

Updates to Nonresidential Hydronic Heat Pump Requirements



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June 2026
Final CASE Report



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Document Information

Category:	Codes and Standards
Keywords:	Statewide Codes and Standards Enhancement (CASE) Initiative; California Statewide Utility Codes and Standards Team; Codes and Standards Enhancements; 2028 California Energy Code; 2028 Title 24, Part 6; California Energy Commission; energy efficiency; heat pump; air-to-water heat pump; water-to-water heat pump; hydronic heat pump; glycol
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Executive Summary

This proposal presents updates to nonresidential hydronic heat pump requirements for consideration in the 2028 California Energy Code (Title 24, Part 6 or Energy Code). The proposals were developed by the Statewide Codes and Standards Enhancement (CASE) Team to improve installed system performance, strengthen compliance consistency, and support California’s long-term energy efficiency and greenhouse gas (GHG) reduction goals. The CASE Report evaluates two measures applicable to nonresidential buildings: (1) alignment of air-to-water and water-to-water heat pump flow stage-off requirements with existing boiler and chiller requirements, and (2) limits on glycol concentration in air-to-water heat pump systems.

The Statewide CASE Team developed these proposed measures for submission to the California Energy Commission (CEC) for potential inclusion in the 2028 update to Title 24, Part 6. To be adopted, each measure must be technically feasible and cost effective. The proposed measures focus on improving real-world performance of hydronic heat pump systems, which are expected to see increasing adoption in California as building electrification accelerates.

Stakeholder engagement played a central role in shaping the proposals. The Statewide CASE Team conducted two public stakeholder workshops, interviewed or received written input from 19 industry stakeholders and subject matter experts, and conducted a survey of designers, manufacturers, and building owners. Feedback generally supported the flow stage-off measure and was neutral to positive regarding glycol concentration limits. Stakeholder input was used to refine code language, define appropriate exceptions, and establish conservative assumptions for market penetration and cost analysis.

The Statewide CASE Team recognizes ongoing systemic inequities in environmental and social justice (ESJ) communities and is developing code change proposals with careful consideration of potential unintended impacts. Each measure was evaluated, and those considerations are documented in the CASE Report.

Measure 1: Alignment with Boiler and Chiller Requirements

Proposed Code Change

This measure would require staged, multi-unit air-to-water heat pump (AWHP) and water-to-water heat pump (WWHP) systems in nonresidential buildings to automatically reduce or stop water flow to heat pump units that are not operating. The requirement would align hydronic heat pump systems with existing boiler and chiller equipment

isolation provisions in Title 24, Part 6. Compliance would be verified using the existing NA7.5.7 valve leakage test procedure (Nonresidential Appendix Section NA7.5.7), which is already used for boilers and chillers.

The requirement would apply to new construction, additions, and alterations involving system replacements in all California climate zones, excluding Group R occupancies. Limited exceptions would allow flow during specific operating conditions such as startup, freeze protection, or heat recovery.

Benefits of Proposed Change

Field studies and stakeholder input indicate that a significant share of installed hydronic heat pump systems operate pumps continuously even when individual units are off. This practice increases pump energy use, degrades system efficiency, and can shorten equipment life. Aligning hydronic heat pump requirements with boiler and chiller isolation requirements would help standardize best practices and prevent inefficient installations from becoming widespread as adoption of the technology increases.

The measure is expected to reduce unnecessary pump energy, improve system performance and reliability, and support statewide GHG reduction goals while adding minimal complexity or cost to system design.

Compliance and Enforcement

Compliance and enforcement would build upon existing boiler and chiller processes, resulting in minimal additional burden for designers, installers, and code officials. Third-party acceptance testing procedures are already established in NA7.5.7 and would be extended to hydronic heat pumps. Compliance forms NRCC-MCH-E and NRCI-MCH-E already document several important specifications for boilers, chillers, and hydronic heat pumps, but additional fields will be added to document automatic isolation controls. Minor updates to compliance software would be required to either document that the prescriptive requirements are met, or to adjust modeled performance based on the actual system control strategy.

Market Assessment

The measure is technically feasible and reflects practices already used by many experienced designers. Stakeholder interviews with hydronic heat pump designers and manufacturers indicated that about 65% of current multi-unit systems include automatic controls to stage-off pumps and adjust control valves to minimize flow to non-operating heat pumps. However, these interviews also indicated that some manufacturers and designers prefer continuous flow to all units to simplify the system and avoid potential damage during equipment start-up. The CASE Team developed a properly defined

measure with appropriate exceptions to address these concerns and ensure the measure can be implemented in practice at minimal cost.

Cost Effectiveness

Cost-effectiveness analysis shows benefit-to-cost ratios (BCRs)¹ well above 1.0 across all climate zones, indicating strong long-term systemwide cost savings. The estimated BCR varies significantly depending on building type and climate zone, ranging from 1.1 to 23.9. Building simulations indicated that hydronic heat pumps in climates with larger weather extremes and more variable space conditioning loads will achieve larger energy savings. Incremental costs would be relatively low, about 1% of total HVAC system cost, and the measure would not introduce new technologies or require major changes in system design beyond improved pumps, valves, and system controls.

First-Year Statewide Impacts

Table 1: Summary of Statewide Impacts – Alignment with Boiler and Chiller Requirements

Metric ^a	New Construction & Additions	Alterations	Total
Annual Electricity Savings (GWh)	0.26	0.58	0.84
Peak Demand Reduction (MW)	0.02	0.04	0.05
Annual Natural Gas Savings (Million Therms)	-	-	-
Annual Source Energy Savings (Million kBtu)	0.33	0.75	1.08
30-Year Long-term System Cost Savings (Million 2029 PV\$)	\$2.12	\$4.71	\$6.83
Annual Avoided GHG (Metric Tons CO ₂ e/yr)	17.1	39.9	57.0

- a. Values represent impacts from buildings permitted during the first year the code is in effect. Total values reflect the sum of the weighted impacts associated with the applicable fenestration types included in the proposal.

Measure 2: AWHP Glycol Concentration Limits

Proposed Code Change

This measure would establish mandatory limits on glycol concentration in air-to-water heat pump systems based on climate-specific freeze protection needs. Excessive glycol

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

concentrations increase fluid viscosity, reduce heat transfer efficiency, and raise pumping energy requirements. The proposed limits would use Heating Median of Extremes data from Joint Appendix 2 (JA2) and cap glycol concentration at 50 percent.

The measure would apply to nonresidential new construction, additions, and alterations, with targeted exceptions for systems serving process loads, heating-only systems, or systems integrated with boilers or chillers.

Benefits of the Proposed Change

Limiting glycol concentration to levels necessary for freeze protection would improve hydronic heat pump efficiency, reduce operating costs, and support consistent system performance without requiring changes to equipment. Stakeholders indicated that most experienced designers already follow similar practices, making this measure a low-impact way to formalize best practice across the market.

Compliance and Enforcement

Compliance would rely on minor changes to existing compliance forms and software, with no acceptance testing required. Design teams would be required to specify glycol type and concentration in construction documents and in compliance form NRCC-MCH-E, ensuring it aligns with the established limits for freeze protection. Installed concentration and method of measurement or calculation must be documented by the installer in form NRCI-MCH-E. Enforcement would be practical and feasible for code officials, as it relies on information that is typically already documented and does not require complex calculations or new tools. Minor updates to compliance software would be needed to capture glycol concentration design values compared to the mandatory limit calculated by the software based on geographic location.

Market Assessment

The measure aligns with standard design practice and does not introduce market barriers. Based on interviews with hydronic heat pump system designers and manufacturers, most experienced engineers already specify glycol concentrations based on necessary freeze protection requirements rather than overly conservative assumptions, meaning the measure largely formalizes existing best practices rather than introducing new methods. However, there is evidence that glycol concentration is often rounded up by designers, and the code currently has no penalty for excessive glycol concentration. There are several methods available for determining installed glycol concentration, and the approach must simply be documented.

Cost Effectiveness

Because the incremental first cost is estimated to be zero, the measure is cost effective in all climate zones, with infinite benefit-to-cost ratios. The CASE Team assumed that any small increase in cost to document and verify that glycol limits have been met would be more than overcome because of the cost reduction associated with lower glycol concentration. Energy savings was strongly dependent on climatic conditions in each climate zone, and the difference between the specified glycol concentration limits and estimated standard practice in the region.

First-Year Statewide Impacts

Table 2: Summary of Statewide Impacts – AWHP Glycol Concentration Limits

Metric ^a	New Construction & Additions	Alterations	Total
Annual Electricity Savings (GWh)	0.03	0.07	0.10
Peak Demand Reduction (MW)	0.00	0.00	0.01
Annual Natural Gas Savings (Million Therms)	-	-	-
Annual Source Energy Savings (Million kBtu)	0.03	0.07	0.10
30-Year Long-term System Cost Savings (Million 2029 PV\$)	\$0.25	\$0.56	\$0.81
Annual Avoided GHG (Metric Tons CO2e/yr)	1.6	3.5	5.1

- a. Values represent impacts from buildings permitted during the first year the code is in effect. Total values reflect the sum of the weighted impacts associated with the applicable fenestration types included in the proposal.

Acronyms

Table 3 presents a list of acronyms used in this report. Title24stakeholders.com also maintains a [glossary of terms](#).

Table 3: List of Acronyms

Acronym	Definition
ACM	Alternative Calculation Method Reference Manual
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

Acronym	Definition
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
NRCC	Nonresidential Certificate of Compliance
NRCI	Nonresidential Certificate of Installation
PEP	Public Engagement Plan
PV	Present Value
SOC	Standard Occupational Classification
W	Watt
WTW HX	Water-to-Water Heat Exchanger
WWHP	Water-to-Water Heat Pump

1. Introduction

1.1 Report Context

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

1.2 Proposal Sponsors

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

1.3 Stakeholder Engagement to Inform Proposal

When developing the code change proposal and associated technical information presented in this report, the Statewide CASE Team worked with many industry stakeholders including manufacturers, 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 two public stakeholder workshops that the Statewide CASE Team held on October 29, 2025 (Statewide CASE Team 2025a) (Statewide CASE Team 2025b) (Statewide CASE Team 2025c) and on March 10, 2026 (Statewide CASE Team 2026a) (Statewide CASE Team 2026b) (Statewide CASE Team 2026c).

In addition to feedback during the first Stakeholder Meeting, the Statewide CASE Team interviewed or received written input from 19 stakeholders and SMEs to help define the proposed measures, estimate incremental costs, and better understand industry

concerns. At least eleven of the stakeholders have HVAC design experience, and eight represent manufacturers.

Finally, the Statewide CASE Team conducted a survey to obtain insights from industry experts and building owners on important questions related to both measures.

These discussions led to the following key takeaways:

1. There was general support for the AWHP/WWHP flow stage-off measure, and mostly neutral feelings toward the glycol concentration limits because most energy-conscious designers already balance efficiency with freeze/burst protection. The minimal opposition provided confidence that the proposed measures would be reasonable to implement in the field.
2. 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. This information provided guidance for the fraction of new and existing buildings that would likely be affected by the measures.
3. The stakeholders stated that the HVAC designer is responsible for equipment staging controls and glycol concentration specifications, but manufacturers, installers, and building owners play a vital role in the process. This confirmed that designers would be able to design systems that comply with the proposed code changes but may rely on support from other industry partners and installers to ensure compliance in practice.
4. 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. This input led to code language that allowed a reasonable amount of flexibility for designers based on specific applications.
5. 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. This led to incremental cost assumptions of one percent of total system cost for the flow stage-off measure, and zero percent for the glycol concentration measure.

6. Several stakeholders identified special cases that might require exceptions in the code language. For AWHP flow stage-off, these included flow just prior to startup to avoid equipment damage, flow after shutdown for heat recovery, and a minimum flow rate during cold weather to prevent frozen pipes. For glycol concentration, concerns were raised about ice storage, ventilation-air heating, and semi-conditioned spaces. Several exceptions were added for both proposed measures to address these legitimate concerns.
7. Most stakeholders with experience selecting glycol concentration focused on burst protection rather than freeze protection, but most also felt that flexibility should be given to building owners and designers who wanted the extra safety margin of using the freeze protection limit as the basis for selecting glycol concentration. This feedback resulted in the use of freeze protection as the basis for the concentration limits.
8. Several stakeholders offered insights into current and future market penetration for various categories of hydronic heat pumps in various building types, along with the fraction of hydronic heat pump installations that would be affected by each measure. These inputs were used to define assumptions for the baseline and proposed building models, and multipliers for statewide impact analysis.

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

1.4 Addressing Energy Equity and Environmental Justice

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

When analyzing impacts for nonresidential buildings, the Statewide CASE Team reviewed each nonresidential building type through the lens of the four criteria: cost, health, resiliency, and comfort. The Statewide CASE Team examined which building

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

types are used by ESJ communities most frequently and evaluated the allocation of impacts related to the following areas among all populations. Some building types have unique environmental justice concerns due to their common uses, location, or other factors.

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

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 and Water-to-Water Heat Pumps (WWHPs) in Sections 401.3.13 [Section 140.4(k)] and mandatory acceptance test requirements in Section 401.2.7 [Section 120.5] of Title 24, Part 6, to align water flow stage-off requirements with those for chillers and boilers in nonresidential buildings. For staged, multi-unit AWHP and WWHP systems, the measure would require preventing or minimizing the pump flow to any heat pump unit that is not operating without impacting the flow to operating units. AWHPs and WWHPs that require flow stage-off controls would be tested in accordance with the requirements in section NA7.5.7 of the nonresidential reference appendices, which already applies to other hydronic systems including chillers, boilers, and variable flow hydronic systems. These requirements would be applied to all stand-alone electric or gas AWHP and WWHP installations where multiple units or modules 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 4.

Table 4: Scope of Proposed Code Change

A indicates the proposed code change is relevant.

Building Type(s)		Construction Type(s)		Type of Change	
<input type="checkbox"/> Single Family		<input checked="" type="checkbox"/> New Construction		<input checked="" type="checkbox"/> Mandatory	
<input type="checkbox"/> Multifamily		<input checked="" type="checkbox"/> Additions		<input checked="" type="checkbox"/> Prescriptive	
<input checked="" type="checkbox"/> Nonresidential (not Group R uses)		<input checked="" type="checkbox"/> Alterations		<input checked="" type="checkbox"/> Performance	

Application Climate Zones	Energy Code Sections	Compliance Documents	Sections of ACM Reference Manuals
Climate Zones 1-16	Part 6, Sections 201 [100.1], 401.2.7 [120.5], and 401.3.13 [140.4(k)]	NRCC-MCH-E, NRCI-MCH-E and NRCC-PRF-E	TBD

Third Party Verification)	Updates to Compliance Software
<input type="checkbox"/> No changes to third party verification	<input type="checkbox"/> No updates
<input checked="" type="checkbox"/> Update existing verification requirements	<input checked="" type="checkbox"/> Update existing feature
<input type="checkbox"/> Add new verification requirements	<input type="checkbox"/> Add new feature

2.1.2 Benefits of Proposed Change

Improper design and installation of AWHPs and WWHPs can lead to decreased energy efficiency, higher utility bills, and shorter useful life. Adoption of hydronic heat pumps 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 hydronic heat pump deployment, these practices may become commonplace and ingrained within 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 apply to boilers and chillers.

Another benefit is that average installed efficiency of AWHP/WWHP systems would increase in many nonresidential buildings because unnecessary pump energy and

associated thermal losses would be greatly reduced, and primary loop supply temperature would be more easily met without overburdening operating heat pumps when non-operating units 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 but is estimated at 35 percent of all hydronic heat pump installations.

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 relatively 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 to conditioned spaces 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 schematic for a relatively simple AWHP system with multiple staged units and both primary and secondary loops is shown in Figure 1.

Packaged 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 use, reduced likelihood of refrigerant leaks, easier maintenance, and a faster and safer path to the future use of near-zero global warming potential refrigerants.

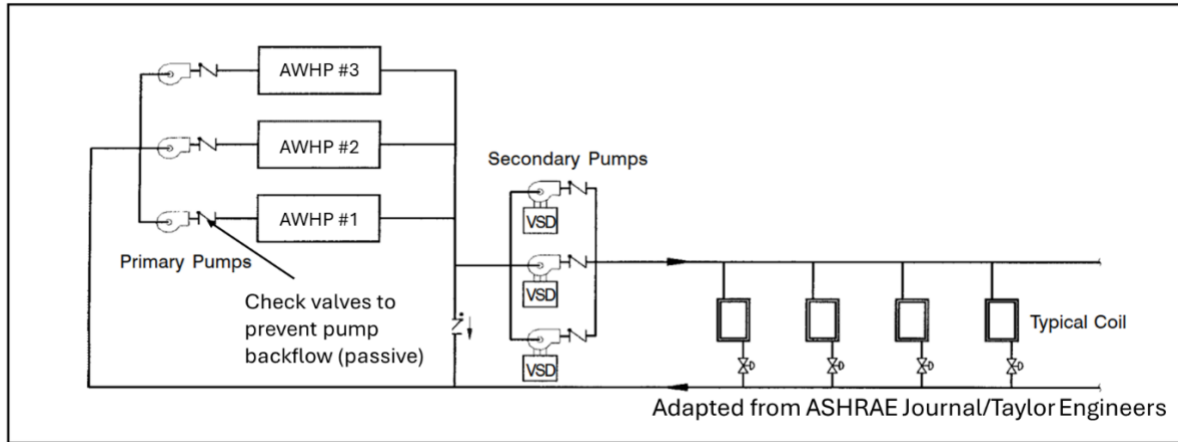


Figure 1: Schematic of a basic AWHP system with primary and secondary loops.

Image credit: Adapted from ASHRAE Journal (Taylor 2002)

While AWHPs can seem like a nascent technology, they have actually been around longer than mini-split heat pumps and heat pump water heaters. The first AWHP was certified by the CEC and listed in the Appliances Database 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 for new construction in the nonresidential sector appears to be more established based on discussions with stakeholders (possibly as high as 10-15 percent across all nonresidential building types). 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 packaged hydronic heat pump systems is increasing among policymakers and manufacturers, as they provide safer implementation of near-zero global warming potential (GWP) refrigerants (such as propane) compared to split systems where a greater volume of refrigerant is used and much of 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 and take advantage of incentive programs. 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 flammable refrigerants become more common.

The Statewide 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 codes and standards. ASHRAE 90.1 has recently drafted equipment isolation language for hydronic heat pumps similar to the proposed code change for Title 24, but the change has not yet been formally approved by the ASHRAE 90.1 Committee as of March 2026.

The proposed measure addresses staged, multi-unit AWHP or WWHP systems where individual units or modules are activated as the space-conditioning load increases in nonresidential buildings. These units are typically connected in parallel so units can be turned off with minimal effect on operating units.

A typical parallel configuration using AWHPs is shown in Figure 2, illustrating the effects of proper unit isolation. If instead the pump serving AWHP #3 does not stage off when the unit is inactive, pump energy would be wasted and the unconditioned water would be added to the mixed water serving the secondary loop, forcing the other units to work harder to meet the required delivery temperature. In the Figure 22^(b), 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.

Another common system configuration is shown in Figure 3, where a single variable-speed pump serves multiple AWHP units. To conserve energy, the central pumps should reduce the flow rate by 33 percent and the control valve at the unit should be automatically closed when the associated unit is not operational (with limited exceptions such as during startup).

A typical WWHP system with dedicated pumps on the load side and a manifolded configuration on the source side is shown in Figure 4. To comply with the proposed measure, the water flow would be staged off on both the load side and the source side by deactivating the pumps or closing the control valves, as appropriate.

The proposed measure is already 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 nonresidential sites (Weitze, Stober and Gantley 2024) indicate that primary pumps in AWHP systems often run continuously at full capacity 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, and potential difficulty maintaining the desired supply-water temperature.

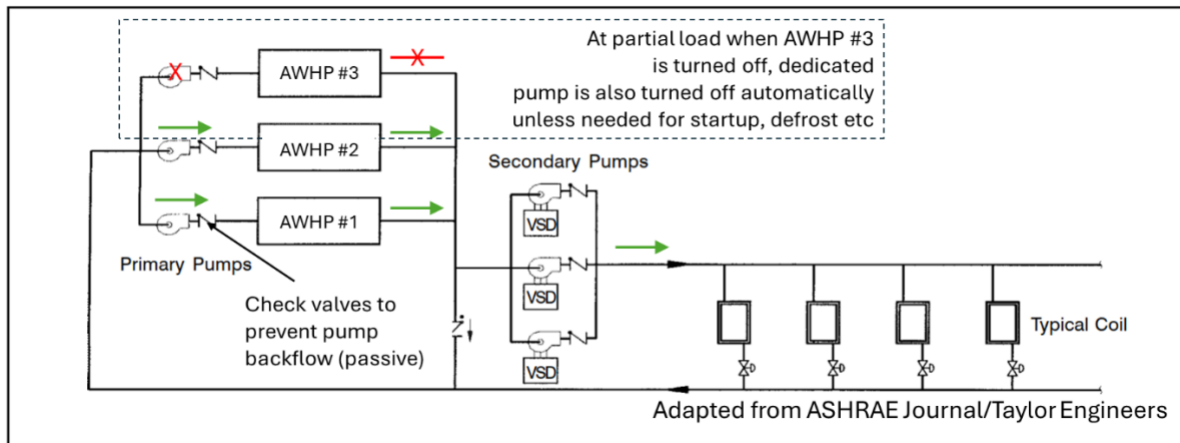


Figure 2: Multi-unit AWHP system with dedicated pump turned off when associated heat pump is not operating.

Image credit: Adapted from ASHRAE Journal (Taylor 2002)

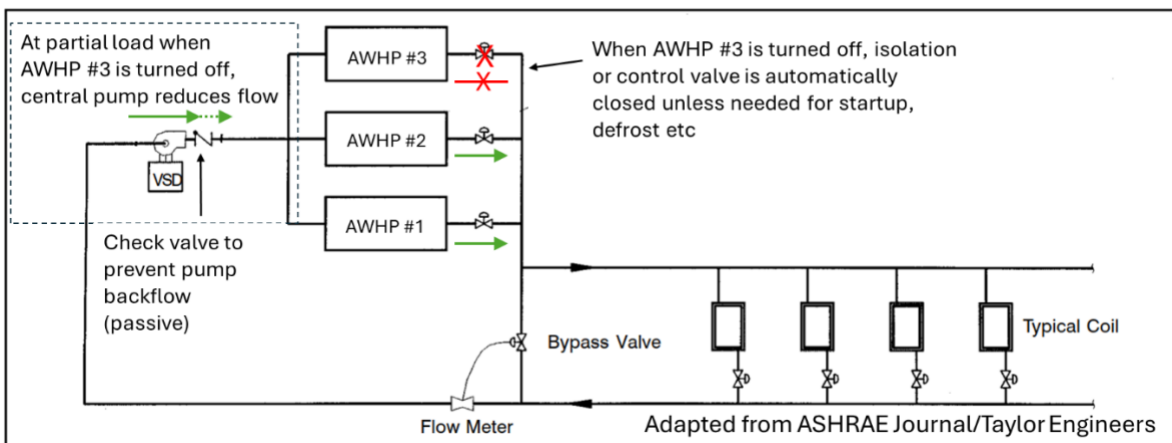


Figure 3: Multi-unit AWHP system with reduced flow from central pump and valve closed when associated heat pump is not operating.

