0.06)	0	0.73	3.22
16	0.25	0.15	0	0.61	2.80

Alterations are assumed to use a 90 E_t boiler for heating. Table 12 presents total per-unit energy cost savings for newly constructed buildings and additions in terms of LSC savings realized over a 30-year period, in 2029 present value dollars (2029 PV$). The LSC methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

Table 12: 2029 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations – Medium Office

Climate Zone	30-Year LSC Electricity Savings (2029 PV$)	30-Year LSC Natural Gas Savings (2029 PV$)	Total 30-Year LSC Savings (2029 PV$)
1	0.61	0.03	0.64
2	1.70	0.03	1.72
3	2.28	0.04	2.32
4	1.93	0.02	1.95
5	2.38	0.03	2.42
6	4.75	0.04	4.79
7	5.15	0.04	5.18
8	4.40	0.03	4.43
9	3.20	0.03	3.22
10	3.13	0.02	3.16
11	1.99	0.02	2.01
12	1.31	0.01	1.32
13	2.16	0.02	2.18
14	1.78	0.02	1.79
15	1.97	0.02	1.99
16	1.33	0.01	1.34

2.4.3 Incremental First Cost

The Draft CASE Report showed cost-effectiveness for PVAV RTUs that could provide mechanical cooling at 15 percent of design airflow and showed a positive benefit-to cost ratio in all cases. However, due to concerns about availability of such equipment, a compliance path using either a bypass duct or a dump damper was added.

We believe that using a bypass method will be the most common method to comply with the measure. Since this path was added very recently, the Statewide CASE Team did not have time to research the cost of a bypass duct or duct damper. To be conservative, the Statewide CASE Team used a value four times the cost assumed for Addendum u to ASHRAE 90.1-2022 of $2,500, which is $10,000, bringing the first cost of the prototype to $30,000.

Since the Statewide CASE Team proposes a modification to acceptance testing that would take longer to complete, an additional eight hours of technician time at $250 per hour has been included. No additional labor costs are expected.

2.4.4 Incremental Maintenance and Replacement Costs

Description of the incremental maintenance and replacement costs, and estimation of the present value of maintenance and replacement costs, are provided in the 2028 CASE Methodology Report. In addition, the Statewide CASE Team assumed an actuator replacement after 15 years at the cost of $3,000 each.

2.4.5 Cost Effectiveness

Results of the per-unit cost-effectiveness analyses are presented in Table 13 and Table 14 for new construction/additions and alterations, respectively.

In the tables below, all values are presented in 2026 present value dollars (2029 PV$). Benefits represent 30-year LSC savings and other savings, including incremental first-cost savings if the proposed first cost is less than the current first cost, incremental maintenance cost savings if the proposed maintenance costs are less than the current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at the end of the 30-year period of analysis. Costs represent the total incremental PV cost, including equipment, replacement, and maintenance costs over the analysis period. The analysis treats a negative incremental maintenance cost as a positive benefit. If total incremental costs are zero, the benefit-to-cost ratio (BCR) is considered infinite. Costs and other savings are discounted at a real (inflation-adjusted) three percent rate. If there are no total incremental PV costs, the BCR is infinite.

For new construction heated with an AWHP, the BCR is strongly positive in all cases. For alterations heated with natural gas, the BCR is positive across all climate zones except CZ01. Therefore, systems installed in buildings primarily heated with gas in CZ01 are exempted.

Table 13: 30-Year Cost-Effectiveness Summary Per Square Foot – New Construction and Additions

Climate Zone	Benefits LSC Savings + Other PV Savings (2029 PV$)	Costs Total Incremental PV Costs (2029 PV$)	Benefit-to-Cost Ratio
1	3.93	0.70	5.58
2	4.60	0.70	6.53
3	5.73	0.70	8.13
4	4.22	0.70	5.99
5	5.79	0.70	8.22
6	7.74	0.70	10.98
7	7.89	0.70	11.20
8	6.61	0.70	9.38
9	5.11	0.70	7.25
10	4.94	0.70	7.01
11	3.86	0.70	5.48
12	2.11	0.70	2.99
13	3.93	0.70	5.58
14	3.21	0.70	4.55
15	3.22	0.70	4.57
16	2.80	0.70	3.97

Table 14: 30-Year Cost-Effectiveness Summary Per Square Foot – Alterations

Climate Zone	Benefits LSC Savings + Other PV Savings (2029 PV$)	Costs Total Incremental PV Costs (2029 PV$)	Benefit-to-Cost Ratio
1	0.64	0.70	0.91
2	1.72	0.70	2.45
3	2.32	0.70	3.30
4	1.95	0.70	2.77
5	2.42	0.70	3.43
6	4.79	0.70	6.80
7	5.18	0.70	7.36
8	4.43	0.70	6.29
9	3.22	0.70	4.58
10	3.16	0.70	4.48
11	2.01	0.70	2.86
12	1.32	0.70	1.87
13	2.18	0.70	3.10
14	1.79	0.70	2.54
15	1.99	0.70	2.82
16	1.34	0.70	1.90

2.5 PVAV Turndown - Statewide Impacts

2.5.1 Statewide Energy and Energy Cost Savings

See the 2028 CASE Methodology Report for details on how statewide savings are calculated. Appendix C presents the assumptions on the percentage of the total construction forecast that the proposed measure would impact.

For more details on the methodology and context of estimating the current market share rate, as well as statewide energy and energy cost savings, see the 2028 CASE Methodology Report.

The tables below present the first-year statewide energy and LSC savings from newly constructed buildings and additions (Table 15) and alterations (Table 16) by climate zone. Table 17 presents first-year statewide savings from new construction, additions, and alterations.

Peak demand is increasing in many climate zones. These are all during very hot hours when cooling demand was high. VAV boxes would not be at their minimum airflows at this time and should not have been affected by this measure. Since the measure and baseline models have identical cooling systems, the Statewide CASE Team does not have an explanation for this.

Table 15: Statewide Energy and LSC Impacts – New Construction and Additions

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Million Square Feet)	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2029 PV$)
1	44,578	0.02	0.00	-	0.03	$0.18
2	340,115	0.17	0.05	-	0.30	$1.56
3	710,400	0.46	0.06	-	0.74	$4.07
4	495,150	0.23	0.04	-	0.41	$2.09
5	196,565	0.13	0.01	-	0.20	$1.14
6	720,850	0.62	(0.02)	-	1.02	$5.58
7	443,590	0.38	(0.01)	-	0.65	$3.50
8	1,038,650	0.73	(0.03)	-	1.23	$6.86
9	1,282,450	0.72	(0.04)	-	1.21	$6.55
10	664,300	0.35	(0.02)	-	0.61	$3.28
11	205,505	0.09	0.00	-	0.14	$0.79
12	517,500	0.12	0.04	-	0.20	$1.09
13	273,255	0.12	0.01	-	0.21	$1.07
14	162,635	0.06	0.00	-	0.10	$0.52
15	110,350	0.04	(0.01)	-	0.08	$0.36
16	48,340	0.01	0.01	-	0.03	$0.14
Total	**7,254,232**	**4.26**	**0.09**	**-**	**7.17**	**$38.78**

Table 16: Statewide Energy and LSC Impacts – Alterations

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Million Square Feet)	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2029 PV$)
1	131,852	0.01	0.02	0.00	0.01	$0.08
2	1,193,400	0.25	(0.01)	0.04	0.28	$2.06
3	3,007,600	0.83	(0.02)	0.14	1.12	$6.99
4	1,640,960	0.36	(0.06)	0.04	0.47	$3.20
5	512,120	0.15	0.00	0.02	0.16	$1.24
6	2,026,840	1.08	(0.04)	0.09	1.58	$9.70
7	1,857,480	1.03	(0.02)	0.08	1.64	$9.63
8	2,517,320	1.15	(0.07)	0.09	1.72	$11.15
9	3,455,040	1.19	(0.11)	0.11	1.73	$11.14
10	2,885,720	0.94	(0.09)	0.08	1.42	$9.11
11	695,000	0.15	(0.03)	0.02	0.21	$1.40
12	4,103,200	0.56	(0.24)	0.04	0.87	$5.41
13	1,045,760	0.26	(0.04)	0.03	0.36	$2.28
14	556,280	0.10	(0.02)	0.01	0.15	$1.00
15	438,520	0.10	(0.03)	0.01	0.15	$0.87
16	168,720	0.02	(0.01)	0.00	0.03	$0.23
Total	**26,235,812**	**8.16**	**(0.79)**	**0.81**	**11.92**	**$75.49**

Table 17: Statewide Energy and LSC Impacts – New Construction, Additions, and Alterations

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2029 PV$)
New Construction & Additions	4.3	0.1	-	7.2	39
Alterations	8.2	-0.8	0.8	11.9	75
Total	**12.5**	**-0.7**	**0.8**	**19.1**	**114**

2.5.2 Statewide Greenhouse Gas Emissions Reductions

Table 18 presents the estimated first-year reduction in GHG emissions resulting from the proposed code change. In this initial year, the Statewide CASE Team expects to avoid 1,015 metric tons of carbon dioxide equivalent (CO_2e) emissions. These reductions, along with their associated monetary value, were calculated using hourly GHG emissions factors published alongside the LSC hourly factors and source energy hourly factors in the research versions of CBECC, and data from the CEC's 2028 Metrics Report. See the [2028 CASE Methodology Report] for additional information.

Table 18: First-Year Statewide GHG Emissions Impacts

Construction Type	Reduced GHG Emissions from Electricity Savings (Metric Tons CO2e)	Reduced GHG Emissions from Natural Gas Savings (Metric Tons CO2e)	Total Reduced GHG Emissions (Metric Ton CO2e)	Total Monetary Value of Reduced GHG Emissions ($)
New Construction & Additions	379	0	379	46,697
Alterations	594	42	636	78,363
Total	**973**	**42**	**1,015**	**125,060**

2.5.3 Statewide Water Use Impacts

The proposed code change would not result in water use impacts.

2.5.4 Statewide Material Impacts

This measure is not expected to result in a meaningful change to materials.

2.5.5 Environmental Impacts

This proposal would result in improved building energy efficiency and corresponding GHG emissions reductions. The requirement ensures that PVAV systems can efficiently turn down fan speeds during part load conditions without disabling compressoroperation if needed.

There are no identified indirect adverse environmental impacts nor indirect environmental benefits from this code change proposal.

2.5.6 Other Non-Energy Impacts

This measure is not expected to result in any non-energy impacts.

2.6 PVAV Turndown - Proposed Code Language

2.6.1 Guide to Markup Language

The proposed changes to the standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2025 documents should be marked with dark blue underlining (new language) and ~~strikethroughs~~ (deletions). New to the 2028 energy code is to *italicize defined terms* when the terms are being used in its defined context. In-line comments that are not part of the proposed code language but are used to help describe the purpose of what is proposed are included *with greyed highlight and italics.*

Markups are provided to the restructured 2025 Energy Code that the CEC developed in response to feedback that aligning the structure of Title 24, Part 6 with other parts of the California Building Standards Code (Title 24) would improve readability, usability, and navigation.[8] New section numbers are shown as bold followed square brackets that document the section in the 2025 Title 24, Part 6 section numbers prior to the restructuring. For example, "**Section 601.1** [Section 130.0(a)] **General"** contains the content that is in the current Section 130.0(a).

Posting the proposed code language in this format is useful as it helps describe how the Energy Code changes proposed for nonresidential occupancies are isolated from the requirements for residential occupancies which are prohibited from being changed until the 2031 code cycle by Assembly Bill 130.

2.6.2 Administrative Code (Title 24, Part 1)

There are no proposed changes to Title 24, Part 1.

2.6.3 Energy Code (Title 24, Part 6)

401.3 *[Section 140.4]* – Prescriptive requirements (Newly Constructed)

…

401.3.14 *[Section 140.4(m)]* **Fan and mechanical cooling control.**

Each cooling system listed in Table 401.3-J *[Table 140.4-I]* shall be designed to vary the indoor fan airflow as a function of load and shall comply with the following requirements:

…

4. *Multiple zone systems* shall meet one of the following:

4.1 Be able and configured to be able to reduce airflow from the supply fan to the larger of 15 percent of design airflow or the minimum outdoor airflow required in

Section 401.3.21 *[New section]*.[16] The system shall be capable of providing *mechanical cooling* at that airflow; or

4.2 Where equipment cannot reduce airflow and provide *mechanical cooling* as required in Section 401.3.14.4.1, the following shall be met:

4.2.1 Provide an *automatic* method to return excess airflow greater than what is required in accordance with the airflow requirements specified in Section 401.2.1.1.3 [Section 120.1(c)3] and Section 401.3.6.2 [Section 140.4(d)(2)(A)(ii) and 140.4(d)(2)(B)(ii)] to the central air handler or air conditioner.

4.2.2 The excess air shall be returned through a bypass duct or return plenum without entering the *conditioned space*.

4.2.3 The central air handler or air conditioner shall be capable of and configured to provide mechanical cooling at not more than 200 cfm per nominal ton of cooling capacity.

Exception 1 to Section 401.3.14.4 : *Hotel/motel* buildings and *nonresidential* buildings with Group R occupancies.

Exception 2 to Section 401.3.14.4 : Buildings in Climate Zone 1 where not less than 75 percent of the *conditioned floor area* is heated with a *gas heating system*.

Exception 3 to Section 401.3.14.4 : Systems without DDC.

401.5.2.2 *[Section 141.0(b)2]* **Prescriptive requirements (Alterations).**

401.5.2.2.1 *[Section 141.0(b)2C]* **New or Replacement Space-Conditioning Systems or Components**

New or Replacement Space-Conditioning Systems or Components other than new or replacement space-conditioning system ducts shall meet the requirements of Section 401.3 *[Section 140.4]* applicable to the systems or components being altered and meet the requirements of Sections 401.5.2.2.1.1, ~~and~~ 401.5.2.2.1.2, and 401.5.2.2.1.3.

…

401.5.2.2.1.3 [New section] Where the central *air handler* or *air conditioner* of a *multiple zone system* is replaced or more than 50 percent of the air terminal

[16] See the description of the proposed new Section 401.3.21 to Title 24 Part 6 in section 3.1.1 and the proposed code change in section 3.6.3. This footnote is not intended to be part of the final Title 24 Part 6 code language.

units, calculated by design airflow, are replaced, the requirements of Section 401.3.14.4 shall be met.

Exception 1 to 401.5.2.2.1.3 [New Section]: Where only air terminal units are replaced and there is no return ceiling plenum or it is demonstrated to the enforcement authority that it is not feasible to use the ceiling plenum due to plenum congestion or safety concerns.

Exception 2 to 401.5.2.2.1.3 [New Section]: Where only air terminal units are replaced and the return system is fully ducted.

Exception 3 to 401.5.2.2.1.3 [New Section]: Where only a packaged *air conditioner* or *heat pump* located indoors is replaced and it is demonstrated to the enforcement authority that there is insufficient space for a bypass.

2.6.4 Reference Appendices

NA7.5.6 **Supply Fan Variable Flow Controls**

NA7.5.6.1 Construction Inspection

Prior to Functional Testing, verify and document the following:

(a) Supply fan includes device(s) for modulating airflow, such as variable speed drive

or electrically commutated motor.

(b) For multiple zone systems:

1. Discharge static pressure sensors are either factory calibrated or field calibrated.
2. The static pressure location, setpoint, and reset control meets the requirements of §140.4(c)2A and §140.4(c)2B.

NA7.5.6.2 Functional Testing

Step 1: Simulate demand for full design airflow. Verify and document the following:

(a) Supply fan controls modulate to increase capacity.

(b) For multiple zone systems, supply fan maintains discharge static pressure within

+/-10 percent of the current operating setpoint.

(c) Supply fan controls stabilize within a 5 minute period.

Step 2A: For *multiple zone systems* with DDC that do not serve *Hotel/motel* buildings and *nonresidential* buildings with Group R occupancies, s~~S~~imulate demand for reduced or minimum airflow. Verify and document the following:

(d) For systems that do not comply using Section 401.4 [Section 100.2], verify that the system has a method of bypass that meets the requirements of Section 401.3.14.4 *[140.4(m)4]* or that the central fan(s) and compressor(s) are capable of and configured to meet the requirements of Section 401.3.14.4 *[140.4(m)4]*.

(e) Close the outdoor air dampers.

(f) For systems that comply using Section 401.4 [Section 100.2] set the flow through the air terminal units such that the sum is equal to the minimum airflow for mechanical cooling shown on the compliance form plus 5 percent.

For all other systems, set the flow through the air terminal units to the minimum value specified on the compliance form

(g) Reduce the temperature setpoint in the zones enough to engage mechanical cooling.

(h) Confirm that mechanical cooling is operating by showing a temperature drop of not less than 5ºF between the return and supply air.

(i) fan maintains discharge static pressure within +/-10 percent of the current operating setpoint.

(j) Supply fan controls stabilize within a 5 minute period.

Step 2B: For all other systems, sSimulate demand for reduced or minimum airflow. Verify and document the following:

(d) Supply fan controls modulate to decrease capacity.

(e) Current operating setpoint has decreased (for systems with DDC to the zone level).

(f) For multiple zone systems, supply fan maintains discharge static pressure within
+/-10 percent of the current operating setpoint.

(g) Supply fan controls stabilize within a 5 minute period.

Step 3: Restore the system to the correct operating conditions.

2.6.5 Compliance Manuals

The Statewide CASE Team will provide the CEC with recommended revisions to compliance manuals after the 45-Day Language is published.

2.6.6 ACM Reference Manual

5.1.3 HVAC System Map

Table 2: System Descriptions

System Type	Description	Detail
System 5 – PVAV	Packaged VAV	Multizone packaged system with variable-air-volume fan, direct expansion cooling, and hot water heating provided by central gas boiler. See Table 3: System 5 – PVAV and System 6 – VAV: Standard Design Criteria for additional system details.
System 6 – VAV	Built-up VAV	Multizone built-up system with variable-air-volume fan, chilled water cooling provided by a central water-cooled chiller and cooling tower, and hot water heating provided by central gas boiler. See Table 3: System 5 – PVAV and System 6 – VAV: Standard Design Criteria for additional system details.
System 15 – PVAVAWHP	Packaged VAV with AWHP heating	Multi-zone packaged system with variable-air-volume fan, direct expansion cooling, and hot water heating provided by an air to water heat pump (AWHP). See Table ~~3~~4: System 15 – PVAVAWHP: Standard Design Criteria for additional system details based on occupancy served and climate zone.

Table 3: System 5 – PVAV and System 6 – VAV: Standard Design Criteria

Note: all other rows remain unchanged.	
Supply air turndown	The PVAV unit is capable of reducing airflow the greater of 15 percent of the system design airflow or the minimum outdoor airflow required in Section 401.2.1.1.3 *[120.1(c)3]*.
Mechanical Cooling	Mechanical cooling is available at all airflows.

Outdoor airflow control	Demand control ventilation and occupied standby required in Section 401.2.1 *[120.1]* are enabled. *Note: The Statewide CASE Team will work with the CEC to create zone occupancy schedules that reflect real-world zone occupancies.*

Table ~~3~~4: System 15 – PVAVAWHP: Standard Design Criteria

	Schools	Offices
Note: all other rows remain unchanged.		
Supply air turndown	The PVAV unit is capable of reducing airflow the greater of 15 percent of the system design airflow or the minimum outdoor airflow required in Section 401.2.1.1.3 *[120.1(c)3]*.	
Mechanical Cooling	Mechanical cooling is available at all airflows.	
Outdoor airflow control	Demand control ventilation and occupied standby required in Section 401.2.1 *[120.1]* are enabled. *Note: The Statewide CASE Team will work with the CEC to create zone occupancy schedules that reflect real-world zone occupancies.*	

5.6.7 Terminal Airflow

5.6.7.1 Variable Air Volume (VAV) Airflow

TERMINAL MINIMUM AIRFLOW

Applicability: Systems that vary the volume of air at the zone level

Definition: The minimum airflow that will be delivered by a terminal unit.

Units: Unitless fraction of airflow

Input Restrictions: Input must be greater than or equal to the outside air ventilation rate. For packaged VAV, built-up VAV, and built-up VAV with AWHP heating where the Control System Type Certified Guideline 36 Libraries specify that certified Guideline 36 libraries are not being used, the modeled minimum airflow shall be the maximum of 2 times the minimum airflow input and 2 times the minimum outside air ventilation rate. For laboratories, users may input separate minimum rates for occupied and unoccupied. The unoccupied rates shall be used when the occupancy schedule indicates an occupancy fraction below 0.10.

Standard Design: For healthcare facilities, same as the Proposed Design. For systems 5, ~~and~~ 6, and 15, packaged VAV units and built-up VAV air handling units, set the minimum airflow to be the maximum of the minimum outside air ventilation rate or 10 percent of the design airflow.

For laboratories, the occupied minimum airflow fraction shall be fixed at a value equivalent to the greater of the proposed design occupied minimum exhaust requirements or the occupied minimum ventilation rate. The unoccupied minimum airflow fraction shall be 0.33 cfm/ft2 less than the occupied minimum airflow fraction.

5.7.5.3 Direct Expansion

Mechanical cooling availability– MULTIPLE ZONE PACKAGED VAV SYSTEMS

Applicability: Multiple zone packaged VAV systems that are not healthcare facilities, *Hotel/motel* buildings and *nonresidential* buildings with Group R occupancies.

Definition: The minimum airflow at which the multiple zone system can provide mechanical cooling.

Input Restrictions: The user shall enter the value for the PVAV equipment that will be used and whether a bypass method to return air not needed in the zones to meet ventilation, heating or cooling loads. If there is no bypass method, anytime the system airflow is less than this value and there are zones with a call for mechanical cooling, the other zones shall open sufficiently to enable mechanical cooling. If a bypass method is provided, the airflow to the zones shall not be affected by a call for mechanical cooling, and if there is excess airflow, it shall be bypassed.

Standard design: For healthcare facilities, same as proposed design. The system shall have mechanical cooling available at an airflow equal to 200 cfm/ton of the nominal capacity of the unit and a method of bypass. The airflow to the zones shall not be affected by a call for mechanical cooling, and if there is excess airflow, it shall be bypassed.

2.6.7 Compliance Forms

The compliance forms would change by adding fields to NRCC-MCH-E that describe how the zone supply air turndown requirements will be met: either using the bypass provisions or certifying that the equipment can turn down to the greater of 15 percent of the design supply airflow or the minimum outdoor air requirement in Section 401.2.1.1.3 [Section 120.1(c)3] and be able to provide mechanical cooling at all airflows. In addition, where the bypass method is used, the form shall show that mechanical cooling can be provided at 200 cfm per nominal ton of cooling capacity.

The existing space on NRCC-MCH-E that is intended to show the minimum deadband airflow for each VAV box is based on Section 401.2.1.1.3 [Section 120.1(c)3] and is not value selected by the designer must be clarified.

Where buildings comply through the performance path, a new section that show the minimum airflow at which mechanical cooling is available will be needed.

Finally, the NRCA-MCH-07-A “Supply Fan Variable Flow Controls” form would be modified to reflect the proposed changes to the acceptance test.

3. Modulating DOAS

3.1 Modulating DOAS - Measure Description

3.1.1 Proposed Code Change

This measure seeks to establish mandatory and prescriptive requirements for Dedicated Outdoor Air Systems (DOAS) in nonresidential new construction and additions and alterations, aligning with cost-effective best practices. In addition, this measure would modify sections of the Energy Code in ways that impact both DOAS and mixed-air systems to improve efficiency and enforceability of existing requirements.

The mandatory submeasures would apply to new construction. The prescriptive submeasures would apply to new construction, additions, and alterations (specifically, system replacements and new installations). All submeasures would apply in all 16 California climate zones.

The proposal would add the following mandatory requirements to Section 401.2 *[Section 120.1]:*

(a) Modify subsection 401.2.1.2 *[120.1(d)]* require DOAS systems in buildings with 3,000 or more cfm of design outdoor airflow to include a means (such as modulating dampers) to modulate and/or shut off airflow to individual thermal zone required to have DCV or occupied standby, while maintaining required ventilation to all zones served by the system. The proposal would also make minor changes to 401.2.2 [120.2] to make it clear that ventilation systems are covered. Finally, the proposal would make a minor change to 401.3.5.2 [140.4(c)2] to ensure that modulating DOAS systems include a duct static pressure sensor to ensure efficient fan operation.

(b) Clarify where Occupied Standby is currently required in Section 401.2.1.2.5 *[Section 120.1(d)5A].* This change is intended to improve the efficacy of the HVAC occupied standby measure in both mixed air as well as DOAS systems. The 2028 Lighting Controls CASE report is proposing to add some new spaces to its list, and the proposal contained here includes those which also include spaces in Table 120.1-A with the "F" designation, indicating that occupied standby is allowable. Finally, editorial changes to Table 401.2-A [Table 120.1-A] in section 401.2.1.1.3 are being proposed to align with recent ASHRAE 62.1 addenda. ASHRAE 62.1-2022 Addendum w changes the term "Computer Lab" in the Educational Facilities occupancy category and "Computer (not printing)" in Miscellaneous Spaces to "Information technology equipment facilities (occupiable)" in both occupancy categories. Similarly, ASHRAE 62.1-2022

Addendum b strikes “Breakrooms” in the Office Buildings occupancy category, because there is a related space type in the General occupancy category called “Break rooms.” The presence of two similar space types for break rooms causes ambiguity, and we propose following ASHRAE 62.1 with these editorial changes.

Additionally, the following prescriptive changes are proposed in Section 401.3 *[Section 140.4]:*

(c) Addition of a prescriptive option to the language at 401.3.17.2 *[140.4(p)2]* that would allow DOAS ventilation air to be delivered to the return air inlet of a fan coil unit (with language to ensure efficient design). The intent of this adjustment is to provide an additional economical yet efficient prescriptive option for the designer.

(d) Revise 401.3.17.4 *[140.4(p)4]* to adjust the Supply Air Temperature (SAT) requirement from 60°F to 55°F when the building is in heating mode, and add language that limits the system from providing air below 75°F when the system is in cooling mode to prevent re-heating or re-cooling. The measure applies to DOASes with mechanical cooling and heating.

(e) Add a new prescriptive subsection at 401.3.21 that places an upper limit to the design minimum airflow rate. This value would be the greater of 110 percent of the calculated value derived from Equation 401.2-B *[Equation 120.1-F]* located in the mandatory section 401.2.1.1.3 *[Section 120.1(c)2]*, the rate required for make-up of process exhaust systems minus available transfer air, per 401.3.16 *[Section 140.4(o)]*, or the rate required to meet special pressurization relationships required for health or safety. The benefit of this addition would be energy savings from ensuring that buildings are designed with minimum airflows at or near the minimum required to maintain healthy indoor air quality. This submeasure would mimic Addendum p to ASHRAE 90.1-2022. The ACM Reference Manual already sets an upper limit to the design minimum airflow rate in section 5.6.9, so this prescriptive addition would simply ensure that buildings complying prescriptively would be held to the same standard that buildings complying using the performance approach are already held to.

Table 19 summarizes the scope of the proposed code change.

Table 19: Scope of Proposed Code Change

A ☑ indicates the proposed code change is relevant.

Building Type(s)	Construction Type(s)	Type of Change
☐ Single Family	☑ New Construction (all submeasures)	☑ Mandatory (submeasures a and b)
☐ Multifamily	☑ Additions (submeasures c, d, and e)	☑ Prescriptive (submeasures c, d, and e)
☑ Nonresidential (Not Group R uses)	☑ Alterations (submeasures c, d, and e)	☐ Performance

Application Climate Zones	Energy Code Sections	Compliance Forms	Sections of ACM Reference Manuals
Climate Zones 1-16	• Part 6, Sections 401.2.1, 401.2.2, 401.3, 401.5 *[Sections 120.1, 120.2, 120.5, 140.4, 141.0]*	NRCC-MCH-E, NRCA-MCH-06-A, NRCA-MCH-19-A	5.6.9, 5.7.2

Third Party Verification)	Updates to Compliance Software
☑ No changes to third party verification	☐ No updates
☐ Update existing verification requirements	☑ Update existing feature
☐ Add new verification requirements	☐ Add new feature

The sub-measures are further distinguished in Table 20. This table shows which aspects of the proposal require a cost-effectiveness analysis and the sections of the code to which they apply, as well as some other key information.

Table 20: Modulating DOAS Submeasure Information

No	Submeasure Name	Code Section	Applicable To	Scope Detail	Upfront Costs	Supporting Analysis
a	Modulating DOAS (Modulating dampers)	Mandatory	New Construction	DOAS in buildings with > 3,000 cfm design OA	Yes	Full cost-effectiveness
b	Occupied Standby Cleanup	Mandatory	New Construction	DOAS and mixed-air systems	No	None
c	DOAS Supply Air Delivery Option	Prescriptive option	New Construction, Additions, Alterations	All DOAS	No	LSC/source parity
d	DOAS Supply Air Temperature Revisions	Prescriptive requirement	New Construction, Additions, Alterations	All DOAS	No	None
e	Design Min OA	Prescriptive requirement	New Construction, Additions, Alterations	DOAS and mixed-air systems	No	None

3.1.2 Benefits of Proposed Change

3.1.2.1 Submeasure a: Modulating Dampers

The most important substantive change in this proposal is the inclusion of a new mandatory requirement in Section 401.2.1.2.6 *[New section]*, which specifies that larger buildings (with design airflows greater than 3,000 cfm) DOASes must modulate airflow. Currently, some DOAS designs do not have an outlet for each thermal zone; instead, there is just one outlet for several thermal zones. This causes the DOAS system to effectively behave like a constant-air-volume system and prevents the system from meeting occupied standby and DCV. The 2025 edition of the Energy Code requires airflow-limiting measures for mixed-air variable-air-volume systems but is silent regarding DOAS systems, creating ambiguity and a perception in the market that DOAS do not need to limit airflow. Requiring airflow modulation equipment in DOAS systems enables compliance with occupied-standby and DCV, saving energy by dynamically ventilating the zones as needed.

