Codes and Standards Enhancement (CASE) Initiative

2025 California Energy Code

Nonresidential HVAC Space Heating

Category Name: Nonresidential HVAC
Bryan Boyce and Shaojie Wang, Energy Solutions
Jeff Stein and Hwakong Cheng, Taylor Engineers

May 2023
Draft CASE Report

This report was prepared by the California Statewide Codes and Standards Enhancement (CASE) Program that is funded, in part, by California utility customers under the auspices of the California Public Utilities Commission.

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; 2025 California Energy Code; 2025 Title 24, Part 6; California Energy Commission; energy efficiency; boiler; electric resistance heating; heat pump; heat recovery; hydronic heating; HVAC; thermal energy storage
Authors:	Bryan Boyce, Shaojie Wang (Energy Solutions); Jeff Stein, Hwakong Cheng (Taylor Engineers)
Prime Contractor	Energy Solutions
Project Management:	California Statewide Utility Codes and Standards Team: Pacific Gas and Electric Company, Southern California Edison, San Diego Gas & Electric Company, Sacramento Municipal Utility District, and Los Angeles Department of Water and Power.

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Executive Summary

This is a draft report. The Statewide CASE Team encourages readers to provide comments on the proposed code changes and the analyses presented in this draft report. When possible, provide supporting data and justifications in addition to comments. Suggested revisions will be considered when refining proposals and analyses. The Final CASE Report will be submitted to the California Energy Commission in summer 2023.

Email comments and suggestions to bboyce@energy-solution.com *and* info@title24stakeholders.com *by Monday, June 12, 2023. Comments will not be released for public review or will be anonymized if shared.*

Introduction

The Codes and Standards Enhancement (CASE) Initiative presents recommendations to support the California Energy Commission's (CEC's) efforts to update the California Energy Code (Title 24, Part 6) to include new requirements or to upgrade existing requirements for various technologies. Three California Investor-Owned Utilities (IOUs) — Pacific Gas and Electric Company, San Diego Gas and Electric, and Southern California Edison — and two Publicly Owned Utilities — Los Angeles Department of Water and Power, and Sacramento Municipal Utility District (herein referred to as the Statewide CASE Team when including the CASE Author) — sponsored this effort. The program goal is to prepare and submit proposals that would result in cost-effective enhancements to improve energy efficiency and energy performance in California buildings. This report and the code change proposals presented herein are a part of the effort to develop technical and cost-effectiveness information for proposed requirements on building energy-efficient design practices and technologies.

The Statewide CASE Team submits code change proposals to the CEC, the state agency that has authority to adopt revisions to Title 24, Part 6. The CEC will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The CEC may revise or reject proposals. See the CEC's 2025 Title 24 website for information about the rulemaking schedule and how to participate in the process: https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2025-building-energy-efficiency.

The Statewide CASE Team gathered input from stakeholders to inform the proposal and associated analyses and justifications. Stakeholders also provided input on the code compliance and enforcement process. Key stakeholders included mechanical designers, manufacturers, and distributors. Stakeholders were engaged to assess the viability of the proposed measures, determine information about analytical aspects including equipment and material costs. In addition, the utility custom program administrators were engaged to learn about trends with system designs.

See Appendix F for a summary of stakeholder engagement.

The goal of this CASE Report is to present a set of cost-effective code change proposals for measures related to nonresidential space heating. The report contains pertinent information supporting the code change.

Proposal Description

Limit Hot Water Supply Temperature

This measure would place a mandatory limit on design space heating hot water supply temperatures (HWST) of 130°F for new construction, additions, and alterations. The measure would apply to all nonresidential buildings that use hydronics to provide comfort space heating and reheat. This proposal would apply to systems that use gas boilers as well as all-electric designs. The savings from this measure are realized through lower pipe distribution network thermal losses throughout the building. A major driver for this measure is to provide “electric readiness,” since hydronic heat pumps are generally incapable of providing HWST equal to what gas boilers can provide. Even if a site were to continue to meet its space heating needs with gas boilers, were this measure to be added to Part 6, then presumably the future retrofit to heat pumps would be more cost effective.

Condenser Heat Recovery and Thermal Energy Storage

The measure is being pursued as a prescriptive addition to Section 140.4(r) and would apply to newly constructed large buildings pursuing all-electric space heating. The new prescriptive code language is needed to ensure that large buildings pursuing all-electric space heating do so efficiently, with the specific goal of ensuring that building waste heat is leveraged in a way to minimize the installed capacity of air source heat pump equipment. Large buildings would have challenges meeting their space heating needs solely with air source heat pumps due to space, cost, and efficiency barriers. The proposal includes requirements for thermal energy storage and/or heat recovery equipment depending on how well that cooling and heating loads overlap. For buildings with low overlapping loads, the thermal energy storage requirement is intended to store waste heat from when the building is in cooling mode so that it can be re-used later when the building is in heating mode.

Electric Resistance Heating

This measure proposes updates to prescriptive language limiting electric resistance for space heating at 140.4(g). The current ban on electric resistance heating is wide ranging and includes electric boilers, electric furnaces (except as backup for heat pumps) and electric resistance VAV reheat. There are currently six exceptions allowing various configurations that presumably do not consume much resistance electricity. The prescriptive ban on electric boilers and unitary furnaces would remain, but code would be updated to allow electric resistance heat for spaces with decoupled ventilation, assuming certain energy efficient conditions are met. The proposal includes some editorial cleanup to the remainder of the exceptions to 140.4(g).

For additions, Exception 2 to 141.0(a) would be deleted. This exception allowed electric resistance heat for a narrow range of conditions, and our intent is to broaden its applicability. We would preserve the requirements specified in the new exception to 140.4(g), which would ensure the existing building is efficient.

For alterations, Exception 6 to 141.0(b)2C would be added. This exception clarifies that the new exception allowing electric resistance heat can only be used if the envelope of the associated spaces meets the prescriptive envelope requirements for new construction in section 140.3.

Proposed Code Changes

This proposal would modify the following sections of the California Energy Code as shown below. See Section 5 of this report for marked-up code language.

SECTION 120.2 – REQUIRED CONTROLS FOR SPACE-CONDITIONING SYSTEMS

Section 120.2(l) – HVAC Hot Water Temperature: The purpose of this change is to limit the hot water supply temperature in buildings using hydronic space heating to 130°F or less.

SECTION 140.4 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

Section 140.4(g) – Electric resistance heating (new construction): The purpose of this change is to add a new exception that would allow electric resistance heating in spaces with very low space heating needs. This is accomplished by including a list of requirements intended to minimize heating loads (including requiring demand-controlled ventilation and occupied standby controls where possible, decoupling ventilation from space heating, and recovering heat from nearby computer rooms)

Section 140.4(r) – Condenser heat recovery: (new subsection) The purpose of this change is to require heat recovery in large nonresidential buildings. The recovered heat would be applied to the building’s space and/or domestic hot water needs. Buildings with misaligned cooling and heating loads would also be required to include thermal energy storage, which would enable the recovered heat to be used later.

SECTION 141.0 – ADDITIONS, ALTERATIONS, AND REPAIRS TO EXISTING NONRESIDENTIAL

Section 141.0(a) Electric resistance heating (additions): The purpose of this change is to delete exception 2 to 141.0(a), which would mean that requirements for additions would align with those proposed for new construction.

Justification

Hot Water Supply Temperature Limit

This measure is being pursued to ensure hydronic space heating "electric readiness." Historically, hydronic hot water systems were designed around a supply temperature of 180°F. As described below, this was needed to protect non-condensing boilers from experiencing condensation in the exhaust gas stream. Today, within hydronic space heating, the design trend has been toward lower supply hot water temperatures. This is because for condensing boilers, it is preferable to design around lower supply hot water temperatures to ensure the boiler operates in condensing mode. And second, lower supply temperatures facilitate all-electric hydronic designs. This is because most hydronic heat pump equipment is currently limited from producing supply hot water temperatures above roughly 140°F. The purpose of this measure will be to ensure that starting with the 2025 edition of Title 24 Part 6, the state does not continue adding hydronic space heating systems to the building stock designed around hot water supply temperatures that cannot be achieved by hydronic heat pump equipment.

In addition to the electric-readiness goal, there are energy efficiency reasons to pursue this proposal. As noted, for gas boiler systems using condensing equipment, lower supply and return temperatures are desirable since they ensure the boiler operates in condensing mode most of the time. At lower supply water temperatures, the heat lost through the distribution system will be reduced.

Even more than boilers, heat pump efficiency is very sensitive to hot water supply temperature. The same heat pump will be considerably more efficient when operated at 130°F compared to 140°F.

Lowering the hot water supply temperature (HWST) results in lower waterside delta T (dT) across the heating coils. For example, systems designed for 180°F HWST are typically designed for a 40°F dT across the hot water coils. Using the same hot water coils with a 130°F HWST reduces the dT to about 25°F. This means that flow rates and pipe sizes will increase as will pump sizes and to some extent, pump energy. As documented in this report, the energy savings of 130°F HWST are more than enough to compensate for the increased first cost.

Condenser Heat Recovery and Thermal Energy Storage

For small and medium size commercial buildings, a variety of existing heat pump-based solutions exist on the market. These options include unitary single zone ASHPs and variable refrigerant flow systems. However, large commercial buildings have been considered harder to electrify due to space and equipment capacity issues. The early emerging default all-electric hydronic system consists of an air-to-water heat pump bank supplying hot water sized to meet the building's peak heating load. Even if legacy design practices around space heating, including designing to ultra-hot water temperatures (e.g., 140°F or higher) and oversizing the system design capacity, as was commonly done with natural gas boilers, are overcome, the resulting system is still unattractive for several reasons. First, the space requirement for AWHPs is typically significant and may be hard to achieve in dense urban areas. Second, the efficiency of an AWHP delivering a HWST of 120°F is in the 2.0 to 2.5 COP range at a heating design temperature of 30°F (this would be even lower in climate zone 16 where design temperatures are generally lower than 20°F). Third, an AWHP system sized to meet heating demand is expensive.

Despite its drawbacks, AWHP systems serving hydronic reheat are being promoted as an all-electric option for large buildings. This measure seeks to improve upon the default AWHP system that is typically installed in large buildings when all-electric solutions are pursued. The Statewide CASE Team surveyed the literature and market of available designs and have concluded that the inclusion of concepts such as condenser water thermal energy storage and dedicated heat recovery chillers are critical components of an efficient and cost-effective all electric hydronic system design. Determining the specific requirements and triggers around heat recovery chiller sizing and when a TES tank should be specified was the focus of this measure.

Electric Resistance Heating

Recent research conducted by the University of California (UC) Berkeley Center for the Built Environment (CBE) has demonstrated a low rate of delivery of input boiler energy to useful heating at the occupied zone level. A study on an existing building put the fraction at 17 percent of input energy. It is likely the case that a newly constructed hydronic system with Title 24 compliant HVAC controls and a condensing boiler would perform better than an existing building with higher operating hours and a less efficient boiler. However, the alternative of electric resistance reheat is appealing as an alternative to installing a hydronic system altogether, if the heating loads are small enough.

Background Information

Limit Hot Water Supply Temperatures

Design supply hot water temperatures of 180°F were the norm in the era when atmospheric non-condensing boilers were the dominant equipment type used to provide hot water in buildings. High supply water temperatures were needed to ensure that return hot water temperatures were above the dew point of boiler exhaust gases, which is roughly at 135°F. If condensation occurred in non-condensing boilers, then damage could occur to the boiler system, so high supply and return water temperatures were needed to avoid this possibility. There was never a space conditioning need to have such high temperatures. Today, condensing boilers are much more commonly specified for sites still making use of natural gas boilers, and lower supply hot water temperatures will provide a substantial energy efficiency benefit since it will be all but guaranteed that the equipment will continuously operate in condensing mode when the supply hot water temperature is 130°F.

Condenser Heat Recovery and Thermal Energy Storage

Interest in all-electric HVAC systems for commercial new construction has been sharply growing in recent years. Evidence of this trend can be found in the adoption of all-electric reach codes by local jurisdictions. Based on localenergycodes.com, between 2019 and early 2023, jurisdictions representing roughly 11 million Californians, or 28 percent of the state population have enacted all-electric reach codes. Most of this activity is centered around the Bay Area (including San Francisco) and southern California (including Los Angeles), making this a statewide trend. In addition, indications from government agencies such as the California Air Resources Board (CARB) have made it clear that natural gas for space heating will end, though the exact target date for large commercial boilers has yet to be determined. The underlying message is clear: all-electric space heating systems are poised to become extremely popular in California in the coming years. Large buildings face unique challenges when pursuing all-electric space heating due to the need for significant space requirements of air to water heat pump (when serving hydronic heating) or other types of air source heat pumps if other systems are used. System configurations that include heat recovery and thermal energy storage can effectively shrink the capacity of air source equipment. This can save significant roof space and reduce upfront costs due to reduced ASHP equipment capacity needs. In addition, the plant efficiency (including chillers, heaters, heat rejection, and pumping) can increase by 20-40 percent relative to an all two-pipe AWHP and WCC system. The result is that Title 24 Part 6 has a unique opportunity to steer designers and installers toward the most efficient and cost-effective options available on the market, as the all-electric commercial building stock is starting to be constructed.

Electric Resistance Heating

Electric resistance heating has long been prescriptively banned in Section 140.4(g). However, recent research pointing to the inefficiencies in the hydronic system distribution network and a steady shift toward cleaner electricity have resulted in a need to revisit the tradeoff between hydronic and electric resistance (ER) heating. Electric boilers retain the least attractive characteristics of hydronic heating (i.e., expensive piping networks and distribution losses which reduce efficiency) and deserve to remain prescriptively banned, however, airside electric resistance heating at the zone level can be a compelling alternative to hydronic heating systems. The inherent drawback to any resistance heating is the fact that the efficiency is capped at a 1.0 COP, which is easily surpassed by heat pumps. However, as demonstrated by UC Berkeley CBE research, a gas boiler fired hydronic space heating system falls well short of its traditionally assumed efficiency level for several reasons. This includes the greater runtime hours of hydronic space heating systems than assumed, distribution system thermal losses when the building is economizing or in mechanical cooling mode, and poor gas boiler efficiency encountered in low part-load conditions. These factors are described in greater detail in Section 2.3.1.1 to support the Limit HWST energy savings but they are pertinent to this measure as well.

These significant downsides to hydronic systems present an opportunity to allow designers to bypass the need for a hydronic distribution system in favor of a zone-level ER heating system. The zone-level ER system option should only be pursued for sites with a relatively minimal heating load, otherwise the inefficient resistance heating (relative to heat pump hydronics) becomes too expensive to be justified. However, if heating loads can be sufficiently minimized, the lower upfront cost of the zone-level ER heating system design can be cost-effective. Adding an exception to 140.4(g) to allow zone-level ER heating with conditions to ensure low heating loads would provide a cost-effective all-electric space heating option for designers.

Scope of Code Change Proposal

Table 1, Table 2, and Table 3 summarize the scope of the proposed changes and which sections of standards, Reference Appendices, Alternative Calculation Manual (ACM) Reference Manuals, and compliance documents that would be modified as a result of the proposed changes.

Table 1: Scope of Code Change Proposal - Limit HWST

Proposal Name	Limit HWST
Type of Requirement	Mandatory
Applicable Climate Zones	All
Modified Section(s) of Title 24, Part 6	120.2(l) (new)
Modified Title 24, Part 6 Appendices	No
Would Compliance Software Be Modified	Yes; 5.8.1
Modified Compliance Document(s)	NRCC-MCH-01-E, 2022-NRCI-MCH-E

Table 2: Scope of Code Change Proposal - HR + TES

Proposal Name	HR + TES
Type of Requirement	Prescriptive, Performance (Compliance Option)
Applicable Climate Zones	All
Modified Section(s) of Title 24, Part 6	140.4(r) (new)
Modified Title 24, Part 6 Appendices	No
Would Compliance Software Be Modified	Yes; 5.8.8, and 5.8.9 (new section)
Modified Compliance Document(s)	NRCC-MCH-01-E, 2022-NRCI-MCH-E, NRCA-MCH-15-A

Table 3: Scope of Code Change Proposal – ER Heating

Proposal Name	ER Heating
Type of Requirement	Alternative to Prescriptive Requirements
Applicable Climate Zones	All
Modified Section(s) of Title 24, Part 6	140.4(g), 141.0(a)
Modified Title 24, Part 6 Appendices	No
Would Compliance Software Be Modified	No
Modified Compliance Document(s)	NRCC-MCH-01-E

Market Analysis and Regulatory Assessment

Limit Hot Water Supply Temperature

Our research indicates that as of 2023, the market generally specifies HWSTs at 140°F (with roughly 30 dT across the coil) for condensing boiler systems. Historically, design HWSTs were typically 180°F (with 40 dT) when non-condensing boilers were the default boiler type. The analysis contained in this report indicates that the same coils can meet space heating needs with a 130°F HWST and 25 dT if the associated distribution system is upsized to enable the higher flow rates needed at lower dTs. More information on the market can be found in Section 2.2.

Condenser Heat Recovery and Thermal Energy Storage

Hydronic heat recovery and thermal storage complementing space heating are proven measures to increase the efficiency of space heating systems in large buildings. As noted throughout this proposal, the shift from natural gas to electric space heating in nonresidential buildings will require a shift in design strategy. This is driven by the larger footprint that air source heat pumps demand relative to gas fired boilers as well as the greater cost per unit of heating capacity of ASHPs. The market penetration of thermal energy storage and heat recovery in nonresidential buildings is growing, spurred by requirements being put into place by local jurisdictions to require all-electric new construction in reach codes. A wide array of approaches to thermal energy storage are detailed in Section 3.2.

Electric Resistance Heating

Historically, electric resistance heating has been strongly discouraged in Title 24 Part 6 due to its inferior performance relative to hydronics. Recent research by the University of California (UC) Berkeley Center for the Built Environment (CBE) indicating poorer performance of hydronic systems in existing buildings than previously understood and the steady reduction in carbon intensity of the electric grid have caused the Statewide CASE Team to revisit the prescriptive ban on electric resistance heating in certain conditions. Were the electric resistance heating measure to be enacted, the Statewide CASE Team is confident that the market would be ready to leverage this new prescriptive compliance pathway. The proposed measure is much simpler and has lower up-front cost than a hydronic system. Zone-level electric resistance heating systems are currently allowed if the performance path were to be used, meaning that the design is already familiar to the market. More information on the market can be found in Section 4.2.

Cost Effectiveness

The proposed code changes were found to be cost effective for all climate zones where it is proposed to be required. For the limit HWST measure, the benefit-to-cost (B/C) ratio over the 30-year period of analysis ranged between 1.00 and 3.06 depending on climate zone. See more details in Section 2.4.5.[1] For the heat recovery and thermal energy storage measure, the benefit-to-cost (B/C) ratio over the 30-year period of analysis ranged between 8.25 and infinite (an infinite benefit-to-cost ratio is attained when the proposed design costs less than the baseline design and results in immediate payback) depending on climate zone and measure (i.e., heat recovery with or without thermal

[1] The benefit-to-cost (B/C) ratio compares the benefits or cost savings to the costs over the 30-year period of analysis. Proposed code changes that have a B/C ratio of 1.0 or greater are cost effective. The larger the B/C ratio, the faster the measure pays for itself from energy cost savings.

energy storage). See more details in Section 3.4.5. For the electric resistance heating measure, the benefit-to-cost (B/C) ratio over the 30-year period of analysis ranged between 0.94 and 4.14 depending on climate zone. See more details in Section 4.4.5.

California consumers and businesses would save more money on energy than they would spend to finance efficiency measures. As a result, over time this proposal would leave more money available for discretionary and investment purposes once the initial cost is paid off.

See Sections 2.4, 3.4, and 4.4 for the methodology, assumptions, and results of the cost-effectiveness analysis.

Statewide Energy Impacts: Energy, Water, and Greenhouse Gas (GHG) Emissions, and Embodied Carbon Impacts

Table 4, Note: Savings are only presented for large office and hospital. Additional prototypes (medium office, large school, hotel, high-rise mixed-use) will be added in April 2023 as additional analysis is completed.

Table 5, and Table 6 presents the estimated impacts of the proposed code change that would be realized statewide during the first 12 months that proposed requirements are in effect. The draft CASE Report does not include the large school (all measures) or hotel (the electric resistance heating measure only) prototypes, which when modeled for the final CASE Report will impact statewide energy and greenhouse gas savings.

First-year statewide energy impacts are represented by the following metrics: electricity savings in gigawatt-hours per year (GWh/yr), peak electrical demand reduction in megawatts (MW), natural gas savings in million therms per year (million Therms/yr), source energy savings in millions of kilo British thermal units per year (million kBtu/y), and lifecycle energy savings in millions of kilo British thermal units per year (million kBtu/y). See Sections 2.5,0, and 4.5 for more details on the first-year statewide impacts. Sections 2.3.2, 3.3.2, and 4.3.2 contain details on the per-unit energy savings.

Avoided GHG emissions are measured in metric tons of carbon dioxide equivalent (metric tons CO2e). Assumptions used in developing the GHG savings are provided in Sections 2.5.2, 3.5.2, and 4.5.2 and Appendix C of this report. The monetary value of avoided GHG emissions is included in the Long-term Systemwide Cost (LSC) hourly factors provided by CEC and is thus included in the cost-effectiveness analysis.

As the tables show, the measures are cost effective (except for climate zone 16 for the electric resistance heating measure for the large office prototype), and in many cases are well above a 1.0 B/C ratio. In fact, the analysis for the condenser heat recovery and thermal energy storage measure indicated a lower up-front cost and positive LSC energy savings, yielding an immediate payback. Per-unit energy savings are large for the condenser HR + TES measure as well, but since this proposal will not impact a large portion of statewide construction, the gross energy and greenhouse gas savings values are modest (we also assume no applicability of the HR +TES measure to alterations, which limits the construction impacts). The electric resistance heating measure includes negative electricity savings mainly stemming from the assumption that the system uses a natural gas boiler in the base case, so the impact of switching to electric heating results in negative electricity but positive natural gas savings. Shifting from an AWHP hydronic base case to the ER zone heating measure would result in negative electric savings as well, due to the reduction in system coefficient of performance. The electric resistance heating proposed case includes a much lower incremental measure cost, which offsets the increase in electric energy consumption. When compared against a gas baseline, the electric resistance heating measure shows positive source energy savings (a metric which compares changes to gas and electric energy consumption on an apples-to-apples basis). Furthermore, the electric resistance heating energy savings analysis is currently conservative and doesn't capture all elements of the measure case, such as the computer room heat recovery clause.