Image credit: Adapted from ASHRAE Journal (Taylor 2002)

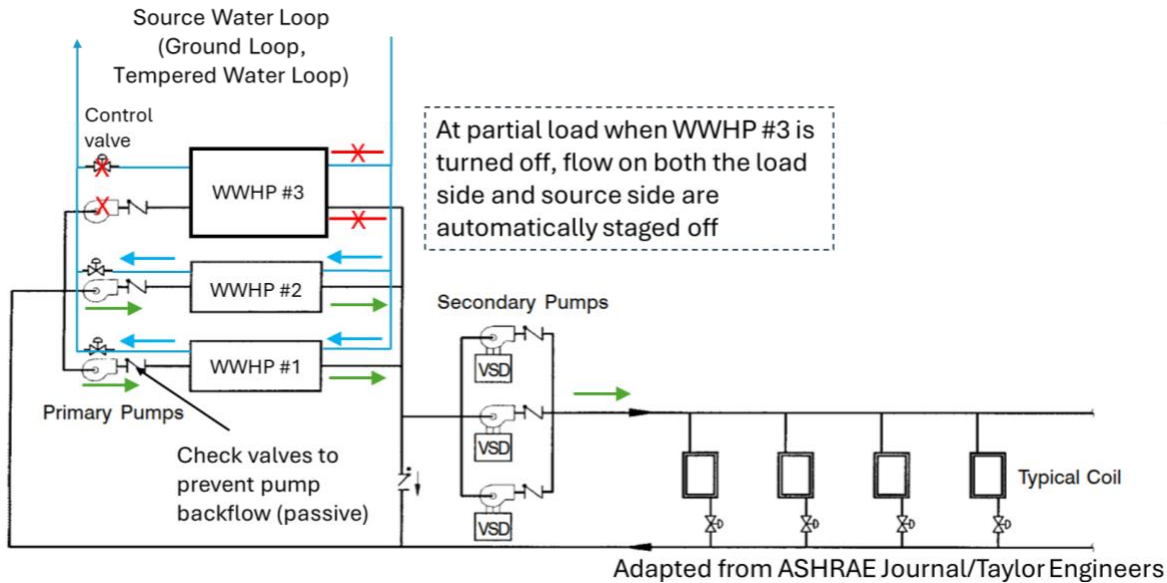


Figure 4: Multi-unit WWHP system with dedicated pumps turned off and valves closed for both source and load loops when associated heat pump is not operating.

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 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 nonresidential buildings except those with Group R occupancy.

SECTION 201– DEFINITIONS

Adds a definition of water-to-water heat pumps similar to the definition of AWHPs and removes the packaged system requirement so split systems would be covered by the code change.

SECTION 401.3 [Section 140.4] – PRESCRIPTIVE REQUIREMENTS (NEWLY CONSTRUCTED).

Subsection 401.3.13 [140.4(k)]: Add sub-elements 1 and 2 under 401.3.13.2 for chillers and boilers (respectively) and add a separate record 401.3.13.2.3 under 401.3.13.2 for AWHP and WWHP in nonresidential buildings other than Group R, requiring flow to be staged off for units that are not operating, by turning off water flow from dedicated pumps, closing a control valve and reducing water flow from a central pump, or other methods that meet the same objective.

SECTION 401.2.7 [Section 120.5] – MECHANICAL SYSTEM ACCEPTANCE.

Subsection 401.2.7.8 [120.5(a)8]: AWHP/WWHPs that require control valves as specified by Section 401.3.13.2 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 in the code, but the existing language in NA7.5.7 does not need to be altered because the application of the acceptance test is not limited to boilers and chillers.

2.1.4.3 Compliance Manuals Change Summary

Changes to the Nonresidential Compliance Manual are anticipated but have not yet been defined. The exception for Group R Occupancy would apply to AWHPs and WWHPs, and to minor language revisions for boilers and chillers. This would be fully explained in the manual to minimize confusion.

2.1.4.4 Alternative Calculation Method (ACM) Reference Manual Change Summary

Changes to Section 5.8.5 of the Nonresidential and Multifamily Alternative Calculation Method (ACM) Reference Manual will be needed to address modeling of pump design and controls for AWHPs and WWHPs that do not comply with the prescriptive requirement. Energy savings credit or penalty would be excluded for Group R buildings because the measure does not apply to those building types.

2.1.4.5 Compliance Documents Change Summary

Changes to the NRCC-MCH-E and NRCI-MCH-E Compliance Documents may be needed to address hydronic heat pump isolation controls, although there are already entries that may be adequate. These documents may also need a check box or other indication that a building includes Group R occupancy, has single-stage systems, or another exception applies.

The NRCI-MCH-E compliance document provides tables to define the boiler efficiency and controls and chiller & air to water heat pump efficiency and controls (see Figure 5).

The Statewide CASE Team may recommend that a column be added to both tables to include valves and controls to ensure limiting flow to units that are not in use, but that may be unnecessary.

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											

Figure 5: NRCI-MCH-E compliance document data entry tables for boiler and chiller systems.

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 and 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 chiller and boiler isolation, but references ASHRAE 36 for the detailed control sequence. As of April 2, 2026, the ASHRAE 90.1 committee is reviewing a proposed flow shut-off requirement for hydronic heat pumps that is similar to the proposed code change for Title 24.

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. California AB130 requires that Group R occupancy buildings such as residential buildings, hotels/motels, and multi-use buildings be exempted from proposed measures that increase the stringency of the code, including public use areas. 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 401.3.13 [Section 140.4(k)], except the proposed measure would be limited to buildings without Group R occupancies. Some of the code language for chillers and boilers would be modified as part of the code change to improve clarity for compliance-enforcement officials. Performance form NRCC-PRF-E may also need revisions to document whether the prescriptive requirement was met and if not, how the proposed design was modeled in the compliance software. There may be additional entries for hydronic heat pumps on Compliance Documents NRCC-MCH-E and NRCI-MCH-E to make verification easier for the plan reviewer. Hydronic heat pump isolation is already included, but that entry is likely intended to address isolation valves, not automatic flow controls. NRCC-MCH-E and NRCI-MCH-E would be modified to specifically include an entry that indicates automatic flow controls for inactive units have been designed and installed. 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). These acceptance test requirements already exist for boilers chillers and would remain unchanged for hydronic heat pumps.

2.2.2 Impact on Market Actors

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

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

Market Actor	Impact(s)	Suggested Outreach and Education
Owner / Developer ^a	Ensure flow stage-off requirements are understood by all parties and implemented in practice. The measure will save energy and have no effect on comfort or building operations.	Educational materials such as fact sheets that explain how and why boiler and chiller flow stage-off requirements have been extended to hydronic heat pumps, and options for meeting the new requirement.
Design Professional ^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 flow stage-off requirements and verify they are implemented in practice.	Educational material explaining how and why boiler and chiller flow stage-off requirements have been extended to hydronic heat pumps. Any additional maintenance requirements related to controls and valves needed for compliance will be explained.
Building Department ^d	Understand verification processes and changes to compliance documents.	Educational material explaining how and why boiler and chiller flow stage-off requirements have been extended to hydronic heat pumps.
Verification Tester ^e	Additional testing of AWHP and WWHP systems will be required, but	No new test procedures are recommended, but educational material explaining the extension of

Market Actor	Impact(s)	Suggested Outreach and Education
	the process will be the same as boilers and chillers.	valve testing requirements to hydronic heat pumps will be developed.
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. Owner/Developer is funding the project and is the primary decision-maker.
- b. Design professionals include architects, engineers (mechanical, electrical, plumbing, structural), specification writers, cost estimators, commissioning agents, lighting designers, and energy consultants.
- c. Construction team includes general contractors, home builders, design-build contractors, installation contractors (e.g., HVAC, plumbing, electrical), commissioning agents, and tradespeople.
- d. Building departments include plans reviewers, building inspectors, specialty inspectors, permit counter technicians and third-party plan review and inspection.
- e. Verification testers include commissioning agents, ECC Raters, and Acceptance Test Technicians

The 2028 CASE [Methodology Report](#) presents a quantitative assessment of how changes to the California building code impact builders, building designers and energy consultants, and building owners and occupants. While the analysis in the methodology report is not specific to the code change(s) presented in this report, this measure focuses on designers, installers, building departments, and building owners since these market actors are expected to experience the most direct impacts from automatic flow stage-off requirements for non-operating hydronic heat pumps. 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 6 shows the commercial building subsectors that the Statewide CASE Team expects to be impacted by the changes proposed in this report. These subsectors consist primarily of HVAC installers.

Building occupants (owners and tenants). The proposed code change would have incremental costs and would reduce building owners’ utility bills throughout

the measure lifetime. See the 2028 [Methodology Report](#) for a description of how LSC savings relate to occupant utility bill savings.

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

Construction Subsector	Establishments	Employment	Annual Payroll (Billions \$)
Commercial Building Construction	4,919	83,028	9.0
Nonresidential Electrical Contractors	3,137	74,277	7.0
Nonresidential Plumbing & HVAC Contractors	2,346	55,572	5.5
Other Nonresidential Equipment Contractors	556	9,594	1.0
Nonresidential Site Preparation Contractors	1,159	18,322	1.6
All Other Nonresidential Trade Contractors	940	18,027	1.6

Source: (State of California n.d.)

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 automatically reduce flow to non-operating 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 hydronic heat pump market.

2.2.3 Compliance Software Updates

Compliance software updates may be needed to model the proposed prescriptive measure accurately and document 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 Alternative Calculation Method (ACM) Reference Manual, but minor clarifications are 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 understanding of the measure and to verify the design information on the NRCC-MCH-E form. The performance path documentation in NRCC-PRF-E may also need to be reviewed by code enforcement staff to verify that the hydronic heat pump system has been modeled correctly. The process for inspection review would ensure that the information on the NRCI-MCH-E form is consistent with the NRCC-MCH-E form, 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 in circumstances where the test is not currently required.

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 percent 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 percent 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 nonresidential buildings. Based on initial stakeholder interviews and a literature search, it is evident that adoption is currently low—about ten percent across all building types—but the market is growing faster in the nonresidential sector compared to the residential sector because of greater use of hydronic space conditioning systems in larger nonresidential buildings. The 2025 Energy Code introduced new prescriptive requirements in most climate zones for AWHPs to serve as one option (along with variable refrigerant flow systems) for office and school buildings no greater than

150,000 square feet with multi-zone equipment. Given the push toward all-electric buildings, the market share is likely to grow to at least five percent for all building types in the coming years, and 20 percent for medium and large office buildings, large schools, and hospitals, which are the building types most well-suited to hydronic heat pump systems. Given that about 60 percent of nonresidential buildings nationwide use hydronic heating (Salimian Rizi and Heidarinejad 2022), and an understanding from stakeholders that designers of replacement systems are less likely to switch from forced air systems to hydronic, we recommend reducing the estimated market penetration in replacement applications by 40 percent compared to new construction. 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 percent 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 do not 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 a 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 by designers and manufacturers that do not currently implement automatic flow controls for non-operating heat pumps.

2.3.1.2 Market Challenges and Solutions

Based on stakeholder interviews and a careful literature review, there are several market barriers that slow the adoption of AWHPs and WWHPs, including proper flow-control 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-operating heat pumps without risk of failures during restart due to lack of adequate flow.

The proposed measure will help overcome the second and third barriers, 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 hydronic heat pump systems in nonresidential 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 risk of damaging equipment during start-up or cold weather.

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 5 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

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

Based on a preliminary review, the Statewide CASE Team does not expect the proposed code change to have any significant impacts – positive or negative – on the health, safety, or comfort to ESJ communities. Though the proposed code change would add modest costs, they are expected to be outweighed by the benefits. Specifically, energy costs would decrease, which would result in lower utility bills for ESJ communities. The Statewide CASE Team does not expect any impact on the health and safety of ESJ communities, or on their disaster preparedness. The comfort of ESJ communities is unlikely to be impacted by the proposed code changes.

2.3.4 Impacts on Jobs and Businesses

The Statewide CASE Team does not anticipate significant employment or financial impacts on any particular sector of the California economy. However, the proposed change may have modest impacts on employment in California. The Statewide CASE Team estimates the proposed change would affect statewide employment and economic output directly and indirectly through its impact on builders, designers, energy consultants, and building inspectors. Table 7, Table 8, and Table 9 outline the statewide implications for these job categories. For more information on the Statewide CASE Team’s economic impacts methodology, see the 2028 CASE [Methodology Report](#).

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

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

Type of Economic Impact	Employment (Jobs)	Labor Income	Total Value Added	Output
Direct Effects (Additional spending by Commercial Builders)	2.8	\$219,247	\$297,294	\$593,360
Indirect Effect (Additional spending by firms supporting Commercial Builders)	1.2	\$98,080	\$164,613	\$291,832
Total Economic Impacts	4.0	\$317,328	\$461,907	\$885,192

Source: Statewide CASE Team analysis of data from the IMPLAN modeling software.³

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

Type of Economic Impact	Employment (Jobs)	Labor Income	Total Value Added	Output
Direct Effects (Additional spending by building designers and energy consultants)	2.3	\$254,163	\$251,618	\$397,706
Indirect Effect (Additional spending by firms supporting building designers and energy consultants)	0.9	\$75,677	\$105,176	\$169,312
Total Economic Impacts	3.2	\$329,840	\$356,794	\$567,018

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

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

Type of Economic Impact	Employment (Jobs)	Labor Income	Total Value Added	Output
Direct Effects (Additional spending by building inspectors)	0.1	\$8,626	\$10,229	\$12,430
Indirect Effect (Additional spending by firms supporting building inspectors)	0.0	\$799	\$1,244	\$2,167
Total Economic Impacts	0.1	\$9,424	\$11,473	\$14,597

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

³ IMPLAN® model, 2020 Data, IMPLAN Group LLC, IMPLAN System (data and software), 16905 Northcross Dr., Suite 120, Huntersville, NC 28078 www.IMPLAN.com

The proposed change represents a modest adjustment, which is not expected to excessively burden or competitively disadvantage California businesses, nor is it expected to lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not expect the proposed code changes to result in the creation of new businesses or the elimination of existing ones.

The proposed code changes would apply to all businesses operating in California, regardless of whether the business is incorporated inside or outside of the state.⁴ Therefore, the Statewide CASE Team does not anticipate that the proposed changes would have advantageous or an adverse effect on the competitiveness of California businesses.

The Statewide CASE Team derived a reasonable estimate of the change in investment by California businesses based on the estimated change in economic activity associated with the proposed measure and its expected effect on business income. The Statewide CASE Team's IMPLAN modeling resulted in an estimated \$123,103 increase in California business income due to the proposed code change. The Statewide CASE Team assumed that net business investment is positively correlated with business income and that a portion of business income will be allocated to net business investment.⁵

The Statewide CASE Team analyzed national data on corporate profits and net capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI).⁶ As Table 10 shows, between 2020 and 2024, NPDI as a percentage of corporate profits ranged from a low of 18 percent in 2020 due to the worldwide economic slowdowns associated with the COVID 19 pandemic to a high of 28 percent in 2022, with an average of 23 percent. While only an approximation of the proportion of business income used for net capital investment, it provides a reasonable estimate of the proportion of proprietor income that business owners would reinvest into expanding their capital stock.

⁴ Gov. Code, §§ 11346.3(c)(1)(C), 11346.3(a)(2); 1 CCR § 2003(a)(3) Competitive advantages or disadvantages for California businesses currently doing business in the state.

⁵ 26 percent of proprietor income was assumed to be allocated to net business investment; see Table 10.

⁶ Net private domestic investment is the total amount of investment in capital by the business sector that is used to expand the capital stock, rather than maintain or replace due to depreciation. Corporate profit is the money left after a corporation pays its expenses.

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

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

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

Given the estimated total increase in California business income and net business investment ratio described above, the Statewide CASE Team estimates the proposed code change would result in a \$28,897 increase in net private investment by California businesses.

2.3.5 Economic and Fiscal Impacts

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

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

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

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

Cost to State: The state government already has a budget for code development, education, and compliance enforcement. While the state government would be allocating resources to update the Title 24, Part 6 Standards, including updating

education and compliance materials and responding to questions about the revised requirements, these activities are already covered by existing state budgets. The costs for the state government are small when compared to the overall cost savings and policy benefits associated with the code change proposals. 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 hydronic heat pump 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 and installation 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 and installation 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 and installation 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 for federal funding to the state because the proposed measure improves the energy efficiency of certain nonresidential buildings and better aligns Title 24 with ASHRAE 90.1.

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-to-cost ratio (BCR) is 1.0 or greater, amortized over the economic life of the structure. The Statewide CASE Team calculates BCR by dividing total dollar benefits by total dollar costs over a 30-year analysis period.

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

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

2.4.2 Energy and Energy Cost Savings Results

First-year energy savings (electricity, natural gas, and source energy) and peak demand reductions per unit are presented in Table 11 through Table 14 for the four prototypes that were modeled (Large Office, Medium Office, Large School, Hospital) along with the other nonresidential prototypes. The four building types that were modeled are expected to have significantly higher market penetration of multi-stage hydronic heat pumps. However, the proposed measure would apply to all building types, and it was assumed that despite being more uncommon, multi-unit hydronic heat pump systems in these buildings would have energy and cost savings per square foot comparable to the medium-sized office building.

Per-square foot electricity savings for the first year are expected to range from 0.02 to 0.30 kWh/yr, depending upon climate zone, with 0 therms/yr in gas savings for all climate zones because the prototype uses an electric AWHP. Demand reductions/increases are predicted to be relatively small for all climate zones, because the savings for the measure occur primarily under part load conditions, not during peak periods. The highest per-square-foot electricity and source energy savings are expected in hospitals, and the lowest per-square-foot expected savings among buildings that were modeled was for large office buildings.

The results vary by climate zone based on the equipment capacity and range of heating and cooling loads encountered in the building, which affects the amount of time when the second-stage AWHP does not need to operate. The results are somewhat conservative because two-stage systems are assumed. If more than two staged units are present, there would be additional time periods when one or more units are turned off, and flow could be staged off or reduced. In addition, energy savings for buildings that were not modeled are based on the Medium Office, which is on the low-end of energy savings on a per square foot basis. Assuming proper maintenance of pumps, valves, and controls, the predicted energy savings are expected to be persistent over time. Table 15 presents total per-unit energy cost savings for newly constructed buildings, additions, and alterations in terms of LSC savings realized over a 30-year period for each building type, in 2029 present value dollars (2029 PV\$). Table 16 presents the 30-year LSC savings per square foot as an average across all building types for new construction and additions. Table 17 presents similar results for alterations. The LSC methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

Table 11: First-Year Electricity Savings (kWh) Per Square Foot – Alignment with Boiler and Chiller Requirements

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Large Office	0.03	0.03	0.04	0.03	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.03
Medium Office	0.04	0.06	0.08	0.07	0.07	0.09	0.10	0.11	0.10	0.09	0.08	0.08	0.09	0.08	0.12	0.05
Small Office	0.04	0.06	0.08	0.07	0.07	0.09	0.10	0.11	0.10	0.09	0.08	0.08	0.09	0.08	0.12	0.05
Large Retail	0.04	0.06	0.08	0.07	0.07	0.09	0.10	0.11	0.10	0.09	0.08	0.08	0.09	0.08	0.12	0.05
Medium Retail	0.04	0.06	0.08	0.07	0.07	0.09	0.10	0.11	0.10	0.09	0.08	0.08	0.09	0.08	0.12	0.05
Strip Mall	0.04	0.06	0.08	0.07	0.07	0.09	0.10	0.11	0.10	0.09	0.08	0.08	0.09	0.08	0.12	0.05
Large School	0.12	0.14	0.16	0.14	0.16	0.17	0.18	0.16	0.15	0.15	0.14	0.14	0.13	0.14	0.13	0.14
Small School	0.04	0.06	0.08	0.07	0.07	0.09	0.10	0.11	0.10	0.09	0.08	0.08	0.09	0.08	0.12	0.05
Non-refrigerated Warehouse	0.04	0.06	0.08	0.07	0.07	0.09	0.10	0.11	0.10	0.09	0.08	0.08	0.09	0.08	0.12	0.05
Assembly	0.04	0.06	0.08	0.07	0.07	0.09	0.10	0.11	0.10	0.09	0.08	0.08	0.09	0.08	0.12	0.05
Hospital	0.17	0.19	0.25	0.20	0.24	0.29	0.30	0.26	0.26	0.25	0.21	0.22	0.23	0.22	0.24	0.20
Laboratory	0.04	0.06	0.08	0.07	0.07	0.09	0.10	0.11	0.10	0.09	0.08	0.08	0.09	0.08	0.12	0.05
Restaurant	0.04	0.06	0.08	0.07	0.07	0.09	0.10	0.11	0.10	0.09	0.08	0.08	0.09	0.08	0.12	0.05

Table 12: First-Year Peak Demand Reduction (kW) Per Square Foot – Alignment with Boiler and Chiller Requirements

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Large Office	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Medium Office	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00
Small Office	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00
Large Retail	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00
Medium Retail	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00
Strip Mall	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00
Large School	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Small School	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Non-refrigerated Warehouse	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00
Assembly	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00
Hospital	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.02
Laboratory	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00
Restaurant	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00

Table 13: First-Year Natural Gas Savings (kBtu) Per Square Foot – Alignment with Boiler and Chiller Requirements

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Large Office	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Medium Office	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Small Office	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Large Retail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Medium Retail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Strip Mall	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Large School	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Small School	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-refrigerated Warehouse	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Assembly	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hospital	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Laboratory	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Restaurant	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 14: First-Year Source Energy Savings (kBtu) Per Square Foot – Alignment with Boiler and Chiller Requirements

