Codes and Standards Enhancement (CASE) Initiative

2028 California Energy Code

Compressed Air Dryers

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Draft CASE Report

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Table of Contents

List of Tables

List of Figures

Acronyms

Table 1 presents a list of acronyms used in this report. Title24stakeholders.com also maintains a glossary of terms.

Table 1: 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
CAGI	The Compressed Air & Gas Institute
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
CBECC-Res	California Building Energy Code Compliance for Residential Buildings 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
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
LED	Light Emitting Diode
LPD	Lighting Power Density
LSC	Long-term System Cost
MeasureSET	CASE Measure Savings Estimation Template
MG	Million Gallons of Water
NAICS	North American Industry Classification System
NPDI	Net Private Domestic Investment
PEP	Public Engagement Plan
PV	Present Value
SDD	Standards Data Dictionary
SOC	Standard Occupational Classification
SPMS	Saturation Pressure Measurement Sensors
SRIA	Standardized Regulatory Impact Assessment
UL	Underwriters Laboratories
W	Watt

1. Introduction

This is a draft report. The Statewide Codes and Standards Enhancement (CASE) Team encourages readers to provide comments on the proposed code changes and supporting analyses. The CEC will evaluate proposals that the Statewide CASE Team and other stakeholders submit and may revise or reject proposals. More information about the rulemaking schedule and how to participate in the process can be found on CEC's 2028 code cycle website. Suggested revisions will be considered when refining proposals and analyses. The final CASE Report will be submitted to the CEC later in 2026.

For this report, the Statewide CASE Team is requesting input on the following:

1. *Feedback on the proposed code language,*
2. *Market adoption rates of the proposed requirements, and*
3. *Measure costs for the proposed requirements.*

Email comments and suggestions to info@title24stakeholders.com *and* valmiki@askenergyinc.com. *Comments will either not be released for public review or will be anonymized if shared.*

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 sponsored this effort as a group. Where the term, "Statewide CASE Team" is used in this report, it refers the authors of the CASE report and the Codes & Standards programs of the supporting California Investor-Owned Utilities.

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 of compressed air dryers, compressed air system designers, industry association representatives, 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 October 29, 2025 (Statewide CASE Team 2025a) (Statewide CASE Team 2025b).

After presenting the initial code language and proposal during the public stakeholder workshop, the Statewide CASE Team conducted extensive interviews with experts from five major manufacturers of compressed air dryers and representatives of the preeminent air compressor industry association: The Compressed Air & Gas Institute (CAGI). These subject matter experts have deep knowledge of air dryers and how entire compressed air systems are designed, specified, operated, and maintained. The Statewide CASE Team also interviewed experts from four compressed air system consultant firms who conduct various design, specification, and energy efficiency services. All these interviewees were previously familiar with Title 24 and the California marketplace and were thereby able to provide feedback on the preliminary proposed code language.

The interviews also were instrumental in gathering information on design practices, market adoption rates, barriers, technical details, and other details that only subject matter experts would be able to fully explain. The Statewide CASE Team has incorporated this collective feedback into the code language included in this Draft CASE Report as well as accounted for the gathered information in the calculations underlying the proposal.

See Appendix E for details on the Statewide CASE Team’s stakeholder engagement.

2. Measure Description

2.1 Proposed Code Change

This measure would add air dryer requirements to compressed air systems with total combined compressor horsepower (hp) greater than or equal to 25 hp. Efficient dryer selection and controls would be required for new compressed air systems or when dryers in existing systems are replaced. Since the dryer selection requirements depend on whether a system requires a dew point above or below 35°F, it would require construction or compliance form documents to list the required dew point for a compressed air system if it is below 35°F. In addition to the required dew point, certain provisions would also depend on system size.

If the required dew point is 35°F or greater, an energy-saving refrigerated dryer is required. An energy-saving refrigerated dryer is one that has load-matching features such as cycling, thermal mass, digital scroll compressors, or variable speed drive (VSD) compressors instead of constant speed operation.

All desiccant air dryers, which serve dew points below 35°F, would be required to have load-following regeneration controls that reduce energy consumption by limiting regeneration time and the associated energy consumption from purge air, blowers, or heaters. This requirement would not apply to heat-of-compression dryers.

Finally, all desiccant dryers with capacity greater than 300 cfm would be required to have internal or external heating to reduce the use of purge air for desiccant regeneration.

Table 2 summarizes the scope of the proposed code change.

Table 2: 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 100.1 • Part 6, Section 120.6 • Part 6, Section 141.1 • Nonresidential Reference Appendix Section NA7.13	• 2025-NRCC-PRC-E • 2025-NRCI-PRC-E • 2025-NRCA-PRC-01-F	N/A

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

2.2 Benefits of Proposed Change

This proposal builds on previous efforts to reduce energy consumption of compressed air systems. Air compressor systems were first covered by Title 24, Part 6 in 2013 . Mandatory measures stipulated sizing and control requirements for baseload and trim air compressors. The Statewide CASE Team recommended compressed air system requirements as part of the 2022 code cycle update with a focus on optimization and sustained efficiency of the distribution and load-side components. The 2022 code changes added mandatory pipe sizing, monitoring, and leak testing measures.

The proposed 2025 air dryer code change proposals originated during the development of compressed air system measures for the 2022 Title 24, Part 6 code cycle. Air dryer measures were not pursued at that time because they did not align with the selected measures focus on the distribution system and load-side of compressed air. Air dryer requirements were identified as a possible measure during discussion and measure selection amongst the Statewide CASE team but were not prioritized at the time and were instead reserved for future efforts.

This proposal would advance this multi-cycle effort, substantially reducing energy consumption for compressed air systems and minimizing the unnecessary specification of energy-intensive dryers. The proposed language would reduce energy bills and consumption for industrial facilities without any negative impact on operating capacity or manufacturing flexibility. The proposed changes would also add definitions and clarity on the coverage of additions and alterations that would ease the compliance process for the existing compressed air measures.

In covered situations, the proposed measures would reduce dryer energy consumption dramatically. While the savings would depend on the prototype in question, energy savings are about 50 percent for an energy-saving versus non-cycling refrigerated dryer, 85 percent for an energy-saving refrigerated dryer versus a heatless desiccant dryer, 30 percent for desiccant dryer with regeneration controls versus one without, and 15 percent for a heated desiccant dryer over a heatless desiccant dryer. (Previously, "energy-saving" dryers were often referred to as "cycling." In this report, "energy-saving" is used as it is more comprehensive and a better representation of the variety of techniques for reducing refrigerated air dryer energy consumption.)

2.3 Background Information

Compressed air systems greater than 25 hp in size (roughly equivalent to 100 cfm) are typically found in industrial facilities. Industrial facilities use compressed air for motive power for pneumatic machinery, hand tools, controls, material handling, and automation. It is often called the "fourth utility" due to its common presence in manufacturing facilities. It is present in about 82 percent of industrial buildings accounting for about 10 percent of total industrial sector electrical energy use (Xenergy 2001, Greenstone, et al. 2019, Beneditti, et al. 2016)

Compressed air systems are highly custom and the design at any given location will depend on process needs, space, and building environmental conditions. They typically include several primary components: one or more compressors, air treatment, storage volume, and distribution piping throughout the facility. This proposal targets the dryer, the primary energy consumer in the compressed air treatment component.

Compressed air dryers lower the moisture content of compressed air to an acceptable level for the plant needs, typically represented by a pressure dew point value. Dryers are essential in industrial compressed air systems to protect piping, equipment, and processes from damaging moisture. Dryers should be specified based on the plant's needs and operating conditions. The plant's necessary dew point or air quality level typically drives air dryer selection. The dew point is dictated by critical moisturesensitive end-uses or by piping that is exposed ambient temperatures cold enough to cause condensation.

There are several kinds of dryers: refrigerated, regenerative desiccant, deliquescent, and membrane (CAGI 2017). Each of these work under a different principle and have different applications:

- Refrigerated dryers use a refrigeration cycle to condense moisture out of the compressed air on condensing coils within the dryer. Under the operating principles of refrigeration cycles and the thermodynamic properties of common refrigerants, these dryers typically produce air at a dew point down to 35°F. These are the most common type of dryer and suffice for most operating conditions and plant needs.
- Regenerative desiccant dryers (hereafter called “desiccant dryers”) use a bed of desiccant material to adsorb moisture from the compressed air. Regenerative desiccant dryers use twin towers of material to adsorb moisture, alternating cycles so one tower dries air while the other regenerates. Delivering dew points from -40°F to -100°F, they are essential for plants with critical low-moisture processes or piping is exposed to freezing temperatures (below 35°F) during operation.
- Deliquescent dryers absorb moisture with a consumable material that dissolves over time. They provide dew point suppression rather than a fixed rating and are rarely used for whole-plant treatment.
- Membrane dryers are not used for whole plant air treatment. They are more commonly used for point-of-use drying at a specific, critical end-use or for gas separation.

This proposal focuses on energy efficiency improvements for refrigerated or desiccant dryers, which provide plant-wide drying. Refrigerated dryers can use design and control features to match capacity to load – compressed air systems will virtually always have varying load. Desiccant dryers can use design and control features to limit the energy consumption of the necessary material regeneration process.

Refrigerated dryers operate either as non-cycling units (constant energy consumption) or energy-saving models that modulate to match load power via compressor cycling, digital scroll compressor controls, or variable speed drives. Cycling dryers use a thermal mass to retain drying capacity while the compressor turns on and off. Digital scroll dryers load and unload the compressors to match drying power to the load. Variable speed dryers do the same by varying the speed of the compressor. Thus, an energy-saving refrigerated dryer matches energy consumption to load, avoiding waste via the hot gas bypass typically used in non-cycling models.

When energy-saving refrigerated dryers are sized in accordance with manufacturer instructions for the design point conditions (where the loads and pressures are most extreme), they will be operating below capacity at almost all times and will use less energy by operating at part-load capacity. Non-cycling dryers constantly use the energy for the design point conditions, without any part-load efficiencies.

Desiccant dryers must periodically regenerate the material once it becomes saturated. This can be done in a few different ways, each with their own energy intensity.

- The most energy intensive method is heatless, purge air regeneration, where compressed air is passed through the tower being regenerated to remove water from the desiccant. Heatless purge air is typically about 17 percent of the total rated capacity of the dryer – a huge consumption of energy intensive compressed air. Heatless purge air desiccant dryers are often the largest compressed air load in plants where they are used.
- Internal or external heating of the purge air can amplify its drying ability and therefore reduce the amount of air needed. Purge air is heated via electrical resistance but that additional electrical load reduces the energy intensive purge air down to about seven percent of the rated capacity. Other heat sources, such as waste heat from the air compressors ("heat of compression dryers") can be used to heat purge air.
- Instead of compressed purge air, a blower can be added to pass heated ambient air through the desiccant. The combination of blower and heater energy is less than the energy consumption of compressed air.
- While basic fixed timers often cause excessive regeneration, demand-based controls monitor dew point or moisture levels to initiate cycles only when strictly necessary. This load-matching strategy significantly reduces energy consumption across all desiccant dryer types by aligning regeneration with actual air usage. Even dryers that serve compressed air systems with constant compressed air loads face varying moisture loads.

These dryer design choices and controls are well-established and widely available in the California market.

There are no existing codes or standards that would conflict with the code change proposal. Cycling refrigerated dryers were once included in California programs via a deemed measure workpaper which has since expired (Southern California Edison 2017).

The primary rating program for compressed air dryers has been developed by the Compressed Air and Gas Institute (CAGI). CAGI is a trade association of compressed air equipment manufacturers which undertake efforts to standardize the industry, provide training and documentation for market actors, and support high quality, reliable compressed air products. CAGI has established a voluntary ratings program for refrigerated dryers and is working on a similar standard for desiccant dryers. Manufacturers of air compressors and compressed air dryers can, and often do, submit their equipment for rating under this program to produce independently verified performance data sheets. Refrigerated dryers are rated at standard conditions of 100 °F inlet saturated compressed air temperature, 100 psig.

The proposed Title 24, Part 6 code targets scenarios where dryer selection ignores best practices, accelerating the adoption of proven but underutilized efficiency measures.

2.4 Modifications to Energy Code Documents

This section provides descriptions of how the proposed code change will affect each Energy Code document. See Section 7: Proposed Language of this report for detailed revisions to code language.

