Codes and Standards Enhancement (CASE) Initiative

2028 California Energy Code

Updates to Nonresidential Hydronic Heat Pump Requirements

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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
AHRI	Air-Conditioning, Heating, and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
ATT	Acceptance Test Technician
AWHP	Air-to-Water Heat Pump
BAS	Building Automation System
BCR	Benefit-to-cost Ratio
Btu	British Thermal Units
CALGreen	California Green Building Standards Code
CARB	California Air Resources Board
CASE	Codes and Standards Enhancement
CBSC	California Building Standards Commission
CBECC	California Building Energy Code Compliance Software
CEC	California Energy Commission
CEQA	California Environmental Quality Act
CBO	Community-Based Organization
CPUC	California Public Utilities Commission
CZ	Climate Zone
DAC	Disadvantaged Community
DOAS	Dedicated Outdoor Air System
DOSH	Division of Occupational Safety and Health
ECC	Energy Code Compliance
EIR	Environmental Impact Report
ESJ	Environmental and Social Justice
FSOR	Final Statement of Reasons
GHG	Greenhouse Gas
GWh	Gigawatt-Hour
GWP	Global Warming Potential
HVAC	Heating, Ventilation, and Air Conditioning
IECC	International Energy Conservation Code

IOU	Investor-Owned Utility
ISO	International Organization for Standardization
ISOR	Initial Statement of Reasons
kWh	Kilowatt-Hour
kWh/year	Kilowatt-Hour Per Year
LSC	Long-term System Cost
MeasureSET	CASE Measure Savings Estimation Template
PEP	Public Engagement Plan
PV	Present Value
SOC	Standard Occupational Classification
W	Watt
WWHP	Water-to-Water Heat Pump

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. *Existing field studies that evaluate design and installation practices that have positive or negative impacts on installed efficiency of air-to-water heat pumps (AWHPs) and water-to-water heat pumps (WWHPs), especially practices related to reducing water flow to non-operating equipment, and selecting the optimal glycol concentration for AWHPs.*
2. *Potential first cost and maintenance cost implications of the proposed measures.*
3. *Input on whether acceptance testing is warranted and feasible for the proposed measures.*
4. *Possible exceptions that may be necessary for uncommon applications and system designs.*

Email comments and suggestions to info@title24stakeholders.com and bhendron@frontierenergy.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.

1.2.1 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, HVAC designers, installers, researchers, subject matter experts, Title 24 energy analysts, and others involved in the code compliance process. The proposal incorporates feedback received during a public stakeholder workshop that the Statewide CASE Team held on October 29, 2025 (Statewide CASE Team 2025a) (Statewide CASE Team 2025b) (CEC 2025).

In addition to feedback during the first Stakeholder Meeting, the Statewide CASE Team interviewed or received written input from 12 stakeholders and SMEs to help define the proposed measures, estimate incremental costs, and better understand industry concerns. At least nine of the stakeholders have HVAC design experience, and six represent manufacturers.

These discussions led to the following key takeaways:

- There was general support for the AWHP/WWHP isolation measure, and mostly neutral feelings toward the glycol concentration limits because most energy-conscious designers already balance efficiency with freeze/burst protection.
- The designers generally felt that their company makes a thorough effort to minimize energy use and would not be significantly affected by either measure. But they acknowledge that some designers, manufacturers, and installers may not be as conscientious and the measures would help ensure a base level of energy efficiency in all hydronic heat pump installations.
- The stakeholders confirmed that the HVAC designer is responsible for equipment isolation and glycol concentration specifications, but manufacturers, installers, and building owners play a vital role in the process.
- Several stakeholders pointed out that some manufacturers advocate strongly for continuous flow even when individual AWHPs are turned off, partly for simplicity and cost for controls and plumbing, and partly to ensure adequate flow is

available during AWHP startup to avoid damaging equipment. In these cases, designers must negotiate a reasonable solution, potentially including changes to equipment controls provided by the manufacturer, to properly limit water flow through non-operating heat pumps.

- All stakeholders felt that incremental first costs and maintenance costs for both measures would be very low or zero, because most of the needed plumbing and controls would already be available for the AWHP isolation measure, and glycol management and tracking processes would already be in place.
- Several stakeholders identified special cases that might require exceptions in the code language. For AWHP isolation, this included flow just prior to startup to avoid equipment damage, or a minimum flow rate during cold weather to prevent burst or frozen pipes. For glycol concentration, concerns were expressed about ice storage, ventilation air heating, and semi-conditioned spaces when considering the prohibition of glycol if the entire water loop is inside the building envelope. There were also concerns from one manufacturer about relying on JA2 heating median of extremes in case global warming or microclimates result in colder temperatures than expected.
- All stakeholders with experience selecting glycol concentration focused on burst protection rather than freeze protection, but several felt that flexibility should be given to building owners who wanted the extra safety margin of using the freeze protection limit as the basis for selecting glycol concentration.

These inputs were factored into the code language and justification for the two proposed measures. Further interviews are planned prior to the Final CASE Report.

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

2. Alignment with Boiler and Chiller Requirements

2.1 Alignment with Boiler and Chiller Requirements - Measure Description

2.1.1 Proposed Code Change

This proposal seeks to introduce prescriptive requirements for AWHPs/Water-to-Water Heat Pumps (WWHPs) in Sections 140.4(k) and mandatory acceptance test requirements in Section 120.5 of Title 24, Part 6, to align water flow shut-off requirements with those for chillers and boilers in non-residential buildings. For staged, multi-unit AWHP/WWHP systems, the measure would require preventing or minimizing the pump flow to any heat pump unit that is in not operating without impacting the flow to active units. AWHPs and WWHPs that require flow shut-off controls would be tested in accordance with NA7.5.7, which already applies to other hydronic systems including chillers and boilers. These requirements would be applied to all non-residential electric or gas AWHP/WWHP installations where multiple units are staged to meet space conditioning and hot water needs, irrespective of climate zone, building and space type (Other than Group R Occupancy), and construction type.

The scope of the proposed code change is summarized in Table 2.

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 120.5 and 140.4(k) Possible changes to Reference Appendices TBD	NRCC-MCH-E, NRCI-MCH-E and NRCC-PRF-E	TBD

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

2.1.2 Benefits of Proposed Change

Improper design and installation of AWHPs and WWHPs can lead to overall performance degradation resulting in decreased energy efficiency and higher utility bills. Adoption of this technology in accordance with design and installation best practices is crucial as the State of California looks to significantly increase heat pump usage over the next decade. If substandard design and installation practices take hold at this early stage in AWHP deployment, these practices may become commonplace and ingrained with the design and installation community, resulting in performance below expectations and a poor reputation for the technology.

One important benefit to the proposed code change is that it helps clarify that certain hydronic system requirements already established for boilers and chillers also apply to AWHPs and WWHPs. This helps put heat pump technology on an equal footing with more traditional heating and cooling systems, while also ensuring that certain basic quality assurance requirements are met for all system types. More specifically, the proposed measure requires that AWHPs and WWHPs comply with the equipment isolation requirements and acceptance testing that currently applies to boilers and chillers.

Another benefit is that average installed efficiency of AWHP/WWHP systems will increase in many non-residential buildings because unnecessary pump energy and associated thermal losses will be greatly decreased when unused AWHPs/WWHPs are turned off. This equipment isolation issue has been identified through field studies and interviews with stakeholders as highly detrimental to energy efficiency, and common enough that action should be taken through the energy code. The exact frequency of the issue being addressed is not yet known, and further field studies may be necessary.

Finally, it is important to intervene before improper AWHP/WWHP staging and equipment isolation practices become more difficult to change as the market rapidly increases in the coming years. The proposed measure is a simple and straightforward step that is unlikely to meet resistance from the industry.

2.1.3 Background Information

AWHPs and WWHPs use a refrigerant loop, compressor, and heat exchangers to heat and cool a working fluid (typically water), which is then used to heat and cool interior building zones or provide service hot water. Systems that use water as the medium for the distribution of heating and cooling energy are generally referred to as hydronic space conditioning systems. Chillers and boilers also fit into this category. AWHPs draw and reject energy from outside air, while WWHPs use a water source, such as a ground loop or a separate building tempered water loop. Most hydronic heat pumps are all-electric, but the compressor may also be powered by a natural gas engine. A representative AWHP rooftop application is shown in Figure 1.

AWHPs and WWHPs distribute water into a building instead of refrigerant, which gives the technology a variety of non-energy benefits over traditional split systems including reduced refrigerant charge, reduced likelihood of refrigerant leaks, easier maintenance, and a faster and safer path to the future use of near-zero global warming potential refrigerants.

Figure 1. Trane Ascend AWHP

Photo credit: Trane

While AWHPs seem like a nascent technology, they have actually been around longer than mini-split heat pumps and heat pump water heaters. The first AWHP certified by the CEC was listed in the Appliances Database was the Aermec ANK series in 2013, but AWHPs have been sold in California as far back as the late 1980s, with gas absorption heat pumps reaching the market in 2004 (ROBUR Corporation 2025). Additionally, the ancestor of the AWHP, the residential chiller, has been “generally available” since at least the 1960s(ASHRAE 1967) in both electric and natural gas versions.

Despite this, AWHPs have remained a niche technology in California’s HVAC market, although market penetration in the non-residential sector appears to be more established based on discussions with stakeholders. As interest in electrification has increased due to code changes and incentive programs, more developers and designers are specifying and installing all-electric heat pump technologies.

Additionally, interest in AWHP-based hydronic systems is increasing among policymakers and manufacturers, as they provide safer implementation of near-zero global warming potential (GWP) refrigerants, such as R-290 (propane, GWP < 1), than split system equipment where a greater volume of refrigerant is used and it passes inside the building envelope. Interest in AWHPs among designers and installers is also increasing. AWHPs can serve both space conditioning and hot water production loads, providing a way to sell all-electric retrofits, taking advantage of incentive programs, without the need for breaker panel or utility service upgrades. For designers, certain hydronic delivery methods, such as radiant, provide greater architectural freedom. For installers, the advantage of no longer interacting with refrigerants during installation, commissioning, and maintenance calls is attractive, especially as refrigerants become more flammable.

The CASE Team has decided to pursue this measure due to a confluence of factors indicating an imminent rise in AWHP adoption in California, and to help address concerns and complaints from stakeholders received over many years surrounding the compliance process for AWHPs. It has been difficult to get projects approved, as designers, plans examiners, and inspectors struggle to discern which requirements and forms to apply. Chiller and boiler requirements are more straightforward in the code, and the proposed measure will be a step toward clarifying code requirements that should apply to all hydronic space conditioning systems.

There are currently no minimum performance standards required for AWHPs or WWHPs under either Title 20 or federal Appliance and Equipment standards, nor are there methods of test specific to space conditioning operation. AWHPs are not SEER or HSPF rated, although they are currently rated as chillers using AHRI 550/590 and have EER and IPLV ratings. California and other states have adopted minimum AWHP and WWHP requirements consistent with ASHRAE 90.1 or other model standards.

The proposed measure addresses staged, multi-unit AWHP or WWHP systems where individual units are activated as the space conditioning load increases in larger non-residential buildings. These units may be connected in parallel or in series. A typical parallel configuration using AWHPs is shown in Figure 2. In this configuration, individual units are plumbed in parallel in a primary loop, and each is served by a dedicated pump. The secondary loop serves the loads in each zone and includes variable speed pumps to adjust flow rate depending on the load. To conserve energy, the individual pumps associated with each AWHP should turn off when the unit is not operational, and this is a requirement for chillers and boilers in the current version of Title 24, Part 6. However, stakeholder feedback and a Code Readiness study of four non-residential sites (Weitze, Stober and Gantley 2024) have indicated that pumps in AWHP systems often run continuously to simplify control logic or to ensure the flow is available immediately when the inactive unit is turned on. The result is wasted pump energy, thermal losses in the non-operating unit, and potential difficulty maintaining the desired supply water temperature.

Figure 2. Multi-Unit AWHP System with Pump Turned Off when Associated Unit is Turned Off

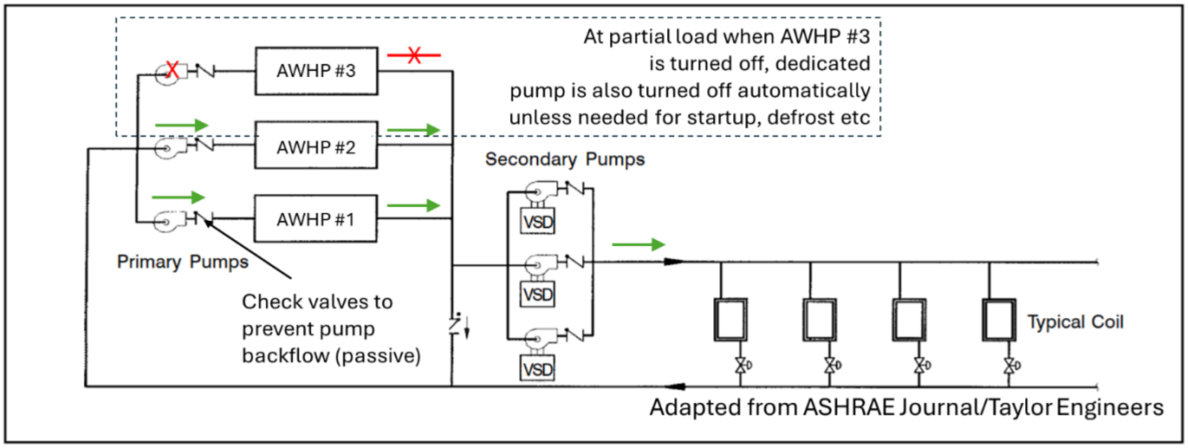

Image credit: Adapted from ASHRAE Journal(Taylor 2002)

2.1.4 Modifications to Energy Code Documents

This section provides descriptions of how the proposed code change will affect each Energy Code document. See Section 2.6: Alignment with Boiler and Chiller Requirements - Proposed Language Code of this report for detailed revisions to code language.

2.1.4.1 Energy Code Change Summary

The proposal code change would revise language currently geared toward chillers and boilers to accommodate AWHP and WWHP considerations. Similar to equipment isolation requirements for other hydronic plant equipment such as chillers and boilers, this measure would require preventing or minimizing the pump flow to any AWHP/WWHP that is in the off condition without impacting the flow to active units. The measure would be applicable to new construction, additions, and alterations (system replacements only) in all climate zones. The measure would only be relevant to multi-unit, staged systems found in larger non-residential buildings.

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

Adds a definition of water-to-water heat pumps similar to the definition of AWHPs.

SECTION 140.4 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

Subsection 140.4(k): Convert 140.4(k)2 and 140.4(k)3 to sub-elements A and B under 140.4(k)2, and add a separate record 140.4(k)2C under 140.4(k)2, requiring isolation of

AWHP and WWHP units that are not operating, by either or turning off water flow from dedicated pumps or closing a control valve and reducing water flow from a central pump. 140.4(k)3 would be reserved.

SECTION 120.5 – REQUIRED NONRESIDENTIAL MECHANICAL SYSTEM ACCEPTANCE

Subsection 120.5(a)8: AWHP/WWHPs that require control valves as specified by Section 140.4(k)4 would be tested in accordance with NA7.5.7.

2.1.4.2 Reference Appendices Change Summary

No changes to Reference Appendices are proposed. There is a new reference to NA7.5.7, but the existing language in that section does not mention the types of hydronic systems it applies to.

2.1.4.3 Compliance Manuals Change Summary

Changes to the Nonresidential Compliance Manual are anticipated, but have not yet been defined.

2.1.4.4 Alternative Calculation Method Reference Manual Change Summary

Changes to Section 5.8.5 of the Non-Residential and Multifamily Alternative Calculation Method (ACM) Reference Manual will be needed to address application of pump design and controls to AWHPs and WWHPs.

2.1.4.5 Compliance Forms Change Summary

Changes to the NRCC-MCH-E and NRCI-MCH-E Compliance Forms may be needed to address hydronic heat pump isolation controls, although there are already entries that seem adequate.

The NRCI-MCH-E compliance form provides tables to define the boiler efficiency and controls and chiller & air to water heat pump efficiency and controls (see Figure 3). The Statewide CASE Team may recommend that a column be added to both tables to include additional valves and controls to ensure limiting flow to units that are not in use, but that is probably unnecessary.

Figure 3: NRCI-MCH-E compliance form data entry tables for boiler and chiller systems.

Boiler Efficiency and Controls

01	02	03	04	05	06	07	08	09	10	11
Tag/Plan Detail ID	Model #	Equipment Type	Quantity	Rated Input (Btu/h)	Rated Efficiency	Efficiency Unit	Controls		Hot Water Supply Temperature	Equipment Compliance
							Isolation Valve	Temperature Reset		
Per C of C										
As-built Conditions										

Chiller & Air to Water Heat Pump Efficiency and Controls

01	02	03	04	05	06	07	08	09	10	11	12
Tag/Plan Detail ID	Model #	Equipment Type	Quantity	Size (tons)	Rated Efficiency #1	Efficiency Unit #1	Rated Efficiency #2	Efficiency Unit #2	Controls		Equipment Compliance
									Isolation Valve	Temperature Reset	
Per C of C											
As-built Conditions											

NRCA-MCH-08-A is an existing valve leakage test referenced in the measure for hydronic heat pumps, but no change to the form is required.