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Large Office	0.05	0.05	0.06	0.05	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.05	0.04	0.05
Medium Office	0.03	0.06	0.09	0.08	0.09	0.12	0.12	0.13	0.12	0.11	0.09	0.08	0.09	0.09	0.17	0.06
Small Office	0.03	0.06	0.09	0.08	0.09	0.12	0.12	0.13	0.12	0.11	0.09	0.08	0.09	0.09	0.17	0.06
Large Retail	0.03	0.06	0.09	0.08	0.09	0.12	0.12	0.13	0.12	0.11	0.09	0.08	0.09	0.09	0.17	0.06
Medium Retail	0.03	0.06	0.09	0.08	0.09	0.12	0.12	0.13	0.12	0.11	0.09	0.08	0.09	0.09	0.17	0.06
Strip Mall	0.03	0.06	0.09	0.08	0.09	0.12	0.12	0.13	0.12	0.11	0.09	0.08	0.09	0.09	0.17	0.06
Large School	0.14	0.15	0.17	0.16	0.17	0.21	0.22	0.20	0.18	0.19	0.16	0.15	0.15	0.17	0.19	0.17
Small School	0.03	0.06	0.09	0.08	0.09	0.12	0.12	0.13	0.12	0.11	0.09	0.08	0.09	0.09	0.17	0.06
Non-refrigerated Warehouse	0.03	0.06	0.09	0.08	0.09	0.12	0.12	0.13	0.12	0.11	0.09	0.08	0.09	0.09	0.17	0.06
Hospital	0.21	0.24	0.36	0.27	0.33	0.43	0.43	0.38	0.39	0.37	0.28	0.29	0.31	0.28	0.38	0.30
Laboratory	0.21	0.24	0.36	0.27	0.33	0.43	0.43	0.38	0.39	0.37	0.28	0.29	0.31	0.28	0.38	0.30
Restaurant	0.03	0.06	0.09	0.08	0.09	0.12	0.12	0.13	0.12	0.11	0.09	0.08	0.09	0.09	0.17	0.06

Table 15: Total 30-Year LSC Savings (2029 PV\$) Per Square Foot – Alignment with Boiler and Chiller Requirements

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Large Office	0.28	0.25	0.36	0.25	0.33	0.32	0.31	0.25	0.26	0.24	0.25	0.25	0.21	0.25	0.19	0.28
Medium Office	0.28	0.45	0.60	0.60	0.60	0.71	0.78	0.88	0.80	0.75	0.65	0.62	0.67	0.70	0.97	0.46
Small Office	0.28	0.45	0.60	0.60	0.60	0.71	0.78	0.88	0.80	0.75	0.65	0.62	0.67	0.70	0.97	0.46
Large Retail	0.28	0.45	0.60	0.60	0.60	0.71	0.78	0.88	0.80	0.75	0.65	0.62	0.67	0.70	0.97	0.46
Medium Retail	0.28	0.45	0.60	0.60	0.60	0.71	0.78	0.88	0.80	0.75	0.65	0.62	0.67	0.70	0.97	0.46
Strip Mall	0.28	0.45	0.60	0.60	0.60	0.71	0.78	0.88	0.80	0.75	0.65	0.62	0.67	0.70	0.97	0.46
Large School	0.64	1.02	1.08	1.17	1.15	0.90	1.28	1.62	1.46	1.68	1.20	1.26	1.23	1.44	1.00	1.11
Small School	0.28	0.45	0.60	0.60	0.60	0.71	0.78	0.88	0.80	0.75	0.65	0.62	0.67	0.70	0.97	0.46
Non-refrigerated Warehouse	0.28	0.45	0.60	0.60	0.60	0.71	0.78	0.88	0.80	0.75	0.65	0.62	0.67	0.70	0.97	0.46
Assembly	0.28	0.45	0.60	0.60	0.60	0.71	0.78	0.88	0.80	0.75	0.65	0.62	0.67	0.70	0.97	0.46
Hospital	1.34	1.54	2.07	1.70	1.98	2.42	2.45	2.18	2.16	2.07	1.75	1.80	1.88	1.83	2.04	1.84
Laboratory	0.28	0.45	0.60	0.60	0.60	0.71	0.78	0.88	0.80	0.75	0.65	0.62	0.67	0.70	0.97	0.46
Restaurant	0.28	0.45	0.60	0.60	0.60	0.71	0.78	0.88	0.80	0.75	0.65	0.62	0.67	0.70	0.97	0.46

Table 16: 2029 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions

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	0.51	0.00	0.51
2	0.67	0.00	0.67
3	0.75	0.00	0.75
4	0.68	0.00	0.68
5	0.85	0.00	0.85
6	0.76	0.00	0.76
7	0.94	0.00	0.94
8	0.91	0.00	0.91
9	0.77	0.00	0.77
10	0.95	0.00	0.95
11	0.86	0.00	0.86
12	0.63	0.00	0.63
13	0.92	0.00	0.92
14	0.83	0.00	0.83
15	1.05	0.00	1.05
16	0.67	0.00	0.67

Table 17: 2029 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations

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	0.53	0.00	0.53
2	0.66	0.00	0.66
3	0.76	0.00	0.76
4	0.68	0.00	0.68
5	0.88	0.00	0.88
6	0.77	0.00	0.77
7	0.88	0.00	0.88
8	0.82	0.00	0.82
9	0.75	0.00	0.75
10	0.86	0.00	0.86
11	0.86	0.00	0.86
12	0.76	0.00	0.76
13	0.90	0.00	0.90
14	0.74	0.00	0.74
15	1.01	0.00	1.01
16	0.66	0.00	0.66

2.4.3 Incremental First Cost

Based on interviews with HVAC system designers and manufacturers from October to December 2025 and March to April 2026, the additional first cost for procuring and installing AWHPs and WWHPs with the 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 two percent of total system cost if additional plumbing and controls must be added. Based on the confidence levels and experience of the experts making these estimates, we recommend one percent of total HVAC costs as a reasonable estimate of average incremental costs.

Incremental first costs for WWHPs were not analyzed separately, but it would be expected that both the incremental cost and energy savings would increase because of the additional flow stage-off on the source side of the system. As a result, it was assumed that WWHPs would not affect the overall cost-effectiveness of the measure, and the statewide impacts are conservative.

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, 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. For replacement applications, the cost depends on the extent of existing hydronic piping reuse and any electrical service upgrades for fuel switching alterations.

A literature review conducted by the Statewide CASE Team in November 2025 yielded a range of estimates for total AWHP system first cost. 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).⁷ The same report summarizes California State University (CSU 2019) estimates of first costs for AWHP systems at \$90-\$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.

CEC's 'Air-to-Water Heat Pump Incremental Costs – Additional Detail' workbook (CEC n.d.) provides the 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 large 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 four-pipe fan coils. 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 in November 2025 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 but not including integration into a building automation system (BAS).

Combining all sources, incremental first cost for the proposed measure is estimated as \$30/ton (one percent of \$3,000/ton) for systems larger than 100 tons (1,200 MBH), and \$50/ton for smaller systems (one percent of \$5,000/ton). Applying these estimates to the space conditioning capacities for the prototype buildings in Climate Zone 12 (fairly representative of California's average climate) results in the estimated incremental first costs shown in Table 18.

⁷ MBH is 1,000 Btu/hour and one ton of cooling is 12,000 Btu/hour.

Table 18: Incremental First Cost Estimates by Prototype Building

Prototype Building	Floorspace (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	\$ 0.08	\$ 37,395
Medium Office	53,627	1,210	134	1,609	\$ 0.08	\$ 4,023
Small Office	5,502	173	14	165	\$ 0.13	\$ 721
Large Retail	233,250	7,347	583	6,997	\$ 0.08	\$ 18,368
Medium Retail	24,563	774	61	737	\$ 0.13	\$ 3,225
Strip Mall	9,375	270	21	248	\$ 0.12	\$ 1,125
Large School	210,886	5,069	772	9,269	\$ 0.11	\$ 23,173
Small School	23,408	737	59	702	\$ 0.13	\$ 3,071
Non-refrigerated Warehouse	17,548	308	24	284	\$ 0.07	\$ 1,283
Assembly	315,339	7,830	866	10,390	\$ 0.08	\$ 25,975
Hospital	241,501	8,665	737	8,842	\$ 0.09	\$ 22,105
Laboratory	53,628	1,827	173	2,075	\$ 0.10	\$ 5,188
Restaurant	2,501	71	8	97	\$ 0.16	\$ 404

2.4.4 Incremental Maintenance and Replacement Costs

Descriptions 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](#).

The proposed measure may result in a need for updated controls and several additional control valves that require a small amount of maintenance on occasion, but stakeholders interviewed from October to December 2025 felt confident these costs would be negligible. For replacement costs, the Statewide CASE Team made the conservative assumption that approximately the same incremental first cost (as discussed in Section 2.4.3) would be incurred after 15 years (\$30/ton for systems larger than 100 tons and \$50/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 19 and Table 20 for new construction/additions and alterations, respectively. The modeling results indicate that the benefit-to-cost ratio exceeds 3.3 in all 16 climate zones for new construction and alterations. The results reflect the weighted average for all building

types, but analysis of the four individual buildings that were modeled showed benefit-to-cost ratios ranging from 1.6 to 16.3 depending on building type and climate zone. For other building types, the benefit-to-cost ratio ranged from 1.1 to 23.9, indicating that cost-effectiveness may be marginal in a few cases but is generally very good. The slightly different benefit-to-cost ratio for alterations is due to a different mix of floor areas for each building type compared to new construction, and the effect of that mix on weighted averages.

In the tables below, all values are presented in 2029 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.

Table 19: 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	0.51	0.15	3.35
2	0.67	0.15	4.61
3	0.75	0.14	5.38
4	0.68	0.14	4.90
5	0.85	0.14	5.86
6	0.76	0.14	5.46
7	0.94	0.14	6.66
8	0.91	0.14	6.55
9	0.77	0.14	5.57
10	0.95	0.14	6.60
11	0.86	0.14	6.12
12	0.63	0.14	4.56
13	0.92	0.16	5.86
14	0.83	0.15	5.69
15	1.05	0.14	7.58
16	0.67	0.14	4.65

Table 20: 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	0.53	0.16	3.39
2	0.66	0.14	4.52
3	0.76	0.14	5.48
4	0.68	0.14	4.92
5	0.88	0.15	5.99
6	0.77	0.14	5.54
7	0.88	0.14	6.30
8	0.82	0.14	5.99
9	0.75	0.14	5.52
10	0.86	0.14	6.23
11	0.86	0.14	6.07
12	0.76	0.14	5.42
13	0.90	0.15	6.12
14	0.74	0.14	5.39
15	1.01	0.14	7.40
16	0.66	0.14	4.65

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 21) and alterations (Table 22) by climate zone. Table 23 presents first-year statewide savings from new construction, additions, and alterations. The total predicted LSC savings for all building types is \$6.8 million.

The analysis includes all nonresidential building types with available prototype buildings. To be conservative, the analysis does not include WWHPs, which are less common

than AWHPs but would increase the per unit energy savings because of the energy savings on the source water loop. The fraction of floor space affected by the measure reflects the market penetration assumptions described in Section 2.3.1.1.

- 20 percent of new buildings for the four modeled building types will have hydronic heat pumps for space conditioning in 2029 (5 percent for other building types)
- 12 percent of replacement HVAC systems will be hydronic heat pumps (60 percent of the adoption rate for new construction)
- Existing HVAC systems replaced after a 15-year useful life
- 60 percent of buildings will have staged, multi-unit systems
- 35 percent of multi-unit systems will not have flow stage-off controls consistent with the proposed measure

These market penetration values are all toward the low end of stakeholder inputs. Therefore, the results are conservative from a statewide impact standpoint.

Table 21: 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	12,072	0.00	0.00	0.00	0.00	\$0.01
2	68,182	0.01	0.00	0.00	0.01	\$0.05
3	348,662	0.03	0.00	0.00	0.04	\$0.26
4	178,172	0.01	0.00	0.00	0.02	\$0.12
5	33,609	0.00	0.00	0.00	0.00	\$0.03
6	219,307	0.02	0.00	0.00	0.03	\$0.17
7	166,788	0.02	0.00	0.00	0.03	\$0.16
8	321,989	0.03	0.00	0.00	0.04	\$0.29
9	533,795	0.05	0.00	0.00	0.06	\$0.41
10	238,566	0.03	0.00	0.00	0.04	\$0.23
11	47,947	0.01	0.00	0.00	0.01	\$0.04
12	313,643	0.02	0.00	0.00	0.03	\$0.20
13	89,114	0.01	0.00	0.00	0.01	\$0.08
14	54,313	0.01	0.00	0.00	0.01	\$0.04
15	31,818	0.00	0.00	0.00	0.01	\$0.03
16	17,200	0.00	0.00	0.00	0.00	\$0.01
Total	2,675,178	0.26	0.02	0.00	0.33	\$2.12

Table 22: 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 Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2029 PV\$)
1	20,738	0.00	0.00	0.00	0.00	\$0.01
2	130,526	0.01	0.00	0.00	0.01	\$0.09
3	709,771	0.07	0.01	0.00	0.09	\$0.54
4	359,166	0.03	0.00	0.00	0.04	\$0.25
5	61,128	0.01	0.00	0.00	0.01	\$0.05
6	521,749	0.05	0.00	0.00	0.07	\$0.40
7	387,075	0.04	0.00	0.00	0.06	\$0.34
8	738,759	0.07	0.00	0.00	0.10	\$0.61
9	1,184,081	0.11	0.01	0.00	0.14	\$0.89
10	597,328	0.06	0.00	0.00	0.08	\$0.52
11	111,647	0.01	0.00	0.00	0.01	\$0.10
12	687,196	0.06	0.00	0.00	0.08	\$0.52
13	212,643	0.02	0.00	0.00	0.03	\$0.19
14	137,676	0.01	0.00	0.00	0.01	\$0.10
15	75,391	0.01	0.00	0.00	0.01	\$0.08
16	42,020	0.00	0.00	0.00	0.00	\$0.03
Total	5,976,893	0.58	0.04	0.00	0.75	\$4.71

Table 23: 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	0.26	0.02	0.00	0.33	2.12
Alterations	0.58	0.04	0.00	0.75	4.71
Total	0.84	0.05	0.00	1.08	6.83

2.5.2 Statewide Greenhouse Gas Emissions Reductions

Table 24 presents the estimated first-year reduction in GHG emissions resulting from the proposed code change. In the initial year, the Statewide CASE Team expects to avoid 57 metric tons of carbon dioxide equivalent (CO₂e) 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 (California Building Energy Code Compliance Software), as well as data from the CEC’s 2028 Metrics Report. See the 2028 CASE [Methodology Report](#) for additional information.

Table 24: First-Year Statewide GHG Emissions Impacts

Construction Type	Reduced GHG Emissions from Electricity Savings (Metric Tons CO ₂ e)	Reduced GHG Emissions from Natural Gas Savings (Metric Tons CO ₂ e)	Total Reduced GHG Emissions (Metric Ton CO ₂ e)	Total Monetary Value of Reduced GHG Emissions (\$)
New Construction & Additions	17.1	0.0	17.1	2,102
Alterations	39.9	0.0	39.9	4,918
Total	57.0	0.0	57.0	7,020

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

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

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

2.6.2 Administrative Code (Title 24, Part 1)

No changes.

2.6.3 Energy Code (Title 24, Part 6)

The proposed measure will clarify in the AWHP definition that hydronic heat pumps are not necessarily packaged units, will add a definition of water-to-water heat pumps similar to the definition of AWHPs.

SECTION 201 [SECTION 100.1] DEFINITIONS

AIR-TO-WATER HEAT PUMP (AWHP) is a factory-made ~~packaged~~ *heat pump* system containing one or more compressors and heat exchangers for transferring heat between refrigerant and air, as well as between refrigerant and water, 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.

WATER-TO-WATER HEAT PUMP (WWHP) is a factory-made *heat pump system containing one or more compressors, heat exchangers for transferring heat between refrigerant and water distributed to meet building loads, as well as between refrigerant and a separate water loop serving as the heating or cooling energy source, 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 AHP/WWHP considerations by combining chillers and boilers under 401.3.13.2 as items 1 and 2, adding a separate requirement for hydronic heat pumps in 401.3.13.2.3, and clarifying language for all hydronic system types.

SECTION 401.3 [SECTION 140.4] – PRESCRIPTIVE REQUIREMENTS (NEWLY CONSTRUCTED).

401.3.13 [140.4(k)] Hydronic System Measures.

401.3.13.1 [140.4(k)1] Hydronic variable flow systems.

401.3.13.2 [140.4(k)2] Hydronic variable flow systems flow stage-off for non-operating units.

401.3.13.2.1 Chillers isolation.

For Hotel/Motel buildings and Nonresidential buildings with Group R occupancies, the following requirements apply:

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 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.

For all other Nonresidential buildings, the following requirements apply:

When a chilled water system includes more than one chiller, provisions shall be made to automatically stage off, reduce, or otherwise minimize flow through any chiller evaporator, and *condenser* if applicable, that is off or staged off while maintaining flow through operating chiller(s). Chillers that are piped in series to increase temperature differential shall be considered one chiller. Minimum flow may be maintained where required by the manufacturer for safe and reliable operation, including:

- Start-up operations
- Post-purge heat recovery
- Defrost cycles

- Burst or freeze protection during cold weather or for heat recovery systems

401.3.13.3 [140.4(k)3] 401.3.13.2.2 Boilers isolation.

For Hotel/Motel buildings and Nonresidential buildings with Group R occupancies, the following requirements apply:

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 shut off while still maintaining flow through other operating *boiler(s)*.

For all other Nonresidential buildings, the following requirements apply:

When a hot water plant includes more than one *boiler*, provisions shall be made to automatically stage off, reduce, or otherwise minimize flow through any *boiler* that is off or staged off while maintaining flow through operating *boiler(s)*. Minimum flow may be maintained where required by the manufacturer for safe and reliable operation, including:

- Start-up operations
- Post-purge heat recovery
- Burst or freeze protection during cold weather or for heat recovery systems

401.3.13.2.3 Air-to-Water Heat Pump (AWHPs) and Water-to-Water Heat Pumps (WWHPs). When a central plant includes more than one AWHP or WWHP, provisions shall be made to automatically stage off, reduce, or otherwise minimize water flow through the evaporator and/or condenser for any *heat pump* that is off or staged off while maintaining flow through operating *heat pump(s)*. This requirement also applies to each module of modular *heat pumps* if the modules are intended to be staged. The control approach may use valves, pumps, or other control strategies, and shall be noted on mechanical drawings. Minimum flow may be maintained where required by the manufacturer for safe and reliable operation, including:

- Start-up operations
- Post-purge heat recovery
- Defrost cycles
- Burst or freeze protection during cold weather or for heat recovery systems

Hydronic heat pumps piped in series to increase temperature differential shall be considered one heat pump.

Exception to Section 401.3.13.2.3 [Section 140.4(k)2C]: Hotel/Motel buildings and Nonresidential buildings with Group R occupancies.

401.3.13.3 [140.4(k)3] Reserved

The following additional change is proposed for mandatory mechanical system requirements in Section 401.2.7.

SECTION 401.2.7 [Section 120.5] – MECHANICAL SYSTEM ACCEPTANCE.

401.2.7.8 [120.5(a)8]: Boiler, ~~or~~ chiller, air-to-water heat pump or water-to-water heat pump that require isolation controls as specified by Section 401.3.13.2 ~~or 140.4(k)3~~ shall be tested in accordance with NA7.5.7.

2.6.4 Reference Appendices

There are no proposed changes to the Reference Appendices.

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 Alternative Calculation Method (ACM) Reference Manual

Several minor changes are proposed for Section 5.8.5 of the Nonresidential 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 off 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 controlledassumed 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 equipmentchiller, and the heating hot water pumps are tied to the *boiler*, AWHP, or WWHP operation.

2.6.7 Compliance Documents

As discussed in Section 2.1.4.5, the NRCC-MCH-E and NRCI-MCH-E compliance documents would be updated to reflect the proposed change, or to document the basis for an exception such as manufacturers' literature. 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, reducing the negative impacts on heat exchanger performance, capacity, and pump power associated with high levels of glycol concentration. WWHPs are not included in this measure because of uncertainties about freeze protection on the source side of the system, but they may be included in a future code cycle. The measure would add new mandatory requirements to Section 400.5 [Section 110.2], specifying maximum glycol concentrations ranging from 0 percent to 50 percent depending on the winter median of extremes for the location as documented in JA2. These limits are above the freeze protection limits for both propylene and ethylene glycol mixtures established by glycol manufacturers. These requirements would be applied to all nonresidential 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 nonresidential 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 deliver water colder than 36°F. Further research is needed to understand the implications of glycol limitations on process loads and other loads that may require lower supply water delivery temperatures than are necessary for space conditioning.

Table 25 summarizes the scope of the proposed code change.

Table 25: Scope of Proposed Code Change

A indicates the proposed code change is relevant.

Building Type(s)		Construction Type(s)		Type of Change			
<input type="checkbox"/> Single Family		<input checked="" type="checkbox"/> New Construction		<input checked="" type="checkbox"/> Mandatory			
<input type="checkbox"/> Multifamily		<input checked="" type="checkbox"/> Additions		<input type="checkbox"/> Prescriptive			
<input checked="" type="checkbox"/> Nonresidential (Not Group R uses)		<input checked="" type="checkbox"/> Alterations		<input type="checkbox"/> Performance			
Application Climate Zones		Energy Code Sections		Compliance Documents		Sections of ACM Reference Manuals	
Climate Zones 1-16		Part 6, Section 400.5 [Section 10.2]		NRCC-MCH-E and NRCI-MCH-E		No changes	
Third Party Verification)				Updates to Compliance Software			
<input type="checkbox"/> No changes to third party verification				<input type="checkbox"/> No updates			
<input checked="" type="checkbox"/> Update existing verification requirements				<input type="checkbox"/> Update existing feature			
<input type="checkbox"/> Add new verification requirements				<input checked="" type="checkbox"/> 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 AWHP 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 freeze protection.

An important benefit of the proposed measure is that average installed efficiency of AWHP systems will increase in many nonresidential 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 often places a hard limit of a 50 percent glycol solution with recommended ranges based on climate, but this guidance may not be specific enough to help designers minimize concentration for specific applications. 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 or rounding up to the nearest ten percent.

Finally, it is important to intervene before standard practice becomes more difficult to change as the market expands in the coming years and suboptimal 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 has met minimal 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 without affecting system efficiency. 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 26 (assumes flow rate is maintained to meet capacity requirements as concentration increases).