2.4.1 Energy Code Change Summary

SECTION 100.1 – DEFINITIONS AND RULES OF CONTSTRUCTION

Subsection 100.1(b): The proposed changes include new definitions to provide context and clarity to the requirements language in subsequent sections. These definitions include Desiccant Air Dryer, Heat of Compression Air Dryer, Point-of-Use Air Dryer, Refrigerated Air Dryer, Energy-Saving Refrigerated Air Dryer, and Desiccant Regeneration Controls. The proposal also suggests removing the definition for Online Compressors since it no longer applies after the changes made in the 2022 code cycle and modifying the definitions for Compressed Air System and Trim Compressor for added clarity.

SECTION 120.6 – MANDATORY REQUIREMENTS FOR COVERED PROCESSES

Subsection 120.6(e): The proposed changes include new requirements for compressed air dryers. These include the use of energy-saving refrigerated dryers where applicable, the use of regeneration controls for desiccant dryers, and the use of heated dryers when desiccant dryers above a threshold of 300 cfm are specified. Existing exceptions related to additions and alterations are removed from this section and moved to Section 141.1(f).

SECTION 141.1 – MANDATORY REQUIREMENTS FOR COVERED PROCESSES IN ADDITIONS, ALTERATIONS TO EXISTING NONRESIDENTIAL, AND HOTEL/MOTEL BUILDINGS

Subsection 141.1(f): The proposed changes include new language for compressed air systems in additions and alterations and moves existing language from 120.6(e) without increasing or decreasing stringency.

2.4.2 Reference Appendices Change Summary

NA7.13 Compressed Air System Acceptance Tests: The proposed changes add verification testing of the dryer desiccant regeneration controls to the existing compressed air reference appendix language in NA7.13.

2.4.3 Compliance Manuals Change Summary

Nonresidential Compliance Manual Section 10.8 – Compressed Air Systems: The proposed changes add sections to provide clarifying examples of newly covered equipment. Recommended sizing methodology for dryers may be included although the proposed code does not require sizing, because appropriate sizing is a useful means of ensuring quality design, specification, and installation and of improving savings persistence. Existing examples would be modified to align with proposed modifications to existing language, as necessary.

2.4.4 Alternative Calculation Method Reference Manual Change Summary

The proposed code change would not modify the Alternative Calculation Method Manual.

2.4.5 Compliance Forms Change Summary

The proposed code change would modify some existing compliance forms (NRCC-PRC-E, NRCI-PRC-01-E and NRCA-PRC-01-F) and would not require any new forms. These documents would require certification of dryer type aligned with the specified required dew point and would include results of additional steps of the field verification test to be performed by a field technician.

2.5 Measure Context

2.5.1 Comparable Model Codes or Standards

There are no relevant model codes or standards for the efficiency of compressed air dryers at the local, state, federal, or international level. Air dryers are not currently covered by any energy, mechanical, or appliance code.

2.5.2 Interactions with Other Regulations

There are no existing regulations at any level that would conflict with the proposed language for compressed air dryers. The proposed changes and resultant savings are do not overlap with existing Title 24, Part 6 compressed air requirements or savings attribution.

There is a single test standard for compressed air dryers which establishes rating test conditions and procedures for refrigerated and desiccant models: ISO 7183 (ISO 2007). However, this is not codified and can voluntarily be employed by manufacturers at their discretion. CAGI has established a voluntary program through which manufacturers can submit their products for independent testing and verification to produce data sheets that are then assured to be accurate and independent from the manufacturers, themselves (CAGI 2025). This program currently provides refrigerated dryer ratings and data sheets while a similar desiccant dryer program is yet forthcoming. The CAGI program does not conflict with the proposed code changes but does support market actors in their compliance by providing reliable performance data that can be used in the dryer specification process.

3. Compliance and Enforcement

3.1 Compliance Considerations

The Statewide CASE Team believes that compliance and enforcement of the proposed measure is feasible and would not add significant compliance or enforcement burden to building code officials. Confirmation steps would need to be taken during permit application to ensure compliance with the proposed compressed air dryer requirements. Plans must indicate the required dew point of a compressed air system. New fields in the Process Systems Certificate of Compliance document NRCC-PRC-E, the Process System Certificate of Installation document NRCI-PRC-E, and The Compressed Air Systems Acceptance document NRCA-PRC-01-F would need to be created and completed.

Designers: Designers would need to be aware of the new compressed air dryer requirements in section 120.6(e) (for new systems) and 141.1(d) (for modifications) so they can design compliant compressed air systems. They would need to fill out an updated NRCC-PRC-E form and submit design documents indicating a compliant design.

Plan Reviewers: During the permit application phase, reviewers would confirm that the design documents contain the compressed air system required dew point and that the submitted NRCC-PRC-E form meets the requirements for compressed air dryers.

Installation contractors: Installation contractors would need to correctly install compliant compressed air dryers, which is already part of normal operating procedures. The installation contractor would also need to fill in the NRCI-PRC-E form.

Field technicians: Field technicians would not be substantially impacted by the proposed measure, though some additional maintenance would be necessary to maintain sensors associated with required dew point controls.

AHJ building inspectors: The AHJ building inspector would need to verify the installation of a compliant compressed air dryer.

The Statewide CASE Team is not aware of any conflict with any existing definitions in other parts of Title 24.

3.2 Impact on Market Actors

Table 3 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 3: Impacts on Market Actors and Suggested Training and Education Opportunities

Market Actor	Impact(s)	Suggested Outreach and Education
Builders [a]	Be aware of compressed air dryer requirements, and plan for additional costs where relevant.	Additional training likely unnecessary.
Design Professionals [b]	Be aware of new requirements and code triggers when designing compressed air systems. Ensure that dew point requirements are included on plans or procurement documents, if possible, so that they can be referenced when completing dew point fields in compliance documentation. Complete new fields of NRCC-PRC-E Compressed Air section.	Industrial process compressed air design firms should be provided training on the energy code including compliance requirements and compliance documentation.
Construction Team [c]	Install a compressed air dryer consistent with the proposed requirements, consistent with standard practice. Complete fields in compressed air dryer section of NRCI-PRC-E. Perform verification testing to confirm controls comply with requirements. Put results on NRCA-PRC-01-F form and submit to building inspector and building owner.	System installer should be provided training on the energy code updates and supporting documentation, compliance requirements, acceptance testing, and compliance documentation.
Building Departments [d]	Plan Reviewers will have an additional requirement to check when reviewing NRCC form and design documents. Building inspectors will need to review NRCA and NRCI forms and confirm that installed air dryers meet new requirements.	Provide education and training to local building department plans examiners to familiarize with new code language.
Verification Testers [e]	See construction team, as installing technician will typically act as the field technician performing acceptance testing.	Additional outreach likely unnecessary.
Building Owners, Managers, and Occupants	Higher upfront cost in most cases and reduced energy bills.	Outreach to owners and operations personnel could improve understanding of the benefits of compressed air dryer requirements.
Manufacturers and Distributors	Be aware of compressed air dryer requirements when working with clients on product selection.	Outreach to manufacturers and distributors to make sure they are aware of requirements. Consider developing a compressed air Fact Sheet.

a. Developers plan the project, manage finances, and manage risks from start to finish.

b. Design professionals include architects, interior designers, engineers (mechanical, electrical, plumbing, structural), specification writers, cost estimators, commissioning agents, lighting designers, and energy consultants.
c. Construction team includes general contractors, 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 sustainability department staff.
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 changes 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 industrial and 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 industrial 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.

Table 4: 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	5,491	87,450	10.6
Other Nonresidential Exterior Contractors	234	2,259	0.1
Nonresidential Electrical Contractors	3,245	72,794	7.8
Nonresidential Plumbing & HVAC Contractors	2,270	55,182	5.8
Other Nonresidential Equipment Contractors	580	9,749	1.1
Nonresidential Site Preparation Contractors	1,147	19,273	1.9
All Other Nonresidential Trade Contractors	948	17,084	1.7

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

b. *An establishment is single economic unit, typically at one physical location, that engages in one, or predominantly one, type of economic activity for which a single industrial classification may be applied. Many businesses are composed of multiple establishments. US Bureau of Labor Statistics, Handbook of Methods. https://www.bls.gov/opub/hom/cew/concepts.htm

Building owners. Owners of facilities with compressed air dryer systems would face higher upfront costs for energy-saving controls but would save money on reduced energy bills due to lower dryer energy consumption. Some owners may also save money on upfront costs if they would have unnecessarily specified a more expensive desiccant dryer when a cheaper refrigerated dryer would have been sufficient.

Manufacturers. As discussed in Section 4.1.1, multiple manufacturers and installers of compressed air systems operate in California, and these businesses would sell and install compressed air dryers. Refer to Section 4.4 for more information on the resultant impact to California jobs.

3.3 Compliance Software Updates

Compliance software updates are not required for this measure proposal.

3.4 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.

Costs of enforcement would include costs to deliver training to enforcement officials to enable them to adequately enforce the proposed measure.

The incremental enforcement requirement additions are small, as Title 24, Part 6 already includes requirements for compressed air systems that mandate plan reviews and acceptance testing. Additional costs include providing education and training to local building officials to enable them to adequately enforce the proposed measure. Plans examiners would need to review the plans to ensure correct dryer, dew point, and desiccant specification. System installers would also need training on requirements for measure compliance. Field technicians would need to confirm verification of the dryer desiccant regeneration controls through acceptance testing. Because requirements for compressed air systems already exist, additional steps would be added to existing inspections, but no additional inspections will be required.

The Statewide CASE Team will work with the Compliance Improvement Team to estimate the total cost of enforcement for the Final CASE Report.

4. Market and Economic Analysis

4.1 Market Structure and Availability

4.1.1 Current Market Structure and Availability

The market for compressed air systems includes air compressor manufacturers, auxiliary equipment manufacturers, equipment distributors, contractors and architect engineering firms compressed air system users, and trade associations. Air compressor manufacturers sell compressors and packages, while auxiliary manufacturers supply components like dryers, filters, and piping. Air compressor and equipment distributors provide information, bids, and sale of compressor system components to end users, service providers, or design-build contractors. Distributors may provide design services, but otherwise contractors and architect-engineering firms provide planning and specifications for the given needs and loads, including the dew point required for a particular compressed air application. Compressed air system owners and operators are typically responsible for the operation and maintenance of compressed air systems. Trade associations are organizations of industry representatives who collaborate to promote co-operation amongst stakeholders, provide training and best practices, develop standards, and improve the quality of the compressed air dryer marketplace offerings for the general public. In addition to these stakeholders, various consultants provide services such as energy efficiency, design services, and performance assessments to practice end users. The relationship between these stakeholders is shown in Figure 2.

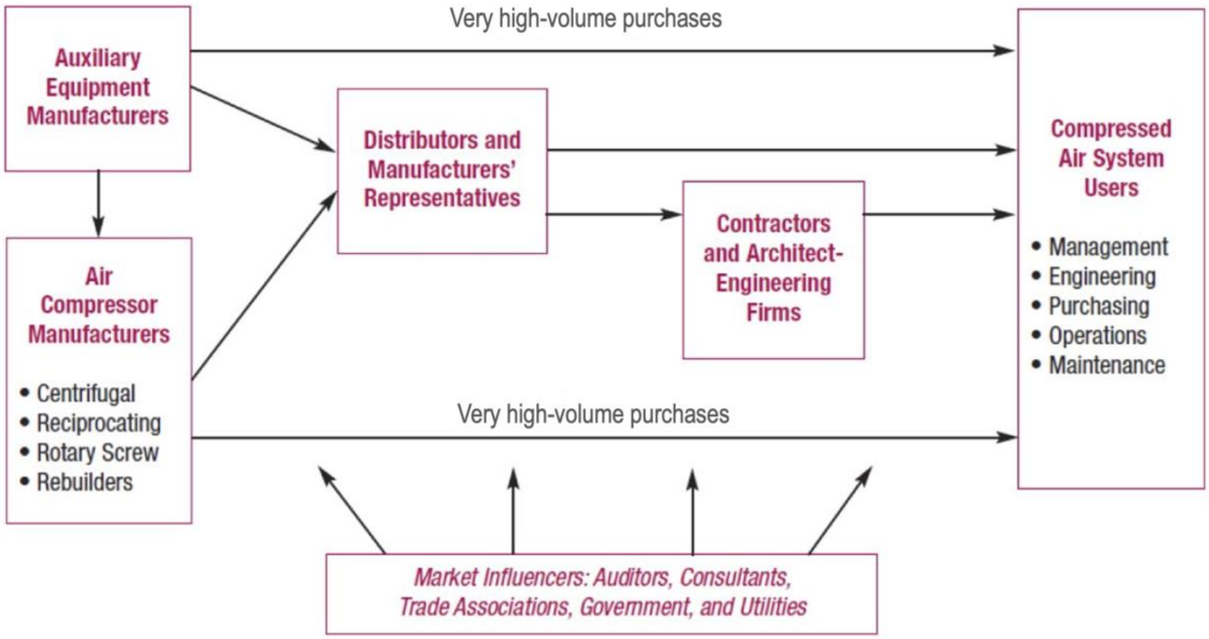

Figure 1: Compressed air system market.