2.1.5 Measure Context

2.1.5.1 Comparable Model Codes or Standards

There are no federal equipment standards that establish minimum efficiency requirements for AWHPs and WWHPs. Currently, Title 24 establishes minimum efficiency levels for AWHPs and water-cooled heat recovery chillers based on the test procedures in AHRI standard 550/590-2023: Performance Rating of Water-chilling and Heat Pump Water-heating Packages Using the Vapor Compression Cycle (AHRI 2023). This standard is also referenced in ASHRAE 90.1-2022(ASHRAE 2022). AHRI standard 550/590 includes standard test conditions of 105°F, 120°F, and 140°F heating hot water supply temperature and 47°F and 17°F ambient air dry-bulb temperature on the source side.

The 2024 IECC model code includes multiple requirements for hydronic heat pumps. It references the nationally recognized standard ASHRAE 90.1-2022 for AWHPs and establishes efficiency for WWHPs based on testing according to ISO 13256-1(ISO 2021).

The International Organization for Standardization (ISO) has published several other test procedures for hydronic heat pumps, though none of them have seen widespread adoption in the U.S.

Both ASHRAE 90.1 or IECC 2024 standards specify cooling evaporator flow rate based on the full load cooling rating and the same flow rate for a reverse cycle AWHP in heating mode.

Section C403.4: Heating and Cooling Systems in the 2024 IECC code requires pump isolation in subsection 5 to limit flow through the plant when the chiller and/or boiler is shut down. ASHRAE 90.1 requires a verification of automatic flow adjustment and offline chillers and boilers isolation, but references ASHRAE 36 for the detailed control sequence.

2.1.5.2 Interactions with Other Regulations

The proposed measure does not conflict with any known local, state, or federal requirements for AWHPs and WWHPs. Current ASHRAE 90.1-2022 requirements for boiler and chiller isolation are essentially the same as Title 24, Part 6, and no conflict would be created by including AWHPs and WWHPs.

2.2 Alignment with Boiler and Chiller Requirements - Compliance and Enforcement

2.2.1 Compliance Considerations

Compliance with prescriptive requirements would be enforced in the same manner as it would be for boilers and chillers under Section 140.4(k). Prescriptive form NRCC-PRF-E may also need revisions to document whether the prescriptive requirement was met and how the proposed design was modeled. There may be additional entries for hydronic heat pumps on Compliance Forms NRCC-MCH-E and NRCI-MCH-E to make verification easier for the plan reviewer, but it appears that hydronic heat pump isolation is already included. For the mandatory component of the proposed measure, HVAC design documentation must demonstrate that equipment control valves and plumbing meet the code requirements in accordance with NA7.5.7 Valve Leakage Test. Functional testing would also be performed according to NA7.5.7 and documented on NRCA-MCH-08-A by an Acceptance Test Technician (ATT).

2.2.2 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]	Ensure equipment isolation requirements are understood by all parties and implemented in practice.	Educational materials such as a fact sheets that explains the reason for the measure and options for meeting the new requirement.

Design Professionals [b]	HVAC designers may need to negotiate with manufacturers, who sometimes recommend constant pump flow for simplicity of operations and to ensure adequate flow upon system start-up. A sequence of operations consistent with current Title 24 requirements for boilers and chillers may be required to control water flows as heat pumps turn on and off.	Educational material will be developed, such as a fact sheet that explains the reason for the measure and options for meeting the new requirement. Best practice guidance may need to be developed for less experienced designers to understand the options for meeting requirements and the pros and cons of each. Instructions for documenting compliance on NRCC forms will be developed.
Construction Team [c]	Installation contractors and commissioning agents must understand the isolation requirements and verify they are implemented in practice.	Educational material explaining how and why boiler and chiller isolation requirements have been extended to hydronic heat pumps.
Building Departments [d]	Understand verification processes and changes to compliance forms.	Educational material explaining how and why boiler and chiller isolation requirements have been extended to hydronic heat pumps.
Verification Testers [e]	Additional testing of AWHP and WWHP systems will be required, but the process will be the same as boilers and chillers.	No new test procedures are recommended, but educational material explaining the extension of valve testing requirements to hydronic heat pumps will be developed.
Building Owners, Managers, and Occupants	Reduced energy bills. A proper staging and equipment isolation design should have no effect on comfort or building operations.	Educational material explaining how and why boiler and chiller isolation requirements have been extended to hydronic heat pumps. Any additional maintenance requirements related to controls and valves needed for compliance will be explained.
Manufacturers and Distributors	Manufacturers and distributors may prefer continuous pump operation to ensure minimum flow is available upon restart. The proposed measure may require a more sophisticated approach to protect the equipment without wasting energy.	Best practice guidance and closer coordination with designers may be needed. A white paper can be provided to manufacturers demonstrating the magnitude of savings that can be achieved.

a. Builders include builders and developers.

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.
f. Concise description of market actor. You can add more detail to the narrative below.

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

Builders. The proposed change would likely affect commercial builders and industrial building construction and retrofitting, but would likely not impact utility systems, public infrastructure, or other heavy construction. The proposed change would not affect all firms and workers in the 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
Nonresidential Electrical Contractors	3,245	55,182	$5.8
Nonresidential Plumbing & HVAC Contractors	2,270	55,182	$5.8
Other Nonresidential Equipment Contractors	580	9,749	0.13
Nonresidential Site Preparation Contractors	1,147		$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

Manufacturers. Manufacturers would not be affected from a sales standpoint, but they may need to collaborate with designers to ensure the proper plumbing and controls are in place to isolate AWHPs and WWHPs. The measure is intended to level the playing field with boilers and chillers, clarify requirements for optimal system efficiency, and facilitate long-term growth in the AWHP/WWHP market.

Other Market Actor(s). None

2.2.3 Compliance Software Updates

Compliance software updates may be needed to model the proposed prescriptive measure accurately and demonstrate that all requirements are met, or to derate system performance if the requirements are not met. Guidance currently exists in the 2025 Nonresidential and Multifamily ACM Reference Manual, but minor clarifications may be warranted. If derating is needed (possibly for chillers and boilers as well), the performance path documentation in NRCC-PRF-E may need to be updated.

2.2.4 Cost of Enforcement

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

For sites with staged, multi-unit AWHPs or WWHPs, enforcement costs will likely be very small and perhaps negligible since other aspects of system design are already being verified and the proposed verification is already being done for chillers and boilers. The process for Plans Examiners to review forms and drawings may not change but some training would be required to ensure and understanding of the measure. The process for inspection review would ensure that the information on the NRCI forms is consistent with the NRCC forms, and matches what is actually installed. The process would not be new, but training may be required for inspectors to understand the requirements of the proposed measure. There may also be some added cost related to verifying acceptance testing related to valve leakage.

2.3 Alignment with Boiler and Chiller Requirements - Market and Economic Analysis

In California, an aggressive decarbonization target was set to cut GHG emissions by 40% below 1990 levels by 2030 and achieve carbon neutrality by 2045 (CARB 2022). To meet these aggressive targets, significant investigation of alternative technologies involving natural gas substitution and uptake are critical within California. The California Energy Commission (CEC) has set a goal of installing at least six million heat pumps by 2030 in residential and commercial buildings, which account for about 24% of GHG emissions in the state(Governor Gavin Newsom Website 2022). AWHPs and WWHPs are expected to be significant contributors to electrification efforts in California.

2.3.1 Market Structure and Availability

2.3.1.1 Current Market Structure and Availability

Limited information is available about the market share for AWHPs and WWHPs in non-residential buildings. Based on initial stakeholder interviews, it is evident that adoption is currently low, probably under 5%, but the market is growing faster in the non-residential sector compared to the residential sector because of greater use of hydronic space conditioning systems. The 2025 Energy Code introduced new prescriptive requirements in most climate zones for AWHPs to serve office and school buildings no greater than 150,000 square feet with multi-zone equipment. In future years, given the push toward all-electric buildings, the market share is likely to grow to at least 20% for all building types in the coming years, and 30% for small and medium offices and schools, given that about 60% of non-residential buildings nationwide use hydronic heating (Salimian Rizi and Heidarinejad 2022). Based on inputs from designers and manufacturers, staged multi-unit systems affected by the proposed measure are more common than systems dedicated to individual building zones, and likely represent about 60% of all hydronic systems.

Designers interviewed generally comply with the proposed measure, but one of the manufacturers typically uses continuous pump flow for modular AWHP units even when they don't operate, unless requested otherwise by the designer. One designer indicated the continuously operating pumps are a common topic of disagreement between parties involved in the design process. 35 percent appears to be a reasonable estimate of buildings that would not have the recommended automatic equipment isolation measures in place and would be affected by the proposed code change.

There is a perception that a significant gap may exist between the efficiency of AWHP and WWHPs advertised in manufacturer literature and the actual in-situ efficiency. This concern may cause slower market growth unless steps are taken in the energy code to help ensure expected performance is achieved. This will not only help California realize the promised energy efficiency of hydronic heat pump technologies, but will also assist in achieving the overall goal of decarbonization and carbon free economy.

Significant efforts have been made to understand how the proposed code change may impact the market as well as the individual market actors, primarily through stakeholder interviews. The market (particularly distributors, manufacturers, and designers) is a primary source of data for many aspects of this measure.

Without intervention through Title 24, Part 6, it is unlikely that the measure would be adopted naturally.

2.3.1.2 Market Challenges and Solutions

Based on stakeholder interviews and literature research, there are several market barriers that slow the adoption of AWHPs and WWHPs, including proper isolation practices:

- Limited number of AWHP and WWHPs on the market, though competition has been growing and new products appear every year.
- Uncertain code requirements and enforcement for AWHPs and WWHPs, which are sometimes absent or lumped in with chiller systems that may not have the same design and installation issues.
- Lack of industry-accepted best practices for isolating non-operational systems without risk of failures during restart due to lack of adequate flow.

The proposed measure will help overcome the second barrier, although additional clarifications and best practice guidance may be needed in future code cycles.

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

2.3.2 Design and Construction Practices

2.3.2.1 Current Design and Construction Practices

In general, HVAC designers are responsible for the design and controls for AWHP and WWHP systems in non-residential buildings. They work collaboratively with manufacturers, distributors, and installers to ensure the designs will operate effectively in the relevant building application. According to several stakeholders, issues of equipment isolation can sometimes be a source of contention between designers and manufacturers, because of the trade-off between energy efficiency, simplicity, cost, and manufacturers' conservative approach to equipment start-up.

2.3.2.2 Health and Safety Considerations

There are no health and safety considerations for the proposed measure.

2.3.2.3 Design and Construction Challenges and Solutions

The proposed measure would likely require greater collaboration and compromise in some situations to achieve the optimal solution for isolating inactive units while ensuring adequate flow when units are turned back on. This collaboration is already standard procedure for many energy conscious designers, but there is evidence from field studies and stakeholder interviews that many AWHPs and WWHPs are provided with continuous flow even when the unit is turned off (Weitze, Stober and Gantley 2024). A conservative estimate informed by stakeholders is that 35 percent of systems do not have proper isolation controls to avoid wasted pump energy and related performance issues.

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

2.3.3 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. There is no clear connection between energy equity and the proposed measure, other than the benefits related to indoor air quality when natural gas boilers are replaced with electric AWHPs for space heating. Benefits resulting from better air quality in the workplace would likely be more important for economically disadvantaged workers and those with pre-existing health issues such as asthma.

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 Robert Hendron (bhendron@frontierenergy) if you have input on how this proposal may impact ESJ communities or if you would like to offer your perspective.

2.3.4 Impacts on Jobs and Businesses

This section will be completed for the Final CASE Report.

2.3.5 Economic and Fiscal Impacts

This section will be completed for the Final CASE Report.

[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).

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

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

Cost to State: The state government already has a budget for code development, education, and compliance enforcement. While the state government would be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, these activities are already covered by existing state budgets. The costs for the state government are small when compared to the overall cost savings and policy benefits associated with the code change proposals. The proposed measure would apply to construction and alterations to state buildings with staged AWHP or WWHP systems, but analysis has demonstrated that the measure is cost-effective and will have no negative effects on state expenditures in the long-term.

Cost to Local Governments: All proposed code changes to Title 24, Part 6 would result in changes to compliance determinations. Local governments would need to train building department staff on the revised Title 24, Part 6 Standards. While this retraining is an expense to local governments, it is not a new cost associated with the 2025 code change cycle. The building code is updated on a triennial basis, and local governments plan and budget for retraining every time the code is updated. There are numerous resources available to local governments to support compliance training that can help mitigate the cost of retraining, including tools, training, and resources provided by the IOU Codes and Standards program (such as Energy Code Ace). As noted in Section 2.2.2, the Statewide CASE Team considered how the proposed code change might impact various market actors involved in the compliance and enforcement process and aimed to minimize negative impacts on local governments.

2.3.5.2 Mandates on Local Agencies or School Districts

There are no relevant mandates to local agencies or school districts. The proposed code change would only impact the requirements for building construction and major alterations involving HVAC systems.

2.3.5.3 Costs to Local Agencies or School Districts

There are no costs to local agencies or school districts beyond a small incremental design cost during the initial building construction. These costs would be very small compared to the expected energy cost savings.

2.3.5.4 Costs or Savings to Any State Agency

There are no costs to any state agencies beyond a small incremental design cost during the initial building construction. These costs would be very small compared to the expected energy cost savings.

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

There are no non-discretionary costs or savings to any local agencies beyond a small incremental design cost during the initial building construction. These costs would be very small compared to the expected energy cost savings.

2.3.5.6 Costs or Savings in Federal Funding to the State

There are no costs or savings to federal funding to the state, because the proposed measure improves the energy efficiency of certain non-residential buildings and better aligns Title 24 with ASHRAE 90.1.

2.3.6 Cost of Enforcement

Minimal additional training costs would be required because the proposed measure already applies to boilers and chillers, and only education related to hydronic heat pumps would be needed. There would likely be a small incremental cost to verify code compliance for the proposed measure for each non-residential building affected.

2.4 Alignment with Boiler and Chiller Requirements - Cost Effectiveness

2.4.1 Cost Effectiveness Methodology

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

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

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

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

2.4.2 Energy and Energy Cost Savings Results

First year energy savings (electricity, natural gas, and source energy) and peak demand reductions per unit are presented in Table 5 and Table 6 for new construction/additions and alterations, respectively, for the Large School prototype with AWHPs serving space heating and cooling. This is the only prototype modeled for the Draft CASE Report. All other prototypes with significant market penetration, including gas AWHPs and WWHPs will be modeled for the Final CASE Report. Per-square foot savings for the first year are expected to range from 0.01 to 0.30 kWh/yr, depending upon climate zone, and are 0 therms/yr in gas savings for all climate zones because the prototype uses an electric AWHP. Demand reductions/increases are expected to negligible for all climate zones.

Table 7 presents total per-unit energy cost savings for newly constructed buildings and additions in terms of LSC savings realized over a 30-year period, in 2029 present value dollars (2029 PV$). Table 8 presents similar results for alterations. The LSC methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

Table 5: Energy and Energy Cost Savings – Per Square Foot – New Construction and Additions – Large School

Climate Zone	First Year Electricity Savings (kWh)	First Year Peak Demand Reduction (kW)	First Year Natural Gas Savings (kBtu)	First Year Source Energy Savings (kBtu)	Total 30-Year LSC Savings (2029 PV$)
1	0.03	0.00	-0.00	0.02	0.20
2	0.02	0.00	0.00	-0.02	0.05
3	0.01	0.00	0.00	-0.00	0.01
4	0.05	-0.01	0.00	-0.03	0.13
5	0.02	0.00	0.00	0.00	0.05
6	0.03	0.00	0.00	-0.03	0.07
7	0.03	0.00	0.00	-0.05	0.02
8	0.08	0.00	0.00	-0.04	0.21
9	0.07	0.00	0.00	-0.03	0.16
10	0.09	0.00	0.00	-0.03	0.28
11	0.09	0.00	-0.00	-0.02	0.32
12	0.04	-0.01	0.00	-0.04	0.06
13	0.10	0.00	-0.00	-0.03	0.41
14	0.13	0.00	0.00	0.00	0.61
15	0.30	0.00	0.00	-0.02	1.49
16	0.03	0.00	0.00	-0.01	0.11

Table 6: Energy and Energy Cost Savings – Per Square Foot – Alterations – Large School

Climate Zone	First Year Electricity Savings (kWh)	First Year Peak Demand Reduction (kW)	First Year Natural Gas Savings (kBtu)	First Year Source Energy Savings (kBtu)	Total 30-Year LSC Savings (2029 PV$)
1	0.03	0.00	-0.00	0.02	0.20
2	0.02	0.00	0.00	-0.02	0.05
3	0.01	0.00	0.00	-0.00	0.01
4	0.05	-0.01	0.00	-0.03	0.13
5	0.02	0.00	0.00	0.00	0.05
6	0.03	0.00	0.00	-0.03	0.07
7	0.03	0.00	0.00	-0.05	0.02
8	0.08	0.00	0.00	-0.04	0.21
9	0.07	0.00	0.00	-0.03	0.16
10	0.09	0.00	0.00	-0.03	0.28
11	0.09	0.00	-0.00	-0.02	0.32
12	0.04	-0.01	0.00	-0.04	0.06
13	0.10	0.00	-0.00	-0.03	0.41
14	0.13	0.00	0.00	0.00	0.61
15	0.30	0.00	0.00	-0.02	1.49
16	0.03	0.00	0.00	-0.01	0.11

Table 7: 2029 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions – Large School

Climate Zone	30-Year LSC Electricity Savings (2029 PV$)	30-Year LSC Natural Gas Savings (2029 PV$)	Total 30-Year LSC Savings (2029 PV$)
1	0.20	0.00	0.20
2	0.05	0.00	0.05
3	0.01	0.00	0.01
4	0.13	0.00	0.13
5	0.05	0.00	0.05
6	0.07	0.00	0.07
7	0.02	0.00	0.02
8	0.21	0.00	0.21
9	0.16	0.00	0.16
10	0.28	0.00	0.28
11	0.32	0.00	0.32
12	0.06	0.00	0.06
13	0.41	0.00	0.41
14	0.61	0.00	0.61
15	1.49	0.00	1.49
16	0.11	0.00	0.11

Table 8: 2029 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations – Large School

Climate Zone	30-Year LSC Electricity Savings (2029 PV$)	30-Year LSC Natural Gas Savings (2029 PV$)	Total 30-Year LSC Savings (2029 PV$)
1	0.20	0.00	0.20
2	0.05	0.00	0.05
3	0.01	0.00	0.01
4	0.13	0.00	0.13
5	0.05	0.00	0.05
6	0.07	0.00	0.07
7	0.02	0.00	0.02
8	0.21	0.00	0.21
9	0.16	0.00	0.16
10	0.28	0.00	0.28
11	0.32	0.00	0.32
12	0.06	0.00	0.06
13	0.41	0.00	0.41
14	0.61	0.00	0.61
15	1.49	0.00	1.49
16	0.11	0.00	0.11

2.4.3 Incremental First Cost

Based on interviews with HVAC system designers in 2025, the additional first cost for designing and installing AWHPs and WWHPs with controls and plumbing necessary for isolation of individual units is small, ranging from no incremental cost because existing valves and controls can just be used properly to turn off or reduce flow for non-operating units, up to 3% of total system cost if additional plumbing and controls must be added.