Table 26: Estimated Performance Impacts of Glycol Concentration on AWHP System Components

Glycol Concentration	Cooling Mode Pump Power Increase ^a	Cooling Mode Heat Exchanger Film Coefficient ^b
0%	0.0%	0%
10%	65.2%	-22.0%
30%	192.0%	-58.5%
50%	465.5%	-79.9%

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

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

Laboratory testing in cooling mode was performed at Frontier Energy’s Building Science Research Laboratory for two glycol concentrations (zero percent and 50 percent) using an AWHP and heat exchanger with simulated cooling loads. The results are

summarized in Table 27. The energy efficiency ratio (EER) for the AWHP was reduced by seven 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). Further details of the laboratory test results are included in Appendix G.

Table 27: Laboratory Test Results for 50 Percent Propylene Glycol Compared to Pure Water in Cooling Mode (95°F Chamber Temperature)

Performance Metric	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
WTW 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 6. For split systems, the evaporator is indoors, and the water loop may be entirely within the conditioned building envelope, as shown in Figure 7. 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.

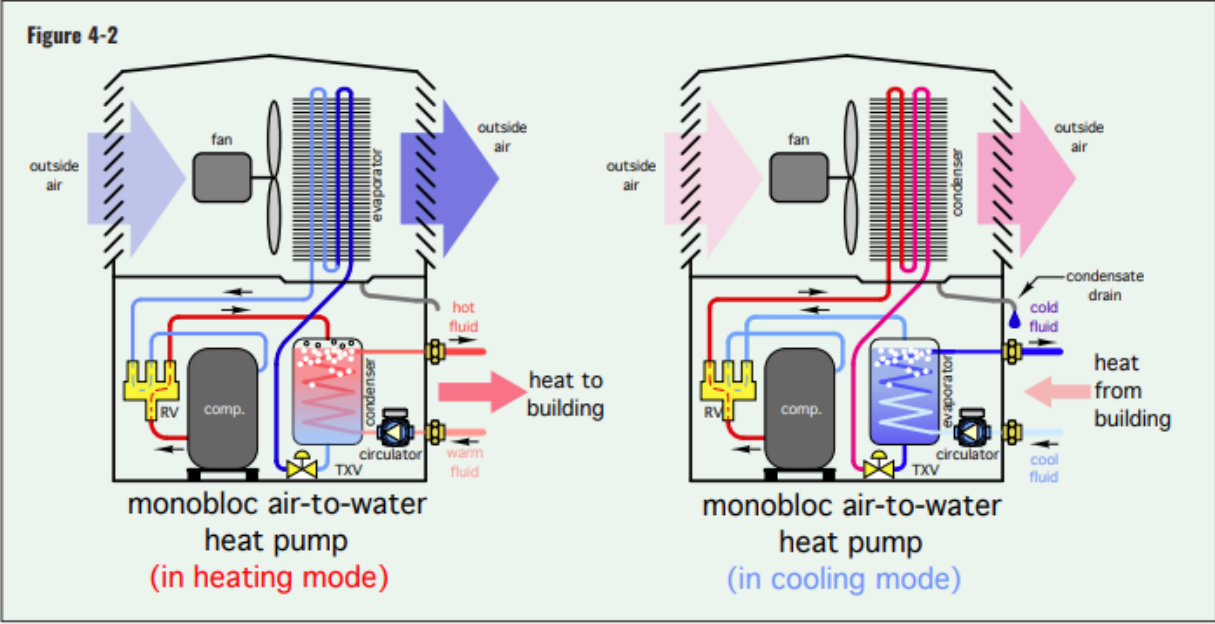


Figure 6: Monobloc AWHP schematic.

Image credit: idronics™27: *Air-to-Water Heat Pump Systems* © Caleffi North America, Inc. (<https://www.caleffi.com/en-us/blog/air-water-heat-pump-configurations>)

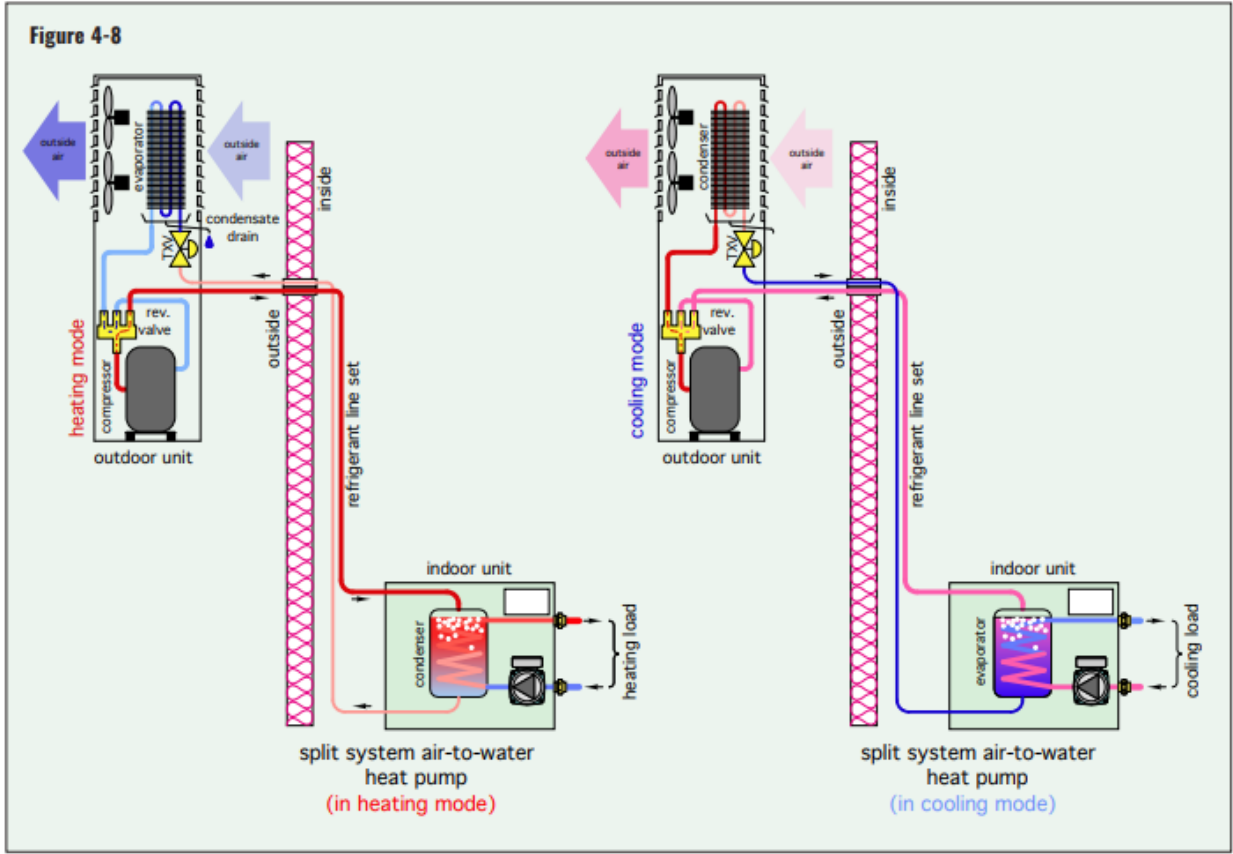


Figure 7: Split system AWHP schematic.

Image credit: idronics™27: *Air-to-Water Heat Pump Systems* © Caleffi North America, Inc. (<https://www.caleffi.com/en-us/blog/air-water-heat-pump-configurations>)

As glycol mixtures begin to freeze, the fluid becomes slushy and harder to circulate. As long as this situation is infrequent, partial freezing may be only a minor concern. For many designers, the specified 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 28. It should be noted that the temperatures represent fluid temperature, not ambient air temperature.

Table 28: Glycol Concentration Needed to Prevent Freezing and Burst Pipes

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%

Sources: (Dow 2008a, Dow 2008b)

The freeze protection limits for propylene glycol mixtures were selected as the basis for the proposed concentration limits presented in this measure proposal in order to provide flexibility to HVAC designers. Although burst protection is the more relevant criterion for some designers, stakeholder feedback indicated that many take a more conservative approach and prefer to avoid freezing altogether. Propylene glycol mixtures freeze at a slightly higher temperature than ethylene glycol mixtures and is the more conservative choice as the basis for the proposed measure. 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 hard limit of 50 percent is commonly recommended by manufacturers of both hydronic heat pumps and commercial boilers, and this overall limit is also applied in our recommendations. A summary of the proposed glycol concentration limits is shown in Table 29.

Table 29: Proposed Glycol Concentration Limits

Heating Median of Extremes (From JA2-4)	Allowed Range of Glycol Concentration
Above 37°F	0
25°F to 37°F	≤19%
15°F to 24°F	≤30%
5°F to 14°F	≤38%
-5°F to 4°F	≤44%
-15°F to -6°F	≤48%
Below -15°F	≤50%

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 calculate the effects of high-viscosity glycol/water mixtures on pump power. Recommended mandatory glycol concentration limits in the proposed measure are meant to be conservative because the limitations in test standards and compliance software make accurate energy savings estimates difficult, and stakeholders have expressed concerns about the variety of potential system designs that may present concerns related to freezing. 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 during future code change cycles.

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 3.6: 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 400.5 [SECTION 110.2] – MANDATORY REQUIREMENTS FOR SPACE-CONDITIONING EQUIPMENT

Subsection 400.5.7 [New section] Glycol Concentration: The proposed measure would add a new mandatory requirement limiting the glycol concentration for AWHPs. A sliding scale between 0 percent and 50 percent would be established as a function of Heating Median of Extremes, as specified in Table 2-3 in Joint Appendix JA-2: Reference Weather/Climate Data. Exceptions would include AWHPs serving process or other low-temperature loads, AWHPs that operate only in heating mode, and AWHPs that are integrated into a fluid loop that includes other hydronic space conditioning plants (boilers or chillers).

3.1.4.2 Reference Appendices Change Summary

No changes to Reference Appendices are proposed. Verification will be based on information provided in compliance documents and compliance software checks as discussed below. No acceptance testing is recommended.

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 (ACM) Reference Manual Change Summary

The proposed measure is mandatory, therefore the only change to the Nonresidential Alternative Calculation Method (ACM) Reference Manual would be to document the procedure for verifying that the proposed glycol concentration is below the maximum allowed.

3.1.4.5 Compliance Documents Change Summary

Changes to the NRCI-MCH-E Compliance Document are recommended. The NRCC-MCH-E and NRCI-MCH-E compliance documents provide tables to define the boiler, chiller, and air to water heat pump efficiency and controls, as shown in Figure 8.

The Statewide CASE Team proposes that the “Boiler Efficiency and Control” table title 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/installed value as appropriate. For NRCI-MCH-E, there will also be an entry for method of verification (glycol management system, refractometer test, volumetric calculation).

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											

Figure 8: NRCI-MCH-E compliance document data entry tables for boiler and chiller systems.

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 percent 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.

The 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 at or below the maximum allowed in Compliance Documents NRCC-MCH-E and NRCI-MCH-E. Two columns would be added to the NRCC-MCH-E and completed by the designer, one indicating the glycol concentration limit based on the heating median of extremes 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. The plans examiner will verify eligibility for exceptions during design, and the building inspector will verify eligibility during construction. Four columns would be added to NRCI-MCH-E, documenting the actual concentration, method of

verification, maximum concentration, and labeling of the AWHP near the fill point. No acceptance testing is recommended.

To help ensure that the glycol concentration is maintained below the limit over time, a note or sticker would 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 five to seven years, with annual checks on concentration level unless the system includes a glycol control system that automatically monitors concentration and adjusts the mixture as needed. This sticker would indicate the design glycol concentration and communicate that higher or lower levels present energy performance or freezing risks.

In addition, the compliance software would 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 30 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 30: Impacts on Market Actors and Suggested Training and Education Opportunities

Market Actor	Impact(s)	Suggested Outreach and Education
Owner/ Developer ^a	Ensure maximum glycol concentrations are understood by all parties and implemented in practice. Equipment capacity will be higher with less glycol.	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 Professional ^b	HVAC designers must confirm their specified glycol concentration complies with the limits and the system is designed to meet performance expectations. Most energy conscious designers 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 and apply the label at the fill point documenting design concentration. Commissioning agents must verify the concentration and labeling are implemented in practice. For some systems glycol concentration is verified and maintained through an automated glycol management system. For others, concentration must be verified using a refractometer or other device, or by quantifying the volume of glycol and water added to the mixture.	Minimal training required beyond understanding new concentration limits, verification options, and requirements for labeling the equipment.
Building Department ^d	Understand changes to compliance documents.	Training or fact sheets explaining the proper use of glycol to prevent freezing, and an understanding of new concentration limits.
Verification Tester ^e	No additional testing is proposed.	None required
Manufacturers and Distributor	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. Owner/Developer is funding the project and is the primary decision-maker.
- b. Design professionals include architects, engineers (mechanical, electrical, plumbing, structural), specification writers, cost estimators, commissioning agents, lighting designers, and energy consultants.
- c. Construction team includes general contractors, home builders, design-build contractors, installation contractors (e.g., HVAC, plumbing, electrical), commissioning agents, and tradespeople.
- d. Building departments include plans reviewers, building inspectors, specialty inspectors, permit counter technicians and third-party plan review and inspection.
- e. Verification testers include commissioning agents, ECC Raters, and Acceptance Test Technicians.

The 2028 CASE [Methodology Report](#) presents a quantitative assessment of how changes to the California building code impact builders, building designers and energy consultants, and building owners and occupants. While the analysis in the methodology report is not specific to the code change(s) presented in this report, this measure focuses on designers, installers, building departments, and building owners, since these market actors are expected to experience the most direct impacts from restrictions on glycol concentration. 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 31 shows the commercial building subsectors that the Statewide CASE Team expects to be impacted by the changes proposed in this report. These subsectors consist primarily of HVAC installers.

Building occupants (owners and tenants). The proposed code change would have no incremental costs and would reduce building owners' utility bills throughout the measure lifetime. See the 2028 [Methodology Report](#) for a description of how LSC savings relate to occupant utility bill savings.

Table 31: Specific Subsectors of the California Commercial Building Industry Impacted by Proposed Change to Code/Standard by Subsector in 2025 (Estimated)

Construction Subsector	Establishments	Employment	Annual Payroll (Billions \$)
Commercial Building Construction	4,919	83,028	9.0
Nonresidential Electrical Contractors	3,137	74,277	7.0
Nonresidential Plumbing & HVAC Contractors	2,346	55,572	5.5
Other Nonresidential Equipment Contractors	556	9,594	1.0
Nonresidential Site Preparation Contractors	1,159	18,322	1.6
All Other Nonresidential Trade Contractors	940	18,027	1.6

Source: (State of California n.d.)

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 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 minor 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.

3.2.3 Compliance Software Updates

To assist in compliance verification, it is recommended the software be modified to automatically determine the appropriate glycol concentration limit based on the geographic location, compare this value to the actual design concentration entered by the building owner, and report if the proposed concentration is within the mandatory limit. In a future code cycle, 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.

Negligible incremental cost for enforcement for plans examiners is expected because both actual and maximum allowed glycol concentration will be documented on the revised compliance documents NRCC-MCH-E and verified in the compliance software. However, there would be a small enforcement cost to for inspectors to confirm the glycol concentration specified on NRCC-MCH-E matches what is installed and documented on NRCI-MCH-E, to verify the concentration has been tested or calculated following installation, and that a label is present on the equipment documenting the design concentration and the potential risks for deviating from that concentration over time. 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 market trends for AWHPs was provided in Section 2.3.1.1. However, the 60 percent multiplier related to frequency of stage, multi-unit systems is not applicable to the glycol concentration measure. One additional market assumption relevant for the proposed measure is that about 35 percent of AWHPs operate in heating-only mode, which is important because these systems are exempt from the proposed glycol-concentration limitations due to the much smaller impact on efficiency compared to AWHPs in cooling mode. Therefore, a 65 percent multiplier was applied to the market-impact numbers for both new construction/additions and alterations.

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 percent provided in most AWHP and boiler manufacturer's literature, and there is anecdotal evidence from stakeholders that concentration is usually a round number like 30 percent, indicating there may not be much fine-tuning of the concentration. For the purpose of statewide impact analysis, it is assumed that 10 percent of nonresidential buildings with AWHPs in climates where the outside temperatures occasionally drop below 32°F would have excessive glycol-concentration levels ranging from 30 percent to 50 percent. This translates to a market share rate of 90 percent, including AWHP systems other than heating-only systems (discussed above) that meet one of the exceptions and to which the proposed measure does not apply.

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 are expected, except possibly in extremely cold locations where hydronic systems may not be an 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 percent of the time. Because there is currently no restriction on glycol concentration or a performance path penalty for higher concentration levels, building owner satisfaction and energy-conscious design are the primary motivation for keeping glycol concentrations low. This code requirement would close a loophole to minimize the opportunity for poor design practices.

3.3.1.2 Market Challenges and Solutions

Stakeholder interviews and a careful literature review indicate several market barriers that slow the adoption of AWHPs:

- Limited number of AWHP units 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 selecting the lowest possible glycol concentration that protects against freezing with an adequate safety margin.

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

3.3.2 Design and Construction Practices

3.3.2.1 Current Design and Construction Practices

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 quite 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 system. In most scenarios, glycol concentration will 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 percent glycol to ensure there is no risk of freezing without performing a more detailed analysis of system efficiency under expected weather conditions.

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 additional 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 30 in Section 3.2.2 for a description of workforce trainings that could support effective design, installation, and commissioning.

3.3.3 Energy Equity and Environmental Justice

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

Overall, this proposal is expected to benefit ESJ communities by establishing consistent rules that may expand the market for AWHPs, leading to the following impacts:

- As noted in Section 3.5.5, these systems provide indirect IAQ benefits for affected buildings by enabling greater use of all-electric space conditioning equipment, thereby reducing site emissions associated with natural gas boilers inside conditioned space. 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 system uses about half the refrigerant of split systems and refrigerant cannot leak to the indoor space. The measure would also reduce the use of ethylene glycol, which is toxic and requires special handling. This makes the system safer, with less impact to occupant health and the environment compared to other HVAC options.
- The refrigerant loop is not accessible from the exterior of the pre-charged outdoor unit and therefore is not interacted with by an installer, which makes AWHP systems easier and cheaper for the building owner to maintain themselves. Similarly, replacement is simpler and cheaper because none of the plumbing or indoor delivery system needs to be replaced to accommodate new refrigerants. The replacing installer simply disconnects the AWHP from the plumbing and electrical, and plugs in the new AWHP.
- Three-function AWHPs can use the existing breakers from the furnace and AC, which eases electrification retrofits by reducing the need for expensive breaker panel and utility service upgrades.
- Resilience is improved by ensuring that proper attention is paid to glycol concentrations that balance energy use with the risk of freezing during extreme cold or power outages, reducing the risk of extended facility shut-down periods.
- No impact on comfort is expected for the proposed measure.

3.3.4 Impacts on Jobs and Businesses

The Statewide CASE Team does not anticipate significant employment or financial impacts on any particular sector of the California economy. However, the proposed change may have modest impacts on employment in California. The Statewide CASE Team estimates the proposed change would affect statewide employment and economic output directly and indirectly through its impact on builders, designers, energy consultants, and building inspectors. Table 32, Table 33, and Table 34 outline the statewide implications for these job categories. For more information on the Statewide CASE Team’s economic impacts methodology, see the 2028 CASE [Methodology Report](#).

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

Table 32: Estimated Impact that Adoption of the Proposed Measure would have on the California Nonresidential Construction Sector

Type of Economic Impact	Employment (Jobs)	Labor Income	Total Value Added	Output
Direct Effects (Additional spending by Commercial Builders)	0.0	\$0	\$0	\$0
Indirect Effect (Additional spending by firms supporting Commercial Builders)	0.0	\$0	\$0	\$0
Total Economic Impacts	0.0	\$0	\$0	\$0

Source: Statewide CASE Team analysis of data from the IMPLAN modeling software.⁸

⁸ IMPLAN® model, 2020 Data, IMPLAN Group LLC, IMPLAN System (data and software), 16905 Northcross Dr., Suite 120, Huntersville, NC 28078 www.IMPLAN.com

Table 33: Estimated Impact that Adoption of the Proposed Measure would have on the California Building Designers and Energy Consultant Sectors

Type of Economic Impact	Employment (Jobs)	Labor Income	Total Value Added	Output
Direct Effects (Additional spending by building designers and energy consultants)	0.3	\$34,418	\$34,073	\$53,856
Indirect Effect (Additional spending by firms supporting building designers and energy consultants)	0.1	\$10,248	\$14,243	\$22,928
Total Economic Impacts	0.4	\$44,666	\$48,316	\$76,784

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

Table 34: Estimated Impact that Adoption of the Proposed Measure would have on California Building Inspectors

Type of Economic Impact	Employment (Jobs)	Labor Income	Total Value Added	Output
Direct Effects (Additional spending by building inspectors)	0.1	\$9,344	\$11,081	\$13,466
Indirect Effect (Additional spending by firms supporting building inspectors)	0.0	\$865	\$1,348	\$2,348
Total Economic Impacts	0.1	\$10,210	\$12,429	\$15,814

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

The proposed change represents a modest adjustment, which is not expected to excessively burden or competitively disadvantage California businesses, nor is it expected to lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not expect the proposed code changes to result in the creation of new businesses or the elimination of existing ones.

The proposed code changes would apply to all businesses operating in California, regardless of whether the business is incorporated inside or outside of the state.⁹ Therefore, the Statewide CASE Team does not anticipate that the proposed changes would have advantageous or an adverse effect on the competitiveness of California businesses.

The Statewide CASE Team derived a reasonable estimate of the change in investment by California businesses based on the estimated change in economic activity associated with the proposed measure and its expected effect on business income. The Statewide CASE Team’s IMPLAN modeling resulted in an estimated \$7,507 increase in California business income due to the proposed code change. The Statewide CASE Team assumed that net business investment is positively correlated with business income and that a portion of business income will be allocated to net business investment.¹⁰

To estimate the portion of business income that would be allocated to net investment, the Statewide CASE Team analyzed national data on corporate profits and net capital investment by businesses that expand a firm’s capital stock (referred to

⁹ Gov. Code, §§ 11346.3(c)(1)(C), 11346.3(a)(2); 1 CCR § 2003(a)(3) Competitive advantages or disadvantages for California businesses currently doing business in the state.