Source: DOE 2016

The market for compressed air systems is mature, with multiple manufacturers and suppliers providing designers and contractor with many options for compressed air system and auxiliary equipment. Multiple air dryer manufacturers serve the refrigerated and desiccant markets, as and offer load-following controls for desiccant regeneration. Table 5 lists companies that the Statewide CASE Team has identified as major market actors.

Table 5: Major Compressed Air System Market Actors

Company	Market Actor Type	Product Offering	Headquartered in California
Atlas Copco	Manufacturer	Compressor and auxiliary equipment	No
Blueline Air Systems	Supplier	Air compressor	Yes
CASEI	Distributor	Compressor and auxiliary Equipment	Yes
CAGI	Trade Association	-	No
California Air Tools	Manufacturer	Compressor and auxiliary equipment	Yes
Champion Air Dryers	Manufacturer	Air dryers	No
Compressed Air Challenge	Trade Association	-	No
Compressed Air Consultants	Compressed air system experts	-	No
Elgi North America	Manufacturer	Compressor and auxiliary equipment	No
Ingersoll-Rand	Manufacturer and Distributor	Compressor and auxiliary equipment	No
Kaeser	Manufacturer and Supplier	Compressor and auxiliary equipment	No
KSI	Manufacturer	Compressor and auxiliary equipment	No
Thomasnet	Distributor	Compressor and auxiliary equipment	No
Machine Tools	Distributor	Compressor and auxiliary equipment	No
Q Air California	Manufacturer	Compressed air auxiliary equipment	Yes
Pattons	Distributor	Compressor and auxiliary equipment	Yes
ZEKS	Manufacturer and Supplier	Auxiliary Equipment	No

The Statewide CASE Team originally proposed a requirement to have a dedicated air dryer per trim compressor but has dropped this requirement based on this stakeholder input. However, stakeholder interviews indicated that optimization of the number of compressors per air dryer is an emerging trend in the compressed air system market. Previously, market actors preferred to have a dedicated air dryer for each compressor, but more recently they have opted to use a single air dryer for multiple compressors. Another emerging trend is ongoing commissioning (OCx) being pursued as ￼￼￼. Energy-saving regeneration controls and ongoing commissioning mutually reinforce facility benefits.

4.1.2 Market Challenges and Solutions

See Section 3 for a description of workforce trainings that may be needed to ensure effective design, installation, and commissioning.

The Statewide CASE Team surveyed manufacturer websites and interviewed various manufacturers to confirm the availability of dew point controls and dryer types to comply with this code proposal. Through these stakeholder interviews, the Statewide CASE Team confirmed that manufacturers offer various types of dryers and dew point controls are widely available as part of a package or as an after-market item.

The specification of dew point to determine dryer type needs, sizing dryers based on peak loads, and incorporating load-based dew point controls are all common practice in design strategy in the current market. These practices avoid overspecification which leads to higher initial and ongoing maintenance costs and promote energy efficiency by reducing purge air usage. However, many site practices for dryer specification often don’t align with these best practices. Through stakeholder outreach, the Statewide CASE Team determined that overspecification is due to a lack of awareness on how to properly specify a compressed air system, including dew point and varying load capacities, resulting from a lack of standardized documentation. Stakeholder education and development of public documentation would address this challenge. The Statewide CASE Team plans to create documentation on these practices in the compliance manual. The Statewide CASE Team is also aware of CAGI developing performance standards for desiccant dryers, which may complement the code in the future.

4.2 Design and Construction Practices

4.2.1 Current Design and Construction Practices

The proposed measure introduces several requirements; each aligned with established best practices to enhance energy efficiency in compressed air systems.

Energy-Saving Refrigerated Dryers

The first part of this measure would require energy-saving refrigerated dryers to be specified for applications with dew point requirements of 35°F or higher. This approach supports current design standards and prevents the unnecessary use of desiccant dryers, which demand additional equipment and higher energy consumption. Energy-saving refrigerated dryers incorporate capacity control features that adjust energy consumption in response to varying compressor loads. Energy-saving refrigerated dryers include cycling, thermal mass, digital scroll, and variable speed drive technologies. Although not always specified for baseload or trim compressor applications, these dryers are widely available and commonly used in the market. They may require increased floorspace for auxiliary equipment, such as thermal mass or glycol reservoirs, and enhanced ventilation due to longer cycling periods. Additionally, they involve greater electrical demand to support advanced sensors and control logic, but they achieve overall energy savings by reducing compressor operation in proportion to actual load.

Dew-Point Controllers

The second requirement would be the use of dew point controllers on desiccant air dryer to optimize energy use by matching operation to the drying load. According to manufacturer input during a stakeholder interview, approximately 50 percent of desiccant dryers are currently sold with dew point controls. While the added sensors, controllers, and wiring for dew point controllers introduce minimal electrical requirements, their incorporation into dryer control design is justified by the energy savings achieved through load-based operation.

Heated Desiccant Dryers

The third requirement would be to specify an internally or externally heated dryer for desiccant dryers with a capacity of at least 300 cfm. Heated desiccant dryers require additional floorspace to accommodate additional he additional heating equipment, as well as increased electrical capacity for heaters and blowers.

Together, these requirements ensure that compressed air systems are designed to meet actual operational needs and reinforce current product availability and best practices while minimizing unnecessary energy expenditure.

4.2.2 Health and Safety Considerations

This 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. Occupants and those involved with the construction, commissioning, and maintenance of the site would not experience any adverse impacts on safety or health associated with the proposed code change. The proposed code change would reduce GHG emissions associated with a reduction in electrical energy consumption.

4.2.3 Design and Construction Challenges and Solutions

See Table 3: Impacts on Market Actors and Suggested Training and Education Opportunities in Section 3.2 for a description of workforce trainings that could support effective design, installation, and commissioning.

The Statewide CASE Team identified two potential challenges for compressed air system design and construction. The first was that operational needs beyond required dew point for end-uses may necessitate the use of desiccant dryers. Through stakeholder outreach, the Statewide CASE found that outdoor equipment in freezing conditions or certain specialized processes may require extremely low dew. However, manufacturer and system designer stakeholders also confirmed that such needs can be addressed directly through dryer specification. The second challenge identified by the Statewide CASE Team was the feasibility of add-on load matching controls and dew point measurement. Several manufacturers confirmed the availability of dew point controls as an option for a baseline compressed air dryer design as well as after-market options, allowing purchasers flexibility while preserving existing product lines.

Several of the requirements for this measure would also affect maintenance practices. Replacing overspecified desiccant dryers with refrigerated units lowers overall maintenance. Dew point controllers require regular calibration and dew point sensor replacement, increasing maintenance required compared to a system without these controls.

4.3 Energy Equity and Environmental Justice

The Statewide CASE Team evaluated the potential impact on environmental and social justice (ESJ) communities,[1] including impacts related to race, class, and gender. Although general reductions in GHG emissions are expected due to reduced energy consumption as a result of this measure proposal, it was not identified as having a significant impact on any ESJ communities.

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[1] 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 identified potential impacts of the proposed code change via research and stakeholder input. While the listed potential impacts should be comprehensive, they may not yet be exhaustive. Recognizing the importance of engaging ESJ communities and gathering their input to inform the code change process and proposed measures, the Statewide CASE Team is working to build relationships with community-based organizations (CBOs) to facilitate meaningful engagement. Please reach out to Joe Vukovich (joevukovich@2050partners.com) if you have input on how this proposal may impact ESJ communities or if you would like to offer your perspective.

4.4 Impacts on Jobs and Businesses

This section will be completed for the Final CASE Report.

4.5 Economic and Fiscal Impacts

This section will be completed for the Final CASE Report.

5. Cost Effectiveness

5.1 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-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.

Energy usage calculations built upon previous methodology used in the 2013 and 2022 code cycles (Statewide CASE Team 2020). Four prototype compressed air systems and their respective load profiles were previously established based on program data, engineering judgement, and stakeholder engagement. The four prototypes represent a range of system sizes found in industrial settings with baseload and trim load shapes derived from empirical program data. The systems range in size from 125 to 800 total combined horsepower, each with two or three compressors and a shared single dryer.

5.2 Energy and Energy Cost Savings Results

To remain consistent with those methods and with savings attributed to existing code measures, the analysis for air dryer energy usage and savings use these same load profiles.

Appendix A outlines the energy savings calculation methodology and prototypes, in detail.

The Standard Design (baseline) and Proposed Design (measure) conditions for the air dryer measures are the same for new construction, additions, and alterations, and use the same prototype systems and load profiles. Although outside air conditions at compressor and dryer inlets could have a small impact on equipment efficiency, the effect is marginal and equipment is typically located inside buildings, thereby buffering equipment efficiency from weather impacts in the prototype cases. Therefore, climate zones do not impact the modeled energy usage.

Energy savings are presented on a per-hp basis for the total installed air compressor power. Horsepower is a natural base unit for energy usage and impacts for compressed air systems in the manufacturing sector. Per-hp savings for the first year vary across the different cases and prototypes as seen in Table 6.

Table 7 lists these same per-hp first year savings for source energy savings in kBtu. Peak demand reduction is not expected from any of the proposed code language; refrigerated dryer and air compressors will still have the same overall maximum peaks despite energy savings.

Table 8 presents total per-hp energy cost savings for newly constructed buildings, alterations, 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.

These savings will persist throughout the lifetime of the equipment with proper maintenance and management of the dryers. These maintenance practices are largely driven by the need for reliable, dry air in any given plant and are thus dependable. For both refrigeration and desiccant dryers, energy usage is inherent to the equipment's operating principles and do not need much ongoing commissioning or attention to setpoints. However, the regeneration controls submeasure will require some proactive maintenance and attention by plant staff to ensure persistence of savings. The necessary costs for this maintenance are further detailed in Section 5.4.

In Tables 6-8, each column relates to the proposed changes to Title 24 as follows:

* 120.6(e)(6)(A), (B)

† 120.6(e)(A), (B)

‡ 120.6(e)(C)

§ 120.6(e)(D)

Table 6: First Year Electricity Savings (kWh) Per hp – All Measures

Prototype	Non-cycling Refrigerated Dryer to Energy-Saving Refrigerated Dryer*	Heatless Desiccant Dryer without Regeneration Controls to Energy-Saving Refrigerated Dryer†	Heatless Desiccant Dryer without Regeneration Controls to Heatless Desiccant Dryer with Regeneration Controls‡	Heatless Desiccant Dryer to Heated Desiccant Dryer§
Prototype 1	227.6	592.4	200.7	65.7
Prototype 2	237.4	586.0	210.8	51.4
Prototype 3	238.2	570.7	204.4	46.3
Prototype 4	286.6	528.6	196.9	-0.4

Table 7: First Year Source Energy Savings (kBtu) Per hp – All Measures

Prototype	Non-cycling Refrigerated Dryer to Energy-Saving Refrigerated Dryer*	Heatless Desiccant Dryer without Regeneration Controls to Energy-Saving Refrigerated Dryer†	Heatless Desiccant Dryer without Regeneration Controls to Heatless Desiccant Dryer with Regeneration Controls‡	Heatless Desiccant Dryer to Heated Desiccant Dryer§
Prototype 1	334.4	829.6	317.7	89.9
Prototype 2	348.7	832.1	337.8	73.5
Prototype 3	349.9	807.2	326.6	65.9
Prototype 4	421.1	739.2	331.3	1.8

Table 8: Total 30-Year LSC Savings (2029 PV$) Per hp – All Measures

Prototype	Non-cycling Refrigerated Dryer to Energy-Saving Refrigerated Dryer*	Heatless Desiccant Dryer without Regeneration Controls to Energy-Saving Refrigerated Dryer†	Heatless Desiccant Dryer without Regeneration Controls to Heatless Desiccant Dryer with Regeneration Controls‡	Heatless Desiccant Dryer to Heated Desiccant Dryer§
Prototype 1	$1,846	$4,845	$1,667	$528
Prototype 2	$1,925	$4,808	$1,756	$417
Prototype 3	$1,931	$4,681	$1,700	$376
Prototype 4	$2,323	$4,330	$1,631	$2

5.3 Incremental First Cost

Incremental first costs were calculated for each prototype in Table 22 and set of Standard and Proposed Design cases defined in Table 23. Four baseline and proposed measure cases were evaluated based on the sub measures in the proposed code language for each of the four prototypes.