The condenser heat recovery and thermal energy storage measure is expected to result in water savings due to reduced cooling tower runtime for systems using condenser water thermal energy storage. First-year statewide water savings are presented in Table 97 of Section 3.5.3 along with the associated embedded electricity savings. The methodology used to calculate embedded electricity in water is presented in Appendix B.

In addition to the emissions reductions noted in Table 4, the Statewide CASE Team calculated impacts on GHG emissions for these measures associated with embodied carbon. The statewide CASE Team is in the process of quantifying the embodied carbon impacts of the electric resistance heating measure. This measure is meant to induce systems to forego a hydronic space heating system in favor of zone-level electric resistance heating. This shift would result in a significant reduction in material in the building, including hydronic distribution piping, water pumps, boilers or AWHPs, and refrigerant for heat pump equipment. See Section 4.5.4 for more details on the results and Appendix D for details on the methodology.

Table 4: Summary of Impacts for Limit Hot Water Supply Temperature

Category	Metric	New Construction & Additions	Alterations
Cost Effectiveness	Benefit-Cost Ratio Range (varies by climate zone and building type)	0.86–25.9	0.86–25.9
Statewide Impacts During First Year	Electricity Savings (GWh)	1.39	2.82
	Peak Electrical Demand Reduction (MW)	0.24	0.49
	Natural Gas Savings (Million Therms)	0.79	1.58
	Source Energy Savings (Million kBtu)	74.35	148.72
	Lifecycle Electricity Savings (Million kBtu)	8.56	17.30
	Lifecycle Gas Savings (Million kBtu)	44.33	88.57
	Total Lifecycle Energy Savings (Million kBtu)	52.90	105.87
	Avoided GHG Emissions (Metric Tons CO2e)	4,476.22	8,955.71
	Monetary Value of Avoided GHG Emissions ($2026)	551,234.91	1,102,873.86
	On-site Indoor Water Savings (Gallons)	N/A	N/A
	On-site Outdoor Water Savings (Gallons)	N/A	N/A
	Embedded Electricity in Water Savings (kWh)	N/A	N/A
Per square foot Impacts During First Year	Electricity Savings (kWh)	0.08	0.09
	Peak Electrical Demand Reduction (W)	0.01	0.01
	Natural Gas Savings (kBtu)	2.41	2.42
	Source Energy Savings (kBtu)	2.37	2.39
	LSC Energy Savings (kBtu)	1.88	1.89
	Avoided GHG Emissions (kg CO2e)	0.14	0.14
	On-site Indoor Water Savings (Gallons)	N/A	N/A
	On-site Outdoor Water Savings (Gallons)	N/A	N/A
	Embedded Electricity in Water Savings (kWh)	N/A	N/A

Note: Savings are only presented for large office and hospital. Additional prototypes (medium office, large school, hotel, high-rise mixed-use) will be added in April 2023 as additional analysis is completed.

Table 5: Summary of Impacts for Condenser Heat Recovery and Thermal Energy Storage

Category	Metric	New Construction & Additions	Alterations
Cost Effectiveness	Benefit-Cost Ratio Range (varies by climate zone and building type)	8.25 - infinite[a]	-
Statewide Impacts During First Year	Electricity Savings (GWh)	3.46	0
	Peak Electrical Demand Reduction (MW)	0.42	0
	Natural Gas Savings (Million Therms)	0.00	0
	Source Energy Savings (Million kBtu)	6.26	0
	Lifecycle Electricity Savings (Million kBtu)	19.24	0
	Lifecycle Gas Savings (Million kBtu)	0.00	0
	Total Lifecycle Energy Savings (Million kBtu)	19.24	0
	Avoided GHG Emissions (Metric Tons CO2e)	331.04	0
	Monetary Value of Avoided GHG Emissions ($2026)	40,766.37	0
	On-site Indoor Water Savings (Gallons)	N/A	N/A
	On-site Outdoor Water Savings (Gallons)	3,242,852.97	N/A
	Embedded Electricity in Water Savings (kWh)	10,636.56	N/A
Per square foot Impacts During First Year	Electricity Savings (kWh)	1.24	0
	Peak Electrical Demand Reduction (W)	0.17	0
	Natural Gas Savings (kBtu)	0.00	0
	Source Energy Savings (kBtu)	2.46	0
	Lifecycle Energy Savings (kBtu)	7.15	0
	Avoided GHG Emissions (kg CO2e)	0.13	0
	On-site Indoor Water Savings (Gallons)	0.00	0
	On-site Outdoor Water Savings (Gallons)	0.77	0
	Embedded Electricity in Water Savings (kWh)	0.00	0

a. For the measure with thermal energy storage, we're projecting lower up-front costs and positive LSC savings, giving that measure an immediate payback or infinite B/C ratio.

Note: Savings are only presented for large office and hospital. Additional prototypes (medium office, large school, hotel, high-rise mixed-use) will be added in April 2023 as additional analysis is completed.

Table 6: Summary of Impacts for Electric Resistance Heating

Category	Metric	New Construction & Additions	Alterations
Cost Effectiveness	Benefit-Cost Ratio Range (varies by climate zone and building type)	0.94–infinite	0.94–infinite
Statewide Impacts During First Year	Electricity Savings (GWh)	(1.79)	(12.91)
	Peak Electrical Demand Reduction (MW)	(0.43)	(3.05)
	Natural Gas Savings (Million Therms)	0.11	0.86
	Source Energy Savings (Million kBtu)	5.15	41.67
	Lifecycle Electricity Savings (Million kBtu)	(11.92)	(85.42)
	Lifecycle Gas Savings (Million kBtu)	6.52	50.38
	Total Lifecycle Energy Savings (Million kBtu)	(5.41)	(35.04)
	Avoided GHG Emissions (Metric Tons CO2e)	342.65	2,810.30
	Monetary Value of Avoided GHG Emissions ($2026)	42,195.95	346,082.01
	On-site Indoor Water Savings (Gallons)	0.00	
	On-site Outdoor Water Savings (Gallons)	0.00	
	Embedded Electricity in Water Savings (kWh)	0.00	0.00
Per square foot Impacts During First Year	Electricity Savings (kWh)	(0.97)	(0.62)
	Peak Electrical Demand Reduction (W)	(0.24)	(0.15)
	Natural Gas Savings (kBtu)	5.23	4.13
	Source Energy Savings (kBtu)	2.08	2.01
	Lifecycle Energy Savings (kBtu)	(3.45)	(1.69)
	Avoided GHG Emissions (kg CO2e)	0.14	0.14
	On-site Indoor Water Savings (Gallons)	N/A	N/A
	On-site Outdoor Water Savings (Gallons)	N/A	N/A
	Embedded Electricity in Water Savings (kWh)	N/A	N/A

Note: Savings are only presented for Large Office. Additional prototypes (medium office, large school, hospital, hotel, high-rise mixed-use) will be added in April 2023 as additional analysis is completed.

Compliance and Enforcement

Overview of Compliance Process

The compliance process is described in Sections 2.1.5, 3.1.5, and 4.1.5. Impacts that the proposed measure would have on market actors is also described in these sections and Appendix E. The Statewide CASE Team worked with stakeholders to develop a recommended compliance and enforcement process and to identify the impacts this process would have on various market actors.

The key issues related to compliance and enforcement are summarized below:

- Training designers to integrate thermal energy storage into space heating systems for large buildings.
- Enforcing the hot water supply temperature limit in existing buildings (for additions/alterations).
- Ensuring performance criteria for the new thermal energy storage and heat recovery are met in the field.
- Verifying all of the efficiency requirements identified in the proposed new exception to the prescriptive electric resistance heating ban.

We are proposing modifications to the mechanical compliance and installation forms (NRCC-MCH-01-E and NRCI-MCH-E, respectively) to capture the new requirements being proposed. These include new fields to capture the relevant parameters of the air-to-water heat pump, heat recovery chiller, and thermal energy storage equipment. We are also proposing new fields to track the design hot water supply temperature, and fields to ensure compliance with the list of clauses needed to qualify for the new proposed exception to the electric resistance heating ban.

Field Verification and Acceptance Testing

The only modification that we're proposing to the field verification and acceptance testing requirements is to modify the existing NA7.5.14 Thermal Energy Storage acceptance test so that it can verify performance of thermal energy storage equipment to complement space heating. Currently, the acceptance test is structured to verify TES performance to complement chillers or other space cooling equipment.

Addressing Energy Equity and Environmental Justice

The Statewide CASE Team recognizes, acknowledges, and accounts for a history of prejudice and inequality in disproportionately impacted populations (DIPs) and the role this history plays in the environmental justice issues that persist today. DIPs refers to the populations throughout California that most suffer from a combination of economic, health, and environmental burdens. These burdens include poverty, high unemployment, air and water pollution, presence of hazardous wastes, as well as high incidence of asthma and heart disease. DIPs also incorporate race, class, and gender since these intersecting identity factors affect how people frame issues, interpret, and experience the world.[2] While the term disadvantaged communities (DACs) is often used

[2] Environmental disparities have been shown to be associated with unequal harmful environmental exposure correlated with race or ethnicity, gender, and socioeconomic status. For example, chronic diseases, such as respiratory diseases, cardiovascular disease, and cancer, associated with environmental exposure have been shown to occur in higher rates in the LGBTQ+ population than in the cisgender, heterosexual population (Goldsmith L 2022). Socioeconomic inequities, climate, energy, and other inequities are inextricably linked and often mutually reinforcing.

in the energy industry and state agencies, the Statewide CASE Team chose to use terminology that is more acceptable to and less stigmatizing for those it seeks to describe (DC Fiscal Policy Institute 2017).

Including impacted communities in the decision-making process, ensuring that the benefits and burdens of the energy sector are evenly distributed, and grappling with the unjust legacies of the past all serve as critical steps to achieving energy equity. Code change proposals must be developed and adopted with intentional screening for unintended consequences, otherwise they risk perpetuating systemic injustices and oppression.

The Statewide CASE Team assessed the potential impacts of the proposed measure, and based on a preliminary review, the measure is unlikely to have significant impacts on energy equity or environmental justice, therefore reducing the impacts of disparities in DIPs. The Statewide CASE Team does not recommend further research or action at this time but is open to receiving feedback and data that may prove otherwise. These measures are primarily intended to impact large buildings, which are typically not thought to uniquely impact DIPs. Full details addressing energy equity and environmental justice can be found in Sections 2.6, 3.6, and 4.6 of this report.

1. Introduction

This is a draft report intended to allow for public review and comment before the Final Report is issued. The Statewide CASE Team encourages readers to provide comments on the proposed code changes and the analyses presented. When possible, include supporting data and justifications in addition to comments. The Statewide CASE Team will review all suggestions and consider them when revising and refining proposals and analyses. The Final CASE Report will be submitted to the California Energy Commission in summer 2023.

Email comments and suggestions to bboyce@energy-solution.com *and* info@title24stakeholders.com *by Monday June 12, 2023. Comments will not be released for public review or will be anonymized if shared.*

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support the California Energy Commission's (CEC's) efforts to update California's Energy Code (Title 24, Part 6) to include new requirements or to upgrade existing requirements for various technologies. The three California Investor-Owned Utilities (IOUs) — Pacific Gas and Electric Company, San Diego Gas and Electric, and Southern California Edison – and two Publicly Owned Utilities — Los Angeles Department of Water and Power and Sacramento Municipal Utility District (herein referred to as the Statewide CASE Team when including the CASE Author) — sponsored this effort. The program goal is to prepare and submit proposals that would result in cost-effective enhancements to improve energy efficiency and energy performance in California buildings. This report and the code change proposal presented herein are a part of the effort to develop technical and cost-effectiveness information for proposed requirements on building energy-efficient design practices and technologies.

The CEC is the state agency that has authority to adopt revisions to Title 24, Part 6. One of the ways the Statewide CASE Team participates in the CEC's code development process is by submitting code change proposals to the CEC for consideration. CEC will evaluate proposals the Statewide CASE Team and other stakeholders submit and may revise or reject proposals. See the CECs 2025 Title 24 website for information about the rulemaking schedule and how to participate in the process.

The goal of this CASE Report is to present a code change proposal regarding nonresidential space heating energy efficiency. The report contains pertinent information supporting the proposed code change.

When developing the code change proposal and associated technical information presented in this report, the Statewide CASE Team worked with industry stakeholders including manufacturers, distributors, contractors, builders, utility incentive program managers, Title 24 energy analysts, and others involved in the code compliance process. The proposal incorporates feedback received during public stakeholder workshops that the Statewide CASE Team held on February 27, 2023, and plans to hold on May 18, 2023.

The following is a summary of the contents of this report:

Section 2 – Hot Water Supply Temperature Limit

- Section 2.1 – Measure Description of this CASE Report provides a description of the measure and its background. This section also presents a detailed description of how this code change is accomplished in the various sections and documents that make up the Title 24, Part 6 Standards.
- Section 2.2 – Market Analysis includes a review of the current market structure. Section 2.2.2 describes the feasibility issues associated with the code change, including whether the proposed measure overlaps or conflicts with other portions of the building standards, such as fire, seismic, and other safety standards, and whether technical, compliance, or enforceability challenges exist.
- Section 2.3 – Energy Savings presents the per-unit energy, demand reduction, and energy cost savings associated with the proposed code change. This section also describes the methodology that the Statewide CASE Team used to estimate per-unit energy, demand reduction, and energy cost savings.
- Section 2.4 – Cost and Cost Effectiveness presents the lifecycle cost and cost-effectiveness analysis. This includes a discussion of the materials and labor required to implement the measure and a quantification of the incremental cost. It also includes estimates of incremental maintenance costs, i.e., equipment lifetime and various periodic costs associated with replacement and maintenance during the period of analysis.
- Section 2.5 – First-Year Statewide Impacts presents the statewide energy savings and environmental impacts of the proposed code change for the first year after the 2025 code takes effect. This includes the amount of energy that would be saved by California building owners and tenants and impacts (increases or reductions) on material with emphasis placed on any materials that are considered toxic. Statewide water consumption impacts are also reported in this section.
- Section 2.6 – Addressing Energy Equity and Environmental Justice presents the potential impacts of proposed code changes on disproportionately impacted populations (DIPs), as well as a summary of research and engagement methods.

Section 3 – Condenser Heat Recovery and Thermal Energy StorageHot Water Supply Temperature Limit

- Measure DescriptionSection 3.1 – Measure Description of this CASE Report provides a description of the measure and its background. This section also presents a detailed description of how this code change is accomplished in the various sections and documents that make up the Title 24, Part 6 Standards.
- Section 3.2 – Market Analysis includes a review of the current market structure. Section 3.2.2 describes the feasibility issues associated with the code change, including whether the proposed measure overlaps or conflicts with other portions of the building standards, such as fire, seismic, and other safety standards, and whether technical, compliance, or enforceability challenges exist.
- Section 3.3 – Energy Savings presents the per-unit energy, demand reduction, and energy cost savings associated with the proposed code change. This section also describes the methodology that the Statewide CASE Team used to estimate per-unit energy, demand reduction, and energy cost savings.
- Section 3.4 – Cost and Cost Effectiveness presents the lifecycle cost and cost-effectiveness analysis. This includes a discussion of the materials and labor required to implement the measure and a quantification of the incremental cost. It also includes estimates of incremental maintenance costs, i.e., equipment lifetime and various periodic costs associated with replacement and maintenance during the period of analysis.
- Section 3.5 – First-Year Statewide Impacts presents the statewide energy savings and environmental impacts of the proposed code change for the first year after the 2025 code takes effect. This includes the amount of energy that would be saved by California building owners and tenants and impacts (increases or reductions) on material with emphasis placed on any materials that are considered toxic. Statewide water consumption impacts are also reported in this section.
- Section 3.6 – Addressing Energy Equity and Environmental Justice presents the potential impacts of proposed code changes on disproportionately impacted populations (DIPs), as well as a summary of research and engagement methods.

Section 4 – Electric Resistance Heating

- Section 4.1 – Measure Description of this CASE Report provides a description of the measure and its background. This section also presents a detailed description of how this code change is accomplished in the various sections and documents that make up the Title 24, Part 6 Standards.
- Section 4.2 – Market Analysis includes a review of the current market structure. Section 4.2.2 describes the feasibility issues associated with the code change, including whether the proposed measure overlaps or conflicts with other portions

of the building standards, such as fire, seismic, and other safety standards, and whether technical, compliance, or enforceability challenges exist.

- Section 4.3 – Energy Savings presents the per-unit energy, demand reduction, and energy cost savings associated with the proposed code change. This section also describes the methodology that the Statewide CASE Team used to estimate per-unit energy, demand reduction, and energy cost savings.
- Section 4.4 – Cost and Cost Effectiveness presents the lifecycle cost and cost-effectiveness analysis. This includes a discussion of the materials and labor required to implement the measure and a quantification of the incremental cost. It also includes estimates of incremental maintenance costs, i.e., equipment lifetime and various periodic costs associated with replacement and maintenance during the period of analysis.
- Section 4.5 – First-Year Statewide Impacts presents the statewide energy savings and environmental impacts of the proposed code change for the first year after the 2025 code takes effect. This includes the amount of energy that would be saved by California building owners and tenants and impacts (increases or reductions) on material with emphasis placed on any materials that are considered toxic. Statewide water consumption impacts are also reported in this section.
- Section 4.6 – Addressing Energy Equity and Environmental Justice presents the potential impacts of proposed code changes on disproportionately impacted populations (DIPs), as well as a summary of research and engagement methods.

Section 5 – Proposed Revisions to Code Language concludes the report with specific recommendations with ~~strikeout~~ (deletions) and underlined (additions) language for the Standards, Reference Appendices, and Alternative Calculation Manual (ACM) Reference Manual. Generalized proposed revisions to sections are included for the Compliance Manual and compliance forms.

Section 6 – Bibliography presents the resources that the Statewide CASE Team used when developing this report.

Appendix A: Statewide Savings Methodology presents the methodology and assumptions used to calculate statewide energy impacts.

Appendix B: Embedded Electricity in Water Methodology presents the methodology and assumptions used to calculate the electricity embedded in water use (e.g., electricity used to draw, move, or treat water) and the energy savings resulting from reduced water use.

Appendix C: California Building Energy Code Compliance (CBECC) Software Specification presents relevant proposed changes to the compliance software.

Appendix D: Environmental Analysis presents the methodologies and assumptions used to calculate impacts on GHG emissions and water use and quality.

Appendix E: Discussion of Impacts of Compliance Process on Market Actors presents how the recommended compliance process could impact identified market actors.

Appendix F: Summary of Stakeholder Engagement documents the efforts made to engage and collaborate with market actors and experts.

Appendix G: Energy Cost Savings in Nominal Dollars presents energy cost savings over the period of analysis in nominal dollars.

Appendix H: TIER Compliance Modeling Procedure Memorandum provides an in-depth step-by-step procedure for modeling TIER plant energy consumption since this system has not yet been modeled in EnergyPlus.

Appendix I: Memo Discussing All-Electric Plant Options for a Large Office reproduces a narrative developed to assist with system selection for a building deciding which all-electric option to pursue.

The California IOUs offer free energy code training, tools, and resources for those who need to understand and meet the requirements of Title 24, Part 6. The program recognizes that building codes are one of the most effective pathways to achieve energy savings and GHG reductions from buildings – and that well-informed industry professionals and consumers are key to making codes effective. With that in mind, the California IOUs provide tools and resources to help both those who enforce the code, as well as those who must follow it. Visit EnergyCodeAce.com to learn more and to access content, including a glossary of terms.

2. Hot Water Supply Temperature Limit

2.1 Measure Description

2.1.1 Proposed Code Change

The purpose of this measure is to place a mandatory limit on design space heating hot water supply temperatures (HWST) of 130°F for new construction and additions and alterations. The measure would apply to all nonresidential buildings that use hydronics to provide comfort space heating and reheat. This proposal would apply to systems that use gas boilers as well as all-electric designs.

This proposal would necessitate a modification to the ACM Reference Manual since it is currently assumed that hydronic systems deliver 160°F water. The ACM Reference Manual would be adjusted to reflect the new requirement of 130°F supply hot water. The baseline design hot water return temperature would also be lowered from 120°F to 105°F.

This requirement is proposed to be included in section 120.2, "Required Controls for Space-conditioning Systems." See Section 5 of this report for marked-up code language.

2.1.2 Justification and Background Information

2.1.2.1 Justification

This measure is being pursued to ensure hydronic space heating "electric readiness." Historically, hydronic hot water systems were designed around a supply temperature of 180°F. As described below, this was needed to protect non-condensing boilers from experiencing condensation in the exhaust gas stream. Today, within hydronic space heating, the design trend has been toward lower supply hot water temperatures. This is because for condensing boilers, it is preferable to design around lower supply hot water temperatures to ensure the boiler operates in condensing mode. And second, lower supply temperatures facilitate all-electric hydronic designs. This is because most hydronic heat pump equipment is currently limited from producing supply hot water temperatures above roughly 140°F. The purpose of this measure will be to ensure that starting with the 2025 edition of Title 24 Part 6, the state does not continue adding hydronic space heating systems to the building stock designed around hot water supply temperatures that cannot be achieved by hydronic heat pump equipment.

In addition to the electric-readiness goal, there are energy efficiency reasons to pursue this proposal. As noted, for gas boiler systems using condensing equipment, lower supply and return temperatures are desirable since they ensure the boiler operates in condensing mode most of the time. At lower supply water temperatures, the heat lost through the distribution system will be reduced.

Even more than boilers, heat pump efficiency is very sensitive to hot water supply temperature. The same heat pump will be more efficient when operated at 130°F compared to 140°F.