¹⁰ 26 percent of proprietor income was assumed to be allocated to net business investment; see Table 10.

as net private domestic investment, or NPDI).¹¹ As Table 35 shows, between 2020 and 2021, NPDI as a percentage of corporate profits ranged from a low of 18 percent in 2020 due to the worldwide economic slowdowns associated with the COVID-19 pandemic to a high of 28 percent in 2022, with an average of 23 percent. While only an approximation of the proportion of business income used for net capital investment, it provides a reasonable estimate of the proportion of proprietor income that business owners will reinvest into expanding their capital stock.

Table 35: Net Domestic Private Investment and Corporate Profits, U.S.

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

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

Given the estimated total increase in California business income and net business investment ratio described above, the Statewide CASE Team estimates the proposed code change would result in a \$1,762 increase in net private investment by California businesses.

3.3.5 Economic and Fiscal Impacts

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

Adoption of this code change proposal would result in minimal economic impacts through the additional direct spending by HVAC and controls designers, installers, and building inspectors to comply with the measure. There would also be a very small decrease in the amount of glycol purchased by installers, and overall costs to building

¹¹ Net private domestic investment is the total amount of investment in capital by the business sector that is used to expand the capital stock, rather than maintain or replace due to depreciation. Corporate profit is the money left after a corporation pays its expenses.

owners would be smaller. The Statewide CASE Team does not anticipate that money saved by commercial building owners or other organizations affected by the proposed 2028 code cycle regulations would result in additional spending by those businesses.

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

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

Cost to State: The state government already has a budget for code development, education, and compliance enforcement. While the state government would be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, these activities are already covered by existing state budgets. The costs for the state government are small when compared to the overall cost savings and policy benefits associated with the code change proposals. 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 3.2.2, the Statewide CASE Team considered how the proposed code change might impact various market actors involved in the compliance and enforcement process and aimed to minimize negative impacts on local governments.

3.3.5.2 Mandates on Local Agencies or School Districts

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

3.3.5.4 Costs or Savings to Any State Agency

There are no net costs to any state agencies. There is expected to be no incremental design and installation 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 net costs to any local agencies. There is expected to be no incremental design and installation 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 for federal funding to the state because the proposed measure only improves the energy efficiency of certain nonresidential buildings.

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 36 through Table 39 for the four prototypes that were modeled (Large Office, Medium Office, Large School, Hospital) along with all other nonresidential prototypes. The four modeled building types were expected to have significantly higher market penetration of hydronic heat pumps by 2029 (20 percent) compared to other building types (five percent). However, the proposed measure would apply to all building types. It was assumed that the buildings that were not modeled would have similar energy and cost savings per-square-foot to the Medium Office, which is the most similar in size among the modeled building types. 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 electricity savings for the first year are expected to range from 0 to 0.10 kWh/yr depending upon climate zone, with 0 therms/yr in gas savings in all climate zones because the prototypes use electric AWHPs. Demand reductions/increases are predicted to be relatively small for all climate zones, but the measure will have the greatest impact during extremely hot weather when chilled water will be used the most. Among the modeled building types, the highest per square foot electricity and source energy savings are expected in medium-size office buildings, and the lowest in large office buildings.

The results vary by climate zone based on the magnitude of cooling loads encountered in the building, and the difference between the assumed base case glycol concentration and the limit imposed by the proposed measure. In Climate Zones 2, 11, and 13, the savings are predicted to be zero because the base case concentration and mandatory limit happen to be the same for the specific cities representing those climate zones (see Appendix A). However, many other cities within the same climate zones would have significant savings. The results are somewhat conservative because of the buildings left out of the analysis for Climate Zones 2, 11, and 13, and because the savings in heating mode are neglected. Assuming proper maintenance of the water-glycol mixture, the predicted energy savings are expected to be persistent over time.

Table 40 presents total per-unit energy cost savings for newly constructed buildings, additions, and alterations in terms of LSC savings realized over a 30-year period for each building type, in 2029 present value dollars (2029 PV\$). Table 41 presents the 30-year LSC savings per square foot as an average across all building types for new construction and additions. Similar results are presented in Table 42 for alterations. The LSC methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

Table 36: First-Year Electricity Savings (kWh) Per Square Foot – AWHP Glycol Concentration Limits

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Large Office	0.00	0.00	0.01	0.01	0.01	0.01	0.03	0.02	0.01	0.02	0.00	0.01	0.00	0.00	0.03	0.00
Medium Office	0.02	0.00	0.04	0.05	0.04	0.06	0.09	0.07	0.07	0.07	0.00	0.05	0.00	0.02	0.10	0.01
Small Office	0.02	0.00	0.04	0.05	0.04	0.06	0.09	0.07	0.07	0.07	0.00	0.05	0.00	0.02	0.10	0.01
Large Retail	0.02	0.00	0.04	0.05	0.04	0.06	0.09	0.07	0.07	0.07	0.00	0.05	0.00	0.02	0.10	0.01
Medium Retail	0.02	0.00	0.04	0.05	0.04	0.06	0.09	0.07	0.07	0.07	0.00	0.05	0.00	0.02	0.10	0.01
Strip Mall	0.02	0.00	0.04	0.05	0.04	0.06	0.09	0.07	0.07	0.07	0.00	0.05	0.00	0.02	0.10	0.01
Large School	0.01	0.00	0.03	0.03	0.03	0.04	0.06	0.04	0.04	0.04	0.00	0.03	0.00	0.01	0.04	0.01
Small School	0.02	0.00	0.04	0.05	0.04	0.06	0.09	0.07	0.07	0.07	0.00	0.05	0.00	0.02	0.10	0.01
Non-refrigerated Warehouse	0.02	0.00	0.04	0.05	0.04	0.06	0.09	0.07	0.07	0.07	0.00	0.05	0.00	0.02	0.10	0.01
Assembly	0.02	0.00	0.04	0.05	0.04	0.06	0.09	0.07	0.07	0.07	0.00	0.05	0.00	0.02	0.10	0.01
Hospital	0.01	0.00	0.03	0.03	0.03	0.04	0.07	0.04	0.04	0.04	0.00	0.03	0.00	0.01	0.05	0.01
Laboratory	0.02	0.00	0.04	0.05	0.04	0.06	0.09	0.07	0.07	0.07	0.00	0.05	0.00	0.02	0.10	0.01
Restaurant	0.02	0.00	0.04	0.05	0.04	0.06	0.09	0.07	0.07	0.07	0.00	0.05	0.00	0.02	0.10	0.01

Table 37: First-Year Peak Demand Reduction (kW) Per Square Foot – AHP Glycol Concentration Limits

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Large Office	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Medium Office	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Small Office	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Large Retail	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Medium Retail	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Strip Mall	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Large School	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Small School	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Non-refrigerated Warehouse	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Assembly	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Hospital	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laboratory	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Restaurant	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00

Table 38: First-Year Natural Gas Savings (kBtu) Per Square Foot – AWHP Glycol Concentration Limits

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Large Office	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Medium Office	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Small Office	0.00	0.00	0.00	0.00	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 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
Medium 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
Strip Mall	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Small School	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-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
Assembly	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hospital	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laboratory	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Restaurant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 39: First-Year Source Energy Savings (kBtu) Per Square Foot – AWHP Glycol Concentration Limits

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Large Office	0.00	0.00	0.01	0.01	0.01	0.01	0.03	0.02	0.01	0.02	0.00	0.01	0.00	0.00	0.03	0.00
Medium Office	0.01	0.00	0.04	0.04	0.04	0.06	0.09	0.07	0.06	0.06	0.00	0.04	0.00	0.02	0.10	0.01
Small Office	0.01	0.00	0.04	0.04	0.04	0.06	0.09	0.07	0.06	0.06	0.00	0.04	0.00	0.02	0.10	0.01
Large Retail	0.01	0.00	0.04	0.04	0.04	0.06	0.09	0.07	0.06	0.06	0.00	0.04	0.00	0.02	0.10	0.01
Medium Retail	0.01	0.00	0.04	0.04	0.04	0.06	0.09	0.07	0.06	0.06	0.00	0.04	0.00	0.02	0.10	0.01
Strip Mall	0.01	0.00	0.04	0.04	0.04	0.06	0.09	0.07	0.06	0.06	0.00	0.04	0.00	0.02	0.10	0.01
Large School	0.01	0.00	0.03	0.02	0.02	0.03	0.06	0.03	0.03	0.03	0.00	0.02	0.00	0.01	0.04	0.01
Small School	0.01	0.00	0.04	0.04	0.04	0.06	0.09	0.07	0.06	0.06	0.00	0.04	0.00	0.02	0.10	0.01
Non-refrigerated Warehouse	0.01	0.00	0.04	0.04	0.04	0.06	0.09	0.07	0.06	0.06	0.00	0.04	0.00	0.02	0.10	0.01
Assembly	0.01	0.00	0.04	0.04	0.04	0.06	0.09	0.07	0.06	0.06	0.00	0.04	0.00	0.02	0.10	0.01
Hospital	0.01	0.00	0.04	0.03	0.03	0.05	0.08	0.04	0.04	0.04	0.00	0.04	0.00	0.01	0.06	0.01
Laboratory	0.01	0.00	0.04	0.04	0.04	0.06	0.09	0.07	0.06	0.06	0.00	0.04	0.00	0.02	0.10	0.01
Restaurant	0.01	0.00	0.04	0.04	0.04	0.06	0.09	0.07	0.06	0.06	0.00	0.04	0.00	0.02	0.10	0.01

Table 40: Total 30-Year LSC Savings (2029 PV\$) Per Square Foot – AWHP Glycol Concentration Limits

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Large Office	0.02	0.00	0.02	0.09	0.02	0.06	0.13	0.10	0.13	0.14	0.00	0.12	0.00	0.20	0.41	0.16
Medium Office	0.11	0.00	0.30	0.39	0.33	0.46	0.68	0.59	0.54	0.54	0.00	0.41	0.00	0.15	0.78	0.08
Small Office	0.11	0.00	0.30	0.39	0.33	0.46	0.68	0.59	0.54	0.54	0.00	0.41	0.00	0.15	0.78	0.08
Large Retail	0.11	0.00	0.30	0.39	0.33	0.46	0.68	0.59	0.54	0.54	0.00	0.41	0.00	0.15	0.78	0.08
Medium Retail	0.11	0.00	0.30	0.39	0.33	0.46	0.68	0.59	0.54	0.54	0.00	0.41	0.00	0.15	0.78	0.08
Strip Mall	0.11	0.00	0.30	0.39	0.33	0.46	0.68	0.59	0.54	0.54	0.00	0.41	0.00	0.15	0.78	0.08
Large School	0.09	0.00	0.22	0.23	0.25	0.25	0.44	0.28	0.28	0.26	0.00	0.22	0.00	0.07	0.29	0.06
Small School	0.11	0.00	0.30	0.39	0.33	0.46	0.68	0.59	0.54	0.54	0.00	0.41	0.00	0.15	0.78	0.08
Non-refrigerated Warehouse	0.11	0.00	0.30	0.39	0.33	0.46	0.68	0.59	0.54	0.54	0.00	0.41	0.00	0.15	0.78	0.08
Assembly	0.11	0.00	0.30	0.39	0.33	0.46	0.68	0.59	0.54	0.54	0.00	0.41	0.00	0.15	0.78	0.08
Hospital	0.09	0.00	0.23	0.24	0.24	0.35	0.59	0.34	0.31	0.31	0.00	0.26	0.00	0.08	0.42	0.07
Laboratory	0.11	0.00	0.30	0.39	0.33	0.46	0.68	0.59	0.54	0.54	0.00	0.41	0.00	0.15	0.78	0.08
Restaurant	0.11	0.00	0.30	0.39	0.33	0.46	0.68	0.59	0.54	0.54	0.00	0.41	0.00	0.15	0.78	0.08

Table 41: 2029 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions – AHP Glycol Concentration Limits

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	0.09	0.00	0.09
2	0.00	0.00	0.00
3	0.23	0.00	0.23
4	0.24	0.00	0.24
5	0.24	0.00	0.24
6	0.35	0.00	0.35
7	0.59	0.00	0.59
8	0.34	0.00	0.34
9	0.31	0.00	0.31
10	0.31	0.00	0.31
11	0.00	0.00	0.00
12	0.26	0.00	0.26
13	0.00	0.00	0.00
14	0.08	0.00	0.08
15	0.42	0.00	0.42
16	0.07	0.00	0.07

Table 42: 2029 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations– AWHP Glycol Concentration Limits

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	0.09	0.00	0.09
2	0.00	0.00	0.00
3	0.23	0.00	0.23
4	0.24	0.00	0.24
5	0.24	0.00	0.24
6	0.35	0.00	0.35
7	0.59	0.00	0.59
8	0.34	0.00	0.34
9	0.31	0.00	0.31
10	0.31	0.00	0.31
11	0.00	0.00	0.00
12	0.26	0.00	0.26
13	0.00	0.00	0.00
14	0.08	0.00	0.08
15	0.42	0.00	0.42
16	0.07	0.00	0.07

3.4.3 Incremental First Cost

Based on interviews with HVAC designers and manufacturers conducted from October through December 2025 and from March to April 2026, the proposed measure would not result in higher first costs for AWHP systems. Any small cost to document glycol concentration in the compliance documents would be outweighed by the reduced cost of purchasing glycol. The price of propylene glycol in late 2025 was \$1,357/metric ton (ChemAnalyst 2025). As an example, based on an assumption of six tons of water per ton of cooling (ClimaCool 2019), the estimated cost of glycol is \$7,128 for a 30-percent concentration in the Large School prototype buildings. This would result in savings of \$1,000-\$2,000 depending on climate each time the system is filled or refilled.

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 conducted in October through December 2025, 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.

3.4.5 Cost Effectiveness

Results of the per-unit cost-effectiveness analyses are presented in Table 43 and Table 44 presents results for new construction/additions and alterations, respectively. The values represent the weighted average across all prototypes. In Climate Zones 2, 11, and 13, no energy savings are projected for the prototype buildings because the standard practice glycol concentration is estimated to be the same as the proposed concentration limit. However, the prototypes are associated with specific cities in each climate zone, and there are other cities in the same climate zone where savings would occur. Therefore, for the proposed measure, total incremental costs are estimated to be zero, and infinite LSC savings are expected for affected buildings in all climate zones.

The difference in energy savings for alterations is due to a different mix of floor areas for each building type compared to new construction, and the effect of that mix on weighted averages.

In the tables below, all values are presented in 2029 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 the 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. Costs and other savings are discounted at a real (inflation-adjusted) three-percent rate.

Table 43: 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	0.10	0.00	infinite
2	0.00	0.00	infinite
3	0.21	0.00	infinite
4	0.26	0.00	infinite
5	0.31	0.00	infinite
6	0.34	0.00	infinite
7	0.52	0.00	infinite
8	0.41	0.00	infinite
9	0.34	0.00	infinite
10	0.44	0.00	infinite
11	0.00	0.00	infinite
12	0.26	0.00	infinite
13	0.00	0.00	infinite
14	0.11	0.00	infinite
15	0.69	0.00	infinite
16	0.08	0.00	infinite

Table 44: 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	0.10	0.00	infinite
2	0.00	0.00	infinite
3	0.21	0.00	infinite
4	0.26	0.00	infinite
5	0.29	0.00	infinite
6	0.30	0.00	infinite
7	0.50	0.00	infinite
8	0.37	0.00	infinite
9	0.32	0.00	infinite
10	0.43	0.00	infinite
11	0.00	0.00	infinite
12	0.31	0.00	infinite
13	0.00	0.00	infinite
14	0.11	0.00	infinite
15	0.68	0.00	infinite
16	0.07	0.00	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 45) and alterations (Table 46) by climate zone. Table 47 presents first-year statewide savings from new construction, additions, and alterations. The total predicted LSC savings for all building types is \$0.81 million.

The analysis includes all building types, although the large office, medium office, large school, and hospital prototypes are the most likely to have AWHPs for space

conditioning. The fraction of floor space affected by the measure includes the market penetration assumptions described in Section 3.3.1.1.

- 20 percent of new buildings for the four modeled building types will have hydronic heat pumps for space conditioning in 2029, along with five percent of other nonresidential building types
- 12 percent of replacement HVAC systems will be hydronic heat pumps (60 percent of the 20 percent estimated for new construction) for the four modeled building types, and three percent of other nonresidential building types
- 65 percent of AWHPs will serve both heating and cooling loads
- 90 percent of AWHP systems will already have minimized glycol concentrations below the limits established by the proposed measure

These market penetration values are all toward the low end of stakeholder inputs. Therefore, the results are conservative from a statewide impact standpoint.

Table 45: 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	3,737	0.00	0.00	0.00	0.00	\$0.00
2	21,104	0.00	0.00	0.00	0.00	\$0.00
3	107,919	0.00	0.00	0.00	0.00	\$0.02
4	55,149	0.00	0.00	0.00	0.00	\$0.01
5	10,403	0.00	0.00	0.00	0.00	\$0.00
6	67,881	0.00	0.00	0.00	0.00	\$0.02
7	51,625	0.00	0.00	0.00	0.00	\$0.03
8	99,663	0.01	0.00	0.00	0.01	\$0.04
9	165,222	0.01	0.00	0.00	0.01	\$0.06
10	73,842	0.00	0.00	0.00	0.00	\$0.03
11	14,841	0.00	0.00	0.00	0.00	\$0.00
12	97,080	0.00	0.00	0.00	0.00	\$0.03
13	27,583	0.00	0.00	0.00	0.00	\$0.00
14	16,811	0.00	0.00	0.00	0.00	\$0.00
15	9,848	0.00	0.00	0.00	0.00	\$0.01
16	5,324	0.00	0.00	0.00	0.00	\$0.00
Total	828,031	0.03	0.00	0.00	0.03	\$0.25

Table 46: 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 Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2029 PV\$)
1	6,419	0.00	0.00	0.00	0.00	\$0.00
2	40,401	0.00	0.00	0.00	0.00	\$0.00
3	219,691	0.01	0.00	0.00	0.01	\$0.05
4	111,170	0.00	0.00	0.00	0.00	\$0.03
5	18,921	0.00	0.00	0.00	0.00	\$0.01
6	161,494	0.01	0.00	0.00	0.01	\$0.05
7	119,809	0.01	0.00	0.00	0.01	\$0.06
8	228,664	0.01	0.00	0.00	0.01	\$0.08
9	366,501	0.01	0.00	0.00	0.01	\$0.12
10	184,887	0.01	0.00	0.00	0.01	\$0.08
11	34,557	0.00	0.00	0.00	0.00	\$0.00
12	212,703	0.01	0.00	0.00	0.01	\$0.07
13	65,818	0.00	0.00	0.00	0.00	\$0.00
14	42,614	0.00	0.00	0.00	0.00	\$0.00
15	23,335	0.00	0.00	0.00	0.00	\$0.02
16	13,006	0.00	0.00	0.00	0.00	\$0.00
Total	1,849,991	0.07	0.00	0.00	0.07	\$0.56

Table 47: 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	0.03	0.00	0.00	0.03	0.25
Alterations	0.07	0.00	0.00	0.07	0.56
Total	0.10	0.01	0.00	0.10	0.81

3.5.2 Statewide Greenhouse Gas Emissions Reductions

Table 48 presents the estimated first-year reduction in GHG emissions resulting from the proposed code change. In the initial year, the Statewide CASE Team expects to avoid 5.1 metric tons of carbon dioxide equivalent (CO₂e) 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 48: First-Year Statewide GHG Emissions Impacts

Construction Type	Reduced GHG Emissions from Electricity Savings (Metric Tons CO ₂ e)	Reduced GHG Emissions from Natural Gas Savings (Metric Tons CO ₂ e)	Total Reduced GHG Emissions (Metric Ton CO ₂ e)	Total Monetary Value of Reduced GHG Emissions (\$)
New Construction & Additions	1.6	0.0	1.6	195.6
Alterations	3.5	0.0	3.5	437.1
Total	5.1	0.0	5.1	632.7

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.

Statewide Material Impacts

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

3.5.4 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.

3.5.5 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. Changes to the 2025 documents should be marked with dark blue [underlining](#) (new language) and ~~strikethroughs~~ (deletions). New to the 2028 energy code is to *italicize defined terms* when the terms are being used in its defined context. In-line comments that are not part of the proposed code language but are used to help describe the purpose of what is proposed are included *with greyed highlight and italics*.

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

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

3.6.2 Administrative Code (Title 24, Part 1)

No changes.

3.6.3 Energy Code (Title 24, Part 6)

The recommended measure would add mandatory requirements for glycol concentration to Section 400.5 [Section 110.2].

SECTION 400.5 [SECTION 110.2] – MANDATORY REQUIREMENTS FOR SPACE-CONDITIONING EQUIPMENT

400.5.7 [New section] Glycol Concentration: For air-to-water heat pumps (AWHPs), volumetric glycol concentration shall be less than or equal to the values in Table 400.5.7-N [Table 110.2-M] as a function of the heating median of extremes for the location as specified in Appendix JA2. If necessary, a minimum flow rate may be used to prevent freezing during certain periods when pipes are exposed to outdoor temperatures, or for heat recovery systems where the potential for freezing exists. A note or sticker specifying the design concentration

shall be prominently displayed on the AWHP system near the point where water/glycol mixture is refilled.

Exception 1 to Section 400.5.7: AWHPs that must deliver chilled water below 36°F.

Exception 2 to Section 400.5.7: AWHPs integrated with a hydronic space conditioning system that includes boilers or chillers.

Exception 3 to Section 400.5.7: AWHPs that only operate in heating mode, for which efficiency is not strongly affected by glycol concentration.

Exception 4 to Section 400.5.7 : Hotel/motel buildings and nonresidential buildings with Group R Occupancy, and common or public use areas serving that Occupancy

TABLE 400.5-N [TABLE 110.2-M] AIR-TO-WATER HEAT PUMP GLYCOL CONCENTRATION LIMITS

<u>Heating Median of Extremes (From JA2-4)</u>	<u>Allowable Range of Glycol Concentration by Volume</u>
<u>Above 37°F</u>	<u>0</u>
<u>25°F to 37°F</u>	<u>≤19%</u>
<u>15°F to 24°F</u>	<u>≤30%</u>
<u>5°F to 14°F</u>	<u>≤38%</u>
<u>-5°F to 4°F</u>	<u>≤44%</u>
<u>-15°F to -6°F</u>	<u>≤48%</u>
<u>Below -15°F</u>	<u>≤50%</u>

3.6.4 Reference Appendices

There are no proposed changes to the Reference Appendices. No acceptance testing is recommended, but installers must document that actual concentration is within the mandatory limits using NRCI-MCH-E.