With this measure, DOAS systems serving spaces required to have occupant sensing ventilation controls shall include modulating pressure independent dampers or other means of modulating outside air at all space conditioning zones. This shall be done to limit ventilation to unoccupied zones while maintaining measured outside air ventilation rates to occupied zones within ten percent of the design minimum outside air ventilation rate per 401.2.1.4.2 *[120.1(f)2]* and shall include demand ventilation controls for high-density spaces per 401.2.1.2.3 *[120.1.(d)3].*

This aspect of the measure would also ensure that in-scope DOAS systems provide more precise ventilation and airflow management. This would reduce energy consumption and fine-tune the total airflow based on the individual zone requirement, which may consequently result in cooling and heating savings.

Requiring the DOAS system to be variable air volume (VAV) would result in energy savings when controlled properly, in addition to providing system balancing and reducing stress on motors and other components during startup and operation.

3.1.2.2 Submeasure b: Occupied Standby Cleanup

The proposal also seeks to clarify the occupied standby language in Section 401.2.1.2.5 *[Section 120.1(d)5].* Currently, occupied standby requirements are drawn from Table 401.2-A and Sections 601.2.2.3.5 and 601.2.2.3.6 *[Table 120.1-A and Section 130.1(c)5 and 6],* which is believed to result in poor compliance rates since it is very time consuming to understand when which space type may or may not be required to include occupied standby controls for ventilation. This editorial change proposes to simply list the required ventilation occupied standby spaces in one place at 401.2.1.2.5 *[120.1(d)5]*, which should improve compliance rates and save energy. The Venn Diagram in Figure 3 displays the relationship between three separate code sections (shown in the figure):

1. Where occupied standby is permitted for ventilation. Occupied standby is “permitted” for space types that include “footnote F” in this table.[17]
2. Where occupied standby is required for lighting
3. Where occupied standby is required for ventilation.

The issue is that while items 1 and 2 are well articulated in the code, item 3 is just a reference to Table 401.2-A and Section 601.2.2.3 and has therefore suffered from poor understanding and compliance in the market.

[17] Footnote F reads: “Ventilation air for this occupancy category shall be permitted to be reduced to zero when the space is in occupied-standby mode.”

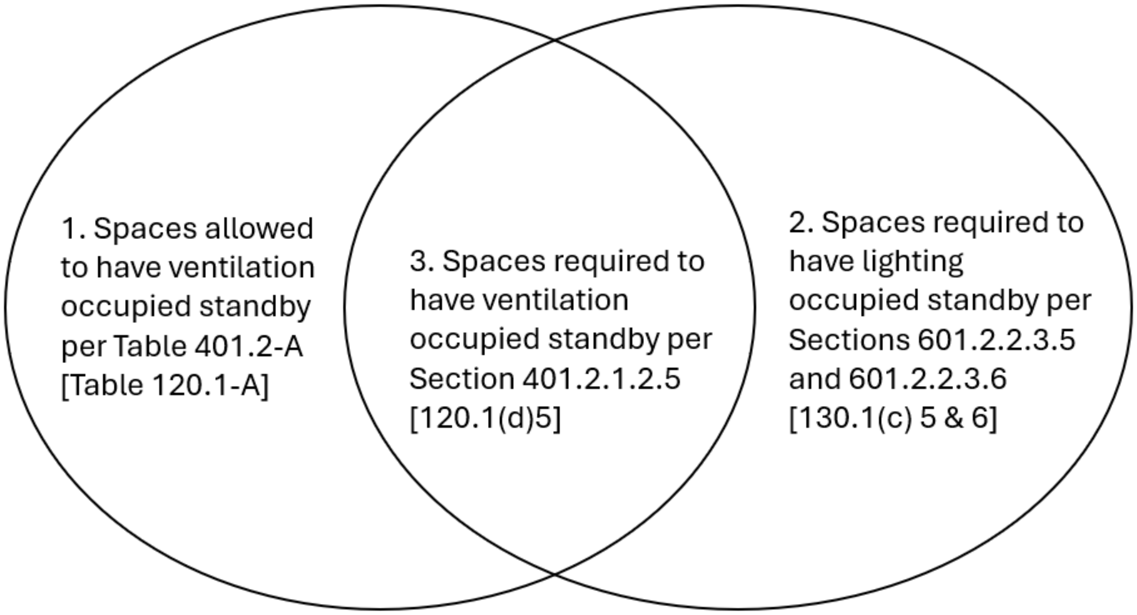

Figure 3: Venn Diagram of Title 24 Occupied Standby Requirements

Note that a separate CASE study in the 2028 code cycle is focused on expanding the list of occupied standby spaces for lighting. This proposal is leveraging the potential expanded number of space types and adding them to this report's list of proposed spaces where occupied standby would be required at Section 401.2.1.2.5, but ONLY for those spaces where the "F" designation is already present in Table 401.2-A. These spaces are shown in Table 21. Note that the lighting proposal and code language uses slightly different wording, the Statewide CASE Team proposes using wording identical to what is already in Table 401.2-A *[Table 120.1-A]* for the new required occupied standby table for consistency within the ventilation code requirements. Finally, note that while this technically represents an expansion of the scope of required occupied standby spaces for ventilation, this report does not claim any savings because savings are being claimed in Indoor Lighting Controls.

Table 21: Spaces that include Footnote "F" in Table 401.2-A that are in Lighting Controls CASE Report

Occupancy Category	Space Type
Office Buildings	Main entry lobbies
Miscellaneous Spaces	Bank vaults/safe deposit
Miscellaneous Spaces	Banks or bank lobbies
Miscellaneous Spaces	Information technology equipment facilities (occupiable)[18]
Miscellaneous Spaces	Transportation waiting
Public Assembly Spaces	Lobbies

3.1.2.3 Submeasure c: DOAS Supply Air Delivery Option

The Statewide CASE Team proposes edits to the allowable ventilation air delivery language at 401.3.17.2 *[140.4(p)2].*

The current language states that the zonal system "shall cycle off any zone heating and cooling equipment fans, circulation pumps and terminal unit fans when there is no call for heating or cooling in the zone." Cycling off the zonal system just means that the "critical zone" on the DOAS system adds approximately 0.2" in additional external static pressure (ESP) to the central DOAS system. Of course, this means that every other zone also is supplied with that added 0.2" of static and throttles as necessary at terminal units. So, in practice little to no fan energy is saved since it is just shifting from the turned-down/low speed zonal fan coil units (FCU) to the DOAS. The other issue is that it means—unless engineers intend to provide separate diffusers for DOAS and zonal terminals—that the DOAS air is discharging into the discharge duct of the FCU. The issue here is that the DOAS modulating damper and sensible conditioning unit typically do not communicate with one another, meaning there is the potential that the FCU may be operating at high speed while the DOAS' modulating damper is providing at least minimum ventilation—and possibly more airflow if the DOAS modulating damper has been sized for economizer duty. There are three issues with that:

1. It means that the discharge ductwork and diffusers need to be sized for the worst case combined FCU + DOAS airflow
2. If this is not done, it creates a situation where the FCU discharge ductwork is over-pressurized, possibly causing the FCU to ride back on its curve and deliver less airflow/capacity.

[18] Note that this category is currently listed in Title 24 Part 6 as "Computer (not printing)," but as Section 3.1.1 describes, this measure proposes updating the terminology to align with recent updates to ASHRAE 62.1.

3. It means the DOAS unit, when FCUs are in heating/cooling, still has to overcome the ESP of the FCU discharge ductwork (which is now greater because the FCU is on, too).

In summary: this approach likely saves no energy, adds costs at the zonal level (larger or more ducts and diffusers) and the central DOAS system (fans sized for greater external static pressure), and creates a possible operational risk without very thoughtful design on the part of the engineer (fans riding back on curves/coil icing). The proposed revisions increase flexibility and would allow air delivery to the inlet of the FCU and let the airflow decrease to the ventilation minimum, avoiding this problem.

A schematic of the new proposed option is shown in Figure 4. When the fan coil unit is off the outside air must go backwards through the un-ducted return grille into the space before it can go into the ducted return grille back to the air handler.

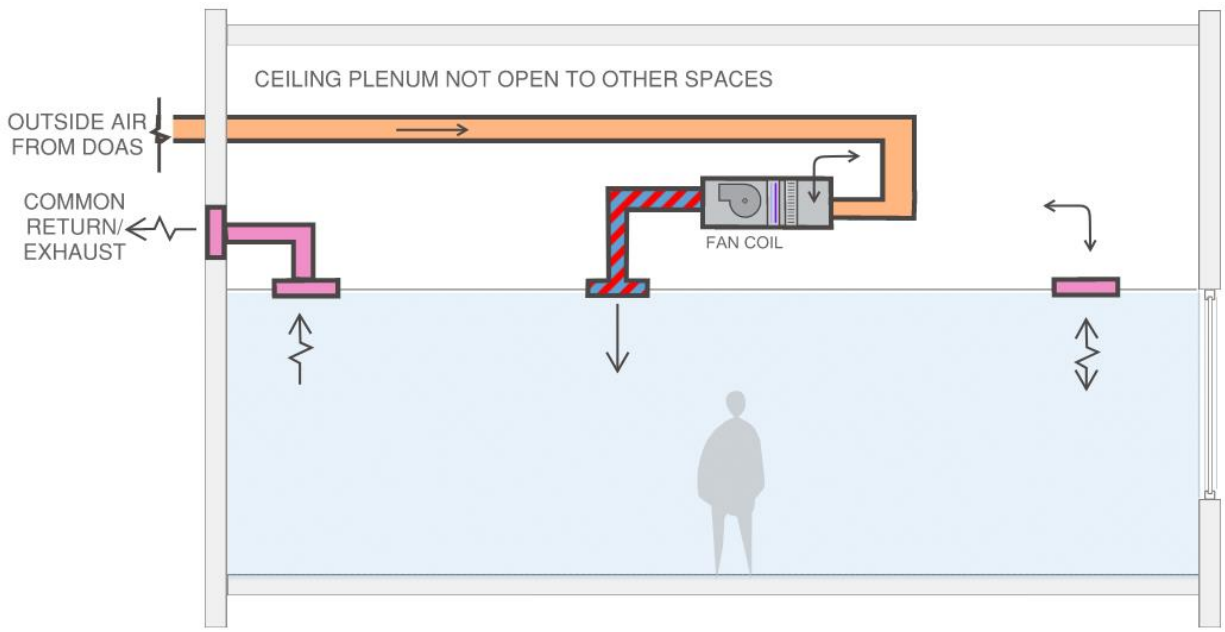

Figure 4: Schematic demonstrating proposed return air delivery option.

A similar but non-compliant version of this compliance option is shown in Figure 5. In this scenario, it is possible for the ventilation air to leave the FCU, enter the plenum, and then make its way to the common return/exhaust cavity without ever entering the zone itself. The prescriptive language is worded in such a way that this scenario would not be allowed.

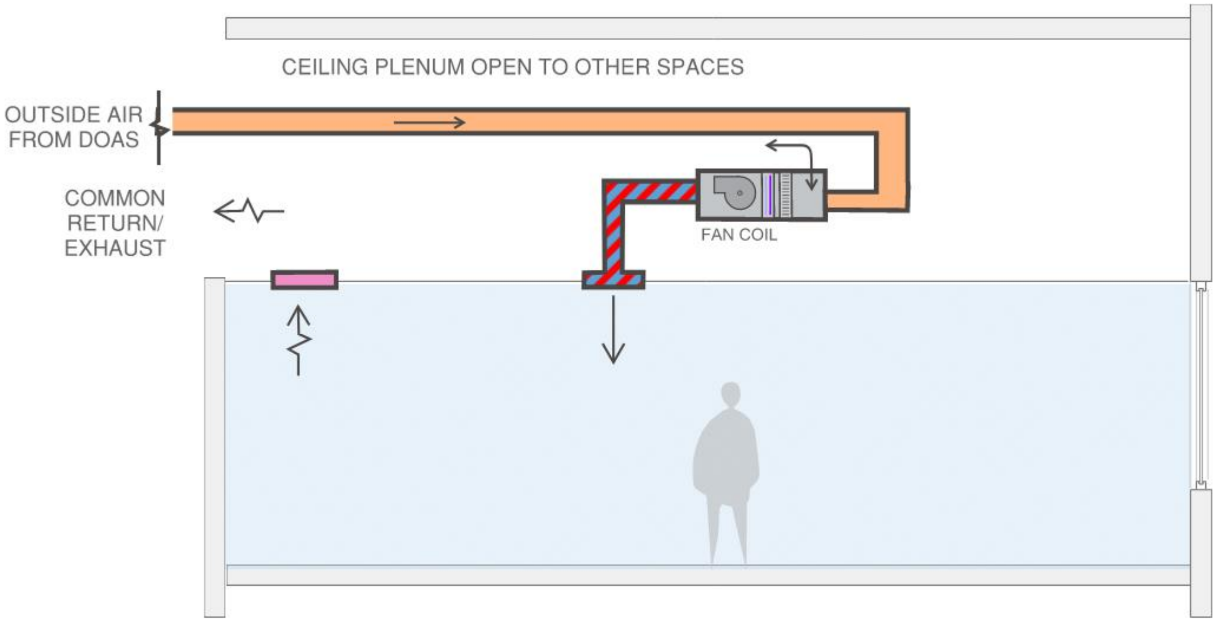

Figure 5: Schematic demonstrating non-compliant return air inlet delivery option.

3.1.2.4 Submeasure d: DOAS Supply Air Temperature Revisions

In the prescriptive Section 401.3.17 *[Section 140.4(p)],* the Statewide CASE Team also proposes to reduce the DOAS supply air temperature (SAT) from current 60ºF under heating or heat recovery mode to 55°F when most zones require cooling. This would result in energy savings, as preventing warmer air from entering the space would decrease the energy for the space cooling equipment. The current 60°F was based on ASHRAE 90.1 Section 6.5.2.6. ASHRAE TC1.4 has completed a research project (DOAS RP-1865: Optimizing Supply Air Temperature Control for Dedicated Outdoor Air Systems) on revising the SAT. The Statewide CASE Team is proposing 55°F based on this research.

The proposed recommendations would reduce fan energy at part load, eliminate or reduce re-cooling energy of warm ventilation air when the majority of the zones call for cooling, and reduce ventilation system cooling and heating energy for all zones.

Submeasure (e): This submeasure is based on Addendum p to ASHRAE 90.1-2022 (now incorporated into ASHRAE 90.1-2025). The Statewide CASE Team is advocating for this submeasure due to the current lack of an upper limit on ventilation air, which can lead to energy inefficiency in buildings that overventilate. The 2025 edition of the Energy Code specifies a required minimum ventilation rate in section 401.2.1.1.3 *[120.1(c)3]*, but no maximum.

Addendum p prescriptively limits the design minimum for each zone and each system to 30 percent above the required minimum based on ventilation and pressurization.

Addendum p also requires any system that exceeds the required minimum by five percent to include automatic zone flow control dampers or automatic outside air zone flow control dampers. This means that any DOAS system supplying more than five percent above the required ASHRAE Standard 62.1 ventilation rate must include modulating dampers at each zone. The 30 percent above the design minimum outdoor air rates contained in ASHRAE 62.1 Addendum p were deliberately chosen to allow buildings to prescriptively comply with the LEED EQ Credit Enhanced Indoor Air Quality Strategies Option 1, Enhanced Ventilation. This credit can be achieved by raising minimums 30 percent above ASHRAE 62.1. As described below, this 30 percent airflow elevation also ensures compliance with the California Energy Code.

Before Addendum p to 90.1 there were no limits in ASHRAE 90.1 on minimum outside air. A 100 percent outside air constant volume reheat system could comply prescriptively with ASHRAE 90.1. Furthermore, in the ASHRAE 90.1 performance approach the base case ventilation rate previously matched the proposed case ventilation. So, there was no modeling penalty for a 100 percent outside air constant volume reheat system. Addendum p also changed the modeling rules such that the baseline ventilation rate is capped at the 30 percent value. Thus, any system exceeding this prescriptive limit is penalized accordingly.

Prior to the COVID-19 pandemic it was rare for buildings to be designed with minimum ventilation more than 30 percent above ASHRAE 62.1 because there is both a first cost penalty and annual energy penalty to do so. However, with the fear, uncertainty, and rampant misinformation that followed the pandemic it became more important for ASHRAE to provide reasonable guidance to prevent excessive energy waste with little to no health benefit. A key part of this guidance is a new standard: ASHRAE Standard 241-2023, Control of Infectious Aerosols.[19] Standard 241 can be met without exceeding the 30 percent above ASHRAE 62.1 prescriptive limit set in Addendum p. In fact, Addendum p explicitly states, “Where ventilation is used to mitigate disease transmission to meet ASHRAE Standard 241 or ANSI/ASHRAE/ASHE Standard 170, the outdoor air component of the ventilation rate shall meet the limitation of Section 6.5.3.8.1” (the section with the 30 percent limit). ASHRAE Standard 241 can be met by increasing the ventilation rate, but it can also be met by other means, such as MERV-13 filtration, which has a lower first cost and energy cost compared to increasing ventilation. Note that MERV-13 filters are required in the California Energy Code at Section 401.2.1.1.1 *[120.1(c)1]*.

Like ASHRAE 90.1 before Addendum p, the 2025 edition of Title 24 Part 6 does not currently have any mandatory or prescriptive limits on ventilation. A 100 percent outside

[19] https://www.ashrae.org/technical-resources/bookstore/ashrae-standard-241-control-of-infectious-aerosols.

air constant volume reheat system can comply prescriptively with Title 24 Part 6. However, unlike ASHRAE 90.1 before Addendum p, the Title 24 Part 6 performance path standard design ventilation rate does not allow the proposed case ventilation to match if it is significantly above the code minimum. The base case ventilation rate only tracks the proposed ventilation rate up to 110 percent or 120 percent of code minimum ventilation rates (the distinction depends on the proposed exhaust rate vs the proposed ventilation rate). See ACM Reference Manual Section 5.6.9 “BUILDING FLOOR VENTILATION REQUIREMENT.” Therefore, there is a modeling penalty for a 100 percent outside air constant volume reheat system.

3.1.2.5 Submeasure e: Design Minimum Outdoor Air

This submeasure would prescriptively limit the Title 24 Part 6 design outside air rate to the minimum rate needed to meet the ventilation requirement (plus 10 percent, as a buffer) or as necessary to meet exhaust makeup or pressurization requirements. Please note that the minimum ventilation rates in Title 24 Part 6 are already higher than the minimum ventilation rates in ASHRAE 62.1. For example, the Title 24 Part 6 minimum ventilation rate in most office spaces is 0.15 cfm/ft2. Title 24 Part 6 takes the higher of the people component (typically 15 cfm/person) and the area component (typically 0.15 cfm/ft2). The ASHRAE 62.1 minimum ventilation rate is the sum of the people component and the area component, but in ASHRAE 62.1 these components are typically smaller than the Title 24 Part 6 components. For example, in most office spaces the ASHRAE 62.1 area component is 0.06 cfm/ft2 and the people component is 5 cfm/person. Typical office densities range from 100-200 ft2/person so the ASHRAE 62.1 minimum ranges from 0.085 – 0.11 cfm/ft2. Title 24 Part 6 is 36 to 76 percent higher than ASHRAE 62.1 in this case. Thus, in most cases LEED EQ Credit Enhanced Indoor Air Quality Strategies Option 1 Enhanced Ventilation can be achieved with Title 24 Part 6 minimum ventilation rates. Similarly, ASHRAE Standard 241 can be met with Title 24 Part 6 minimum ventilation rates.

This submeasure would result in energy savings by preventing HVAC systems from delivering greater than required ventilation airflow to zones. Exceeding ventilation airflow requirements places additional energy demand on the HVAC system’s fans as well as cooling and heating equipment since outdoor conditions vary from indoor air temperature and humidity setpoints throughout much of the year. Savings have not been quantified for this measure due to the absence of incremental first costs.

3.1.3 Background Information for Submeasure a

Allowance for occupied standby in HVAC systems has been in Title 24, Part 6 beginning with the 2013 edition and required for a selection of space types since the 2019 edition. Submeasure a, modulating dampers, improves upon the current practice of low levels of

DOAS compliance with occupied standby and DCV measures that are interpreted to only apply to mixed-air systems.

A DOAS is an energy-efficient HVAC system that maintains indoor air quality by bringing fresh air into interior spaces and handling ventilation independently from heating or cooling (Bulger N. W., 2024). Unlike multi-zone VAV systems (e.g., VAV reheat) that mix large portions of return air with outdoor air, it brings in a dedicated supply of 100 percent outdoor air, dehumidifies it, conditions it, and then delivers at the right temperature and humidity to occupied spaces, decoupling the latent loads from sensible loads.

Modulating DOAS incorporates existing acceptance testing and automatically complies with both the demand control ventilation (DCV) and energy recovery requirements. It uses Variable Frequency Drive (VFD) fans to match ventilation demand, and leverages energy recovery ventilators to precondition the incoming air – reducing cooling and heating loads.

Most DOAS systems are constant-air-volume (CAV). As an example, the PG&E DOAS code-readiness research found that three of 15 DOAS systems were operated as variable air volume, with the remaining 80 percent operated as CAV (Bulger N. W., 2022). Design ventilation is provided whenever the building is scheduled for occupancy. For most low-density spaces (e.g., open office), the ventilation rate is 0.15 cfm/ft^2. For high-density spaces (e.g., conference rooms, classrooms), the ventilation rate depends on the density, with a common ventilation rate of 0.75 cfm/ft^2. This design or maximum ventilation is provided even when the zones are unoccupied or partially occupied. With constant volume DOAS manual volume dampers (MVDs) are required in every zone. The dampers are manually balanced to maintain the design ventilation rate to all zones. The DOAS air handing unit that serves the zones is constant speed and constant volume.

Figure 6 is an example of a constant volume DOAS system.

A constant volume (CAV) DOAS unit cannot have a full economizer and is not required to have an economizer by Title 24. Though as CAV ventilation systems, all DOAS units can provide partial economizing during favorable ambient conditions (i.e., when the ambient temperature is below the room temperature and the zone is in cooling mode) by virtue of the fact that they are always providing outdoor air to zones. The economizer requirement in 401.3.7 *[140.4(e)]* is based on the capacity of the “cooling air handler.” The common interpretation is that the cooling air handler is the unit doing most or all the cooling. For DOAS, that is the zonal unit (e.g., the VRF fan coil). This interpretation is reinforced by exception 6, which states that the economizer refers to the fan coil, not the DOAS. Most fan coil zones are less than 33 kBtu/h so do not need economizers. Even zones between 33 kBtu/h and 54 kBtu/h do not need economizers if the DOAS has ERV and is oversized, also per exception 6. Note the only way to comply with Exception 6 without zonal modulating dampers the only way to economize is to exceed minimum ventilation for all zones, but if some zones are in cooling and some are in heating then you incur extra reheat by overcooling zones in heating or end up driving zones into heating. Thus, an oversized DOAS system that can modulate at the system level, but not at the zone level, may waste more energy than it saves by attempting to economize. Adding ERV and oversizing all DOAS zones so that one zone between 33 kBtu/h and 54 kBtu/h can avoid an economizer is expensive. That is why it is common to “divide and conquer” by using multiple fan coils < 33 kBtu/h for zones over 33 kBtu/h. The analysis herein assumes zones are less than 33 kBtu/h in baseline and the proposed case.

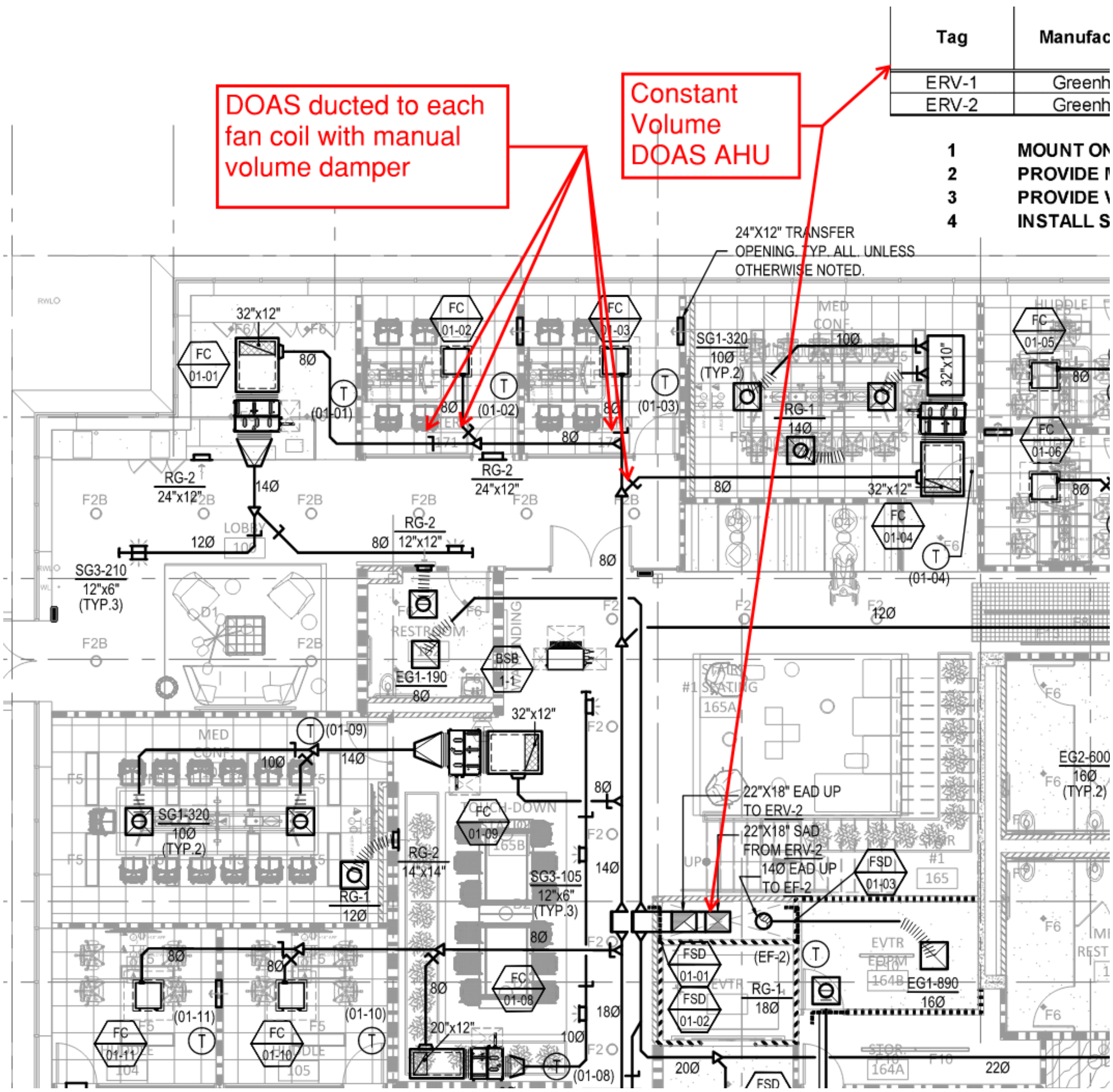

Figure 6: Constant volume DOAS example.

With a modulating DOAS system, the MVDs are replaced with modulating control dampers (a.k.a. modulating dampers) and airflow monitoring stations (AFMS). The modulating dampers and AFMS ensure that the correct ventilation is maintained at all times. The main advantage of modulating DOAS is that it allows the implementation of Occupied Standby (OS) and Demand Control Ventilation (DCV). OS uses occupancy sensors (that are separately required for lighting controls) to shut off ventilation to zones that are scheduled to be occupied but are currently unoccupied. DCV allows ventilation rates in high density spaces (e.g., classrooms) to be modulated during partial occupancy based on CO2 concentration. This effectively tailors the ventilation rate to 15 cfm/person based on the current occupancy. For example, if the design ventilation rate is 0.75 cfm/ft2 but the current occupancy is only about 50 percent of the design occupancy then the DCV controls would modulate the ventilation rate to about 0.38 cfm/ft2. OS and DCV have been required in Title 24 for multi-zone VAV reheat systems for many years. This requirement would simply expand OS and DCV to a portion of DOAS systems going forward. Figure 7 is an example of a Modulating DOAS system.