The first baseline case was a non-cycling refrigerated dryer with the proposed case being an energy-saving refrigerated dryer. The incremental first cost between the baseline and proposed is the difference in cost between a non-cycling and an energy-saving refrigerated dryer obtained through a survey of an air compressor distributor website, shown in Figure 2. Retail list costs for the set of available products were cataloged in November 2025 and will be updated for the Final CASE Report with additional datapoints at that time. The Statewide CASE Team assumes that all shipping, handling, and installation costs are the same between the two types.

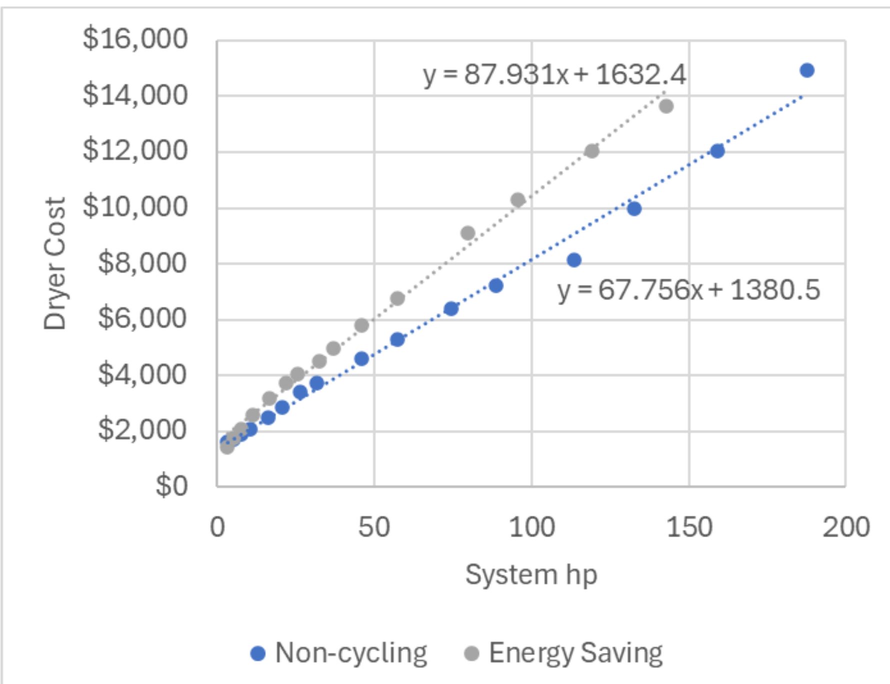

Figure 2: Refrigerated dryer costs

The second baseline case was a heatless desiccant dryer without dew point regeneration controls and the proposed case was an energy-saving refrigerated dryer. The incremental first cost between the baseline and proposed case is the cost difference between a desiccant dryer, obtained from manufacturing stakeholder interviews and a refrigerated cycling dryer with costs shown in Figure 2. Heatless desiccant dryers were found to be roughly $66 per hp in system size from data gathered in November 2025. Additional cost data for desiccant dryers will be gathered for the Final CASE Report.

The third baseline case was a heatless desiccant dryer without regeneration controls and the proposed case was a heatless desiccant dryer with regeneration controls. The incremental first cost is the addition of regeneration controls to the dryer system which were obtained from several stakeholder interviews. Interviews with multiple manufacturing stakeholders indicated that regeneration controls cost about $2,625 per dryer, regardless of system size. (Costs of the sensors, electronics, and valving do not vary with system size.) Regeneration controls are added to equipment during manufacturing and thus do not incur installation labor costs.

The fourth baseline case was a heatless desiccant dryer with dew point regeneration controls and the proposed case was a heated desiccant dryer with dew point regeneration controls. The incremental first cost for this measure is the additional equipment required for to heat the purge air for desiccant regeneration, also obtained from manufacturer stakeholder interviews. The incremental cost according to these stakeholders was about a 19 percent cost premium over heatless models. Additional cost data for heated desiccant dryers will be collected for the Final CASE Report.

The incremental costs for these four system types and baseline cases are summarized in Table 9 on a per prototype basis and in Table 10 on a per-hp basis. Per-hp impacts were calculated by dividing each per-prototype results by the total installed system air compressor hp as listed in Table 22.

Table 9: Compressed Air System Incremental First Cost by Prototype

Prototype	Non-cycling Refrigerated Dryer to Energy-Saving Refrigerated Dryer	Heatless Desiccant Dryer without Regeneration Controls to Energy-Saving Refrigerated Dryer	Heatless Desiccant Dryer without Regeneration Controls to Heatless Desiccant Dryer with Regeneration Controls	Heatless Desiccant Dryer to Heated Desiccant Dryer
Prototype 1	$2,773.75	$18,100.00	$2,625.00	$1,567.50
Prototype 2	$4,286.90	$28,131.70	$2,625.00	$2,508.00
Prototype 3	$9,330.65	$61,570.70	$2,625.00	$5,643.00
Prototype 4	$16,391.90	$108,385.30	$2,625.00	$10,032.00

Table 10: Compressed Air System Incremental First Cost by Prototype per hp

Prototype	Non-cycling Refrigerated Dryer to Energy-Saving Refrigerated Dryer	Heatless Desiccant Dryer without Regeneration Controls to Energy-Saving Refrigerated Dryer	Heatless Desiccant Dryer without Regeneration Controls to Heatless Desiccant Dryer with Regeneration Controls	Heatless Desiccant Dryer to Heated Desiccant Dryer
Prototype 1	$22.19	$144.80	$21.00	$12.54
Prototype 2	$21.43	$140.66	$13.13	$12.54
Prototype 3	$20.73	$136.82	$5.83	$12.54
Prototype 4	$20.49	$135.48	$3.28	$12.54

5.4 Incremental Maintenance and Replacement Costs

Incremental maintenances costs were evaluated per sub measure between the baseline case and the proposed case. For the first baseline case of non-cycling refrigerated dryers, the proposed case of energy-saving refrigerated dryers incurs no additional maintenance cost over the 30-year analysis period for the measure. The maintenance needs for refrigerated dryers are minimal and there is no incremental maintenance cost associated with switching from non-cycling to energy-saving dryers.

For the second baseline case of a heatless desiccant dryer and the proposed case of a cycling refrigerated dryer, the incremental maintenance cost was negative, representing a net savings. This is due to desiccant dryers requiring a desiccant material replacement every 10 years. Despite a negative incremental maintenance cost, multiple stakeholders stated that a significant number of facilities incur these costs despite a cheaper refrigerated dryer being sufficient for their needs. Reasons given include a belief that desiccant-dried air is inherently higher quality or previous under sizing of dryers leading to a belief that only desiccant dryers can serve the facility's needs.

Desiccant material replacement frequency was estimated based on manufacturer stakeholder interview input for desiccant material lifetime. The cost for desiccant replacement was estimated to be $2,500 for a 580 cfm dryer (Prototype 1 size) based on input from stakeholders. This cost was then extrapolated linearly to the sizes for the remaining prototypes. The Statewide CASE Team plans to gather more information on desiccant replacement frequency and cost through additional stakeholder outreach for the Final CASE Report.

For the third baseline case of adding of desiccant regeneration controls, the incremental maintenance cost was the cost associated with the regular recalibration and periodic replacement of the dew point or temperature probe. Through manufacturer stakeholder interviews, the Statewide CASE Team obtained costs for sensor recalibration, calibration frequency, and probe replacement. The probe was estimated to need recalibration every three years and replacement every ten years, which resulted in six total recalibrations and three replacements after initial installation over the 30-year period analysis.

For the fourth baseline case of heatless desiccant dryer and the proposed case of heated desiccant dryer, the incremental maintenance cost is associated with the additional upkeep for the blower, heating element, PLC controller, and additional valves required. Per one manufacturer in a stakeholder interview, the maintenance costs associated with heated are approximately double when compared to those of heatless. The Statewide CASE Team plans to supplement the costs estimates for this heated desiccant dryers through further stakeholder outreach and equipment research for the Final CASE Report.

Table 11: Compressed Air System Incremental Maintenance Cost by Prototype

Prototype	Non-cycling Refrigerated Dryer to Energy-Saving Refrigerated Dryer	Heatless Desiccant Dryer without Regeneration Controls to Energy-Saving Refrigerated Dryer	Heatless Desiccant Dryer without Regeneration Controls to Heatless Desiccant Dryer with Regeneration Controls	Heatless Desiccant Dryer to Heated Desiccant Dryer
Prototype 1	$0	-$6,127	$7,444	$3,063
Prototype 2	$0	-$9,803	$7,435	$4,901
Prototype 3	$0	-$22,056	$7,433	$11,028
Prototype 4	$0	-$39,210	$7,430	$19,605

Table 12: Compressed Air System Incremental Maintenance Cost by Prototype per hp

Prototype	Non-cycling Refrigerated Dryer to Energy-Saving Refrigerated Dryer	Heatless Desiccant Dryer without Regeneration Controls to Energy-Saving Refrigerated Dryer	Heatless Desiccant Dryer without Regeneration Controls to Heatless Desiccant Dryer with Regeneration Controls	Heatless Desiccant Dryer to Heated Desiccant Dryer
Prototype 1	$0	-$49	$60	$25
Prototype 2	$0	-$49	$37	$25
Prototype 3	$0	-$49	$17	$25
Prototype 4	$0	-$49	$9	$25

5.5 Cost Effectiveness

Results of the per-unit cost-effectiveness analyses are presented in Table 13 through Table 16 for each of the sub measures and prototypes. Cost-effectiveness results are the same for new construction, additions, and alterations. Cost-effectiveness will vary slightly across climate zone due to variation in the LSC with climate zone, but the Statewide CASE Team does not expect the climate zone effect on cost-effectiveness to be substantial. For the purposes of the Draft CASE Report, a weighted average of each hourly LSC energy cost factor was used for calculating cost benefits. The factor was weighted according to the existing market size across each climate zone from the CEC Construction Forecast. Cost-effectiveness results will be presented for each sub measure and each prototype across each climate zone in the Final CASE Report. However, the Statewide CASE Team expects only small variation in results across climate zone.

The proposed measures would be cost effective for each prototype and climate zone with one exception. For Prototype 4, the savings for the heated desiccant dryer measure are minimal and result in a BCR value of less than one. However, this is not intuitive, and the Statewide CASE Team will investigate further and update the Draft CASE Report accordingly prior to its publication. Heated desiccant dryers are typically recommended in larger size systems such as the one represented by Prototype 4. If there is indeed evidence that one or more of the sub measures is not cost-effective for certain climate zones or system sizes, the proposed code language will be modified in the Final CASE Report to ensure that only cost-effective conditions are covered. Aside from this one instance, the proposed measures save money over the 30-year period of analysis relative to the Standard Design conditions based on the analysis conducted for this Draft CASE Report.

The BCRs below are large, which suggests that many businesses may already choose to comply with these practices. This is supported by interviews with stakeholders. However, these stakeholders also emphasized that an important percentage of businesses do not implement these practices despite the cost-effectiveness as evidenced in the market adoption rates in Table 31. In other words, many, though not all businesses follow these practices already, but for those that do not, choosing to do so would be highly cost effective. As a result, the Statewide CASE team believes that the proposed measures would result in significant energy and monetary savings.