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 Alternative Calculation Method (ACM) Reference Manual

The only proposed changes to the Alternative Calculation Method (ACM) Reference Manual will be to describe the process for automatic calculation of maximum concentration based on location and verification that the design concentration is below that limit in the compliance software.

3.6.7 Compliance Documents

As discussed in Section 3.1.4.5, the NRCC-MCH-E and NRCI-MCH-E Compliance Documents would be updated to include additional columns that verify compliance with the proposed change, including required labeling of equipment with the specified design concentration. 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 proposed measure requires automatic flow shut-off controls for inactive units in staged, multi-unit hydronic heat pump systems. In a typical multi-unit hydronic plant, two or more units are connected in parallel on a shared hydronic loop, each with a dedicated pump on its supply branch. When building loads are low, one unit may be turned off while the others meet the full load. Without proper flow controls, the inactive unit's pump may continue to operate at full capacity, circulating water through the inactive unit and wasting pump energy.

The Statewide CASE Team simulated the energy impacts in every climate zone using EnergyPlus and the standard prototype building models and applied the climate-zone-specific LSC hourly factors when calculating energy and energy-cost impacts.

The prototype HVAC systems were converted to separate hydronic heating and cooling systems, served by two staged AWHPs. Each AWHP unit had a dedicated variable-speed pump modeled in EnergyPlus, with no separation of primary and secondary loops. In the Standard Design, the second unit's pump operated at full design speed whenever the loop was active, regardless of whether that unit was providing space conditioning. Total pumping energy use in the Proposed Design was calculated via post-processing by extracting the second unit's pump energy during all hours in which the second unit's AWHP had zero load-side heat transfer, and setting the power to zero. The share of pump energy that represented the primary loop was approximated based on the AWHP capacity, using recommendations from a stakeholder with HVAC design expertise. The pump energy associated with the secondary distribution loop was excluded from the energy savings analysis, because those pumps are unaffected by the proposed measure.

Stakeholder input contributed to the selection of important prototype building types to model, the development of the baseline assumption of continuous full capacity flow for primary and secondary pumps where one or more AWHPs are not needed to meet the load, and to the selection of an AWHP system serving space heating and cooling loads, but not hot water.

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 49 presents the prototype buildings that were modeled directly. The Large School, Large Office, Medium Office, and Hospital prototypes were selected because they represent the largest nonresidential building types most likely to include multi-unit AWHP systems that benefit from automatic flow stage-off controls. All four prototypes also featured existing hydronic HVAC systems that could be more readily adapted to AWHP systems than some of the other prototype building types. Energy savings for building types that were not modeled were estimated based on the energy savings per-square-foot for the Medium Office prototype.

Table 49: Prototype Buildings Modeled 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.
Large Office	12	498,638	Large office served by two chiller and two boiler plants, with variable air volume distribution and terminal reheat. Chillers and boilers replaced with two AWHP cooling and two AWHP heating plants meeting minimum efficiency requirements.
Medium Office	3	53,633	Medium office served by two boiler plants with packaged variable air volume systems. Boilers and packaged direct expansion cooling replaced with two AWHP cooling and two AWHP heating plants, with central chilled water and hot water distribution and terminal reheat.
Hospital	5	241,525	Hospital served by one chiller and two boiler plants, with variable air volume distribution and terminal reheat. Chiller and boilers supplemented with two AWHP cooling and two AWHP heating plants meeting minimum efficiency requirements.

There is an existing Title 24, Part 6 requirement that covers the HVAC systems in all four prototype buildings, applying to both new construction/additions and alterations, so the Standard Design was minimally compliant with the 2025 Title 24 requirements. However, none of the prototype buildings had AWHP systems serving space-conditioning loads in the original models. 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 exclusively space-heating or space-cooling loads, rather than operating in both modes as most AWHP systems

do. Each AWHP cooling and heating loop includes two parallel supply branches, with each branch containing a dedicated AWHP unit and its associated variable-speed pump. In the Standard Design, both pumps operate whenever the loop is active, regardless of whether both units are needed to meet the load.

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 50 presents the parameters modified and the values used in the Standard Design and Proposed Design. Proposed Design savings were derived from the Standard Design simulation by removing Unit 2 primary pump energy during hours of zero AWHP Unit 2 load-side heat transfer. The energy savings resulting from reduced thermal losses in the circulation system and the improved system efficiency by avoiding unconditioned water mixing with chilled water were not included in the analysis, making the energy savings estimates more conservative.

Table 50: 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
All (Large Office, Medium Office, Large School, Hospital)	All	CHW Unit 2 pump, HHW Unit 2 pump	Pump Flow Rate Schedule	Pumps for paired systems operate at full design speed whenever loop is active	Pump energy during idle hours removed via post-processing

The energy impacts of the proposed code change vary by climate zone and building type. 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 analysis was to quantify the energy impacts of varying propylene glycol 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 propylene glycol was selected because it is more representative of AWHP hydronic loops.

The Statewide CASE Team simulated the energy impacts in every climate zone except Climate Zones 2, 11, and 13, where the base case and proposed glycol concentrations happened to be identical, and applied the climate-zone-specific LSC hourly factors when calculating energy and energy cost impacts.

The base case represented AWHP systems with 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 0 percent, 10 percent, 30 percent, or 40 percent depending on climate zone. The proposed case used the mandatory maximum concentration level based on the minimum freeze protection required for each location using the heating median of extreme temperatures in JA2. Propylene glycol concentrations were assigned by temperature group as follows: climate zones with Heating Median of Extremes above 37°F used zero percent propylene glycol (pure water); climate zones with heating median of extremes of 25°F to 37°F used 19 percent propylene glycol; climate zones with heating median of extremes of 15°F to 24°F retained 30 percent propylene glycol (same as baseline, no savings claimed); and zones with heating median of extremes of 5°F to 14°F used a glycol concentration of 38 percent.

Although stakeholders were very reluctant to provide typical numbers for glycol concentration, their input was sufficient to establish a baseline assumption of 30 percent as the most common glycol concentration when AWHPs are exposed to temperatures below freezing, with 50 percent as the highest value in even the most extreme climates.

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 51 presents the prototype buildings that were modeled directly. The Large School, Large Office, Medium Office, and Hospital prototypes were selected because they represent the largest nonresidential building types most likely to have AWHP systems and realize meaningful energy savings from reduced glycol concentrations. All four prototypes featured existing hydronic HVAC systems that could be more readily adapted to AWHP systems than other prototype building types. They also include less complex HVAC systems without additional chillers or boilers, which would have fallen under one of the exceptions for the measure. Energy savings for other nonresidential building types were estimated based on the per-square-foot energy savings of the Medium Office, which was the most similar in floor area among the four modeled building types.

Table 51: 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.
Large Office	12	498,638	Large office served by two chiller and two boiler plants, with variable air volume distribution and terminal reheat. Chillers and boilers replaced with two AWHP cooling and two AWHP heating plants meeting minimum efficiency requirements.
Medium Office	3	53,633	Medium office served by two boiler plants with packaged variable air volume systems. Boilers and packaged direct expansion cooling replaced with two AWHP cooling and two AWHP heating plants, with central chilled water and hot water distribution and terminal reheat.
Hospital	5	241,525	Hospital served by one chiller and two boiler plants, with variable air volume distribution and terminal reheat. Chiller and boilers replaced with two AWHP cooling and two AWHP heating plants meeting minimum efficiency requirements.

There is an existing Title 24, Part 6 requirement that covers the HVAC systems in all four prototype buildings, applying to both new construction/additions and alterations, so the Standard Design is minimally compliant with the 2025 Title 24 requirements. However, none of the prototype buildings have AWHP systems serving space conditioning loads in the original models. 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, rather than operating in both modes as would most AWHP systems.

The Standard Model included a fairly high glycol concentration (see Table 52). The values in Table 52 were determined based on stakeholder feedback and estimated as 30 percent, 40 percent, or 50 percent in climates exposed to freezing temperatures. The common use of round numbers instead of specific concentrations implies some level of unnecessary conservatism in the design concentration. Because stakeholder feedback also indicated that some designers use glycol for corrosion resistance, we also assume 10 percent glycol concentration in warmer climates. These higher concentrations may be an uncommon practice (estimated as 10 percent of nonresidential buildings in

California), but they are allowed by the 2025 code and represent a realistic scenario in which expected AWHP efficiency will not be achieved in practice.

Glycol concentration changes were only applied to the cooling loop and only cooling-side energy savings are claimed in this analysis. EnergyPlus predicts almost no energy savings with increasing glycol concentration in heating mode, which is inconsistent with the inferior thermal properties of glycol compared to water and with lab testing performed at Frontier’s laboratory in Davis. Since the Statewide CASE Team did not have adequate confidence in the savings calculated by EnergyPlus in the context of the prototype models, heating loop savings were not quantified for cost-effectiveness or statewide impact analysis. This represents a conservative estimate of energy savings.

Table 52: Standard Design Assumed Glycol Concentration

Heating Median of Extremes (From JA2-4)	Common Practice Glycol Concentration
Above 37°F	10%
25°F to 37°F	30%
15°F to 24°F	30%
5°F to 14°F	40%
-5°F to 4°F	40%
-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 53 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. Chilled-water pump design head was adjusted in both the Standard and Proposed Designs to account for the increased viscosity of propylene glycol relative to water, using a concentration-dependent correction factor derived from published glycol-viscosity correction data (Hall 2022).

Table 53: 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
All (Large Office, Medium Office, Large School, Hospital)	1, 3-6, 8-10, 12, 15	CHW loop working fluid, CHW pumps	Glycol concentration; pump head correction factor	30%; CF = 1.41	19%; CF = 1.29
All (Large Office, Medium Office, Large School, Hospital)	7	CHW loop working fluid, CHW pumps	Glycol concentration; pump head correction factor	10%; CF = 1.18	0%; CF = 1.00
All (Large Office, Medium Office, Large School, Hospital)	14, 16	CHW loop working fluid, CHW pumps	Glycol concentration; pump head correction factor	40%; CF = 1.56	38%; CF = 1.52
All (Large Office, Medium Office, Large School, Hospital)	2, 11, 13	CHW loop working fluid, CHW pumps	Glycol concentration; pump head correction factor	30%; CF = 1.41	30%; CF = 1.41 (no change)

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 Climate Zones 2, 11, and 13, where the standard and proposed glycol concentrations were identical, and applied the climate-zone-specific LSC hourly factors when calculating energy and LSC impact results.

Appendix B: Purpose and Necessity of Proposed Code Changes

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

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

Alignment with Boiler and Chiller Requirements

Purpose and Necessity of Changes to Title 24, Part 1

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

Purpose and Necessity of Changes to Title 24, Part 6

Section: Section 201

Purpose: The purpose of this change is to add a definition of water-to-water heat pumps similar to the definition of AWHPs, and to modify the definition so that split systems are included instead of only packaged units.

Necessity: The necessity for this change is to clarify which hydronic heat pumps are classified as WWHPs and therefore would be covered by the proposed code change.

Section: Section 401.3.13.2 [*Section 140.4(k)2*] and 401.3.13.3 [*Section 140.4(k)3*]

Purpose: The purpose of this change is to revise prescriptive language currently geared toward chillers and boilers to factor in AWHP/WWHP considerations by combining chillers and boilers under 401.3.13.2 [*Section 140.4(k)2*] as items 1 and 2, adding a separate requirement for hydronic heat pumps in 401.3.13.2.3 [*Section 140.4(k)2*], removing the term “isolation” and replacing the term “shut off” with “staged off” or “not operating” depending on context.

Necessity: The necessity for this change is to level the playing field for hydronic heat pumps by applying the same flow stage-off requirements that apply to chillers and boilers, with modifications that reflect the unique characteristics of hydronic heat pumps.

Section: Section 401.2.7.8 [*Section 120.5(a)8*]

Purpose: The purpose of this change is to require mandatory acceptance testing for control valves and pumps using the same procedures that apply to chillers and boilers.

Necessity: The necessity for this change is to create consistency in acceptance test requirements for all hydronic systems.

Purpose and Necessity of Changes to the Reference Appendices

There are no proposed changes to reference appendices.

AWHP Glycol Concentration Limits

Purpose and Necessity of Changes to Title 24, Part 1

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

Purpose and Necessity of Changes to Title 24, Part 6

Section: Section 400.5.7 [*Section 110.2*] and Table 400.5.7-N [*Table 110.2-M*]

Purpose: The purpose of this change is to add mandatory glycol concentration limits for AWHPs that protect against freezing while preventing excessive concentrations that would significantly reduce system efficiency.

Necessity: The necessity for this change is to ensure that all AWHPs use an appropriate amount of glycol to prevent freezing, which has higher viscosity and inferior thermal properties compared to water. Manufacturer guidance is often not specific enough to establish an optimal concentration for each application.

Purpose and Necessity of Changes to the Reference Appendices

There are no proposed changes to reference appendices.

Appendix C: Assumptions for Statewide Savings Estimates

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 54 presents the projected nonresidential new construction that the proposed code change would impact in 2029. Table 55 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. All nonresidential building types except Group R buildings would be affected, but only those with established prototypes were included in the statewide savings analysis.

The Statewide CASE Team estimated the percentage of newly constructed floor space that the proposed code change would impact. Table 56 shows the assumed percentage of affected 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 flow stage-off requirements with similar chiller and boiler requirements, it is assumed that 20 percent of new large and medium office buildings, hospitals, and schools, along with five percent of other new nonresidential buildings (excluding Group R Occupancy and building types with no prototype model) will include AWHPs or WWHPs, and 60 percent of those systems will be multi-unit staged systems based on discussions with HVAC designers and manufacturers. It is likely that existing buildings will have lower market penetration for hydronic heat pumps than new construction because of relatively high incremental costs during replacement compared to maintaining the existing HVAC system type. Therefore, the Statewide CASE Team assumed the adoption rate for new equipment in existing buildings will be about 60 percent of the adoption rate for new construction. It is also

assumed that 65 percent of AWHPs and WWHPs already comply with the proposed measure, as described earlier in this section when discussing current market-share rate.

Table 57 represents the assumed percentage of affected floorspace in existing buildings by climate zone. HVAC replacements were assumed to occur every 15 years based on expected useful life, which greatly reduces the savings per unit for alterations.

No exceptions are included based on climate zone. The cost-effectiveness analysis provided in Section 2.4.5 indicated that application in all climate zones would be cost-effective on average across building types, but the energy savings would vary depending on the weather conditions and the specific hydronic system design.

Table 54: 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	0.11	0.05	0.00	0.06	0.04	0.08	0.20	0.03	0.00	0.14	0.00	0.01	0.00	0.00	0.72
Medium Office	0.00	0.03	0.05	0.04	0.02	0.06	0.04	0.09	0.11	0.06	0.02	0.02	0.02	0.01	0.01	0.01	0.58
Small Office	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Large Retail	0.00	0.00	0.02	0.00	0.00	0.01	0.01	0.01	0.02	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.10
Medium Retail	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.02	0.02	0.00	0.02	0.01	0.00	0.00	0.00	0.14
Strip Mall	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Data Center	0.00	0.00	0.00	0.00	0.00	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	0.03	0.02	0.04	0.05	0.02	0.00	0.01	0.01	0.00	0.00	0.00	0.27
Small School	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.12
Non-refrigerated Warehouse	0.00	0.00	0.02	0.01	0.00	0.01	0.01	0.02	0.03	0.02	0.01	0.03	0.01	0.01	0.00	0.00	0.19
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	0.00	0.01	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	0.10
Hospital	0.00	0.01	0.04	0.02	0.00	0.02	0.02	0.02	0.04	0.03	0.01	0.04	0.01	0.01	0.00	0.00	0.28
Laboratory	0.00	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.06
Restaurant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.04
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

Building Type	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16	All
Vehicle Service	0.00	0.00	0.00	0.00	0.00	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	0.2	0.0	0.2	0.2	0.3	0.5	0.2	0.0	0.3	0.1	0.1	0.0	0.0	2.7

Table 55: 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	0.22	0.11	0.00	0.18	0.12	0.29	0.51	0.10	0.00	0.15	0.01	0.03	0.01	0.01	1.76
Medium Office	0.00	0.05	0.12	0.07	0.02	0.08	0.08	0.10	0.14	0.12	0.03	0.16	0.04	0.02	0.02	0.01	1.06
Small Office	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.02	0.01	0.00	0.00	0.00	0.09
Large Retail	0.00	0.00	0.03	0.01	0.00	0.01	0.01	0.02	0.03	0.02	0.01	0.03	0.01	0.01	0.00	0.00	0.20
Medium Retail	0.00	0.01	0.02	0.01	0.00	0.02	0.02	0.03	0.05	0.03	0.00	0.03	0.01	0.01	0.00	0.00	0.24
Strip Mall	0.00	0.00	0.02	0.01	0.00	0.02	0.01	0.03	0.04	0.03	0.01	0.02	0.01	0.01	0.00	0.00	0.20
Data Center	0.00	0.00	0.00	0.00	0.00	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	0.09	0.04	0.01	0.06	0.03	0.05	0.09	0.03	0.01	0.06	0.01	0.01	0.00	0.00	0.50
Small School	0.00	0.01	0.02	0.01	0.00	0.02	0.02	0.04	0.05	0.04	0.01	0.04	0.02	0.01	0.01	0.00	0.31
Non-refrigerated Warehouse	0.00	0.01	0.05	0.02	0.00	0.04	0.02	0.06	0.09	0.08	0.01	0.06	0.02	0.02	0.01	0.01	0.50
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	0.01	0.03	0.04	0.03	0.01	0.03	0.01	0.01	0.00	0.00	0.24
Hospital	0.00	0.02	0.09	0.04	0.01	0.05	0.05	0.07	0.12	0.07	0.02	0.09	0.04	0.02	0.01	0.01	0.71
Laboratory	0.00	0.00	0.02	0.02	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.08
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	0.08

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
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	0.7	0.4	0.1	0.5	0.4	0.7	1.2	0.6	0.1	0.7	0.2	0.1	0.1	0.0	6.0

Table 56: 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%	0.2%
Medium Office	4%	0.2%
Small Office	1%	0.0%
Large Retail	1%	0.0%
Medium Retail	1%	0.0%
Strip Mall	1%	0.0%
Mixed-Use Retail	0%	0.0%
Large School	4%	0.2%
Small School	1%	0.0%
Non-refrigerated Warehouse	1%	0.0%
Hotel	0%	0.0%
Assembly	1%	0.0%
Hospital	4%	0.2%
Laboratory	1%	0.0%
Restaurant	1%	0.0%
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 57: Percentage of Nonresidential Floorspace Impacted by Proposed Measure, by Climate Zone

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

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 58 presents the projected nonresidential new construction that the proposed code change will impact in 2029. Table 59 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. All nonresidential building types except Group R buildings were included in the statewide energy savings analysis.

The Statewide CASE Team estimated the percentage of newly constructed floor space that the proposed code change would impact. Table 60 shows the assumed percentage of affected floorspace by building type. If a proposed code change does not apply to a specific building type, the Statewide CASE Team assumes that zero percent of the floor space would be impacted. If the assumed percentage is non-zero, but less than 100 percent, the proposal is expected to affect some—but not all—buildings. For the proposed measure limiting glycol concentration for AWHPs, it is assumed that 20 percent of new medium and large office buildings, hospitals, and large schools, and 5 percent of other new nonresidential 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 because of higher incremental costs during replacement compared to maintaining the existing HVAC system type. The Statewide CASE Team assumes the adoption rate for AWHPs in existing buildings will be about 60 percent of the adoption rate for new construction. It is also assumed that 90 percent 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 61 represents the assumed percentage of affected floorspace by climate zone.

No exceptions are included based on climate zone. The cost-effectiveness analysis provided in Section 3.4.5 indicated that the measure would be 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 base case, resulting in no expected savings. But on the whole, there would be energy savings in all climate zones.

Table 58: 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	0.03	0.02	0.00	0.02	0.01	0.03	0.06	0.01	0.00	0.04	0.00	0.00	0.00	0.00	0.22
Medium Office	0.00	0.01	0.02	0.01	0.00	0.02	0.01	0.03	0.03	0.02	0.01	0.00	0.01	0.00	0.00	0.00	0.18
Small Office	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Large Retail	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Medium Retail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.04
Strip Mall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Data Center	0.00	0.00	0.00	0.00	0.00	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	0.01	0.01	0.00	0.01	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.08
Small School	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.04
Non-refrigerated Warehouse	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.06
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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Hospital	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.09
Laboratory	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Restaurant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
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	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.2	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.8

Table 59: 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	0.07	0.03	0.00	0.06	0.04	0.09	0.16	0.03	0.00	0.05	0.00	0.01	0.00	0.00	0.54
Medium Office	0.00	0.02	0.04	0.02	0.01	0.03	0.02	0.03	0.04	0.04	0.01	0.05	0.01	0.01	0.01	0.00	0.33
Small Office	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.03
Large Retail	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.06
Medium Retail	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.07
Strip Mall	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.06
Data Center	0.00	0.00	0.00	0.00	0.00	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	0.01	0.00	0.02	0.01	0.02	0.03	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.15
Small School	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.02	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.10
Non-refrigerated Warehouse	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.02	0.03	0.03	0.00	0.02	0.01	0.01	0.00	0.00	0.16
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	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.08
Hospital	0.00	0.01	0.03	0.01	0.00	0.02	0.02	0.02	0.04	0.02	0.01	0.03	0.01	0.00	0.00	0.00	0.22
Laboratory	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Restaurant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
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	0.0	0.2	0.1	0.0	0.2	0.1	0.2	0.4	0.2	0.0	0.2	0.1	0.0	0.0	0.0	1.8

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

Building Type	New Construction Impacted (Percent Square Footage)	Existing Building Stock (Alterations) Impacted (Percent Square Footage)
Large Office	1%	0.1%
Medium Office	1%	0.1%
Small Office	0%	0.0%
Large Retail	0%	0.0%
Medium Retail	0%	0.0%
Strip Mall	0%	0.0%
Mixed-Use Retail	0%	0.0%
Large School	1%	0.1%
Small School	0%	0.0%
Non-refrigerated Warehouse	0%	0.0%
Hotel	0%	0.0%
Assembly	0%	0.0%
Hospital	1%	0.1%
Laboratory	0%	0.0%
Restaurant	0%	0.0%
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 61: Percentage of Nonresidential Floorspace Impacted by Proposed Measure, by Climate Zone

Climate Zone	New Construction Impacted (Percent Square Footage)	Existing Building Stock (Alterations) Impacted (Percent Square Footage)
1	0.6%	0.0%
2	0.5%	0.0%
3	0.5%	0.0%
4	0.4%	0.0%
5	0.6%	0.0%
6	0.5%	0.0%
7	0.5%	0.0%
8	0.5%	0.0%
9	0.5%	0.0%
10	0.4%	0.0%
11	0.4%	0.0%
12	0.5%	0.0%
13	0.4%	0.0%
14	0.4%	0.0%
15	0.5%	0.0%
16	0.4%	0.0%

Appendix D: Environmental Analysis

Alignment with Boiler and Chiller Requirements

Potential Significant Environmental Effect of Proposal

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

Direct Environmental Impacts

Direct Environmental Benefits

Direct environmental benefits of the proposed measure include energy savings and GHG emission reductions. Details are provided in Sections 2.5.1 and 2.5.2.