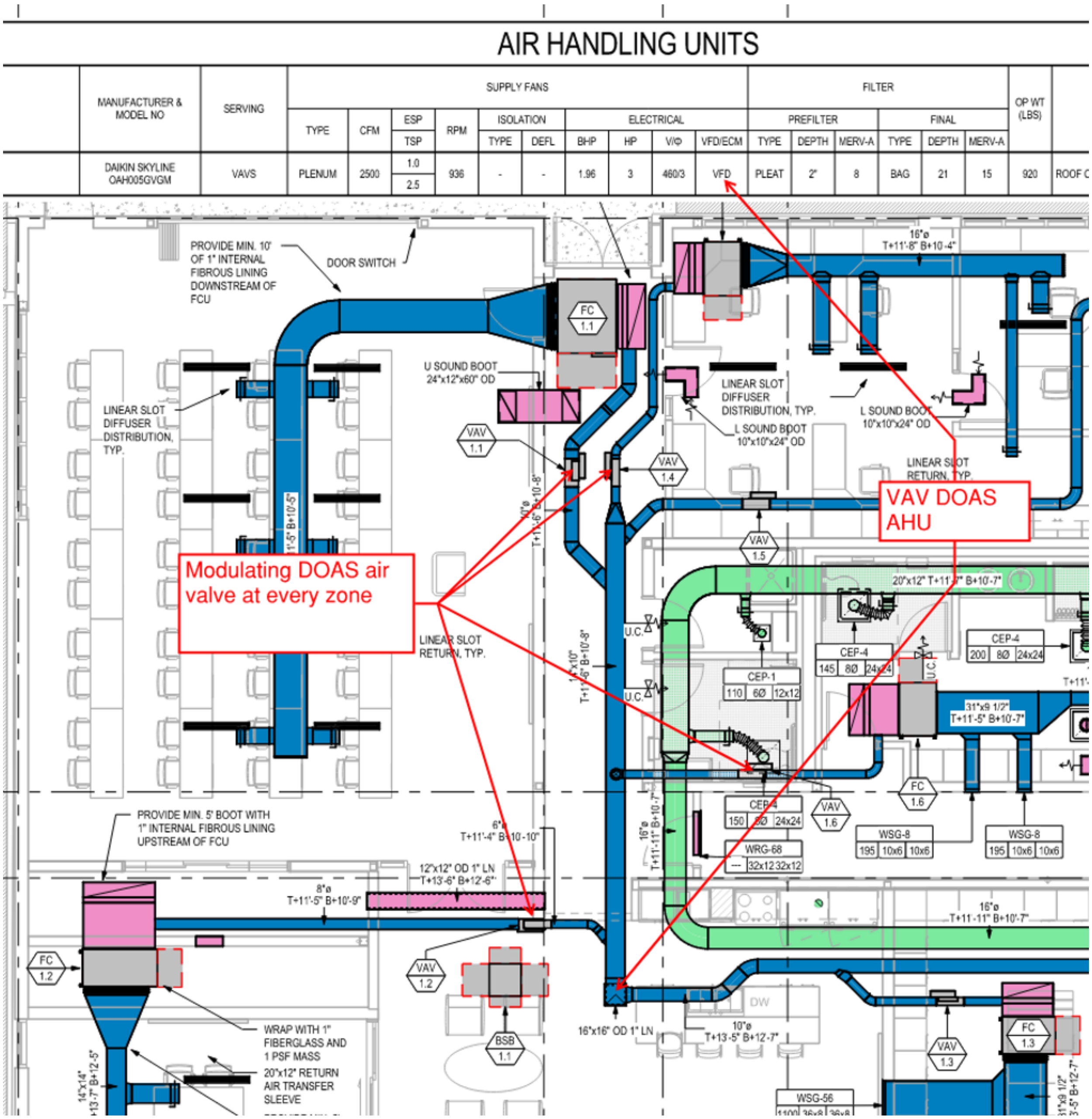

Figure 7: Modulating DOAS example.

3.1.3.1 DX Compressor Lockout

California has a drier climate and frequently, DOAS is handled by a supply fan with or without an energy recovery ventilator and no direct expansion (DX) coil. However, some DOAS units in California have DX mechanical cooling/heating. In most applications, heating and cooling are provided by the zone terminal units (e.g., VRF fan coils, 4-pipe chilled water fan coils, water-source heat pumps). Thus, it is usually not necessary to include DX at the DOAS unit. If the DOAS unit has energy recovery, then there is even less need/value for DX.

However, some DOAS units do have DX. A common misperception in the industry is that DX DOAS is needed to “neutralize” the outside air to 70F to reduce the outside air load on the terminal units. This is not true (terminal units can be sized for the outside air load) and it is in fact not allowed by Title 24, Part 6 at section 140.4(p)4. DOAS units cannot heat outside air above 60 °F because this incurs unnecessary reheat.

Sometimes there are legitimate reasons for DX DOAS. If the zonal system cannot do latent cooling (e.g., chilled beams) then DX or chilled water is typically required in the DOAS unit for dehumidification. Note that DX DOAS makes a lot more sense in high humidity climates on the East Coast where dehumidification at the central DOAS unit can reduce maintenance costs at the zone level and avoid condensation problems. But it comes at a high cost of reheat, which is why it is largely prohibited in California, where high humidity loads are very rare.

Most DX units of all categories (e.g., DOAS units, single zone unitary heat pumps, multizone rooftop units) cannot operate DX at low airflow, with most products ranging from 15 to 60 percent of design airflow. If the building is largely unoccupied such that the sum of the zone air flows is less than the minimum airflow for DX operation and DX operation is required (e.g., for dehumidification) then some or all of the zone modulating damper flow setpoints would need to be raised in order to allow DX operation.

Most of the time a DX DOAS unit can safely operate without DX. DX DOAS units are typically only sized for the peak ventilation rate (e.g., 0.2 cfm/ft2). So, if some zones are unoccupied and the ventilation rate only calls for 0.1 cfm/ft2 then the DX DOAS system would be at 50 percent airflow.

There are several reasons why DX DOAS units should not be exempt from the proposed modulating DOAS requirement:

- The measure is still cost effective for DX DOAS units that have high minimum flow requirements for DX operation. DX operation is only required a small percentage of the time. As shown in Section 3.4, the measure is cost effective even if zones are occupied 85 percent of the time. So, if the minimum flow on the DX unit was 85 percent of the maximum flow, the measure is still cost effective. Again, the forced higher-than-minimum airflow only comes into play when DX is required to avoid lockout.
- DX is not required for DOAS units, particularly in most of California’s mild climates. It might be required for chilled beam or radiant systems, but these systems are not required by the Energy Code. They are also more expensive than most of the alternatives and less efficient. So, the code should not encourage them with an exception to the proposed requirement.
- An exception for DX DOAS would create an unacceptable loophole: Owners and contractors would simply include DX in DOAS units to avoid modulating DOAS.

Another unintended consequence is that it would encourage the wasteful practice of "neutralizing" outside air with DX (which is prescriptively banned in the current edition of Title 24, Part 6).

- DX units are improving in terms of minimum flows for DX operation. Manufacturers would be improving their products due to ASHRAE 90.1 Addendum u to 90.1-2022 (and the analogous Packaged VAV measure of this CASE effort), which requires DX units to be able to operate DX at 15 percent airflow.

3.1.3.2 DOAS Unit Minimum Airflow

If the DOAS unit does not have DX or does not need to operate DX at that moment, then the DOAS unit minimum airflow is effectively zero. For example, if the DOAS unit serves 20 zones, all with occupied standby and only one zone is occupied then the DOAS unit can provide 5 percent of its design flow to serve just that one zone. There would be a minimum fan speed (e.g., 10 percent or 6 Hz) but the zone modulating damper would modulate to maintain its flow rate at setpoint. The DOAS fan would ride back on its curve and thus meet the zone setpoint. The duct static pressure may be slightly above setpoint at this point, but the fan energy penalty is completely insignificant because the fan is already at about 2 percent of design power at 10 percent fan speed.

3.1.3.3 PG&E Code Readiness DOAS Research

Between 2018 and 2024 PG&E funded a significant body of field research into DOAS systems to better understand the technology and its real-world performance. The research findings, while relevant, are fundamentally only partially usable for this measure due to the fact that the field sites being evaluated were all existing buildings whereas this proposal would only apply to new construction. Nevertheless, the reports contain a wealth of significant data points and insights regarding variable air volume DOAS opportunities as well as other insights regarding the market for this technology. Key findings that relate to this proposal are reproduced in the bullets below.

- One report within the body of research asserted that the energy code already requires DCV for DOAS systems at Section 120.1(d)3 (Section 401.2.1.2.3 of the restructured code). Though this is clearly not a universally shared view—which is the driver of submeasure a of this proposal—it is meaningful to note that market actors are interpreting the code in this way, a point that further buttresses the submeasure's viability (Weitze H. , 2023). The study implemented DCV in an existing building and found a 30 percent demand reduction (2.5 kW vs 3.5 kW prior to DCV). It is noteworthy that the report recommended changes to the DCV requirements for DOAS systems, however, the analysis that was developed for this proposal indicates that DCV is overwhelmingly cost-effective on an LSC and benefit to cost ratio basis when considering up-front costs. Note, however, that the study only focused on fan energy savings, while this analysis indicates that the vast majority (roughly 90 percent) of the energy savings are derived from cooling and heating savings.

- The work addressed the opportunity to add clarification to Title 24 Part 6 to be more explicit that DOAS systems are to be covered by occupied standby and DCV requirements (Bulger N. W., 2024).
- The Sacramento site employed DCV in its DOAS system but did not include a duct static pressure sensor to reset the fan. The site found an energy penalty at airflow values less than 3,000 cfm. The analysis found a six-percent fan-energy savings from employing DCV in the DOAS system, which the authors note is very conservative because the savings estimate excludes the cooling and heating energy. As noted above, this CASE measure's energy savings driver is cooling and heating savings, making the relevance of this savings figure marginal to this analysis (Weitze H. B., 2022).
- Out of the entire study, eight of 15 DOAS units had VFDs though only three were operated as VAV (Bulger N. W., 2022). This shows a) the prevalence of VFDs in DOAS equipment (noting that at this point, the market data would be roughly a decade old relative to when this measure would take effect) and b) the opportunity to increase savings in the field by requiring more sites to include DCV at the time of new construction. Furthermore, the study found indoor CO2 levels were maintained below 1,000 ppm at sites without DCV, indicating the opportunity for additional savings by limiting airflow during periods of low occupancy.
- The site at Santa Rosa explored retrofitting the building to add modulating dampers and DCV however, the retrofit cost came in at $9 per square foot, which was deemed too high to pursue (Weitze H. B., 2023). Note that this measure would not apply to retrofits, making this data point of limited utility. Also note that this proposal found an upfront cost under $2 per square foot.

To conclude, the studies were relevant but of limited value to this measure due to their quantification of benefits and costs to existing buildings rather than new construction. The authors were of the view that DCV already applied to DOAS systems based on existing Title 24 requirements. Finally, when savings were quantified, heating and cooling benefits were excluded, making the conclusions of limited utility.

3.1.4 Modifications to Energy Code Documents

This section provides descriptions of how the proposed code change would affect each Energy Code document. See Section 3.6 of this report for detailed revisions to code language.

3.1.4.1 Energy Code Change Summary

SECTION 401.2.1 *[SECTION 120.1]* – REQUIREMENTS FOR VENTILATION AND INDOOR AIR QUALITY

Subsection 401.2.1.1.3 *[Subsection 120.1(c)3]*: The proposed regulations would make editorial changes to Table 401.2-A to align with recently finalized ASHRAE 62.1 addenda. These include Addenda b and w to ASHRAE 62.1-2022. The purpose of this change is to improve the clarity and enforceability of the energy code.

Subsection 401.2.1.2 *[Subsection 120.1(d)]:* The proposed regulations would add a requirement to modulate airflow delivered by the DOAS unit based on the actual ventilation needed by each space type with considerations given to occupancy status (e.g., occupancy or CO2 sensors), rather than simply rely on the minimum ventilation airflow rate set by Section 401.2.1.1 *[Section 120.1(c)].* This requirement is proposed to apply to DOAS systems delivering greater than 3,000 cfm. Furthermore, the language describing which spaces are required to meet occupied standby controls requirements is proposed to be clarified and improved, thereby improving compliance rates. These changes cost-effectively increase the stringency of the Energy Code, thereby minimizing the energy use of nonresidential buildings, which in turn improves the state's economic and environmental health.

SECTION 401.2.2 *[SECTION 120.2]* – REQUIRED CONTROLS FOR SPACE CONDITIONING SYSTEMS

Subsection 401.2.2.5 *[Subsection 120.2(e)]:* The proposed regulation would add some clarifying language indicating that shut-off controls apply to both space conditioning and ventilation systems.

Subsection 401.2.2.6 *[Subsection 120.2(f)]:* The proposed regulation would add some clarifying language indicating that outdoor air supply and exhaust equipment dampers shall automatically close upon fan shutdown or during periods of non-occupancy.

Subsection 401.2.2.7 [Subsection 120.2(g)]: The proposed regulation would change "space conditioning" to "HVAC" to ensure that DOAS systems are considered in scope for this section.

SECTION 401.3 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

Subsection 401.3.5.2 *[Subsection 140.4(c)2]:* The proposed regulation would change this section to explicitly include modulating DOAS systems in the scope of the requirement for a duct static pressure sensor. The purpose of this change is to ensure that modulating DOAS systems can receive signals to determine whether it is appropriate to turn down fan speed, when possible, which would save energy.

Subsection 401.3.6 [Subsection 140.4(d)]: The proposed change to this subsection would ensure that the designer complies with the newly proposed subsection 401.3.21, which would ensure that design minimum airflow rates are not excessive. The purpose of this change is to prevent over ventilating spaces when it is not necessary and save energy.

Subsection 401.3.17 *[Subsection 140.4(p)]:* This section would also be modified by altering the supply air temperature requirement to more clearly state that mechanical cooling shall not be used to reduce outside air below 75 °F during a call for heating; and heating shall not be used to raise outside air above 55 °F during a call for cooling before delivery to the zone. The purpose of this is to prevent re-cooling or reheating of air. These changes cost-effectively increase the stringency of the Energy Code in all 16 climate zones, thereby minimizing the energy use of nonresidential buildings, which in turn improves the state's economic and environmental health. In addition, this section would be modified to allow for additional flexibility regarding how supply ventilation air is delivered to the zone by allowing the designer to duct it into the return pathway of a fan coil unit.

Subsection 401.3.21 *[New section]*: This new section would specify minimum required ventilation airflow rates set based on the airflow required to maintain acceptable indoor air quality, plus a 10 percent adder. The purpose of this change is to save energy and prevent excessive ventilation during low occupancy.

Section 401.5 *[SECTION 141.0]* – Additions and alterations to existing buildings

401.5.1.1 [Section 141.0(a)] Mandatory requirements (Additions): An exception is proposed for this section to exempt DOAS systems that do not already have modulating dampers from having to comply with the modulating DOAS requirements while undergoing additions.

401.5.2.1 [Section 141.0(b)1] Mandatory Requirements (Alterations): An exception is proposed for this section to exempt DOAS systems that do not already have modulating dampers from having to comply with the modulating DOAS requirements while undergoing alterations.

3.1.4.2 Reference Appendices Change Summary

No changes to the reference appendices are anticipated due to any aspects of this measure.

3.1.4.3 Compliance Manuals Change Summary

Chapter 4 of the Nonresidential Compliance Manual would be updated. The new requirement for airflow modulating controls on DOAS systems serving >3,000 cfm, the change from 3-speed to variable speed fans for such systems, and the changes to supply air temperatures for all DOAS systems would be explained in the revisions to the Compliance Manual.

3.1.4.4 Alternative Calculation Method Reference Manual Change Summary

Section 5.7 of the nonresidential Alternative Calculation Method (ACM) Reference Manual would be modified to ensure that the standard design reflects the new airflow modulation requirements for in-scope DOAS systems. The details of the object type "VAVDOAS" would be reviewed for accuracy. Additionally, the supply air settings would be reviewed and modified as necessary to align with the proposed new prescriptive supply air temperature requirements.

3.1.4.5 Compliance Forms Change Summary

The existing nonresidential compliance form NRCC-MCH-E would need to be modified to ensure that DCV and occupied standby controls are present if the DOAS system is triggered by the new mandatory requirement for airflow modulation. Additionally, NRCA-MCH-06-A (DCV) and NRCA-MCH-19-A (occupied standby) may be determined to need modifications to factor in DOAS equipment.

3.1.5 Measure Context

3.1.5.1 Comparable Model Codes or Standards

IECC and ASHRAE 90.1 both contain occupied standby and DCV requirements, similar to the 2025 edition of Title 24, Part 6. However, there is no explicit requirement for DOAS systems to meet these measures in either of these two model codes.

3.1.5.2 Interactions with Other Regulations

The proposed mandatory and prescriptive measures do not conflict with other state or federal laws and regulations. The mandatory component of this measure can be complied with by installing actuated dampers on the DOAS system zone terminal units, which does not trigger federal pre-emption. Other state and local requirements are not expected to be impacted by this proposal either.

3.2 Modulating DOAS - Compliance and Enforcement

3.2.1 Compliance Considerations

This measure would likely result in a change in design approach for certain projects that rely on DOAS systems. Most crucially, designers would need to more actively consider whether their projects can take advantage of DCV and occupied standby opportunities and design their DOAS systems accordingly.

There are no major changes or additional concepts being introduced by this measure. Instead, what this measure is doing is forcing existing technologies and controls methods to be considered together in cases where they had not been thought to overlap. Currently, there is an inconsistent awareness that DOAS systems should be complying with DCV and occupied standby. However, both DOAS and airflow modulating measures are widely understood and leveraged by designers. This measure simply combines these two approaches and makes it explicit when they need to be jointly leveraged.

Any additional commissioning or field verification required on DOAS systems would simply borrow current methodologies and approaches used for mixed air VAV systems; no new field-testing strategies are required.

Compliance rates with existing occupied standby requirements are expected to improve with the code language markups being proposed here due to the introduction of explicit space types listed in 120.1(d)5.

3.2.2 Impact on Market Actors

Table 22 summarizes impacts on market actors and suggests outreach and education that might be helpful to support market actors as they prepare for the effective date of the requirements.

Table 22: Impacts on Market Actors and Suggested Training and Education Opportunities

Market Actor	Impact(s)	Suggested Outreach and Education
Owner/Developer [a]	Would be expected to factor airflow modulating controls into more of their DOAS systems.	Coordination with design professionals and the compliance improvement team to raise awareness.
Design Professional [b]	Improved awareness of which space types and system types are required to use occupied standby. Increased requirements to use occupied standby and DCV with DOAS systems where triggered. Increased flexibility regarding DOAS supply air to the zones.	Newsletter or email announcement of new requirements. Lunch and learn or other virtual training sponsored by compliance improvement or local ASHRAE chapter leading up to new requirements being in effect.
Construction Team [c]	More systems require controls for DCV and occupied standby.	Announcement of changes via compliance improvement team.
Building Department [d]	Awareness of when to look for DCV and occupied standby controls specifications on drawings and compliance forms.	Raise awareness of these measures via the compliance improvement team.
Verification Tester [e]	DOAS systems would be much more likely to be paired with airflow modulating equipment that would need to be verified for proper functionality.	Any changes to acceptance testing are minor and incremental to current requirements, so it is expected that a high-level announcement should suffice.
Manufacturers and Distributors	Not applicable.	Not applicable.

a. Owner/Developer is funding the project and is the primary decision-maker.
b. Design professionals include architects, engineers (mechanical, electrical, plumbing, structural), specification writers, cost estimators, commissioning agents, lighting designers, and energy consultants.
c. Construction team includes general contractors, home builders, design-build contractors, installation contractors (e.g., HVAC, plumbing, electrical), commissioning agents, and tradespeople.
d. Building departments include plans reviewers, building inspectors, specialty inspectors, permit counter technicians and third-party plan review and inspection.
e. Verification testers include commissioning agents, ECC Raters, and Acceptance Test Technicians.

The 2028 CASE Methodology Report presents a quantitative assessment of how changes to the California building code impact builders, building designers and energy consultants, and building owners and occupants. The analysis in the methodology report is not specific to the code change presented in this report. The following provides a qualitative description of how this specific code change affects various market actors and additional quantitative analyses of its potential impacts on building industry subsectors.

Builders. The proposed change would likely affect commercial builders; however, it would likely not impact firms focused on the construction or retrofitting of industrial buildings, utility systems, public infrastructure, or other heavy construction. The proposed change would not affect all firms and workers in the residential and commercial building industries equally; instead, it would primarily affect specific subsectors within the industry. Table 23 shows the commercial building subsectors that the Statewide CASE Team expects to be impacted by the changes proposed in this report. Commercial builders would likely have to modestly adapt their construction practices to be able to meet the new hardware and controls requirements included in this proposal.

Table 23: Specific Subsectors of the California Commercial Building Industry Impacted by Proposed Change to Code/Standard by Subsector in 2025 (Estimated)

Construction Subsector	Establishments	Employment	Annual Payroll (Billions $)
Commercial Building Construction	4,919	83,028	9.0
Nonresidential Plumbing & HVAC Contractors	2,346	55,572	5.5
Other Nonresidential Equipment Contractors	556	9,594	1.0

Source: (State of California, n.d.)

3.2.3 Compliance Software Updates

This proposal is anticipated to result in minimal adjustments to the compliance software since the main energy saving element (i.e., the airflow modulation requirement for large DOAS systems) is a mandatory requirement and cannot be "traded" by energy modelers. There could be an opportunity to add these measures to the compliance software for buildings that fall below the minimum outdoor airflow threshold of 3,000 cfm as an energy efficiency credit, but this is not critical for the success of this measure. The Statewide CASE Team can work with the compliance software team to determine what, if any of the prescriptive changes need to be reflected in the compliance software. A potential adjustment would be to change the DOAS supply air setpoint to align with the changes in 401.3.17 intended to eliminate reheat and recooling. The proposed new section at 401.3.21 specifying an upper limit to minimum airflow rates is already reflected in the ACM Reference Manual in Section 5.6.9.

3.2.4 Cost of Enforcement

The Statewide CASE Team acknowledges that changes to the code will impact enforcement costs. This report is an evaluation of specific measures, and the collective impact of all proposed changes for the 2028 Title 24, Part 6 may represent an increase in training and/or workload for enforcement personnel.

Compliance costs are expected to be very minor for this measure mainly because this is simply a broadening of existing energy efficiency measures to additional HVAC system types. Raising awareness of the new measure requirements in advance is expected to reduce ongoing compliance costs. The Statewide Compliance Improvement Team can emphasize which DOAS systems would be required to comply with the new measure.

The existing nonresidential compliance form NRCC-MCH-E would need to be modified to ensure that DCV and occupied standby controls are present if the DOAS system is triggered by the new mandatory requirement for airflow modulation. Additionally, NRCA-MCH-06-A (DCV) and NRCA-MCH-19-A (occupied standby) may be determined to need modifications to factor in DOAS equipment.

3.3 Modulating DOAS - Market and Economic Analysis

3.3.1 Market Structure and Availability

3.3.1.1 Current Market Structure and Availability

DOAS is a mature technology with numerous installations in California and nationwide. The DOAS market is fundamentally a subset of the broader HVAC supply chain and manufacturer base.

The global dedicated outdoor air system (DOAS) market is valued at USD 5.2 billion in 2025 and is projected to reach USD 12.4 billion by 2035.[20] Growth is driven by the expanding commercial building sector, rising preference for energy-efficient ventilation solutions, and the need for optimized indoor air quality in high-occupancy environments. DOAS systems offer fresh air delivery capabilities, enhanced energy recovery opportunities, and independent ventilation control solutions, making them suitable for office buildings, healthcare facilities, educational institutions, and mixed-use commercial developments.

Nearly all commercial unitary HVAC manufacturers produce a 100 percent outdoor air version of their standard unitary air to air products. DOAS units are brought to the marketplace through distributors and manufacturer representatives, just like other pieces of HVAC equipment.

DCV and occupied standby are mature efficiency measures that have been in the energy code for over a decade. However, this code enhancement is needed because designers typically specify DOAS systems without airflow modulating controls, which

20 https://www.futuremarketinsights.com/reports/dedicated-outdoor-air-system-market.

effectively results in constant air volume (CAV) systems, which are less efficient than systems that modulate airflow based on zone occupancy levels. However, this approach is cheaper and simpler to design and install, and therefore many designers favor it.

Many DOAS systems in the field today are specified with airflow modulating measures such as DCV and occupied standby. One example of a manufacturer that highlights the potential of this measure is the Trane CoolSense® Integrated Outdoor Air System catalog, which highlights the energy efficiency opportunity of including DCV with DOAS.[21] Page two of the catalog states: "The airflow-measuring damper in each terminal unit maintains the outdoor airflow required in each zone at any given time. Plus, demand-controlled ventilation (DCV) sequences (using either a CO2 sensor or occupancy sensor) are pre-engineered into the factory-mounted unit controller. All these features lead to efficient operation." Another example comes from a DOAS manufacturer, which lists CO2 sensors in the duct or in the room as "optional accessories" for their equipment.[22]

3.3.1.2 Market Challenges and Solutions

Historically, a major challenge for occupied standby for HVAC has been the opacity around which zones and space types are required to comply with this measure. This challenge is broader than HVAC systems that use DOAS and apply to all nonresidential HVAC systems. A key aspect of this measure, intended to improve compliance rates with occupied standby requirements, is the inclusion of clearer and more explicit language specifying the space types to which occupied standby applies. This would make it more obvious to the user whether a given space type needs to comply with occupied standby.

DOAS systems have traditionally been understood to be exempt from airflow modulation measures, though there is no inherent reason for this to be the case. This has resulted in inefficiently designed and installed DOAS systems which effectively function as CAV air distribution systems. Since the pandemic, nonresidential space usage patterns have changed significantly, with the trend toward lower nonresidential occupancy rates (i.e., greater rates of remote work by employees). This underscores the opportunity to design DOAS systems more efficiently by using airflow modulating strategies so that airflow rates can be reduced during periods of light or non-occupancy.

The Statewide CASE Team views the market challenges for the proposed modulating DOAS requirement to be very limited because this measure is simply broadening the

21 https://www.trane.com/content/dam/Trane/Commercial/global/products-systems/equipment/terminal-devices/sensible-cooling/APP-PRC004E-EN.pdf.

22 https://www.ventacity.com/products/ventilation-family/.

scope of airflow limiting measures from mixed air distribution systems to DOAS systems. All necessary compliance tools are fully at the market's disposal. The only remaining step is the adoption of the code requirement to introduce these measures to DOAS systems moving forward. The prescriptive changes in this proposal also do not have market challenges because the measure is simply making some minor adjustments to the required supply air temperature and broadening zone delivery options to add flexibility for designers.

See Section 3.2 for a description of workforce training that may be needed to ensure effective design, installation, and commissioning.

3.3.2 Design and Construction Practices

3.3.2.1 Current Design and Construction Practices

In the 2025 edition of Title 24, Part 6, the typical DOAS system is designed to provide steady delivery of code minimum ventilation air to the zones during occupied periods. Occupied standby and DCV measures are typically interpreted to only apply to mixed air systems by most designers and other stakeholders.

DCV and occupied standby are measures that improve the building's energy efficiency performance during low or unoccupied time periods during times when the building is scheduled to be occupied. The measures are capable of benefiting both mixed air and DOAS systems.

As noted, the typical DOAS air distribution network today has no ability to sense and adjust the airflow rate being supplied to the zones. There are no modulating dampers or dampers at the terminal units capable of limiting air delivery. This means that when there is an opportunity to reduce the amount of ventilation air delivered to the zones, the system cannot respond accordingly.

Although this practice is not particularly common today, some designers include airflow modulation in their DOAS system designs.

3.3.2.2 Health and Safety Considerations

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 (DOSH). All existing health and safety rules would 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.

3.3.2.3 Design and Construction Challenges and Solutions

As described above, this measure is not commonly applied in California buildings. However, the Statewide CASE Team does not anticipate significant challenges or adjustments would be required to incorporate this measure into future designs, should it be adopted into code. This is because the strategies being promoted for this measure are commonly applied to mixed air VAV systems, which are familiar to all commercial HVAC designers. The adjustment needed for this measure would be the notion that this approach would now need to also be applied to in-scope DOAS systems.

See Table 22 in Section 3.2.2 for a description of workforce training that could support effective design, installation, and commissioning.

3.3.3 Energy Equity and Environmental Justice

Each measure in this CASE Report was evaluated for ESJ impacts using 4 criteria: cost, health, resiliency, and comfort. The details of that evaluation can be found in Section 1.4 and the 2028 CASE Methodology Report.

With this measure improving building efficiency, it additionally has the potential to improve building resiliency. This measure has the potential to improve occupancy comfort and health by providing more stable temperatures and ventilation. This measure is expected to have no disproportionate impact on the cost or disaster preparedness of ESJ communities.

3.3.4 Impacts on Jobs and Businesses

The Statewide CASE Team does not anticipate significant employment or financial impacts on any particular sector of the California economy. However, the proposed change may have modest impacts on employment in California. The Statewide CASE Team estimates the proposed change would affect statewide employment and economic output directly and indirectly through its impact on builders, designers, energy consultants, and building inspectors. Table 24, Table 25, and Table 26 outline the statewide implications for these job categories. For more information on the Statewide CASE Team's economic impacts methodology, see the 2028 CASE Methodology Report.

The Statewide CASE Team does not anticipate that the proposed changes would lead to the creation of new types of jobs or the elimination of existing types of jobs. In other words, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. Rather, it would lead to modest changes in the employment of existing jobs.

Table 24: Estimated Impact that Adoption of the Proposed Measure would have on the California Nonresidential Construction Sector

Type of Economic Impact	Employment (Jobs)	Labor Income (Million)	Total Value Added (Million)	Output (Million)
Direct Effects (Additional spending by Commercial Builders)	22	$1.7	$2.0	$3.4
Indirect Effect (Additional spending by firms supporting Commercial Builders)	5	$0.5	$0.7	$1.4
Total Economic Impacts	**28**	**$2.2**	**2.8**	**$4.8**

Source: Statewide CASE Team analysis of data from the IMPLAN modeling software.[1]

Table 25: Estimated Impact that Adoption of the Proposed Measure would have on the California Building Designers and Energy Consultant Sectors

Type of Economic Impact	Employment (Jobs)	Labor Income	Total Value Added	Output
Direct Effects (Additional spending by building designers and energy consultants)	0	$26,656	$26,389	$41,710
Indirect Effect (Additional spending by firms supporting building designers and energy consultants)	0	$7,937	$11,030	$17,757
Total Economic Impacts	**0**	**$34,592**	**$37,419**	**$59,467**

Source: Statewide CASE Team analysis of data from the IMPLAN modeling software.