The first cost of an AWHP system can vary widely with system configuration and site conditions. Important cost drivers include whether the project is new construction or a retrofit, the extent of existing hydronic piping reuse, and any electrical service upgrades for fuel switching alterations. Costs also depend on whether the system is two-pipe or four-pipe with heat recovery, whether the AWHP is used for space heating only or includes cooling and hot water, and the need for thermal storage or buffer tanks.

Manufacturer and distributor interviews in a CalNEXT AWHP market study(Rodriguez, Camacho and Karasawa 2023) suggest installed AWHP plant costs on the order of $2,000-$6,000 per ton ($170-$500/MBH)[2]. The same report summarizes California State University (CSU 2019) estimates of first costs for AWHP systems at $90-

[2] MBH is 1000 Btu/hour and one ton of cooling is 12,000 Btu/hour.

$170/MBH (no heat recovery) and $150-$200/MBH (with heat recovery). These studies focus on the heat pump plant installation cost and do not provide separate costs for building-level hydronic distribution. The study does not provide cost estimates as a function of system capacity.

CEC's 'Air-to-Water Heat Pump Incremental Costs – Additional Detail' workbook (CEC n.d.) provides plant and distribution cost basis for AWHP systems, although the document is undated and the context unclear. The Plant-side Costs sheet includes vendor quotes for Trane ACSA AWHPs, resulting in AWHP plant costs of $1,200-1,400/ton ($100-120/MBH). The Air-side Costs sheet includes distribution costs (material and labor) for ductwork of about $270 per linear foot and hydronic piping of about $56.65 per linear foot, as well as terminal unit costs for VAV boxes and FPFCs. Costs for a full system including design and installation would be significantly higher.

A Minnesota Department of Commerce report(Hill, Tudawe and Quinnell 2023) provided installed costs for two AWHP systems that provided space heating, cooling, and hot water. Costs at each site totaled about $40,000 for a 5-ton system ($8000/ton, $667/MBH). The authors indicated that costs were likely higher than typical long-term costs because the AWHP market in Minnesota is small, resulting in minimal contractor experience and competition among distributors.

One of the manufacturers interviewed for stakeholder input estimated the typical cost of a complete hydronic space conditioning system at $3,000/ton for larger systems over 100 tons, and $5,000/ton for smaller systems under 100 tons, including equipment controls provided by the manufacturer not including integration into a building automation system (BAS). Another stakeholder estimated $500,000 for a complete AWHP system in a smaller non-residential building, and $3-4 million in a large building.

Combining all sources, incremental first cost for the proposed measure is estimated as $60/ton (2% of $3,000/ton) for systems larger than 100 tons (1,200 MBH), and $100/ton for smaller systems (2% of $5,000/ton). Applying these estimates to the space conditioning capacities for the prototype buildings in Climate Zone 12 results in the estimated incremental first costs shown in Table 9.

Table 9: Incremental First Cost Estimates by Prototype Building

	Size (ft^2)	Heating capacity (MBH)	Cooling capacity (tons)	Cooling capacity (MBH)	First Cost/ft^2	First Cost
Large Office	498,589	11,254	1,247	14,958	$ 0.15	$ 74,790
Medium Office	53,627	1,210	134	1,609	$ 0.15	$ 8,045
Small Office	5,502	173	14	165	$ 0.26	$ 1,442
Large Retail	233,250	7,347	583	6,997	$ 0.16	$ 36,735
Medium Retail	24,563	774	61	737	$ 0.26	$ 6,450
Strip Mall	9,375	270	21	248	$ 0.24	$ 2,250
Mixed-use Retail	9,375	263	20	242	$ 0.23	$ 2,192
Large School	210,886	5,069	772	9,269	$ 0.22	$ 46,345
Small School	23,408	737	59	702	$ 0.26	$ 6,142
Non-refrigerated Warehouse	17,548	308	24	284	$ 0.15	$ 2,567
Hotel	15,283	345	38	458	$ 0.25	$ 3,817
Assembly	315,339	7,830	866	10,390	$ 0.16	$ 51,950
Hospital	241,501	8,665	737	8,842	$ 0.18	$ 44,210
Laboratory	53,628	1,827	173	2,075	$ 0.19	$ 10,375
Restaurant	2,501	71	8	97	$ 0.32	$ 808
Open Parking Garage	40	0.02	0.06	0.76	$ 0.16	$ 6

2.4.4 Incremental Maintenance and Replacement Costs

Description of the incremental maintenance and replacement costs, as well as estimation of present value of maintenance and replacement costs, are provided in the 2028 CASE Methodology Report.

Changes to controls would not result in added maintenance costs. However, the proposed measure may result in a need for updated controls and several additional control valves that require occasional maintenance and replacement after a useful life of about 15 years. Because less expensive shutoff valves would be installed anyway, no incremental maintenance costs are expected. A conservative assumption is that approximately the same incremental first cost would be incurred after 15 years ($60/ton for systems larger than 100 tons and $100/ton for smaller systems) to cover the cost of replacing controls, valves, and other plumbing at the end of their useful life. After the 30-year analysis period, no residual value is expected because the replacement systems would have reached the end of their 15-year useful life.

2.4.5 Cost Effectiveness

Results of the per-unit cost-effectiveness analyses are presented in Table 10 and Table 11 for new construction/additions and alterations, respectively. The initial modeling results indicate that the Benefit-To-Cost ratio exceeds 1.0 for only 5 of the 16 Climate

Zones. However, additional refinements to the modeling are planned, and a more detailed first cost estimate based on specific plumbing and controls changes for a typical hydronic heat pump system will be developed in consultation with stakeholders to make sure they are realistic. The Statewide CASE Team anticipates that incremental costs may be lower and energy savings higher than estimated in this Draft CASE Report, improving the cost-effectiveness outcome.

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 10: 30-Year Cost-Effectiveness Summary Per Square Foot – New Construction and Additions

Climate Zone	Benefits LSC Savings + Other PV Savings (2029 PV$)	Costs Total Incremental PV Costs (2029 PV$)	Benefit-to-Cost Ratio
1	0.20	0.22	0.89
2	0.05	0.22	0.21
3	0.01	0.22	0.03
4	0.13	0.22	0.60
5	0.05	0.22	0.22
6	0.07	0.22	0.31
7	0.02	0.22	0.08
8	0.21	0.22	0.96
9	0.16	0.22	0.70
10	0.28	0.22	1.24
11	0.32	0.22	1.45
12	0.06	0.22	0.28
13	0.41	0.22	1.83
14	0.61	0.22	2.72
15	1.49	0.22	6.65
16	0.11	0.22	0.47

Table 11: 30-Year Cost-Effectiveness Summary Per Square Foot – Alterations

Climate Zone	Benefits LSC Savings + Other PV Savings (2029 PV$)	Costs Total Incremental PV Costs (2029 PV$)	Benefit-to-Cost Ratio
1	0.20	0.22	0.89
2	0.05	0.22	0.21
3	0.01	0.22	0.03
4	0.13	0.22	0.60
5	0.05	0.22	0.22
6	0.07	0.22	0.31
7	0.02	0.22	0.08
8	0.21	0.22	0.96
9	0.16	0.22	0.70
10	0.28	0.22	1.24
11	0.32	0.22	1.45
12	0.06	0.22	0.28
13	0.41	0.22	1.83
14	0.61	0.22	2.72
15	1.49	0.22	6.65
16	0.11	0.22	0.47

2.5 Alignment with Boiler and Chiller Requirements - Statewide Impacts

2.5.1 Statewide Energy and Energy Cost Savings

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

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

The tables below present the first-year statewide energy and LSC savings from newly constructed buildings and additions (Table 12) and alterations (Table 13) by climate zone.

Table 14 presents first-year statewide savings from new construction, additions, and alterations.

The analysis only includes the large school prototype with AWHPs for space conditioning and is therefore very conservative from a statewide impact standpoint. Additional building types will be modeled for the Final CASE Report.

Table 12: Statewide Energy and LSC Impacts – New Construction and Additions

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Square Feet)	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2029 PV$)
1	240	0.00	0.00	0.00	0.00	$0.00
2	4,710	0.00	0.00	0.00	0.00	$0.00
3	32,417	0.00	0.00	0.00	0.00	$0.00
4	16,347	0.00	0.00	0.00	0.00	$0.00
5	1,345	0.00	0.00	0.00	0.00	$0.00
6	21,983	0.00	0.00	0.00	0.00	$0.00
7	22,512	0.00	0.00	0.00	0.00	$0.00
8	33,494	0.00	0.00	0.00	0.00	$0.01
9	52,580	0.00	0.00	0.00	0.00	$0.01
10	31,581	0.00	0.00	0.00	0.00	$0.01
11	13,117	0.00	0.00	0.00	0.00	$0.00
12	42,626	0.00	0.00	0.00	0.00	$0.00
13	22,753	0.00	0.00	0.00	0.00	$0.01
14	6,146	0.00	0.00	0.00	0.00	$0.00
15	3,172	0.00	0.00	0.00	0.00	$0.00
16	2,520	0.00	0.00	0.00	0.00	$0.00
Total	**307,545**	**0.02**	**0.00**	**0.00**	**0.01**	**$0.05**

Table 13: Statewide Energy and LSC Impacts – Alterations

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Square Feet)	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction	First-Year Natural Gas Savings (Million Therms)	First-Year Natural Gas Savings (Million Therms) First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2029 PV$)
1	2,125	0.00	(0.00)	(0.00)	0.00	$0.00
2	22,456	0.00	(0.00)	-	(0.00)	$0.00
3	97,524	0.00	(0.00)	-	(0.00)	$0.00
4	39,060	0.00	(0.00)	-	(0.00)	$0.01
5	5,799	0.00	0.00	-	0.00	$0.00
6	79,436	0.00	(0.00)	0.00	(0.00)	$0.01
7	63,112	0.00	(0.00)	-	(0.00)	$0.00
8	120,148	0.01	(0.00)	0.00	(0.00)	$0.03
9	206,024	0.02	(0.00)	0.00	(0.01)	$0.03
10	156,828	0.01	(0.00)	-	(0.00)	$0.04
11	28,364	0.00	(0.00)	(0.00)	(0.00)	$0.01
12	149,464	0.01	(0.00)	-	(0.01)	$0.01
13	73,948	0.01	(0.00)	(0.00)	(0.00)	$0.03
14	33,768	0.00	(0.00)	0.00	0.00	$0.02
15	21,339	0.01	0.00	-	(0.00)	$0.03
16	10,049	0.00	0.00	-	(0.00)	$0.00
Total	**1,109,444**	**0.08**	**(0.00)**	**0.00**	**(0.03)**	**$0.22**

Table 14: 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	0.02	(0.00)	0.00	(0.01)	0.05
Alterations	0.08	(0.00)	0.00	(0.03)	0.22
Total	**0.09**	**(0.00)**	**0.00**	**(0.04)**	**0.27**

2.5.2 Statewide Greenhouse Gas Emissions Reductions

Table 15 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 add 39 metric tons of carbon dioxide equivalent (CO_2e) emissions based on the initial analysis. However, further refinements of the model for the Final CASE Report are expected to result in GHG emission reductions. 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 15: 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	(2.2)	0.0	(2.2)	(268)
Alterations				
Total	**(2.2)**	**0.0**	**(2.2)**	**(268)**

2.5.3 Statewide Water Use Impacts

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

2.5.4 Statewide Material Impacts

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

2.5.5 Environmental Impacts

No environmental impacts are anticipated for the proposed measure.

2.5.6 Other Non-Energy Impacts

The proposed measure provides IAQ benefits for affected buildings by enabling greater use of all-electric space conditioning equipment and reducing site emissions associated with natural gas boilers inside conditioned space.

2.6 Alignment with Boiler and Chiller Requirements - Proposed Language Code

2.6.1 Guide to Markup Language

The proposed changes to the standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2025 documents are marked with dark blue underlining (new language) and ~~strikethroughs~~ (deletions).

2.6.2 Administrative Code (Title 24, Part 1)

No changes.

2.6.3 Energy Code (Title 24, Part 6)

The proposed measure will add a definition of water-to-water heat pumps similar to the definition of AWHPs.

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

WATER-TO-WATER HEAT PUMP (WWHP) is a factory-made packaged heat pump system containing one or more compressors and heat exchangers for transferring heat between refrigerant and a separate water loop serving as the heating or cooling energy source, as well as between refrigerant and water distributed to meet building loads, and various other components. Its primary purpose is to generate heated or cooled water to meet space conditioning loads, domestic hot water loads, or both.

The proposed measure will revise language currently geared toward chillers and boilers to factor in AWHP/WWHP considerations by combining chillers and boilers under 140.4(k)2 as items A and B, adding a separate requirement for hydronic heat pumps in 140.4(k)2C, removing the term “isolation” and replacing the term “shut off” with “not operating” to improve clarity, and marking 140.4(k)3 as “Reserved” because it is no longer needed.

SECTION 140.4 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

140.4(k)2: **Hydronic system flow shutoff for non-operating units**

A. **Chillers** ~~isolation~~. When a chilled water system includes more than one chiller, provisions shall be made so that flow through any chiller is automatically shut off when that chiller is not operating ~~shut off~~ while still maintaining flow through other operating chiller(s). Chillers that are piped in series for the purpose of increased temperature differential shall be considered as one chiller.

140.4(k)3: B. **Boilers isolation**. When a hot water plant includes more than one boiler, provisions shall be made so that flow through any boiler is automatically shut off when that boiler is not operating shut off while still maintaining flow through other operating boiler(s).

C. **AWHPs and Water-to-Water Heat Pumps (WWHP)**: When a central plant includes more than one AWHP or WWHP, provisions shall be made so that flow through any heat pump is automatically shut off and the corresponding pump flow rate is automatically reduced when that heat pump is not operating while still maintaining flow through other operating heat pump(s), except as required by the manufacturer to ensure equipment protection, such as during start-up operations, defrost cycles or burst protection during cold weather. Hydronic heat pumps that are piped in series for the purpose of increased temperature differential shall be considered as one heat pump.

Exception to Section 140.4(k)2C: Group R Occupancy, and common or public use areas serving that Occupancy

140.4(k)3: Reserved

The following additional change is proposed for mandatory mechanical system requirements in Section 120.5(a)8

SECTION 120.5 – REQUIRED NONRESIDENTIAL MECHANICAL SYSTEM ACCEPTANCE

120.5(a)8: Boiler, or chiller, AWHP or WWHP that require isolation controls as specified by Section 140.4(k)2 or 140.4(k)3 shall be tested in accordance with NA7.5.7.

2.6.4 Reference Appendices

There may be minor proposed changes to the Reference Appendices, but none have been identified yet.

2.6.5 Compliance Manuals

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

2.6.6 ACM Reference Manual

Proposed change to Section 5.8.5 of the Non-Residential and Multifamily Alternative Calculation Method (ACM) Reference Manual.

PUMP OPERATION

Applicability: All pumps.

Definition: The type of pump operation can be either on-demand, standby, or scheduled. On-demand operation means the pumps are only pumping when their associated equipment is cycling. Chiller and condenser pumps are on when the chiller is on and the heating hot water pump operates when its associated boiler is cycling. Standby operation allows hot or chilled water to circulate through the primary loop of a primary/secondary loop system or through a reduced portion of a primary-only system, assuming the system has appropriate three-way valves. Scheduled operation means that the pumps and their associated equipment are turned completely off according to occupancy schedules, time of year, or outside conditions. Under scheduled operation, when the systems are on, they are assumed to be in on-demand mode.

Units: List (see above).

Input Restrictions: As designed.

Standard Design: The standard design system pumps are controlled~~assumed~~ to operate in on-demand mode. The chilled water and condenser pumps are tied to the chiller, AWHP, or WWHP operation, cycling on and off with the equipment~~chiller~~, and the heating hot water pumps are tied to the boiler, AWHP, or WWHP operation.

2.6.7 Compliance Forms

As discussed in Section 2.1.4.5, the NRCC-MCH-E and NRCI-MCH-E compliance form may need to 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.