Lowering the hot water supply temperature (HWST) results in lower waterside delta T across the heating coils. For example, systems designed for 180°F HWST are typically designed for a 40°F dT across the hot water coils. Using the same hot water coils with a 130°F HWST reduces the dT to about 25°F (see section 2.3.1.1 for a detailed discussion of the interplay between flowrate and temperature difference in a hydronic space heating system). This means that flow rates and pipe sizes will increase as will pump sizes and pump energy. As documented in this report, the energy savings of 130°F HWST are more than enough to compensate for the increased first cost.

2.1.2.2 Additions and Alterations

The HWST limit proposal applies to additions and alterations. The economics are different for additions/alterations versus new construction but are still compelling. There are several scenarios of additions/alterations that should be considered. One scenario is an addition/alteration that includes a new hot water (HW) plant and new zoning. In this case the system would be able to operate at the new HWST from Day 1 and the economics would be the same as new construction. Another scenario is an addition/alteration that includes new zoning to be served by an existing HW plant with non-condensing boilers that also serves existing-to-remain zones sized for 180 °F. This is a common scenario for high-rise office buildings when a new tenant moves into one floor. In this case, the piping to the new zones would need to be upsized to accommodate the lower HWST of 130 °F (no other cost impacts) but the plant would still need to operate at 180 °F until at least one boiler is replaced with a non-condensing boiler. With the upsized piping, the coils would not need to be upsized. Even then the plant might need to operate above 130°F some of the time to satisfy the existing zones. So therefore, there would be no energy savings at first. Most, but not necessarily all of the savings, would not occur until the boiler is replaced. Note that upsizing the piping is only about 20 percent of the total first cost for this measure, while upgrading from non-condensing to condensing boilers is about 75 percent of the total first cost. Therefore, in this case, most of the cost is not incurred until the boilers are replaced.

A parametric analysis of the gas baseline for medium and large offices in all climate zones was performed. In the analysis the incremental cost for larger piping is incurred in year 0 but the incremental cost for condensing boilers and larger pumps is not incurred until year 15 and the energy savings do not begin until year 15. The B/C ratio is still > 1.0 in all climate zones. Assuming the boiler is upgraded to condensing in year 15 is a conservative assumption. The typical lifespan for a boiler is 20-30 years. So, the average boiler is 10-15 years old and will be replaced in 10-15 years. Furthermore, many existing boilers are already condensing. One reason is because air quality management districts, (e.g., the Bay Area Air Quality Management District and South Coast Air Quality Management District), have promulgated regulations limiting boiler NOx and SOx emissions and the regulations are retroactive to existing buildings (e.g., BAAQMD Reg 9 Rule 6 and SCAQMD Rule 1146.2). Typically, only condensing boilers can meet the requirements. Thus, hundreds of existing boilers have been replaced with condensing boilers to comply with these regulations. In addition, prescriptive language added to Title 24 Part 6 section 140.4(k)8 in 2022 requiring condensing boilers for systems between 1 and 10 MMBtu/h in most California climate zones further increases the likelihood that existing gas boilers will be condensing by the time this measure takes effect in 2026.

2.1.2.3 Background Information

Design supply hot water temperatures of 180°F were the norm in the era when atmospheric non-condensing boilers were the dominant equipment type used to provide hot water in buildings. High supply water temperatures were needed to ensure that return hot water temperatures were above the dew point of boiler exhaust gases, which is roughly at 135°F. If condensation occurred in non-condensing boilers, then damage could occur to the boiler system, so high supply and return water temperatures were needed to avoid this possibility. There was never a space conditioning need to have such high temperatures. Today, condensing boilers are much more commonly specified for sites with natural gas boilers, and lower supply hot water temperatures will provide a substantial energy efficiency benefit since it will be all but guaranteed that the equipment will continuously operate in condensing mode when the supply hot water temperature is 130°F. Note that this measure would not pre-empt non-condensing boilers since the intention is to ensure the distribution network and space heating coils are optimized around “heat pump friendly” temperatures. Higher boiler temperatures would be allowed if there is a secondary distribution network designed to comply with the 130°F limit.

2.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manuals, and compliance forms would be modified by the proposed change.[3] See Section 5 of this report for detailed proposed revisions to code language.

[3] Visit EnergyCodeAce.com for training, tools, and resources to help people understand existing code requirements.

2.1.3.1 Specific Purpose and Necessity of Proposed Code Changes

Each proposed change to language in Title 24, Part 1 and Part 6 as well as the reference appendices to Part 6 are described below. See Section 5.2 of this report for marked-up code language.

Section: **120.2**

Specific Purpose: The specific purpose of the addition to 120.2 is to limit hot water supply temperatures for space heating hydronic systems to 130°F or lower.

Necessity: This addition is necessary to increase energy efficiency via cost-effective building design standards, as mandated by the California Public Resources Code, Sections 25213 and 25402.

2.1.3.2 Specific Purpose and Necessity of Changes to the Nonresidential ACM Reference Manual

The purpose and necessity of proposed changes to the Nonresidential ACM Reference Manual are described below. See Section 5.4 of this report for the detailed proposed revisions to the text of the ACM Reference Manual.

This measure would result in several changes to the ACM Reference Manual to ensure that the standard design reflects the mandatory code requirements being recommended by this measure. The changes would be focused on adjusting the hot water supply temperature and hot water temperature difference in the standard design under section 5.8.1

Section: **5.8.1**

Specific Purpose: The specific purpose is to modify the standard design to reflect the mandatory code changes being recommended in this measure. The changes would be to modify the "Hot Water Supply Temperature" from 160°F to 130°F, to modify the "Hot Water Temperature Difference" from 40°F to 25°F, and finally to modify the "Hot Water Supply Temperature Reset" from fixed at 160°F to 130°F in the standard design.

Necessity: These changes are necessary to ensure the standard design in the ACM Reference Manual accurately matches the new language being added to Title 24 Part 6.

2.1.3.3 Summary of Changes to the Nonresidential Compliance Manual

Chapter 4 of the Nonresidential Compliance Manual would need to be revised. We recommend focusing the updates on Section 4.6, "HVAC System Control Requirements." A discussion of how different types of boilers would be able to comply with the measure should be included. For example, specific considerations for non-condensing boilers, condensing boilers, and air-to-water heat pump systems should be described in the compliance manual. In addition, it will be critical to include a discussion of how retrofit situations would be able to comply.

2.1.3.4 Summary of Changes to Compliance Forms

The compliance forms would need to be updated to ensure that the HWST limit of 130°F is on the designs. A similar approach to how the current prescriptive return water temperature limit of 120°F (found at section 140.4(k)8B) is checked would be appropriate.

2.1.4 Regulatory Context

2.1.4.1 Determination of Inconsistency or Incompatibility with Existing State Laws and Regulations

There are no relevant state or local laws or regulations.

2.1.4.2 Duplication or Conflicts with Federal Laws and Regulations

There are no relevant state or local laws or regulations.

2.1.4.3 Difference From Existing Model Codes and Industry Standards

The Statewide CASE Team is aware of a parallel effort in IECC to also set a limit to HWSTs ("403.15 Hydronic Heating Design Requirements"). The limit being discussed in that standard is also 130°F. The intent of this proposal is to align with that effort.

2.1.5 Compliance and Enforcement

When developing this proposal, the Statewide CASE Team considered methods to streamline the compliance and enforcement process and how negative impacts on market actors that are involved in the process could be mitigated or reduced. This section describes how to comply with the proposed code change. It also describes the compliance verification process. Appendix E presents how the proposed changes could impact various market actors.

The compliance verification activities related to this measure that need to occur during each phase of the project are described below:

- **Design Phase:** Small, incremental changes anticipated to comply with HWST Limit.
- **Permit Application Phase:** No changes are anticipated because of this measure.
- **Construction Phase:** Equipment and hydronic distribution networks will be familiar to contractors.

- **Inspection Phase:** Inspection would be similar to the process currently in place to ensure HWRTs are below 120 °F, which is a requirement in 140.4(k)8B.

2.2 Market Analysis

2.2.1 Current Market Structure

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. It then considered how the proposed standard may impact the market in general as well as individual market actors. Information was gathered about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, CEC staff, and a wide range of industry actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during a public stakeholder meeting that the Statewide CASE Team held on February 27, 2023.

The market structure is consistent with how standard boiler systems are developed today. Based on a communication with a Bay Area boiler distributor in December 2022, 90 percent of boilers sales are condensing (i.e., 88 percent or greater thermal efficiency) in California. The typical HWST for condensing boilers is 140°F but there are no issues with operating them at the proposed HWST of 130°F. The remaining 10 percent of boilers that are still non-condensing are generally installed at 180°F.

The market actors involved in implementing this measure include:

- Building Owners
- Architects
- Mechanical Designers
- Electrical Designers
- Controls Designers
- Plumbing Designers
- Energy Consultants
- Builders
- Installers
- Plans Examiners
- Building Inspectors
- Manufacturers
- Commissioning Agents

2.2.2 Technical Feasibility and Market Availability

Designing new buildings with hydronic hot water supply temperatures of 130°F or less is technically feasible. The primary barrier to universal adoption of this design practice is the fact that historically, much higher HWSTs were the norm, and some segments of the industry have not yet evolved to use lower temperatures.

A design change from higher to lower HWSTs does not involve a large-scale redesign of the entire hydronic plant. Instead, some adjustments are needed to some aspects of the system to account for the reduced heat per unit volume of water being delivered to the zones. These adjustments may include wider pipe diameters, more powerful pumps due to the higher water flowrate at lower HWST, and deeper coils at the terminal units (though our analysis shows that deeper coils are not needed to comply with the proposed 130°F limit). Some or all of these aspects could be impacted by this proposal. It would be up to the designer to determine how the system is configured at the new design HWST. These changes are incremental relative to previous design practices. The necessary equipment and market actors would not change as a result of this measure, simply the capacity and size of the various aspects of the hydronic system would need to change. Please refer to section 2.3.1.1 for an in-depth discussion of the impacts that a lower HWST would have on the different aspects of the hydronic distribution system.

This measure ensures that California does not continue to add buildings using high HWSTs to the stock. The savings claimed by this measure are expected to persist over time, since the building infrastructure would be optimized around lower HWSTs and would not be easily revised upward. There are not expected to be any adverse occupant comfort impacts, since presumably the hot water distribution system would still be designed to furnish the necessary heat to satisfy the anticipated building loads.

2.2.3 Market Impacts and Economic Assessments

2.2.3.1 Impact on Builders

Builders of commercial structures are directly impacted by many of the measures proposed by the Statewide CASE Team for the 2025 code cycle. It is within the normal practices of these businesses to adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training to remain compliant with changes to design practices and building codes.

California's construction industry comprises approximately 93,000 business establishments and 943,000 employees (see Table 7). For 2022, total estimated payroll will be about $78 billion. Nearly 72,000 of these business establishments and 473,000 employees are engaged in the residential building sector, while another 17,600 establishments and 369,000 employees focus on the commercial sector. The remainder of establishments and employees work in industrial, utilities, infrastructure, and other heavy construction roles (the industrial sector).

Table 7: California Construction Industry, Establishments, Employment, and Payroll in 2022 (Estimated)

Building Type	Construction Sectors	Establish-ments	Employ-ment	Annual Payroll (Billions $)
Residential	**All**	**71,889**	**472,974**	**31.2**
Residential	Building Construction Contractors	27,948	130,580	9.8
Residential	Foundation, Structure, & Building Exterior	7,891	83,575	5.0
Residential	Building Equipment Contractors	18,108	125,559	8.5
Residential	Building Finishing Contractors	17,942	133,260	8.0
Commercial	**All**	**17,621**	**368,810**	**35.0**
Commercial	Building Construction Contractors	4,919	83,028	9.0
Commercial	Foundation, Structure, & Building Exterior	2,194	59,110	5.0
Commercial	Building Equipment Contractors	6,039	139,442	13.5
Commercial	Building Finishing Contractors	4,469	87,230	7.4
Industrial, Utilities, Infrastructure, & Other (Industrial+)	**All**	**4,206**	**101,002**	**11.4**
Industrial+	Building Construction	288	3,995	0.4
Industrial+	Utility System Construction	1,761	50,126	5.5
Industrial+	Land Subdivision	907	6,550	1.0
Industrial+	Highway, Street, and Bridge Construction	799	28,726	3.1
Industrial+	Other Heavy Construction	451	11,605	1.4

Source: (State of California Employment Development Department 2022)

The proposed change to limit hot water supply temperatures would likely affect commercial builders but would not impact firms that focus on construction and retrofit of industrial buildings, utility systems, public infrastructure, or other heavy construction. The effects on the commercial building industry would not be felt by all firms and workers, but rather would be concentrated in specific industry subsectors. Table 8 shows the commercial building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report. Electrical contractors and plumbing & HVAC contractors will be impacted very slightly by the different designs based on higher water flow rates and lower temperature differences (a.k.a. ΔT or dT) that will result from this measure. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 2.2.4 Economic Impacts.

Table 8: Specific Subsectors of the California Commercial Building Industry Impacted by Proposed Change to Code/Standard by Subsector in 2022 (Estimated)

Construction Subsector	Establishments	Employment	Annual Payroll (Billions $)
Nonresidential Electrical Contractors	3,137	74,277	7.0
Nonresidential plumbing & HVAC contractors	2,346	55,572	5.5

Source: (State of California Employment Development Department 2022)

2.2.3.2 Impact on Building Designers and Energy Consultants

Adjusting design practices to comply with changing building codes is within the normal practices of building designers. Building codes (including Title 24, Part 6) are typically updated on a three-year revision cycle and building designers and energy consultants engage in continuing education and training to remain compliant with changes to design practices and building codes.

Businesses that focus on residential, commercial, institutional, and industrial building design are contained within the Architectural Services sector (North American Industry Classification System, or NAICS,[4] 541310). Table 9 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The proposed code changes would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for hot water supply temperature limit to affect firms that focus on nonresidential construction.

There is not a NAICS code specific to energy consultants. Instead, businesses that focus on consulting related to building energy efficiency are contained in the Building Inspection Services sector (NAICS 541350), which is comprised of firms primarily engaged in the physical inspection of residential and nonresidential buildings.[5] It is not possible to determine which business establishments within the Building Inspection

[4] NAICS is the standard used by federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS was development jointly by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadistica y Geografia, to allow for a high level of comparability in business statistics among the North American countries. NAICS replaced the Standard Industrial Classification (SIC) system in 1997.

[5] Establishments in this sector include businesses primarily engaged in evaluating a building's structure and component systems and includes energy efficiency inspection services and home inspection services. This sector does not include establishments primarily engaged in providing inspections for pests, hazardous wastes or other environmental contaminates, nor does it include state and local government entities that focus on building or energy code compliance/enforcement of building codes and regulations.

Services sector are focused on energy efficiency consulting. The information shown in Table 9 provides an upper bound indication of the size of this sector in California.

Table 9: California Building Designer and Energy Consultant Sectors in 2022 (Estimated)

Sector	Establishments	Employment	Annual Payroll (Millions $)
Architectural Services [a]	4,134	31,478	3,623.3
Building Inspection Services [b]	1,035	3,567	280.7

Source: (State of California Employment Development Department 2022)

a. Architectural Services (NAICS 541310) comprises private-sector establishments primarily engaged in planning and designing residential, institutional, leisure, commercial, and industrial buildings and structures.

b. Building Inspection Services (NAICS 541350) comprises private-sector establishments primarily engaged in providing building (residential & nonresidential) inspection services encompassing all aspects of the building structure and component systems, including energy efficiency inspection services.

2.2.3.3 Impact on Occupational Safety and Health

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

2.2.3.4 Impact on Building Owners and Occupants

Commercial Buildings

The commercial building sector includes a wide array of building types, including offices, restaurants, lodging, retail, mixed-use establishments, and warehouses (including refrigerated) (Kenney M 2019). Energy use by occupants of commercial buildings also varies considerably, with electricity used primarily for lighting, space cooling and conditioning, and refrigeration, while natural gas is used primarily for water heating and space heating. According to information published in the 2019 California Energy Efficiency Action Plan, there is more than 7.5 billion square feet of commercial floor space in California consuming 19 percent of California's total annual energy use (Kenney M 2019). The diversity of building and business types within this sector creates a challenge for disseminating information on energy and water efficiency solutions, as does the variability in sophistication of building owners and the relationships between building owners and occupants.

Estimating Impacts

Building owners and occupants would benefit from lower energy bills. As discussed in Section 2.2.4.1, when building occupants save on energy bills, they tend to spend it elsewhere in the economy thereby creating jobs and economic growth for the California economy. The Statewide CASE Team does not expect the proposed code change for the 2025 code cycle to impact building owners or occupants adversely.

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

As noted above, this measure is expected to produce incremental changes to hot water system design elements in that sizing of pipes, fittings, pumps, and coils, but the systems as a whole will largely resemble higher temperature systems. Therefore, the Statewide CASE Team anticipates the proposed change would have no material impact on California component retailers.

2.2.3.6 Impact on Building Inspectors

Table 10 shows employment and payroll information for state and local government agencies in which many inspectors of residential and commercial buildings are employed. Building inspectors participate in continuing education and training to stay current on all aspects of building regulations, including energy efficiency. The Statewide CASE Team, therefore, anticipates the proposed change would have no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections.

Table 10: Employment in California State and Government Agencies with Building Inspectors in 2022 (Estimated)

Sector	Govt.	Establishments	Employment	Annual Payroll (Million $)
Administration of Housing Programs[a]	State	18	265	29.0
	Local	38	3,060	248.6
Urban and Rural Development Admin[b]	State	38	764	71.3
	Local	52	2,481	211.5

Source: (State of California Quarterly Census of Employment and Wages 2010)

a. Administration of Housing Programs (NAICS 925110) comprises government establishments primarily engaged in the administration and planning of housing programs, including building codes and standards, housing authorities, and housing programs, planning, and development.

b. Urban and Rural Development Administration (NAICS 925120) comprises government establishments primarily engaged in the administration and planning of the development of urban and rural areas. Included in this industry are government zoning boards and commissions.

2.2.3.7 Impact on Statewide Employment

As described in Sections 2.2.3.1 through 2.2.3.6, the Statewide CASE Team does not anticipate significant employment or financial impacts to any particular sector of the California economy. This is not to say that the proposed change would not have modest impacts on employment in California. In Section 2.2.4, the Statewide CASE Team estimated the proposed change in hot water supply temperatures would affect statewide employment and economic output directly and indirectly through its impact on builders, designers, and energy consultants, and building inspectors. In addition, the Statewide CASE Team estimated how energy savings associated with the proposed change in hot water supply temperatures would lead to modest ongoing financial savings for California businesses, which would then be available for other economic activities.

2.2.4 Economic Impacts

For the 2025 code cycle, the Statewide CASE Team used the IMPLAN model software[6], along with economic information from published sources, and professional judgement to develop estimates of the economic impacts associated with each of the proposed code changes. Conceptually, IMPLAN estimates jobs created as a function of incoming cash flow in different sectors of the economy, due to implementing a code or a standard. The jobs created are typically categorized into direct, indirect, and induced employment. For example, cash flow into a manufacturing plant captures direct employment (jobs created in the manufacturing plant), indirect employment (jobs created in the sectors that provide raw materials to the manufacturing plant) and induced employment (jobs created in the larger economy due to purchasing habits of people newly employed in the manufacturing plant). Eventually, IMPLAN computes the total number of jobs created due to a code. The assumptions of IMPLAN include constant returns to scale, fixed input structure, industry homogeneity, no supply constraints, fixed technology, and constant byproduct coefficients. The model is also static in nature and is a simplification of how jobs are created in the macro-economy.

The economic impacts developed for this report are only estimates and are based on limited and to some extent speculative information. The IMPLAN model provides a relatively simple representation of the California economy and, though the Statewide CASE Team is confident that the direction and approximate magnitude of the estimated economic impacts are reasonable, it is important to understand that the IMPLAN model is a simplification of extremely complex actions and interactions of individual, businesses, and other organizations as they respond to changes in energy efficiency codes. In all aspects of this economic analysis, the CASE Authors rely on conservative assumptions regarding the likely economic benefits associated with the proposed code

[6] IMPLAN employs economic data and advanced economic impact modeling to estimate economic impacts for interventions like changes to the California Title 24, Part 6 code. For more information on the IMPLAN modeling process, see www.IMPLAN.com.

change. By following this approach, the economic impacts presented below represent lower bound estimates of the actual benefits associated with this proposed code change.

Adoption of this code change proposal would result in relatively modest economic impacts through the additional direct spending by those in the commercial building industry, architects, energy consultants, and building inspectors, as shown in Table 11. The Statewide CASE Team does not anticipate that money saved by commercial building owners or other organizations affected by the proposed 2025 code cycle regulations would result in additional spending by those businesses.

Table 11: Estimated Impact that Adoption of the Proposed Measure would have on the California Commercial Construction Sector

Type of Economic Impact	Employ-ment (Jobs)	Labor Income (Million)	Total Value Added (Million)	Output (Million)
Direct Effects (Additional spending by Commercial Builders)	153.9	$11,954,319	$13,815,434	$23,530,561
Indirect Effect (Additional spending by firms supporting Commercial Builders)	37.6	$3,256,432	$5,109,944	$9,410,297
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	64.0	$4,367,720	$7,820,045	$12,446,563
Total Economic Impacts	**255.5**	**$19,578,472**	**$26,745,422**	**$45,387,421**

Source: CASE Team analysis of data from the IMPLAN modeling software. (IMPLAN Group LLC 2020)

2.2.4.1 Creation or Elimination of Jobs

The Statewide CASE Team does not anticipate that the measures proposed for the 2025 code cycle regulation 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, the estimates of economic impacts discussed in Section 2.2.4 would lead to modest changes in employment of existing jobs.

2.2.4.2 Creation or Elimination of Businesses in California

As stated in Section 2.2.4.1, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. The proposed change represents a modest change to hydronic system design practices, which would not excessively burden or competitively disadvantage California businesses – nor would it necessarily lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not foresee any new businesses being created, nor does the Statewide CASE Team think any existing businesses would be eliminated due to the proposed code changes.

2.2.4.3 Competitive Advantages or Disadvantages for Businesses in California

The proposed code changes would apply to all businesses incorporated in California, regardless of whether the business is located inside or outside of the state.[7] Therefore, the Statewide CASE Team does not anticipate that these measures proposed for the 2025 code cycle regulation would have an adverse effect on the competitiveness of California businesses. Likewise, the Statewide CASE Team does not anticipate businesses located outside of California would be advantaged or disadvantaged.