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 incremental equipment, replacement, and maintenance costs over the period of analysis. The analysis treats a negative incremental maintenance cost as a positive benefit. If total incremental costs are zero, the benefit-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 13: 30-Year Cost-Effectiveness Summary Per hp – Non-cycling Refrigerated Dryer to Energy Saving Refrigerated Dryer

Building Prototype	Benefits LSC Savings + Other PV Savings (2029 PV$)	Costs Total Incremental PV Costs (2029 PV$)	Benefit-to-Cost Ratio
Prototype 1	$1,846	$22	83.2
Prototype 2	$1,925	$21	89.8
Prototype 3	$1,931	$21	93.1
Prototype 4	$2,323	$20	113.4

Table 14: 30-Year Cost-Effectiveness Summary Per hp – Heatless Desiccant Dryer without Regeneration Controls to Energy Saving Refrigerated Dryer

Building Prototype	Benefits LSC Savings + Other PV Savings (2029 PV$)	Costs Total Incremental PV Costs (2029 PV$)	Benefit-to-Cost Ratio
Prototype 1	$4,845	$145	33.5
Prototype 2	$4,808	$141	34.2
Prototype 3	$4,681	$137	34.2
Prototype 4	$4,330	$135	32.0

Table 15: 30-Year Cost-Effectiveness Summary Per hp – Heatless Desiccant Dryer without Regeneration Controls to Heatless Regeneration Dryer with Regeneration Controls

Building Prototype	Benefits LSC Savings + Other PV Savings (2029 PV$)	Costs Total Incremental PV Costs (2029 PV$)	Benefit-to-Cost Ratio
Prototype 1	$1,667	$81	20.7
Prototype 2	$1,756	$50	34.9
Prototype 3	$1,700	$22	76.0
Prototype 4	$1,631	$13	129.8

Table 16: 30-Year Cost-Effectiveness Summary Per hp – Heatless Desiccant Dryer to Heated Desiccant Dryer

Building Prototype	Benefits LSC Savings + Other PV Savings (2029 PV$)	Costs Total Incremental PV Costs (2029 PV$)	Benefit-to-Cost Ratio
Prototype 1	$528	$37	14.3
Prototype 2	$417	$37	11.3
Prototype 3	$376	$37	10.2
Prototype 4	$2	$37	0.1

6. Statewide Impacts

6.1 Statewide Energy and Energy Cost Savings

Statewide energy and energy cost impacts were calculated for the proposed measures as they would apply to both new construction in the manufacturing sector as well as replacements in the existing manufacturing building stock (i.e. alterations). The existing and new construction market sizes in compressed air hp were determined based on several datapoints including total U.S. manufacturing compressed air energy usage, California statewide share of total U.S. manufacturing, market distribution across prototype sizes based on previous code cycle CASE Reports, and available market shares that are available for code influence.

Appendix C presents these details and assumptions in further detail. Additionally, see the 2028 CASE Methodology Report for details on how statewide new construction growth rates are calculated.

The tables below present the first-year statewide energy and LSC savings from newly constructed buildings and additions (Table 17) and alterations (Table 18) by climate zone.

Table 19 presents first-year statewide savings from new construction, additions, and alterations. The statewide impacts are dominated by alterations when existing dryers reach their end of life since compressed air systems in the existing building stock are far greater in magnitude than expected new construction in the manufacturing sector.

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

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (hp)	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	7	0.00	0.00	-	-	$0.01
2	156	0.04	0.00	-	-	$0.33
3	472	0.12	0.01	-	-	$0.98
4	224	0.06	0.01	-	-	$0.47
5	70	0.02	0.00	-	-	$0.15
6	150	0.04	0.00	-	-	$0.31
7	104	0.03	0.00	-	-	$0.22
8	126	0.03	0.00	-	-	$0.27
9	111	0.03	0.00	-	-	$0.24
10	134	0.03	0.00	-	-	$0.29
11	71	0.02	0.00	-	-	$0.15
12	182	0.05	0.00	-	-	$0.38
13	24	0.01	0.00	-	-	$0.05
14	29	0.01	0.00	-	-	$0.06
15	20	0.01	0.00	-	-	$0.04
16	15	0.00	0.00	-	-	$0.03
Total	**1,894**	**0.49**	**0.05**	**-**	**-**	**$3.97**

Table 18: Statewide Energy and LSC Impacts – Alterations

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (hp)	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	11	0.00	0.00	-	-	$0.02
2	45	0.01	0.00	-	-	$0.09
3	164	0.04	0.00	-	-	$0.33
4	211	0.05	0.00	-	-	$0.43
5	15	0.00	0.00	-	-	$0.03
6	194	0.05	0.00	-	-	$0.39
7	88	0.02	0.00	-	-	$0.18
8	325	0.08	0.01	-	-	$0.67
9	446	0.11	0.01	-	-	$0.92
10	131	0.03	0.00	-	-	$0.27
11	34	0.01	0.00	-	-	$0.07
12	151	0.04	0.00	-	-	$0.31
13	69	0.02	0.00	-	-	$0.14
14	45	0.01	0.00	-	-	$0.09
15	14	0.00	0.00	-	-	$0.03
16	25	0.01	0.00	-	-	$0.05
Total	**1,968**	**0.49**	**0.05**	**-**	**-**	**$4.00**

Table 19: 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	0.5	0.0	-	-	4
Alterations	0.5	0.0	-	-	4
Total	**1.0**	**0.1**	**-**	**-**	**8**

6.2 Statewide Greenhouse Gas Emissions Reductions

Table 20 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 1,082 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 20: 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	35	0	35	4368
Alterations	36	0	36	4404
Total	**71**	**0**	**71**	**8772**

6.3 Statewide Water Use Impacts

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

6.4 Statewide Material Impacts

The primary material contribution for this measure is associated with the dew point controls. These controls rely on dew point sensors, whose main material component is the stainless-steel housing (ATO n.d.). For estimation purposes, a conservative assumption was applied: one pound of stainless steel per dew point sensor probe, allocated to 50% of the forecasted new desiccant dryers to account for current market adoption. The Statewide CASE Team will continue to review manufacturer data to refine estimates of material contributions from dew point sensors. For more information on the Statewide CASE Team's methodology and assumptions used to calculate embodied GHG emissions, see the 2028 CASE Methodology Report.

Table 21: First-Year Statewide Impacts on Material Use

Material	Impact (response options: Increase, Decrease, No Change)	Per-Unit Impacts (Pounds per Square Foot)	First-Year Statewide Impacts (Pounds)	Embodied GHG emissions saved (Metric Tons CO2e)
Mercury	NC	0.000000	0	0
Lead	NC	0.000000	0	0
Copper	NC	0.000000	0	0
Steel	I	0.000119	0	-0.0003
Plastic	NC	0.000000	0	0
TOTAL	**N/A**	**0.000119**	**7**	**-0.0003**

6.5 Environmental Impacts

This measure aims to reduce the overspecification of desiccant dryers in cases where refrigerated dryers, which consume less energy, can adequately meet system dew point requirements. This measure also calls for the use of dew point controls to minimize compressed air consumption during desiccant dryer regeneration, thereby lowering overall energy demand. The reduction in energy consumption through lower electricity usage results in lower GHG emissions and improved local air quality.

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

6.6 Other Non-Energy Impacts

The Statewide CASE Team did not identify any other non-energy impacts of the proposed code language. Productivity and reliability of compressed air quality in manufacturing facilities would be the same for each set of Standard and Design conditions.

7. Proposed Language Code

7.1 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).

7.2 Administrative Code (Title 24, Part 1)

7.3 Energy Code (Title 24, Part 6)

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

Section 100.1(b) – Definitions: Recommends new or revised definitions for the following terms:

COMPRESSED AIR SYSTEM is a system of at least one compressor providing compressed air at 40 psig or higher and all its components upstream of pneumatic end uses.

LARGEST NET CAPACITY INCREMENT is the largest increase in capacity when switching between combinations of base compressors that is expected to occur under the compressed air system control scheme.

~~ONLINE COMPRESSORS are all the compressors that are physically connected to compressed air piping and are available to serve peak load. Online compressors do not include back up compressors whose only purpose is to be available when an online compressor fails.~~

TRIM COMPRESSOR is a compressor that is designated for part-load operation at least part of the time, handling the short-term variable trim load of end uses, in ~~addition to the~~ contrast to always fully loaded base compressors.

DESICCANT AIR DRYER is an air dryer that uses regenerative desiccant material to remove moisture from compressed air with or without supplemental heat and with or without purge air supplied by the air compressor for regenerating the desiccant material.

HEAT OF COMPRESSION AIR DRYER is a desiccant air dryer that uses heat recovered from the compression process to regenerate the desiccant media.

POINT-OF-USE AIR DRYER is an air dryer that operates at the same point that compressed air is intended to be used.

REFRIGERATED AIR DRYER is an air dryer that uses a refrigeration cycle to remove moisture from compressed air. This includes equipment with a hot gas bypass to prevent freezing at low loads.

ENERGY-SAVING REFRIGERATED AIR DRYER is a refrigerated dryer that includes capacity control features to reduce energy consumption in response to varying compressed air load. Capacity control features include cycling, thermal mass, digital scroll, and variable speed drives.

DESICCANT REGENERATION CONTROLS are controls that reduce energy consumption during the regenerative process of the desiccant material in a desiccant air dryer. The controls shall reduce regeneration cycle times and reduce overall energy consumption in response to the direct measurement of air dew point directly or indirect dew point measurement via other measures of desiccant material moisture and absorption.

SUBCHAPTER 3 – NONRESIDENTIAL, HOTEL/MOTEL OCCUPANCIES, AND COVERED PROCESSES – MANDATORY REQUIREMENTS

SECTION 120.6 – MANDATORY REQUIRMENTS FOR COVERED PROCESSES

(e) Mandatory requirements for compressed air systems.

All new compressed air systems~~, and all additions or alterations of compressed air systems~~ where the total combined horsepower (hp) of the compressor(s) is 25 hp or more shall meet the requirements of Subsections 1 through ~~5~~7. These requirements apply to the compressors, related piping systems, dryers, and related controls that provide compressed air and do not apply to any equipment or controls that use ~~or process~~ the compressed air.

EXCEPTION 1 to Section 120.6(e): Medical gas compressed air systems serving healthcare facilities.

1. Trim compressor and storage. The compressed air system shall be equipped with an appropriately sized trim compressor and primary storage to provide acceptable performance across the range of the system and to avoid control gaps. The compressed air system shall comply with Subsection A or B below:

A. The compressed air system shall include one or more variable speed drive (VSD) compressors. For systems with more than one compressor, the total combined capacity of the VSD compressor(s) acting as trim compressors must be at least 1.25 times the largest net capacity increment between combinations of compressors. The compressed air system shall include primary storage of at least one gallon per actual cubic feet per minute (acfm) of the largest trim compressor; or,

B. The compressed air system shall include a compressor or set of compressors with total effective trim capacity at least the size of the largest net capacity increment between combinations of compressors, or the size of the smallest compressor, whichever is larger. The total effective trim capacity of single compressor systems shall cover at least the range from 70 percent to 100 percent of rated capacity. The effective trim capacity of a compressor is the size of the continuous operational range where the specific power of the compressor (kW/100 acfm) is within 15 percent of the specific power at its most efficient operating point. The total effective trim capacity of the system is the sum of the effective trim capacity of the trim compressors. The system shall include primary storage of at least 2 gallons per acfm of the largest trim compressor.

~~**EXCEPTION 1 to Section 120.6(e)1**: Alterations where the total combined added or replaced compressor horsepower is less than the average per-compressor horsepower of all compressors in the system.~~

~~**EXCEPTION 2 to Section 120.6(e)1**: Alterations where all added or replaced compressors are variable speed drive (VSD) compressors and compressed air system includes primary storage of at least one gallon per actual cubic feet per minute (acfm) of the largest trim compressor.~~

EXCEPTION ~~3~~1 to Section 120.6(e)1: Compressed air systems that have been approved by the Energy Commission Executive Director as having demonstrated that the system serves loads for which typical air demand fluctuates less than 10 percent.

~~**EXCEPTION 4 to Section 120.6(e)1:** Alterations of existing compressed air systems that include one or more centrifugal compressors.~~

2. Controls. Compressed air systems with three or more compressors and a combined horsepower rating of more than 100 hp shall operate with controls that are able to choose the most energy efficient combination and loading of compressors within the system based on the current compressed air demand.

3. Monitoring. Compressed air systems having a combined horsepower rating equal to or greater than 100 hp shall have an energy and air demand monitoring system with the following minimum requirements:

A. Measurement of system pressure.

B. Measurement of amps or power of each compressor.

C. Measurement or determination of total airflow from compressors in cfm.

D. Data logging of pressure, power in kW, airflow in cfm, and compressed air system specific efficiency in kW/100 cfm at intervals of 5 minutes or less.

E. Maintained data storage of at least the most recent 24 months.

F. Visual trending display of each recorded point, load, and specific energy.

4. Leak testing of compressed air piping. Compressed air system piping greater than 50 adjoining feet in length shall be pressure tested after being isolated from the compressed air supply and end uses. The piping shall be pressurized to the design pressure and test pressures shall be held for a length of time at the discretion of the authority having jurisdiction, but in no case for less than 30 minutes, with no perceptible drop in pressure.

If dial gauges are used for conducting this test, these gauges must conform with California Plumbing Code Sections 318.3, 318.4, and 318.5.

Piping less than or equal to 50 adjoining feet in length shall be pressurized and inspected. Connections shall be tested with a noncorrosive leak-detecting fluid or other leak detecting methods at the discretion of the Authority Having Jurisdiction.

5. Pipe sizing. Compressed air piping greater than 50 adjoining feet in length shall be designed and installed to minimize frictional losses in the distribution network. These piping installations shall meet the requirements of Section 120.6(e)5A and either Section 120.6(e)5B or 120.6(e)5C:

A. Service line piping shall have inner diameters greater than or equal to ¾ inch. Service line piping are pipes that deliver compressed air from distribution piping to end uses.