3. AWHP Glycol Concentration Limits

3.1 AWHP Glycol Concentration Limits - Measure Description

3.1.1 Proposed Code Change

The proposed measure would place reasonable mandatory limits on glycol concentration for AWHPs, with adjustments based on climate zone and system type, reducing the negative impacts on heat exchanger performance and pump power associated with high levels of glycol concentration. WWHPs are not included in this measure, but the distribution side of WWHP systems may be added as we discuss this option further with stakeholders prior to the Final CASE Report. The measure would add new mandatory requirements to Section 110.2, specifying maximum glycol concentrations ranging from 0% to 35% depending on the winter median of extremes for the nearest weather station as documented in JA2, and disallowing glycol use in most AWHP systems where the water loop is entirely in conditioned space. These limits are above the burst protection limits for both propylene and ethylene glycol mixtures, but allow partial freezing under extreme conditions. These requirements would be applied to all non-residential new construction (except Group R Occupancy), additions, and alterations (HVAC system replacements only) in all climate zones. Labeling on the AWHP would be required to document compliance and provide guidance to facility managers that will help ensure the concentration is maintained at the specified level over time. Exceptions are made for the following situations:

- AWHPs that are integrated into more complex hydronic space conditioning systems that include boilers, chillers, or outdoor air systems. The range of possible HVAC configurations for non-residential buildings is limitless. Further research is required to evaluate the potential freezing and energy efficiency impacts in more complex hydronic systems that include other plant types and dedicated outdoor air systems (DOAS).
- AWHPs that only provide space and/or water heating. The energy impacts of higher glycol concentrations are less significant when the mixture is warm compared to when it is cold, and there is inadequate justification for imposing restrictions on glycol concentration.
- AWHPs that serve process loads. Further research is needed to understand the implications of glycol limitations on process loads that may require lower supply water delivery temperatures than are necessary for space conditioning.

Table 16 summarizes the scope of the proposed code change.

Table 16: 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 110.2	TBD	No changes

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

3.1.2 Benefits of Proposed Change

Improper design and installation of AWHPs can lead to a decrease in energy efficiency and increased utility bills. Adhering to design and installation best practices is essential as California aims to significantly increase heat pump usage over the next decade. Adoption of substandard practices could give the technology a poor reputation at this early stage in deployment. The proposed measure is a step toward codifying important best practices for ensuring common AWHP designs are energy efficient, while allowing design flexibility and providing safeguards against burst protection.

An important benefit of the proposed measure is that average installed efficiency of AWHP systems will increase in many non-residential buildings because lower glycol concentrations would reduce pump energy and enhance heat exchanger effectiveness. Glycol concentration levels can be overly conservative to prevent even partial freezing. Manufacturer guidance is often limited to a hard limit of a 50% glycol solution with recommended ranges based on climate, and established test methods do not provide data regarding decreased energy performance with glycol added to the system. The exact frequency of excessive glycol concentration is difficult to quantify even following stakeholder interviews, but sufficient data exist to establish reasonable limits that prevent poor practices that may result from rule-of-thumb approaches to glycol concentration.

Finally, it is important to intervene before standard practice becomes more difficult to change as the market expands in the coming years and practices become ingrained. The proposed measure is a simple and straightforward step that is consistent with best design practices already employed by energy conscious HVAC designers, and it is unlikely to meet resistance from industry.

3.1.3 Background Information

An overview of AWHP technology and its history as related to Title 24, Part 6 was provided in Section 2.1.3. Additional background related to the proposed glycol concentration measure is included in this section.

Either propylene glycol or ethylene glycol is commonly used in combination with water to prevent freezing in AWHP water loops that may be exposed to cold temperatures. Ethylene glycol is a toxic liquid and requires special handling according to Title 24 and other regulatory requirements, while propylene glycol is non-toxic. In addition to freeze protection, glycol also inhibits corrosion, although there are many other design options that address this concern. Glycol is more viscous than water, and has a lower specific heat and thermal conductivity, resulting in lower thermal performance in hydronic systems when compared to pure water. Under warmer conditions, including heating mode operation, glycol has a very small effect on system performance, although this mode usually presents the greatest risk of freezing and drives the selected glycol concentration. When operating in cooling mode, the thermal performance suffers significantly when glycol concentrations are high, as shown in Table 17.

Table 17: Estimated performance impacts of glycol concentration on AWHP system components (assumes flow rate is maintained to meet capacity requirements as concentration increases)

Glycol Concentration	Cooling Mode Pump Power Increase[1]	Cooling Mode Heat Exchanger Film Coefficient[2]
0%	0.0%	0%
10%	65.2%	-22.0%
30%	192.0%	-58.5%
50%	465.5%	-79.9%

a. [1] Fluid properties from Dow Chemical sizing tool (Dow 2025).

b. [2] Average of lowest power draw Grundfos(Grundfos 2025) and Taco (Taco 2020) pump curves that met head for 100 ft of 1 inch PEX pipe at 50°F and 12.2 gpm.

Preliminary laboratory testing in cooling mode was performed at Frontier Energy's Building Science Research Laboratory for two glycol concentrations (0% and 50%) using an AWHP and heat exchanger with simulated cooling loads. The results are summarized in Table 18. The energy efficiency ratio (EER) for the AWHP was reduced by 7 percent when glycol was added, primarily due to a large decrease in heat exchanger effectiveness (17 percent) and a large increase in pump energy (27 percent).

Table 18: Laboratory Test Results for 50% Propylene Glycol Compared to Pure Water (95°F Chamber Temperature).

	0% PG	50% PG	% Change
Chamber Temperature (°F)	95.1	95.7	
AWHP Chassis Internal Temperature (°F)	96.8	97.4	
AWHP Entering Water Temperature (°F)	51.9	53.0	
AWHP Leaving Water Temperature (°F)	45.4	45.7	
AWHP EER (kBtu/hour/kW)	9.39	8.63	-7.01
AWHP Capacity (kBtu/hour)	19.1	17.5	-8.60
AWHP Power (kW)	2.04	2.02	-0.54
AWHP Compressor Speed (%)	78.0	77.9	-0.19
AWHP Flow Rate (gpm)	5.92	5.51	-6.95
W2W HX Effectiveness (%)	63.6	52.5	-17.4
Secondary Loop Head Loss (ft)	7.05	7.86	+11.5
Secondary Loop Flow Rate (gpm)	5.53	5.48	-0.97
Secondary Loop Pump Power (W)	30.4	38.6	+27.0
Secondary Loop In-Line Heater (kW)	4.54	4.61	-1.54

The risk of freezing and burst pipes depends not only on weather, but on the configuration of the AWHP system. If the system is a packaged unit (often referred to as monobloc), the evaporator is generally located outdoors and water flow must pass through the ambient air, as shown in Figure 4. For split systems, the evaporator is indoors, and the water loop is entirely within the building envelope, as shown in Figure 5. Split AWHPs generally do not require glycol to protect against freezing, except in unusual situations where the water loop serves an ice storage tank, heats incoming air in a dedicated outside air unit (DOAS) or fan coil with high outside air fractions in cold climates, or serves process loads involving cold temperatures. Packaged systems must have freeze and/or burst protection in climates where the air temperature can drop below 32°F. There is less risk of bursting if a small continuous flow of water is maintained when outside temperatures are below the freezing point of the mixture.

Figure 4: Monobloc AWHP Schematic

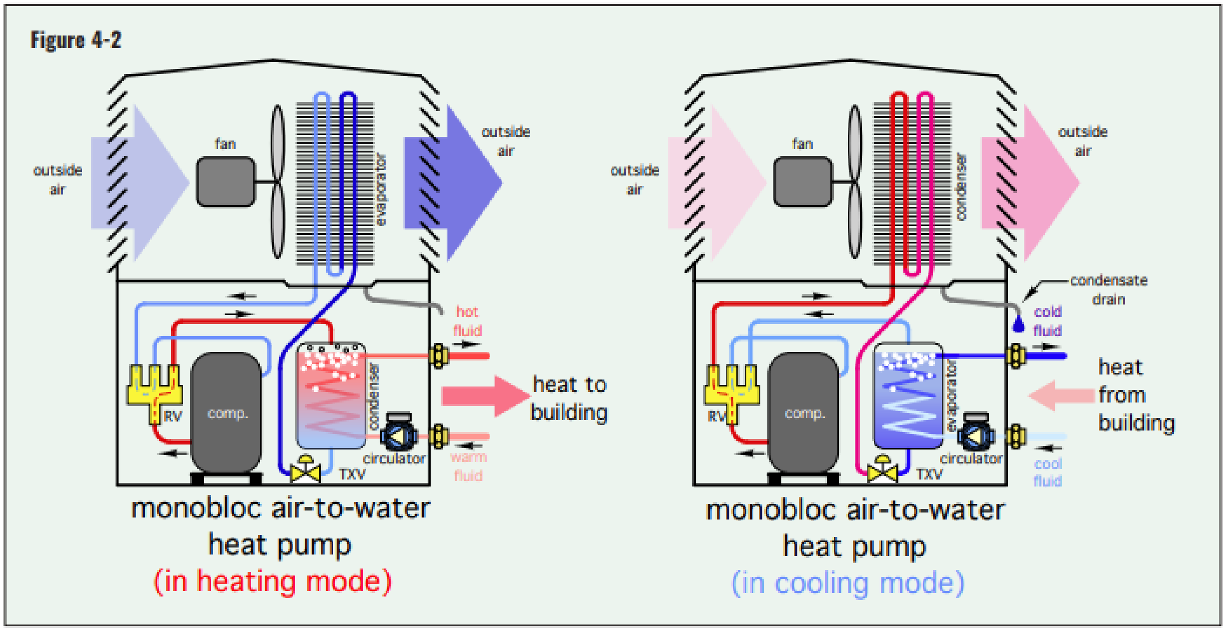

Image credit: Idronics (https://climatefriendlylifestyle.substack.com/p/electrify-everything-part-3b-specialized)

Figure 5: Split System AWHP Schematic

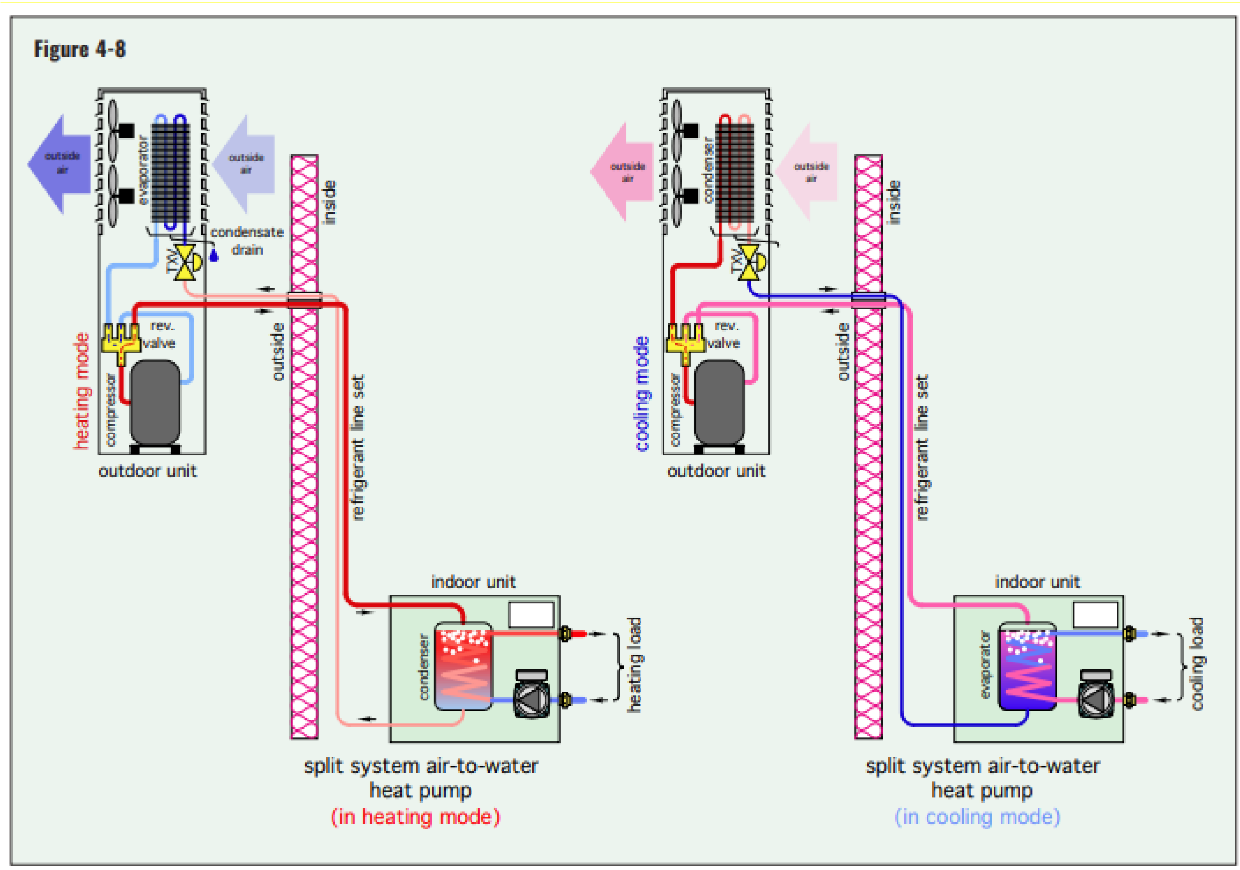

Image credit: Idronics (https://climatefriendlylifestyle.substack.com/p/electrify-everything-part-3b-specialized)

As glycol mixtures begin to freeze, the fluid becomes slushy and harder to circulate. As long as this situation is infrequent, partial freezing is widely recognized as only a minor concern. For most designers, the required glycol concentration is based on providing the necessary protection against burst pipes, which occurs when the glycol mixture becomes fully frozen and the thermal expansion cannot be contained by the pipes. Dow Chemical provides the glycol concentrations necessary to prevent freezing and burst protection for two of their common products, as shown in Table 19. It should be noted that the temperatures represent fluid temperature, not ambient air temperature.

Table 19: Glycol concentration needed to prevent freezing and burst pipes (Dow 2008a) (Dow 2008b)

Fluid Temperature	Ethylene Glycol (DOWTHERM SR-1) Concentration (% Volume) for Freeze Protection	Ethylene Glycol (DOWTHERM SR-1) Concentration (% Volume) for Burst Protection	Propylene Glycol (DOWFROST) Concentration (% Volume) for Freeze Protection	Propylene Glycol (DOWFROST) Concentration (% Volume) for Burst Protection
20°F	17%	12%	19%	13%
10°F	26%	18%	30%	21%
0°F	35%	23%	38%	25%
-10°F	41%	27%	44%	29%
-20°F	46%	31%	48%	31%
-30°F	50%	31%	52%	35%
-40°F	55%	31%	57%	37%
-50°F	59%	31%	60%	37%
-60°F	63%	31%	63%	37%

The burst protection limits for propylene glycol mixtures were selected as the basis for the proposed concentration limits presented in this measure proposal. As discussed earlier, burst protection is the more relevant criterion for preventing damage to the system at cold temperatures, because even with a multi-day power outage, the pipes will not fully freeze. Propylene glycol mixtures freeze at a slightly higher temperature than ethylene glycol mixtures, and is the more conservative choice. Heating median of extremes provides a reasonable estimate of the coldest temperature the system is likely to experience, and it is assumed that the glycol mixture may drop to that temperature during an extended power outage or if the system breaks down for more than a day. Heating median of extremes was broken into 10°F intervals, and the glycol concentration recommended by Dow at the coldest temperature in the range was selected. A safety margin of 5°F to cover uncertainties in concentration and freezing point was added to the heating median of extremes, as recommended by Dow in their Engineering and Operating Guide for propylene glycol mixtures (Dow 2008a). A summary of the proposed glycol concentration limits is shown in Table 20.

Table 20: Proposed glycol concentration limits

Heating Median of Extremes (From JA2-4)	Maximum Glycol Concentration
Above 37°F	0
25°F to 37°F	13%
15°F to 24°F	21%
5°F to 14°F	25%
-5°F to 4°F	29%
-15°F to -6°F	31%
Below -15°F	35%

An alternative approach that provides additional safeguards and flexibility for HVAC designers is currently being researched and discussed with stakeholders. This alternative approach would include the following elements:

- If a split-system AWHP is used and all refrigerant-to-water heat exchangers and all water pipes are installed within the conditioned space:
  - The use of glycol in the system would be prohibited except under special circumstances identified through manufacturer and designer interviews to prevent any unexpected risks.
  - The minimum flow rate must meet the manufacturer's requirements.
- For packaged monobloc systems with hydronic lines that are exposed to freezing ambient conditions, glycol concentration will be limited as a function of the median of winter extremes per manufacturer requirements.
  - Glycol concentration would be engineered based on the lowest expected ambient or fluid temperature, the protection objective (freeze or burst), and the glycol type, and would not exceed 35%. If the maximum allowable 35% glycol concentration does not provide adequate freeze/burst/rust protection, the designer would be permitted to increase the minimum flow rate to maintain safe operating conditions for all hydronic piping and the AWHP.
  - Minimum flow rate would be established based on the manufacturers' recommendations.
- The measure would only apply to "stand-alone" AWHP systems that are not integrated into a larger system with other major space conditioning equipment including but not limited to boilers, cooling tower and chillers.
- A straightforward method would be developed for plan checkers to verify that insufficient indoor space would have been available for a split system, in situations where a monobloc system is recommended.

The proposed measure highlights the need for improvements to standard AWHP test methods that do not currently include testing with various glycol concentrations. In addition, the EnergyPlus software engine used for CBECC does not properly calculate the effects of high-viscosity glycol/water mixtures on pump power. Recommended mandatory glycol concentration limits in the proposed measure are conservative because the limitations in test standards and compliance software make accurate energy savings estimates difficult. Better information about installed performance of water/glycol mixtures in AWHPs could provide an opportunity to include glycol concentration as a trade-off in the Title 24 performance path.