2.2.4.4 Increase or Decrease of Investments in the State of California

The Statewide CASE Team analyzed national data on corporate profits and capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI).[8] As Table 12 shows, between 2017 and 2021, NPDI as a percentage of corporate profits ranged from a low of 18 in 2020 due to the worldwide economic slowdowns associated with the COVID 19 pandemic to a high of 35 percent in 2019, with an average of 26 percent. While only an approximation of the proportion of business income used for net capital investment, the Statewide CASE Team believes it provides a reasonable estimate of the proportion of proprietor income that would be reinvested by business owners into expanding their capital stock.

Table 12: 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)
2017	518.473	1882.460	28
2018	636.846	1977.478	32
2019	690.865	1952.432	35
2020	343.620	1908.433	18
2021	506.331	2619.977	19
5-Year Average	***539.227***	***2068.156***	**26**

Source: (Federal Reserve Economic Data, FRED 2022)

[7] 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.

[8] 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.

The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed measure would lead to significant change (increase or decrease) in investment, directly or indirectly, in any affected sectors of California's economy. Nevertheless, the Statewide CASE Team can derive 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 proprietor income, which was used a conservative estimate of corporate profits, a portion of which was assumed to be allocated to net business investment.[9]

2.2.4.5 Incentives for Innovation in Products, Materials, or Processes

The HVAC industry is trending toward all-electric space heating designs. The purpose of this measure is to support this trend by further solidifying the notion that all hydronic systems will be installed with the maximum hot water supply temperature that can easily facilitate future air to water heat pump system retrofits. This measure is not expected to limit innovation in the nonresidential HVAC industry.

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

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

Cost of Enforcement

Cost to the State: State government already has budget for code development, education, and compliance enforcement. While state government will be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, these activities are already covered by existing state budgets. The costs to state government are small when compared to the overall costs savings and policy benefits associated with the code change proposals. To the extent that new state buildings are still being designed with gas boilers, this proposal would require that they be limited to 130°F HWSTs.

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 re-training 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

[9] 26 percent of proprietor income was assumed to be allocated to net business investment; see Table 12.

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 2.1.5 and Appendix E, 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.

2.2.4.7 Impacts on Specific Persons

While the objective of any of the Statewide CASE Team's proposal is to promote energy efficiency, the Statewide CASE Team recognizes that there is the potential that a proposed code change may result in unintended consequences. This code change proposal is not expected to impact specific persons. Refer to Section 2.6 for more details addressing energy equity and environmental justice.

2.2.5 Fiscal Impacts

2.2.5.1 Mandates on Local Agencies or School Districts

There are no relevant mandates to local agencies or school districts to our knowledge.

2.2.5.2 Costs to Local Agencies or School Districts

There are no costs to local agencies or school districts.

2.2.5.3 Costs or Savings to Any State Agency

There are no costs or savings to any state agencies.

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

There are no added non-discretionary costs or savings to local agencies.

2.2.5.5 Costs or Savings in Federal Funding to the State

There are no costs or savings to federal funding to the state.

2.3 Energy Savings

The Statewide CASE Team gathered stakeholder input to inform the energy savings analysis. Since CBECC does not model distribution system losses, a collaboration was formed with the UC Berkeley Center for the Built Environment (CBE) to utilize their analysis on hot water distribution losses. These values are critical inputs to help understand the costs and benefits of lower HWSTs. In addition, to develop incremental first costs, the Statewide CASE Team conducted market outreach to Bay Area distributors (for boiler costs) and contractors (for piping costs). See Appendix F for a summary of stakeholder engagement.

Energy savings benefits may have potential to disproportionately impact DIPs. Refer to Section 2.6 for more details addressing energy equity and environmental justice.

2.3.1 Energy Savings Methodology

2.3.1.1 Key Assumptions for Energy Savings Analysis

To model the energy savings for the 130°F HWST limit, the Statewide CASE Team used applicable prototypes provided by the Energy Commission, specifically, those that make use of hydronic heating. These include medium office, large office, large school, hotel, and hospital.

A significant portion of the energy savings come from reduced piping losses. Unfortunately, CBECC assumes adiabatic pipes and does not have a way to capture pipe losses. Therefore, a combination of CBECC modeling and spreadsheet post-processing was used.

CBECC was used to determine the total hourly heating load for each of the prototype models. Two baselines/proposed cases were then modeled outside of CBECC using Excel-based post-processing techniques. These cases, along with several key assumptions that impact energy performance, are summarized in Table 13.

Table 13: Summary of Assumptions Used in Limit HWST Analysis

Parameter	Gas Baseline	Gas Proposed	Elec Baseline	Elec Proposed
Equipment Type and Efficiency	Non-condensing, 85% TE[a]	Condensing, 94% TE	AWHP, 2.31 COP[b]	AWHP, 2.54 COP[b]
HWST (°F)	180	130	140	130
dT (°F)	40	25	30	25
VAV Box	Standard 2-row	Standard 2-row	Standard 2-row	Standard 2-row
Operating Hours Criteria	OAT<65 °F and building is occupied	OAT<65 °F and building is occupied	OAT<65 °F and building is occupied	OAT<65 °F and building is occupied

a. The decision to use a non-condensing boiler in the base case and a condensing boiler in the proposed case was intended to bound the analysis by choosing the lowest first cost option possible (e.g., smallest pipe, least expensive boiler, smallest pump), resulting in the largest incremental cost hurdle to be overcome. This does not imply that non-condensing boilers cannot comply with the proposal.

b. Air to water heat pump (AWHP) COPs taken from Title 24 Part 6 2022 Table 110.2-N. COP at 130 °F is the interpolated value between 120 and 140 °F.

Delta-T (dT) Data: The analysis is sensitive to the dT because this drives the pipe sizing and piping costs. Lowering the HWST results in a lower dT (which has the consequence of higher water flow rates and thus, larger pipes). The relationship between HWST and dT depends on the coil selection. Figure 1 shows typical VAV box coil performance data derived from a major VAV box manufacturer's coil selection software. It shows performance for a standard 2 row coil (which is by far the most commonly selected VAV box coil) and an oversized (OS) 2 row coil. This figure shows that at 130°F HWST the standard coil has a dT of about 30°F and the oversized coil has a dT of about 35°F. The coil dT is sensitive to the design entering air temperature (EAT), i.e., the temperature entering the coil at the peak heating condition. Figure 1 assumes a 55°F EAT which is a typical EAT when the building is occupied and minimum ventilation (cold outside air) is required. The Statewide CASE Team's assumption is that that the peak heating condition is during morning warmup, before occupancy, when no outside air is required. **Error! Reference source not found.** shows similar VAV box reheat coil performance at 65°F, which is more typical for morning warmup. This figure gives the more conservative result of 25°F dT for a standard coil at 130°F HWST. This more conservative assumption is used in our analysis.

While standard 2-row coils are by far the most common, some engineers use oversized and/or high-capacity coils (12 fins/inch versus 10 fins/inch for standard) to increase the dT. For simplicity, this analysis assumes standard 2-row coils in the base case and proposed case. The Statewide CASE Team also could have analyzed oversized and/or high-capacity coils in the proposed case to increase dT (and reduce incremental piping costs) but then it would have been necessary to include the incremental coil costs. Note that Figure 1 and Figure 2 both show that a standard coil can accommodate higher than a 40°F dT at 180°F. However, a design dT of 40°F (or lower) is industry standard practice for 180°F HWST and is therefore used in Baseline 1.

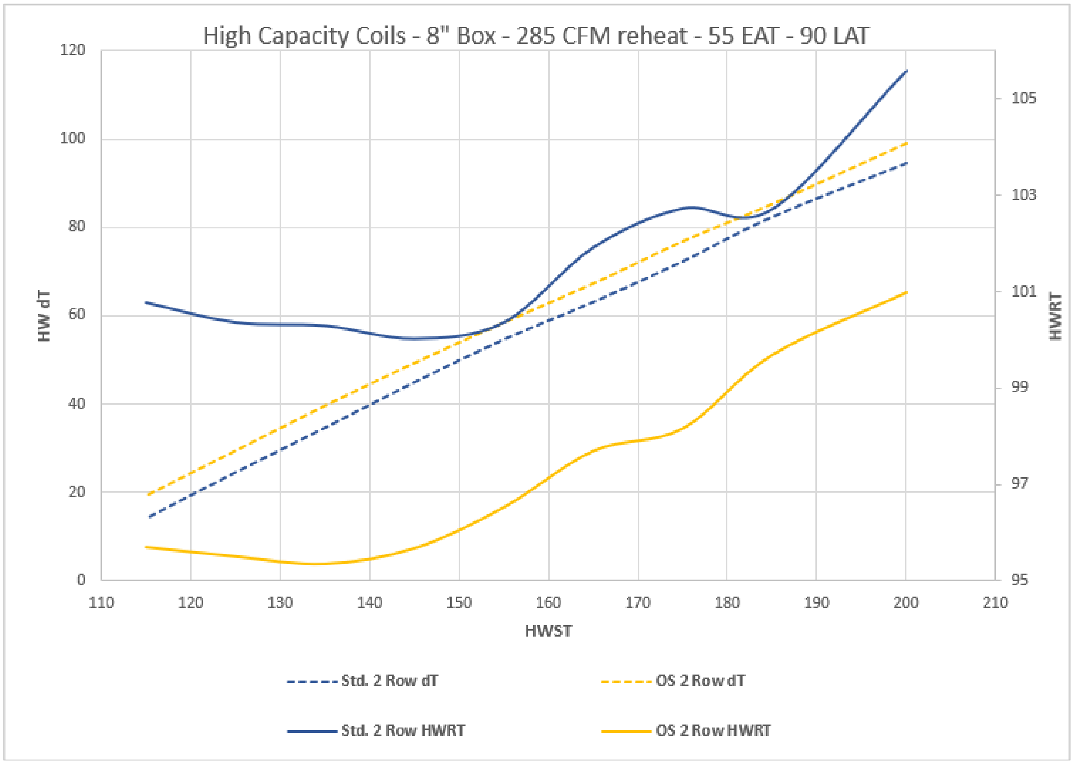


Figure 1: Typical VAV Box Coil Selections (55 EAT)

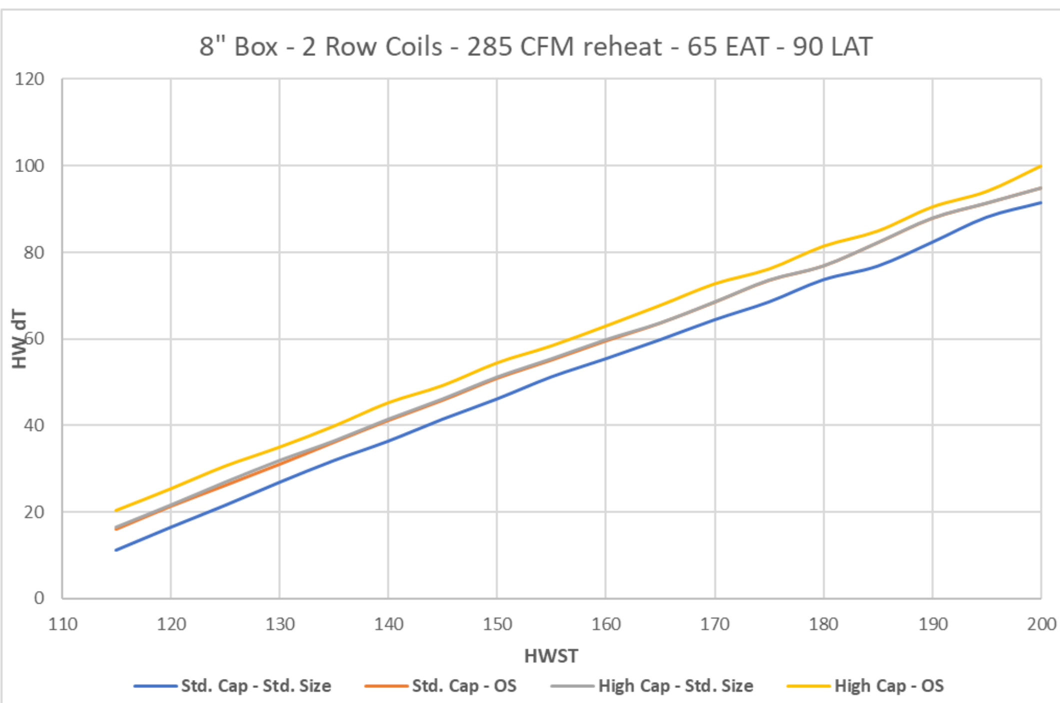


Figure 2: Typical VAV Box Coil Selections (65 EAT)

Piping Loss Data: The UC Berkeley Center for the Built Environment is wrapping up a major study on heating hot water system efficiency (Raftery 2018). That soon to be published study, collected measured piping loss data from several buildings (Figure Figure 3). This data was used to develop a regression of typical piping losses as a function of HWST from 130°F to 180°F.

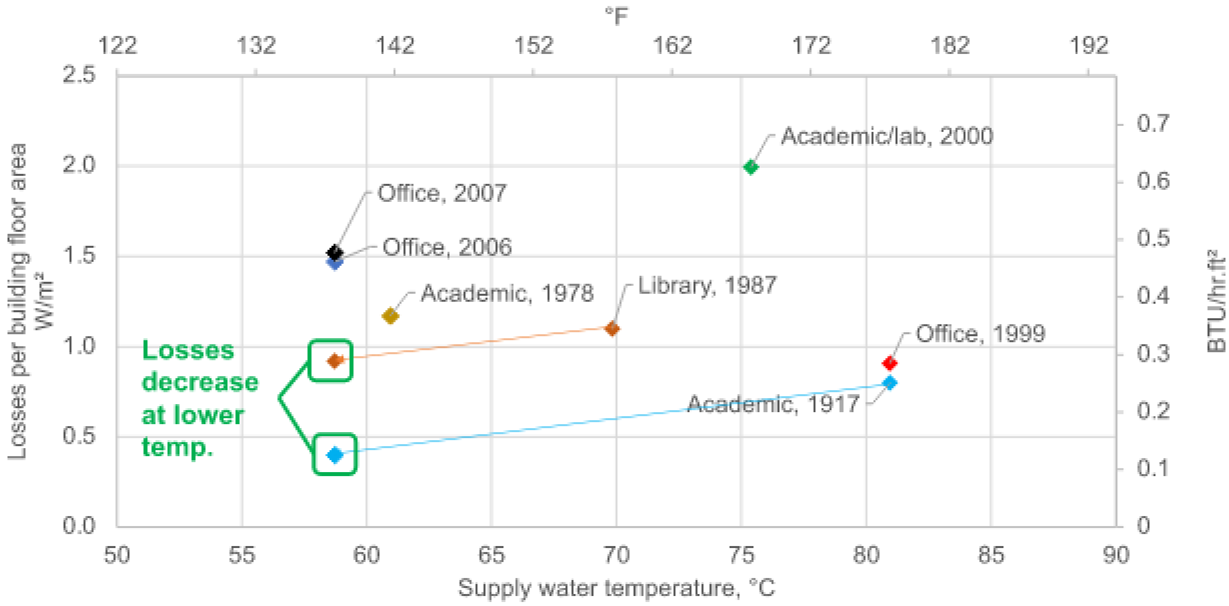


Figure 3: UC Berkeley CBE HW Piping Loss Data (with year each building was built)

The CBE study also included a survey of several hundred existing buildings and found that the median HW system operates 78 percent of the time (i.e., 19 hours/day for every day of the year). SeeFigure 4 for a histogram demonstrating the fraction of operating hours of buildings in the CBE study. This is considerably more hours than what is assumed for the CBECC prototypes. For example, the large office prototype model in CZ03 assumes the HW system operates for only 44 percent of the year. There are several reasons for this discrepancy. One reason is that building operators have a habit of operating buildings far longer than they are typically occupied to minimize the risk of hot/cold complaints when someone comes in after-hours. Another reason is that the prototype models assume uniform load/occupancy profiles (which is not realistic) and do not include “rogue zones” (meaning, zones where the HVAC system does not operate as expected due to factors such as malfunctioning controls, errors during construction, or poor design). Unfortunately, most buildings have some form of rogue zones that can cause the entire hot system to operate (and trigger nearly all the piping losses) when most zones do not need heat. For example, if the minimum flow rate is set higher than necessary in an interior zone then that zone will likely be over-cooled, even when the outside air temperature is 90°F and one would expect the heating system to be off. When over-cooling occurs, then the space heating system must be activated to offset the over-cooling to bring the temperature of the conditioned space back up to the given setpoint.

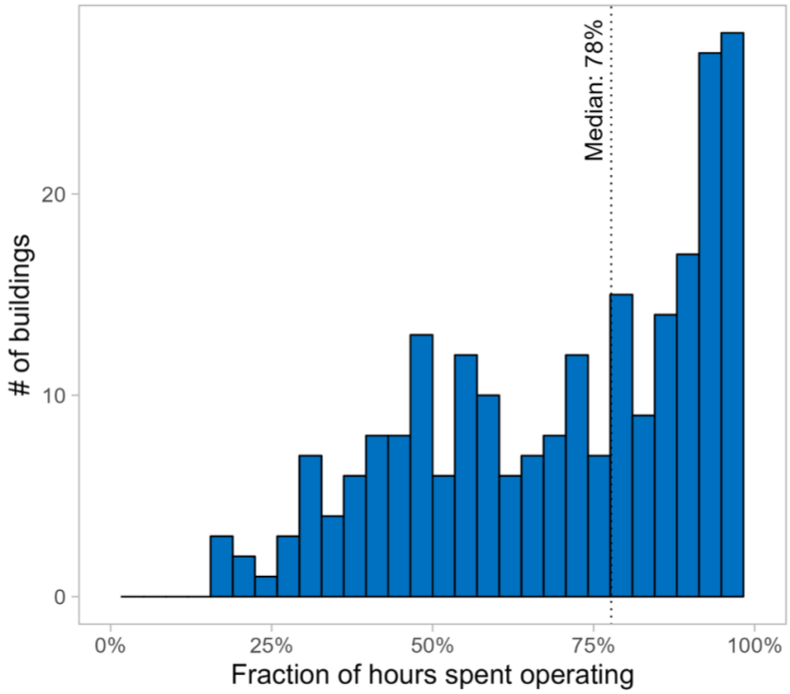


Figure 4: Histogram of HW System Operating Hours (ref: UCB CBE)

To account for this discrepancy and to more accurately capture the piping losses, the analysis assumes the HW system is running when CBECC indicates a HW load and when both of the following criteria are met: the building is in occupied mode and the outside air temperature is below 65°F. For CZ03 large office, this increased the HW system hours of operation from 44 to 63 percent (still well below the median of 78 percent from the CBE survey).

Boiler Efficiency: Boiler energy consumption was post-processed using the boiler performance curves used by DOE-2.2 and EnergyPlus. This curve determines the boiler efficiency as a function of the part load ratio and the boiler entering water temperature, with the curve normalized to the nominal efficiency at 100% full-load and 80°F EWT. These curves were validated by PG&E/Taylor Engineers research projects that tested several boilers using the ASHRAE 155P Method of Test (PG&E 2012a and PG&E 2012b). The curves are valid for both condensing and non-condensing boilers.

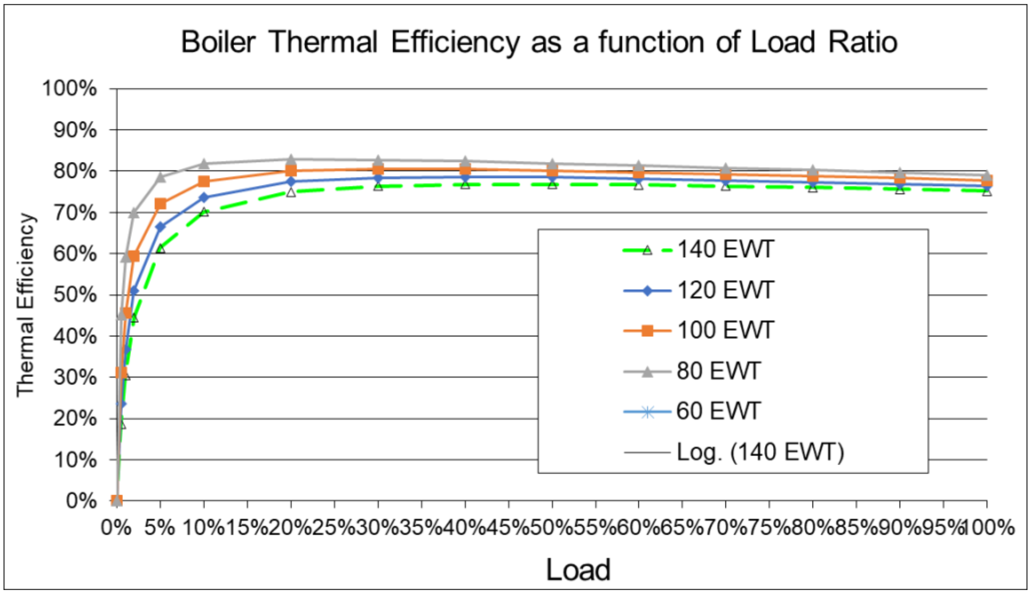


Figure 5: Boiler Efficiency Curve

Nominal condensing and non-condensing boiler efficiencies were determined based on a survey of boiler manufacturers of both types of boilers. The average nominal non-condensing boiler efficiency was 85 percent, and the average condensing boiler efficiency was 94 percent.

AWHP Efficiency: AWHP efficiency was assumed to match the minimum efficiencies listed in Title 24-2022 Table 110.2-N (minimum efficiencies for heat pumps).