Table 26: Estimated Impact that Adoption of the Proposed Measure would have on California Building Inspectors

Type of Economic Impact	Employment (Jobs)	Labor Income	Total Value Added	Output
Direct Effects (Additional spending by building inspectors)	0	$2,895	$3,433	$4,172
Indirect Effect (Additional spending by firms supporting building inspectors)	0	$268	$418	$727
Total Economic Impacts	**0**	**$3,163**	**$3,850**	**$4,899**

Source: Statewide CASE Team analysis of data from the IMPLAN modeling software.

The proposed change represents a modest adjustment to DOAS systems to modulate airflow to individual thermal zones, clarify when Occupied Standby is required, revise language to prevent re-heating or re-cooling of air, and place an upper limit to the design minimum airflow rate, which is not expected to excessively burden or competitively disadvantage California businesses, nor is it expected to lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not expect the proposed code changes to result in the creation of new businesses or the elimination of existing ones.

The proposed code changes would apply to all businesses operating in California, regardless of whether the business is incorporated inside or outside of the state.2 Therefore, the Statewide CASE Team does not anticipate that the proposed changes would have an advantageous or an adverse effect on the competitiveness of California businesses.

The Statewide CASE Team derived a reasonable estimate of the change in investment by California businesses based on the estimated change in economic activity associated with the proposed measure and its expected effect on business income. The Statewide CASE Team's IMPLAN modeling resulted in an estimated $520,422 increase in California business income due to the proposed code change. The Statewide CASE Team assumed that net business investment is positively correlated with business income and that a portion of business income will be allocated to net business investment.

To estimate the portion of business income that would be allocated to net investment, the Statewide CASE Team analyzed national data on corporate profits and net capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI). As Table 4 shows, between 2020 and 2024, NPDI as a percentage of corporate profits ranged from a low of 18 percent in 2020 due to the worldwide economic slowdowns associated with the COVID-19 pandemic to a high of 28 percent in 2022, with an average of 23 percent. While only an approximation of the proportion of business income used for net capital investment, it provides a reasonable estimate of the proportion of incremental income that business owners would reinvest into expanding their capital stock.

Table 27: Net Domestic Private Investment and Corporate Profits, U.S.

Year	Net Domestic Private Investment by Businesses, Billions of Dollars	Corporate Profits After Taxes, Billions of Dollars	Ratio of Net Private Investment to Corporate Profits (Percent)
2020	389	2,212	18
2021	545	2,888	19
2022	825	2,951	28
2023	836	3,069	27
2024	885	3,441	26
5-Year Average	Intentionally blank	Intentionally blank	23

Source: (Federal Reserve Economic Data (FRED) n.d.)

Given the estimated total increase in California business income and net business investment ratio described above, the Statewide CASE Team estimates the proposed code change would result in a $122,163 increase in net private investment by California businesses.

3.3.5 Economic and Fiscal Impacts

The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed measure would lead to a significant change (increase or decrease) in investment, directly or indirectly, in any affected sectors of California's economy. The proposed change would not result in economic disruption to any sector of the California economy. For more information on the Statewide CASE Team's economic and fiscal impacts methodology, see the 2028 CASE Methodology Report.

Adoption of this code change proposal would result in relatively modest economic impacts through the additional direct spending by those in the commercial building industry, architects, energy consultants, and building inspectors. The Statewide CASE Team does not anticipate that money saved by commercial building owners or other organizations affected by the proposed 2028 code cycle regulations would result in additional spending by those businesses.

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

The Statewide CASE Team does not expect the proposed code changes to have a measurable impact on California's General Fund, any state special funds, or local government funds.

Cost to State: The state government already has a budget for code development, education, and compliance enforcement. While the state government would be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, these activities are already covered by existing state budgets. The costs for the state government are small when compared to the overall cost savings and policy benefits associated with the code change proposals. State buildings would also be impacted by the proposed measure because they would be required to comply with the new requirement (new construction, additions, and alterations). However, the proposed measure has been found to be cost effective, so there is a net benefit in complying with the new requirements.

Cost to Local Governments: All proposed code changes to Title 24, Part 6 would result in changes to compliance determinations. Local governments would need to train building department staff on the revised Title 24, Part 6 Standards. While this retraining is an expense to local governments, it is not a new cost associated with the 2025 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 Statewide Codes & Standards Utilities program (such as Energy Code Ace). As noted in Section 3.2.2, 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.

3.3.5.2 Mandates on Local Agencies or School Districts

There are no relevant mandates to local agencies or school districts because the requirements are widely applicable and not specific to local agencies or school districts.

3.3.5.3 Costs to Local Agencies or School Districts

There are no costs to local agencies or school districts because the requirements are widely applicable and not specific to local agencies or school districts. There are incremental costs associated with the proposed measure (as outlined in Section 3.4) but they are not specific to local agencies or school districts, and the proposal has been shown to be cost effective.

3.3.5.4 Costs or Savings to Any State Agency

There are no costs or savings to any state agencies beyond what is already described in Section 3.3.5.1. The proposed measure would not impose additional costs on state agencies because it does not have any requirements specific to any state agencies.

3.3.5.5 Other Non-Discretionary Cost or Savings Imposed on Local Agencies

There are no added non-discretionary costs or savings to local agencies as the proposed measure does not have any requirements specific to any local agencies.

3.3.5.6 Costs or Savings in Federal Funding to the State

There are no costs or savings to federal funding to the state. There proposed measure would not require federal funding to implement the proposed measure.

3.4 Modulating DOAS - Cost Effectiveness

Other than subsection 3.4.6, the cost-effectiveness analysis presented in this section of the report only applies to submeasure a, Modulating dampers.

3.4.1 Cost Effectiveness Methodology

The Statewide CASE Team collaborated with CEC staff to confirm that the cost-effectiveness methodology aligns with CEC guidelines, including cost inclusion parameters. The 2028 CASE Methodology Report and Appendix A provide reproducibility details.

Per California Law (Public Resources Code 25000), a measure is considered cost effective if its benefit-to-cost ratio (BCR) is 1.0 or greater, amortized over the economic life of the structure. The Statewide CASE Team calculates BCR by dividing total dollar benefits by total dollar costs over a 30-year analysis period.

Benefits are based on Long-term System Cost (LSC), which assigns an hourly dollar value to energy use. LSC hourly factors weigh the long-term value of each hour differently, where times of peak demand are valued more than off-peak hours. These factors are not utility rates, forecasts, or bill estimates. The CEC develops and publishes LSC hourly conversion factors for each code cycle.

Costs include first costs and ongoing maintenance costs assessed over the 30-year period. Benefits and costs are evaluated incrementally, relative to the most recently adopted Energy Code. The analysis excludes design costs and incremental code compliance verification costs.

3.4.2 Energy and Energy Cost Savings Results

The Statewide CASE Team has found that EnergyPlus (and subsequently, CBECC) does not straightforwardly model the modulating DOAS technology that comprises submeasure a. As a workaround, energy savings were calculated using a hybrid EnergyPlus and spreadsheet approach as follows:

1. The CBECC large office prototype was simulated in EnergyPlus with single zone heat pumps. This model has five zones per floor: four perimeter zones and one interior zone.
2. In both cases, the DOAS provides partial economizing benefits when ambient air is below the room temperature and the zone is in cooling mode. In the base case, this benefit is passively provided by CAV DOAS units because they always provide the outdoor fresh air at design airflow rates. In the measure case, this benefit would be programmed into the controls logic to ensure that the supply fan is operated to provide partial economizer efficiency benefits.
3. The default schedules in the prototypes do not accurately reflect real-world conditions. Therefore, the Statewide CASE Team developed two new sets of occupancy, lighting, and plug load schedules:
    a. OS Schedule: to calculate the theoretical maximum potential savings from reducing ventilation to unoccupied zones, this schedule represents a zone that is always unoccupied. See Table 28 and Table 29.
    b. DCV Schedule: this set of schedules represents realistic occupancy patterns in order to capture DCV savings. See Table 30 and Table 31.
4. One of the key assumptions in the models is the HVAC hours of operation: 6a-8p weekdays, 8a-6p weekends (90 hours/week). The same HVAC hours are used in the base case and the proposed case.
    a. Two recent studies supporting this assumption:
        i. Strategic Energy Group HVAC Scheduling Study: Typical HVAC runtime:14 hours per day, Monday–Saturday, Off on Sundays. 14 x 6 = 84 hours/week (SEM Hub, n.d.)
        ii. UC Berkeley Center for the Built Environment survey of hundreds of buildings found typical HW heating systems operate 130 hours/week (Raftery, 2018)
    b. A sensitivity analysis was also performed showing the measure is cost effective at 53 hours/week of HVAC operation (this represents an 8 am – 6 pm weekday and 9 am – noon Saturday schedule). 10 x 5 + 3 = 53 hours/week. See 3.4.2.
5. The plug load (receptacle) schedule was used to capture the DOAS AHU fan energy savings. The fan energy consumption of the unitary heat pump object in the EnergyPlus model could have been changed rather than the plug load but this would have been extremely tedious and error-prone because then every zone in every climate for every case (high density, low density, etc.) would have to be adjusted to get it right. Adjusting the plug load schedules to include the DOAS fan power only had to be done twice: for the OS schedules and for the DCV schedule. This also accounts for the differences in fan energy cost and the impact of the fan heat.

Therefore, the OS Schedules and DCV Schedules were both split into Base Case and Proposed Case versions, with the only difference being the receptacle schedule. The average DOAS fan power for the 10 real buildings surveyed was 0.58 W/cfm. In the OS models the DOAS flow is 0.15 cfm/ft2. So, 0.58 x 0.15 = 0.087 W/ft2 was added to the plug loads in the base case. In the proposed case the Statewide CASE Team made the conservative assumption that average DOAS fan speed would be 80 percent of full speed. Using the cube law of fan power, 80 percent speed corresponds to 51 percent power. So, 0.51 x 0.087 = 0.044 W/ft2 was added to the plug loads in the proposed case. In the DCV models the DOAS flow is 0.75 cfm/ft2. So, 0.58 x 0.75 = 0.44 W/ft2 was added to the plug loads in the base case and 0.44 x 0.51 = 0.22 W/ft2 is added in the proposed case.

6. All spaces were modeled as open office space (low density) and again as conference rooms (high density) to determine savings per square foot for low density and high-density space types. Low density has occupied standby savings. High density has occupied standby and DCV savings.
7. The proposed case single zone heat pump models included partial air-side economizers with maximum outside air flow rates matching the design ventilation rates, i.e., 0.15 cfm/ft2 for low density and 0.75 cfm/ft2 for high density. So, for occupied standby if the space is unoccupied the modulating dampers do not have to bring in any outside air but can bring in between 0 and 0.15 cfm/ft2 if the space is in cooling and the outside air temperature is below the cooling setpoint. Full economizer free cooling is not required by the proposed measure, but partial economizing is common practice for systems with modulating DOAS and is negligible cost (no additional hardware and minimal additional programming/commissioning once it becomes a standard feature of DOAS systems). Note that the base case also provides economizing benefits (in favorable conditions) due to the fact that it is always providing the same volume of air to the zones.
8. In addition to the low density occupied standby model and the high density occupied standby + DCV model, the model was also run with neither OS nor DCV, just with the modified plug loads representing the DOAS fan savings. This is used to represent the zones that require ventilation but are not required to have OS or DCV (e.g., storage, toilet rooms). The only difference between base case and proposed case is the plug load schedule representing the fan energy savings. Fan savings are applied for these zones because the DOAS fan serves all zones and would modulate accordingly.
9. As a parametric analysis, the heat pumps were also modeled with energy recovery ventilators (ERV) to see if the measure is still cost effective for DOAS systems that include energy recovery.

10. The following cases were simulated in EnergyPlus in all climates, with each case having a baseline model and proposed model:
    a. low density spaces with OS in the proposed – always unoccupied – to achieve theoretical maximum OS savings for low density spaces.
    b. high density spaces with OS without DCV – always unoccupied – to achieve theoretical maximum OS savings for high density spaces.
    c. low density spaces without OS – to capture fan savings for spaces without OS or DCV.
    d. high density spaces with DCV without OS – to capture the DCV savings from realistic schedules.
    e. same as ‘a’ but with ERV
    f. same as ‘b’ but with ERV
    g. save as ‘d’ but with ERV
11. The total annual hourly energy cost savings for each of the Cases above for each climate zone was exported to a spreadsheet.
12. The spreadsheet modifies and aggregates the simulated savings as follows:
    a. Separate analyses for each building type: large office, primary school, and secondary school
    b. Surveys of 12 actual buildings of each of these types were used to determine the typical fraction of the building, which is each of the following space types:
        i. Low density OS spaces (e.g., 70 percent for office buildings, 20 percent for schools)
        ii. High density DCV + OS spaces (e.g., 20 percent for office buildings, 70 percent for higher ed. schools)
        iii. High density DCV without OS spaces (e.g., K-12 classrooms are required to have DCV but not allowed to have OS, while higher education classrooms are required to have OS and DCV)
    c. The spreadsheet includes the ability to iterate on the following to determine under what assumptions the measure is cost effective:
        i. Low Density Occupancy Rate – 0 percent is the theoretical maximum savings from OS. 100 percent means the space is always occupied and there are no savings from OS. 70 percent means the space is occupied 70 percent of the time and unoccupied 30 percent. See Spreadsheet Results below for assumed values.
        ii. High Density Occupancy Rate – 0 percent means the space is always unoccupied and can go down to 0.15 cfm/ft2 if it has only DCV or down to 0 cfm/ft2 if it has both DCV and OS. 100 percent means the space is

always occupied but still able to capture DCV savings using realistic schedules, i.e., not always at design occupancy. See Spreadsheet Results below for assumed values.

13. The spreadsheet also incorporates the cost data as follows:
    a. Adjustable building total area – this is needed for cost modeling because the DOAS AHU costs are per building, while the zone costs are per zone.
    b. Adjustable zone size – again this is needed to calculate zone costs per building. Surveys of each building type were used to determine average zone size for each building type.
    c. Both first costs and incremental O&M costs are included per building and per zone.

Table 28: OS Schedules - Base Case

			Hour of Day																							
Description		Daily Sch	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Occupancy	Fraction	WD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Sat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Sun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lights	Fraction	WD	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		Sun	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Receptacle	Fraction	WD	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		Sun	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Receptacle (with fan heat)	Fraction	WD	0.03	0.03	0.03	0.03	0.03	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.03	0.03	0.03	0.03	0.03
		Sat	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.03	0.03	0.03	0.03	0.03	0.03	0.03
		Sun	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.03	0.03	0.03	0.03	0.03	0.03	0.03
HVAC Avail	OnOff	WD	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
		Sat	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
		Sun	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
HtgSetpt	Temperature	WD	66	67	68	69	70	71	71	71	71	71	71	71	71	71	71	71	71	71	71	71	65	65	65	65
		Sat	66	67	68	69	70	71	71	71	71	71	71	71	71	71	71	71	71	71	71	65	65	65	65	65
		Sun	66	67	68	69	70	71	71	71	71	71	71	71	71	71	71	71	71	71	71	65	65	65	65	65
ClgSetpt	Temperature	WD	80	78	76	75	74	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	80	80	80	80
		Sat	80	80	78	76	75	74	73	73	73	73	73	73	73	73	73	73	73	73	80	80	80	80	80	80
		Sun	80	80	78	76	75	74	73	73	73	73	73	73	73	73	73	73	73	73	80	80	80	80	80	80
Infiltration	Fraction	WD	1.00	1.00	1.00	1.00	1.00	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
		Sat	1.00	1.00	1.00	1.00	1.00	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	1.00	1.00	1.00	1.00	1.00
		Sun	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

			Hour of Day																							
OACtrl Schedule	OnOff	WD	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00
		Sat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
		Sun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
		Holiday	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 29: OS Schedules - Proposed Case

			Hour of Day																							
Description		Daily Sch	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Occupancy	Fraction	WD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Sat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Sun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lights	Fraction	WD	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		Sun	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Receptacle	Fraction	WD	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		Sun	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Receptacle (with fan heat)	Fraction	WD	0.03	0.03	0.03	0.03	0.03	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.03	0.03	0.03	0.03	0.03
		Sat	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.03	0.03	0.03	0.03	0.03	0.03	0.03
		Sun	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.03	0.03	0.03	0.03	0.03	0.03	0.03
HVAC Avail	OnOff	WD	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
		Sat	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
		Sun	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
HtgSetpt	Temperature	WD	66	67	68	69	70	71	71	71	71	71	71	71	71	71	71	71	71	71	71	71	65	65	65	65
		Sat	66	67	68	69	70	71	71	71	71	71	71	71	71	71	71	71	71	71	71	65	65	65	65	65
		Sun	66	67	68	69	70	71	71	71	71	71	71	71	71	71	71	71	71	71	71	65	65	65	65	65
ClgSetpt	Temperature	WD	80	78	76	75	74	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	80	80	80	80
		Sat	80	80	78	76	75	74	73	73	73	73	73	73	73	73	73	73	73	73	80	80	80	80	80	80
		Sun	80	80	78	76	75	74	73	73	73	73	73	73	73	73	73	73	73	73	80	80	80	80	80	80
Infiltration	Fraction	WD	1.00	1.00	1.00	1.00	1.00	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
		Sat	1.00	1.00	1.00	1.00	1.00	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	1.00	1.00	1.00	1.00	1.00
		Sun	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

		Hour of Day																								
OACtrl Schedule	OnOff	WD	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00
		Sat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
		Sun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
		Holiday	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 30: DCV Schedules - Base Case

			Hour of Day																							
Description		Daily Sch	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Occupancy	Fraction	WD	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.15	0.45	0.50	0.53	0.50	0.33	0.55	0.55	0.50	0.46	0.15	0.05	0.05	0.05	0.05	0.02	0.01
		Sat	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Sun	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Lights	Fraction	WD	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.15	0.55	0.55	0.55	0.58	0.58	0.58	0.58	0.55	0.55	0.18	0.08	0.08	0.08	0.07	0.05	0.05
		Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.10	0.30	0.30	0.30	0.30	0.15	0.15	0.15	0.15	0.15	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		Sun	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Receptacle	Fraction	WD	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.15	0.45	0.50	0.53	0.50	0.33	0.55	0.55	0.50	0.46	0.18	0.08	0.08	0.08	0.07	0.05	0.05
		Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.10	0.30	0.30	0.30	0.30	0.15	0.15	0.15	0.15	0.15	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		Sun	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Receptacle (with fan heat)	Fraction	WD	0.03	0.03	0.03	0.03	0.03	0.46	0.49	0.51	0.66	0.69	0.70	0.69	0.60	0.71	0.71	0.69	0.67	0.52	0.47	0.04	0.04	0.04	0.03	0.03
		Sat	0.03	0.03	0.03	0.03	0.03	0.03	0.05	0.49	0.59	0.59	0.59	0.59	0.51	0.51	0.51	0.51	0.51	0.03	0.03	0.03	0.03	0.03	0.03	0.03
		Sun	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.03	0.03	0.03	0.03	0.03	0.03	0.03
HVAC Avail	OnOff	WD	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
		Sat	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
		Sun	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
HtgSetpt	Temperature	WD	66	67	68	69	70	71	71	71	71	71	71	71	71	71	71	71	71	71	71	71	65	65	65	65
		Sat	66	67	68	69	70	71	71	71	71	71	71	71	71	71	71	71	71	71	71	65	65	65	65	65
		Sun	66	67	68	69	70	71	71	71	71	71	71	71	71	71	71	71	71	71	71	65	65	65	65	65
ClgSetpt	Temperature	WD	80	78	76	75	74	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	80	80	80	80
		Sat	80	80	78	76	75	74	73	73	73	73	73	73	73	73	73	73	73	73	80	80	80	80	80	80
		Sun	80	80	78	76	75	74	73	73	73	73	73	73	73	73	73	73	73	73	80	80	80	80	80	80
Infiltration	Fraction	WD	1.00	1.00	1.00	1.00	1.00	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
		Sat	1.00	1.00	1.00	1.00	1.00	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	1.00	1.00	1.00	1.00	1.00
		Sun	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
OACtrl Schedule	OnOff	WD	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00

			Hour of Day																							
		Sat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
		Sun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
		Holiday	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 31: DCV Schedules - Proposed Case

			Hour of Day																							
Description		Daily Sch	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Occupancy	Fraction	WD	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.15	0.45	0.50	0.53	0.50	0.33	0.55	0.55	0.50	0.46	0.15	0.05	0.05	0.05	0.05	0.02	0.01
		Sat	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Sun	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Lights	Fraction	WD	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.15	0.55	0.55	0.55	0.58	0.58	0.58	0.58	0.55	0.55	0.18	0.08	0.08	0.08	0.07	0.05	0.05
		Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.10	0.30	0.30	0.30	0.30	0.15	0.15	0.15	0.15	0.15	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		Sun	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Receptacle	Fraction	WD	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.15	0.45	0.50	0.53	0.50	0.33	0.55	0.55	0.50	0.46	0.18	0.08	0.08	0.08	0.07	0.05	0.05
		Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.10	0.30	0.30	0.30	0.30	0.15	0.15	0.15	0.15	0.15	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		Sun	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Receptacle (with fan heat)	Fraction	WD	0.03	0.03	0.03	0.03	0.03	0.25	0.28	0.30	0.45	0.48	0.49	0.48	0.39	0.50	0.50	0.48	0.46	0.31	0.26	0.04	0.04	0.04	0.03	0.03
		Sat	0.03	0.03	0.03	0.03	0.03	0.03	0.05	0.28	0.38	0.38	0.38	0.38	0.30	0.30	0.30	0.30	0.30	0.03	0.03	0.03	0.03	0.03	0.03	0.03
		Sun	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.03	0.03	0.03	0.03	0.03	0.03	0.03
HVAC Avail	OnOff	WD	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
		Sat	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
		Sun	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
HtgSetpt	Temperature	WD	66	67	68	69	70	71	71	71	71	71	71	71	71	71	71	71	71	71	71	71	65	65	65	65
		Sat	66	67	68	69	70	71	71	71	71	71	71	71	71	71	71	71	71	71	71	65	65	65	65	65
		Sun	66	67	68	69	70	71	71	71	71	71	71	71	71	71	71	71	71	71	71	65	65	65	65	65
ClgSetpt	Temperature	WD	80	78	76	75	74	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	80	80	80	80
		Sat	80	80	78	76	75	74	73	73	73	73	73	73	73	73	73	73	73	73	80	80	80	80	80	80
		Sun	80	80	78	76	75	74	73	73	73	73	73	73	73	73	73	73	73	73	80	80	80	80	80	80
Infiltration	Fraction	WD	1.00	1.00	1.00	1.00	1.00	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
		Sat	1.00	1.00	1.00	1.00	1.00	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	1.00	1.00	1.00	1.00	1.00
		Sun	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

			Hour of Day																							
OACtrl Schedule	OnOff	WD	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00
		Sat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
		Sun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
		Holiday	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00

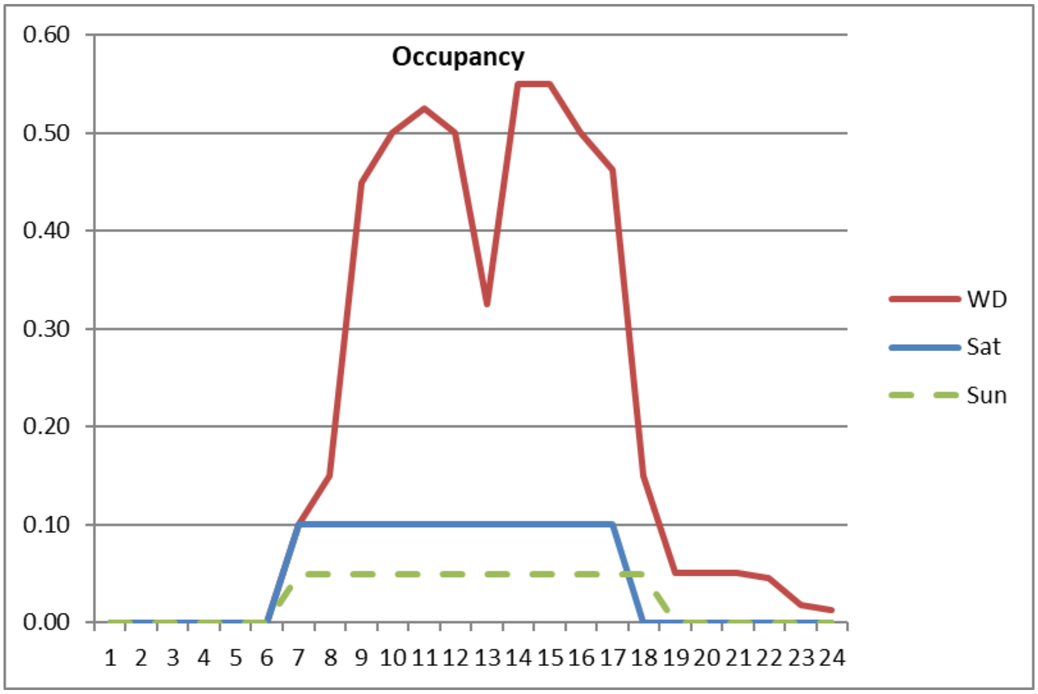

Figure 8: Occupancy Profile from the DCV Schedules.

SPREADSHEET RESULTS:

Table 32 shows the spreadsheet result for several parametric analyses for each building type (office, K-12, Higher Ed.) For every row in the table the benefit-to-cost ratio exceeds 1.0 for every climate zone. The first row for each building type represents the default assumptions for each building type. For example, the first Office row shows results for an office buildings large enough to have more than 3,000 cfm of outside, without ERV, with average zone size of 825 ft2, with Integrated Controls, with 70 percent of the building being low density occupied standby spaces (e.g., private office, open offices, corridors, etc.) and 20 percent of the building being high density DCV spaces (e.g., conference rooms, auditoria, break rooms, etc.) that the measure is cost effective even if all spaces are occupied 100 percent of the time the HVAC system is scheduled to operate, i.e., the DCV savings alone are sufficient without taking any credit for the occupied standby savings. The footnotes indicate areas where the parameters were changed for each parametric run. For example, the second office rows show it is cost effective under the same assumptions but with ERV. The third row shows it is cost effective with non-integrated controls if the occupancy rate is 65 percent or lower.

Table 32: Modulating DOAS Cost Effectiveness Sensitivity Results

Building Type[a]	Outdoor Air CFM	ERV	Zone ft2	Ctrl Option	HVAC hrs/week	O.S. Space Type	O.S.+DCV Space Type	O.S. Occupancy Rate	O.S. + DCV Occupancy Rate
Office	≥3,000	No	825	Integrated	90	70%	20%	100%	100%
Office	≥3,000	Yes[b]	825	Integrated	90	70%	20%	100%	100%
Office	≥3,000	No	825	Non-Integated [b]	90	70%	20%	65%	70%
Office	≥1,000[b]	No	825	Integrated	90	70%	20%	100%	100%
Office	≥3,000	No	300[a]	Integrated	90	70%	20%	65%	100%
Office	≥3,000	Yes[b]	550[a]	Integrated	90	70%	20%	65%	100%
Office	≥3,000	Yes[b]	700[a]	Integrated	53[b]	70%	20%	80%	80%
K-12 school	≥3,000	No	720	Integrated	90	10%	80%	100%	100%
K-12 school	≥2,000[b]	No	720	Integrated	90	10%	80%	100%	100%
K-12 school	≥2,000[b]	Yes[b]	720	Integrated	90	10%	80%	100%	100%
K-12 school	≥2,000[b]	No	720	Non-Integated [b]	90	10%	80%	100%	100%
K-12 school	≥2,000[b]	Yes[b]	720	Non-Integated [b]	90	10%	80%	100%	100%
K-12 school	≥3,000	Yes[b]	720	Non-Integated [b]	53[b]	10%	80%	100%	100%
Higher Ed.	≥3,000	No	1200	Integrated	90	20%	70%	100%	100%
Higher Ed.	≥2,000[b]	No	1200	Integrated	90	20%	70%	100%	100%
Higher Ed.	≥2,000[b]	Yes[b]	1200	Integrated	90	20%	70%	100%	100%
Higher Ed.	≥2,000[b]	No	1200	Non-Integated [b]	90	20%	70%	100%	100%
Higher Ed.	≥2,000[b]	Yes[b]	1200	Non-Integated [b]	90	20%	70%	100%	100%
Higher Ed.	≥3,000	Yes[b]	800[a]	Non-Integated [b]	90	20%	70%	100%	100%
Higher Ed.	≥3,000	Yes[b]	800[a]	Non-Integated [b]	53[b]	20%	70%	100%	100%

a. The first instance of each building type represents the primary run of each group
b. These cells represent sensitivity adjustments to parameters

Research on actual occupancy rates shows that the measure is highly cost effective because actual occupancy rates are much lower than the ones in Table 32. The lower the actual occupancy rates, the more cost-effective the measure is.

Additional parametric analyses

Table 32 shows many of the parametric analyses that were run. It shows that the measure is cost-effective even at OA flow rates below 3,000 cfm and at smaller zone sizes than the average zone sizes from the survey of actual DOAS buildings. It also shows the measure is cost effective if the HVAC system only operates 53 hours per week (e.g., 8am-6pm weekdays, 9-12 Saturdays, off Sundays).

Additional parametric analyses not shown in Table 32:

- Higher Zone Cost: The measure remains cost-effective in all climate zones if the cost per zone increases by $2,000 above the default costs listed in Section 3.4.3. This is clearly a very large safety margin.
- Higher AHU Cost: The measure remains cost-effective in all climate zones if the cost per AHU increases from $6,000 as listed in Section 3.4.3 to $40,000, which is more than a sixfold increase.