3.1.4 Modifications to Energy Code Documents

This section provides descriptions of how the proposed code change will affect each Energy Code document. See Section 2.6: AWHP Glycol Concentration Limits - Proposed Language Code of this report for detailed revisions to code language.

3.1.4.1 Energy Code Change Summary

SECTION 110.2 – MANDATORY REQUIREMENTS FOR SPACE-CONDITIONING EQUIPMENT

Subsection 110.2(g) Glycol Concentration: The proposed measure would add a new mandatory requirement limiting the glycol concentration for AWHPs. A sliding scale between 0% and 35% would be established as a function of Heating Median of Extremes, as specified for the nearest weather station listed in Table 2-3 in Joint Appendix JA-2: Reference Weather/Climate Data. Exceptions would include AWHPs serving process loads, AWHPs that operate only in heating mode, locations that are not near a weather station or have microclimates, and AWHPs that are integrated into a fluid loop that includes other hydronic space conditioning plants such as boilers or chillers.

3.1.4.2 Reference Appendices Change Summary

No changes to Reference Appendices are proposed. Verification will be based on certification through compliance forms or compliance software checks.

3.1.4.3 Compliance Manuals Change Summary

Changes to the Nonresidential Compliance Manual are anticipated, but have not yet been defined.

3.1.4.4 Alternative Calculation Method Reference Manual Change Summary

The proposed measure is mandatory, therefore no changes to the Nonresidential Alternative Calculation Method (ACM) are proposed.

3.1.4.5 Compliance Forms Change Summary

Changes to the NRCI-MCH-E Compliance Form are recommended. The NRCC-MCH-E and NRCI-MCH-E compliance forms provide tables to define the boiler, chiller, and air to water heat pump efficiency and controls, as shown in Figure 6. The Statewide CASE Team proposes that the “Boiler Efficiency and Control” table label be updated to “Boiler & Air to Water Heat Pump Efficiency and Controls.” In addition, both tables would have new columns added to include AWHP glycol percentage, both the mandatory limit and the design value.

Figure 6: NRCI-MCH-E compliance form data entry tables for boiler and chiller systems.

Boiler Efficiency and Controls

01		02	03	04	05	06	07	08	09	10	11
Tag/Plan Detail ID		Model #	Equipment Type	Quantity	Rated Input (Btu/h)	Rated Efficiency	Efficiency Unit	Controls		Hot Water Supply Temperature	Equipment Compliance
								Isolation Valve	Temperature Reset		
Per C of C											
As-built Conditions											

Chiller & Air to Water Heat Pump Efficiency and Controls

01		02	03	04	05	06	07	08	09	10	11	12
Tag/Plan Detail ID		Model #	Equipment Type	Quantity	Size (tons)	Rated Efficiency #1	Efficiency Unit #1	Rated Efficiency #2	Efficiency Unit #2	Controls		Equipment Compliance
										Isolation Valve	Temperature Reset	
Per C of C												
As-built Conditions												

3.1.5 Measure Context

3.1.5.1 Comparable Model Codes or Standards

There are no federal equipment standards that establish minimum efficiency requirements for AWHPs and WWHPs. Currently, Title 24 establishes minimum efficiency levels for AWHPs and water-cooled heat recovery chillers based on the test procedures in AHRI standard 550/590-2023: Performance Rating of Water-chilling and Heat Pump Water-heating Packages Using the Vapor Compression Cycle (AHRI 2023). This standard is also referenced in ASHRAE 90.1-2022(ASHRAE 2022). AHRI standard 550/590 includes standard test conditions of 105°F, 120°F, and 140°F heating hot water supply temperature and 47°F and 17°F ambient air dry-bulb temperature on the source side. These ratings are based on 100% water, and do not yet include rated efficiency for AWHPs that use glycol mixtures.

The 2024 IECC model code includes multiple requirements for hydronic heat pumps. It references the nationally recognized standard ASHRAE 90.1-2022 for AWHPs and establishes efficiency for WWHPs based on testing according to ISO 13256-1(ISO 2021).

The International Organization for Standardization (ISO) has published several test procedures for hydronic heat pumps, though none of them have seen widespread adoption in the U.S.

There are no glycol concentration limits for AWHPs in ASHRAE 90.1 or IECC 2024, but both standards list minimum performance requirements for floor- and ceiling-mounted computer-room air conditioners that are glycol cooled based on the AHRI 1361 test standard.

3.1.5.2 Interactions with Other Regulations

The proposed measure does not conflict with any known local, state, or federal requirements for AWHPs.

3.2 AWHP Glycol Concentration Limits - Compliance and Enforcement

3.2.1 Compliance Considerations

Compliance with the proposed measure can be performed by verifying that the glycol concentration is below the maximum allowed in Compliance Forms NRCC-MCH-E and NRCI-MCH-E. Two columns would be added to the form and completed by the designer, one indicating the glycol concentration limit based on the value specified for the nearest weather station in JA2, and the other documenting the actual design concentration which must be equal to or lower than the specified limit unless an exception is claimed. Plans examiner will verify eligibility for exception during design and building inspector will verify eligibility during construction. No acceptance testing is recommended.

To help ensure that the glycol concentration is maintained below the limit over time, a note or sticker may be required on the AWHP system near the point where water/glycol mixture is refilled. Typical replacement of the water/glycol mixture would occur every 5-7 years, with annual checks on concentration level unless the system includes a glycol control system that automatically monitors concentration and adjusts the mixure as needed. This sticker would indicate the design glycol concentration, and provide a warning that higher or lower levels present energy performance or freezing risks.

Alternatively, the compliance software could be updated to perform the calculation of maximum glycol concentration based on the location entered into the model. Proposed glycol concentration would be entered by the user, and the software would perform a compliance check before proceeding with the simulation. This approach would be more convenient for the plan reviewer to verify, and would also enable future enhancements to the software that could accommodate an analysis of the energy impacts of glycol concentration when using the performance path.

3.2.2 Impact on Market Actors

Table 21 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 21: Impacts on Market Actors and Suggested Training and Education Opportunities

Market Actor	Impact(s)	Suggested Outreach and Education
Builders [a]	Ensure maximum glycol concentrations are understood by all parties and implemented in practice.	Educational material such as a fact sheet that explains the use of glycol to prevent freezing, the negative effects on energy efficiency, and the basis for the glycol limits.
Design Professionals [b]	HVAC designers must confirm their specified glycol concentration complies with the limits and the system is designed to meet performance expectations. For most energy conscious designers, they likely already meet the proposed requirements. Others may need to reduce their safety margin or use alternative solutions for corrosion resistance.	Some designers may need greater awareness of freeze protection analysis, proper safety margins, efficiency impacts, and alternative methods for corrosion resistance in warmer climates.
Construction Team [c]	Installation contractors must add glycol consistent with design specifications. Commissioning agents must verify they are implemented in practice. For some systems glycol concentration is verified and maintained through an automated glycol management system.	None required beyond understanding new concentration limits.
Building Departments [d]	Understand changes to compliance forms.	Training or fact sheets explaining the proper use of glycol to prevent freezing or burst damage, and an understanding new concentration limits.
Verification Testers [e]	No additional testing is proposed.	None required
Building Owners, Managers, and Occupants	Reduced energy bills compared to potentially excessive glycol. Carefully selected glycol concentration should have a positive effect on comfort and building operations because the capacity and efficiency will be higher.	None required

Manufacturers and Distributors	May need to advise HVAC designers on alternative methods for minimizing burst risk and corrosion damage with adequate safety margin. Controls to provide minimum flow rate under the coldest weather conditions may be needed.	Best practice guidance and closer coordination with designers may be needed.

a. Builders include builders and developers.
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 (ATT).
f. Concise description of market actor. You can add more detail to the narrative below.

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

Builders. The proposed change would likely affect commercial builders; however, it would likely not impact firms focused on the construction or retrofitting of industrial buildings, utility systems, public infrastructure, or other heavy construction. The proposed change would not affect all firms and workers in the commercial building industries equally; instead, it would primarily affect specific subsectors within the industry. Table 22 shows the commercial building subsectors that the Statewide CASE Team expects to be impacted by the changes proposed in this report.

Table 22: 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
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

Manufacturers. Equipment manufacturers would not be affected in terms of total AWHP sales, but they may be able to offer more affordable bids using smaller pumps and heat exchangers if typical glycol concentrations are reduced, Manufacturers may need to collaborate with designers to ensure the proper measures are in place to protect AWHPs from burst pipes and corrosion, potentially including minimum flow requirements in cold weather. Glycol manufacturers may see a small decrease in sales, but this will be small compared to the expected increase in AWHP sales as recent code changes and other California's electrification initiatives drive market changes. The measure is intended to avoid glycol concentrations that are significantly higher than necessary and helps facilitate long-term growth in the AWHP market by ensuring maximum energy efficiency.

Other Market Actor(s). None.

3.2.3 Compliance Software Updates

Software changes may not be necessary because the proposed measure would only affect mandatory requirements and is not proposed to be incorporated into the performance model. However, to assist in compliance verification, the software could be modified to automatically determine the appropriate glycol concentration limit based on the geographic location, and compare this value to the actual design concentration entered by the building owner. In the long term, it may be appropriate to include glycol concentration as a trade-off in the performance path, but the current lack of rated performance data with differing glycol concentrations makes this approach impractical for the time being.

3.2.4 Cost of Enforcement

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

No incremental cost for enforcement is expected because both actual and maximum allowed glycol concentration will be documented on the revised compliance forms, although there may be a learning curve and training required as enforcement officials become more familiar with glycol concentration limits and exceptions. No acceptance testing is recommended.

3.3 AWHP Glycol Concentration Limits - Market and Economic Analysis

A general discussion of the general market trends for heat pumps was provided in Section 2.3.

3.3.1 Market Structure and Availability

3.3.1.1 Current Market Structure and Availability

A discussion of the general market for AWHPs was provided in Section 2.3.1.1.

Both propylene and ethylene glycol are commonly used in colder climates where pipe freezing would be likely with pure water, typically where the heating design temperature is below or near 32°F (such as Climate Zones 1, 2, 5, 11, 12, 13, 14, 15, and 16). Glycol may be used for corrosion protection in warmer climates, but it is uncommon according to designers and manufacturers interviewed during the CASE development process.

The fraction of buildings affected by the measure is currently expected to be relatively small. Interviews with stakeholders indicate that most experienced designers take great care in selecting the glycol concentration level that provides an adequate safety margin against damage from freezing while maximizing energy efficiency. Other designers may use rules of thumb or rely on the maximum recommended concentration of 50% provided in most AWHP manufacturer’s literature, and there is anecdotal evidence from stakeholders that concentration is usually a round number like 30%, indicating there may not be much fine-tuning of the concentration. For the purpose of statewide impact analysis, it is assumed that 10% of non-residential buildings with AWHPs in climates where the outside temperatures occasionally drop below 32°F would have excessive glycol concentration levels ranging from 30% to 50%. This translates to a Market Share Rate of 90%.

Significant efforts have been made to understand how the proposed code change may impact the market as well as the individual market actors, primarily through stakeholder interviews. The market (particularly distributors, manufacturers, and designers) is a primary source of data for many aspects of this measure. No negative impacts on the market for AWHPs is expected, except possibly in extremely cold locations where hydronic systems may not be the ideal solution for space conditioning anyway because necessary glycol levels severely degrade operational performance.

Without intervention through Title 24, Part 6, it is unlikely that the measure would be adopted beyond the present rate, which is assumed to be 90% of the time. Because there is currently no restriction on glycol concentration or a performance path penalty for higher concentration levels, customer satisfaction and energy-conscious design are the primary motivation for keeping glycol concentrations low, and this code requirement would close a loophole to minimize the opportunity for poor design practices.

3.3.1.2 Market Challenges and Solutions

Based on stakeholder interviews and literature research, there are several market barriers that slow the adoption of AWHPs:

- Limited number of AWHP on the market, though competition has been growing and new products appear every year.
- Uncertain code requirements and enforcement for AWHPs, which are sometimes absent or lumped in with chiller systems that may not have the same design and installation issues.
- Lack of industry-accepted best practices for design and installation.

The proposed measure will help overcome the second and third barriers by adding clear boundaries to allowable glycol concentration, although additional clarifications and best practice guidance may be needed in future code cycles. Glycol concentration itself has not been identified as a market barrier by stakeholders, but it contributes to performance uncertainty, which remains a barrier to widespread adoption of AWHPs.

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

3.3.2 Design and Construction Practices

3.3.2.1 Current Design and Construction Practices

Based on interviews with designers, manufacturers, and industry experts, the responsibility for selecting AWHP glycol concentration lies with the HVAC designer. This decision is guided by equipment manufacturer recommendations in combination with the freezing risk associated with the specific application. Collaboration between designers, manufacturers, and installers is very common when the selection of glycol concentration is made, and other options for freeze protection (such as split systems or minimum flow rates during cold weather) and corrosion protection are generally considered. On occasion, installers or building managers may deviate from the specified concentration and rely on their own judgement or experience, but designers and manufacturers often track the installed glycol levels to ensure compliance with design specifications, and may even include a glycol monitoring and feeder systems. In most scenarios, glycol concentration would be below the limits proposed for this measure.

However, manufacturers literature does not typically recommend specific glycol concentrations for AWHPs under the full range of possible design scenarios. As a result, some designers may choose the upper limit of 50% glycol to ensure there is no risk of freezing without performing a more detailed analysis of system operation under expected weather conditions. Further discussions with a more diverse set of HVAC designers will help determine the frequency of this scenario, and this feedback will inform the Final CASE Report.

3.3.2.2 Health and Safety Considerations

There are no adverse health and safety considerations for the proposed measure. Ethylene glycol is a toxic liquid that requires special handling, but the proposed measure would only reduce its usage.

3.3.2.3 Design and Construction Challenges and Solutions

The proposed measure could require greater collaboration between designers, manufacturers, and installers to achieve the necessary freeze protection without exceeding the glycol concentration limits. As discussed in the previous section, this collaboration is already standard procedure for most energy conscious designers. In addition, glycol concentration is often controlled over time using a glycol management system, and deviations create an alert for designers and other interested parties. However, these practices are not requirements, and further education on best practices may be needed to help designers with less experience or fewer resources select optimal glycol concentrations for the AWHP systems they design.

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

3.3.3 Energy Equity and Environmental Justice

The Statewide CASE Team evaluated the potential impact on environmental and social justice (ESJ) communities, including impacts related to race, class, and gender. There is no clear connection between energy equity and the proposed measure, other than the benefits related to indoor air quality when natural gas boilers are replaced with electric AWHPs for space heating. Benefits resulting from better air quality in the workplace would likely be more important for economically disadvantaged workers and those with pre-existing health issues such as asthma.

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 Robert Hendron (bhendron@frontierenergy) if you have input on how this proposal may impact ESJ communities or if you would like to offer your perspective.

3.3.4 Impacts on Jobs and Businesses

This section will be completed for the Final CASE Report.

3.3.5 Economic and Fiscal Impacts

This section will be completed for the Final CASE Report.

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

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

Cost to State: The state government already has a budget for code development, education, and compliance enforcement. While the state government would be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, these activities are already covered by existing state budgets.

The costs for the state government are small when compared to the overall cost savings and policy benefits associated with the code change proposals. The proposed measure would apply to state buildings with AWHP systems, but analysis has demonstrated that the measure is cost-effective and will have no negative effects on state expenditures in either the short-term or long-term.

Cost to Local Governments: All proposed code changes to Title 24, Part 6 would result in changes to compliance determinations. Local governments would need to train building department staff on the revised Title 24, Part 6 Standards. While this retraining is an expense to local governments, it is not a new cost associated with the 2025 code change cycle. The building code is updated on a triennial basis, and local governments plan and budget for retraining every time the code is updated. There are numerous resources available to local governments to support compliance training that can help mitigate the cost of retraining, including tools, training, and resources provided by the IOU Codes and Standards program (such as Energy Code Ace). As noted in Section , the Statewide CASE Team considered how the proposed code change might impact various market actors involved in the compliance and enforcement process and aimed to minimize negative impacts on local governments.

3.3.5.2 Mandates on Local Agencies or School Districts

There are no relevant mandates to local agencies or school districts. The proposed code change would only impact the requirements for building construction and major alterations involving AWHP systems.

3.3.5.3 Costs to Local Agencies or School Districts

There are no costs to local agencies or school districts. There is expected to be no incremental design cost during the initial building construction or renovation.

3.3.5.4 Costs or Savings to Any State Agency

There are no costs to any state agencies. There is expected to be no incremental design cost during the initial building construction or renovation.

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

There are no costs to any local agencies. There is expected to be no incremental design cost during the initial building construction or renovation.

3.3.5.6 Costs or Savings in Federal Funding to the State

There are no costs or savings to federal funding to the state because the proposed measure only improves the energy efficiency of certain non-residential buildings.

3.3.6 Cost of Enforcement

No significant training costs are expected because compliance with the proposed measure would be readily verified in the revised compliance forms, which will include both the glycol concentration limit and the actual design concentration. Some training or fact sheets may be necessary to increase familiarity with glycol usage and the specific code requirements. No changes to existing compliance and verification processes are needed, but glycol concentrations must be included in the design documentation for the plans examiner.