B. Piping section average velocity. Compressor room interconnection and main header piping shall be sized so that at coincident peak flow conditions, the average velocity in the segment of pipe is no greater than 20 ft/sec. Compressor room interconnection and main header piping are the pipes that deliver compressed air from the compressor outlets to the inlet to the distribution piping. Each segment of distribution and service piping shall be sized so that at coincident peak flow conditions, the average velocity in the segment of pipe is no greater than 30 ft/sec. Distribution piping are pipes that deliver compressed air from the compressor room interconnection piping or main header piping to the service line piping.

C. Piping total pressure drop. Piping shall be designed such that piping frictional pressure loss at coincident peak loads is less than 5 percent of operating pressure between the compressor and end use or end use regulator.

6. Compressed air dryers. Compressed air dryers, other than point-of-use dryers, and their controls shall comply with Subsections A, B, C, and D below:

A. Any refrigerated air dryer shall be an energy-saving refrigerated air dryer.

B. Where required facility dewpoints are greater than 35°F, refrigerated air dryers shall be specified.

EXCEPTION 1 to 120.6(e)6B: Air dryers specified for applications that must maintain a precise dewpoint across all operating conditions.

C. All desiccant air dryers shall have controls that reduce regeneration time based on measurement of the desiccant material moisture load.

EXCEPTION 1 to 120.6(e)6C: Heat of compression air dryers.

D. Desiccant air dryers with capacity of 300 cfm or greater shall have internal or external heating to reduce purge compressed air.

EXCEPTION 1 to 120.6(e)6D: Air dryers that are supplying conditioned air to plants that need dew points less than or equal to -40 °F.

EXCEPTION 2 to 120.6(e)6D: Air dryers specified for applications that must maintain a precise dewpoint across all operating conditions.

~~6~~7. **Compressed Air System Acceptance**. Before an occupancy permit is granted for a compressed air system subject to Section 120.6(e), the 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 specified in NA7.13.

SUBCHAPTER 6 NONRESIDENTIAL, AND HOTEL/MOTEL OCCUPANCIES – ADDITIONS, ALTERATIONS, AND REPAIRS

SECTION 141.1 –REQUIRMENTS FOR COVERED PROCESSES IN ADDITIONS, ALTERATIONS TO EXISTING NONRESIDENTIAL, AND HOTEL/MOTEL BUILDINGS

(f) Mandatory requirements for compressed air systems.

All added or replaced compressed air systems where the total combined horsepower (hp) of the compressor(s) is 25 hp or more shall meet the requirements of Subsections 1 through 7. These requirements apply to the compressors, related piping systems, dryers, and related controls that provide compressed air and do not apply to any equipment or controls that use the compressed air.

EXCEPTION 1 to Section 141.1(f): Medical gas compressed air systems serving healthcare facilities.

1. Trim compressor and storage. All added and replacement air compressors shall meet the requirements of 120.6(e)1.

EXCEPTION 1 to Section 141.1(f)1: Alterations where the total combined added or replaced compressor horsepower is less than the average per-compressor horsepower of all compressors in the system.

EXCEPTION 2 to Section 141.1(f)1: Alterations where all added or replaced compressors are variable speed drive (VSD) compressors and compressed air system includes primary storage of at least one gallon per actual cubic feet per minute (acfm) of the largest trim compressor.

EXCEPTION 3 to Section 141.1(f)1: Compressed air systems that have been approved by the Energy Commission Executive Director as having demonstrated that the system serves loads for which typical air demand fluctuates less than 10 percent.

EXCEPTION 4 to Section 141.1(f)1: Alterations of existing compressed air systems that include one or more centrifugal compressors.

2. Controls. All added and replacement air compressors shall meet the requirements of 120.6(e)2.

EXCEPTION 1 to Section 141.1(f)2: Additions or replacements of less than a combined 100 hp in air compressor capacity.

3. Monitoring. All added and replacement air compressors shall meet the requirements of 120.6(e)3.

EXCEPTION 1 to Section 141.1(f)3: Additions or replacements of less than a combined 100 hp in air compressor capacity.

4. Leak testing of compressed air piping. All added and replacement compressed air piping greater than 50 adjoining feet in length shall meet the requirements of 120.6(e)4.

5. Pipe sizing. All added and replacement compressed air piping greater than 50 adjoining feet in length shall meet the requirements of 120.6(e)5.

6. Compressed air dryers. All added or replacement compressed air dryers shall meet the requirements of 120.6(e)6.

7. Compressed Air System Acceptance. Before an occupancy permit is granted for a compressed air system subject to Section 141.1(f), the 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 specified in NA7.13.

7.4 Reference Appendices

The Statewide CASE Team will provide recommended changes to the compressed air NA7.13 reference appendix in the Final CASE Report.

7.5 Compliance Manuals

There are no proposed changes to compliance manuals.

7.6 ACM Reference Manual

There are no proposed changes to the ACM Reference Manual.

7.7 Compliance Forms

As discussed in Section 2.4.5, the NRCC-PRC-E, PRCI-PRC-E, and NRCA-PRC-01-F compliance forms would be updated to reflect the proposed change. The Statewide CASE Team can support the CEC in implementing these updates if the proposed change is adopted.

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Appendix A: Assumptions for Cost-effectiveness Analysis

Key Assumptions for Energy Savings Analysis

Key assumptions for the energy savings analysis include:

- No climate zone dependence on dryer energy usage. This would be the case for the typical compressed air system which is installed inside a building with relatively constant ambient air conditions.
- Each prototype shares a common dryer for all the associated air compressors. This assumption may be altered in the Final CASE Report for Prototype 3 and 4.
- Prototypes and air compressor loads are consistent with previous code cycles.
- There is no peak demand reduction due to the proposed measures. Equipment will still reach the same instantaneous peak electrical demand despite energy savings.
- There will be no interactive effects with any other energy uses in the building, such as HVAC equipment.
- The location of the dryer will be consistent with the ISO7183 rated conditions.
- Dryer specifications are based on average equipment performance across the market and available products.
- The performance curve of energy-saving refrigerated dryers is linear across load. In other words, the electrical energy demand is linearly proportional between the ten percent and full load conditions as reported on CAGI datasheets.
- Regeneration energy consumption is also linearly proportional to load fractions when regeneration load-following controls are installed.

Energy Savings Methodology per Prototypical Building

The four prototype systems are shown in Table 22.

Table 22: Compressed Air System Prototypes

Variable	Prototype 1	Prototype 2	Prototype 3	Prototype 4
Rated Flow (cfm)	579	966	2,181	4,666
Nominal Operating Base Load (cfm)	342	729	1,417	3,138
Nominal Trim Load (cfm)	237	237	764	1,528
Primary Receiver Size (gall)	474	474	1,528	3,050
Compressor 1 (baseload)	75 hp, load/unload, single stage, lubricant injected, reciprocating	150 hp, load/unload, single stage, lubricant injected, reciprocating	300 hp, load/unload, single stage, lubricant injected, reciprocating	500 hp, inlet vane, multiple stage, centrifugal
Compressor 2 (trim)	50 hp, VSD, single stage, lubricant injected, rotary screw	50 hp, VSD, single stage, lubricant injected, rotary screw	150 hp, VSD, single stage, lubricant injected, rotary screw	150 hp, VSD, single stage, lubricant injected, rotary screw
Compressor 3 (trim)	N/A	N/A	N/A	150 hp, VSD, single stage, lubricant injected, rotary screw

Each prototype has two load profiles, one for weekdays and one for weekends, to match two shift, seven-day operation. Figure 3 through Figure 6 show weekday profiles, and Figures 7-10 show weekend profiles. The load profile shapes shown in are the same across prototypes, scaled to match the capacity of each system.