2.3.1.2 Energy Savings Methodology per Prototypical Building

The Statewide CASE Team measured per unit energy savings expected from the proposed code changes in several ways to quantify key impacts. First, savings are calculated by fuel type. Electricity savings are measured in terms of both energy use and peak demand reduction. Natural gas savings are quantified in terms of energy use. Second, the Statewide CASE Team calculated Source Energy Savings. Source Energy represents the total amount of raw fuel required to operate a building. In addition to all energy used from on-site production, source energy incorporates all transmission, delivery, and production losses. The hourly Source Energy values provided by CEC are proportional to GHG emissions. Finally, the Statewide CASE Team calculated Long-term Systemwide Cost (LSC) savings, formerly known as Time Dependent Value (TDV) energy cost savings. LSC savings are calculated using hourly energy cost metrics for both electricity and natural gas provided by the CEC. These LSC hourly factors are projected over the 30-year life of the building. The LSC factors incorporate the hourly cost of marginal generation, transmission and distribution, fuel, capacity, losses, and cap-and-trade-based CO_2 emissions. More information on source energy and LSC hourly factors is available in the March 2020 CEC Staff Workshop on Energy Code

Compliance Metrics and the July 2022 CEC Staff Workshop on Energy Code Accounting for the 2025 Building Energy Efficiency Standards.

The CEC directed the Statewide CASE Team to model the energy impacts using specific prototypical building models that represent typical building geometries for different types of buildings (California Energy Commission 2022). The prototype buildings that the Statewide CASE Team used in the analysis are presented in Table 14.

Table 14: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name	Number of Stories	Floor Area (Square Feet)	Description
HighRiseMixedUse	10	125,400	10-story (9-story residential, 1-story commercial), 117-unit building. Avg dwelling unit size: 850 ft2. Central gas storage DHW.
Hospital	5	241,501	5-Story Hospital plus basement. Source: DOE Standard 90.1 Hospital prototype and scorecard. The prototype contains Title 24, Part 6, minimally compliant envelope features and lighting. For HVAC systems, the AIA guidelines recommended using VAV systems wherever possible.
HotelSmall	4	42,554	4 story Hotel with 77 guest rooms. WWR-11%
OfficeLarge	12	498,589	12 story + 1 basement office building with 5 zones and a ceiling plenum on each floor. WWR-0.40.
OfficeMedium	3	53,628	3 story office building with 5 zones and a ceiling plenum on each floor. WWR-0.33
SchoolLarge	2	210,866	High school with WWR of 35% and SRR 1.4%

The Statewide CASE Team estimated LSC energy and energy cost savings, source energy, electricity, natural gas, peak demand, and GHG impacts by simulating the proposed code change in EnergyPlus using prototypical buildings and rulesets from the 2025 Research Version of the California Building Energy Code Compliance (CBECC) software.

CBECC generates two models based on user inputs: the Standard Design and the Proposed Design. The Standard Design represents the geometry of the prototypical building and a design that uses a set of features that result in a LSC energy budget and Source energy budget that is minimally compliant with 2022 Title 24, Part 6 code requirements. Features used in the Standard Design are described in the 2022 Nonresidential ACM Reference Manual. The Proposed Design represents the same geometry as the Standard Design, but it assumes the energy features that the software user describes with user inputs.

Although CBECC gives the user the ability to alter HWSTs, this functionality was not used for this analysis due to the inability for CBECC to model pipe distribution losses. This limitation rendered CBECC inadequate other than as a source for heating and cooling load profiles for each prototype. The Statewide CASE Team exported the building loads for each applicable prototype in 16 climate zones and then performed post-processing on this data consistent with the methodology described in Section 2.3.1.1, Key Assumptions for Energy Savings Analysis. For example, piping losses as a function of temperature were applied to both the baseline and proposed cases, which then impacted the demand on the boiler or air to water heat pump. In addition, the boiler performance curves developed as part of the ASHRAE 155P research project were used instead of the CBECC default curves. The implication of these types of changes is that the standard design is less efficient than an unaltered CBECC prototype made to match the 2022 code requirements. However, since capturing distribution losses is an important aspect of the cost effectiveness analysis for this measure, this change was necessary.

As noted above, the Statewide CASE Team created two separate savings estimates, one meant to capture sites using gas heating, and another to capture sites using heat pump hydronics. This drove the need to further modify the standard design from gas to electric. This is because the Statewide CASE Team was interested in estimating the savings and demonstrating cost-effectiveness for buildings using an all-electric space heating hydronic system. To accomplish this, the gas boiler was changed to an ATWHP with a 140°F HWST in the standard design.

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 15 presents precisely which parameters were modified and what values were used in the Standard Design and Proposed Design. Section 2.3.1.1, Key Assumptions for Energy Savings Analysis, describes the changes between the baseline and proposed cases in detail.

Table 15: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change

Prototype ID	Climate Zone	Objects Modified	Para-meter Name	Standard Design Parameter Value	Proposed Design Parameter Value
HighRiseMixedUse	All	Boiler or AWHP	HWST	G: 180°F ; E: 140°F	G & E: 130°F
Hospital	All	Boiler or AWHP	HWST	G: 180°F ; E: 140°F	G & E: 130°F
HotelSmall	All	Boiler or AWHP	HWST	G: 180°F ; E: 140°F	G & E: 130°F
OfficeLarge	All	Boiler or AWHP	HWST	G: 180°F ; E: 140°F	G & E: 130°F
OfficeMedium	All	Boiler or AWHP	HWST	G: 180°F ; E: 140°F	G & E: 130°F
SchoolLarge	All	Boiler or AWHP	HWST	G: 180°F ; E: 140°F	G & E: 130°F

CBECC calculates whole-building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/y) and therms per year (Therms/yr). It then applies the 2025 LSC hourly factors to calculate LSC energy use in kilo British thermal units per year (kBtu/y), Source Energy factors to calculate Source Energy Use in kilo British thermal units per year (kBtu/y), and hourly GHG emissions factors to calculate annual GHG emissions in metric tons of carbon dioxide emissions equivalent (MT or "tonnes" CO_2e/y) (California Energy Commission 2022). CBECC also generates LSC savings values measured in 2026 present value dollars (2026 PV$) and nominal dollars. CBECC also calculates annual peak electricity demand measured in kilowatts (kW).

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

Per-unit energy impacts for nonresidential buildings are presented in savings per square foot. Annual energy, GHG, and peak demand impacts for each prototype building were translated into impacts per square foot by dividing by the floor area of the prototype building. This step allows for an easier comparison of savings across different building types and enables a calculation of statewide savings using the construction forecast that is published in terms of floor area by building type.

2.3.1.3 Statewide Energy Savings Methodology

The per-unit energy impacts were extrapolated to statewide impacts using the statewide construction forecasts that the CEC provided. The statewide construction forecasts estimate new construction/additions that would occur in 2026, the first year that the 2025 Title 24, Part 6 requirements are in effect. They also estimate the amount of total existing building stock in 2026, which the Statewide CASE Team used to approximate savings from building alterations (California Energy Commission 2022). The construction forecast provides construction (new construction/additions and existing building stock) by building type and climate zone, as shown in Appendix A.

For this measure, a "gas-to-gas" and "electric-to-electric" baseline to proposed design framework was used. This means that the measure was separately analyzed for systems that use a gas boiler and air to water heat pump hydronic system. The gas-to-gas analysis results in natural gas (i.e., therms) savings and the electric-to-electric analysis results in electric (i.e., kWh) savings. To ensure that impacts are not over counted, the construction forecast was adjusted to account for the estimated number of buildings using electric vs. gas for space heating. The Statewide CASE Team assumed that the fraction of electric buildings statewide would be consistent with the number of local jurisdictions that have adopted all-electric reach codes.

Appendix A presents additional information about the methodology and assumptions used to calculate statewide energy impacts.

2.3.2 Per-Unit Energy Impacts Results

Energy savings and peak demand reductions per unit and by climate zone are presented in Table 16 through Table 22. Savings are presented for new construction and additions. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. Per-unit savings for the first year are expected to range from 0.03 to 0.13 kWh/y (using the electric baseline) and 0.92 to 4.00 kBtu/y (using the gas baseline) depending upon climate zone. Demand reductions/increases are expected to range between 0.01 kW and 0.02 kW (using the electric baseline) depending on the climate zone.

Table 16: First Year Natural Gas Savings (kBtu) Per Square Foot—Hot Water Supply Temperature Limit (Gas Baseline)

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
Highrisemixeduse	1.83	1.22	1.41	1.09	1.27	0.89	0.82	0.67	0.74	0.70	0.93	1.04	0.85	0.94	0.41	1.37
Hospital	8.61	8.24	7.90	7.94	7.98	7.15	7.06	7.31	7.17	7.27	7.75	7.83	7.49	7.32	6.87	7.31
Hotelsmall	3.71	2.94	2.93	2.67	2.93	1.72	1.56	1.54	1.71	1.77	2.19	2.50	1.90	2.14	0.96	3.01
Officelarge	4.41	3.28	3.40	2.99	3.20	1.93	1.71	1.65	1.78	1.79	2.69	2.73	2.17	2.62	1.02	3.88
Officemedium	4.51	3.25	3.31	2.84	3.12	1.68	1.53	1.41	1.65	1.60	2.76	2.84	2.24	2.70	1.06	4.01

Table 17: First Year Source Energy Savings (kBtu) Per Square Foot—Hot Water Supply Temperature Limit (Gas Baseline)

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
Highrisemixeduse	1.65	1.11	1.28	0.99	1.15	0.80	0.73	0.60	0.67	0.63	0.84	0.94	0.77	0.85	0.37	1.23
Hospital	7.79	7.46	7.15	7.19	7.23	6.43	6.33	6.58	6.45	6.54	7.02	7.09	6.78	6.58	6.18	6.57
Hotelsmall	3.36	2.66	2.65	2.42	2.65	1.55	1.40	1.39	1.54	1.59	1.98	2.26	1.72	1.93	0.86	2.71
Officelarge	4.00	2.97	3.08	2.71	2.89	1.74	1.53	1.48	1.60	1.61	2.44	2.47	1.96	2.36	0.92	3.49
Officemedium	4.09	2.94	3.00	2.57	2.82	1.51	1.37	1.27	1.49	1.44	2.50	2.57	2.03	2.43	0.95	3.60

Table 18: First Year LSC Energy Savings ($) Per Square Foot—Hot Water Supply Temperature Limit (Gas Baseline)

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
Highrisemixeduse	0.98	0.68	0.78	0.62	0.70	0.51	0.48	0.39	0.43	0.41	0.55	0.60	0.50	0.56	0.26	0.78
Hospital	4.63	4.43	4.27	4.29	4.30	3.87	3.84	3.98	3.90	3.96	4.20	4.24	4.06	4.00	3.73	3.98
Hotelsmall	2.00	1.62	1.61	1.50	1.60	0.99	0.92	0.91	0.99	1.03	1.28	1.42	1.12	1.26	0.59	1.71
Officelarge	2.40	1.82	1.88	1.70	1.76	1.10	0.99	0.97	1.03	1.05	1.58	1.57	1.29	1.56	0.63	2.22
Officemedium	2.47	1.83	1.84	1.62	1.72	0.96	0.90	0.83	0.97	0.94	1.63	1.64	1.33	1.62	0.66	2.30

Table 19: First Year Electricity Savings (kWh) Per Square Foot—Hot Water Supply Temperature Limit (Electric Baseline)

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
Highrisemixeduse	0.05	0.03	0.04	0.03	0.04	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.03	0.01	0.04
Hospital	0.43	0.40	0.38	0.38	0.38	0.31	0.31	0.33	0.32	0.33	0.36	0.37	0.35	0.33	0.30	0.34
Hotelsmall	0.12	0.09	0.09	0.08	0.09	0.05	0.04	0.04	0.05	0.05	0.07	0.08	0.06	0.07	0.03	0.10
Officelarge	0.13	0.11	0.10	0.10	0.10	0.05	0.04	0.05	0.05	0.05	0.09	0.09	0.07	0.09	0.03	0.13
Officemedium	0.14	0.10	0.09	0.09	0.09	0.04	0.04	0.04	0.05	0.05	0.09	0.09	0.07	0.09	0.03	0.14

Table 20: First Year Peak Demand Reduction (W) Per Square Foot—Hot Water Supply Temperature Limit (Electric Baseline)

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
Highrisemixeduse	0.003	0.002	0.002	0.002	0.002	0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.003
Hospital	0.065	0.063	0.065	0.062	0.061	0.052	0.050	0.057	0.058	0.057	0.064	0.062	0.061	0.057	0.054	0.053
Hotelsmall	0.015	0.014	0.013	0.014	0.013	0.008	0.007	0.009	0.009	0.010	0.013	0.014	0.012	0.013	0.008	0.014
Officelarge	0.018	0.017	0.016	0.018	0.016	0.008	0.006	0.009	0.010	0.011	0.018	0.017	0.015	0.019	0.008	0.021
Officemedium	0.020	0.016	0.015	0.017	0.015	0.007	0.006	0.008	0.009	0.009	0.018	0.017	0.014	0.018	0.008	0.020

Table 21: First Year Source Energy Savings (kBtu) Per Square Foot—Hot Water Supply Temperature Limit (Electric Baseline)

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
Highrisemixeduse	0.08	0.06	0.07	0.06	0.06	0.04	0.04	0.04	0.04	0.04	0.06	0.06	0.05	0.06	0.03	0.07
Hospital	0.88	0.83	0.80	0.78	0.79	0.65	0.68	0.69	0.68	0.69	0.77	0.78	0.74	0.71	0.62	0.70
Hotelsmall	0.23	0.20	0.19	0.19	0.18	0.11	0.12	0.11	0.12	0.12	0.18	0.19	0.16	0.18	0.09	0.22
Officelarge	0.26	0.24	0.22	0.24	0.22	0.12	0.13	0.12	0.13	0.14	0.24	0.22	0.19	0.24	0.09	0.30
Officemedium	0.31	0.25	0.21	0.23	0.21	0.11	0.13	0.11	0.13	0.13	0.25	0.24	0.20	0.25	0.10	0.32

Table 22: First Year LSC Energy Savings ($) Per Square Foot—Hot Water Supply Temperature Limit (Electric Baseline)

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
Highrisemixeduse	0.28	0.21	0.22	0.17	0.20	0.13	0.11	0.10	0.11	0.11	0.15	0.16	0.14	0.15	0.07	0.22
Hospital	2.57	2.43	2.31	2.23	2.29	1.90	1.95	1.98	1.95	1.98	2.17	2.21	2.08	1.99	1.80	2.03
Hotelsmall	0.71	0.57	0.54	0.50	0.52	0.28	0.30	0.27	0.30	0.30	0.44	0.47	0.38	0.43	0.18	0.62
Officelarge	0.79	0.67	0.62	0.60	0.61	0.30	0.32	0.30	0.32	0.34	0.56	0.54	0.44	0.56	0.20	0.82
Officemedium	0.90	0.67	0.58	0.57	0.56	0.27	0.30	0.26	0.30	0.29	0.57	0.56	0.46	0.57	0.19	0.86

2.4 Cost and Cost Effectiveness

2.4.1 Energy Cost Savings Methodology

Energy cost savings were calculated by applying the LSC hourly factors to the energy savings estimates that were derived using the methodology described in Section 2.3.1. LSC hourly factors are a normalized metric to calculate energy cost savings that accounts for the variable cost of electricity and natural gas for each hour of the year, along with how costs are expected to change over the period of analysis. In this case, the period of analysis used is 30 years.

The CEC requested energy cost savings over the 30-year period of analysis in both 2026 present value dollars (2026 PV$) and nominal dollars. The cost effectiveness analysis uses energy cost values in 2026 PV$. Costs and cost-effectiveness using and 2026 PV$ are presented in Section 2.4 of this report. CEC uses results in nominal dollars to complete the Economic and Fiscal Impacts Statement (From 399) for the entire package of proposed change to Title 24, Part 6. Appendix G presents energy cost savings results in nominal dollars.

2.4.2 Energy Cost Savings Results

Per-unit energy cost savings for newly constructed buildings, additions, and alterations that are realized over the 30-year period of analysis are presented 2026 precent value dollars (2026 PV$) in Table 23 through Table 46.

The LSC hourly factors methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. Discuss the peak savings attributed to the code change (e.g., what percentage of the savings occur during peak periods?).

Any time code changes impact cost, there is potential to disproportionately impact certain populations. Refer to Section 2.6 for more details addressing energy equity and environmental justice.

The Statewide CASE Team is presenting the electric and natural gas LSC values together in Table 23 through Table 46 for simplicity. However, the electrical and gas savings are separate and depend on which type of fuel the building uses for space heating. Any row with “NA” indicates that the given climate zone does not have any construction forecast over the period of analysis.

Table 23: 2026 PV LSC Cost Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions– HighRiseMixedUse – Hot Water Supply Temperature Limit (Gas Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	0.00	0.98	0.98
2	0.00	0.68	0.68
3	0.00	0.78	0.78
4	0.00	0.62	0.62
5	0.00	0.70	0.70
6	0.00	0.51	0.51
7	0.00	0.48	0.48
8	0.00	0.39	0.39
9	0.00	0.43	0.43
10	0.00	0.41	0.41
11	0.00	0.55	0.55
12	0.00	0.60	0.60
13	0.00	0.50	0.50
14	0.00	0.56	0.56
15	0.00	0.26	0.26
16	0.00	0.78	0.78

[a] "NA" refers to the fact that the CEC forecasts 0 square feet of construction activity in this climate zone for this building type in 2026.

Table 24: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions – Hospital – Hot Water Supply Temperature Limit (Gas Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	0.00	4.63	4.63
2	0.00	4.43	4.43
3	0.00	4.27	4.27
4	0.00	4.29	4.29
5	0.00	4.30	4.30
6	0.00	3.87	3.87
7	0.00	3.84	3.84
8	0.00	3.98	3.98
9	0.00	3.90	3.90
10	0.00	3.96	3.96
11	0.00	4.20	4.20
12	0.00	4.24	4.24
13	0.00	4.06	4.06
14	0.00	4.00	4.00
15	0.00	3.73	3.73
16	0.00	3.98	3.98

Table 25: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions – HotelSmall – Hot Water Supply Temperature Limit (Gas Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	0.00	2.00	2.00
2	0.00	1.62	1.62
3	0.00	1.61	1.61
4	0.00	1.50	1.50
5	0.00	1.60	1.60
6	0.00	0.99	0.99
7	0.00	0.92	0.92
8	0.00	0.91	0.91
9	0.00	0.99	0.99
10	0.00	1.03	1.03
11	0.00	1.28	1.28
12	0.00	1.42	1.42
13	0.00	1.12	1.12
14	0.00	1.26	1.26
15	0.00	0.59	0.59
16	0.00	1.71	1.71

Table 26: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions –OfficeLarge – Hot Water Supply Temperature Limit (Gas Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	NA	NA	NA
2	NA	NA	NA
3	0.00	1.88	1.88
4	0.00	1.70	1.70
5	NA	NA	NA
6	0.00	1.10	1.10
7	0.00	0.99	0.99
8	0.00	0.97	0.97
9	0.00	1.03	1.03
10	0.00	1.05	1.05
11	0.00	1.58	1.58
12	0.00	1.57	1.57
13	NA	NA	NA
14	0.00	1.56	1.56
15	0.00	0.63	0.63
16	0.00	2.22	2.22

Table 27: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions – OfficeMedium – Hot Water Supply Temperature Limit (Gas Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	0.00	2.47	2.47
2	0.00	1.83	1.83
3	0.00	1.84	1.84
4	0.00	1.62	1.62
5	0.00	1.72	1.72
6	0.00	0.96	0.96
7	0.00	0.90	0.90
8	0.00	0.83	0.83
9	0.00	0.97	0.97
10	0.00	0.94	0.94
11	0.00	1.63	1.63
12	0.00	1.64	1.64
13	0.00	1.33	1.33
14	0.00	1.62	1.62
15	0.00	0.66	0.66
16	0.00	2.30	2.30

[a] "NA" refers to the fact that the CEC forecasts 0 square feet of construction activity in this climate zone.

Table 28: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions – All Prototypes– Hot Water Supply Temperature Limit (Gas Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	0.00	2.56	2.56
2	0.00	1.91	1.91
3	0.00	1.83	1.83
4	0.00	1.70	1.70
5	0.00	1.91	1.91
6	0.00	1.09	1.09
7	0.00	1.19	1.19
8	0.00	0.95	0.95
9	0.00	1.05	1.05
10	0.00	1.34	1.34
11	0.00	1.33	1.33
12	0.00	1.60	1.60
13	0.00	1.23	1.23
14	0.00	1.55	1.55
15	0.00	1.11	1.11
16	0.00	1.92	1.92

Table 29: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations – HighRiseMixedUse – Hot Water Supply Temperature Limit (Gas Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	0.00	0.98	0.98
2	0.00	0.68	0.68
3	0.00	0.78	0.78
4	0.00	0.62	0.62
5	NA	NA	NA
6	0.00	0.51	0.51
7	0.00	0.48	0.48
8	0.00	0.39	0.39
9	0.00	0.43	0.43
10	0.00	0.41	0.41
11	0.00	0.55	0.55
12	0.00	0.60	0.60
13	0.00	0.50	0.50
14	0.00	0.56	0.56
15	0.00	0.26	0.26
16	0.00	0.78	0.78

Table 30: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations – Hospital – Hot Water Supply Temperature Limit (Gas Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	0.00	4.63	4.63
2	0.00	4.43	4.43
3	0.00	4.27	4.27
4	0.00	4.29	4.29
5	0.00	4.30	4.30
6	0.00	3.87	3.87
7	0.00	3.84	3.84
8	0.00	3.98	3.98
9	0.00	3.90	3.90
10	0.00	3.96	3.96
11	0.00	4.20	4.20
12	0.00	4.24	4.24
13	0.00	4.06	4.06
14	0.00	4.00	4.00
15	0.00	3.73	3.73
16	0.00	3.98	3.98

Table 31: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations – HotelSmall – Hot Water Supply Temperature Limit (Gas Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	0.00	2.00	2.00
2	0.00	1.62	1.62
3	0.00	1.61	1.61
4	0.00	1.50	1.50
5	0.00	1.60	1.60
6	0.00	0.99	0.99
7	0.00	0.92	0.92
8	0.00	0.91	0.91
9	0.00	0.99	0.99
10	0.00	1.03	1.03
11	0.00	1.28	1.28
12	0.00	1.42	1.42
13	0.00	1.12	1.12
14	0.00	1.26	1.26
15	0.00	0.59	0.59
16	0.00	1.71	1.71

Table 32: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations –OfficeLarge – Hot Water Supply Temperature Limit (Gas Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	0.00	2.40	2.40
2	0.00	1.82	1.82
3	0.00	1.88	1.88
4	0.00	1.70	1.70
5	0.00	1.76	1.76
6	0.00	1.10	1.10
7	0.00	0.99	0.99
8	0.00	0.97	0.97
9	0.00	1.03	1.03
10	0.00	1.05	1.05
11	0.00	1.58	1.58
12	0.00	1.57	1.57
13	0.00	1.29	1.29
14	0.00	1.56	1.56
15	0.00	0.63	0.63
16	0.00	2.22	2.22

Table 33: 2026 PV LSC Cost Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations – OfficeMedium – Hot Water Supply Temperature Limit (Gas Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	0.00	2.47	2.47
2	0.00	1.83	1.83
3	0.00	1.84	1.84
4	0.00	1.62	1.62
5	0.00	1.72	1.72
6	0.00	0.96	0.96
7	0.00	0.90	0.90
8	0.00	0.83	0.83
9	0.00	0.97	0.97
10	0.00	0.94	0.94
11	0.00	1.63	1.63
12	0.00	1.64	1.64
13	0.00	1.33	1.33
14	0.00	1.62	1.62
15	0.00	0.66	0.66
16	0.00	2.30	2.30

Table 34: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations – All Prototypes– Hot Water Supply Temperature Limit (Gas Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	0.00	2.63	2.63
2	0.00	2.01	2.01
3	0.00	1.72	1.72
4	0.00	1.73	1.73
5	0.00	2.05	2.05
6	0.00	1.17	1.17
7	0.00	1.12	1.12
8	0.00	1.05	1.05
9	0.00	1.10	1.10
10	0.00	1.19	1.19
11	0.00	1.82	1.82
12	0.00	1.72	1.72
13	0.00	1.57	1.57
14	0.00	1.48	1.48
15	0.00	0.95	0.95
16	0.00	1.87	1.87

Table 35: 2026 PV LSC Cost Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions– HighRiseMixedUse – Hot Water Supply Temperature Limit (Electric Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	0.28	0.00	0.28
2	0.21	0.00	0.21
3	0.22	0.00	0.22
4	0.17	0.00	0.17
5	0.20	0.00	0.20
6	0.13	0.00	0.13
7	0.11	0.00	0.11
8	0.10	0.00	0.10
9	0.11	0.00	0.11
10	0.11	0.00	0.11
11	0.15	0.00	0.15
12	0.16	0.00	0.16
13	0.14	0.00	0.14
14	0.15	0.00	0.15
15	0.07	0.00	0.07
16	0.22	0.00	0.22

[a] "NA" refers to the fact that the CEC forecasts 0 square feet of construction activity in this climate zone for this building type in 2026.