3.4 AWHP Glycol Concentration Limits - Cost Effectiveness

3.4.1 Cost Effectiveness Methodology

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

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

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

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

3.4.2 Energy and Energy Cost Savings Results

Energy savings (electricity, natural gas, and source energy) and peak demand reductions per unit are presented in Table 23 and Table 24 for new construction/additions and alterations respectively. For the Draft CASE Report, only electric heat pumps were considered in the energy savings analysis because they are much more common than natural gas powered heat pumps. Per-square foot savings for the first year are expected to range from 0 to 0.14 kWh/yr depending upon climate zone, with no impact on natural gas use. Demand reductions/increases are expected to range between 0 kW and 0.01 kW, depending on climate zone

Table 25 presents total per-unit energy cost savings for newly constructed buildings and additions in terms of LSC savings realized over a 30-year period, in 2029 present value dollars (2029 PV$). Similar results are presented in Table 26 for alterations. The LSC methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

Table 23: Energy and Energy Cost Savings – Per Square Foot – New Construction and Additions– Large School

Climate Zone	First Year Electricity Savings (kWh)	First Year Peak Demand Reduction (kW)	First Year Natural Gas Savings (kBtu)	First Year Source Energy Savings (kBtu)	Total 30-Year LSC Savings (2029 PV$)
1	0.02	0.00	-	0.01	0.14
2	0.03	0.00	-	0.02	0.18
3	0.05	0.00	-	0.04	0.34
4	0.07	0.00	-	0.04	0.49
5	0.06	0.00	-	0.04	0.43
6	0.09	0.01	-	0.07	0.64
7	0.00	0.00	-	-	0.00
8	0.10	0.01	-	0.07	0.77
9	0.09	0.01	-	0.07	0.71
10	0.10	0.01	-	0.07	0.73
11	0.04	0.00	-	0.02	0.31
12	0.07	0.00	-	0.04	0.53
13	0.05	0.00	-	0.03	0.36
14	0.02	0.00	-	0.01	0.15
15	0.14	0.01	-	0.10	1.03
16	0.01	0.00	-	0.01	0.07

Table 24: Energy and Energy Cost Savings – Per Square Foot – Alterations – Large School

Climate Zone	First Year Electricity Savings (kWh)	First Year Peak Demand Reduction (kW)	First Year Natural Gas Savings (kBtu)	First Year Source Energy Savings (kBtu)	Total 30-Year LSC Savings (2029 PV$)
1	0.02	0.00	-	0.01	0.14
2	0.03	0.00	-	0.02	0.18
3	0.05	0.00	-	0.04	0.34
4	0.07	0.00	-	0.04	0.49
5	0.06	0.00	-	0.04	0.43
6	0.09	0.01	-	0.07	0.64
7	0.00	0.00	-	-	0.00
8	0.10	0.01	-	0.07	0.77
9	0.09	0.01	-	0.07	0.71
10	0.10	0.01	-	0.07	0.73
11	0.04	0.00	-	0.02	0.31
12	0.07	0.00	-	0.04	0.53
13	0.05	0.00	-	0.03	0.36
14	0.02	0.00	-	0.01	0.15
15	0.14	0.01	-	0.10	1.03
16	0.01	0.00	-	0.01	0.07

Table 25: 2029 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions – Large School

Climate Zone	30-Year LSC Electricity Savings (2029 PV$)	30-Year LSC Natural Gas Savings (2029 PV$)	Total 30-Year LSC Savings (2029 PV$)
1	0.14	0.00	0.14
2	0.18	0.00	0.18
3	0.34	0.00	0.34
4	0.49	0.00	0.49
5	0.43	0.00	0.43
6	0.64	0.00	0.64
7	0.00	0.00	0.00
8	0.77	0.00	0.77
9	0.71	0.00	0.71
10	0.73	0.00	0.73
11	0.31	0.00	0.31
12	0.53	0.00	0.53
13	0.36	0.00	0.36
14	0.15	0.00	0.15
15	1.03	0.00	1.03
16	0.07	0.00	0.07

Table 26: 2029 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations– Large School

Climate Zone	30-Year LSC Electricity Savings (2029 PV$)	30-Year LSC Natural Gas Savings (2029 PV$)	Total 30-Year LSC Savings (2029 PV$)
1	0.14	0.00	0.14
2	0.18	0.00	0.18
3	0.34	0.00	0.34
4	0.49	0.00	0.49
5	0.43	0.00	0.43
6	0.64	0.00	0.64
7	0.00	0.00	0.00
8	0.77	0.00	0.77
9	0.71	0.00	0.71
10	0.73	0.00	0.73
11	0.31	0.00	0.31
12	0.53	0.00	0.53
13	0.36	0.00	0.36
14	0.15	0.00	0.15
15	1.03	0.00	1.03
16	0.07	0.00	0.07

3.4.3 Incremental First Cost

Based on interviews with HVAC designers and manufacturers, the proposed measure would not result in higher first costs for AWHP systems. Any small cost to document glycol concentration in the compliance forms would be outweighed by the reduced cost of purchasing glycol. The price of propylene glycol in late 2025 was $1357/metric ton (ChemAnalyst 2025). Based on an assumption of 6 tons of water per ton of cooling (ClimaCool 2019), the estimated cost of glycol is $7,128 for a 30% concentration in the large school prototype buildings.

3.4.4 Incremental Maintenance and Replacement Costs

Description of the incremental maintenance and replacement costs, as well as estimation of present value of maintenance and replacement costs, are provided in the 2028 CASE Methodology Report.

Based on interviews with stakeholders, there would be no meaningful increase in maintenance or replacement costs for the proposed measure. In general, glycol concentrations are already managed and tracked over time to ensure freeze protection, and some sites may gain the benefit of no longer having to track glycol levels.

3.4.5 Cost Effectiveness

Results of the per-unit cost-effectiveness analyses are presented in Table 27 and Table 28 for new construction/additions and alterations, respectively.

In the tables below, all values are presented in 2026 present value dollars (2029 PV$). Benefits represent 30-year LSC savings and other savings, including incremental first-cost savings if the proposed first cost is less than the current first cost, incremental maintenance cost savings if the proposed maintenance costs are less than the current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at the end of the 30-year period of analysis. Costs represent the total incremental PV cost, including incremental equipment, replacement, and maintenance costs over the period of analysis. For the proposed measure, total incremental costs are estimated to be zero, and positive LSC savings are expected in all Climate Zones. Therefore, the benefit-cost ratio (BCR) is considered infinite. Costs and other savings are discounted at a real (inflation-adjusted) three percent rate.

Table 27: 30-Year Cost-Effectiveness Summary Per Square Foot – New Construction and Additions

Climate Zone	Benefits LSC Savings + Other PV Savings (2029 PV$)	Costs Total Incremental PV Costs (2029 PV$)	Benefit-to-Cost Ratio
1	0.14	$0	Infinite
2	0.18	$0	Infinite
3	0.34	$0	Infinite
4	0.49	$0	Infinite
5	0.43	$0	Infinite
6	0.64	$0	Infinite
7	0.00	$0	N/A
8	0.77	$0	Infinite
9	0.71	$0	Infinite
10	0.73	$0	Infinite
11	0.31	$0	Infinite
12	0.53	$0	Infinite
13	0.36	$0	Infinite
14	0.15	$0	Infinite
15	1.03	$0	Infinite
16	0.07	$0	Infinite

Table 28: 30-Year Cost-Effectiveness Summary Per Square Foot – Alterations

Climate Zone	Benefits LSC Savings + Other PV Savings (2029 PV$)	Costs Total Incremental PV Costs (2029 PV$)	Benefit-to-Cost Ratio
1	0.14	$0	Infinite
2	0.18	$0	Infinite
3	0.34	$0	Infinite
4	0.49	$0	Infinite
5	0.43	$0	Infinite
6	0.64	$0	Infinite
7	0.00	$0	Infinite
8	0.77	$0	Infinite
9	0.71	$0	Infinite
10	0.73	$0	Infinite
11	0.31	$0	Infinite
12	0.53	$0	Infinite
13	0.36	$0	Infinite
14	0.15	$0	Infinite
15	1.03	$0	Infinite
16	0.07	$0	Infinite

3.5 AWHP Glycol Concentration Limits - Statewide Impacts

3.5.1 Statewide Energy and Energy Cost Savings

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

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

The tables below present the first-year statewide energy and LSC savings from newly constructed buildings and additions (Table 29) and alterations (Table 30) by climate zone.

Table 31 presents first-year statewide savings from new construction, additions, and alterations. The analysis only includes the large school prototype with AWHPs for space conditioning, and is therefore very conservative. Additional building types will be modeled for the Final CASE Report.

Table 29: Statewide Energy and LSC Impacts – New Construction and Additions

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Square Feet)	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction	First-Year Natural Gas Savings (Million Therms)	First-Year Natural Gas Savings (Million Therms) First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2029 PV$)
1	114	0.00	0.00	-	0.00	$0.00
2	2,243	0.00	0.00	-	0.00	$0.00
3	15,437	0.00	0.00	-	0.00	$0.01
4	7,785	0.00	0.00	-	0.00	$0.00
5	641	0.00	0.00	-	0.00	$0.00
6	10,468	0.00	0.00	-	0.00	$0.01
7	10,720	-	-	-	-	$0.00
8	15,950	0.00	0.00	-	0.00	$0.01
9	25,038	0.00	0.00	-	0.00	$0.02
10	15,039	0.00	0.00	-	0.00	$0.01
11	6,246	0.00	0.00	-	0.00	$0.00
12	20,298	0.00	0.00	-	0.00	$0.01
13	10,835	0.00	0.00	-	0.00	$0.00
14	2,927	0.00	0.00	-	0.00	$0.00
15	1,511	0.00	0.00	-	0.00	$0.00
16	1,200	0.00	0.00	-	0.00	$0.00
Total	**146,450**	**0.01**	**0.00**	**-**	**0.01**	**$0.08**

Table 30: Statewide Energy and LSC Impacts – Alterations

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Square Feet)	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction	First-Year Natural Gas Savings (Million Therms)	First-Year Natural Gas Savings (Million Therms) First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2029 PV$)
1	1,012	0.00	0.00	-	0.00	$0.00
2	10,693	0.00	0.00	-	0.00	$0.00
3	46,440	0.00	0.00	-	0.00	$0.02
4	18,600	0.00	0.00	-	0.00	$0.01
5	2,761	0.00	0.00	-	0.00	$0.00
6	37,827	0.00	0.00	-	0.00	$0.02
7	30,053	-	-	-	-	$0.00
8	57,213	0.01	0.00	-	0.00	$0.04
9	98,107	0.01	0.00	-	0.01	$0.07
10	74,680	0.01	0.00	-	0.01	$0.05
11	13,507	0.00	0.00	-	0.00	$0.00
12	71,173	0.00	0.00	-	0.00	$0.04
13	35,213	0.00	0.00	-	0.00	$0.01
14	16,080	0.00	0.00	-	0.00	$0.00
15	10,161	0.00	0.00	-	0.00	$0.01
16	4,785	0.00	0.00	-	0.00	$0.00
Total	**528,307**	**0.04**	**0.00**	**-**	**0.03**	**$0.29**

Table 31: 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	0.01	0.00	-	0.01	0.08
Alterations	0.04	0.00	-	0.03	0.29
Total	**0.05**	**0.00**	**-**	**0.03**	**0.36**

3.5.2 Statewide Greenhouse Gas Emissions Reductions

Table 32 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 33 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 32: 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	1.8	0	1.8	221.5
Alterations				
Total	**1.8**	**0**	**1.8**	**221.5**

3.5.3 Statewide Water Use Impacts

The proposed code change will not result in water use impacts beyond the negligible amount of water that replaces glycol in the AWHP water loop.

3.5.4 Statewide Material Impacts

The proposed code change will not result in material use impacts, beyond a negligible reduction in glycol use in some buildings.

3.5.5 Environmental Impacts

No environmental impacts are anticipated for the proposed measure beyond slightly less ethylene glycol use, which is considered toxic and must be disposed of carefully when it is replaced in a system.

3.5.6 Other Non-Energy Impacts

The proposed measure indirectly provides IAQ benefits for affected buildings by enabling greater use of all-electric space conditioning equipment and reducing site emissions associated with natural gas boilers inside conditioned space.

3.6 AWHP Glycol Concentration Limits - Proposed Language Code

3.6.1 Guide to Markup Language

The proposed changes to the standards, Reference Appendices, and the ACM Reference Manuals are provided below.

3.6.2 Administrative Code (Title 24, Part 1)

No changes.

3.6.3 Energy Code (Title 24, Part 6)

The recommended measure would add mandatory requirements for glycol concentration to Section 110.2.

SECTION 110.2 – MANDATORY REQUIREMENTS FOR SPACE-CONDITIONING EQUIPMENT

(g) Glycol Concentration: Air-to-water heat pumps shall comply with one of the following:

1. For split AWHPs where the refrigerant-to-water heat exchanger and all water pipes are installed within the conditioned space, no glycol shall be used.
2. For all AWHPs where all or part of the water loop is outside of the building or passes through unconditioned or semi-conditioned areas of the building, volumetric glycol concentration shall be limited as a function of the heating median of extremes for the nearest weather station in accordance with Table 110.2-M. If a minimum flow rate is specified by the manufacturer, it shall be used during periods when the outside air temperature is below 37°F.

Exception 1 to Section 110.2(g): AWHPs serving ice storage systems or process loads.

Exception 2 to Section 110.2(g): AWHPs integrated with a larger hydronic space conditioning system that includes boilers or chillers.

Exception 3 to Section 110.2(g): AWHPs that only operate in heating mode.

Exception 4 to Section 110.2(g): Group R Occupancy, and common or public use areas serving that Occupancy

TABLE 110.2-M AIR-TO-WATER HEAT PUMP GLYCOL CONCENTRATION LIMITS

Heating Median of Extremes (From JA2-4)	**Maximum Glycol Concentration by Volume**
Above 37°F	0
25°F to 37°F	13%
15°F to 24°F	21%
5°F to 14°F	25%
-5°F to 4°F	29%
-15°F to -6°F	31%
Below -15°F	35%

An alternative approach that meets similar objectives for this measure would add similar mandatory requirements for glycol concentration to Section 110.2, but would encourage the use of split AWHPs. This alternative will be further researched and discussed with stakeholders prior to the Final CASE Report, but is not used for the purpose of cost-effectiveness and statewide impact analysis.

SECTION 110.2 – MANDATORY REQUIREMENTS FOR SPACE-CONDITIONING EQUIPMENT

(g) Air-to-Water Heat Pump Design: Split-design AWHPs shall be required to have the evaporator and all water pipes installed within the conditioned space. If space limitations exist that prevent locating the indoor unit inside the building envelope and are clearly documented by the mechanical engineer or architect during plan review, the project may proceed using packaged AWHPs.

Exception to Section 110.2(g): Group R Occupancy, and common or public use areas serving that Occupancy

(h) Glycol Concentration: Air-to-water heat pumps shall comply with one of the following:

1. For split AWHPs where the evaporator and all water pipes are installed within the conditioned space, no glycol shall be used.
2. For packaged AWHPs where all or part of the water loop passes through outside weather conditions, volumetric glycol concentration shall be engineered based on the lowest expected ambient or fluid temperature, the protection objective (freeze or burst), and the glycol type, and shall not exceed 35%. If a minimum flow rate is specified by the manufacturer, it shall be used during periods when the outside air temperature is below 32°F.

Exception 1 to Section 110.2(h): AWHPs serving ice storage systems or process loads.

Exception 2 to Section 110.2(h): AWHPs integrated with a larger hydronic space conditioning system that includes boilers or chillers.

Exception 3 to Section 110.2(h): AWHPs that only operate in heating mode.

Exception 4 to Section 110.2(h): Group R Occupancy, and common or public use areas serving that Occupancy

3.6.4 Reference Appendices

There are no proposed changes to the Reference Appendices.

3.6.5 Compliance Manuals

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

3.6.6 ACM Reference Manual

There are no proposed changes to the ACM Reference Manual.

3.6.7 Compliance Forms

As discussed in Section 3.1.4.5, the NRCC-MCH-E and NRCI-MCH-E Compliance Forms would be updated to reflect the proposed change. Details of compliance form changes will be included in the Final CASE Report. 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

AWHP Alignment with Boiler and Chiller Requirements

Key Assumptions for Energy Savings Analysis

- The Statewide CASE Team simulated the energy impacts in every climate zone and applied the climate-zone-specific LSC hourly factors when calculating energy and energy cost impacts.
- The effect of turning off water flow to unused AWHPs was approximated by running pumps at full speed whenever there was a load. This conservative simplification was necessary for the Draft CASE Report because the existing HVAC systems in the prototype buildings must be replaced with AWHPs, and none of the prototypes had staged, multi-unit systems where the measure could be applied directly. All prototypes will be modified to include AWHPs prior to the Final CASE Report.
- The base case represented standard practice for AWHP systems that continue to provide water flow when individual units are inactive. The proposed case used the default pump control in the model, which increased or decreased flow based on the heating and cooling load being served.
- Stakeholder input contributed to the development of the baseline assumption of continuous or full capacity flow where one or more AWHPs are not needed to meet the load, and to the market share estimate of 65% of buildings with AWHPs that are already in compliance with the proposed measure. Stakeholders also indicated that most non-residential buildings with AWHP systems use several smaller staged units to meet the changing loads, resulting in our assumption of 60% of measured floorspace affected by the measure combined with 30% of new non-residential buildings using AWHPs in 2029.

Energy Savings Methodology per Prototypical Building

The 2028 CASE Methodology Report provides details on estimating energy savings per prototypical building and unit. The CEC directed the Statewide CASE Team to model energy impacts using specific prototypical building models that represent typical building geometries for different building types. Table 33 presents the prototype building used in the analysis, which was limited to one prototype for the Draft CASE Report because the priority was to demonstrate cost-effectiveness and to establish a reasonable analysis methodology and assumptions. The Large School prototype was selected because the original HVAC system was already hydronic and could be more readily adapted to an AWHP system than some of the other prototype HVAC systems. The Final CASE Report will include additional non-residential prototype buildings in all climate zones.