Table 32 shows the results of four studies conducted in 2025 on actual occupancy rates. The studies showed that typical zones are occupied 36-54 percent of normal business hours. The studies assumed normal business hours of 50-60 hours/week. Based on the research cited above, the HVAC hours in the models are 90 hours/week. Normalizing the studies to the 90 hours of HVAC operation indicates that typical zones are only occupied 20-36 percent of the time the HVAC is operating. Table 32 shows that the measure is cost effective even if zones are occupied 80-90 percent of the time, so the measure is highly cost effective.

Table 33: Recent Research on Actual Occupancy Rates

Study / Source	Original study metric	Assumed office-hours window	Hours/wk in metric	HVAC-weighted occupancy
XY Sense – Workplace Utilization Index (Global, Q2–Q3 2025)	43% avg global utilization (business hours) [xysense.com]	08:00–18:00, Mon–Fri (assumed)	50	23.9%
XY Sense – Workplace Utilization Index (North America, Q2–Q3 2025)	36% avg utilization (North America) [xysense.com]	08:00–18:00, Mon–Fri (assumed)	50	20.0%
Density – Workplace Benchmark (Q1 2025)	47% avg daily peak floor utilization (busy-day peak, not all-day average) [density.io]	08:00–18:00, Mon–Fri (assumed)	50	26.1%
Kastle – Back-to-Work Barometer (Jan–Feb 2025)	54.2% of pre-pandemic attendance (weekly avg) [axios.com], [credaily.com]	07:00–19:00, Mon–Fri (badge/activity window, assumed)	60	36.1%

Energy savings (electricity, natural gas, and source energy) and peak demand reductions per unit are presented in Table 34 through Table 37. Per-unit savings for the first year are expected to range from 0.49 to 3.37 kWh/yr depending upon climate zone. Demand reductions/increases are expected to range between 0.06 W and 0.44 W, depending on climate zone.

Table 37 presents total per-unit energy cost savings for newly constructed buildings and additions in terms of LSC savings realized over a 30-year period, in 2029 present value dollars (2029 PV$). The LSC methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

Table 34: First Year Electricity Savings (kWh) Per Square Foot – Modulating DOAS

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Large Office	0.80	0.78	0.60	0.84	0.58	0.49	0.49	0.61	0.60	0.70	0.77	0.70	0.74	0.76	0.93	1.10
Medium Office	0.80	0.78	0.60	0.84	0.58	0.49	0.49	0.61	0.60	0.70	0.77	0.70	0.74	0.76	0.93	1.10
Small Office	0.80	0.78	0.60	0.84	0.58	0.49	0.49	0.61	0.60	0.70	0.77	0.70	0.74	0.76	0.93	1.10
Large School	2.37	2.35	1.78	2.53	1.73	1.45	1.43	1.83	1.78	2.11	2.24	2.04	2.14	2.22	2.73	3.37
Small School	2.21	2.28	1.73	2.48	1.71	1.50	1.50	1.89	1.83	2.14	2.20	2.01	2.13	2.21	2.72	3.18

Table 35: First Year Peak Demand Reduction (W) Per Square Foot – Modulating DOAS

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Large Office	0.10	0.13	0.08	0.14	0.08	0.06	0.06	0.08	0.08	0.08	0.11	0.11	0.11	0.12	0.09	0.13
Medium Office	0.10	0.13	0.08	0.14	0.08	0.06	0.06	0.08	0.08	0.08	0.11	0.11	0.11	0.12	0.09	0.13
Small Office	0.10	0.13	0.08	0.14	0.08	0.06	0.06	0.08	0.08	0.08	0.11	0.11	0.11	0.12	0.09	0.13
Large School	0.29	0.39	0.24	0.44	0.24	0.20	0.19	0.24	0.21	0.25	0.31	0.30	0.30	0.34	0.27	0.39
Small School	0.27	0.37	0.23	0.41	0.23	0.19	0.19	0.23	0.20	0.24	0.28	0.28	0.28	0.31	0.25	0.27

Table 36: First Year Source Energy Savings (kBtu) Per Square Foot – Modulating DOAS

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Large Office	1.11	1.22	0.87	1.31	0.86	0.68	0.67	0.80	0.76	0.90	1.04	0.99	0.96	1.06	0.91	1.73
Medium Office	1.11	1.22	0.87	1.31	0.86	0.68	0.67	0.80	0.76	0.90	1.04	0.99	0.96	1.06	0.91	1.73
Small Office	1.11	1.22	0.87	1.31	0.86	0.68	0.67	0.80	0.76	0.90	1.04	0.99	0.96	1.06	0.91	1.73
Large School	3.38	3.72	2.62	4.01	2.60	2.04	2.00	2.41	2.17	2.71	2.93	2.80	2.74	2.99	2.63	5.36
Small School	3.18	3.53	2.53	3.80	2.51	2.03	2.01	2.38	2.13	2.66	2.75	2.63	2.60	2.77	2.60	4.96

Table 37: Total 30-Year LSC Savings (2029 PV$) Per Square Foot – Modulating DOAS

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Large Office	6.54	6.77	5.00	7.25	4.78	4.00	4.01	5.09	5.24	5.88	6.45	6.07	6.22	6.00	7.45	8.51
Medium Office	6.54	6.77	5.00	7.25	4.78	4.00	4.01	5.09	5.24	5.88	6.45	6.07	6.22	6.00	7.45	8.51
Small Office	6.54	6.77	5.00	7.25	4.78	4.00	4.01	5.09	5.24	5.88	6.45	6.07	6.22	6.00	7.45	8.51
Large School	19.61	20.44	14.94	22.01	14.34	11.91	11.89	15.18	15.33	17.65	18.66	17.51	18.01	17.48	21.68	26.16
Small School	18.38	19.71	14.54	21.34	14.21	12.27	12.32	15.48	15.54	17.71	18.16	17.03	17.68	17.14	21.47	24.79

3.4.3 Incremental First Cost

The content that follows applies to submeasure a, “Modulating dampers.” As noted elsewhere, this was the only submeasure for which a detailed cost-effectiveness analysis was conducted.

In October 2025, the Statewide CASE Team consulted with Bay Area mechanical and controls contractors who have recently installed modulating zonal dampers, occupied standby controls, and demand-controlled ventilation controls on many real buildings in Northern California. The costs provided by the contractors include equipment, labor, and acceptance testing.

The proposed case (measure case) costs are compared against a standard design (base case) DOAS system that does not have modulating dampers and therefore cannot comply with DCV and occupied standby measures. The base case is essentially a CAV DOAS system with manual dampers and no controls or sensors (intended to determine the occupancy status). The base case costs only include a manual volume damper and the labor required to balance the system at the time of construction. By contrast, the proposed case includes actuated modulating dampers, controls to allow the dampers throughout the zones to be able to communicate with the central DOAS equipment, additional CO2 and/or occupancy sensors, and a duct static pressure sensor. All of this additional hardware is needed to enable compliance with modulating DOAS. The proposed case was analyzed in two variations: in one variant, the DOAS system is not integrated with a building automation system (BAS) and in the other variant, the system is integrated with a BAS. The non-integrated case is more expensive, as shown below.

The incremental first costs of the proposed case over to the base case include the following elements. The list below presents a step-by-step procedure by which the base case was modified and converted into the proposed case:

1) Delete manual volume dampers (the manual volume dampers in the base case are replaced by the modulating dampers in the proposed case).
2) Reduced up front labor costs in the measure case for not balancing the manual volume dampers during installation.
3) New modulating damper with air flow sensor, like Price RDV. Note that this measure is vendor neutral, there are a number of modulating dampers that would be able to comply. Price RDV is simply a representative option from the analysis.
4) New or modified zone controller with damper actuator and required programming. Pricing was provided for two scenarios:
    a) Non-integrated: if the modulating damper controller is standalone
    b) Integrated: if the modulating damper control function is integrated into the terminal unit controls (e.g., into a VRF fan coil unit controller)

5) Occupancy sensor for occupied standby zones. Again, pricing was provided for a non-integrated scenario (new standalone sensor) and integrated with existing zone HVAC or lighting controls.
6) CO2 sensor for DCV zones. Again, pricing was provided for a non-integrated scenario (new standalone sensor) and integrated with existing zone HVAC or lighting controls.
7) The incremental first costs include $6,000 per DOAS air handler for duct static pressure sensor and associated fan speed controls. This figure has been divided by the number of zones in the office model (13) in Table 38 to allow for it to be displayed alongside other costs.

See Table 38 below for a breakdown of the incremental first costs.

Table 38: Summary of Costs Incurred in the Base and Measure Cases per Zone

No.	Cost Element	Base Case	Proposed Case Non-Integrated	Proposed Case Integrated
1.	Manual volume damper (MVD)	$150	$ -	$ -
2.	Balancing per MVD	$250	$ -	$ -
3.	Modulating damper (e.g., Price RDV)	$ -	$600	$600
4.	Controls (not including Occupancy or CO2 sensors)	$ -	$1,250	$500
5.	Occupancy Sensor	$ -	$600	$100
6.	CO2 Sensor	$ -	$1,000	$260
7.	Duct Static Pressure Sensor (and associated fan speed controls)	$ -	$462	$462
-	**Total**	**$400**	**$3,912**	**$1,922**

The costs are applied to the proposed case in a manner that aligns with the fraction of space types that compose the different building types. Occupied standby zones include the occupancy sensor cost, DCV zones include the CO2 sensor cost, and zones with neither occupied standby or DCV include neither sensor. All zones include the modulating damper and controls costs because in order for a modulating DOAS system to function, all spaces need to be capable of modulating airflow for balancing purposes.

The cost of a variable-speed drive or electrically commutated motor for the supply fan is not included in the incremental cost, based on the assumption that current industry-standard practice for DOAS equipment includes this capability. The current prescriptive requirement for three speeds of fan control in Title 24, Part 6 at Section 401.3.17.2 *[Section 140.4(p)3]* results in this capability being very frequently available in the market today as industry standard practice. A manufacturer representative of a major North American unitary HVAC manufacturer asserted to the Statewide CASE Team that all

DOAS units come with a VFD by default as of 2026. This is the case even for equipment being installed in a CAV configuration, so that the system can be balanced.

3.4.3.1 Manual Balancing

Manual balancing with manual volume-balancing dampers is required in the baseline to measure airflow rates at steady state to allow zones and confirm they meet the design ventilation airflow rates. The system is constant volume and has no airflow measuring stations. Airflow is measured one time by the balancer during balancing.

In the proposed scenario, manual volume balancing dampers are deleted because the zones all have airflow measuring stations to ensure the measured ventilation airflow rate is correct at all times. The required ventilation airflow is not constant but varies based on occupancy. Each zone’s damper modulates independently to maintain the airflow rate current required at each zone.

As a sensitivity, the Statewide CASE Team tested what eliminating the manual balancing cost would do to the measure, and the measure is still cost effective without this aspect.

3.4.3.2 AFMS Calibration

The cost to field calibrate the AFMS is not included in the incremental cost. Field calibration of terminal unit AFMS is common but is not required by the California Mechanical Code or by Title 24. The Title 24 Acceptance Tests (e.g., NA7.5.x tests) say that outdoor air sensors or flow measuring devices must be either factory calibrated or field calibrated, and results documented on the acceptance test forms.

PG&E’s Code Readiness Program Report CR24PGE0001 found that factory calibration provides accuracy within 10 percent of setpoint, which meets the accuracy requirements in Title 24 section 120.1(f).

ASHRAE Research Project 1353-TRP, compared factory calibration to field calibration of VAV box airflow controls and found that field calibration did not significantly improve accuracy relative to factory calibration.

Note that both the PG&E research and the ASHRAE research evaluated accuracy of VAV reheat boxes at minimum flows. Minimum flows depend on the minimum ventilation rate (e.g., 0.15 cfm/ft2) and the design cooling flow rate, typically in the range of 0.6 to 3.0 cfm/ft2. This means the minimum flow for a VAV reheat box can range from 5 to 25 percent of the maximum. As noted in both of these research reports, accuracy degrades at low flow. Accuracy would be better at 25 percent than at 5 percent and better at 100 percent than at 25 percent. This is because VAV box controllers use velocity pressure sensors for airflow measurement and velocity pressure goes down with the square root of the airflow. For example, at 25 percent flow the pressure is 6 percent of the maximum pressure and at 5 percent flow the pressure is at 0.25 percent of the maximum pressure.

The minimum flow rate on a modulating DOAS damper is 100 percent for low density zones with occupied standby (e.g., open office space). For high density spaces (e.g., conference rooms) the minimum flow can be as low as 20 percent So modulating DOAS AFMS would generally be more accurate than VAV box AFMS, even without field calibration.

As a sensitivity analysis, the Statewide CASE Team tested whether including field calibration of the AFMS, assuming $1,500 per zone. The measure is still cost effective with this assumption included in the measure case. Based on feedback from TAB contractors, field calibration should not exceed $150/zone, so the measure is still cost effective even if field calibration is included.

3.4.4 Incremental Maintenance and Replacement Costs

In October 2025, the Statewide CASE Team consulted with Bay Area mechanical and controls contractors to collect data for the incremental maintenance and replacement costs, as well as estimation of present-value of maintenance and replacement costs, expected useful life, frequency of replacement, and maintenance procedures related to the measure relative to the maintenance requirements for the baseline. c

- Damper and airflow probe: 30 years
- Damper actuator and controls: 20 years
- Occupancy sensor: 15 years
- CO2 sensor: 10 years

The relevant maintenance costs are summarized in Table 39. Costs are discounted to present values because the lifetimes of each element differ, as shown in the bulleted list above. The first three rows of the table show individual element costs, and rows four through six show how those costs combine for different zone types. Row four represents the cost for zones without occupied standby or DCV controls; row five is for occupied standby zones; and row six is for occupied standby and DCV zones. The costs were applied to the cost-effectiveness analysis based on the estimated floor area of each zone type as a percentage of the total building. The final maintenance cost is a weighted average of a combination of rows four, five, and six based on the prevalence each zone type in of each building type.

Table 39: Summary of Incremental Maintenance and Replacement Costs

No.	Cost Element	Non-Integrated Scenario ($/yr/zone)	Integrated Scenario ($/yr/zone)
1	Actuator/controls	$35.86	$14.34
2	Occupancy sensor	$19.95	$3.33
3	CO2 sensor	$67.24	$17.48
4	Total (neither OS/DCV zones, equals row 1)	$35.86	$14.34
5	Total (OS zones, equals rows 1 + 2)	$55.81	$17.70
6	Total (OS+DCV zones, equals rows 1 + 2 + 3)	$123.06	$35.20

3.4.5 Cost Effectiveness

The results of the per-unit cost-effectiveness analyses are presented from Table 40 to Table 44 for new construction/additions. This entire section applies to submeasure a, Modulating dampers.

In the tables below, all values are presented in 2026 present value dollars (2029 PV$). Benefits represent 30-year LSC savings and other savings, including incremental first-cost savings if the proposed first cost is less than the current first cost, incremental maintenance cost savings if the proposed maintenance costs are less than the current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at the end of the 30-year period of analysis. Costs represent the total incremental PV cost, including equipment, replacement, and maintenance costs over the analysis period. The analysis treats a negative incremental maintenance cost as a positive benefit. If total incremental costs are zero, the benefit-to-cost ratio (BCR) is considered infinite. Costs and other savings are discounted at a real (inflation-adjusted) three percent rate. If there are no total incremental PV costs, the BCR is infinite.

Table 40: 30-Year Cost-Effectiveness Summary Per Square Foot – New Construction and Additions – Large Office

Climate Zone	Benefits LSC Savings + Other PV Savings (2029 PV$)	Costs Total Incremental PV Costs (2029 PV$)	Benefit-to-Cost Ratio
1	6.54	1.96	3.33
2	6.77	1.96	3.45
3	5.00	1.96	2.55
4	7.25	1.96	3.70
5	4.78	1.96	2.44
6	4.00	1.96	2.04
7	4.01	1.96	2.04
8	5.09	1.96	2.60
9	5.24	1.96	2.67
10	5.88	1.96	3.00
11	6.45	1.96	3.29
12	6.07	1.96	3.10
13	6.22	1.96	3.17
14	6.00	1.96	3.06
15	7.45	1.96	3.80
16	8.51	1.96	4.34

Table 41: 30-Year Cost-Effectiveness Summary Per Square Foot – New Construction and Additions – Medium Office

Climate Zone	Benefits LSC Savings + Other PV Savings (2029 PV$)	Costs Total Incremental PV Costs (2029 PV$)	Benefit-to-Cost Ratio
1	6.54	1.96	3.33
2	6.77	1.96	3.45
3	5.00	1.96	2.55
4	7.25	1.96	3.70
5	4.78	1.96	2.44
6	4.00	1.96	2.04
7	4.01	1.96	2.04
8	5.09	1.96	2.60
9	5.24	1.96	2.67
10	5.88	1.96	3.00
11	6.45	1.96	3.29
12	6.07	1.96	3.10
13	6.22	1.96	3.17
14	6.00	1.96	3.06
15	7.45	1.96	3.80
16	8.51	1.96	4.34

Table 42: 30-Year Cost-Effectiveness Summary Per Square Foot – New Construction and Additions – Small Office

Climate Zone	Benefits LSC Savings + Other PV Savings (2029 PV$)	Costs Total Incremental PV Costs (2029 PV$)	Benefit-to-Cost Ratio
1	6.54	1.96	3.33
2	6.77	1.96	3.45
3	5.00	1.96	2.55
4	7.25	1.96	3.70
5	4.78	1.96	2.44
6	4.00	1.96	2.04
7	4.01	1.96	2.04
8	5.09	1.96	2.60
9	5.24	1.96	2.67
10	5.88	1.96	3.00
11	6.45	1.96	3.29
12	6.07	1.96	3.10
13	6.22	1.96	3.17
14	6.00	1.96	3.06
15	7.45	1.96	3.80
16	8.51	1.96	4.34

Table 43: 30-Year Cost-Effectiveness Summary Per Square Foot – New Construction and Additions – Large School

Climate Zone	Benefits LSC Savings + Other PV Savings (2029 PV$)	Costs Total Incremental PV Costs (2029 PV$)	Benefit-to-Cost Ratio
1	19.61	4.32	4.54
2	20.44	4.32	4.73
3	14.94	4.32	3.45
4	22.01	4.32	5.09
5	14.34	4.32	3.32
6	11.91	4.32	2.75
7	11.89	4.32	2.75
8	15.18	4.32	3.51
9	15.33	4.32	3.55
10	17.65	4.32	4.08
11	18.66	4.32	4.32
12	17.51	4.32	4.05
13	18.01	4.32	4.16
14	17.48	4.32	4.04
15	21.68	4.32	5.01
16	26.16	4.32	6.05

Table 44: 30-Year Cost-Effectiveness Summary Per Square Foot – New Construction and Additions – Small School

Climate Zone	Benefits LSC Savings + Other PV Savings (2029 PV$)	Costs Total Incremental PV Costs (2029 PV$)	Benefit-to-Cost Ratio
1	18.38	2.70	6.80
2	19.71	2.70	7.29
3	14.54	2.70	5.38
4	21.34	2.70	7.89
5	14.21	2.70	5.26
6	12.27	2.70	4.54
7	12.32	2.70	4.55
8	15.48	2.70	5.72
9	15.54	2.70	5.75
10	17.71	2.70	6.55
11	18.16	2.70	6.72
12	17.03	2.70	6.30
13	17.68	2.70	6.54
14	17.14	2.70	6.34
15	21.47	2.70	7.94
16	24.79	2.70	9.17

3.4.6 Comments Regarding Cost Effectiveness for DOAS Supply Air Compliance Option (Submeasure c)

Submeasure c did not receive a full cost-effectiveness analysis because the Statewide CASE Team asserts that the measure (an alternative prescriptive compliance option) has an equal or lower first cost as well as an equal or lower energy cost than the primary prescriptive pathway for this particular code requirement.

The energy parity of this measure is described in some detail in Section 3.1.2. Essentially, this prescriptive compliance option would result in neutral energy consumption because the guardrails being placed on the FCU require it to cycle off or turn down to the speed needed to deliver the required outdoor air or to 50 percent of maximum speed. This excludes CAV or “near CAV” (e.g., can achieve 75 percent turndown) FCUs from being eligible to comply with this option. The FCU power used to push the outdoor air into the zone offsets the demand on the central DOAS supply fan, which lowers its energy consumption.

The upfront cost is also discussed in Section 3.1.2. The Statewide CASE Team asserts that costs for this compliance option would be reduced or equal compared to the current prescriptive option. This is because in the existing prescriptive pathway, the ductwork and diffusers leaving the FCU need to be sized larger to handle both the conditioning as well as ventilation air. Furthermore, the central DOAS system fans need to be sized to handle static pressure sufficient to deliver air to zones without any "assistance" from the FCU. In the new compliance option, the ductwork/diffuser at the zone and potentially the central DOAS supply fan (due to reduced static pressure demands) can be downsized, which reduces upfront costs.

Due to the combination of these impacts on both the energy consumption and upfront cost that a cost-effectiveness analysis was not conducted for submeasure c.

3.5 Modulating DOAS - Statewide Impacts

Impacts have only been estimated for submeasure a, Modulating dampers.

3.5.1 Statewide Energy and Energy Cost Savings

See the 2028 CASE Methodology Report for details on how statewide savings are calculated. Appendix C presents the assumptions on the percentage of the total construction forecast that the proposed measure would impact.

For more details on the methodology and context about estimating the current market share rate, as well as statewide energy and energy cost savings, see the 2028 CASE Methodology Report.

Table 45 presents first-year statewide savings from new construction, and additions.

Table 45: Statewide Energy and LSC Impacts – New Construction and Additions

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Million Square Feet)	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2029 PV$)
1	20,671	0.03	0	0	0.04	$0.24
2	124,424	0.17	0.03	0	0.26	$1.46
3	479,702	0.35	0.05	0	0.51	$2.96
4	307,403	0.4	0.07	0	0.63	$3.48
5	70,703	0.06	0.01	0	0.1	$0.53
6	379,385	0.28	0.04	0	0.39	$2.31
7	210,231	0.13	0.02	0	0.18	$1.09
8	538,788	0.49	0.06	0	0.64	$4.07
9	963,401	0.86	0.1	0	1.05	$7.38
10	324,039	0.37	0.04	0	0.47	$3.10
11	91,414	0.14	0.02	0	0.18	$1.14
12	528,677	0.56	0.08	0	0.77	$4.83
13	166,050	0.24	0.03	0	0.3	$1.97
14	86,797	0.11	0.02	0	0.14	$0.83
15	51,003	0.08	0.01	0	0.08	$0.64
16	30,333	0.06	0.01	0	0.09	$0.45
Total	**4,373,023**	**4.33**	**0.58**	**0**	**5.81**	**$36.47**

3.5.2 Statewide Greenhouse Gas Emissions Reductions

Table 46 presents the estimated first-year reduction in GHG emissions resulting from the proposed code change. In this initial year, the Statewide CASE Team expects to avoid metric tons of carbon dioxide equivalent (CO_2e) emissions. These reductions, along with their associated monetary value, were calculated using hourly GHG emissions factors published alongside the LSC hourly factors and source energy hourly factors in the research versions of CBECC, as well as data from the CEC's 2028 Metrics Report. See the [2028 CASE Methodology Report] for additional information.

Table 46: First-Year Statewide GHG Emissions Impacts

Construction Type	Reduced GHG Emissions from Electricity Savings (Metric Tons CO2e)	Reduced GHG Emissions from Natural Gas Savings (Metric Tons CO2e)	Total Reduced GHG Emissions (Metric Ton CO2e)	Total Monetary Value of Reduced GHG Emissions ($)
New Construction & Additions	308	0.00	308	37,868
Alterations	0	0	0	0
Total	**308**	**0.00**	**308**	**37,868**

3.5.3 Statewide Water Use Impacts

The proposed code change would not result in water savings.

3.5.4 Statewide Material Impacts

This measure is not expected to result in a meaningful change to materials.

3.5.5 Environmental Impacts

This proposal would result in improved building energy efficiency and corresponding GHG emissions reductions.

There are no identified indirect adverse environmental impacts nor indirect environmental benefits from this code change proposal.

3.5.6 Other Non-Energy Impacts

This measure is not expected to result in any non-energy impacts.

3.6 Modulating DOAS - Proposed Code Language

3.6.1 Guide to Markup Language

The proposed changes to the standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2025 documents should be marked with dark blue underlining (new language) and ~~strikethroughs~~ (deletions). New to the 2028 energy code is to *italicize defined terms* when the terms are being used in its defined context. In-line comments that are not part of the proposed code language but are used to help describe the purpose of what is proposed are included *with greyed highlight and italics.*

Markups are provided to the restructured 2025 Energy Code that the CEC developed in response to feedback that aligning the structure of Title 24, Part 6 with other parts of the California Building Standards Code (Title 24) would improve readability, usability, and navigation.[8] New section numbers are shown as bold followed square brackets that document the section in the 2025 Title 24, Part 6 section numbers prior to the restructuring. For example, "**Section 601.1** [Section 130.0(a)] **General"** contains the content that is in the current Section 130.0(a).

Posting the proposed code language in this format is useful as it helps describe how the Energy Code changes proposed for nonresidential occupancies are isolated from the requirements for residential occupancies which are prohibited from being changed until the 2031 code cycle by Assembly Bill 130.

3.6.2 Administrative Code (Title 24, Part 1)

There are no proposed changes to Title 24, Part 1.

3.6.3 Energy Code (Title 24, Part 6)

401.2.1 *[Section 120.1]* **– Ventilation and indoor air quality**

…

401.2.1.1.3 *[Section 120.1(c)3]* **Mechanical ventilation.**

…

TABLE 401.2-A [TABLE 120.1-A]– MINIMUM VENTILATION RATES

Occupancy Category – Educational Facilities	Minimum Occupant Load Density (persons / 1000 ft^2)	Area-based Minimum Ventilation R_a (cfm/ft^2)	Air Class	Notes
Daycare (through age 4)	14	0.15	2	--
Daycare sickroom	5	0.15	3	--
Classrooms (ages 5-8)	25	0.15	1	--
Classrooms (age 9 -18)	25	0.15	1	--
Lecture/postsecondary classroom	25	0.15	1	F
Lecture hall (fixed seats)	71	0.15	1	F
Art classroom	25	0.15	2	--
Science laboratories	25	0.15	2	--

Occupancy Category – Educational Facilities	Minimum Occupant Load Density (persons / 1000 ft^2)	Area-based Minimum Ventilation R_a (cfm/ft^2)	Air Class	Notes
University/college laboratories	25	0.15	2	--
Wood/metal shop	10	0.15	2	--
~~Computer lab~~ Information technology equipment facilities (occupiable)	25	0.15	1	--
Media center	25	0.15	1	A
Music/theater/dance	33	0.15	1	F
Multiuse assembly	33	0.15	1	F

…

(CONTINUED): TABLE 401.2-A [TABLE 120.1-A]– MINIMUM VENTILATION RATES

Occupancy Category - ***Office Buildings***	Minimum Occupant Load Density (persons / 1000 ft^2)	Area-based Minimum Ventilation R_a (cfm/ft^2)	Air Class	Notes
~~Breakrooms~~	~~33~~	~~0.15~~	~~1~~	~~--~~
Main entry lobbies	33	0.15	1	F
Occupiable storage rooms for dry materials	2	0.15	1	--
Office space	5	0.15	1	F
Reception areas	5	0.15	1	F
Telephone/data entry	33	0.15	1	F

(CONTINUED): TABLE 401.2-A [TABLE 120.1-A]– MINIMUM VENTILATION RATES

Occupancy Category - *Miscellaneous Spaces*	**Minimum Occupant Load Density (persons / 1000 ft^2)**	**Area-based Minimum Ventilation R_a (cfm/ft^2)**	**Air Class**	**Notes**
Bank vaults/safe deposit	5	0.15	2	F
Banks or bank lobbies	5	0.15	1	F
~~Computer (not printing)~~ Information technology equipment facilities (occupiable)	5	0.15	1	F
Freezer and refrigerated spaces (<50oF)	0	*0*	2	E

(CONTINUED): TABLE 401.2-A [TABLE 120.1-A]– MINIMUM VENTILATION RATES

Occupancy Category - *Miscellaneous Spaces*	**Minimum Occupant Load Density (persons / 1000 ft^2)**	**Area-based Minimum Ventilation R_a (cfm/ft^2)**	**Air Class**	**Notes**
General manufacturing (excludes heavy industrial and process using chemicals)	5	0.15	3	
Pharmacy (prep. Area)	5	0.15	2	--
Photo studios	5	0.15	1	--
Shipping/receiving	2	0.15	2	B
Sorting, packing, light assembly	2	0.15	2	--
Telephone closets	5	0.15	1	--
Transportation waiting	33	0.15	1	F
Warehouses	1	0.15	2	B
All others	5	0.15	2	--

401.2.1.2 *[Section 120.1(d)]* **Operation and control requirements for minimum quantities of outdoor air.**

…

401.2.1.2.3 *[Section 120.1(d)3]* **Required demand control ventilation (DCV).**

Nonresidential buildings other than *hotel/motel* buildings and *nonresidential* buildings with *Group R occupancies* shall comply with the following*:*

Demand ventilation controls complying with Section 401.2.1.2.4 *[Section 120.1(d)4]* are required for ~~a~~each space with a design occupant density, or a maximum occupant load factor for egress purposes in the CBC, greater than or equal to 25 people per 1,000 square feet (40 square feet or less per person) if the ~~ventilation system serving the space has one or more of the following~~space is:

1. served by a system with an *air economizer*; or

~~2 modulating *outside air* control; or~~

~~3.~~ 2. in a building with a design outdoor airflow rate > 3,000 cfm

Exception 1 to Section 401.2.1.2.3: Spaces w~~W~~here space exhaust is greater than the design ventilation rate specified in Section 401.2.1.1.3 *[Section 120.1(c)3]* minus 0.2 cfm per square foot of conditioned area.