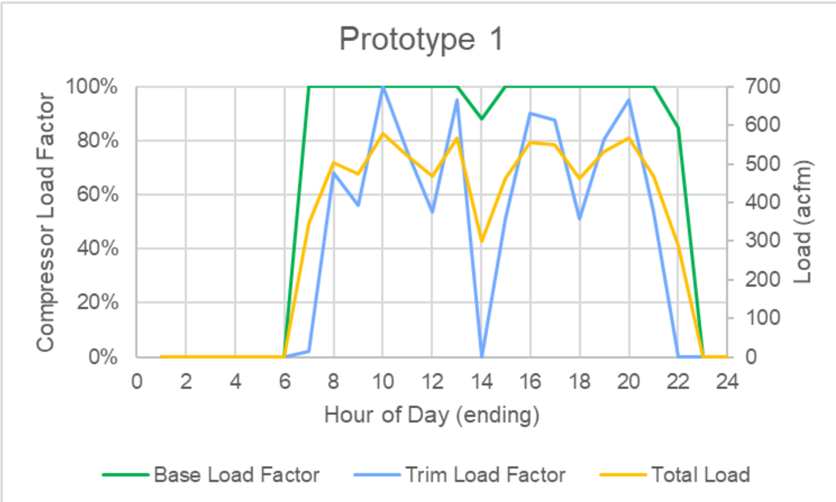

Figure 3: Weekday Load Profile for Prototype 1

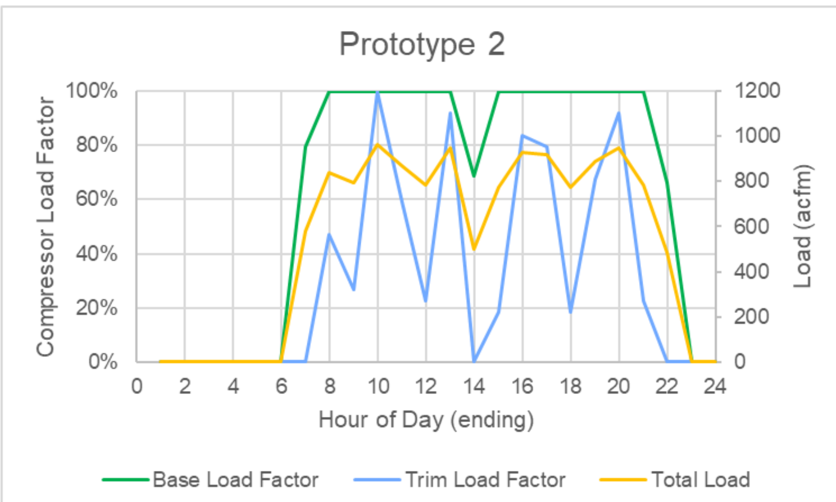

Figure 4: Weekday Load Profile for Prototype 2

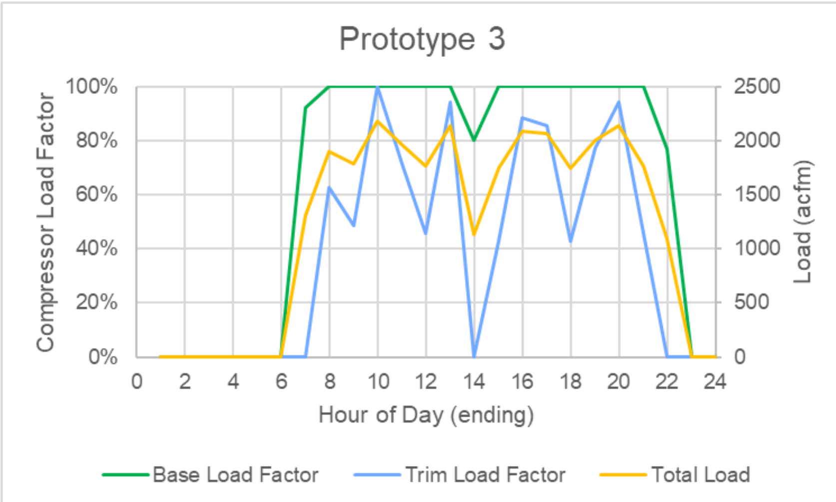

Figure 5: Weekday Load Profile for Prototype 3

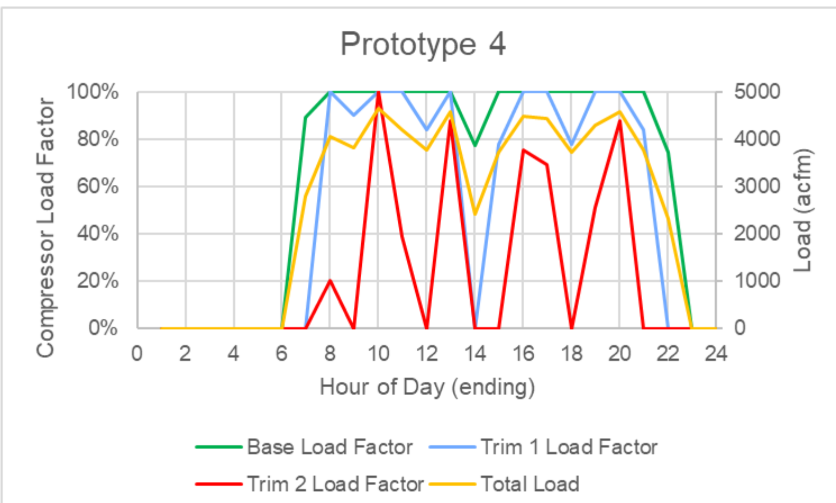

Figure 6: Weekday Load Profile for Prototype 4

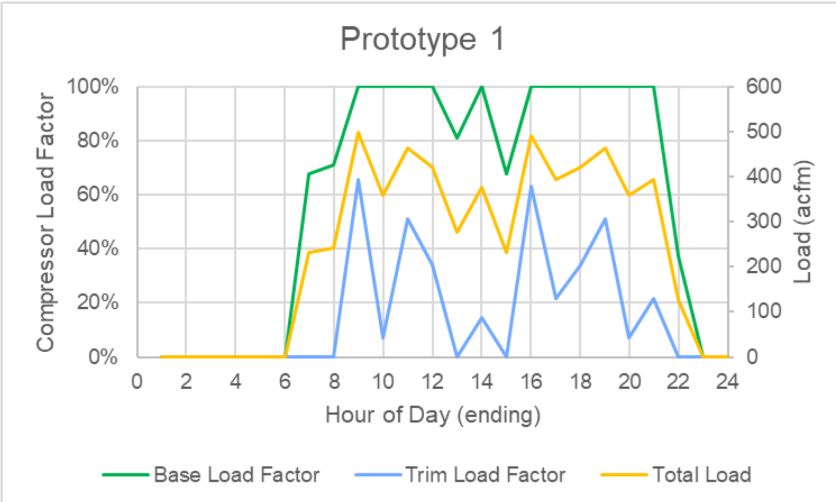

Figure 7: Weekend Load Profile for Prototype 1

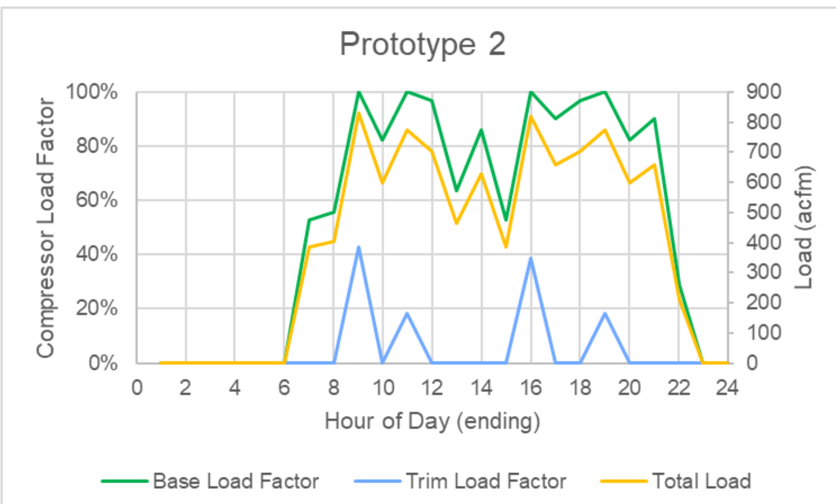

Figure 8: Weekend Load Profile for Prototype 2

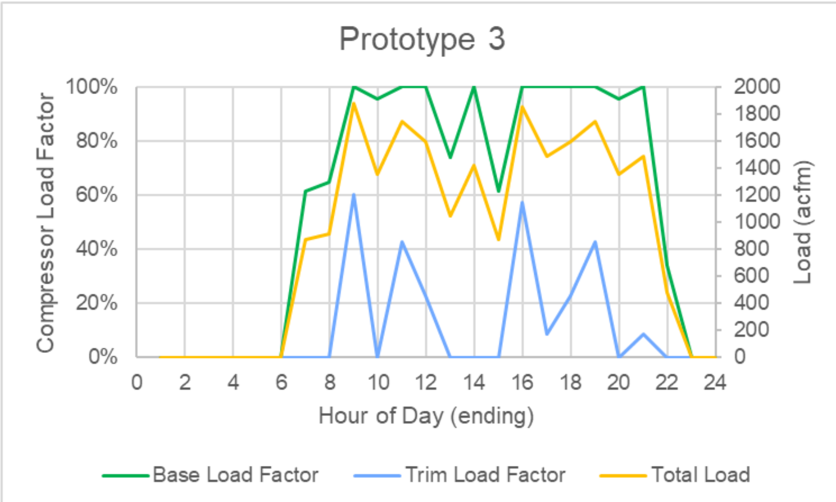

Figure 9: Weekend Load Profile for Prototype 3

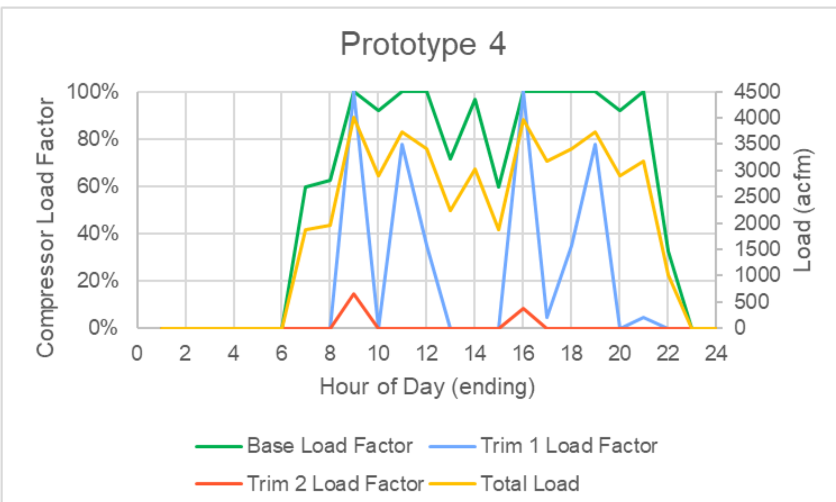

Figure 10: Weekend Load Profile for Prototype 4

Dryer equipment was not included in the air compressor prototypes in previous code cycles, so the Statewide CASE Team specified this equipment for each prototype for the cost effectiveness analysis. For the Draft CASE Report, it is assumed that the compressed air system shares a common dryer, sized to match the total plant peak airflow at ISO 7183 conditions. In the Final CASE Report, multiple dryers will be considered as alternative for Prototypes 3 and 4.

There are four dryer cases that are needed as Standard and Proposed Designs that enable calculation of energy usage and savings of the proposed changes across the four prototypes. These four submeasures are defined in Table 23, each of which was analyzed for each of the four prototype systems.

Table 23: Standard and Proposed Designs

Submeasure	Standard Design	Proposed Design
Submeasure 1	Non-cycling refrigerated dryer	Energy-saving refrigerated dryer
Submeasure 2	Heatless desiccant dryer without regeneration controls	Energy-saving refrigerated dryer
Submeasure 3	Heatless desiccant dryer without regeneration controls	Heatless desiccant dryer with regeneration controls
Submeasure 4	Heatless desiccant dryer with regeneration controls	Heated desiccant dryer with regeneration controls

The specifications for each of these submeasure, shown in Table 24, were determined by gathering performance data for available dryer equipment across the market. Purge rates, heater power, blower power, and specific power were all gathered from the specification sheets and equipment literature for dryers available across the market. This data came from information for 200 non-cycling refrigerated dryers, 156 cycling refrigerated dryers, 215 heatless desiccant dryers, and 135 heated desiccant dryers from both CAGI and manufacturer product literature.

Table 24: Standard and Proposed Air Dryer Specifications

Design	Definition
Non-cycling refrigerated dryer	Specific power at full flow: 0.80 kW/100cfm Specific power at 10% flow: 7.35 kW/100cfm
Energy-saving refrigerated dryer	Specific power at full flow: 0.75 kW/100cfm Specific power at 10% flow: 2.23 kW/100cfm
Heatless desiccant dryer without regeneration controls	Purge rate: 15% of rated capacity Regeneration time: constant across all load conditions
Heatless desiccant dryer with regeneration controls	Purge rate: 15% of rated capacity Regeneration time: proportional to part-load conditions
Heated desiccant dryer with regeneration controls	Purge rate: 7.2% of rated capacity, proportional to part-load conditions Heater specific power: 1.2 kW/100cfm Regeneration time: proportional to part-load conditions

Energy usage for each hour of the weekday and weekend profiles was calculated for each dryer design. For the refrigerated dryer cases, direct energy usage of the dryer was calculated based on the load fraction for each hour of the daily profiles and the specific power as applied to that hourly load:

$$Hourly\ refrigerated\ dryer\ kWh = (Load\ Fraction * a + b) * (Load\ Fraction * Rated\ Flow)/100$$

Where *Load Fraction* is defined hourly by the profiles in Figure 3 and Figure 4, *Rated Flow* is total system capacity listed in Table 22 for each prototype, and *a* and *b* are the linear fit coefficients to the average refrigerated dryer performance curves shown in Figure 1111.

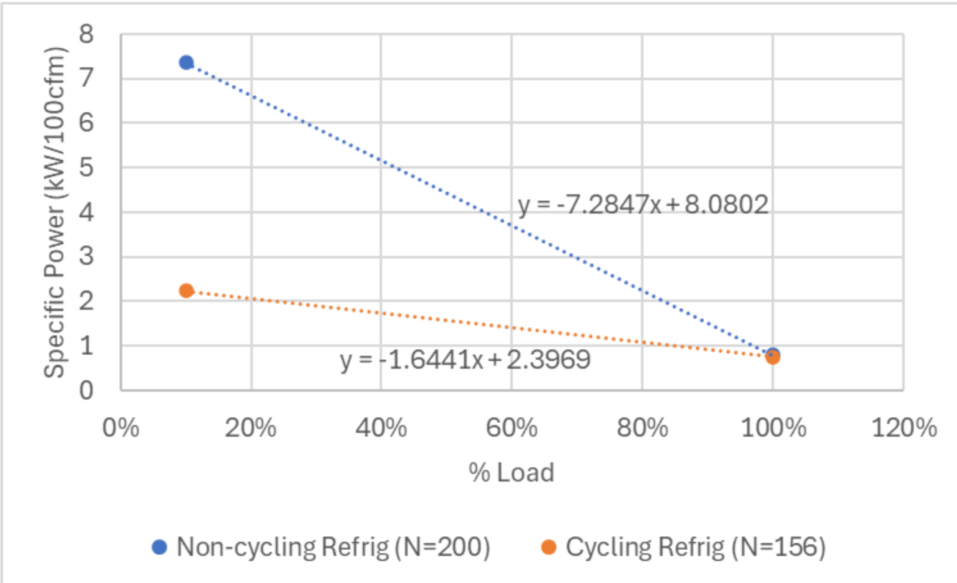

Figure 1111: Refrigerated dryer performance curves

For the desiccant dryer cases, purge air energy was calculated based on the hourly air compressor specific energy, load fraction, and purge rate:

$$
\begin{aligned}
&\mathit{Hourly\ desiccant\ dryer\ kWh} \\
&\quad = \Bigg(\bigg(\mathit{Purge\ rate} * \mathit{Air\ Compressor\ Specific\ Power} \\
&\quad + \begin{cases} 0, & \text{if heatless} \\ \mathit{Heater\ specific\ power}, & \text{if heated} \end{cases}\bigg) * \mathit{Rated\ Flow}/100\Bigg) \\
&\quad * \begin{cases} 1, & \text{without regeneration controls} \\ \mathit{Load\ Fraction}, & \text{with regeneration controls} \end{cases}
\end{aligned}
$$

where the air compressor specific power is determined by the hourly air compressor energy consumption and load profiles defined in previous code cycles after compliance with the existing requirements.

Energy usage for each dryer case was calculated for each hour of the weekend and weekday profiles and then extrapolated to a single calendar year with ten Federal holidays observed. Energy savings for each submeasure in Table 23 is then calculated by comparison of the respective Standard and Proposed Designs.

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 Section 7 of this report for marked-up code language.

Purpose and Necessity of Changes to Title 24, Part 1

No changes are proposed to Title 24, Part 1.

Purpose and Necessity of Changes to Title 24, Part 6

Section: 100.1(b)

Purpose: The purpose of these changes is to aid in the interpretation and implementation of new requirements for compressed air dryers in Title 24, Part 6, Section 120.6(e) by adding new definitions.