Table 33: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name	Number of Stories	Floor Area (Square Feet)	Description
Large School	2	210,866	Large school served by two chiller and two boiler plants, with variable air volume distribution and terminal reheat. Chillers and boilers replaced with AWHPs meeting minimum efficiency requirements.

There is an existing Title 24, Part 6 requirement that covers the Large School HVAC system, and applies to both new construction/additions and alterations, so the Standard Design is minimally compliant with the 2025 Title 24 requirements. However, the Large School prototype did not have an AWHP or WWHP system serving space conditioning loads. The existing boilers and chillers were replaced with AWHPs that meet the minimum efficiency requirements specified in the 2025 code. The AWHPs served exclusively space heating or space cooling loads in the school, rather than operating in both modes as would most AWHP systems. Also, the AWHPs served separate zones, which meant that modeling realistic equipment staging based on load could not be performed for the Draft CASE Report without significant changes to the distribution system and controls in EnergyPlus. These limitations will be addressed for the Final CASE Report. To approximate continuous pump operation for AWHPs that are turned off, which is currently allowed in the 2025 code, the pumps serving each pair of AWHPs were operated at full speed whenever there was a load on either AWHP.

The Proposed Design was identical to the Standard Design in all ways except for the revisions that represent the proposed changes to the code. Table 34 presents the parameters modified and the values used in the Standard Design and Proposed Design. Specifically, the proposed conditions assume that pumps serving non-operating AWHPs reduce flow rate based on the magnitude of the space conditioning load, approximating the number of staged AWHPs needed to meet the load. AWHP flow rate in the proposed design decreases according to the standard control logic in CBECC.

Table 34: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change

Prototype ID	Climate Zone	Objects Modified	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
Large School	All	Base ChW Pumps, AWHP-HW Pumps	Pump Flow Rate Schedule	Optimized	Pumps for paired systems scheduled to run together at max capacity

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

AWHP Glycol Concentration Limits

Key Assumptions for Energy Savings Analysis

The objective of this CASE analysis is to quantify the energy impacts of varying propylene glycol (PG) concentrations in nonresidential AWHP hydronic systems. Propylene glycol is widely used in cold-climate hydronic systems to provide freeze protection; however, glycol mixtures have lower thermal performance and higher pumping energy requirements than pure water due to changes in viscosity, density, and specific heat. Ethylene glycol could also have been used in the modeling, but is used less often than PG.

- The Statewide CASE Team simulated the energy impacts in every climate zone except CZ7 where the standard and proposed glycol concentrations would be the same, and applied the climate-zone-specific LSC hourly factors when calculating energy and energy cost impacts.
- The base case represented standard practice for AWHP systems with conservatively high levels of glycol that go beyond a reasonable safety margin. Based on the California cities representing each Climate Zone as described in JA2, all of the base case models used glycol concentrations of either 0% or 30%. The proposed case used the mandatory maximum concentration level.
- Although stakeholders were very reluctant to provide typical numbers for glycol concentration, their input was sufficient to establish a baseline assumption of 30% as the typical glycol concentration when AWHPs are exposed to temperatures below freezing, with 50% as highest value in even the most extreme climates. The market share estimate is 90% of buildings with AWHPs that are already in compliance with the proposed measure, again based on inputs from stakeholders that the vast majority of HVAC contractors are careful not to increase energy use by using excessive glycol concentrations. Stakeholders also indicated that California policies encouraging electrification will push the market penetration of AWHPs in new non-residential buildings to much higher levels, which is conservatively assumed to be 20% by 2029.

Energy Savings Methodology per Prototypical Building

The 2028 CASE Methodology Report provides details on estimating energy savings per prototypical building and unit. The CEC directed the Statewide CASE Team to model energy impacts using specific prototypical building models that represent typical building geometries for different building types. Table 35 presents the prototype building used in the analysis, which was limited to one prototype for the Draft CASE Report because the priority was to demonstrate cost-effectiveness and to establish a reasonable analysis methodology and assumptions. The Large School prototype was selected because the original HVAC system was already hydronic and could be more readily adapted to an AWHP system than some of the other prototype HVAC systems. The Final CASE Report will include all non-residential prototype buildings in all climate zones where the measure is likely to have an impact on energy savings.

Table 35: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name	Number of Stories	Floor Area (Square Feet)	Description
Large School	2	210,866	Large school served by two chiller and two boiler plants, with variable air volume distribution and terminal reheat. Chillers and boilers replaced with AWHPs meeting minimum efficiency requirements.

There is an existing Title 24, Part 6 requirement that covers the Large School HVAC system, and applies to both new construction/additions and alterations, so the Standard Design is minimally compliant with the 2025 Title 24 requirements. However, the Large School prototype does not have an AWHP system serving space conditioning loads. For the analysis of the proposed measure, the existing boilers and chillers were replaced with AWHPs that meet the minimum efficiency requirements specified in the 2025 code but serve only space heating or space cooling loads in the school, rather than operating in both modes as would most AWHP systems. For the proposed measure, the Standard Model includes a fairly high glycol concentration (see **Table 36**), which may be an uncommon practice (about 10% of non-residential buildings in California), but is allowed by the 2025 code and represents a realistic scenario where expected AWHP efficiency will not be achieved in practice. Glycol was only used for the AWHP providing space cooling, because EnergyPlus currently predicts energy savings with increasing glycol concentration in heating mode. This result is not consistent with the lower thermal properties of glycol compared to water, or the lab testing performed at Frontier's laboratory in Davis. These concerns and limitations will be addressed for the Final CASE Report.

Table 36: Standard Design assumed glycol concentration

Heating Median of Extremes (From JA2-4)	Common Practice Glycol Concentration
Above 37°F	0
25°F to 37°F	30%
15°F to 24°F	30%
5°F to 14°F	30%
-5°F to 4°F	50%
-15°F to -6°F	50%
Below -15°F	50%

The Proposed Design was identical to the Standard Design in all ways except for the revisions that represent the proposed changes to the code. Table 37 presents the parameters modified and the values used in the Standard Design and Proposed Design. Specifically, the Proposed Design applies the maximum glycol concentration based on the Heating Median of Extremes from JA2 for the nearest weather station.

Table 37: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change

Prototype ID	Climate Zone	Objects Modified	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
Large School	1	Working Fluid, Pump	Concentration, Power Multiplier	30%, 1.4	13%, 1.2
Large School	2	Working Fluid, Pump	Concentration, Power Multiplier	30%, 1.4	21%, 1.3
Large School	3	Working Fluid, Pump	Concentration, Power Multiplier	30%, 1.4	13%, 1.2
Large School	4	Working Fluid, Pump	Concentration, Power Multiplier	30%, 1.4	13%, 1.2
Large School	5	Working Fluid, Pump	Concentration, Power Multiplier	30%, 1.4	13%, 1.2
Large School	6	Working Fluid, Pump	Concentration, Power Multiplier	30%,1.4	13%, 1.2
Large School	7 (NA)	Working Fluid, Pump	Concentration, Power Multiplier	0%, 1	0%, 1
Large School	8	Working Fluid, Pump	Concentration, Power Multiplier	30%, 1.4	13%, 1.2
Large School	9	Working Fluid, Pump	Concentration, Power Multiplier	30%, 1.4	13%, 1.2
Large School	10	Working Fluid, Pump	Concentration, Power Multiplier	30%, 1.4	13%, 1.2
Large School	11	Working Fluid, Pump	Concentration, Power Multiplier	30%, 1.4	21%, 1.3

Large School	12	Working Fluid, Pump	Concentration, Power Multiplier	30%, 1.4	13%, 1.2
Large School	13	Working Fluid, Pump	Concentration, Power Multiplier	30%, 1.4	21%, 1.3
Large School	14	Working Fluid, Pump	Concentration, Power Multiplier	30%, 1.4	25%, 1.35
Large School	15	Working Fluid, Pump	Concentration, Power Multiplier	30%, 1.4	13%, 1.2
Large School	16	Working Fluid, Pump	Concentration, Power Multiplier	30%, 1.4	25%, 1.35

The energy impacts of the proposed code change vary by climate zone. The Statewide CASE Team simulated the energy impacts in every climate zone except CZ7 and applied the climate-zone-specific LSC hourly factors when calculating energy and LSC impacts.

Appendix B: Purpose and Necessity of Proposed Code Changes

This section will be written for the Final CASE Report.

Appendix C: Assumptions for Statewide Savings Estimates

The Statewide CASE Team is anticipating updated construction forecasts to be released by the California Energy Commission in February 2026. This will impact statewide energy savings but not the cost effectiveness of the proposal. The final CASE Report will present the updated savings based on the new forecasts.

AWHP Alignment with Boiler and Chiller Requirements

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

The statewide savings and cost estimates take the current market share rate into account. The Statewide CASE Team estimated that the current market share rate for the proposed code change is 65 percent for both the new construction and retrofit markets. The current market share rate was estimated based on interviews with well-informed stakeholders from the HVAC design and manufacturing sectors.

Table 38 presents the projected nonresidential new construction that the proposed code change will impact in 2029. Table 39 shows the projected nonresidential existing statewide building stock that the proposed code change would affect through alterations in 2029. The Statewide CASE Team developed these estimates using the methods described in this section.

The Statewide CASE Team estimated the percentage of newly constructed floor space that the proposed code change would impact. Table 40 shows the assumed percentage of affected floorspace by building type. If a proposed code change does not apply to a specific building type, the Statewide CASE Team assumes that zero percent of the floor space would be impacted. If the assumed percentage is non-zero, but less than 100 percent, the proposal is expected to affect some—but not all—buildings. For the proposed measure aligning AWHP and WWHP isolation requirements with similar chiller and boiler requirement, it is assumed that 30% of new offices and schools under 150,000 ft^2 and 20% of other new and existing non-residential buildings (excluding Group R Occupancy and building types with no prototype model) will include AWHPs or WWHPs, and 60% of those systems are multi-unit staged systems based on discussions with HVAC designers and manufacturers. It is likely that existing buildings have a lower market penetration for AWHPs/WWHPs than new construction, but the measure will apply to new equipment which may have about the same adoption rate for AWHPs/WWHPs as new construction. It is also assumed that 65% of

AWHPs and WWHPs already comply with the proposed measure, as described earlier in this section when discussing market share rate.

Table 41 represents the assumed percentage of affected floorspace by climate zone. No exceptions are included based on climate zone, except that a minimum flow rate is allowed to prevent freezing when necessary. However, the measure applies at all other times in all climate zones. The cost-effectiveness analysis provided in this Draft CASE Report indicates that application in certain climate zones may not be cost-effective, but the first costs and energy savings calculations are being further investigated and refined before any climate zones are excluded from the requirements.

Table 38: Estimated New Nonresidential Construction Impacted by Proposed Code Change in 2029, by Climate Zone and Building Type (Million Square Feet)

Building Type	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16	All
Large Office	0.00	0.00	0.12	0.06	0.00	0.05	0.03	0.09	0.16	0.01	0.00	0.02	0.00	0.01	0.00	0.00	0.56
Medium Office	0.01	0.03	0.09	0.05	0.02	0.08	0.05	0.10	0.20	0.07	0.02	0.18	0.04	0.02	0.02	0.01	0.97
Small Office	0.00	0.03	0.01	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.01	0.03	0.02	0.00	0.01	0.00	0.20
Large Retail	0.00	0.00	0.05	0.02	0.01	0.03	0.02	0.03	0.07	0.03	0.01	0.05	0.01	0.01	0.01	0.00	0.35
Medium Retail	0.00	0.01	0.03	0.02	0.00	0.03	0.01	0.04	0.06	0.03	0.01	0.03	0.02	0.01	0.01	0.00	0.31
Strip Mall	0.00	0.01	0.02	0.01	0.00	0.02	0.02	0.04	0.04	0.06	0.00	0.02	0.01	0.01	0.00	0.00	0.29
Mixed-Use Retail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Large School	0.00	0.00	0.03	0.02	0.00	0.02	0.02	0.03	0.05	0.03	0.01	0.04	0.02	0.01	0.00	0.00	0.31
Small School	0.00	0.02	0.03	0.01	0.01	0.02	0.02	0.02	0.04	0.02	0.01	0.05	0.02	0.01	0.00	0.00	0.28
Non-refrigerated Warehouse	0.00	0.02	0.09	0.05	0.01	0.06	0.03	0.08	0.13	0.06	0.03	0.12	0.03	0.02	0.02	0.01	0.73
Hotel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Assembly	0.00	0.02	0.07	0.02	0.00	0.03	0.03	0.06	0.08	0.05	0.01	0.06	0.01	0.01	0.00	0.00	0.46
Hospital	0.00	0.01	0.03	0.02	0.00	0.01	0.02	0.02	0.03	0.03	0.01	0.03	0.01	0.01	0.00	0.00	0.24
Laboratory	0.00	0.01	0.05	0.03	0.00	0.02	0.01	0.02	0.04	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.23
Restaurant	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.02	0.03	0.02	0.00	0.01	0.01	0.00	0.00	0.00	0.15
Enclosed Parking Garage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Open Parking Garage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grocery	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Refrigerated Warehouse	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Controlled-Environment Horticulture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Vehicle Service	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unassigned	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	**0.0**	**0.2**	**0.6**	**0.3**	**0.1**	**0.4**	**0.3**	**0.6**	**1.0**	**0.5**	**0.1**	**0.7**	**0.2**	**0.1**	**0.1**	**0.0**	**5.1**

Table 39: Estimated Existing Nonresidential Floorspace Impacted by Proposed Code Change in 2029 (Alterations), by Climate Zone and Building Type (Million Square Feet)

Building Type	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16	All
Large Office	0.00	0.01	0.39	0.20	0.01	0.28	0.20	0.46	0.85	0.16	0.01	0.22	0.03	0.06	0.01	0.01	2.89
Medium Office	0.01	0.13	0.33	0.18	0.06	0.20	0.18	0.25	0.36	0.28	0.07	0.43	0.11	0.06	0.04	0.02	2.70
Small Office	0.02	0.05	0.09	0.05	0.03	0.06	0.04	0.06	0.09	0.10	0.04	0.18	0.09	0.02	0.03	0.01	0.96
Large Retail	0.00	0.02	0.16	0.08	0.01	0.09	0.07	0.12	0.19	0.15	0.03	0.16	0.06	0.03	0.03	0.01	1.22
Medium Retail	0.00	0.04	0.12	0.07	0.02	0.12	0.10	0.19	0.30	0.19	0.03	0.17	0.07	0.04	0.02	0.01	1.50
Strip Mall	0.01	0.03	0.10	0.05	0.01	0.11	0.08	0.16	0.23	0.19	0.03	0.14	0.07	0.04	0.02	0.01	1.29
Mixed-use Retail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Large School	0.00	0.02	0.10	0.04	0.01	0.08	0.06	0.12	0.21	0.16	0.03	0.15	0.07	0.03	0.02	0.01	1.11
Small School	0.01	0.05	0.11	0.04	0.03	0.11	0.06	0.14	0.23	0.14	0.06	0.18	0.10	0.04	0.02	0.02	1.31
Non-refrigerated Warehouse	0.01	0.06	0.30	0.15	0.03	0.25	0.14	0.36	0.58	0.51	0.09	0.42	0.14	0.11	0.08	0.03	3.27
Hotel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Assembly	0.01	0.05	0.26	0.13	0.02	0.16	0.11	0.25	0.34	0.26	0.05	0.20	0.08	0.05	0.03	0.02	2.01
Hospital	0.01	0.03	0.14	0.07	0.01	0.08	0.08	0.11	0.20	0.11	0.03	0.15	0.06	0.02	0.01	0.01	1.12
Laboratory	0.00	0.01	0.10	0.08	0.00	0.03	0.05	0.04	0.05	0.03	0.00	0.03	0.01	0.00	0.00	0.00	0.46
Restaurant	0.00	0.01	0.04	0.02	0.00	0.05	0.03	0.07	0.11	0.09	0.01	0.05	0.02	0.02	0.01	0.01	0.54

Enclosed Parking Garage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Open Parking Garage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grocery	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Refrigerated Warehouse	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Controlled-Environment Horticulture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vehicle Service	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unassigned	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	**0.1**	**0.5**	**2.3**	**1.2**	**0.2**	**1.6**	**1.2**	**2.3**	**3.7**	**2.4**	**0.5**	**2.5**	**0.9**	**0.5**	**0.3**	**0.2**	**20.4**

Table 40: Percentage of Nonresidential Floorspace Impacted by Proposed Code Change in 2029, by Building Type

Building Type	New Construction Impacted (Percent Square Footage)	Existing Building Stock (Alterations) Impacted (Percent Square Footage)
Large Office	4%	0.3%
Medium Office	6%	0.4%
Small Office	6%	0.4%
Large Retail	4%	0.3%
Medium Retail	4%	0.3%
Strip Mall	4%	0.3%
Mixed-Use Retail	0%	0.0%
Large School	4%	0.3%
Small School	6%	0.4%
Non-refrigerated Warehouse	4%	0.3%
Hotel	0%	0.0%
Assembly	4%	0.3%
Hospital	4%	0.3%
Laboratory	4%	0.3%
Restaurant	4%	0.3%
Enclosed Parking Garage	0%	0.0%
Open Parking Garage	0%	0.0%
Grocery	0%	0.0%
Refrigerated Warehouse	0%	0.0%
Controlled-Environment Horticulture	0%	0.0%
Vehicle Service	0%	0.0%
Manufacturing	0%	0.0%
Unassigned	0%	0.0%

Table 41: Percentage of Nonresidential Floorspace Impacted by Proposed Measure, by Climate Zone

Climate Zone	New Construction Impacted (Percent Square Footage)	Existing Building Stock (Alterations) Impacted (Percent Square Footage)
1	4%	0.3%
2	4%	0.2%
3	3%	0.2%
4	3%	0.2%
5	4%	0.2%
6	2%	0.2%
7	3%	0.2%
8	3%	0.2%
9	3%	0.2%
10	4%	0.2%
11	4%	0.3%
12	4%	0.2%
13	4%	0.2%
14	4%	0.2%
15	4%	0.3%
16	4%	0.2%

AWHP Glycol Concentration Limits

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

The statewide savings and cost estimates take the current market share rate into account. The Statewide CASE Team estimated that the current market share rate for the proposed code change is 90 percent for both the new construction and retrofit markets. The current market share rate was estimated based on interviews with well-informed stakeholders from the HVAC design and manufacturing sectors.