Direct Adverse Environmental Impacts

No direct adverse environmental impacts are expected for the proposed measure.

Indirect Environmental Impacts

Indirect Environmental Benefits

There may be indirect environmental benefits associated with reduced electricity use, such as less reliance on natural gas generation and other inefficient means of producing electricity.

Indirect Adverse Environmental Impacts

The proposed measure is not expected to cause any adverse indirect environmental impacts. The flow stage-off measure may provide greater confidence in energy savings for hydronic heat pumps, leading to a somewhat higher market share in the medium term. However, any indirect GHG impacts of greater refrigerant use as market penetration of hydronic heat pumps increases would be offset by improved energy efficiency and avoidance of natural gas usage. In addition, the push toward electrification in California will likely lead to the same end point, where heat pumps replace most natural gas boilers in nonresidential buildings.

Mitigation Measures

The Statewide CASE Team has considered opportunities to minimize the environmental impact of the proposal, including an evaluation of “specific economic, environmental, legal, social, and technological factors” (Cal. Code Regs., tit. 14, § 15021). The

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

Reasonable Alternatives to Proposal

The Statewide CASE Team has considered alternatives to the proposal and determined that no alternative would achieve its purpose with less environmental effect, or a more positive environmental benefit. The following section presents the alternatives and the Statewide CASE Team’s justification for not proposing them.

- Alternative 1: Require flow to be shut off for all non-operating hydronic units even if single-unit systems.
 - This approach was strongly considered, but it would have required modifying the existing chiller and boiler requirements, and there may be compelling reasons why flow should not be completely shut off in AWHP systems, such as damage during system start-up and freeze protection. Savings would be significantly larger if pumps did not operate in smaller, single-unit hydronic systems, and this more expansive restriction on flow to non-operating units may be considered in a future code cycle.
- Alternative 2: Eliminate exceptions that allow reduced flow instead of zero flow.
 - This approach was considered, largely because the draft ASHRAE 90.1 proposal did not have exceptions. Some of the exceptions may be unnecessary because the heat pump is technically “operating” during defrost and start-up. But in the interest of clarity and designer flexibility as AWHPs become more common in complex nonresidential building applications, the Statewide CASE Team decided to keep the exceptions during certain time periods.

Water Use and Water Quality Impacts Methodology

There are no impacts to water quality or water use for the proposed measure.

AWHP Glycol Concentration Limits

Potential Significant Environmental Effect of Proposal

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

Direct Environmental Impacts

Direct Environmental Benefits

Direct environmental benefits of the proposed measure include energy savings, GHG emission reductions, and slightly less use of toxic ethylene glycol. Details are provided in Sections 3.5.1, 3.5.2, and 3.5.4.

Direct Adverse Environmental Impacts

No direct adverse environmental impacts are expected for the proposed measure except for a negligible increase in water use as a replacement for glycol. This increased water use would only occur when the system is filled or refilled.

Indirect Environmental Impacts

Indirect Environmental Benefits

There may be indirect environmental benefits associated with reduced electricity use, such as less reliance on natural gas generation and other inefficient means of producing electricity.

Indirect Adverse Environmental Impacts

The proposed measure is not expected to cause any adverse indirect environmental impacts. The limitation on glycol concentration may provide greater confidence in energy savings for AWHPs, leading to a somewhat higher market share in the medium term. But any indirect GHG impacts of greater refrigerant use as market penetration of hydronic heat pumps increases will be offset by improved energy efficiency and avoidance of natural gas usage. In addition, the push toward electrification in California will likely lead to the same end point, where heat pumps replace most natural gas boilers in nonresidential buildings.

Mitigation Measures

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

Reasonable Alternatives to Proposal

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

positive environmental benefit. The following section presents the alternatives and the Statewide CASE Team's justification for not proposing them.

- Alternative 1: Establish prescriptive-path glycol concentrations.
 - This approach was considered, but issues related to modeling of glycol effects on AWHP system efficiency prevent this approach from being effective at the present time. EnergyPlus, the simulation engine for CBECC, does not calculate the effects of viscosity on pump power and friction losses in the system. Savings would be significantly larger if less-conservative glycol concentrations were established in the prescriptive path and designers have the ability to trade-off glycol concentration with other efficiency measures. This approach may be considered in a future code cycle.
- Alternative 2: Eliminate exceptions to glycol limits.
 - An effort was made to minimize exceptions for this measure, but stakeholder inputs identified several scenarios where greater freeze protection is needed beyond the specified limits. In the interest of taking a first step toward addressing glycol as AWHPs become more common, and to avoid opposition to the measure from the AWHP industry, the Statewide CASE Team decided to include the exceptions.
- Alternative 3: No glycol allowed for split AWHPs.
 - This alternative was considered and discussed extensively with stakeholders. However, the limited use of split AWHPs and the freeze potential for systems with water exclusively inside the building envelope (coils serving ventilation, semi-conditioned spaces, power outages) led the Statewide CASE Team to abandon this approach.

Water Use and Water Quality Impacts Methodology

As previously discussed, there will be a very small increase in water use for the proposed measure because water will replace some of the glycol in many systems. No other impacts related to water use or water quality are expected.

Appendix E: Summary of Stakeholder Engagement

Introduction to Stakeholder Engagement

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

Stakeholder engagement for the Final 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, controls, and installation practices. Interview discussions focused on system performance considerations, design and installation practices, operational challenges, cost and constructability impacts, and potential implications for code compliance. A summary of the 19 stakeholders interviewed during the measure development process is provided in Table 62.

In addition to direct interviews, two stakeholder meetings and a stakeholder survey of industry experts were conducted.

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

Table 62: Stakeholders Interviewed for Final CASE Report

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
Robert Glass	Manufacturer/Regulatory Affairs	Daikin
Parth Patel	Manufacturer/Product Designer	LG Electronics
Edison Shen	Manufacturer/Regulatory Affairs	LG Electronics
Chris Bradt	Manufacturer/Regulatory Affairs	LG Electronics
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	West Monroe
Robert Benjamin	HVAC Designer/Manufacturer/Installer	Aris Hydronics
Hillary Weitze	SME/HVAC Designer	Red Car Analytics

Feedback from stakeholder interviews informed the Statewide CASE Team’s understanding of current industry practices and was used to identify areas where additional clarification, refinement, or justification was needed for the Final 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 two stakeholder meetings for the alignment with boiler and chiller requirements measure via webinar, as described in Table 63. Please see below for dates and links to event pages on [Title24Stakeholders.com](https://www.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 63: 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	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • Changes since first stakeholder meeting • Revised code language • Energy savings and cost analysis • Summary of stakeholder input 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 2028 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 2025c). The slides from the presentation are at the same website (Statewide CASE Team 2025a) (Statewide CASE Team 2025b).

The second round of utility-sponsored stakeholder meetings occurred in March 2026 and provided updated details on proposed code changes. These meetings introduced early results of energy, cost-effectiveness, and incremental-cost analyses, and solicited

feedback on refined draft code language. The summary of the second stakeholder meeting and the slides from the presentation are available on the Statewide CASE Team website (Statewide CASE Team 2026c) (Statewide CASE Team 2026a) (Statewide CASE Team 2026b).

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 64. For some organizations, several stakeholders participated in the conversation. These discussions led to numerous improvements to the measure as proposed during the first and second stakeholder meetings and provided valuable input for cost estimation, market penetration, compliance challenges, and other information that helped formulate measures with the greatest potential for stakeholder support.

Table 64: Engaged Stakeholders

Organization/Individual Name	Market Role	Mentioned in CASE Report Sections
Johnson Controls	Manufacturer/Installer	No
Trane Technologies	Manufacturer/Designer/Installer	No
Daikin	Manufacturer	No
LG Electronics	Manufacturer	No
EXP	HVAC Designer	No
Glumac	HVAC Designer	No
Taylor Engineers	HVAC Designer	No
West Monroe	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 were held, because no particular communities were identified as being potentially impacted. However, ESJ communities are invited to become engaged as noted in Section 2.3.3.

Surveys

The Statewide CASE Team developed a survey to help inform the proposed measures. Most of the survey questions focused on the glycol measure, but one important finding was that most AWHP systems are used for both heating and cooling (about 70 percent), but not for hot water. This is consistent with the baseline system used for modeling.

AWHP Glycol Concentration Limits

Utility-Sponsored Stakeholder Meetings

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

Stakeholder engagement for the Final 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, controls, and installation practices. Interview discussions focused on system performance considerations, design and installation practices, operational challenges, cost and constructability impacts, and potential implications for code compliance. A summary of the 19 stakeholders interviewed during the measure development process is provided in Table 65.

In addition to direct interviews, two stakeholder meetings and a stakeholder survey of industry experts were conducted.

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

Table 65: 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	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • Changes since first stakeholder meeting • Revised code language • Energy savings and cost analysis • Summary of stakeholder input 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 2028 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 2025c). The slides from the presentation are at the same website (Statewide CASE Team 2025b).

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feedback on refined draft code language. The summary of the second stakeholder meeting and the slides from the presentation are available on the Statewide CASE Team website (Statewide CASE Team 2026b).

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

The Title 24 Stakeholders listserv is an opt-in service comprising participants from diverse industries and trades, such as manufacturers, advocacy groups, local government, and building and energy professionals. Each meeting was announced on the Title 24 Stakeholders LinkedIn page and cross-promoted on the CEC LinkedIn page approximately two weeks in advance to engage individuals, organizations, and broader channels 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 66. For some organizations, several stakeholders participated in the conversation. These discussions led to numerous improvements to the measure as proposed during the stakeholder meetings, and provided valuable input for cost estimation, market penetration, compliance challenges, and other information that helped formulate measures with the greatest potential for stakeholder support.

Table 66: Engaged Stakeholders

Organization/Individual Name	Market Role	Mentioned in CASE Report Sections
Johnson Controls	Manufacturer/Installer	No
Trane Technologies	Manufacturer/Designer/Installer	No
Daikin	Manufacturer	No
LG Electronics	Manufacturer	No
EXP	HVAC Designer	No
Glumac	HVAC Designer	No
Taylor Engineers	HVAC Designer	No
West Monroe	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 were held, because no particular communities were identified as being potentially impacted. However, potential impacts to ESJ communities and an invitation to become engaged are detailed in Section 3.3.3.

Surveys

The Statewide CASE Team developed a survey to help inform the proposed measures. A summary of key survey results is provided below:

- Most AWHP systems are used for both heating and cooling (about 70 percent), but not hot water. This is consistent with the baseline system used for modeling. This value also provided a basis for reducing the statewide impacts based on the fraction of AWHPs used for heating only, which would be exempt from the proposed measure.
- The number of respondents relying on glycol for corrosion resistance is surprisingly high. This might increase impacts for designers who would need to switch to other corrosion inhibitors in locations where the glycol limit is zero or very low.
- The range of glycol concentration appears to be from 5 percent to 40 percent.
- Only six in ten respondents made use of manufacturer recommendations for glycol concentration. The rest appear to rely on their own analysis.
- A large fraction of respondents use tools for verification of glycol concentration after installation and over time. This provides some additional confidence that compliance rates will be high, or at least that compliance is readily achievable.

Appendix F: Code Language Markup (Not Restructured)

The language below is from the Draft CASE Report and in the non-restructured 2025 Title 24 Part 6 Code Language. The proposed changes to the standards, Reference Appendices, and the Alternative Calculation Method (ACM) Reference Manuals are provided below. Changes to the 2025 documents are marked with dark blue underlining (new language) and ~~strikethroughs~~ (deletions).

Alignment with Boiler and Chiller Requirements - Proposed Language Code

Administrative Code (Title 24, Part 1)

No changes.

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

AIR-TO-WATER HEAT PUMP (AWHP) is a factory-made ~~packaged~~ heat pump system containing one or more compressors and heat exchangers for transferring heat between refrigerant and air, as well as between refrigerant and water, 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.

WATER-TO-WATER HEAT PUMP (WWHP) is a factory-made 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, simplifying language for all hydronic system types 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 stage-off for non-operating units

A. Chillers isolation.

For Hotel/Motel buildings and Nonresidential buildings with Group R occupancies, the following requirements apply:

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 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.

For all other Nonresidential buildings, the following requirements apply:

When a chilled water system includes more than one chiller, provisions shall be made to automatically stage off, reduce, or otherwise minimize flow through any chiller evaporator, and *condenser* if applicable, that is off or staged off while maintaining flow through operating chiller(s). Chillers that are piped in series to increase temperature differential shall be considered one chiller. Minimum flow may be maintained where required by the manufacturer for safe and reliable operation, including:

- Start-up operations
- Post-purge heat recovery
- Defrost cycles
- Burst or freeze protection during cold weather or for heat recovery systems

140.4(k)3: B. Boilers isolation.

For Hotel/Motel buildings and Nonresidential buildings with Group R occupancies, the following requirements apply:

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 shut off while still maintaining flow through other operating *boiler(s)*.

For all other Nonresidential buildings, the following requirements apply:

When a hot water plant includes more than one *boiler*, provisions shall be made to automatically stage off, reduce, or otherwise minimize flow

through any boiler that is off or staged off while maintaining flow through operating boiler(s). Minimum flow may be maintained where required by the manufacturer for safe and reliable operation, including:

- Start-up operations
- Post-purge heat recovery
- Burst or freeze protection during cold weather or for heat recovery systems

C. Air-to-Water Heat Pump (AWHPs) and Water-to-Water Heat Pumps (WWHP): When a central plant includes more than one AWHP or WWHP, provisions shall be made to automatically stage off, reduce, or otherwise minimize water flow through the evaporator and/or condenser for any heat pump that is off or staged off while maintaining flow through operating heat pump(s). This requirement also applies to each module of modular heat pumps if the modules are intended to be staged. The control approach may use valves, pumps, or other control strategies, and shall be noted on mechanical drawings. Minimum flow may be maintained where required by the manufacturer for safe and reliable operation, including:

- Start-up operations
- Post-purge heat recovery
- Defrost cycles
- Burst or freeze protection during cold weather or for heat recovery systems

Hydronic heat pumps piped in series to increase temperature differential shall be considered one heat pump.

Exception to Section 140.4(k)2C: Hotel/Motel buildings and Nonresidential buildings with Group R occupancies.

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, air-to-water heat pump or water-to-water heat pump 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.

Reference Appendices

There are no proposed changes to the Reference Appendices.

AWHP Glycol Concentration Limits - Proposed Language Code

Administrative Code (Title 24, Part 1)

No changes.

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: For *air-to-water heat pumps*, volumetric glycol concentration shall be less than or equal to the values in Table 110.2-M as a function of the heating median of extremes for the location as specified in Appendix JA2. If necessary, a minimum flow rate may be used to prevent freezing during certain periods when pipes are exposed to outdoor temperatures, or for heat recovery systems where the potential for freezing exists. A note or sticker specifying the design concentration shall be prominently displayed on the *AWHP* system near the point where water/glycol mixture is refilled.

Exception 1 to Section 110.2(g): *AWHPs* that must deliver chilled water below 36°F.

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

Exception 3 to Section 110.2(g): *AWHPs* that only operate in heating mode, for which efficiency is not strongly affected by glycol concentration.

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

<u>Heating Median of Extremes (From JA2-4)</u>	<u>Allowable Range of Glycol Concentration by Volume</u>
<u>Above 37°F</u>	<u>0</u>
<u>25°F to 37°F</u>	<u>≤19%</u>
<u>15°F to 24°F</u>	<u>≤30%</u>
<u>5°F to 14°F</u>	<u>≤38%</u>
<u>-5°F to 4°F</u>	<u>≤44%</u>
<u>-15°F to -6°F</u>	<u>≤48%</u>
<u>Below -15°F</u>	<u>≤50%</u>

Reference Appendices

There are no proposed changes to the Reference Appendices. No acceptance testing is recommended, but installers must document that actual concentration is within the mandatory limits using NRCI-MCH-E.

Appendix G: Laboratory Testing of Glycol Performance Impacts

G.1 Introduction

Propylene glycol is a common hydronic system working-fluid additive used to prevent freezing and boiling, inhibit organic growth, and prevent ferrous-component corrosion. This enables lower supply-water temperatures in cooling and prevents pipe bursts in the winter if the system is not operating during a freeze.

Propylene glycol is the focus of this evaluation as its non-toxic properties make it the most used glycol in hydronic space conditioning systems.

However, increased glycol concentration results in reduced specific heat and increased viscosity. While many heat exchanger manufacturers provide thermal capacity data adjusted for the reduced specific heat, and pump manufacturers provide sizing methods adjusted for the increased viscosity, the increased viscosity also thickens the boundary layer between the free-flowing fluid and the wall of the heat exchanger and reduces flow turbulence, significantly diminishing heat transfer.

The laboratory study presented in this appendix measured the steady-state heat exchanger effectiveness through a flat plate heat exchanger, head loss, pumping energy, and energy efficiency of an air-to-water heat pump (AWHP) for multiple glycol concentration levels in cooling.

G.2 Background

Figure 9 and Figure 10 show the change in head loss, Reynolds number, film coefficient, specific heat, and thermal conductivity as glycol concentration of the working fluid increases for 50°F and 110°F water, respectively.

Fluid properties were calculated using a calculator provided by Dow Chemical for their propylene glycol products. Other properties, including head loss and Reynolds Number, were calculated using a hydronic system sizing and design calculator developed by Davis Energy Group for radiant systems, and modified by Frontier Energy for residential hydronics research at the Central Valley Research Homes.

Flow rate is increased with glycol concentration to compensate for the loss in specific heat. However, as can be seen by the drop in film coefficient and thermal conductivity, modest increases to flow rate in response to reduced specific heat are not sufficient to maintain the same rate of overall heat motility. In other words, the capacity of the fluid to store heat is one thing, the rate at which the fluid can take in or release that heat is another.

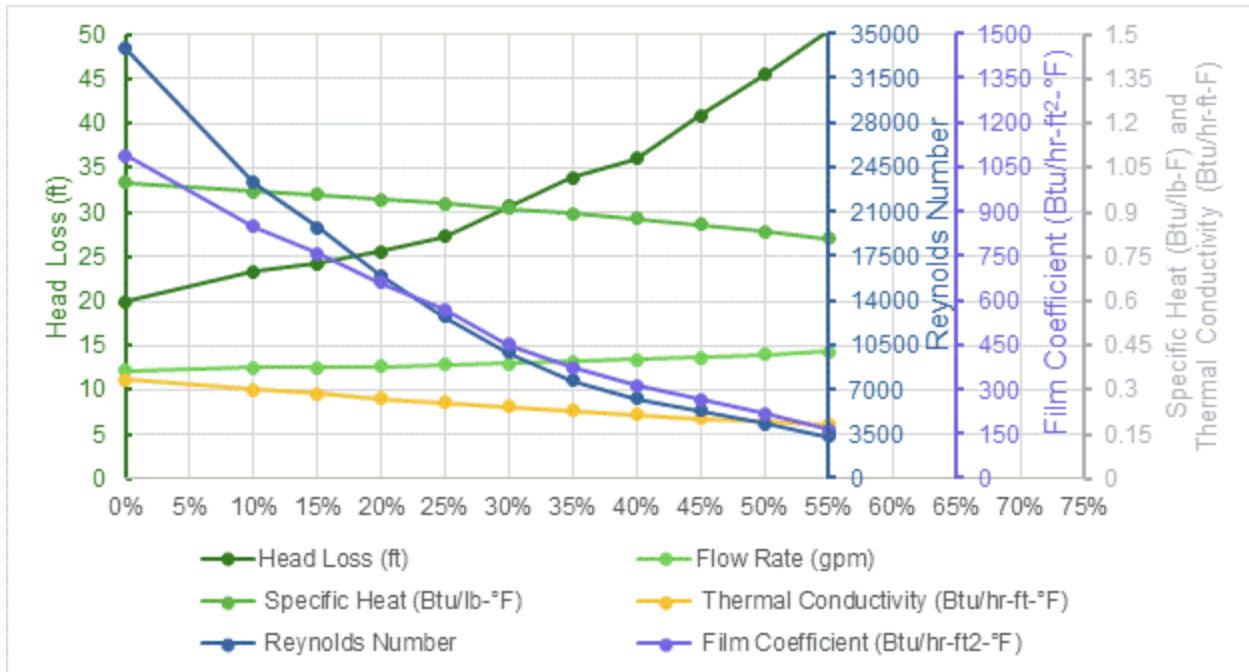


Figure 9: Change in working fluid properties as propylene glycol concentration increases for 100 linear feet of one-inch (nominal) tubing; flow increases with glycol concentration to compensate for heat capacity loss, beginning from pure water, at 12.2 GPM and 50°F.