Necessity: These changes add definitions for desiccant air dryer, heat of compression air dryer, point-of-use air dryer, refrigerated air dryer, energy-saving refrigerated air dryer, and desiccant regeneration controls. They also remove a definition for online compressors that is no longer necessary and modifies definitions for compressed air system and trim compressor.

Section: 120.6(e)

Purpose: The purpose of these changes is to require new compressed air dryers to meet several new requirements. The system's required dew point must be stated on design documents, and the required dew point governs whether a refrigerated dryer or desiccant dryer should be used. In addition, all refrigerated dryers must be an energy-saving type. All desiccant dryers with a capacity of at least 300 cfm must have controls to adjust regeneration depending on measured moisture load. These changes also move some language relating to compressed air dryer system modifications to Section 144.1.

Necessity: These changes are intended to reduce compressed air dryer energy consumption. These adjustments align with the mandated cost-effective building design standards outlined in the California Public Resources Code, specifically Sections 25213 and 25402.

Section: 141.1(d)

Purpose: The purpose of these changes is to add language corresponding to the proposed changes to 120.6(e), relating to new requirements for compressed air dryers. The changes to 141.1(d) would ensure that modifications to compressed air dryer systems trigger the same requirements unless an exception applies. Exceptions relating specifically to system modifications that were originally in 120.6(e) have also been moved to 141.1(d).

Necessity: These changes are intended to reduce compressed air dryer energy consumption. These adjustments align with the mandated cost-effective building design standards outlined in the California Public Resources Code, specifically Sections 25213 and 25402.

Purpose and Necessity of Changes to the Reference Appendices

Section: NA7

Purpose: The purpose of this change is to add acceptance testing requirements for compressed air dryer dew point controls.

Necessity: This change is necessary in order to implement and enforce the proposed requirements for compressed air dryers.

Appendix C: Assumptions for Statewide Savings Estimates

The California compressed air market, construction, and growth rates are not captured in the California Energy Commission construction forecast that is used as a default for 2028 CASE Reports. Compressed air systems covered by code predominately exist in industrial facilities. While these facilities are captured in the existing manufacturing floorspace and project new construction floorspace, these do not correlate with compressed air system capacity. So, an alternate approach to calculating total market size was developed by the Statewide CASE Team.

The total compressed air energy footprint for U.S. manufacturing was calculated for the Department of Energy by Energetics using data from the U.S. Energy Information Administration's 2018 Manufacturing Energy Consumption Survey (Energetics 2022) (U.S EIA 2021). The total national manufacturing sector electrical energy consumption for compressed air was determined to be 263 TBtu per year. Using California's 14.5 percent share of all U.S. manufacturing output, California's compressed air energy usage is about 38.1 TBtu per year or 11,177 GWh/yr[2].

Table 25: Existing statewide compressed air market energy footprint

Data	Variable Name	Value	Source
U.S. Compressed Air Electrical Energy Consumption (TBtu/yr)	A	263	(Energetics 2022)
California Share of U.S. Manufacturing	B	14.5%	(California Manufacturing Technology Consulting 2022)
California Compressed Air Energy Consumption (TBtu/yr)	C	38.1	A*B
California Compressed Air Energy Consumption (GWh/yr)	D	11,177	C*unit conversion

To estimate statewide potential energy savings for the proposed measures, it was necessary to estimate the distribution of compressed air system hp in the existing building stock. The Statewide CASE Team estimated this installed capacity distribution

[2] Using a slightly different approach, the 2022 Final CASE Report for compressed air included an estimated 9,784 GWh/yr based on 2001 survey data. The two market size estimates are in rough agreement, accounting for annual growth rate.

by combining the total California market size, prototype annual energy consumption, and market statistics as reported in a Department of Energy compressed air survey (Xenergy 2001).

Table 26: Existing statewide compressed air market horsepower

Data	Variable Name	Prototype 1	Prototype 2	Prototype 3	Prototype 4	Source
Approximate energy footprint fraction of installed systems by prototype	E	19%	54%	12%	16%	(Statewide CASE Team 2020)
California existing market energy footprint by prototype size (GWh/yr)	F	2.08	5.99	1.36	1.75	E*D
Annual energy consumption per prototype (kWh/yr)	G	501,836	793,903	1,762,067	3,195,834	(Statewide CASE Team 2020)
Statewide number of sites by prototype	H	4,136	7,359	772	549	$F/G/10^9$
Statewide installed hp by prototype	I	517,055	1,507,804	347,624	439,190	H*prototype hp

Table 27: 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
Manufacturing	0.01	0.13	0.40	0.19	0.06	0.13	0.09	0.11	0.10	0.11	0.06	0.16	0.02	0.02	0.02	0.01	1.62

Table 28: 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
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**

Using the distribution of existing floorspace in the manufacturing sector in Table 28 and the new construction forecast in Table 27 to establish growth rates across climate zones, the installed and new construction compressed air system hp by prototype can be calculated. The existing and new construction market size in horsepower for each prototype is shown in Table 29 and

Table 30.

Table 29: Estimated New Nonresidential hp in 2026, by Climate Zone and Prototype (hp)

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
Prototype 1	1.21	28.61	86.86	41.19	12.89	27.62	19.13	23.14	20.46	24.63	12.98	33.46	4.42	5.28	3.74	2.72	348.34
Prototype 2	3.55	83.43	253.26	120.14	37.57	80.59	55.77	67.49	59.64	71.81	37.88	97.61	12.92	15.39	10.91	7.91	1,015.87
Prototype 3	0.80	19.22	58.40	27.69	8.65	18.57	12.85	15.54	13.75	16.56	8.74	22.50	2.97	3.55	2.50	1.82	234.13
Prototype 4	**1.02**	**24.29**	**73.76**	**34.98**	**10.94**	**23.48**	**16.25**	**19.65**	**17.37**	**20.92**	**11.03**	**28.43**	**3.77**	**4.48**	**3.18**	**2.32**	**295.87**

Table 30: Estimated Existing Nonresidential hp in 2026, by Climate Zone and Prototype (thousand hp)

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
Prototype 1	2.00	8.24	30.20	38.79	2.73	35.76	16.22	59.83	81.97	24.18	6.27	27.80	12.66	8.28	2.51	4.52	361.94
Prototype 2	5.84	24.02	88.06	113.11	7.95	104.27	47.31	174.47	239.02	70.50	18.29	81.06	36.93	24.14	7.32	13.19	1,055.46
Prototype 3	1.35	5.54	20.30	26.08	1.83	24.04	10.91	40.22	55.11	16.25	4.22	18.69	8.51	5.57	1.69	3.04	243.34
Prototype 4	**1.70**	**7.00**	**25.65**	**32.95**	**2.32**	**30.37**	**13.78**	**50.82**	**69.62**	**20.53**	**5.33**	**23.61**	**10.76**	**7.03**	**2.13**	**3.84**	**307.43**

Only a portion of this market could be influenced by the proposed code changes. The Statewide CASE Team interviewed stakeholders on the naturally occurring adoption rate of the proposed measures in the compressed air market. From these interviews, the percentage of sites that are not already including the proposed measures are shown in Table 31.

Table 31: Natural Adoption Rates of Proposed Measures

Submeasure	Standard Design	Proposed Design	Market Share without Natural Adoption
Submeasure 1	Non-cycling refrigerated dryer	Energy-saving refrigerated dryer	10%
Submeasure 2	Heatless desiccant dryer without regeneration controls	Energy-saving refrigerated dryer	5%
Submeasure 3	Heatless desiccant dryer without regeneration controls	Heatless desiccant dryer with regeneration controls	11.9%
Submeasure 4	Heatless desiccant dryer with regeneration controls	Heated desiccant dryer with regeneration controls	**4%**

Applying these adoption rates for the proposed measures for the new construction market size and the existing market size with an annual replacement rate of 7.7% (1/EUL), the Statewide CASE Team calculated the total annual impacted horsepower for each sub measure across prototypes and climate zones. The tabulation of annual impacted system hp across sub measures, prototypes, and climate zones will be included in the Final CASE Report.

Appendix D: Environmental Analysis

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 will not result in a significant effect on the environment.

Direct Environmental Impacts

Direct Environmental Benefits

Specifying desiccant dryers where refrigerated units satisfy process requirements results in unjustified energy consumption. Similarly, the absence of dew point controls prolongs regeneration cycles, incurring unnecessary energy expenditure. Improving the specification process for and the operation of compressed air dryers will therefore save energy and reduce GHG emissions resulting from the production of electricity.

The direct environmental benefits of this proposal are demonstrated by the estimated energy reductions, as discussed in Sections 2.5.1 and 2.5.2.

Direct Adverse Environmental Impacts

The Statewide CASE Team has not identified any direct adverse environmental impacts.

Indirect Environmental Impacts

Indirect Environmental Benefits

The Statewide CASE Team has not identified any indirect environmental benefits.

Indirect Adverse Environmental Impacts

The Statewide CASE Team has not identified 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 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 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 this measure would result in significant direct or indirect adverse environmental impacts and therefore did not develop any mitigation measures.

Water Use and Water Quality Impacts Methodology

There are no water use or water quality impacts for this measure.

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 in this Draft CASE Report that reflect broad support. 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.

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 results of analyses
- Data to support assumptions
- Compliance and enforcement
- Technical and market feasibility

The Statewide CASE Team hosted one stakeholder meetings for compressed air drying via webinar, with one forthcoming, as described in Table 32. 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 2025a) (Statewide CASE Team 2025b) (Statewide CASE Team 2025c).

Table 32: Utility-Sponsored Stakeholder Meetings

Meeting Name and Link to Materials	Meeting Date	Summary of Items Discussed
First Round Compressed Air Utility-Sponsored Stakeholder Meeting	Wednesday, October 29, 2025	• Market shares • Data collection processes • Code change intent • Calculation methodology • Market, technical, and compliance barriers and solutions • Requests for input
Second Round of Compressed Air Utility-Sponsored Stakeholder Meeting	TBD, March 2026	• Forthcoming

The first round of utility-sponsored stakeholder meetings began in October 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.

The second Compressed Air Dryer utility-sponsored stakeholder meetings will be held in March 2026 to provide updated details on proposed code changes. These of meetings will introduce early results of energy, cost effectiveness, and incremental cost analyses, and they will also solicit feedback on refined draft code language.

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 a 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 beyond 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.

Statewide CASE Team Communications

The Statewide CASE Team held personal communications over email, phone, and videoconference with numerous stakeholders when developing this report, listed in Table 33. Most stakeholders preferred to be anonymous.

Table 33: Engaged Stakeholders

Organization/Individual Name	Market Role	Mentioned in CASE Report Sections
Anonymous Stakeholder 1	Manufacturer, Dryer Subject Matter Expert	2.1 Proposed Code Language 3. Compliance and Enforcement 4.1.1 Current Market Structure and Availability 5.3 Incremental First Cost 5.4 Incremental Maintenance and Replacement Costs
Anonymous Stakeholder 2	Industry Trade Association	2.1 Proposed Code Language 3. Compliance and Enforcement 4.1.1 Current Market Structure and Availability
Anonymous Stakeholder 3	Industry Consultant and Compressed Air System Designer	2.1 Proposed Code Language 5.3 Incremental First Cost 5.4 Incremental Maintenance and Replacement Costs
Anonymous Stakeholder 4	Manufacturer, Dryer Subject Matter Expert	5.3 Incremental First Cost 5.4 Incremental Maintenance and Replacement Costs
Anonymous Stakeholder 5	Manufacturer, Dryer Subject Matter Expert	2.1 Proposed Code Language 4.1.1 Current Market Structure and Availability 4.1.2 Market Challenges 5.4 Incremental Maintenance and Replacement Costs
Anonymous Stakeholder 6	Manufacturer, Dryer Subject Matter Expert	5.3 Incremental First Cost 5.4 Incremental Maintenance and Replacement Costs
Anonymous Stakeholder 7	Industry Consultant and Compressed Air System Assessor	2.1 Proposed Code Language 5.3 Incremental First Cost 5.4 Incremental Maintenance and Replacement Costs
Anonymous Stakeholder 8	Manufacturer, Dryer Subject Matter Expert	2.1 Proposed Code Language 3. Compliance and Enforcement 4.1.1 Current Market Structure and Availability

Engagement with ESJ communities

The Statewide CASE Team did not conduct stakeholder outreach specifically targeted towards ESJ communities for this proposed code change. The proposed measures would have no direct impact on residential communities in California, and the only indirect anticipated impact is decreased exposure to air pollution due to reduced natural gas combustion at nearby industrial facilities.