Table 36: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions – Hospital – Hot Water Supply Temperature Limit (Electric Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	2.57	0.00	2.57
2	2.43	0.00	2.43
3	2.31	0.00	2.31
4	2.23	0.00	2.23
5	2.29	0.00	2.29
6	1.90	0.00	1.90
7	1.95	0.00	1.95
8	1.98	0.00	1.98
9	1.95	0.00	1.95
10	1.98	0.00	1.98
11	2.17	0.00	2.17
12	2.21	0.00	2.21
13	2.08	0.00	2.08
14	1.99	0.00	1.99
15	1.80	0.00	1.80
16	2.03	0.00	2.03

Table 37: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions – HotelSmall – Hot Water Supply Temperature Limit (Electric Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	0.71	0.00	0.71
2	0.57	0.00	0.57
3	0.54	0.00	0.54
4	0.50	0.00	0.50
5	0.52	0.00	0.52
6	0.28	0.00	0.28
7	0.30	0.00	0.30
8	0.27	0.00	0.27
9	0.30	0.00	0.30
10	0.30	0.00	0.30
11	0.44	0.00	0.44
12	0.47	0.00	0.47
13	0.38	0.00	0.38
14	0.43	0.00	0.43
15	0.18	0.00	0.18
16	0.62	0.00	0.62

Table 38: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions –OfficeLarge – Hot Water Supply Temperature Limit (Electric Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	NA	NA	NA
2	NA	NA	NA
3	0.62	0.00	0.62
4	0.60	0.00	0.60
5	NA	NA	NA
6	0.30	0.00	0.30
7	0.32	0.00	0.32
8	0.30	0.00	0.30
9	0.32	0.00	0.32
10	0.34	0.00	0.34
11	0.56	0.00	0.56
12	0.54	0.00	0.54
13	NA	NA	NA
14	0.56	0.00	0.56
15	0.20	0.00	0.20
16	0.82	0.00	0.82

Table 39: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions – OfficeMedium – Hot Water Supply Temperature Limit (Electric Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	0.90	0.00	0.90
2	0.67	0.00	0.67
3	0.58	0.00	0.58
4	0.57	0.00	0.57
5	0.56	0.00	0.56
6	0.27	0.00	0.27
7	0.30	0.00	0.30
8	0.26	0.00	0.26
9	0.30	0.00	0.30
10	0.29	0.00	0.29
11	0.57	0.00	0.57
12	0.56	0.00	0.56
13	0.46	0.00	0.46
14	0.57	0.00	0.57
15	0.19	0.00	0.19
16	0.86	0.00	0.86

Table 40: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions – All Prototypes– Hot Water Supply Temperature Limit (Electric Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	1.05	0.00	1.05
2	0.83	0.00	0.83
3	0.70	0.00	0.70
4	0.67	0.00	0.67
5	0.74	0.00	0.74
6	0.37	0.00	0.37
7	0.49	0.00	0.49
8	0.34	0.00	0.34
9	0.38	0.00	0.38
10	0.57	0.00	0.57
11	0.56	0.00	0.56
12	0.64	0.00	0.64
13	0.53	0.00	0.53
14	0.62	0.00	0.62
15	0.46	0.00	0.46
16	0.80	0.00	0.80

Table 41: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations – HighRiseMixedUse – Hot Water Supply Temperature Limit (Electric Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	0.28	0.00	0.28
2	0.21	0.00	0.21
3	0.22	0.00	0.22
4	0.17	0.00	0.17
5	NA	NA	NA
6	0.13	0.00	0.13
7	0.11	0.00	0.11
8	0.10	0.00	0.10
9	0.11	0.00	0.11
10	0.11	0.00	0.11
11	0.15	0.00	0.15
12	0.16	0.00	0.16
13	0.14	0.00	0.14
14	0.15	0.00	0.15
15	0.07	0.00	0.07
16	0.22	0.00	0.22

Table 42: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations – Hospital – Hot Water Supply Temperature Limit (Electric Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	2.57	0.00	2.57
2	2.43	0.00	2.43
3	2.31	0.00	2.31
4	2.23	0.00	2.23
5	2.29	0.00	2.29
6	1.90	0.00	1.90
7	1.95	0.00	1.95
8	1.98	0.00	1.98
9	1.95	0.00	1.95
10	1.98	0.00	1.98
11	2.17	0.00	2.17
12	2.21	0.00	2.21
13	2.08	0.00	2.08
14	1.99	0.00	1.99
15	1.80	0.00	1.80
16	2.03	0.00	2.03

Table 43: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations – HotelSmall – Hot Water Supply Temperature Limit (Electric Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	0.71	0.00	0.71
2	0.57	0.00	0.57
3	0.54	0.00	0.54
4	0.50	0.00	0.50
5	0.52	0.00	0.52
6	0.28	0.00	0.28
7	0.30	0.00	0.30
8	0.27	0.00	0.27
9	0.30	0.00	0.30
10	0.30	0.00	0.30
11	0.44	0.00	0.44
12	0.47	0.00	0.47
13	0.38	0.00	0.38
14	0.43	0.00	0.43
15	0.18	0.00	0.18
16	0.62	0.00	0.62

Table 44: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations –OfficeLarge – Hot Water Supply Temperature Limit (Electric Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	0.79	0.00	0.79
2	0.67	0.00	0.67
3	0.62	0.00	0.62
4	0.60	0.00	0.60
5	0.61	0.00	0.61
6	0.30	0.00	0.30
7	0.32	0.00	0.32
8	0.30	0.00	0.30
9	0.32	0.00	0.32
10	0.34	0.00	0.34
11	0.56	0.00	0.56
12	0.54	0.00	0.54
13	0.44	0.00	0.44
14	0.56	0.00	0.56
15	0.20	0.00	0.20
16	0.82	0.00	0.82

Table 45: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations – OfficeMedium – Hot Water Supply Temperature Limit (Electric Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	0.90	0.00	0.90
2	0.67	0.00	0.67
3	0.58	0.00	0.58
4	0.57	0.00	0.57
5	0.56	0.00	0.56
6	0.27	0.00	0.27
7	0.30	0.00	0.30
8	0.26	0.00	0.26
9	0.30	0.00	0.30
10	0.29	0.00	0.29
11	0.57	0.00	0.57
12	0.56	0.00	0.56
13	0.46	0.00	0.46
14	0.57	0.00	0.57
15	0.19	0.00	0.19
16	0.86	0.00	0.86

Table 46: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations – All Prototypes– Hot Water Supply Temperature Limit (Electric Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	1.16	0.00	1.16
2	0.87	0.00	0.87
3	0.66	0.00	0.66
4	0.69	0.00	0.69
5	0.83	0.00	0.83
6	0.41	0.00	0.41
7	0.44	0.00	0.44
8	0.39	0.00	0.39
9	0.41	0.00	0.41
10	0.48	0.00	0.48
11	0.80	0.00	0.80
12	0.70	0.00	0.70
13	0.70	0.00	0.70
14	0.59	0.00	0.59
15	0.39	0.00	0.39
16	0.77	0.00	0.77

2.4.3 Incremental First Cost

Piping Cost Data: Piping cost data was provided by two large Bay Area mechanical contractors. See Table 47. These are fully installed costs and include materials, labor, allowances for elbows, valves, fittings, insulation, etc. Copper pipes are assumed for 2" and smaller, black steel for 3" and 4".

Table 47. HW Pipe Cost Data from Mechanical Contractors

Pipe Size	$/linear foot	Max GPM
3/4	$ 105.05	4.6
1"	$ 110.97	8.9
1-1/4"	$ 121.18	15
1-1/2"	$ 131.15	24
2"	$ 149.72	51
3"	$ 223.56	140
4"	$ 272.50	280

2.4.3.1 Pipe Sizing Methodology

Taylor Engineers has developed a publicly available tool for optimally sizing HW pipes based on pipe cost, pump energy cost, noise considerations, erosion considerations, etc. Using this tool, the Statewide CASE Team derived the maximum GPMs listed in Table 47. These flow rates and pipe costs where then used to derive a regression for pipe cost as a function of gpm (Figure 6).

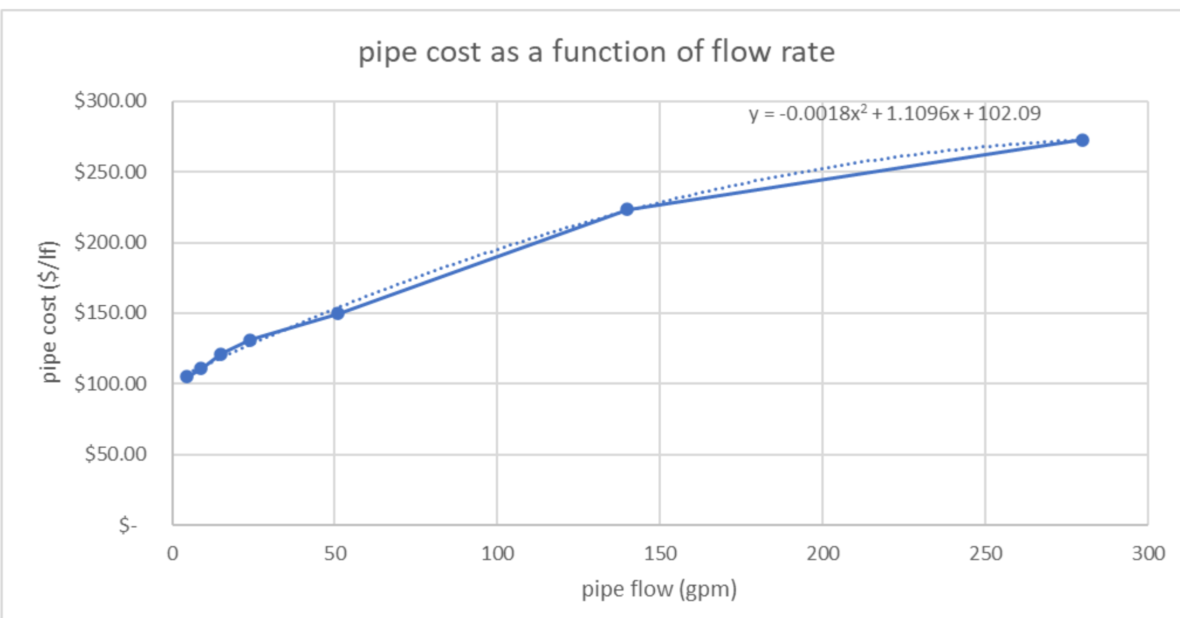


Figure 6: Pipe Cost vs Flow

The Statewide CASE Team took the drawings for two real office buildings (see Figure 7 and Figure 8) with HW reheat systems and measured the linear feet of all the pipes in the building and the calculated the design heating capacity in Btuh of each segment of pipe based on the design gpm and design dT. We then determined the new gpm in each pipe segment based on the new dT. The regression equation from Figure 6 was then used to determine the new pipe cost if for each segment which was multiplied by the segment length to determine the new pipe cost for each segment. Since the two real buildings did not exactly match the areas of the prototype models, the incremental piping costs from the real buildings were normalized to $/ft2 so they could be applied to the energy results from the prototype models based on each prototype's floor area.

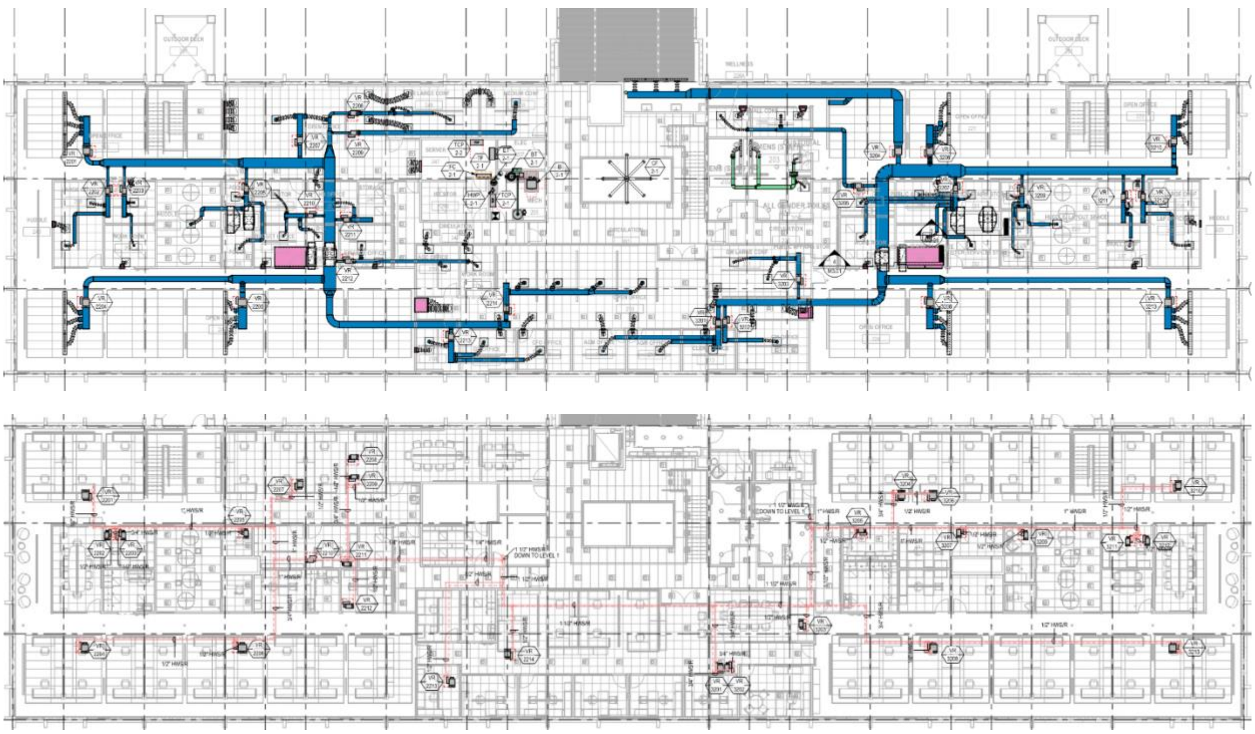


Figure 7: 2nd Floor of 2-Story, 40,000 ft2 Medium Office Building

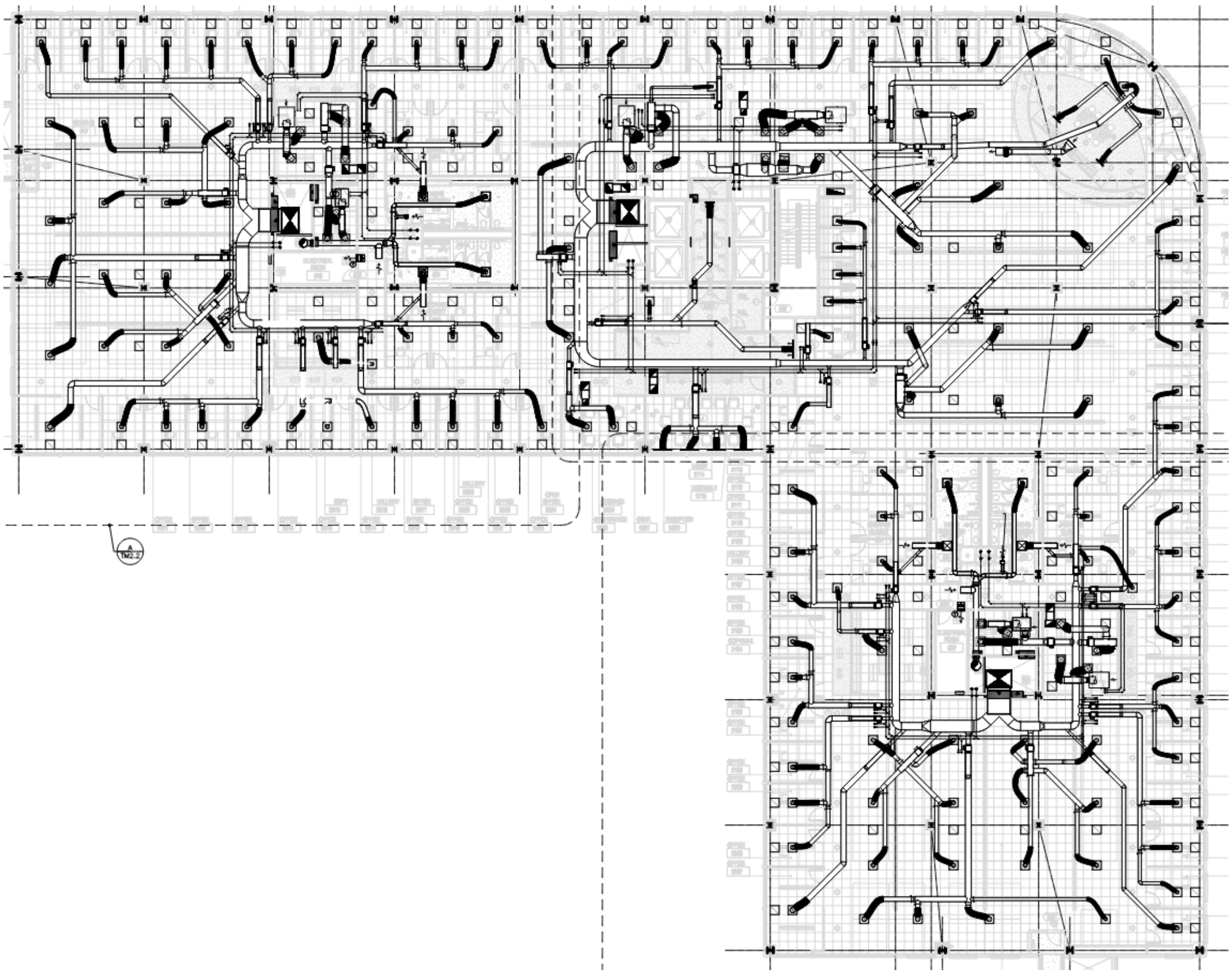


Figure 8: Typical Floor of 5-Story, 200,000 ft2 Large Office Building

2.4.3.2 Boiler Cost Data

We solicited boiler price data from two Bay Area boiler representatives for boilers representing a range of types, sizes, and manufacturers. The data was then averaged to arrive at the equipment costs shown in Table 48.

Table 48: Boiler Cost Data

Boiler type	Avg equip cost ($/kBtuh)
Non-condensing	$29.45
Condensing	$39.81
Equipment Incremental Cost	$10.36

The mechanical contractor advised that an installed cost multiplier of 2.0 could reasonably be applied to the equipment incremental cost of $10.36/kBtuh to arrive at the installed incremental cost of switching from non-condensing in Baseline 1 to condensing in Proposed 1 of $20.72/kBtuh. The peak loads determined by the CBECC prototype models for each climate zone were on the order of 8-11 Btuh/ft2, which is well below typical engineer boiler sizing.[10] To be conservative the Statewide CASE Team doubled the CBECC peak loads to determine the loads for the study buildings and thus the incremental boiler costs. This assumption is conservative because it increases the size of the boilers and pumps and thus the incremental costs. Doubling the CBECC peak loads was consistent with the actual sizing of the boiler plants for the two study buildings.

2.4.3.3 Pump Cost Data

Similarly pump cost data was solicited from Bay Area pump representatives for pumps representing the range of flows seen in the two office buildings above. This survey provided an incremental installed cost of $80/gpm. The new gpm for each building was determined based on the estimated peak loads in each climate and the new dT.

2.4.4 Incremental Maintenance and Replacement Costs

Incremental maintenance cost is the incremental cost of replacing the equipment or parts of the equipment, as well as periodic maintenance required to keep the equipment operating relative to current practices over the 30-year period of analysis. The present value of equipment maintenance costs (or savings) was calculated using a three percent discount rate (d), which is consistent with the discount rate used when developing the 2025 LSC hourly factors. The present value of maintenance costs that occurs in the n^{th} year is calculated as follows:

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

This measure is not expected to result in different maintenance costs relative to the base case.