Exception 2 to Section 401.2.1.2.3: Spaces that have processes or operations that generate dusts, fumes, mists, vapors or gases and are not provided with local exhaust ventilation, such as indoor operation of internal combustion engines or areas designated for unvented food service preparation, daycare sickrooms, science labs, barber shops or beauty and nail salons shall not install demand control ventilation.

Exception 3 to Section 401.2.1.2.3: Spaces with an area of less than 150 square feet, or a design occupancy of less than 10 people as specified by Section 401.2.1.1.3 *[Section 120.1(c)3]*.

401.2.1.2.4 ***[New Section]*** **Required demand control ventilation for *Hotel/motel* buildings and *nonresidential* buildings with *Group R occupancies***

Hotel/motel buildings and *nonresidential* buildings with *Group R occupancies* shall meet the following requirements:

Demand ventilation controls complying with Section 401.2.1.2.4 *[Section 120.1(d)4]* are required for a space with a design occupant density, or a maximum occupant load factor for egress purposes in the CBC, greater than or equal to 25 people per 1,000 square feet (40 square feet or less per person) if the ventilation system serving the space has one or more of the following:

1. an *air economizer*; or

2. modulating *outside air* control; or
3. design outdoor airflow rate > 3,000 cfm

Exception 1 to Section 401.2.1.2.3: Where space exhaust is greater than the design ventilation rate specified in Section 401.2.1.1.3 *[Section 120.1(c)3]* minus 0.2 cfm per square foot of conditioned area.

Exception 2 to Section 401.2.1.2.3: Spaces that have processes or operations that generate dusts, fumes, mists, vapors or gases and are not provided with local exhaust ventilation, such as indoor operation of internal combustion engines or areas designated for unvented food service preparation, daycare sickrooms, science labs, barber shops or beauty and nail salons shall not install demand control ventilation.

Exception 3 to Section 401.2.1.2.3: Spaces with an area of less than 150 square feet, or a design occupancy of less than 10 people as specified by Section 401.2.1.1.3 *[Section 120.1(c)3]*.

401.2.1.2.5 *[Section 120.1(d)4]* **Demand control ventilation devices.**

Nonresidential buildings other than *hotel/motel* buildings and *nonresidential* buildings with *Group R occupancies* shall comply with the following:

1. Ventilation systems, including DOAS, serving space(s) where DCV is required shall include modulating pressure independent dampers or other means of independently modulating outside air to each space conditioning zone or room served by that system.

~~1~~2. ~~For each system with demand control ventilation (DCV),~~ CO_2 sensors shall be installed in each room that meets the criteria of 401.2.1.2.3 *[Section 120.1(d)3]* with no less than one sensor per 10,000 square feet of floor space. When a zone or a space is served by more than one sensor, a signal from any sensor indicating that CO_2 is near or at the setpoint within the zone or space, shall trigger an increase in ventilation.

~~2~~3. CO_2 sensors shall be located in the room between 3 feet and 6 feet above the floor or at the anticipated height of the occupants' heads.

4. When the system is operating during hours of expected occupancy, the *outdoor air* ventilation rate to each space where DCV is required shall be independently modulated from minimum to maximum using ASHRAE Guideline 36 logic to maintain space CO_2 concentration 400 to 600 ppm above the *outdoor air* CO_2 concentration. ~~the controls shall maintain system outdoor air ventilation rates no less than Ra × Az per Equation 401.2-B [Equation 120.1-F] in Section 401.2.1.1.3 for each space with a CO2 sensor(s), plus the greater of either the exhaust air rate or the rate required by Section 401.2.1.1.3 [Section 120.1(c)3] for other spaces served by the system.~~

5. For single zone systems the CO2 control loop shall reset the minimum outside air flow setpoint from the absolute minimum setpoint based on

area to the design minimum outside air flow setpoint based on design occupancy.

6. For multiple zone systems each zone CO2 control loop shall first reset the zone minimum airflow setpoint from Ra × Az (per Section 401.2.1.1.3) to the maximum cooling airflow setpoint. Then the loop shall reset the air handler minimum outside air flow setpoint from the absolute minimum setpoint based on area, to the design minimum setpoint based on design occupancy.

7. For zones with both DCV and Occupied Standby Zone Controls, mechanical ventilation to the zone shall be shut off in 5 minutes or less after entering occupied-standby mode, regardless of CO2 concentration.

~~4~~8. CO_2 sensors shall be certified by the manufacturer to be accurate within plus or minus 75 ppm at a 600 and 1000 ppm concentration 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 failure, the system shall provide a signal which resets to supply the minimum quantity of *outside air* to levels required by Section 401.2.1.1.3 *[Section 120.1(c)3]* to the zone serviced by the sensor at all times that the zone is occupied.

~~5~~9. The CO_2 sensor(s) reading for each ~~zone~~space shall be displayed continuously, and shall be recorded on systems with *DDC* to the zone level.

~~**401.2.1.2.4.1- CO2 concentrations.** Demand ventilation controls shall maintain CO2 concentrations less than or equal to 600 ppm plus the outdoor air CO2 concentration in all rooms with CO2 sensors.~~

~~7~~10. *Outdoor air* CO2 concentration shall be determined by one of the following:

1. CO_2 concentration shall be assumed to be 400 ppm without any direct measurement; or

2. CO_2 concentration shall be dynamically measured using a CO_2 sensor located within 4 feet of the *outdoor air* intake.

~~**Exception to Section 401.2.1.2.4.1:** The outdoor air ventilation rate is not required to be larger than the design outdoor air ventilation rate required by Section 401.2.1.1.3 [Section 120.1(c)3] regardless of CO2 concentration.~~

401.2.1.2.6 *[New Section]* Demand control ventilation devices for *Hotel/motel* buildings and *nonresidential* buildings with *Group R occupancies*

Hotel/motel buildings and *nonresidential* buildings with *Group R occupancies* shall meet the following requirements:

1. For each system with demand control ventilation (DCV), CO_2 sensors shall be installed in each room that meets the criteria of 401.2.1.2.3 *[Section 120.1(d)3]* with no less than one sensor per 10,000 square feet of floor space. When a zone or a space is served by more than one sensor, a signal from any sensor indicating that CO_2 is near or at the setpoint within the zone or space, shall trigger an increase in ventilation.
2. CO_2 sensors shall be located in the room between 3 feet and 6 feet above the floor or at the anticipated height of the occupants' heads.
3. When the system is operating during hours of expected occupancy, the controls shall maintain system *outdoor air* ventilation rates no less than Ra × Az per Equation 401.2-B *[Equation 120.1-F]* in Section 401.2.1.1.3 for each space with a CO_2 sensor(s), plus the greater of either the exhaust air rate or the rate required by Section 401.2.1.1.3 *[Section 120.1(c)3]* for other spaces served by the system.
4. CO_2 sensors shall be certified by the manufacturer to be accurate within plus or minus 75 ppm at a 600 and 1000 ppm concentration 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 failure, the system shall provide a signal which resets to supply the minimum quantity of *outside air* to levels required by Section 401.2.1.1.3 *[Section 120.1(c)3]* to the zone serviced by the sensor at all times that the zone is occupied.
5. The CO_2 sensor(s) reading for each zone shall be displayed continuously, and shall be recorded on systems with *DDC* to the zone level.

401.2.1.2.4.1- CO_2 concentrations. Demand ventilation controls shall maintain CO_2 concentrations less than or equal to 600 ppm plus the *outdoor air* CO_2 concentration in all rooms with CO_2 sensors.

Outdoor air CO_2 concentration shall be determined by one of the following:

1. CO_2 concentration shall be assumed to be 400 ppm without any direct measurement; or
2. CO_2 concentration shall be dynamically measured using a CO_2 sensor located within 4 feet of the *outdoor air* intake.

Exception to Section 401.2.1.2.4.1: The *outdoor air* ventilation rate is not required to be larger than the design *outdoor air* ventilation rate required by Section 401.2.1.1.3 *[Section 120.1(c)3]* regardless of CO_2 concentration.

401.2.1.2.~~5~~7 *[Section 120.1(d)5]* **Occupied standby zone controls.**

Nonresidential buildings other than *hotel/motel* buildings and *nonresidential* buildings with *Group R occupancies* shall comply with the following*:*

Space conditioning zones serving one or more of the following space types listed in Table 401.2.1-A shall include occupied standby controls complying with this section. when all of the following are true:

1. All rooms served by the zone are permitted to have their ventilation air reduced to zero while in occupied-standby mode per Table 401.2-A *[Table 120.1-A]*; and
2. Occupant sensors are required by Sections 601.2.2.3.5 and 601.2.2.3.6 *[Section 130.1(c)5 and 6]*; and

3. The zone and ventilation system is not served by pneumatic controls.

Table 401.2.1-A *[New table]* **– Space Types with Required Occupied Standby Controls**

Occupancy Category	**Space Type**	**Additional Requirement**
Educational Facilities	Lecture/postsecondary classroom	--
Educational Facilities	Lecture hall (fixed seats)	--
Educational Facilities	Multiuse assembly	Less than 1,000 square feet
General	Break rooms	--
General	Conference/meeting	--
General	Corridors	--
Office Buildings	Main entry lobbies	--
Office Buildings	Office space	--
Miscellaneous Spaces	Bank vaults/safe deposit	--
Miscellaneous Spaces	Banks or bank lobbies	--
Miscellaneous Spaces	Information technology equipment facilities (occupiable)	--
Miscellaneous Spaces	Transportation waiting	--
Public Assembly Spaces	Lobbies	--

Note: Space Types listed in this table are taken from space types designated by 401.2-A MINIMUM VENTILATION RATES where footnote “F” is present to allow for occupied standby

401.2.1.2.57.1 *[Section 120.1(d)5B]* **Control functionality.**

Occupied-standby zone controls shall comply with the following:

1. Occupant sensors shall have suitable coverage and placement to detect occupants in the entire space. In 20 minutes or less after no

occupancy is detected by any sensors covering the room, *occupant sensing controls* shall indicate a room is vacant.

2. When occupant sensors controlling *lighting* are also used for ventilation, the ventilation signal shall be independent of daylighting, *manual lighting* overrides or *manual* control of *lighting*.
3. When a single zone serves multiple spaces, there shall be an occupant sensor in each space and the zone shall not be considered vacant until all spaces in the zone are vacant.
4. One hour prior to normal scheduled occupancy, the occupant sensor ventilation control shall allow pre-*occupancy* purge as described in Section 401.2.1.2.2 *[Section 120.1(d)2]*.
5. When the zone is scheduled to be occupied and *occupant sensing controls* in all spaces served by the zone indicate the spaces are unoccupied, the zone shall be placed in occupied-standby mode.
6. In 5 minutes or less after entering occupied-standby mode, mechanical ventilation to the zone shall be shut off until the space becomes occupied or until ventilation is needed to provide space heating or conditioning. When mechanical ventilation is shut off to the zone, the ventilation system serving the zone shall reduce the system *outside air* rate by the amount of *outside air* required for the zone.
7. Where the system providing space conditioning also provides ventilation to the zone, in 5 minutes or less after entering occupied-standby mode, *space-conditioning zone* setpoints shall be reset in accordance with Section 401.2.2.5.3 *[Section 120.2(e)3]*.

Exception to Section 401.2.1.2.7: Zones and ventilation systems served by pneumatic controls.

401.2.1.2.8 *[New Section]* Occupied standby zone controls for *Hotel/motel* buildings and *nonresidential* buildings with *Group R occupancies*

Hotel/motel buildings and *nonresidential* buildings with *Group R occupancies* shall meet the following requirements:

Space conditioning zones shall include occupied standby controls complying with this section when all of the following are true:

3. All rooms served by the zone are permitted to have their ventilation air reduced to zero while in occupied-standby mode per Table 401.2-A *[Table 120.1-A]*; and
4. Occupant sensors are required by Sections 601.2.2.3.5 and 601.2.2.3.6 *[Section 130.1(c)5 and 6]*; and
5. The zone and ventilation system is not served by pneumatic controls.

401.2.1.2.8.1 *[Section 120.1(d)5B]* Control functionality.

Occupied-standby zone controls shall comply with the following:

1. Occupant sensors shall have suitable coverage and placement to detect occupants in the entire space. In 20 minutes or less after no occupancy is detected by any sensors covering the room, *occupant sensing controls* shall indicate a room is vacant.
2. When occupant sensors controlling *lighting* are also used for ventilation, the ventilation signal shall be independent of daylighting, *manual lighting* overrides or *manual* control of *lighting*.
3. When a single zone serves multiple spaces, there shall be an occupant sensor in each space and the zone shall not be considered vacant until all spaces in the zone are vacant.
4. One hour prior to normal scheduled occupancy, the occupant sensor ventilation control shall allow pre-*occupancy* purge as described in Section 401.2.1.2.2 *[Section 120.1(d)2]*.
5. When the zone is scheduled to be occupied and *occupant sensing controls* in all spaces served by the zone indicate the spaces are unoccupied, the zone shall be placed in occupied-standby mode.
6. In 5 minutes or less after entering occupied-standby mode, mechanical ventilation to the zone shall be shut off until the space becomes occupied or until ventilation is needed to provide space heating or conditioning. When mechanical ventilation is shut off to the zone, the ventilation system serving the zone shall reduce the system *outside air* rate by the amount of *outside air* required for the zone.
7. Where the system providing space conditioning also provides ventilation to the zone, in 5 minutes or less after entering occupied-standby mode, *space-conditioning zone* setpoints shall be reset in accordance with Section 401.2.2.5.3 *[Section 120.2(e)3]*.

…

SECTION 401.2.2 *[Section 120.2]* **–CONTROLS FOR SPACE-CONDITIONING AND VENTILATION SYSTEMS**

…

401.2.2.5 *[Section 120.2(e)]* **Shut-off and reset controls for space-conditioning and ventilation systems**.

Each *space-conditioning system* and each ventilation system shall be installed with controls that comply with the following:

Exception 1 to Section 401.2.2.5: Systems serving *healthcare facilities*.

Exception 2 to Section 401.2.2.5: Ventilation systems serving *hotel/motel* buildings and *nonresidential* buildings with Group R *occupancies.*

…

401.2.2.6 *[Section 120.2(f)]* **Dampers for air supply and exhaust equipment**.

Outdoor air supply and exhaust equipment shall be installed with dampers that automatically close upon fan shutdown.

Exception 1 to Section 401.2.2.6: Equipment that serves an area that must operate continuously.

Exception 2 to Section 401.2.2.6: Gravity and other nonelectrical equipment that has readily accessible manual damper controls.

Exception 3 to Section 401.2.2.6: At combustion air intakes and shaft vents.

~~**Exception 4 to Section 401.2.2.6:** Where prohibited by other provisions of law.~~

401.2.2.7 ***[Section 120.2(g)]*** **Isolation area devices.**

Each ~~*space-conditioning*~~ *HVAC system* serving multiple zones with a combined *conditioned floor area* of more than 25,000 square feet shall be designed, installed, and controlled to serve isolation areas.

Each zone, or any combination of zones not exceeding 25,000 square feet, shall be a separate isolation area.

Each isolation area shall be provided with isolation devices, such as valves or dampers, that allow the supply of heating or cooling to be reduced or shut off independently of other isolation areas.

Each isolation area shall be controlled by a device meeting the requirements of Section 401.2.2.5.1 *[Section 120.2(e)1]*.

401.3 *[SECTION 140.4]* – PRESCRIPTIVE REQUIREMENTS (Newly Constructed)

…

401.3.5.2 *[Section 140.4(c)2]* ~~**Variable air volume (**~~**VAV**~~**)**~~ **and modulating DOAS systems.**

Static pressure sensor location. Supply fans in VAV and DOAS systems serving modulating zone dampers shall be controlled by s~~S~~tatic pressure sensors ~~used to control variable air volume fans shall be~~ placed in a position such that the controller set-point is no greater than one-third the total design fan static pressure, except for systems with zone reset control complying with setpoint reset requirements below. If this results in the sensor being located downstream of any major duct split, multiple sensors shall be installed in each major branch with fan capacity controlled to satisfy the sensor furthest below its setpoint; and

Setpoint reset. For systems with *direct digital control* of individual zone boxes reporting to the central control panel:

1. Static pressure setpoints shall be reset based on the zone requiring the most pressure.
2. Control sequences of operation for static pressure setpoint reset shall be in accordance with *ASHRAE Guideline 36*.

401.3.6 *[Section 140.4(d)]* Space-conditioning zone controls. Each *space-conditioning* zone and shall have controls designed in accordance with Section 401.3.6.1 or Section 401.3.6.2.

…

401.3.6.2 *[Section 140.4(d)2]* **Zones served by VAV Systems.**

Zones served by variable air-volume systems that are designed and controlled to reduce, to a minimum, the volume of reheated, recooled, or mixed air are allowed only if the controls meet all of the following requirements:

For each zone with direct digital controls (DDC):

1. The volume of primary air that is reheated, recooled, or mixed air supply shall not exceed the larger of:

   1.1 50 percent of the peak *primary airflow*; or

   1.2 The design zone outdoor airflow rate as specified by Section 401.2.1.1.3 *[Section 120.1(c)3]* for *hotel/motel* buildings and *nonresidential* buildings with Group R *occupancies*; or the design zone outdoor airflow rate as specified by Section 401.3.21 *[New Section]* for all other *nonresidential* buildings.
2. The volume of primary air in the *deadband* shall not exceed the design zone outdoor airflow rate as specified by Section 401.2.1.1.3 *[Section 120.1(c)3]* for *hotel/motel* buildings and *nonresidential* buildings with Group R *occupancies*, or the design outdoor airflow rate as specified by Section 401.3.21 *[New Section]* for all other *nonresidential* buildings.
3. The first stage of heating consists of modulating the zone *supply air* temperature setpoint up to a maximum setpoint no higher than 95ºF while the airflow is maintained at the dead band flow rate.
4. The second stage of heating consists of modulating the airflow rate from the dead band flow rate up to the heating maximum flow rate.
5. Control sequences of operation for *reheat* zones shall be in accordance with *ASHRAE Guideline 36.*

For each zone without DDC:

1. the volume of primary air that is reheated, re-cooled, or mixed air supply shall not exceed the larger of the following:

1.1 30 percent of the peak *primary airflow*; or

1.2 The design zone outdoor airflow rate as specified by Section 401.2.1.1.3 *[Section 120.1(c)3]* for *hotel/motel* buildings and *nonresidential* buildings with Group R *occupancies*; or the design zone outdoor airflow rate as specified by Section 401.3.21 *[New Section]* for all other nonresidential buildings.

…

401.3.17 *[Section 140.4(p)]* **Dedicated outdoor air systems (DOAS).**

…

401.3.17.2 *[Section 140.4(p)2]* The DOAS supply outdoor air shall be delivered using one of the following options:

1.Ddirectly to the occupied space or

2.. Aat the outlet of any terminal heating or cooling coils and shall cycle off any zone heating and cooling equipment fans, circulation pumps and terminal unit fans when there is no call for heating or cooling in the zone.

3.. At the inlet to zonal terminal heating or cooling coils. When there is no call for heating or cooling in the zone, the zone heating and cooling equipment, circulation pumps, and terminal unit fans shall either:

3.1. cycle off if the outside air must flow through the space before being returned or exhausted, or

3.2. be controlled to reduce fan speed to no more than the greater of:

7.2.1 the speed required to achieve a supply airflow equal to the required outdoor air, or

7.2.2 50% of maximum speed

Exception 1 to Section 140.4(p)2: Active chilled beam systems.

Exception 2 to Section 140.4(p)2: Sensible-only cooling terminal units with pressure-independent variable-airflow regulating devices limiting the DOAS supply air to the greater of latent load or minimum ventilation requirements.

401.3.17.3. DOAS supply and exhaust fans not required to modulate by Section 401.2.1.2 *[New section]* shall have a minimum of three speeds to facilitate system balancing.

401.3.17.4. In *hotel/motel* buildings and *nonresidential* buildings with *Group R occupancies*, *DOAS* with *mechanical cooling* providing ventilation to multiple zones and operating in conjunction with zone heating and cooling systems shall not use heating or heat recovery to warm *supply air* above 60°F when representative building loads or outdoor air temperature indicates that the majority of zones require cooling.

401.3.17.5 *[New section].* In all other nonresidential buildings, DOAS providing ventilation to multiple zones and operating in conjunction with zone heating and cooling systems shall not use mechanical heating to warm supply air above 55°F and shall not use mechanical cooling to cool supply air below 75°F. DOAS units serving zonal systems without latent cooling capability, or located where the outdoor dew point temperature is greater than or equal to 64°F at the ASHRAE 0.4% percent annual dehumidification design condition, may mechanically cool supply air below 75°F when the outdoor dewpoint temperature is above 55°F.

…

401.3.21 [New Section] Design Minimum Outdoor Air Rate The design minimum outdoor air rate supplied to each space shall not exceed the larger of the following:

1. 110% of the minimum outdoor air rate required for ventilation by Equation 401.2-B *[Equation 120.1-F]*
2. the rate required for make-up of process exhaust systems minus available transfer air, per 401.3.16 *[Section 140.4(o)]*
3. the rate required to meet special pressurization relationships required for health or safety

Exception to Section 401.3.21: *Hotel/motel* buildings and *nonresidential* buildings with *Group R occupancies*.

401.5 *[SECTION 141.0]* – Additions and alterations to existing buildings

401.5.1 [Section 141.0] Additions.

…

401.5.1.1 [Section 141.0(a)] Mandatory requirements (Additions).

…

Exception 1 to Section 401.5.1.1: Duct Sealing. When ducts are extended from an existing duct system to serve the addition, the existing duct system and the extended ducts shall meet the applicable requirements specified in Section 401.5.2.2.4 [Section 141.0(b)2D].

Exception 2 to Section 401.5.1.1: The requirements of Section 401.2.1.2.3 *[Section 120.1(d)3]* and Section 401.2.1.2.5 *[Section 120.1(d)5]* shall not apply to DOAS systems that do not include modulating pressure independent dampers or other means of independently modulating outside air at each space conditioning zone.

401.5.2 *[Section 141.0(b)]* Alterations

401.5.2.1 *[Section 141.0(b)1]* Mandatory Requirements

…

Exception 1 to Section 401.5.2.1: The requirements of Section 401.2.2.9 *[Section 120.2(i)]* shall not apply to alterations of space-conditioning systems or components.

Exception 2 to Section 401.5.2.1: The requirements of Section 401.2.1.2.3 *[Section 120.1(d)3]* and Section 401.2.1.2.7 *[Section 120.1(d)5]* shall not apply to DOAS systems that do not include modulating pressure independent dampers or other means of independently modulating outside air at each space conditioning zone.

3.6.4 Reference Appendices

There are no proposed changes to the Reference Appendices.

3.6.5 Compliance Manuals

The Statewide CASE Team will provide the CEC with recommended revisions to compliance manuals after the 45-Day Language is published.

3.6.6 ACM Reference Manual

The modulating DOAS requirement is a mandatory requirement so it cannot be traded off using the performance approach. However, it is still important that the modeling software accurately models modulating DOAS so that models are as accurate as possible. Inaccurate models lead to owners/designers selecting suboptimal systems based on bad information. Therefore, any baseline model that includes DOAS and exceeds 3,000 cfm of outside air should include modulating DOAS. Similarly, any proposed case model that includes modulating DOAS (regardless of the OSA rate) should model it accurately. Part of accurately modeling modulating DOAS is realistic loads (design densities and schedules) so that the DCV and occupied standby benefits of modulating DOAS at low loads are correctly captured.

3.6.7 Compliance Forms

As discussed in Section 3.1.4.5, the NRCC-MCH-E compliance form would be updated to reflect the proposed change. Additionally, NRCA-MCH-06-A (DCV) and NRCA-MCH-19-A (occupied standby) may need modifications. The Statewide CASE Team can support the CEC in implementing these updates if the proposed change is adopted.

4. Bibliography

ASHRAE. (2024). *Addendum u to ASHRAE 90.1-2022.* Retrieved from https://www.ashrae.org/file%20library/technical%20resources/standards%20and%20guidelines/standards%20addenda/90_1_2022_u_20241231.pdf

Bulger, N. W. (2022). *Dedicated outdoor air system: Field assessment results (Report No. ET18PGE1902).* acific Gas and Electric Company.

Bulger, N. W. (2024). *Energy efficiency potential of dedicated outdoor air systems in commercial buildings (Final Project Report ET18PGE1902-8).* Pacific Gas and Electric Company.

California Energy Commission. (2022, November 10). *Final Staff Workshop on Energy Accounting for the 2025 Building Energy Efficiency Standards.* Retrieved from California Energy Commission: https://www.energy.ca.gov/event/workshop/2022-11/final-staff-workshop-energy-accounting-2025-building-energy-efficiency

Federal Reserve Economic Data (FRED). (n.d.). *Data series relied on: Net Domestic Private Investment, Corporate Profits After Taxes*. Retrieved September 18, 2022, from https://fred.stlouisfed.org

Jeff Stein, P. W. (2024). *Research Project in Support of ASHRAE Standard 195: Method of Test for Rating Air Terminal Unit Controls.*

OEHHA. (2022). *SB 535 Disadvantaged Communities*. Retrieved 2025, from https://oehha.ca.gov/calenviroscreen/sb535

Raftery, P. A. (2018). *Quantifying Energy Losses in Hot Water Reheat Systems.* Energy and Buildings 179. Retrieved from https://escholarship.org/content/qt3qs8f8qx/qt3qs8f8qx.pdf

Ran Liu, J. W. (2012). *ASHRAE Research Project 1353-TRP, Stability and Accuracy of VAV Box Control at Low Flows.*

SBW Consulting, Inc. (2022). *Water-Energy Calculator 2.0 Project Report.* San Francisco: California Public Utility Commission.

SEM Hub. (n.d.). *SEM Calculation Guide: HVAC Scheduling.* Retrieved from https://semhub.com/assets/resources/SEM_Calculation_Guide_HVAC_Scheduling.pdf

State of California. (n.d.). *Employment Development Department, Quarterly Census of Employment and Wages (data search tool)*. Retrieved September 1, 2022, from https://www.labormarketinfo.edd.ca.gov/cgi/dataanalysis/areaselection.asp?tablename=industry

Statewide CASE Team. (2025). *2025 Final CASE Report - Nonresidential Daylighting.* Retrieved from https://title24stakeholders.com/wp-content/uploads/2023/08/2025_T24_Final-CASE-Report_Daylighting_Final.pdf

Statewide CASE Team. (2025). *First Stakeholder Meeting: Smart Dedicated Outdoor Air System (DOAS).* Retrieved from https://title24stakeholders.com/wp-content/uploads/2025/09/Smart-DOAS-2028-T24-Stakeholder-Meeting-1_Final.pdf

Statewide CASE Team. (2025). *Nonresidential HVAC, Covered Processes Utility-Sponsored Stakeholder Meeting. September 23, 2025*. Retrieved from https://title24stakeholders.com/event/nonresidential-hvac-covered-processes-utility-sponsored-stakeholder-meeting-1/

Statewide CASE Team. (2025). *Reducing Maximum Airflow During Deadband Operation for Variable Air Volume HVAC Systems.* Retrieved from https://title24stakeholders.com/wp-content/uploads/2025/09/Max-Airflow-Deadand-VAV-2028-T24-Stakeholder-Meeting-1_Final.pdf

Statewide CASE Team. (2026). *Nonresidential HVAC – Utility-Sponsored Stakeholder Meeting. April 21, 2026*. Retrieved from https://title24stakeholders.com/event/nonresidential-hvac-utility-sponsored-stakeholder-meeting-2/

Statewide CASE Team. (2026). *Second Stakeholder Meeting: Modulating Dedicated Outdoor Air Systems (DOAS).* Retrieved from https://title24stakeholders.com/wp-content/uploads/2026/04/Modulating-DOAS-2028-T24-Stakeholder-Meeting-2-April-21-2026.pdf

Statewide CASE Team. (2026). *Second Stakeholder Meeting: Reducing Max Airflow During Deadband Operation for VAV HVAC System: Stakeholder Meeting.* Retrieved from https://title24stakeholders.com/wp-content/uploads/2026/04/Reducing-Max-Airflow-During-Deadband-Operation-for-VAV-HVAC-System-Stakeholder-Meeting-4_21.pdf

Weitze, H. (2023). *Evaluation of dedicated outdoor air system and variable refrigerant flow system controls at nonresidential field sites (Final Project Report ET18PGE1902-5).* Pacific Gas and Electric Company.

Weitze, H. B. (2022). *Energy recovery dedicated outdoor air system and heat recovery VRF retrofit: Office building in Sacramento, CA (ET18PGE1902-2 case study).* Pacific Gas and Electric Company.

Weitze, H. B. (2023). *Energy recovery dedicated outdoor air system with heat recovery VRF: Office/classroom building in Santa Rosa, CA (Report No. ET18PGE1902-3).* Pacific Gas and Electric Company.

Appendix A: Assumptions for Cost-Effectiveness Analysis

PVAV Turndown

Key Assumptions for Energy Savings Analysis

- The Statewide CASE Team simulated the energy impacts in every climate zone and applied the climate-zone-zone-specific LSC hourly factors when calculating energy and energy cost impacts.
- To model the energy savings for PVAV turndown, the Statewide CASE Team used the Medium Office prototype. Medium offices, multi-floor schools, and laboratories are the buildings that typically use PVAV systems. Prototypes for schools with PVAV were not available and the search of California VAV plan sets did not include any schools with PVAV, so they were not modeled. For laboratories, their ventilation needs are such that this proposal will not save energy. Therefore, the Statewide CASE Team only modeled and claimed savings for the Medium Office.