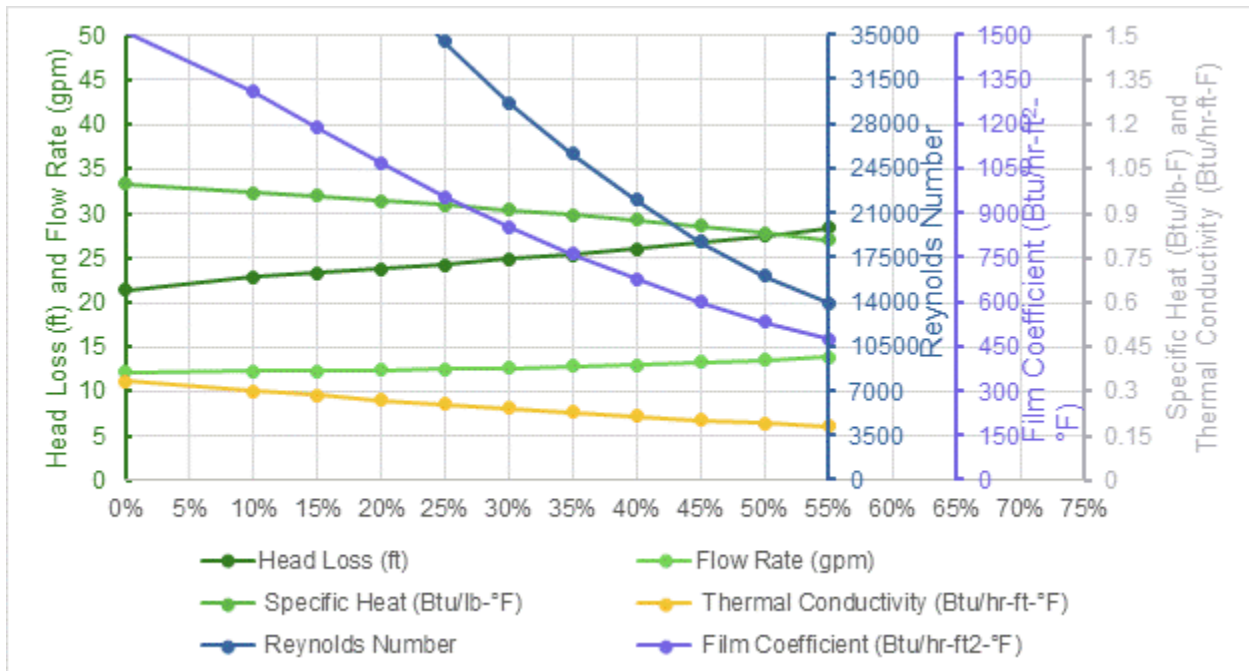


Figure 10: Change in working fluid properties as propylene glycol concentration increases for 100 linear feet of one-inch (nominal) tubing; flow increases with glycol concentration to compensate for heat capacity loss, beginning from pure water, at 12.2 GPM and 110 °F.

Also, as can be seen from Figure 9 and Figure 10, the impacts of increasing glycol concentration in heating and cooling are different. While the reductions in specific heat are similar, the increase in viscosity is slower and therefore the reduction in Reynolds number and film coefficient is also slower. This is why testing focused on impacts to cooling performance.

G.3 Test Plan

Tests were conducted at Frontier Energy’s Building Science Research Laboratory (BSRL) in Davis, CA.

G.3.1 Hydronic Test System

Tests were conducted using a closed-loop hydronic system with a supply loop and a load loop. This hydronic test system was comprised of the following components:

- Plate-type heat exchanger
- Variable-speed pumps
- In-line electrical resistance heater on the supply loop
- An AWHP (cooling tests) on the load loop.

The diagram of the hydronic system used in this lab test is shown in Figure 11 below.

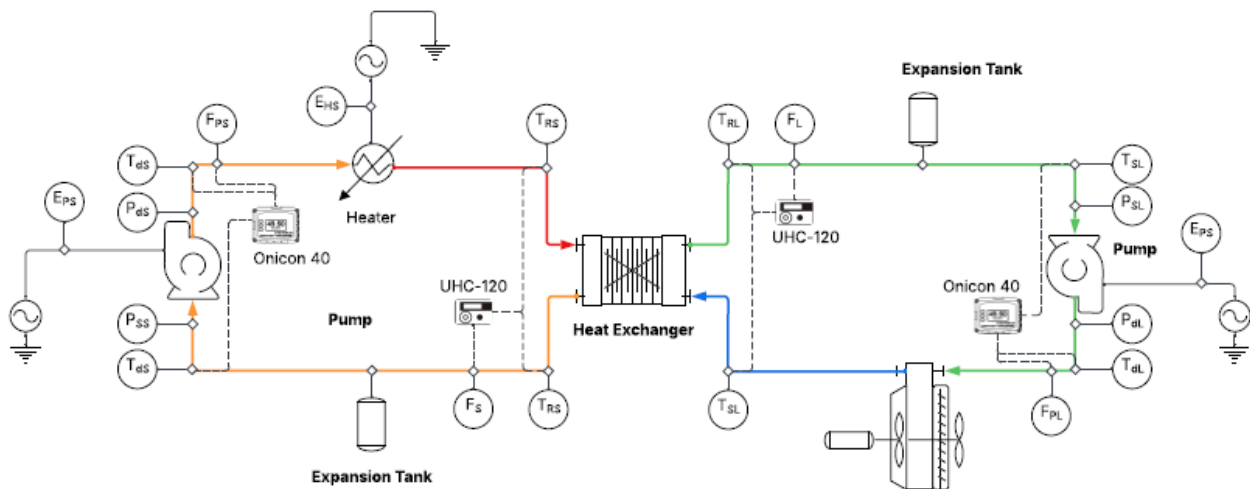


Figure 11: Diagram of the hydronic test system.

The hydronic loop on the left of the heat exchanger is referred to as the “source” loop, while the hydronic loop to the right of the heat exchanger is referred to as the “load” loop. The item on the bottom of the load loop (between the blue and green lines) represents the AWHP.

The AWHP used in the tests was a prototype residential unit using R-290 refrigerant. This AWHP has not been rated using AHRI 550/590, and the manufacturer had not conducted its own cooling-capacity tests because the system will be marketed

exclusively for heating markets. As such, no manufacturer or rating test lab data are available for comparison to the test results presented here.

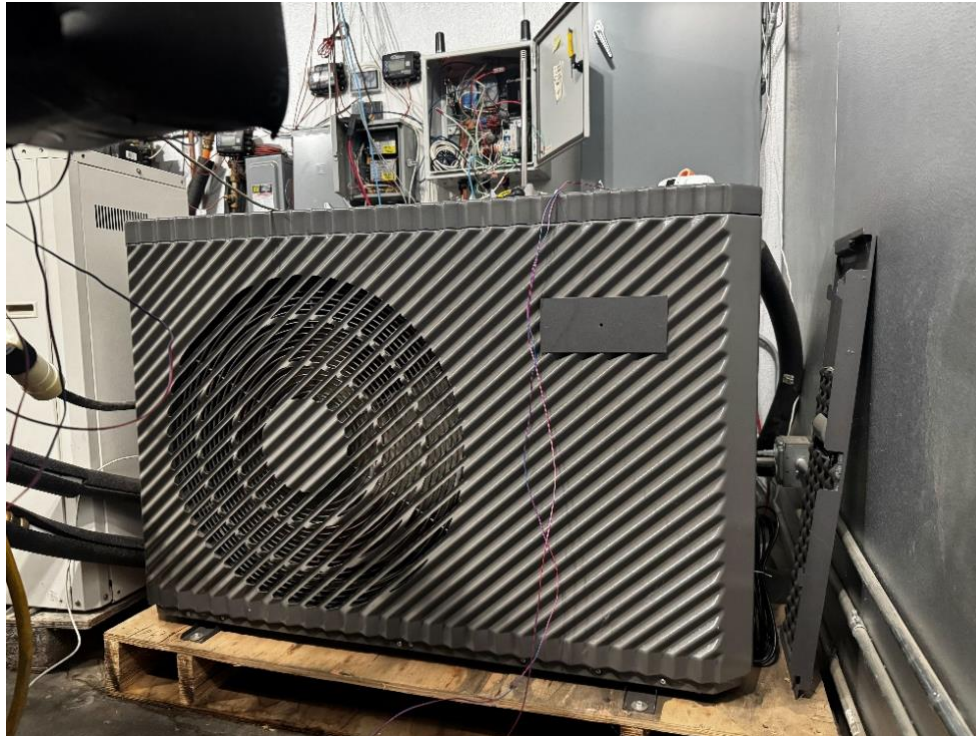


Figure 12: Prototype of residential R-290 AWHP.

G.3.2 Instrumentation

The hydronic test system is instrumented with the sensors listed below and illustrated in Figure 11 above. All thermocouple measurements were differentially calibrated to each other using an ice bath and boil.

Table 67: Instrumentation for Hydronic Test System

Measured Parameter	Abbreviation	Manufacturer/Model	Accuracy
Load loop head loss	ΔP_L	Omega PX409	$\pm 0.08\%$
Supply loop head loss	ΔP_S	Omega PX409	$\pm 0.08\%$
Electrical energy of load pump	E_{PS}	WattNode WR with OptC0.6 Accu-CTs	ANSI C12
Electrical energy of supply pump	E_{PL}	WattNode WR with OptC0.6 Accu-CTs	ANSI C12
Electrical energy of inline heater	E_{HS}	CCS WattNode with OptC0.6 Accu-CTs	ANSI C12
Load loop flow rate	F_L	Onicon System 40 ¹²	$\pm 1\%$
Supply loop flow rate	F_S	Onicon System 40	$\pm 1\%$
Fluid temperatures	(see "T"s in Figure 11)	Omega Type T SLE immersed thermocouples (1/8" steel probes)	0.9 °F

G.3.3 Controls

The system was controlled manually using variable voltage power supplies to control the pump speeds and in-line heater output. The AWHPs built-in controls were used to set a leaving water temperature target of 50°F. Ambient conditions in the test chamber were controlled to 70°F and 95°F.

G.3.4 Test Procedure

For each glycol concentration level:

1. System Prep:
 - Drain and flush the loop.
 - Fill with target glycol concentration.
 - Pressurize to 30 PSI.
 - Purge air from the system.
2. Steady State Operation:
 - Operate the system and record all sensor data at one second intervals.
 - Allow system to stabilize and hold steady state for a minimum of 20 minutes:
 - Maintain ambient temperature $\pm 2^\circ\text{F}$
 - Maintain inline heater input $\pm 0.1\text{ kW}$
 - Maintain supply loop flow rates at $5.5\text{ gpm} \pm 0.1\text{ gpm}$
 - Slope of all temperatures over 20 minutes is approximately 0.
3. Data Collection:

¹² Dynasonics UHC-120 ultrasonic flow meters and an Omega FTB-4605 flow meters (151.4 pulses per gallon) provided redundant flow measurements on each loop. The flows measured by the Onicon System 40 meters were ultimately used in setting pump speed and in the final analysis as these meters automatically compensate for temperature and glycol concentration.

- Record all sensor continuously data at one second intervals for at least 40 minutes.

G.4 Analysis

Sensor readings were averaged over the steady-state periods recorded for each test. Temperatures at the flow-rate measurement points were used with the Python library PyFluids to calculate the density and mass flow rates for each loop. This mass flow rate was used with each recorded temperature to calculate the enthalpy at each temperature sensor.

The difference in enthalpy from the inlet to the outlet of the heat exchanger on both sides of the heat exchanger was used to calculate the heat exchanger effectiveness according to the equation below.

$$HXE = \frac{h_{load,out} - h_{load,in}}{h_{source,in} - h_{load,in}}$$

Where:

HXE is the heat exchanger effectiveness, dimensionless.

$h_{load,out}$ is the enthalpy of the fluid at the outlet of the load side of the water to water heat exchanger, Btu/lbm.

$h_{load,in}$ is the enthalpy of the fluid at the inlet of the load side of the water to water heat exchanger, Btu/lbm.

$h_{source,in}$ is the enthalpy of the fluid at the inlet of the source side of the water to water heat exchanger, Btu/lbm.

The difference in enthalpy from the inlet to the outlet of the AWHP was used to calculate the capacity of the AWHP using the equation below.

$$q_{AWHP} = \dot{m}_{load}(h_{AWHP,in} - h_{AWHP,out}) \times \frac{60}{1000}$$

Where:

q_{AWHP} is the capacity of the AWHP, kBtu/hour.

\dot{m}_{load} is the mass flow rate in the load loop, lbm/min.

$h_{AWHP,in}$ is the enthalpy of the fluid at the inlet of the AWHP, Btu/lbm.

$h_{AWHP,out}$ is the enthalpy of the fluid at the outlet of the AWHP, Btu/lbm.

60 is the conversion from minutes to hours.

1000 is the conversion from Btu to kBtu.

This capacity in kBtu/hour was divided by the electrical power used by the AWHP in kW to obtain the AWHP EER.

$$EER = \frac{q_{AWHP}}{EP_{AWHP}}$$

Where:

EER is the energy efficiency ratio, kBtu/hour/kW.

q_{AWHP} is the capacity of the AWHP, kBtu/hour.

EP_{AWHP} is the electrical power draw of the AWHP, kW.

Pump efficacy (flow per unit energy consumed) was also calculated by dividing the flow rate in gallons per minute (gpm) by electrical power used, as shown below.

$$\epsilon_{pump} = \frac{\dot{V}_{pump}}{EP_{pump}}$$

Where:

ϵ_{pump} is the pump efficacy, gpm/W.

\dot{V}_{pump} is the volumetric flow rate produced by the pump, gpm.

EP_{pump} is the electrical power draw of the pump, W.

G.5 Results

The table below shows the tested cases included in the presented analysis.

Table 68: Test Cases Included in the Analysis

Case	Ambient Temp. (°F)	Inline Heater Output (kW)	Glycol Concentration (%)
1	95	4.5	0
2	95	4.5	5
3	95	4.5	15
4	95	4.5	30
5	95	4.5	50
6	70	5.4	0
7	70	5.4	5
8	70	5.4	15
9	70	5.4	30
10	70	5.4	50
11	70	4.5	0
12	70	4.5	5
13	70	4.5	30

The figures below plot the change in pump efficacy (Figure 13), heat exchanger effectiveness (Figure 14), and AWHP EER (Figure 15) as glycol concentration increases relative to pure water.

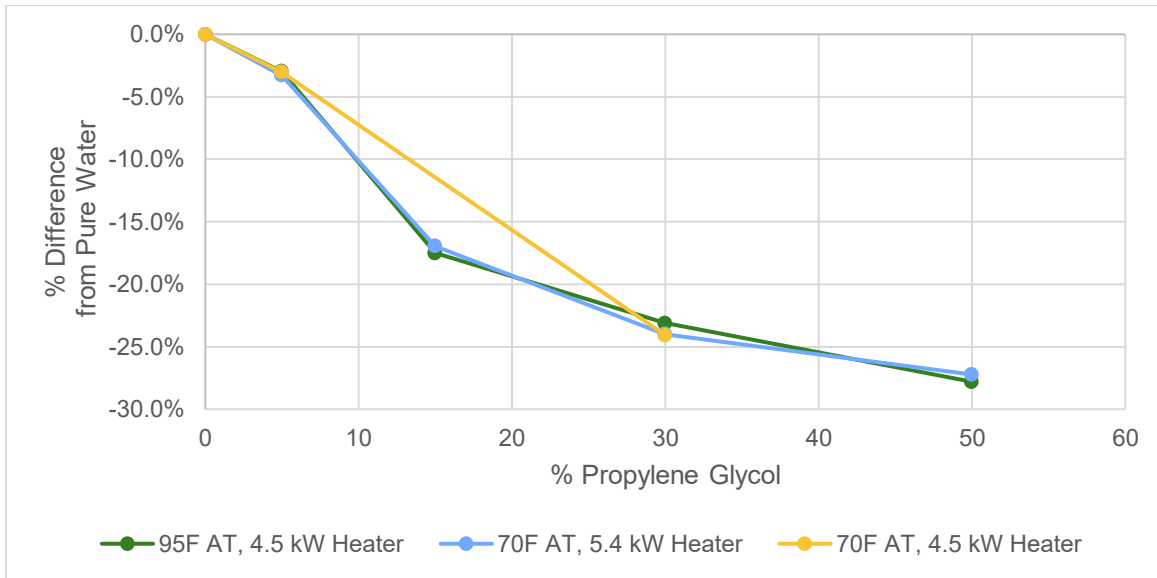


Figure 13: Pump efficacy percent difference from pure water.

As expected, Figure 13 shows significant decreases in pump efficacy as glycol concentration increases. Also as expected, this decrease is almost entirely dependent on the viscosity of the fluid, and there is no appreciable difference with ambient temperature and load. Nonetheless, it is worth noting that pump efficacy drops faster above a five percent glycol concentration, though the rate of decrease slows after 30 percent glycol concentration.

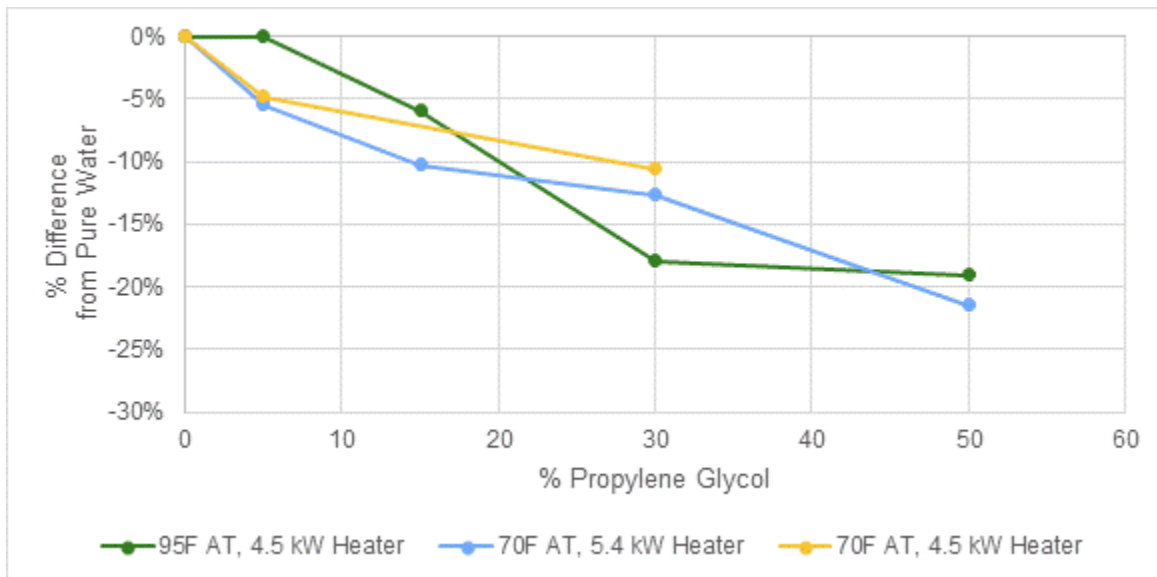


Figure 14: Heat exchanger effectiveness percent difference from pure water.

As seen in Figure 14, heat-exchanger effectiveness shows some dependence on ambient temperature and load—perhaps more on ambient temperature than load—based on a visual comparison, which will be discussed more in the next section.

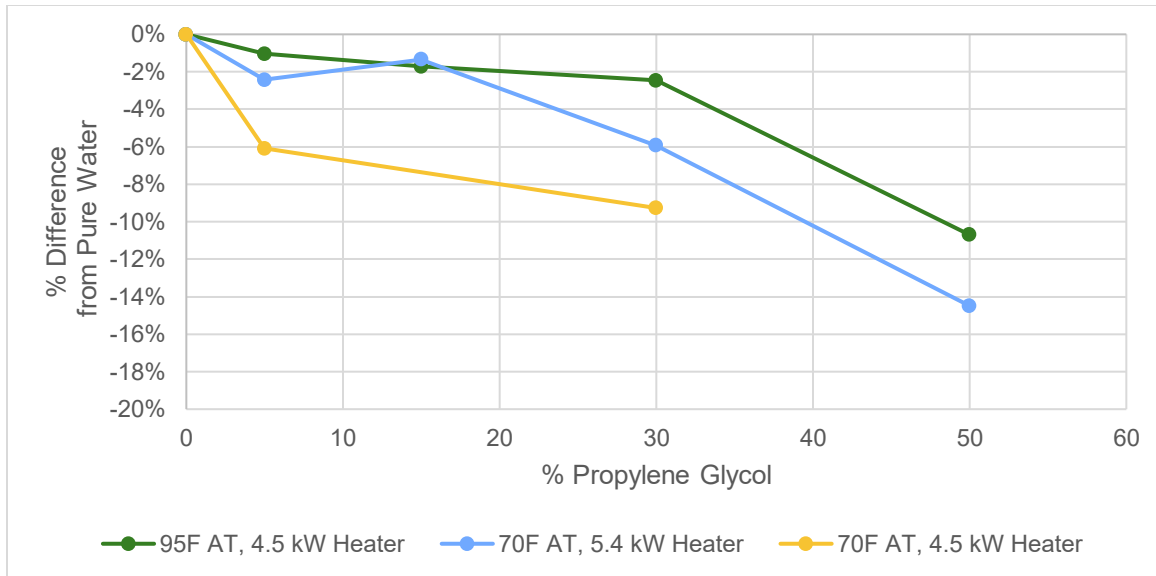


Figure 15: AWP EER percent difference from pure water.

The greatest difference between test conditions is seen in AWP EER shown in Figure 15. These differences are clearly both ambient temperature and load dependent.

G.6 Discussion

Additionally, the AWP’s internal pump could not be directly controlled. This meant that the variable capacity AWP would increase flow rate as well as compressor power to compensate for the reduced heat-exchanger effectiveness and attempt to maintain a constant temperature differential across its heat exchanger.

This makes interpreting results a challenge and results in the heat-exchanger effectiveness appearing to be ambient-temperature dependent. As the ambient temperature increases, the AWP must work harder to reject the same amount of heat. It does this by increasing compressor speed and by adjusting pump speed. Because pump speed could not be controlled for the test, this gives the appearance of an ambient-temperature dependence for the heat-exchanger effectiveness.

As previously mentioned, the AWP used in the tests had no cooling-capacity data, and in some instances tests failed because the load from the inline heater was greater than the cooling capacity of the AWP at those conditions. The maximum steady-state cooling capacity of the AWP therefore had to be determined experimentally for each ambient-temperature condition, which was 4.5 kW (~15.3 kBtu/hour) at 95°F and 5.4 kW (~18.4 kBtu/hour) at 70°F. Therefore, comparing the orange and green data points in the Figure 15 is essentially comparing AWP efficiency at maximum capacity at two different ambient temperatures.

It is clear from this testing that glycol significantly degrades AWHP efficiency relative to pure water, beyond impacts indicated by only the change in specific heat. If the AWHP were a single-capacity unit and the pump speed could be independently controlled to ensure the same flow rate with each glycol concentration, these results would likely show much more significant impacts to efficiency.

G.7 Recommendations

Additional testing is needed to fully understand the implications of glycol's impacts on AWHP performance. It is recommended that lab testing continue with a unit rated under AHRI 550/590. Testing should produce performance maps for multiple glycol concentrations that could be used to evaluate the impacts of glycol concentrations for future code proposals and manufacturer guidance, as well as enable accurate modeling of hydronic systems using glycol and AWHPs.