2.4.5 Cost Effectiveness

Table 49, Table 50, Table 51, and Table 52 summarize the cost-effectiveness calculations for a representative sample of climate zones for large and medium office buildings for both Baseline 1 (gas boilers) and Baseline 2 (AWHPs). In all cases the benefit-to-cost ratio is well above 1.0, indicating that the measure is cost effective in all cases.

[10] This assertion is based on professional judgement and past informal surveys of real designs.

Table 49: Cost Effectiveness Results for Selected Climate Zones (Large Office – Gas Baseline)

Parameter	CZ01	CZ03	CZ06	CZ07	CZ09	CZ12
Plant capacity (Btuh/sf)	22.0	20.9	17.1	15.6	17.8	21.1
Plant capacity (KBH)	10,977	10,439	8,515	7,790	8,884	10,524
Incremental boiler cost ($/KBH)	$20.72	$20.72	$20.72	$20.72	$20.72	$20.72
Incremental boiler cost ($)	$227,395	$216,253	$176,395	$161,391	$184,045	$218,029
Incremental boiler cost ($/ft2)	$0.46	$0.43	$0.35	$0.32	$0.37	$0.44
Incremental gpm	329	313	255	234	267	316
Incremental pump cost ($/gpm)	$80	$80	$80	$80	$80	$80
Incremental pump cost ($)	$26,384	$25,091	$20,467	$18,726	$21,354	$25,297
Incremental pump cost ($/ft2)	$0.05	$0.05	$0.04	$0.04	$0.04	$0.05
Incremental pipe cost 40dT to 25dT ($/ft2)	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19
Total incremental cost ($/ft2)	$0.70	$0.67	$0.59	$0.55	$0.60	$0.68
Energy savings ($/ft2)	$2.40	$1.88	$1.10	$0.99	$1.03	$1.57
Net lifecycle savings ($/ft2)	$1.70	$1.21	$0.51	$0.44	$0.43	$0.89
Benefit-to-Cost Ratio	3.4	2.8	1.9	1.8	1.7	2.3

Table 50: Cost Effectiveness Results for Selected Climate Zones (Large Office – Elec Baseline)

Parameter	CZ01	CZ03	CZ06	CZ07	CZ09	CZ12
Plant capacity (Btuh/sf)	22.0	20.9	17.1	15.6	17.8	21.1
Incremental gpm	146	139	114	104	118	140
Incremental pump cost ($/gpm)	$80	$80	$80	$80	$80	$80
Incremental pump cost ($)	$11,726	$11,152	$9,096	$8,322	$9,491	$11,243
Incremental pump cost ($/ft2)	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02
Incremental pipe cost 30dT to 25dT ($/ft2)	$0.08	$0.08	$0.08	$0.08	$0.08	$0.08
Total incremental cost ($/ft2)	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10
Energy savings ($/ft2)	$0.79	$0.62	$0.30	$0.25	$0.32	$0.54
Net lifecycle savings ($/ft2)	$0.69	$0.52	$0.20	$0.15	$0.22	$0.43
Benefit-to-Cost Ratio	7.6	6.1	3.1	2.6	3.3	5.2

Table 51: Cost Effectiveness Results for Selected Climate Zones (Medium Office – Gas Baseline)

Parameter	CZ01	CZ03	CZ06	CZ07	CZ09	CZ12
Plant capacity (Btuh/sf)	22.8	21.4	15.0	12.8	17.1	22.7
Plant capacity (KBH)	1,224	1,148	806	687	915	1,218
Incremental boiler cost ($/KBH)	$20.72	$20.72	$20.72	$20.72	$20.72	$20.72
Incremental boiler cost ($)	$25,362	$23,789	$16,698	$14,235	$18,956	$25,232
Incremental boiler cost ($/ft2)	$0.47	$0.44	$0.31	$0.27	$0.35	$0.47
Incremental gpm	37	34	24	21	27	37
Incremental pump cost ($/gpm)	$136	$136	$136	$136	$136	$136
Incremental pump cost ($)	$5,010	$4,699	$3,298	$2,812	$3,744	$4,984
Incremental pump cost ($/ft2)	$0.09	$0.09	$0.06	$0.05	$0.07	$0.09
Incremental pipe cost 40dT to 25dT ($/ft2)	$0.16	$0.16	$0.16	$0.16	$0.16	$0.16
Total incremental cost ($/ft2)	$0.73	$0.69	$0.53	$0.48	$0.58	$0.72
Energy savings ($/ft2)	$2.43	$1.75	$0.96	$0.87	$0.96	$1.57
Net lifecycle savings ($/ft2)	$1.71	$1.06	$0.42	$0.39	$0.37	$0.85
Benefit-to-Cost Ratio	3.3	2.5	1.8	1.8	1.6	2.2

Table 52: Cost Effectiveness Results for Selected Climate Zones (Medium Office – Elec Baseline)

Parameter	CZ01	CZ03	CZ06	CZ07	CZ09	CZ12
Plant capacity (Btuh/sf)	22.8	21.4	15.0	12.8	17.1	22.7
Incremental gpm	16	15	11	9	12	16
Incremental pump cost ($/gpm)	$136	$136	$136	$136	$136	$136
Incremental pump cost ($)	$2,227	$2,088	$1,466	$1,250	$1,664	$2,215
Incremental pump cost ($/ft2)	$0.04	$0.04	$0.03	$0.02	$0.03	$0.04
Incremental pipe cost 30dT to 25dT ($/ft2)	$0.07	$0.07	$0.07	$0.07	$0.07	$0.07
Total incremental cost ($/ft2)	$0.11	$0.11	$0.10	$0.09	$0.10	$0.11
Energy savings ($/ft2)	$0.89	$0.58	$0.27	$0.22	$0.30	$0.56
Net lifecycle savings ($/ft2)	$0.78	$0.47	$0.17	$0.13	$0.19	$0.44
Benefit-to-Cost Ratio	8.0	5.3	2.7	2.4	2.9	5.0

This measure proposes a mandatory requirement. As such, a cost analysis is required to demonstrate that the measure is cost effective over the 30-year period of analysis.

The CEC establishes the procedures for calculating cost effectiveness. The Statewide CASE Team collaborated with CEC staff to confirm that the methodology in this report is consistent with their guidelines, including which costs were included in the analysis. The incremental first cost and incremental maintenance costs over the 30-year period of analysis were included. The LSC savings from electricity and natural gas savings were also included in the evaluation. Design costs were not included nor were the incremental costs of code compliance verification.

According to the CEC's definitions, a measure is cost effective if the benefit-to-cost (B/C) ratio is greater than 1.0. The B/C ratio is calculated by dividing the cost benefits realized over 30 years by the total incremental costs, which includes maintenance costs for 30 years. The B/C ratio was calculated using 2026 PV costs and cost savings.

Results of the per-unit cost-effectiveness analyses are presented in Table 53 and Table 54 for new construction/additions and alterations, respectively.

The proposed measure saves money over the 30-year period of analysis relative to the existing conditions. The proposed code change is cost effective in every climate zone.

Table 53: 30-Year Cost-Effectiveness Summary Per Square Foot – New Construction/Additions – Hot Water Supply Temperature Limit (Gas Baseline)

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	2.56	0.61	4.17
2	1.91	0.52	3.65
3	1.83	0.54	3.40
4	1.70	0.56	3.04
5	1.91	0.60	3.17
6	1.09	0.45	2.45
7	1.19	0.40	2.98
8	0.95	0.44	2.15
9	1.05	0.48	2.20
10	1.34	0.44	3.08
11	1.33	0.43	3.07
12	1.60	0.54	2.98
13	1.23	0.39	3.14
14	1.55	0.54	2.87
15	1.11	0.51	2.18
16	1.92	0.52	3.68

a. Benefits: LSC savings + Other PV Savings: Benefits include LSC savings over the period of analysis (Ming, et al. 2016) (California Energy Commission 2022). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

b. Costs: Total Incremental Present Valued Costs: Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) three percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

Table 54: 30-Year Cost-Effectiveness Summary Per Square Foot – Alterations – Hot Water Supply Temperature Limit (Gas Baseline)

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	2.63	0.55	4.80
2	2.01	0.56	3.58
3	1.72	0.50	3.44
4	1.73	0.56	3.06
5	2.05	0.59	3.49
6	1.17	0.44	2.64
7	1.12	0.42	2.69
8	1.05	0.44	2.37
9	1.10	0.46	2.42
10	1.19	0.44	2.69
11	1.82	0.54	3.37
12	1.72	0.54	3.17
13	1.57	0.44	3.53
14	1.48	0.50	2.95
15	0.95	0.46	2.08
16	1.87	0.50	3.77

a. Benefits: LSC savings + Other PV Savings: Benefits include LSC savings over the period of analysis (Ming, et al. 2016) (California Energy Commission 2022). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

b. Costs: Total Incremental Present Valued Costs: Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) three percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

Table 55: 30-Year Cost-Effectiveness Summary Per Square Foot – New Construction/Additions – Hot Water Supply Temperature Limit (Electric Baseline)

Climate Zone	Benefits LSC Savings + Other PV Savings[a] (2026 PV$)	Costs Total Incremental PV Costs[b] (2026 PV$)	Benefit-to-Cost Ratio
1	1.05	0.10	10.77
2	0.83	0.09	9.53
3	0.70	0.09	7.93
4	0.67	0.09	7.56
5	0.74	0.09	7.78
6	0.37	0.08	4.49
7	0.49	0.08	6.39
8	0.34	0.08	4.19
9	0.38	0.08	4.46
10	0.57	0.08	7.43
11	0.56	0.07	8.16
12	0.64	0.08	7.71
13	0.53	0.06	8.16
14	0.62	0.08	7.29
15	0.46	0.08	5.40
16	0.80	0.08	9.92

a. **Benefits: LSC savings + Other PV Savings:** Benefits include LSC savings over the period of analysis (California Energy Commission 2022). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of the CASE analysis period.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) three percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the Benefit-to-Cost ratio is infinite.

Table 56: 30-Year Cost-Effectiveness Summary Per Square Foot – Alterations – Hot Water Supply Temperature Limit (Electric Baseline)

Climate Zone	Benefits LSC savings + Other PV Savings[a] (2026 PV$)	Costs Total Incremental PV Costs[b] (2026 PV$)	Benefit-to-Cost Ratio
1	1.16	0.09	12.94
2	0.87	0.09	9.92
3	0.66	0.09	7.42
4	0.69	0.09	7.44
5	0.83	0.09	8.99
6	0.41	0.08	4.89
7	0.44	0.08	5.25
8	0.39	0.08	4.68
9	0.41	0.08	4.84
10	0.48	0.08	6.18
11	0.80	0.08	9.82
12	0.70	0.08	8.30
13	0.70	0.07	9.65
14	0.59	0.08	7.26
15	0.39	0.08	5.13
16	0.77	0.08	9.41

a. **Benefits: LSC savings + Other PV Savings:** Benefits include LSC savings over the period of analysis (California Energy Commission 2022). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of the CASE analysis period.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) three percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the Benefit-to-Cost ratio is infinite.

2.5 First-Year Statewide Impacts

2.5.1 Statewide Energy and Energy Cost Savings

The Statewide CASE Team calculated the first-year statewide savings for new construction and additions by multiplying the per-unit savings, which are presented in Section 2.3.2, by assumptions about the percentage of newly constructed buildings that would be impacted by the proposed code. The statewide new construction forecast for 2026 is presented in Appendix A, as are the Statewide CASE Team's assumptions about the percentage of new construction that would be impacted by the proposal (by climate zone and building type). As noted above, since both an electric and gas baseline were analyzed, it was assumed that the statewide construction forecast would be split in a manner consistent with the percentage of local jurisdictions that have adopted all-electric reach codes, which is approximately 20 percent of the state as of early 2023.

The methodology for estimating savings in alterations is the same as for new construction. The main driver of savings, i.e., the reduced losses in the distribution network from a lower HWST, is consistent across NC and alterations.

The first-year energy impacts represent the first-year annual savings from all buildings that were completed in 2026. The 30-year energy cost savings represent the energy cost savings over the entire 30-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

The tables below presents the first-year statewide energy and energy cost savings from newly constructed buildings and additions (Table 57) and alterations (Table 58) by climate zone for the gas baseline. Table 59 presents first-year statewide savings from new construction, additions, and alterations for the gas baseline. This data is repeated for the electric baseline in Table 60, Table 61, and

Table 62. The natural gas and electric cases are combined in these tables. The Statewide CASE Team assumed that since 30 percent of the state population lives within jurisdictions that require all-electric space heating (due to local all-electric reach code adoptions, calculated using localenergycodes.com), 30 percent of the floor area would apply to the electric case and 60 percent of the floor area would apply to the gas case (we assumed that the remaining 10 percent of floor area for in-scope prototypes would not use hydronics). Since the gas case only includes natural gas savings and the electric case only includes electricity and peak demand savings, these columns in the tables only reflect the impacts of each respective modeling case. Source energy and energy cost savings are combined.

While a statewide analysis is crucial to understanding broader effects of code change proposals, there is potential to disproportionately impact specific populations that needs to be considered. Refer to Section 2.6 for more details addressing energy equity and environmental justice.

Table 57: Statewide Energy and Energy Cost Impacts – New Construction and Additions (Gas Baseline)

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Million Square Feet)	First-Year[a] 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 Energy Cost Savings (Million 2026 PV$)
1	126,032	0	0	0	1	$0.32
2	640,766	0	0	0	2	$1.23
3	4,661,572	0	0	0	14	$8.51
4	2,348,110	0	0	0	6	$4.00
5	366,812	0	0	0	1	$0.70
6	2,531,101	0	0	0	4	$2.76
7	2,127,305	0	0	0	4	$2.54
8	3,914,863	0	0	0	6	$3.74
9	6,768,889	0	0	0	11	$7.12
10	2,420,554	0	0	0	5	$3.25
11	656,376	0	0	0	1	$0.87
12	3,870,376	0	0	0	10	$6.19
13	1,070,083	0	0	0	2	$1.32
14	642,714	0	0	0	2	$0.99
15	372,869	0	0	0	1	$0.41
16	193,291	0	0	0	1	$0.37
Total	32,711,715	0	0	1	71	$44.33

a. First-year savings from all buildings completed statewide in 2026.

Table 58: Statewide Energy and Energy Cost Impacts – Alterations (Gas Baseline)

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Million Square Feet)	First-Year[a] 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 Energy Cost Savings (Million 2026 PV$)
1	158,107	0	0	0	1	$0.42
2	1,280,686	0	0	0	4	$2.57
3	8,877,000	0	0	0	25	$15.30
4	4,047,400	0	0	0	11	$7.00
5	545,780	0	0	0	2	$1.12
6	5,321,400	0	0	0	10	$6.23
7	4,715,600	0	0	0	8	$5.27
8	8,226,000	0	0	0	14	$8.63
9	14,264,200	0	0	0	25	$15.68
10	5,482,800	0	0	0	10	$6.52
11	964,600	0	0	0	3	$1.75
12	6,747,540	0	0	0	19	$11.59
13	1,936,938	0	0	0	5	$3.03
14	1,380,340	0	0	0	3	$2.04
15	667,184	0	0	0	1	$0.64
16	417,860	0	0	0	1	$0.78
Total	65,033,435	0	0	2	142	$88.57

a. First-year savings from all buildings completed statewide in 2026.

Table 59: Statewide Energy and Energy Cost Impacts – New Construction, Additions, and Alterations (Gas Baseline)

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 Energy Cost Savings (PV$ Million)
New Construction & Additions	0	0	0.79	71.13	$44.33
Alterations	0	0	1.58	142.25	$88.57
Total	0	0	2.36	213.38	$132.91

Table 60: Statewide Energy and Energy Cost Impacts – New Construction and Additions (Electric Baseline)

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Million Square Feet)	First-Year[a] 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 Energy Cost Savings (Million 2026 PV$)
1	63,016	0.01	0.00	0	0.02	$0.07
2	320,383	0.04	0.01	0	0.09	$0.26
3	2,330,786	0.26	0.04	0	0.57	$1.62
4	1,174,055	0.13	0.02	0	0.30	$0.79
5	183,406	0.02	0.00	0	0.05	$0.14
6	1,265,551	0.08	0.01	0	0.17	$0.46
7	1,063,653	0.08	0.01	0	0.20	$0.53
8	1,957,432	0.11	0.02	0	0.26	$0.67
9	3,384,444	0.21	0.04	0	0.50	$1.27
10	1,210,277	0.11	0.02	0	0.25	$0.68
11	328,188	0.03	0.01	0	0.07	$0.18
12	1,935,188	0.20	0.04	0	0.48	$1.24
13	535,042	0.05	0.01	0	0.11	$0.28
14	321,357	0.03	0.01	0	0.08	$0.20
15	186,435	0.01	0.00	0	0.03	$0.09
16	96,645	0.01	0.00	0	0.03	$0.08
Total	16,355,857	1.39	0.24	0	3.22	$8.56

Table 61: Statewide Energy and Energy Cost Impacts – Alterations (Electric Baseline)

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Million Square Feet)	First-Year[a] 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 Energy Cost Savings (Million 2026 PV$)
1	79,054	0.02	0.00	0	0.03	$0.09
2	640,343	0.09	0.01	0	0.20	$0.56
3	4,438,500	0.47	0.07	0	1.02	$2.92
4	2,023,700	0.23	0.04	0	0.52	$1.39
5	272,890	0.04	0.01	0	0.08	$0.23
6	2,660,700	0.18	0.03	0	0.40	$1.09
7	2,357,800	0.15	0.02	0	0.39	$1.03
8	4,113,000	0.27	0.05	0	0.62	$1.62
9	7,132,100	0.48	0.09	0	1.12	$2.92
10	2,741,400	0.21	0.04	0	0.49	$1.31
11	482,300	0.06	0.01	0	0.15	$0.38
12	3,373,770	0.39	0.07	0	0.91	$2.38
13	968,469	0.11	0.02	0	0.25	$0.67
14	690,170	0.07	0.01	0	0.16	$0.41
15	333,592	0.02	0.00	0	0.05	$0.13
16	208,930	0.03	0.00	0	0.06	$0.16
Total	32,516,718	2.82	0.49	0	6.46	$17.30

Table 62: Statewide Energy and Energy Cost Impacts – New Construction, Additions, and Alterations (Electric Baseline)

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 Energy Cost Savings (PV$ Million)
New Construction & Additions	1.39	0.24	0.00	3.22	$8.56
Alterations	2.82	0.49	0.00	6.46	$17.30
Total	4.21	0.73	0.00	9.68	$25.86

2.5.2 Statewide Greenhouse Gas (GHG) Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions associated with energy consumption using the hourly GHG emissions factors that CEC developed along with the 2025 LSC hourly factors and an assumed cost of $123.15 per metric tons of carbon dioxide equivalent emissions (metric tons CO2e) (California Energy Commission 2022).

The 2025 LSC hourly factors used in the lifecycle cost-effectiveness analysis include the monetary value of avoided GHG emissions based on a proxy for permit costs (not social costs).[11] The Cost-Effectiveness Analysis presented in Section 2.4 of this report does not include the cost savings from avoided GHG emissions. To demonstrate the cost savings of avoided GHG emissions, the Statewide CASE Team disaggregated the value of avoided GHG emissions from the other economic impacts. The authors used the same monetary values that are used in the LSC hourly factors.

Table 63 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 4,871 (metric tons CO2e) would be avoided.

Table 63: First-Year Statewide GHG Emissions Impacts

Measure	Electricity Savings[a] (GWh/yr)	Reduced GHG Emissions from Electricity Savings[a] (Metric Tons CO2e)	Natural Gas Savings[a] (Million Therms/yr)	Reduced GHG Emissions from Natural Gas Savings[a] (Metric Tons CO2e)	Total Reduced GHG Emissions[b] (Metric Ton CO2e)	Total Monetary Value of Reduced GHG Emissions[c] ($)
Limit HWST – G to G	0	0	2	12,920	12,920	1,591,007
Limit HWST – E to E	4.21	512	0.00	0	512	63,102
TOTAL	4.21	512	2	12,920	13,432	1,654,109

a. First-year savings from all buildings completed statewide in 2026.

b. GHG emissions savings were calculated using hourly GHG emissions factors are published alongside the in the LSC hourly factors and Source Energy factors by CEC here: https://www.energy.ca.gov/files/2025-energy-code-hourly-factors

c. The monetary value of avoided GHG emissions is based on a proxy for permit costs (not social costs) derived from the 2022 TDV Update Model published by CEC here: https://www.energy.ca.gov/files/tdv-2022-update-model

[11] The permit cost of carbon is equivalent to the market value of a unit of GHG emissions in the California Cap-and-Trade program, while social cost of carbon is an estimate of the total economic value of damage done per unit of GHG emissions. Social costs tend to be greater than permit costs. See more on the Cap-and-Trade Program on the California Air Resources Board website: https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program.

2.5.3 Statewide Water Use Impacts

The proposed code change will not result in water savings.

2.5.4 Statewide Material Impacts

This measure is not expected to result in a meaningful change to materials. Building hydronic distribution systems would be expected to include slightly more material (e.g., steel, iron, copper) to account for larger pipe diameter were this measure to be adopted.

2.5.5 Other Non-Energy Impacts

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

2.6 Addressing Energy Equity and Environmental Justice

The Statewide CASE Team recognizes, acknowledges, and accounts for a history of prejudice and inequality in disproportionately impacted populations (DIPs) and the role this history plays in the environmental justice issues that persist today. DIPs refer to the populations throughout California that most suffer from a combination of economic, health, and environmental burdens. These burdens include poverty, high unemployment, air and water pollution, presence of hazardous wastes, as well as high incidence of asthma and heart disease. DIPs also incorporate race, class, and gender since these intersecting identity factors affect how people frame issues, interpret, and experience the world.[12] While the term disadvantaged communities (DACs) is often used in the energy industry and state agencies, the Statewide CASE Team chose to use terminology that is more acceptable to and less stigmatizing for those it seeks to describe (DC Fiscal Policy Institute 2017).