Energy Savings Methodology per Prototypical Building

The 2028 CASE Methodology Report provides details on estimating energy savings per prototypical building and unit. The CEC directed the Statewide CASE Team to model energy impacts using specific prototypical building models that represent typical building geometries for different building types. Table 47 presents the prototype building used in the analysis.

Table 47: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name	Number of Stories	Floor Area (Square Feet)	Description
Office Medium	3	53,628	3-story office building with 5 zones and a ceiling plenum on each floor. WWR-0.33

The Proposed Design is identical to the revised Standard Design in all ways except for the revisions that represent the proposed changes to the code. Zone air terminal VAV minimums were reduce from 30 percent of full flow to the minimum outdoor air required from Table 401.2-A [Table 120.1-A]– Minimum Ventilation Rates. The difference in fan energy consumption between the two cases was calculated and added back to the measure model to represent compliance by using a bypass method, as that has the least energy savings.

Table 52 presents the parameters modified and the values used in the Standard Design and Proposed Design.

The Standard Design was modified to reflect realistic conditions. Occupancy, lighting, and plug loads are lower than those reflected in CBECC as shown in Table 48 to Table 51.

The energy impacts of the proposed code change do vary by climate zone. The Statewide CASE Team simulated the energy impacts in every climate zone and applied the climate-zone-specific LSC hourly factors when calculating energy and LSC impacts.

Table 48: New Occupancy Weekday Schedule

Hour of Day	CBECC Default Schedule	New Schedule
1	0.00	0.00
2	0.00	0.00
3	0.00	0.00
4	0.00	0.00
5	0.00	0.00
6	0.00	0.00
7	0.10	0.10
8	0.20	0.15
9	0.95	0.45
10	0.95	0.50
11	0.95	0.53
12	0.95	0.50
13	0.50	0.33
14	0.95	0.55
15	0.95	0.55
16	0.95	0.50
17	0.95	0.46
18	0.30	0.15
19	0.10	0.05
20	0.10	0.05
21	0.10	0.05
22	0.10	0.05
23	0.05	0.02
24	0.05	0.01

Table 49: New Occupancy Saturday Schedule

Hour of Day	CBECC Default Schedule	New Schedule
1	0.00	0.00
2	0.00	0.00
3	0.00	0.00
4	0.00	0.00
5	0.00	0.00
6	0.00	0.00
7	0.10	0.10
8	0.10	0.10
9	0.30	0.10
10	0.30	0.10
11	0.30	0.10
12	0.30	0.10
13	0.10	0.10
14	0.10	0.10
15	0.10	0.10
16	0.10	0.10
17	0.10	0.10
18	0.05	0.00
19	0.05	0.00
20	0.00	0.00
21	0.00	0.00
22	0.00	0.00
23	0.00	0.00
24	0.00	0.00

Table 50: New Lighting Weekday Schedule

Hour of Day	CBECC Default Schedule	New Schedule
1	0.05	0.05
2	0.05	0.05
3	0.05	0.05
4	0.05	0.05
5	0.05	0.05
6	0.10	0.05
7	0.10	0.10
8	0.30	0.15
9	0.65	0.55
10	0.65	0.55
11	0.65	0.55
12	0.65	0.58
13	0.65	0.58
14	0.65	0.58
15	0.65	0.58
16	0.65	0.55
17	0.65	0.55
18	0.35	0.18
19	0.30	0.08
20	0.30	0.08
21	0.20	0.08
22	0.20	0.07
23	0.10	0.05
24	0.05	0.05

Table 51: New Plug Load Weekday Schedule

Hour of Day	CBECC Default Schedule	New Schedule
1	0.05	0.05
2	0.05	0.05
3	0.05	0.05
4	0.05	0.05
5	0.05	0.05
6	0.10	0.05
7	0.10	0.10
8	0.30	0.15
9	0.90	0.45
10	0.90	0.50
11	0.90	0.53
12	0.90	0.50
13	0.90	0.33
14	0.90	0.55
15	0.90	0.55
16	0.90	0.50
17	0.90	0.46
18	0.50	0.18
19	0.30	0.08
20	0.30	0.08
21	0.20	0.08
22	0.20	0.07
23	0.10	0.05
24	0.05	0.05

Table 52: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change

Prototype ID	Climate Zone	Objects Modified	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
OfficeMedium	All	AirTerminal:SingleDuct:ParallelPIU:Reheat	Minimum Primary Air Flow Fraction	0.3	Design Outdoor Air
OfficeMedium	All	AirTerminal:SingleDuct:VAV:Reheat	Constant Minimum Air Flow Fraction	0.3	Design Outdoor Air
OfficeMedium (alterations only)	All	Boiler:HotWater:	FuelType	Electric	Gas, 90 E_t
OfficeMedium	All	Schedule:Day:Interval: OfficeOccupancyWD,	Weekday Occupancy Utilization	See Table 48	See Table 48
OfficeMedium	All	Schedule:Day:Interval: OfficeOccupancySat,	Saturday Occupancy Utilization	See Table 49	See Table 49
OfficeMedium	All	Schedule:Day:Interval: OfficeLightsWD,	Weekday Lighting Schedule	See Table 50	See Table 50
OfficeMedium	All	Schedule:Day:Interval, OfficeReceptacleWD,	Weekday Receptacle Schedule	See Table 51	See Table 51

The energy impacts of the proposed code change do vary by climate zone. The Statewide CASE Team simulated the energy impacts in every climate zone and applied the climate-zone-specific LSC hourly factors when calculating energy and LSC impacts.

Modulating DOAS

Key Assumptions for Energy Savings Analysis

- The Statewide CASE Team simulated the energy impacts in every climate zone and applied the climate-zone-specific LSC hourly factors when calculating energy and energy cost impacts.
- To model the energy savings for MODULATING DOAS, the Statewide CASE Team used applicable building prototypes provided by the CEC. These prototypes include assembly, medium office, large office, small school, and large school.
- The impacted space types include offices and conference rooms. However, the CBECC prototypes are simplified "box" models consisting of one core zone and four perimeter zones. To estimate per-unit energy savings for each impacted prototype, the Statewide CASE Team applied the estimated composition of different functional space types from Table 15 of the 2025 Daylighting CASE Report (Statewide CASE Team, 2025).
- The default schedules in the prototypes do not accurately reflect real-world conditions. Therefore, the Statewide CASE Team revised the occupancy, lighting, and plug load schedules provided by Taylor Engineers as shown in the previous section for PVAV turndown and adjusted the plug load from 1.5 W/ft² to 0.5 W/ft² to better represent typical building usage.

Energy Savings Methodology per Prototypical Building

The 2028 CASE Methodology Report provides details on estimating energy savings per prototypical building and unit. The CEC directed the Statewide CASE Team to model energy impacts using specific prototypical building models that represent typical building geometries for different building types. Table 53 presents the prototype buildings used in the analysis.

Table 53: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name	Number of Stories	Floor Area (Square Feet)	Description
OfficeLarge	12	498,589	12 story + 1 basement office building with 5 zones and a ceiling plenum on each floor. WWR-0.40
OfficeMedium	3	53,628	3 story office building with 5 zones and a ceiling plenum on each floor. WWR-0.33
OfficeSmall	1	5,502	1 story, 5 zone office building with pitched roof and unconditioned attic. WWR- 0.24 210,866
SchoolSmall	1	24,413	Elementary school with WWR of 0.36
SchoolLarge	2	210,866	High school with WWR of 35% and SRR 1.4%

The Proposed Design was identical to the Standard Design in all ways except for the revisions that represent the proposed changes to the code. Table 52 presents the parameters modified and the values used in the Standard Design and Proposed Design.

The energy impacts of the proposed code change do vary by climate zone. The Statewide CASE Team simulated the energy impacts in every climate zone and applied the climate-one-specific LSC hourly factors when calculating energy and LSC impacts.

Table 54: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change

Prototype ID	Climate Zone	Objects Modified	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
OfficeLarge	All	DesignSpecification:OutdoorAir	Outdoor Air Flow per Zone Floor Area	0.15 cfm/ft2	0 cfm/ft2
OfficeMedium	All	DesignSpecification:OutdoorAir	Outdoor Air Flow per Zone Floor Area	0.15 cfm/ft2	0 cfm/ft2
OfficeSmall	All	DesignSpecification:OutdoorAir	Outdoor Air Flow per Zone Floor Area	0.15 cfm/ft2	0 cfm/ft2
SchoolSmall	All	DesignSpecification:OutdoorAir	Outdoor Air Flow per Zone Floor Area	0.15 cfm/ft2	0 cfm/ft2
SchoolLarge	All	Controller:OutdoorAir	Economizer Control Type	NoEconomizer	FixedDryBulb
OfficeLarge	All	Controller:OutdoorAir	Economizer Control Type	NoEconomizer	FixedDryBulb
OfficeMedium	All	Controller:OutdoorAir	Economizer Control Type	NoEconomizer	FixedDryBulb
OfficeSmall	All	Controller:OutdoorAir	Economizer Control Type	NoEconomizer	FixedDryBulb
SchoolSmall	All	Controller:OutdoorAir	Economizer Control Type	NoEconomizer	FixedDryBulb
SchoolLarge	All	Controller:OutdoorAir	Economizer Maximum Limit Dry-Bulb Temperature {C}	NA	23.9 °C
OfficeLarge	All	Controller:OutdoorAir	Economizer Maximum Limit Dry-Bulb Temperature {C}	NA	23.9°C
OfficeMedium	All	Controller:OutdoorAir	Economizer Maximum Limit Dry-Bulb Temperature {C}	NA	23.9°C
OfficeSmall	All	Controller:OutdoorAir	Economizer Maximum Limit Dry-Bulb Temperature {C}	NA	23.9°C
SchoolSmall	All	Controller:OutdoorAir	Economizer Maximum Limit Dry-Bulb Temperature {C}	NA	23.9°C
SchoolLarge	All	DesignSpecification:OutdoorAir	Outdoor Air Flow per Zone Floor Area	0.75 cfm/ft2	0 m/ft2

Prototype ID	Climate Zone	Objects Modified	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
OfficeLarge	All	DesignSpecification:OutdoorAir	Outdoor Air Flow per Zone Floor Area	0.75 cfm/ft2	0 m/ft
OfficeMedium	All	DesignSpecification:OutdoorAir	Outdoor Air Flow per Zone Floor Area	0.75 cfm/ft2	0 m/ft
OfficeSmall	All	DesignSpecification:OutdoorAir	Outdoor Air Flow per Zone Floor Area	0.75 cfm/ft2	0 m/ft
SchoolSmall	All	DesignSpecification:OutdoorAir	Outdoor Air Flow per Zone Floor Area	0.75 cfm/ft2	0 m/ft
SchoolLarge	All	Schedule:Week:Daily	Monday/Tuesday/Wednesday/Thursday/Friday Schedule:Day Name	NewOfficeOccupancyWD	NewOfficeOccupancyWD
OfficeLarge	All	Schedule:Week:Daily	Monday/Tuesday/Wednesday/Thursday/Friday Schedule:Day Name	NewOfficeOccupancyWD	NewOfficeOccupancyWD
OfficeMedium	All	Schedule:Week:Daily	Monday/Tuesday/Wednesday/Thursday/Friday Schedule:Day Name	NewOfficeOccupancyWD	NewOfficeOccupancyWD
OfficeSmall	All	Schedule:Week:Daily	Monday/Tuesday/Wednesday/Thursday/Friday Schedule:Day Name	NewOfficeOccupancyWD	NewOfficeOccupancyWD
SchoolSmall	All	Schedule:Week:Daily	Monday/Tuesday/Wednesday/Thursday/Friday Schedule:Day Name	NewOfficeOccupancyWD	NewOfficeOccupancyWD
SchoolLarge	All	Schedule:Week:Daily	Saturday Schedule:Day Name	NewOfficeOccupancySat	NewOfficeOccupancySat
OfficeLarge	All	Schedule:Week:Daily	Saturday Schedule:Day Name	NewOfficeOccupancySat	NewOfficeOccupancySat
OfficeMedium	All	Schedule:Week:Daily	Saturday Schedule:Day Name	NewOfficeOccupancySat	NewOfficeOccupancySat
OfficeSmall	All	Schedule:Week:Daily	Saturday Schedule:Day Name	NewOfficeOccupancySat	NewOfficeOccupancySat
SchoolSmall	All	Schedule:Week:Daily	Monday/Tuesday/Wednesday/Thursday/Friday Schedule:Day Name	NewOfficeLightsWD	NewOfficeLightsWD

Prototype ID	Climate Zone	Objects Modified	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
SchoolLarge	All	Schedule:Week:Daily	Monday/Tuesday/Wednesday/Thursday /Friday Schedule:Day Name	NewOfficeLights WD	NewOfficeLightsWD
OfficeLarge	All	Schedule:Week:Daily	Monday/Tuesday/Wednesday/Thursday /Friday Schedule:Day Name	NewOfficeLights WD	NewOfficeLightsWD
OfficeMedium	All	Schedule:Week:Daily	Monday/Tuesday/Wednesday/Thursday /Friday Schedule:Day Name	NewOfficeOccupa ncyWD	NewOfficeLightsWD
OfficeSmall	All	Schedule:Week:Daily	Monday/Tuesday/Wednesday/Thursday /Friday Schedule:Day Name	NewOfficeOccupa ncyWD	NewOfficeLightsWD
SchoolSmall	All	Schedule:Week:Daily	Monday/Tuesday/Wednesday/Thursday /Friday Schedule:Day Name	NewOfficeOccupa ncyWD	NewOfficeReceptacleWD
SchoolLarge	All	Schedule:Week:Daily	Monday/Tuesday/Wednesday/Thursday /Friday Schedule:Day Name	NewOfficeOccupa ncyWD	NewOfficeReceptacleWD
OfficeLarge	All	Schedule:Week:Daily	Monday/Tuesday/Wednesday/Thursday /Friday Schedule:Day Name	NewOfficeOccupa ncyWD	NewOfficeReceptacleWD
OfficeMedium	All	Schedule:Week:Daily	Monday/Tuesday/Wednesday/Thursday /Friday Schedule:Day Name	NewOfficeOccupa ncySat	NewOfficeReceptacleWD
OfficeSmall	All	Schedule:Week:Daily	Monday/Tuesday/Wednesday/Thursday /Friday Schedule:Day Name	NewOfficeOccupa ncySat	NewOfficeReceptacleWD
SchoolSmall	All	Schedule:Week:Daily	Monday/Tuesday/Wednesday/Thursday /Friday Schedule:Day Name	NewOfficeOccupa ncySat	NewOfficeReceptacleWD
SchoolLarge	All	Schedule:Week:Daily	Monday/Tuesday/Wednesday/Thursday /Friday Schedule:Day Name	NewOfficeOccupa ncySat	NewOfficeReceptacleWD

Appendix B: Purpose and Necessity of Proposed Code Changes

Introduction

The sections below provide the purpose and necessity of proposed changes to Title 24, Part 1; Title 24, Part 6; and the reference appendices. This section intends to provide the CEC with the information needed for the Initial Statement of Reasons.

See Sections 2.6 and 3.6 of this report for marked-up code language.

PVAV Turndown

Purpose and Necessity of Changes to Title 24, Part 1

There are no proposed changes to Title 24, Part 1.

Purpose and Necessity of Changes to Title 24, Part 6

Section: 401.3.14 [140.4(m)]

Purpose: The purpose of this change is to strengthen the current multizone packaged VAV fan turndown capabilities from the current required minimum of 50 percent of design airflow down to the greater of 15 percent of design airflow or the sum of the required zone outdoor airflows or provides a supply air bypass method to be able to comply with DCV and occupied standby mandatory requirements and the prescriptive requirement to set deadband minimum airflows to the design outdoor airflow for the zone.

Necessity: This change is necessary to improve the energy efficiency performance of multizone packaged VAV system designs in nonresidential buildings. Currently, there is no requirement that compressors remain active down to low part load airflow rates. There are a variety of measures throughout Title 24, Part 6 that require airflow turndown capabilities in response to occupancy or part load conditions, and the cumulative impact of these requirements is that PVAV systems frequently are put into low part load airflow conditions. This measure would ensure that PVAV equipment can efficiently deliver space conditioning in low airflow conditions.

Section: 401.5.2.2 [141.0(b)2]

Purpose: The purpose of this change is to clarify additional situations and allowances for this measure in alteration scenarios.

Necessity: This change is necessary to deal with more challenging retrofit situations, where space or other factors may prevent full compliance with the version of this measure as it appears in the new construction code.

Purpose and Necessity of Changes to the Reference Appendices

Section: NA7.5.6

Purpose: The purpose of this change is to ensure that PVAV systems complies with the new requirements regarding providing a bypass method or having fan airflow turndown and elimination of compressor lockout at low airflow settings.

Necessity: This change is necessary to verify that the equipment can meet the required airflow turndown and compressor lockout limitation requirements in the field.

Modulating DOAS

Purpose and Necessity of Changes to Title 24, Part 1

There are no proposed changes to Title 24, Part 1.

Purpose and Necessity of Changes to Title 24, Part 6

Section: 401.2.1.1.3 [120.1(c)3]

Purpose: The proposed regulations would make editorial changes to Table 401.2-A to align with recently finalized ASHRAE 62.1 addenda. These include Addenda b and w to ASHRAE 62.1-2022.

Necessity: This change is necessary to improve the clarity and enforceability of the energy code.

Section: 401.2.1.2 [120.1(d)]

Purpose: The purpose of this change is to improve the clarity and specificity of occupied standby controls requirements for both DOAS and mixed-air system types. Additionally, this change would explicitly include the requirement that certain DOAS systems be capable of achieving airflow modulation to zones based on dynamic primary air requirements, accounting for real time changes to occupancy rates.

Necessity: The change or exception is necessary to cost-effectively improve the energy efficiency performance of DOAS systems in settings where there is a wide range of occupancy patterns. Current Title 24, Part 6 language is not explicit in stating that DOAS systems are required to modulate airflow and this measure addresses this gap. Furthermore, the ventilation occupied standby requirements are difficult to understand and these changes improve clarity and enforceability.

Section: 401.2.2.5 *[120.2(e)]*

Purpose: The proposed regulation would add some clarifying language indicating that shut-off controls apply to both space conditioning and ventilation systems.

Necessity: This change is necessary to ensure that DOAS systems are included in the requirements, which is currently silent regarding the status of DOAS.

Section 401.2.2.6 *[120.2(f)]*

Purpose: The proposed regulation would add some clarifying language indicating that outdoor air supply and exhaust equipment dampers shall automatically close upon fan shutdown or during periods of non-occupancy.

Necessity: This change is necessary to ensure DOAS systems can effectively modulate to ensure efficient operation.

Section 401.2.2.7 [120.2(g)]

Purpose: The proposed regulation would change “space conditioning” to “HVAC” to ensure that DOAS systems are considered in scope for this section.

Necessity: This change is necessary to ensure that DOAS systems are included in the requirements, which is currently silent regarding the status of DOAS.

Section: 401.3.5.2 *[140.4(c)2]*

Purpose: The proposed regulation would change this section to explicitly include modulating DOAS systems in the scope of the requirement for a duct static pressure sensor.

Necessity: This change is necessary to ensure that modulating DOAS systems can receive signals to determine whether it is appropriate to turn down fan speed, when possible, which would save energy.

Section: 401.3.6 [140.4(d)]

Purpose: The proposed change to this subsection would ensure that the designer complies with the newly proposed subsection 401.3.21, which would ensure that design minimum airflow rates are not excessive.

Necessity: This change is necessary to prevent over ventilating spaces when it is not necessary and save energy.

Section: 401.3.17 [140.4(p)]

Purpose: The purpose of this change is to allow for greater flexibility in options to provide outside air to the zone. Additionally, this change would revise the prescriptive DOAS supply air temperature setpoint requirements to further discourage simultaneous cooling and heating of the same airstream.

Necessity: This change is necessary to ensure that designers of DOAS equipment are allowed to prescriptively specify efficient airflow delivery strategies. Additionally, this change is necessary to ensure that DOAS equipment does not excessively re-heat or re-cool ventilation air.

Section: 401.5.1.1 [141.0(a)]

Purpose: An exception is proposed for this section to exempt DOAS systems that do not already have modulating dampers from having to comply with the modulating DOAS requirements while undergoing additions.

Necessity: This change is necessary to ensure that existing buildings without the proper hardware are not triggered by the modulating DOAS requirements being added to the new construction section of the code.

Section: 401.5.2.1 [141.0(b)1]

Purpose: An exception is proposed for this section to exempt DOAS systems that do not already have modulating dampers from having to comply with the modulating DOAS requirements while undergoing alterations.

Necessity: This change is necessary to ensure that existing buildings without the proper hardware are not triggered by the modulating DOAS requirements being added to the new construction section of the code.

Purpose and Necessity of Changes to the Reference Appendices

There are no proposed changes to reference appendices.

Appendix C: Assumptions for Statewide Savings Estimates

PVAV Turndown

The Statewide CASE Team estimated statewide impacts for the first year by multiplying per-unit savings estimates by statewide construction forecasts provided by the CEC. The 2028 CASE Methodology Report includes additional information about the methodology and assumptions used to calculate statewide energy impacts.

The statewide savings and cost estimates consider the current market share rate. The Statewide CASE Team estimated that the current market share for the proposed code change is 50 percent in the new-construction market. This is lower than the historical market share rate of 80 percent because updates to 2025 Title 24 encourage the use of systems other than packaged multi-zone VAV.

Table 55 presents the projected nonresidential new construction that the proposed code change would impact in 2026. The Statewide CASE Team developed these estimates using the methods described in this section.

The Statewide CASE Team estimated the percentage of newly constructed floor space that the proposed code change would impact. Table 56 shows the assumed percentage of affected floor space by building type. If a proposed code change does not apply to a specific building type, the Statewide CASE Team assumes that zero percent of the floor space would be impacted. If the assumed percentage is non-zero, but less than 100 percent, the proposal is expected to affect some—but not all—buildings.

Table 57 represents the assumed percentage of affected floorspace by climate zone.

Table 55: Estimated New Nonresidential Construction Impacted by Proposed Code Change in 2029, by Climate Zone – Medium Office

Climate Zone	New Construction Impacted (Million Square Feet)	Existing Building Stock (Alterations) Impacted (Million Square Feet)	Total Floor Space Impacted (Million Square Feet)
1	0.07	2.7	2.77
2	0.24	24.79	25.03
3	0.69	63.03	63.72
4	0.37	33.82	34.19
5	0.19	10.66	10.85
6	0.6	38.25	38.85
7	0.4	35.1	35.5
8	0.82	47.29	48.11
9	1.59	69.07	70.66
10	0.59	53.35	53.94
11	0.13	13.55	13.68
12	1.4	81.36	82.76
13	0.29	20.14	20.43
14	0.17	10.66	10.83
15	0.13	8.2	8.33
16	0.05	3.25	3.3
Total	**7.73**	**515.23**	**522.96**

Table 56: Percentage of Nonresidential Floorspace Impacted by Proposed Code Change in 2026, by Building Type

Building Type	New Construction Impacted (Percent Square Footage)	Existing Building Stock (Alterations) Impacted (Percent Square Footage)
Medium Office	50%	80%

Table 57: Percentage of Nonresidential Floorspace Impacted by Proposed Measure, by Climate Zone

Climate Zone	New Construction Impacted (Percent Square Footage)	Existing Building Stock (Alterations) Impacted (Percent Square Footage)
1	50%	80%
2	50%	80%
3	50%	80%
4	50%	80%
5	50%	80%
6	50%	80%
7	50%	80%
8	50%	80%
9	50%	80%
10	50%	80%
11	50%	80%
12	50%	80%
13	50%	80%
14	50%	80%
15	50%	80%
16	50%	80%

Modulating DOAS

The Statewide CASE Team estimated statewide impacts for the first year by multiplying per-unit savings estimates by statewide construction forecasts provided by the CEC. The 2028 CASE Methodology Report includes additional information about the methodology and assumptions used to calculate statewide energy impacts.

The statewide savings and cost estimates consider the current market share rate. The Statewide CASE Team estimated that the current market share rate for the proposed code change is 9.36 percent for the new construction market. The current market share rate is estimated based on the 2018 Commercial Buildings Energy Consumption Survey (CBECS). Table 58 presents the projected nonresidential new construction that the proposed code change would impact in 2026. The Statewide CASE Team developed these estimates using the methods described in this section.

The Statewide CASE Team estimated the percentage of newly constructed floor space that the proposed code change would impact. Table 60 shows the assumed percentage of affected floorspace by building type. If a proposed code change does not apply to a specific building type, the Statewide CASE Team assumes that zero percent of the floor space would be impacted. If the assumed percentage is non-zero, but less than 100 percent, the proposal is expected to affect some—but not all—buildings. represents the assumed percentage of affected floorspace by climate zone.

The 2018 Commercial Buildings Energy Consumption Survey (CBECS) includes 5,918 buildings with a total floor space of 96,423 million square feet. Among these buildings, there are 249 buildings with total floor space of 9,027 million square feet served by DOAS. Therefore, CBECS indicates that 9.36 percent of commercial floor space is served by DOAS systems in 2018.

Table 58: Estimated New Nonresidential Construction Impacted by Proposed Code Change in 2026, by Climate Zone and Building Type (Million Square Feet)

Building Type	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16	All
Large Office	0.00	0.00	2.03	0.99	0.00	0.89	0.52	1.44	2.61	0.25	0.07	0.36	0.00	0.13	0.01	0.03	9.32
Medium Office	0.09	0.33	0.96	0.52	0.26	0.84	0.56	1.15	2.23	0.82	0.19	1.96	0.41	0.24	0.18	0.07	10.83
Small Office	0.01	0.30	0.13	0.01	0.04	0.10	0.16	0.11	0.25	0.29	0.06	0.38	0.27	0.03	0.07	0.02	2.25
Large Retail	0.00	0.00	0.77	0.38	0.10	0.49	0.26	0.58	1.16	0.44	0.21	0.91	0.25	0.10	0.13	0.04	5.83
Medium Retail	0.06	0.24	0.56	0.31	0.06	0.42	0.20	0.60	1.00	0.58	0.10	0.44	0.27	0.13	0.09	0.06	5.10
Strip Mall	0.00	0.11	0.35	0.16	0.01	0.39	0.34	0.69	0.75	0.94	0.05	0.41	0.23	0.22	0.07	0.04	4.77
Mixed-Use Retail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Large School	0.00	0.08	0.54	0.27	0.02	0.37	0.38	0.56	0.88	0.53	0.22	0.71	0.38	0.10	0.05	0.04	5.13
Small School	0.05	0.19	0.32	0.16	0.10	0.22	0.21	0.25	0.46	0.24	0.07	0.54	0.21	0.07	0.03	0.03	3.15
Non-refrigerated Warehouse	0.04	0.26	1.51	0.78	0.12	0.95	0.50	1.36	2.11	0.95	0.44	1.99	0.57	0.25	0.26	0.10	12.21
Hotel	0.03	0.15	0.72	0.37	0.08	0.39	0.34	0.55	0.83	0.40	0.11	0.56	0.18	0.10	0.09	0.03	4.91
Assembly	0.01	0.28	1.11	0.39	0.04	0.55	0.56	1.00	1.28	0.80	0.12	0.99	0.21	0.17	0.08	0.06	7.64
Hospital	0.02	0.12	0.57	0.29	0.05	0.22	0.37	0.30	0.53	0.55	0.10	0.56	0.18	0.10	0.08	0.03	4.08
Laboratory	0.01	0.13	0.90	0.50	0.05	0.29	0.19	0.32	0.59	0.24	0.09	0.30	0.08	0.06	0.03	0.02	3.81
Restaurant	0.01	0.06	0.23	0.12	0.02	0.24	0.14	0.35	0.57	0.29	0.05	0.22	0.10	0.07	0.03	0.02	2.52
Enclosed Parking Garage	0.00	0.01	1.28	0.87	0.00	1.81	0.49	1.59	1.07	0.04	0.00	0.03	0.00	0.01	0.00	0.01	7.21
Open Parking Garage	0.00	0.08	1.73	1.18	0.04	2.55	0.84	2.24	1.51	0.46	0.01	0.37	0.03	0.14	0.03	0.07	11.28
Grocery	0.00	0.03	0.07	0.04	0.01	0.03	0.01	0.04	0.06	0.03	0.01	0.03	0.02	0.01	0.01	0.00	0.41
Refrigerated Warehouse	0.00	0.00	0.04	0.04	0.01	0.02	0.00	0.00	0.01	0.03	0.00	0.05	0.08	0.01	0.01	0.00	0.29
Controlled-Environment Horticulture	0.06	0.05	0.22	0.03	0.14	0.18	0.00	0.02	0.02	0.19	0.21	0.21	0.06	0.01	0.03	0.00	1.46
Vehicle Service	0.00	0.05	0.38	0.25	0.02	0.39	0.24	0.56	1.27	0.40	0.02	0.27	0.17	0.14	0.04	0.03	4.23
Manufacturing	0.00	0.01	0.15	0.05	0.01	0.01	0.04	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34
Unassigned	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30
Total	0.4	2.5	14.6	8.0	1.2	11.4	6.3	13.8	19.2	8.5	2.1	11.3	3.7	2.1	1.3	0.7	107.1

Table 59: Estimated Existing Nonresidential Floorspace Impacted by Proposed Code Change in 2026 (Alterations), by Climate Zone and Building Type (Million Square Feet)