Table 42 presents the projected nonresidential new construction that the proposed code change will impact in 2029. Table 43 shows the projected nonresidential existing statewide building stock that the proposed code change would affect through alterations in 2029. The Statewide CASE Team developed these estimates using the methods described in this section.

The Statewide CASE Team estimated the percentage of newly constructed floor space that the proposed code change would impact. Table 44 shows the assumed percentage of affected floorspace by building type. If a proposed code change does not apply to a specific building type, the Statewide CASE Team assumes that zero percent of the floor space would be impacted. If the assumed percentage is non-zero, but less than 100 percent, the proposal is expected to affect some—but not all—buildings. For the proposed measure limiting glycol concentration for AWHPs, it is assumed that 30% of new offices and schools under 150,000 ft^2 and 20% of other new and existing non-residential buildings (excluding Group R Occupancy and building types with no prototype model) will include AWHPs. It is likely that existing buildings have a lower market penetration for AWHPs than new construction, but the measure is assumed to apply to new equipment having about the same 30% adoption rate for AWHPs as new construction. It is also assumed that 90% of AWHPs already comply with the proposed measure, again based on stakeholder interviews indicating that designers are motivated to minimize glycol concentration to the extent possible while protecting against frozen or burst pipes. Table 45 represents the assumed percentage of affected floorspace by climate zone. No exceptions are included based on climate zone, except that the maximum glycol concentration varies. The cost-effectiveness analysis provided in this Draft CASE Report indicates that the measure is cost-effective in all climate zones, because the first cost is likely to be negligible or even negative. There may be several cities in California where the proposed glycol concentration limit is approximately the same as the assumed standard practice, resulting in no expected savings.

Table 42: Estimated New Nonresidential Construction Impacted by Proposed Code Change in 2029, by Climate Zone and Building Type (Million Square Feet)

Building Type	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16	All
Large Office	0.00	0.00	0.06	0.03	0.00	0.03	0.01	0.04	0.07	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.27
Medium Office	0.00	0.01	0.04	0.02	0.01	0.04	0.02	0.05	0.10	0.04	0.01	0.08	0.02	0.01	0.01	0.00	0.46
Small Office	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.02	0.01	0.00	0.00	0.00	0.10
Large Retail	0.00	0.00	0.02	0.01	0.00	0.01	0.01	0.02	0.03	0.01	0.01	0.03	0.01	0.00	0.00	0.00	0.17
Medium Retail	0.00	0.01	0.02	0.01	0.00	0.01	0.01	0.02	0.03	0.02	0.00	0.01	0.01	0.00	0.00	0.00	0.15
Strip Mall	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.02	0.02	0.03	0.00	0.01	0.01	0.01	0.00	0.00	0.14
Mixed-Use Retail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Large School	0.00	0.00	0.02	0.01	0.00	0.01	0.01	0.02	0.03	0.02	0.01	0.02	0.01	0.00	0.00	0.00	0.15
Small School	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.02	0.01	0.00	0.02	0.01	0.00	0.00	0.00	0.13
Non-refrigerated Warehouse	0.00	0.01	0.04	0.02	0.00	0.03	0.01	0.04	0.06	0.03	0.01	0.06	0.02	0.01	0.01	0.00	0.35
Hotel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Assembly	0.00	0.01	0.03	0.01	0.00	0.02	0.02	0.03	0.04	0.02	0.00	0.03	0.01	0.00	0.00	0.00	0.22
Hospital	0.00	0.00	0.02	0.01	0.00	0.01	0.01	0.01	0.02	0.02	0.00	0.02	0.01	0.00	0.00	0.00	0.12
Laboratory	0.00	0.00	0.03	0.01	0.00	0.01	0.01	0.01	0.02	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.11
Restaurant	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.02	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.07
Enclosed Parking Garage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Open Parking Garage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grocery	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Refrigerated Warehouse	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Controlled-Environment Horticulture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vehicle Service	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unassigned	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	**0.0**	**0.1**	**0.3**	**0.1**	**0.0**	**0.2**	**0.1**	**0.3**	**0.5**	**0.2**	**0.1**	**0.3**	**0.1**	**0.1**	**0.0**	**0.0**	**2.4**

Table 43: Estimated Existing Nonresidential Floorspace Impacted by Proposed Code Change in 2029 (Alterations), by Climate Zone and Building Type (Million Square Feet)

Building Type	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16	All
Large Office	0.00	0.00	0.19	0.10	0.00	0.13	0.10	0.22	0.40	0.08	0.00	0.10	0.01	0.03	0.01	0.01	1.38
Medium Office	0.01	0.06	0.16	0.08	0.03	0.10	0.09	0.12	0.17	0.13	0.03	0.20	0.05	0.03	0.02	0.01	1.29
Small Office	0.01	0.03	0.04	0.02	0.02	0.03	0.02	0.03	0.04	0.05	0.02	0.09	0.04	0.01	0.01	0.01	0.46
Large Retail	0.00	0.01	0.08	0.04	0.01	0.04	0.03	0.06	0.09	0.07	0.02	0.08	0.03	0.01	0.01	0.00	0.58
Medium Retail	0.00	0.02	0.06	0.03	0.01	0.06	0.05	0.09	0.14	0.09	0.01	0.08	0.03	0.02	0.01	0.01	0.71
Strip Mall	0.00	0.01	0.05	0.02	0.01	0.05	0.04	0.07	0.11	0.09	0.02	0.06	0.03	0.02	0.01	0.01	0.62
Mixed-use Retail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Large School	0.00	0.01	0.05	0.02	0.00	0.04	0.03	0.06	0.10	0.07	0.01	0.07	0.04	0.02	0.01	0.00	0.53
Small School	0.00	0.02	0.05	0.02	0.01	0.05	0.03	0.07	0.11	0.07	0.03	0.08	0.05	0.02	0.01	0.01	0.63
Non-refrigerated Warehouse	0.00	0.03	0.14	0.07	0.01	0.12	0.07	0.17	0.28	0.24	0.04	0.20	0.07	0.05	0.04	0.02	1.56
Hotel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Assembly	0.01	0.02	0.12	0.06	0.01	0.08	0.05	0.12	0.16	0.12	0.02	0.09	0.04	0.03	0.02	0.01	0.96
Hospital	0.00	0.01	0.06	0.03	0.01	0.04	0.04	0.05	0.09	0.05	0.01	0.07	0.03	0.01	0.01	0.00	0.53
Laboratory	0.00	0.01	0.05	0.04	0.00	0.02	0.02	0.02	0.03	0.01	0.00	0.02	0.01	0.00	0.00	0.00	0.22
Restaurant	0.00	0.00	0.02	0.01	0.00	0.02	0.01	0.03	0.05	0.04	0.00	0.02	0.01	0.01	0.00	0.00	0.26
Enclosed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Parking Garage Open Parking Garage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grocery	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Refrigerated Warehouse	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Controlled-Environment Horticulture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vehicle Service	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unassigned	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	**0.0**	**0.2**	**1.1**	**0.5**	**0.1**	**0.8**	**0.6**	**1.1**	**1.8**	**1.1**	**0.2**	**1.2**	**0.4**	**0.3**	**0.2**	**0.1**	**9.7**

Table 44: Percentage of Nonresidential Floorspace Impacted by Proposed Code Change in 2029, by Building Type

Building Type	New Construction Impacted (Percent Square Footage)	Existing Building Stock (Alterations) Impacted (Percent Square Footage)
Large Office	2%	0.1%
Medium Office	3%	0.2%
Small Office	3%	0.2%
Large Retail	2%	0.1%
Medium Retail	2%	0.1%
Strip Mall	2%	0.1%
Mixed-Use Retail	0%	0.0%
Large School	2%	0.1%
Small School	3%	0.2%
Non-refrigerated Warehouse	2%	0.1%
Hotel	0%	0.0%
Assembly	2%	0.1%
Hospital	2%	0.1%
Laboratory	2%	0.1%
Restaurant	2%	0.1%
Enclosed Parking Garage	0%	0.0%
Open Parking Garage	0%	0.0%
Grocery	0%	0.0%
Refrigerated Warehouse	0%	0.0%
Controlled-Environment Horticulture	0%	0.0%
Vehicle Service	0%	0.0%
Manufacturing	0%	0.0%
Unassigned	0%	0.0%

Table 45: Percentage of Nonresidential Floorspace Impacted by Proposed Measure, by Climate Zone

Climate Zone	New Construction Impacted (Percent Square Footage)	Existing Building Stock (Alterations) Impacted (Percent Square Footage)
1	1.9%	0.1%
2	2.0%	0.1%
3	1.5%	0.1%
4	1.3%	0.1%
5	1.8%	0.1%
6	1.2%	0.1%
7	1.5%	0.1%
8	1.4%	0.1%
9	1.7%	0.1%
10	1.8%	0.1%
11	1.8%	0.1%
12	2.0%	0.1%
13	1.9%	0.1%
14	1.8%	0.1%
15	1.9%	0.1%
16	1.8%	0.1%

Appendix D: Environmental Analysis

This section will be written for the Final CASE Report.

Appendix E: Summary of Stakeholder Engagement

Introduction to Stakeholder Engagement

Stakeholder engagement is a core component of the Statewide Codes and Standards Enhancement (CASE) process. Engagement activities are conducted to identify potential implementation challenges, gather technical and market feedback, and assess the practical implications of proposed code changes prior to the California Energy Commission (CEC).

The Statewide CASE Team engages stakeholders who may be affected by the proposed measures to better understand real-word design, installation, commissioning, compliance, and enforcement considerations. Stakeholder input helps identify barriers to adoption, cost-effectiveness concerns, market readiness issues, and unintended impacts on building performance, occupant comfort, or operational practices. Feedback gathered through stakeholder engagement is used to refine recommendations, validate assumptions used in technical analyses, and ensure that proposed measures are reasonable, enforceable, and aligned with current industry practices.

In some cases, stakeholders also provide qualitative data or field-based operations that supplement the CASE Team's technical review and literature search.

Initial stakeholder engagement for the Draft Case Report consisted of targeted interviews with industry professionals representing manufacturers, designers, installers, and subject matter experts with experience relative to the proposed measures. Interviews were conducted to capture perspectives across multiple roles within the building industry, including equipment manufacturing, system design, operation sequencing, and installation practices.

Stakeholders were selected to provide a range of technical expertise and market viewpoints. Interview discussions focused on system performance considerations, design and installation practices, operational challenges, cost and constructability impacts, and potential implications for code compliance.

This appendix summarizes the stakeholder engagement conducted by the Statewide CASE Team during the development and refinement of the report's recommendations. A summary of the 13 stakeholders during the initial round of engagement is provided in Table 46.

Table 46: Stakeholders Interviewed for Draft CASE Report

Organization/Individual Name	Market Role	Company
Kit Fransen	Manufacturer/Installer	Johnson Controls
Mark Lessans	Manufacturer/Installer	Johnson Controls
Gerald Laumann	Manufacturer/Installer	Johnson Controls
Mike Filler	Manufacturer/Installer	Trane Technologies
Rick Heiden	Manufacturer/Designer	Trane Technologies
Alvah Bickham	HVAC Designer	EXP
Todd Sorbo	HVAC Designer	EXP
Michael Weller	HVAC Designer	Glumac
Michael Adams	HVAC Designer	Glumac
Jeff Stein	HVAC Designer	Taylor Engineers
Steve Taylor	HVAC Designer	Taylor Engineers
Joe Arnstein	HVAC Designer	Taylor Engineers
Dove Feng	SME/ Former HVAC Designer	2050 Partners
Robert Benjamin	HVAC Designer/Manufacturer/Installer	Aris Hydronics
Hillary Weitze	SME/HVAC Designer	Red Car Analytics

Feedback from stakeholder interviews informed the CASE Team's understanding of current industry practices and was used to identify areas where additional clarification, refinement, or justification was needed within the Draft CASE Report. Stakeholder input was considered alongside technical analysis, modeling results, and literature review findings to support development of the proposed recommendations.

Alignment with Boiler and Chiller Requirements

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 Alignment with Boiler and Chiller Requirements via webinar, as described in Table 47. An additional stakeholder meeting is scheduled for early 2026. 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.

Table 47: Utility-Sponsored Stakeholder Meetings

Meeting Name and Link to Materials	Meeting Date	Summary of Items Discussed
First Round of Alignment with Boiler and Chiller Requirements Utility-Sponsored Stakeholder Meeting	Wednesday, October 29, 2025	• Description of measure • Expected benefits • Draft code language • Approach to cost and energy savings analysis
Second Round of Alignment with Boiler and Chiller Requirements Utility-Sponsored Stakeholder Meeting	Tuesday, March 10, 2026	• Changes since first stakeholder meeting • Revised code language • Energy savings and cost analysis • Summary of stakeholder inputs on Draft CASE Report

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 summary of the first stakeholder meeting is available on the Statewide CASE Team website (Statewide CASE Team 2025a).

The second round of utility-sponsored stakeholder meetings will occur in March 2026 and will provide updated details on proposed code changes. These meetings introduced early results of energy, cost effectiveness, and incremental cost analyses, and solicited feedback on refined draft code language.

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 and phone with numerous stakeholders when developing this report, listed in Table 48. For some organizations, several stakeholders participated in the conversation. These discussions led to numerous improvements to the measure as proposed during the first stakeholder meeting, and provided valuable inputs for cost estimation, market penetration, compliance challenges, and other information that helped formulate measures with the greatest potential for stakeholder support. Additional stakeholder interviews with other organizations, and follow-up interviews with many of the same stakeholders will be conducted prior to the Final CASE Report.

Table 48: Engaged Stakeholders

Organization/Individual Name	Market Role	Mentioned in CASE Report Sections
Johnson Controls	Manufacturer/Installer	No
Trane Technologies	Manufacturer/Designer/Installer	No
EXP	HVAC Designer	No
Glumac	HVAC Designer	No
Taylor Engineers	HVAC Designer	No
2050 Partners	SME/HVAC Designer	No
Aris Hydronics	Manufacturer/Designer/Installer	No
Red Car Analytics	SME/HVAC Designer	No

Engagement with ESJ communities

No discussions with ESJ communities have been held at this point, but inputs will be sought for the Final CASE Report.

Surveys

The Statewide CASE Team has developed a survey to help inform many of the proposed measures. The results of this survey will be included in the Final CASE Report.

AWHP Glycol Concentration Limits

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 AWHP Glycol Concentration Limits via webinar, as described in Table 49. An additional stakeholder meeting is scheduled for early 2026. 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.

Table 49: Utility-Sponsored Stakeholder Meetings

Meeting Name and Link to Materials	Meeting Date	Summary of Items Discussed
First Round of AWHP Glycol Concentration Limits Utility-Sponsored Stakeholder Meeting	Wednesday, October 29, 2025	• Description of measure • Expected benefits • Draft code language • Approach to cost and energy savings analysis
Second Round of AWHP Glycol Concentration Limits Utility-Sponsored Stakeholder Meeting	Tuesday, March 10, 2026	• Changes since first stakeholder meeting • Revised code language • Energy savings and cost analysis • Summary of stakeholder inputs on Draft CASE Report

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 summary of the first stakeholder meeting is available on the Statewide CASE Team website (Statewide CASE Team 2025b).

The second round of utility-sponsored stakeholder meetings will occur in March 2026 and will provide updated details on proposed code changes. These meetings introduced early results of energy, cost effectiveness, and incremental cost analyses, and solicited feedback on refined draft code language.

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 and phone with numerous stakeholders when developing this report, listed in Table 50. For some organizations, several stakeholders participated in the conversation. These discussions led to numerous improvements to the measure as proposed during the first stakeholder meeting, and provided valuable inputs for cost estimation, market penetration, compliance challenges, and other information that helped formulate measures with the greatest potential for stakeholder support. Additional stakeholder interviews with other organizations, and follow-up interviews with many of the same stakeholders will be conducted prior to the Final CASE Report.

Table 50: Engaged Stakeholders

Organization/Individual Name	Market Role	Mentioned in CASE Report Sections
Johnson Controls	Manufacturer/Installer	No
Trane Technologies	Manufacturer/Designer/Installer	No
EXP	HVAC Designer	No
Glumac	HVAC Designer	No
Taylor Engineers	HVAC Designer	No
2050 Partners	SME/HVAC Designer	No
Aris Hydronics	Manufacturer/Designer/Installer	No
Red Car Analytics	SME/HVAC Designer	No

Engagement with ESJ communities

No discussions with ESJ communities have been held at this point, but inputs will be sought for the Final CASE Report.

Surveys

The Statewide CASE Team has developed a survey to help inform many of the proposed measures. The results of this survey will be included in the Final CASE Report.