Building Type	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16	All
Large Office	0.10	2.48	111.84	57.88	1.47	79.63	58.17	130.08	242.48	46.78	2.09	62.89	7.41	16.22	3.55	3.73	826.79
Medium Office	2.70	24.79	63.03	33.82	10.66	38.25	35.10	47.29	69.07	53.35	13.55	81.36	20.14	10.66	8.20	3.25	515.23
Small Office	3.34	10.20	17.75	9.06	6.00	10.58	6.81	10.62	16.70	19.54	8.48	35.15	17.18	3.99	4.94	2.14	182.51
Large Retail	0.80	6.93	46.94	21.52	3.36	25.57	20.27	34.77	53.22	42.65	9.12	46.53	18.01	8.73	7.52	2.57	348.51
Medium Retail	0.94	10.49	35.62	20.59	4.35	35.42	27.73	53.38	86.56	53.51	8.30	48.40	19.32	12.42	7.02	4.14	428.17
Strip Mall	2.67	7.87	29.94	14.74	4.08	32.18	22.63	44.61	66.96	53.54	9.80	38.70	19.34	12.22	6.96	3.67	369.90
Mixed-use Retail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Large School	0.61	6.42	27.86	11.16	1.66	22.70	18.03	34.33	58.86	44.81	8.10	42.70	21.13	9.65	6.10	2.87	316.98
Small School	1.78	8.90	20.46	7.98	4.85	20.55	11.97	27.55	43.45	26.42	10.80	33.66	18.75	6.98	3.40	2.92	250.43
Non-refrigerated Warehouse	2.66	16.18	86.64	42.74	7.84	71.98	41.18	102.72	165.84	146.16	26.98	118.64	40.86	31.10	23.24	9.30	934.08
Hotel	1.42	8.42	38.48	19.78	4.01	24.39	26.13	33.58	52.81	29.67	5.77	32.42	10.46	6.40	4.70	1.95	300.40
Assembly	3.46	14.54	73.07	36.05	5.28	45.80	32.72	71.31	96.16	73.40	13.08	55.78	24.10	15.16	9.46	5.15	574.53
Hospital	1.49	8.87	38.66	19.74	4.04	22.60	21.72	32.62	55.90	31.68	8.89	42.54	17.99	7.04	4.03	2.59	320.41
Laboratory	0.14	3.21	29.54	22.45	1.22	9.77	13.75	12.49	15.45	8.65	0.54	9.71	3.52	1.38	0.31	0.46	132.59
Restaurant	0.49	2.89	11.78	6.00	1.24	13.17	8.58	19.02	32.00	25.93	2.81	13.56	6.19	5.49	2.76	1.52	153.42
Enclosed Parking Garage	0.01	0.43	32.57	24.75	0.24	23.32	16.54	46.73	58.02	2.14	0.28	2.47	0.39	0.68	0.13	0.35	209.06
Open Parking Garage	0.18	5.62	44.02	33.46	3.09	32.91	28.14	65.95	81.92	27.66	3.57	31.97	5.05	8.84	1.72	4.49	378.59
Grocery	0.08	1.36	4.70	2.85	0.60	2.73	1.67	3.21	5.56	3.21	0.52	2.99	1.16	0.75	0.43	0.31	32.12
Refrigerated Warehouse	0.00	0.36	0.73	0.17	0.31	0.37	0.02	0.34	0.63	0.52	0.21	1.72	3.13	0.15	0.16	0.12	8.92
Controlled-Environment Horticulture	0.56	0.37	2.10	0.86	5.06	6.61	0.86	0.59	1.28	2.89	2.01	3.63	4.29	0.37	0.52	0.19	32.17

Building Type	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16	All
Vehicle Service	0.73	4.95	26.92	12.78	2.38	26.98	18.46	39.62	65.42	45.23	5.04	30.66	14.59	12.07	4.94	2.83	313.61
Manufacturing	3.28	13.51	49.54	63.64	4.47	58.66	26.62	98.16	134.48	39.66	10.29	45.61	20.78	13.58	4.12	7.42	593.83
Unassigned	0.29	5.26	7.22	5.05	0.18	2.06	0.62	3.02	6.29	2.04	2.69	11.48	2.35	0.62	0.32	0.82	50.31
Total	**27.7**	**164.1**	**799.4**	**467.1**	**76.4**	**606.2**	**437.7**	**912.0**	**1409.1**	**779.5**	**152.9**	**792.6**	**296.1**	**184.5**	**104.5**	**62.8**	**7,272.55**

Table 60: Percentage of Nonresidential Floorspace Impacted by Proposed Code Change in 2029, by Building Type

Building Type	New Construction Impacted (Percent Square Footage)	Existing Building Stock (Alterations) Impacted (Percent Square Footage)
Large Office	9.36%	9.36%
Medium Office	9.36%	9.36%
Small Office	9.36%	9.36%
Large Retail	0%	0%
Medium Retail	0%	0%
Strip Mall	0%	0%
Mixed-Use Retail	0%	0%
Large School	9.36%	9.36%
Small School	9.36%	9.36%
Non-refrigerated Warehouse	0%	0%
Hotel	0%	0%
Assembly	0%	0%
Hospital	0%	0%
Laboratory	0%	0%
Restaurant	0%	0%
Enclosed Parking Garage	0%	0%
Open Parking Garage	0%	0%
Grocery	0%	0%
Refrigerated Warehouse	0%	0%
Controlled-Environment Horticulture	0%	0%
Vehicle Service	0%	0%
Manufacturing	0%	0%
Unassigned	0%	0%

Table 61: Percentage of Nonresidential Floorspace Impacted by Proposed Measure, by Climate Zone

Climate Zone	New Construction Impacted (Percent Square Footage)	Existing Building Stock (Alterations) Impacted (Percent Square Footage)
1	100%	0%
2	100%	0%
3	100%	0%
4	100%	0%
5	100%	0%
6	100%	0%
7	100%	0%
8	100%	0%
9	100%	0%
10	100%	0%
11	100%	0%
12	100%	0%
13	100%	0%
14	100%	0%
15	100%	0%
16	100%	0%

Appendix D: Environmental Analysis

PVAV Turndown

Potential Significant Environmental Effect of Proposal

The Statewide CASE Team has considered the environmental benefits and adverse impacts of its proposal, including—but not limited to—an evaluation of factors contained in the California Code of Regulations, Title 14, section 15064, and has determined that the proposal would not result in a significant effect on the environment.

Direct Environmental Impacts

Direct Environmental Benefits

This measure is expected to result in energy savings (and corresponding GHG emission reductions) due to improved packaged VAV system efficiency. The estimated impact of these benefits has been quantified in this report.

Direct Adverse Environmental Impacts

This measure is expected to not result in any direct adverse environmental impacts.

Indirect Environmental Impacts

Indirect Environmental Benefits

This measure represents a straightforward building energy efficiency enhancement in buildings with multizone packaged VAV systems and as such, is not expected to result in any indirect environmental benefits.

Indirect Adverse Environmental Impacts

This measure represents a straightforward building energy efficiency enhancement in buildings with multizone packaged VAV systems and as such, is not expected to result in any indirect adverse environmental impacts.

Mitigation Measures

The Statewide CASE Team has considered opportunities to minimize the environmental impact of the proposal, including an evaluation of “specific economic, environmental, legal, social, and technological factors” (Cal. Code Regs., tit. 14, § 15021). The Statewide CASE Team did not determine whether this measure would result in significant direct or indirect adverse environmental impacts and therefore, did not develop any mitigation measures.

Reasonable Alternatives to Proposal

The Statewide CASE Team has considered alternatives to the proposal and determined that no alternative would achieve its purpose with less environmental effect.

Water Use and Water Quality Impacts Methodology

There are no impacts on water quality or water use.

Modulating DOAS

Potential Significant Environmental Effect of Proposal

The Statewide CASE Team has considered the environmental benefits and adverse impacts of its proposal, including—but not limited to—an evaluation of factors contained in the California Code of Regulations, Title 14, section 15064, and has determined that the proposal would not result in a significant effect on the environment.

Direct Environmental Impacts

Direct Environmental Benefits

This measure is expected to result in energy savings (and corresponding GHG emission reductions) due to improved airflow turndown capabilities in DOAS systems. The estimated impact of these benefits has been quantified in this report.

Direct Adverse Environmental Impacts

This measure is expected to not result in any direct adverse environmental impacts.

Indirect Environmental Impacts

Indirect Environmental Benefits

This measure represents a straightforward building energy efficiency enhancement for buildings with DOAS systems and as such, is not expected to result in any indirect environmental benefits.

Indirect Adverse Environmental Impacts

This measure represents a straightforward building energy efficiency enhancement for buildings with DOAS systems and as such, is not expected to result in any indirect adverse environmental impacts.

Mitigation Measures

The Statewide CASE Team has considered opportunities to minimize the environmental impact of the proposal, including an evaluation of “specific economic, environmental, legal, social, and technological factors” (Cal. Code Regs., tit. 14, § 15021). The Statewide CASE Team did not determine whether this measure would result in significant direct or indirect adverse environmental impacts and therefore did not develop any mitigation measures.

Reasonable Alternatives to Proposal

The Statewide CASE Team has considered alternatives to the proposal and determined that no alternative would achieve its purpose with less environmental effect.

Water Use and Water Quality Impacts Methodology

There are no impacts on water quality or water use.

Appendix E: Summary of Stakeholder Engagement

Introduction to Stakeholder Engagement

Collaborating with stakeholders who may be affected by proposed code changes is a core component of the Statewide CASE Team's process. The Statewide CASE Team engages interested parties to identify and address issues related to the proposals, with the goal of submitting recommendations to the CEC. Public stakeholders provide valuable feedback on draft analyses and help identify and address adoption challenges, including cost effectiveness, market and technical barriers, compliance and enforcement, and potential impacts on human health or the environment. Some stakeholders also provide data that the Statewide CASE Team uses to support analyses.

This appendix summarizes the stakeholder engagement conducted by the Statewide CASE Team during the development and refinement of the report's recommendations.

PVAV Turndown

Utility-Sponsored Stakeholder Meetings

Utility-sponsored stakeholder meetings provide an opportunity to learn about the Statewide CASE Team's role in the advocacy effort and to hear about specific code change proposals that the Statewide CASE Team is pursuing for the 2025 code cycle. The goal of these meetings is to solicit input on proposals from stakeholders early enough to ensure the proposals and the supporting analyses are vetted and have as few outstanding issues as possible. To promote transparency in the development of code change proposals, the Statewide CASE Team uses stakeholder meetings to solicit feedback on:

- Proposed code changes
- Draft code language
- Draft assumptions and analysis results
- Data to support assumptions
- Compliance and enforcement
- Technical and market feasibility

The Statewide CASE Team hosted two stakeholder meetings for PVAV Turndown via webinar, as described in Table 62. Please see below for dates and links to event pages on Title24Stakeholders.com. Materials from each meeting, such as slide presentations, proposal summaries with code language, and meeting notes, are included in the bibliography section of this report (Statewide CASE Team, 2025) (Statewide CASE Team, 2026).

Table 62: Utility-Sponsored Stakeholder Meeting

Meeting Name and Link to Materials	Meeting Date	Summary of Items Discussed
First Round of HVAC Air Distribution Utility-Sponsored Stakeholder Meeting	Tuesday September 23, 2025	• Introduced the fundamentals of the measure • Fielded questions from stakeholders on the measure
Second Round of HVAC Air Distribution Utility-Sponsored Stakeholder Meeting	Tuesday April 21, 2026	• Provided updates to the measure, including cost-effectiveness analysis and proposed code language • Solicited feedback and fielded questions from stakeholders

Utility-sponsored stakeholder meetings were open to the public. For each stakeholder meeting, two promotional emails were distributed from info@title24stakeholders.com. One email was sent to the full Title 24 Stakeholders listserv, which includes over 3,000 individuals. A second email targeted specific recipients based on their subscription preferences.

The Title 24 Stakeholders listserv is an opt-in service comprising participants from diverse industries and trades, such as manufacturers, advocacy groups, local government, and building and energy professionals. Each meeting was announced on the Title 24 Stakeholders LinkedIn page and cross-promoted on the CEC LinkedIn page approximately two weeks in advance to engage individuals, organizations, and broader channels outside the listserv. The Statewide CASE Team conducted extensive personal outreach to stakeholders identified in initial work plans who had not yet opted in to the listserv. Exported webinar meeting data captured attendance numbers, individual comments, and results from live attendee polls to help evaluate stakeholder participation and support.

The first round of utility-sponsored stakeholder meetings began in September 2025 and served as an early forum to promote transparency and gather stakeholder feedback on measures under consideration by the Statewide CASE Team.

The objectives of the first round of stakeholder meetings were to solicit input on the scope of the 2025 code cycle proposals; request data and feedback on the specific approaches, assumptions, and methodologies for the energy impacts and cost-effectiveness analyses; and understand potential technical and market barriers. The Statewide CASE Team also presented the initial draft code language for stakeholders to review. At this stage, the PVAV measure was largely identical to the ASHRAE 90.1-2022 Addendum u scope, the bypass duct option had yet to be added to the proposal. Manufacturer stakeholders noted the challenges with equipment redesigns that may be required to comply with the measure.

The second round of utility-sponsored stakeholder meeting occurred in April 2026 and provided updated details on proposed code changes.

During the second utility-sponsored stakeholder meeting, stakeholders raised questions and provided feedback on several items. One stakeholder expressed concerns about this measure being proposed for alterations. Their concern was that there may be technical issues—such as an existing roof not having enough capacity to hold the new systems—could lead to projects skipping the permitting process. They suggested loosening requirements to address these concerns. The Statewide CASE

Team noted that compliant equipment would have minimal, if any, differences in weight or curb dimensions, so these physical limitations should not pose an issue but also wanted to discuss this issue further.

Another issue discussed was concerns over turndown of 15 percent of design airflow and A2L mitigation. The stakeholder expressed concern that meeting the required turndown would, in some cases, reduce airflow below the minimum permitted UL 60335-2-40 for equipment that uses lower flammability refrigerants, such as R-32 and R-454B, known as Q_{min}.[23] The Statewide CASE Team contacted an expert on the standard and confirmed that if the unit is equipped with a refrigerant detection system (RDS), it is permitted to operate at airflows lower than Q_{min}. The team later met with the stakeholder, who is also knowledgeable about UL 60335-2-40, and the Statewide CASE Team agreed that the standard does allow operation below Q_{min} where there is an RDS, and that larger units like those used for multi-zone VAV systems will always have an RDS. Therefore, no changes to the measure are proposed due to this concern.

In both instances, the Statewide CASE Team conducted follow-up calls with stakeholders and was able to align on the issues each had raised.

Statewide CASE Team Communications

The Statewide CASE Team held personal communications over email and phone with numerous stakeholders when developing this report, listed in Table 63. Manufacturer engagement is critical to understand the challenges of complying with the PVAV airflow turndown measure.

[23] UL 60335-2-40 Household and Similar Electrical Appliances - Safety - Part 2-40: Particular Requirements for Electrical Heat Pumps, Air-Conditioners and Dehumidifiers is the safety standard that applies to all air conditioners and heat pumps used for comfort cooling, regardless of size.

Table 63: PVAV Engaged Stakeholders

Organization/Individual Name	Market Role	Mentioned in CASE Report Sections
Daikin Applied/Skip Ernst	Manufacturer	No
AAON/Kevin Teakell and Clint Reese	Manufacturer	No
Carrier/Richard Lord	Manufacturer	No
Silicon Valley Mechanical/Liz Becker	Contractor	No
Aozora Consulting/Rusty Tharp	Consultant	Yes – Section 1.3

Modulating DOAS

Utility-Sponsored Stakeholder Meetings

Utility-sponsored stakeholder meetings provide an opportunity to learn about the Statewide CASE Team's role in the advocacy effort and to hear about specific code change proposals that the Statewide CASE Team is pursuing for the 2025 code cycle. The goal of these meetings is to solicit input on proposals from stakeholders early enough to ensure the proposals and the supporting analyses are vetted and have as few outstanding issues as possible. To promote transparency in the development of code change proposals, the Statewide CASE Team uses stakeholder meetings to solicit feedback on:

- Proposed code changes
- Draft code language
- Draft assumptions and analysis results
- Data to support assumptions
- Compliance and enforcement
- Technical and market feasibility

The Statewide CASE Team hosted two stakeholder meetings for Modulating DOAS via webinar, as described in Table 64. Please see below for dates and links to event pages on Title24Stakeholders.com. Materials from each meeting, such as slide presentations, proposal summaries with code language, and meeting notes, are included in the bibliography section of this report (Statewide CASE Team, 2025) (Statewide CASE Team, 2026).

Table 64: Utility-Sponsored Stakeholder Meetings

Meeting Name and Link to Materials	Meeting Date	Summary of Items Discussed
First Round of HVAC Air Distribution Utility-Sponsored Stakeholder Meeting	Tuesday September 23, 2025	• Introduced the fundamentals of the measure • Fielded questions from stakeholders on the measure
Second Round of HVAC Air Distribution Utility-Sponsored Stakeholder Meeting	Tuesday April 21, 2026	• Provide updates to the measure, including cost-effectiveness analysis and proposed code language • Solicited feedback and fielded questions from stakeholders

The first round of utility-sponsored stakeholder meetings began in September 2025 and served as an early forum to promote transparency and gather stakeholder feedback on measures under consideration by the Statewide CASE Team.

The objectives of the first round of stakeholder meetings were to solicit input on the scope of the 2025 code cycle proposals; request data and feedback on the specific approaches, assumptions, and methodologies for the energy impacts and cost-effectiveness analyses; and understand potential technical and market barriers. The Statewide CASE Team also presented the initial draft code language for stakeholders to review.

Craig Silvey with ACCO commented on the draft CASE report that the term “air valve” was misleading and could be interpreted as a venturi style damper commonly used in laboratory settings. As a result of this comment, the Statewide CASE Team changed the name to “modulating damper” for the final report.

The second round of utility-sponsored stakeholder meetings occurred from September 2025 and provided updated details on proposed code changes. These meetings introduced early results of energy, cost effectiveness, and incremental cost analyses, and solicited feedback on refined draft code language.

During the second utility-sponsored stakeholder meeting, stakeholders raised questions and provided feedback on several items. Stakeholders noted concerns about ASHRAE 62.1 minimum ventilation rates and Title 24, Part 6 ventilation rates. However, the Statewide CASE Team clarified there is no conflict because the Title 24, Part 6 ventilation rates are approximately 30 percent higher than ASHRAE 62.1 levels for analogous space types. There was also discussion about whether an exemption to ventilation rates if ASHRAE 62.1 is followed. The Statewide CASE Team noted that this could be further explored to determine if it is feasible in a future code cycle. One stakeholder noted that EnergyPlus does not directly support modeling modulating DOAS. The Statewide CASE Team developed a spreadsheet analysis but wanted to discuss it further with the stakeholder to determine whether better alternatives exist. Another stakeholder expressed concerns that adjusting the supply air requirement from 60 to 55 degrees would not yield energy savings and could create a potential conflict with ASHRAE’s design guide for DOAS. The Statewide CASE Team explained that there is no conflict because there are no humid climates in California that would require dehumidification, and that all cooling (and any necessary dehumidification) can be completed at the zone level by the zonal cooling system. One final concern from stakeholders was that the prescriptive requirement to design for outdoor air might pose a compliance challenge. However, the Statewide CASE Team explained that there is a simple calculation to determine the required ventilation rate per person.

After the stakeholder meeting, several entities docketed comments with the CEC on their pre-rulemaking docket, noting various objections to the Modulating DOAS measure. Throughout May 2026, the Statewide CASE Team devoted resources to respond to these comments and adjust the measures accordingly. A section describing the PG&E Code Readiness research was added. Submeasure c was adjusted to improve the likelihood of energy-efficient designs. Submeasure d was also adjusted to reduce challenges for DOAS systems in humid parts of California (which, to be clear, is a very limited subset of the overall state's climate, mainly restricted to the southwestern corner of the state in the San Diego area). Generally, however, the engagement consisted of more clearly explaining the proposal and its nuances to stakeholders. These explanations and clarifications were included in the relevant sections of this report to better explain the measures.

Statewide CASE Team Communications

The Statewide CASE Team held personal communications over email and phone with numerous stakeholders when developing this report, listed in Table 65. Engagement centered on the ability of DOAS technology to meet the proposed enhancements (e.g., through variable speed supply fans) and designers' ability to adapt to the new requirements.

Table 65: DOAS Engaged Stakeholders

Organization/Individual Name	Market Role	Mentioned in CASE Report Sections
Daikin Applied	Manufacturer	No
Trane	Manufacturer	No
Carrier	Manufacturer	No
ACCO/Craig Silvey	Designer	No
APA HVAC Technologies/Allison Guttadauro	Manufacturer Representative	No
A2 Efficiency/Neil Bulger	Designer	Yes – Section 3.1.3.3
Ecotope/Jon Heller	Designer	No
Linkage Engineers/Andrew Reilman	Designer	No
NEEA/Chris Wolgamott	Regional Energy Efficiency Organization	No
Energy 350/Nick O'Neil	Designer	No

Appendix F: Code Language from Draft CASE Report

The following subsections present the proposed code language as it stood when the draft CASE Report was published in March 2026. The language is presented in the unrestructured version of Title 24 Part 6.

F.1 Draft PVAV Language

Section 140.4 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

(m) Fan and mechanical cooling control. Each cooling system listed in Table 140.4-I shall be designed to vary the indoor fan airflow as a function of load and shall comply with the following requirements:

1. Single-zone DX and chilled water cooling systems ~~that control the capacity of the mechanical cooling directly based on occupied space temperature~~ shall:

   A. Have a minimum of two stages of fan control with no more than 66 percent ~~speed~~ design airflow when operating on stage 1; and

   B. Draw no more than 40 percent of the fan power at ~~full fan speed~~ design airflow, when operating at 66 percent ~~speed~~ of design airflow.

2. ~~All other systems, including but not limited to~~ Multiple-zone VAV DX cooling systems and chilled water systems ~~that control the space temperature by modulating the airflow to the space~~, shall have ~~proportional~~ modulating fan control. ~~such that at~~ At 50 percent air flow the power draw ~~is no more than~~ shall not exceed 30 percent of the fan power at full fan speed.

3. Multiple-zone VAV DX cooling systems and chilled water systems shall be configured to be able to reduce airflow from the supply fan to the larger of 15 percent of design airflow or the minimum outdoor airflow required in Section 120.1(c)3. The system shall be capable of providing mechanical cooling at that airflow.

Exception to Section 140.4(m)3: *Group R occupancies and common or public use areas.*

Reference Appendices

NA7.5.6 **Supply Fan Variable Flow Controls**

NA7.5.6.1 Construction Inspection

Prior to Functional Testing, verify and document the following:

(a) Supply fan includes device(s) for modulating airflow, such as variable speed drive

or electrically commutated motor.

(b) For multiple zone systems:

1. Discharge static pressure sensors are either factory calibrated or field calibrated.
2. The static pressure location, setpoint, and reset control meets the requirements of §140.4(c)2A and §140.4(c)2B.
3. The central fan(s) and compressor(s) are capable of and configured to meet the requirements of §140.4(m)3.

NA7.5.6.2 Functional Testing

Step 1: Simulate demand for full design airflow. Verify and document the following:

(a) Supply fan controls modulate to increase capacity.

(b) For multiple zone systems, supply fan maintains discharge static pressure within

+/-10 percent of the current operating setpoint.

(c) Supply fan controls stabilize within a 5 minute period.

Step 2: For multiple zone systems, ~~Simulate demand for reduced or minimum airflow~~,

1. Close the outdoor air dampers.
2. Close and turn off or reduce the maximum airflow of enough air terminal dampers such that the full airflow of the remaining air terminals is not more than the greater 15 percent of the system design airflow or the minimum outdoor airflow required in Section 120.1(c)3.
3. Reduce the temperature setpoint in those zones enough to engage mechanical cooling.
4. Verify and document the following:

(d) Supply fan controls modulate to decrease ~~capacity~~ airflow to the greater of 15 percent of the system design airflow or the minimum outdoor airflow required in Section 120.1(c)3.

(e) Confirm that mechanical cooling is operating by showing a temperature drop of not less than 5ºF between the return and supply air.

(~~e~~f) Current operating setpoint has decreased (for systems with DDC to the zone

level).

(~~f~~g) The supply fan maintains discharge static pressure within +/-10 percent of the current operating setpoint.

(~~g~~h) Supply fan controls stabilize within a 5 minute period.

Step 3: Restore the system to the correct operating conditions.

F.2 Draft Modulating DOAS Language

120.1 – REQUIREMENTS FOR VENTILATION AND INDOOR AIR QUALITY

(d) Operation and control requirements for minimum quantities of outdoor air.

5. Occupied Standby Zone Controls.

A. Space conditioning zones serving one or more of the following space types shall include occupied standby controls complying with Section 120.1(d)5B: ~~when all of the following are true:~~

~~i. All rooms served by the zone are permitted to have their ventilation air reduced to zero while in occupied-standby mode per Table 120.1-A; and~~

~~ii. Occupant sensors are required by Section 130.1(c)5 and 6; and~~

~~iii.~~ i. ~~The zone and ventilation system is not served by pneumatic controls.~~

1) Post-secondary classrooms
2) Lecture halls
3) Conference, meeting, or training rooms
4) Multipurpose rooms < 1,000 ft2
5) Breakrooms
6) Enclosed offices
7) Open-plan office areas
8) Corridors or stairwells

Exception to Section 120.1(d)5: Additions or alterations to existing ventilation systems served by pneumatic controls and permitted before 2029.

6. Modulating DOAS. DOAS systems in buildings with design outdoor airflow rates > 3,000 cfm shall meet all of the following:

A. Include modulating pressure independent air valves or other means of independently modulating outside air at each space conditioning zone
B. Disable ventilation to unoccupied space conditioning zones while maintaining measured outside air ventilation rates to occupied zones per 120.1(d)5
C. Include demand ventilation controls for high density spaces per 120.1(d)4
D. Modulate DOAS supply fan speed in accordance with 140.4(c)2

Exception to Section 120.1(d)6: Additions or alterations to existing DOAS systems permitted before 2029 that do not include modulating pressure independent air valves or other means of independently modulating outside air at each space conditioning zone.

(f) Design and control requirements for quantities of outdoor air.

1. All mechanical ventilation and space-conditioning systems shall be designed with and have installed ductwork, dampers and controls that allow design minimum outside air rates to be operated at no ~~less~~ more than the larger of (1) the minimum levels specified in Section 120.1(c)3; or (2) the rate required for make-up of exhaust systems that are required for a covered or non-covered process, for control of odors, or for the removal of contaminants within the space.

SECTION 120.2 – REQUIRED CONTROLS FOR SPACE-CONDITIONING AND VENTILATION SYSTEMS

(e) **Shut-off and reset controls for space-conditioning and ventilation systems**. Each space-conditioning system and each ventilation system shall be installed with controls that comply with the following:

1. The control shall be capable of automatically shutting off the system during periods of nonuse and shall have:

   A. An automatic time switch control device complying with Section 110.9 with an accessible manual override that allows operation of the system for up to 4 hours; or

   B. An occupancy sensor; or

   C. A 4-hour timer that can be manually operated.

(f) **Dampers for air supply and exhaust equipment**. Outdoor air supply and exhaust equipment shall be installed with dampers that automatically close upon fan shutdown or during periods of non-occupancy.

Exception 1 to Section 120.2(f): Equipment that serves an area that ~~must operate~~ is continuously occupied.

Exception 2 to Section 120.2(f): Gravity and other nonelectrical equipment that has readily accessible manual damper controls.

Exception 3 to Section 120.2(f): At combustion air intakes and shaft vents.

Exception 4 to Section 120.2(f): Where prohibited by other provisions of law.

Section 120.5 – REQUIRED NONRESIDENTIAL MECHANICAL SYSTEM ACCEPTANCE

(a) Before an occupancy permit is granted, the following equipment and systems shall be certified as meeting the Acceptance Requirements for Code Compliance, as specified by the Reference Nonresidential Appendix NA7. A Certificate of Acceptance shall be submitted to the enforcement agency that certifies that the equipment and systems meet the acceptance requirements.

5. Demand control ventilation systems required by Section ~~120.1(c)3~~120.1(d)4 or 120.1(d)6 shall be tested in accordance with NA7.5.5

18. Occupant sensing zone controls required by Section 120.1(d)5A or 120.1(d)6 shall be tested in accordance with NA7.5.17.

Section 140.4 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

(p) Dedicated outdoor air systems (DOAS).

2. The DOAS ~~supply~~ outdoor air shall be delivered using one of the following options:

A. D~~d~~irectly to the occupied space ~~or~~

B. A~~a~~t the outlet of any terminal heating or cooling coils and shall cycle off any zone heating and cooling equipment fans, circulation pumps and terminal unit fans when there is no call for heating or cooling in the zone.

C. At the inlet to zonal terminal heating or cooling coils. When there is no call for heating or cooling in the zone, the zone heating and cooling equipment, circulation pumps, and terminal unit fans shall either:

i. cycle off if there is a path for the outside air to reach the space, such as a return grille, or

ii. be controlled to reduce supply airflow to no more than the required outdoor air

~~Exception 1 to Section 140.4(p)2: Active chilled beam systems.~~

~~Exception 2 to Section 140.4(p)2: Sensible-only cooling terminal units with pressure-independent variable-airflow regulating devices limiting the DOAS supply air to the greater of latent load or minimum ventilation requirements.~~

3. DOAS supply and exhaust fans not required to modulate by 120.1(d)6 shall have a minimum of three speeds to facilitate system balancing.

4. DOAS ~~with mechanical cooling~~ providing ventilation to multiple zones and operating in conjunction with zone heating and cooling systems shall not use heating or heat recovery to warm supply air above ~~60~~55°F ~~when representative building loads or outdoor air temperature indicates that the majority of zones require cooling~~ and shall not use mechanical cooling to cool supply air below 75°F. DOAS units serving zonal systems without latent cooling capability may mechanically cool supply air below 75°F when the outdoor dewpoint temperature is above 55°F.