Including impacted communities in the decision-making process, ensuring that the benefits and burdens of the energy sector are evenly distributed, and facing the unjust legacies of the past serve as critical steps to achieving energy equity. To minimize the risk of perpetuating inequity, code change proposals are being developed with intentional consideration of the unintended consequences of proposals on DIPs.

The Statewide CASE Team recognizes the importance of engaging DIPs and gathering their input to inform the code change process and proposed measures. A participatory approach allows individuals to address problems, develop innovative ideas, and bring

[12] Environmental disparities have been shown to be associated with unequal harmful environmental exposure correlated with race/ethnicity, gender, and socioeconomic status. For example, chronic diseases, such as respiratory diseases, cardiovascular disease, and cancer, associated with environmental exposure have been shown to occur in higher rates in the LGBTQ+ population than in the cisgender, heterosexual population (Goldsmith L 2022). Socioeconomic inequities, climate, energy, and other inequities are inextricably linked and often mutually reinforcing.

forth a different perspective. The Statewide CASE Team is working to build relationships with community-based organizations (CBOs) to facilitate meaningful engagement with stakeholders and gather feedback on the proposed measures. Please reach out to Bryan Boyce (bboyce@energy-solution.com), Nancy Metayer (nmetayer@energy-solution.com) and Marissa Lerner (mlerner@energy-solution.com) for further engagement.

2.6.1 Potential Impacts

The Statewide CASE Team considered the impacts of the proposal on DIPs using five criteria: cost, health, disaster preparedness, safety, and comfort. The intent of this measure is to facilitate all-electric space heating through the requirement of lower HWSTs, the overriding viewpoint is that this measure will positively impact all building occupants including DIPs through the reduction of on-site pollution emissions caused by natural gas combustion.

This measure would require lower hot water supply temperatures in hydronic space heating applications. The proposal would likely impact piping and pump firsts costs, but these costs would be offset by ongoing energy efficiency benefits through the reduction in thermal losses in the distribution network. As noted, the purpose of the measure is to facilitate all-electric space heating, which again, is viewed as having positive benefits to all building occupants.

There are incremental costs for the proposals (e.g., larger diameter pipes and larger coils which cost more, though recall that our analysis showed that larger coils are not necessary), but there are also energy efficiency benefits (e.g., reduced thermal losses through the hot water pipe network). Both these costs and energy cost savings benefits are relatively minor, and DIPs will not be adversely impacted by this proposal.

Impacts may vary by building type. Offices of all sizes, for example, are expected to be used by all people equally and DIPs are not more or less likely to occupy office spaces than any other population. So, the proposed change is not expected to have an unequal impact on DIPs. The Statewide CASE Team identified schools and hotels as building types that may have disproportional impacts. These building types are discussed below.

2.6.2 Potential Disproportionately Impacted Populations

Proposed code changes have the potential to have an unequal effect on people attending school and working at schools in locations where there are DIPs. Proposed code changes that impact health, disaster preparedness, safety, and comfort especially all have the potential to disproportionately impact those who attend or work in schools. In addition, increased costs for building new schools or renovating schools can present challenges to jurisdictions with lower income populations where the tax base, funding, and budgets may be more constrained.

Proposed code changes to the hotel building type have the potential to disproportionately impact populations for those who work in the hospitality industry, use hotels as a means of temporary housing, or might use hotels for refuge during an extreme weather event (disaster preparedness). Proposed code changes that impact health, disaster preparedness especially have the potential to disproportionately impact those working or residing in hotels. While the costs may increase for this nonresidential building type, the burden of that cost is unlikely to impact DIPs.

3. Condenser Heat Recovery and Thermal Energy Storage

3.1 Measure Description

3.1.1 Proposed Code Change

The measure is being pursued as a prescriptive addition to Section 140.4(r) and would apply to newly constructed large buildings pursuing all-electric space heating. The new prescriptive code language is needed to ensure that large buildings pursuing all-electric space heating do so efficiently, with the specific goal of ensuring that building waste heat is leveraged in a way to minimize the installed capacity of air source heat pump equipment. Large buildings would have challenges meeting their space heating needs solely with air source heat pumps due to space, cost, and efficiency barriers. The proposal includes requirements for thermal energy storage and/or heat recovery equipment depending on how well that cooling and heating loads overlap. For buildings with low overlapping loads, the thermal energy storage requirement is intended to store waste heat from when the building is in cooling mode so that it can be re-used later when the building is in heating mode.

The measure also proposes changes to the ACM Reference Manual rulesets to accommodate the new prescriptive requirements being proposed. For example, the ACM Reference Manual currently does not contain rulesets to model dedicated heat recovery chillers or thermal energy storage oriented toward space heating.

3.1.2 Justification and Background Information

3.1.2.1 Justification

For small and medium size commercial buildings, a variety of existing heat pump-based solutions exist on the market. These options include unitary single zone ASHPs and variable refrigerant flow systems. However, large commercial buildings have been considered harder to electrify due to space and equipment capacity issues. The early emerging default all-electric hydronic system consists of air-to-water heat pumps supplying hot water sized to meet the building’s peak heating load. Even if legacy design practices around space heating – including designing to ultra-hot water temperatures (e.g., 140°F or higher) and oversizing the system design capacity, as was commonly done with natural gas boilers – are overcome, the resulting system is still unattractive for several reasons. First, the space requirement for AWHPs is typically significant and may be hard to achieve in dense urban areas. Second, the efficiency of an AWHP delivering a HWST of 120°F is in the 2.0 to 2.5 COP range at a heating design temperature of 30°F (this would be even lower in climate zone 16 where design temperatures are generally lower than 20°F). Third, an AWHP system sized to meet heating demand is expensive.

Despite its drawbacks, AWHP systems serving hydronic reheat are being promoted as an all-electric option for large buildings. This measure seeks to improve upon the default AWHP system that is typically installed in large buildings when all-electric solutions are pursued. The Statewide CASE Team surveyed the literature and market of available designs and have concluded that the inclusion of concepts such as condenser water thermal energy storage and dedicated heat recovery chillers are critical components of an efficient and cost-effective all electric hydronic system design. Determining the specific requirements and triggers around heat recovery chiller sizing and when a TES tank should be specified was the focus of this measure.

3.1.2.2 Background Information

Interest in all-electric HVAC systems for commercial new construction has been sharply growing in recent years. Evidence of this trend can be found in the adoption of all-electric reach codes by local jurisdictions. Based on localenergycodes.com, between 2019 and early 2023, jurisdictions representing roughly 11 million Californians, or 28 percent of the state population have enacted all-electric reach codes. Most of this activity is centered around the Bay Area (including San Francisco) and southern California (including Los Angeles), making this a statewide trend. In addition, indications from government agencies such as the California Air Resources Board (CARB) have indicated potential upcoming regulations to set emissions-based standards for residential space heating appliances by 2030 (i.e., a zero on-site emissions limit, which would only be achievable with electric-powered equipment), with commercial equipment likely following at a later date (California Air Resources Board 2022). The underlying message is clear: all-electric space heating systems are poised to become extremely popular in California in the coming years. Large buildings face unique challenges when pursuing all-electric space heating due to the need for significant space requirements of air to water heat pump (when serving hydronic heating) or other types of air source heat pumps if other systems are used. System configurations that include heat recovery and thermal energy storage can effectively shrink the capacity of air source equipment. This can save significant roof space and reduce upfront costs due to reduced ASHP equipment capacity needs. In addition, the plant efficiency (including chillers, heaters, heat rejection, and pumping) can increase by 20-40 percent relative to an all two-pipe AWHP and water-cooled chiller (WCC) system. The result is that Title 24 Part 6 has a unique opportunity to steer designers and installers toward the most efficient and cost-effective options available on the market, as the all-electric commercial building stock is starting to be constructed.

3.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manuals, and compliance forms would be modified by the proposed change.[13] See Section 5 of this report for detailed proposed revisions to code language.

3.1.3.1 Specific Purpose and Necessity of Proposed Code Changes

Each proposed change to language in Title 24, Part 1 and Part 6 as well as the reference appendices to Part 6 are described below. See Section 5.2 of this report for marked-up code language.

Section: 140.4(r)1

Specific Purpose: The specific purpose is to require the use of heat recovery for large buildings with significant simultaneous cooling and heating loads pursuing all-electric space heating. Large buildings with significant overlapping cooling and heating loads can leverage cooling waste energy for heating, resulting in energy efficiency benefits and potentially enable equipment installed capacity reductions as well.

Necessity: This addition is necessary to increase energy efficiency via cost-effective building design standards, as mandated by the California Public Resources Code, Sections 25213 and 25402.

Section: 140.4(r)2

Specific Purpose: The specific purpose is to require the use of heat recovery and thermal energy storage for large buildings pursuing all-electric space heating. Thermal energy storage is needed to capture waste heat in buildings without significant overlapping cooling and heating loads. Waste heat is stored and re-used for space or service water heating later. This practice results in energy efficiency and is likely to result in equipment installed capacity reductions as well.

Necessity: This addition is necessary to increase energy efficiency via cost-effective building design standards, as mandated by the California Public Resources Code, Sections 25213 and 25402.

[13] Visit EnergyCodeAce.com for trainings, tools, and resources to help people understand existing code requirements.

Section: 140.4(r)3

Specific Purpose: The specific purpose is to require heat recovery be used for service hot water end-uses when above a certain threshold of service hot water capacity.

Necessity: This addition is necessary to increase energy efficiency via cost-effective building design standards, as mandated by the California Public Resources Code, Sections 25213 and 25402.

3.1.3.2 Specific Purpose and Necessity of Changes to the Nonresidential ACM Reference Manual

The purpose and necessity of proposed changes to the Nonresidential ACM Reference Manual are described below. See Section 5.4 of this report for the detailed proposed revisions to the text of the ACM Reference Manual.

Section: 5.8.8

Specific Purpose: The specific purpose is to revise the section describing thermal energy storage. Currently, the TES section is geared toward cooling peak reduction. The use of TES for space heating is not described in the ACM Reference Manual.

Necessity: These changes are necessary to add functionality to the ACM Reference Manual that would allow designers to take advantage of this technology when seeking compliance for all-electric hydronic space heating systems.

Section: 5.8.10 (new section)

Specific Purpose: The specific purpose is to add a section to the ACM Reference Manual that defines a hydronic heat recovery chiller object.

Necessity: These changes are necessary to add functionality to the ACM Reference Manual that would allow designers to take advantage of this technology when seeking compliance for all-electric hydronic space heating systems.

3.1.3.3 Summary of Changes to the Nonresidential & Multifamily Compliance Manual

Nonresidential and Multifamily Chapter 4 (Section 4.7 HVAC System Requirements) of the Nonresidential Compliance Manual would need to be revised. All-electric hydronic space heating systems are currently a less familiar option to many designers. The compliance manual would be updated in a way that contextualizes the new requirements being added in 140.4(r). The two new subsections are intended to separate out large building hydronic systems into two categories: those with large simultaneous cooling and heating loads, and those without. The prescriptive text should give designers all the tools needed to determine whether thermal energy storage is required for their design, but the compliance manual would further contextualize these requirements along with providing some example scenarios. The examples would touch space heating and service water heating to clearly illustrate the new prescriptive requirements and when they are triggered.

3.1.3.4 Summary of Changes to Compliance Forms

The proposed code change would most likely result in some modifications to the compliance forms. These changes include fields to determine whether the proper amount of thermal energy storage and/or if the correct amount of heat recovery capacity is specified in the design. Examples of the revised forms are presented in Section 5.5.

3.1.4 Regulatory Context

3.1.4.1 Determination of Inconsistency or Incompatibility with Existing State Laws and Regulations

There are no relevant state or local laws or regulations.

3.1.4.2 Duplication or Conflicts with Federal Laws and Regulations

There are no relevant federal laws or regulations.

3.1.4.3 Difference From Existing Model Codes and Industry Standards

ASHRAE 90.1-2022 includes two prescriptive measures that are related to this proposal. These measures are 6.5.6.2 Heat Recovery for Service Water Heating and 6.5.6.3 Heat Recovery for Space Conditioning. Our heat recovery measure is intended to cover a broader range of cases than what is specified in these measures. For example, 6.5.6.3 covers hydronic heat recovery for acute inpatient hospitals, whereas our measure sets a condition of simultaneous cooling and heating loads and then any building type that meets it would be covered.

3.1.5 Compliance and Enforcement

When developing this proposal, the Statewide CASE Team considered methods to streamline the compliance and enforcement process and how negative impacts on market actors who are involved in the process could be mitigated or reduced. This section describes how to comply with the proposed code change. It also describes the compliance verification process. Appendix E presents how the proposed changes could impact various market actors.

The compliance verification activities related to this measure that need to occur during each phase of the project are described below:

- **Design Phase:** The requirement for hydronic heat recovery and thermal energy storage would require new design strategies. Workforce education around equipment sizing and HVAC controls configuration would be needed.
- **Permit Application Phase:** The design phase changes affect the energy consultant and the permit application process. Energy consultants often inform the design team of these requirements and work with them on how best to incorporate into their design. Energy Consultants also need training to understand the energy code changes. Documentation will need to be revised to properly demonstrate compliance.
- **Construction Phase:** Minor changes to this phase are expected from this measure. The novelty of this measure is not with the types of equipment being required but instead their configuration. Most aspects of construction would look the same before and after this measure. Large volume thermal energy storage tanks to reduce peak space heating demand are not common today but are relatively straightforward pieces of equipment to install.
- **Inspection Phase:** Changes to the inspection phase are expected to be minor. Inspectors would need to check that the necessary equipment has been installed as indicated by the prescriptive heat recovery and thermal energy storage requirements included in this measure.

3.2 Market Analysis

3.2.1 Current Market Structure

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. It then considered how the proposed standard may impact the market in general as well as individual market actors. Information was gathered about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, CEC staff, and a wide range of industry actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during a public stakeholder meeting that the Statewide CASE Team held on February 27, 2023.

The market structure of heat recovery systems and thermal energy storage systems can be considered separately, though both trends reinforce each other, and the best examples of projects leverage both techniques.

The most compelling system configuration is one that draws both from thermal energy storage and heat recovery. The principle is that large buildings tend to generate reasonable to significant amounts of heat year round, even in the winter. This internal building load generation in commercial buildings tends to be high. Daytime heating loads from people, data centers, and other processes can be stored overnight to be used for the next morning warm-up period. This diurnal trend should suffice to provide most of the heating loads in many California nonresidential buildings, with some ASHP backup for peak periods.

The California State University (CSU) system has committed to incorporating thermal energy storage and/or heat recovery into its campuses for decarbonization and teaching purposes (CSU 2019). The educational benefit of these actions far outweighs the efficiency benefits because thousands of engineering students statewide are being exposed to heat recovery and thermal energy storage concepts in their own buildings, making them familiar and comfortable with this technology when entering their careers. Many other university campuses throughout the state make sure of heat recovery in their campus HVAC systems as well.

Heat recovery without thermal energy storage has also gained traction. Over the past five years, key California HVAC distributors and designers have observed that the installation rate of heat recovery chillers has increased from almost negligible to a common occurrence, driven mainly by local all-electric reach code requirements and corporate and institutional decarbonization goals.

3.2.2 Technical Feasibility and Market Availability

All-electric hydronic space heating with condenser water storage is growing but is not yet widespread. Other types of commonly used TES systems include ice storage (see Figure 9), chilled water storage and hot water storage (see Figure 10). The different options have pros and cons. CALMAC produces a widely commercially available ice storage option that has been commercially available for decades, with thousands of successful installations. Ice thermal storage has the advantage of a lower footprint due to the latent capacity boost from freezing water (MacCracken 2020). Condenser water storage is an appealing option in the mild California climate (Gill 2021). Condenser water storage, ice storage and CHW/HW storage systems would all meet the proposed requirement.

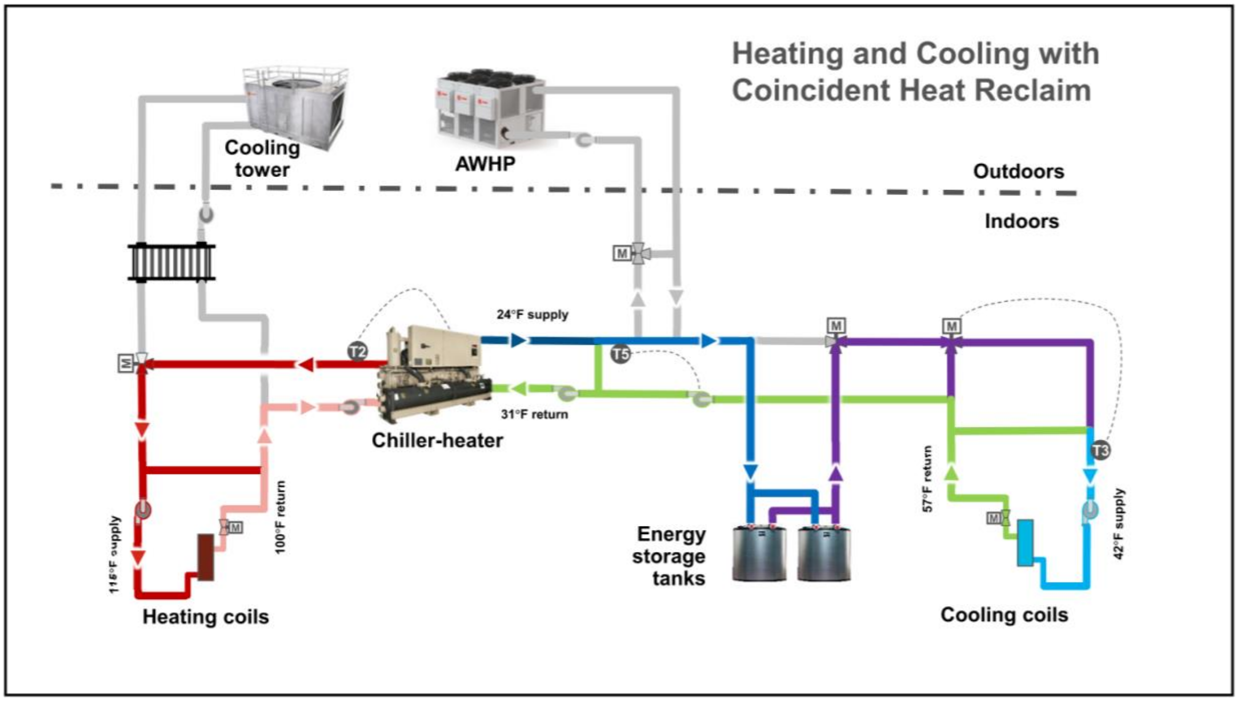


Figure 9: Schematic of Ice Storage TES System

Source: Trane seminar on Electrification of Cooling and Heating with Thermal Energy Storage, used with permission.

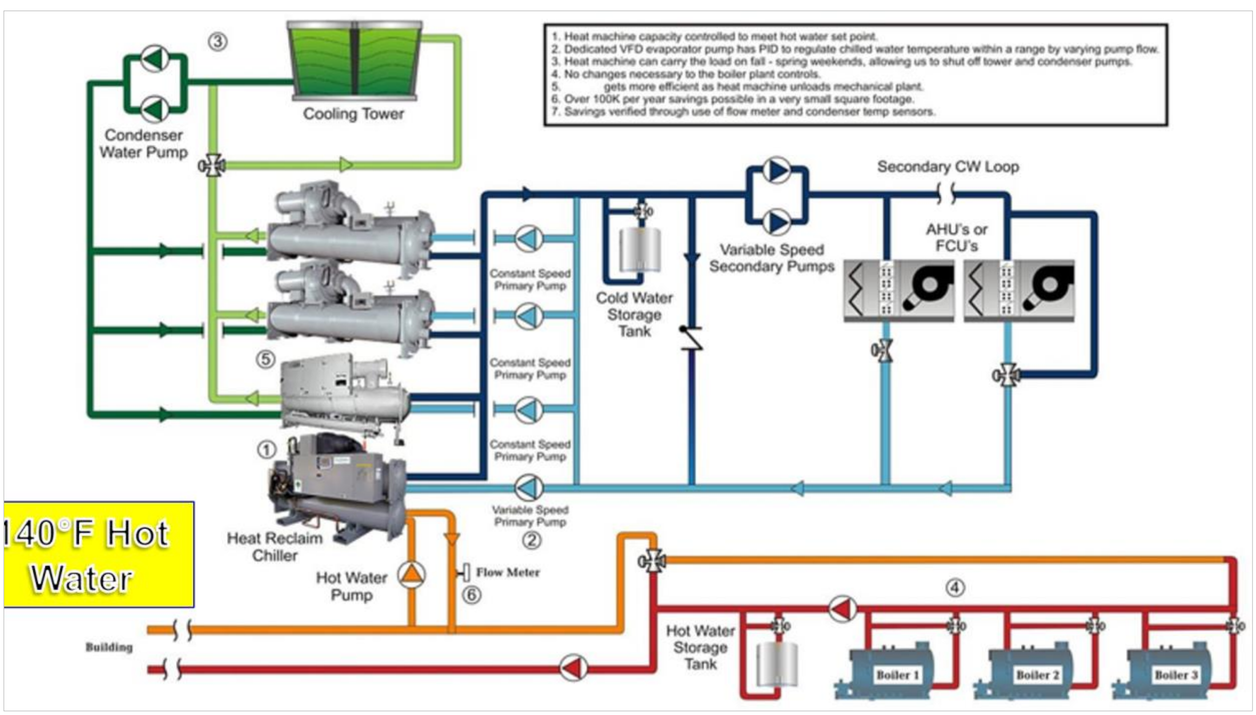


Figure 10: Schematic of CHW+HW Storage TES System

Source: Carrier seminar on All Electric Central Plant Design, used with permission

There are several types of condenser water storage systems that would meet the proposed TES requirement including:

1. TIER (Time Independent Energy Recovery)
2. Water-cooled VRF with TES
3. Water-source heat pumps (WSHP) with TES

These are all described in more detail below.

TIER systems

TIER systems typically include chilled water air handlers, VAV boxes with hot water reheat, and water-cooled heat recovery chillers. Additional heating is typically provided by air source heat pumps. Additional heat rejection is typically provided by water-cooled chillers served by cooling towers.

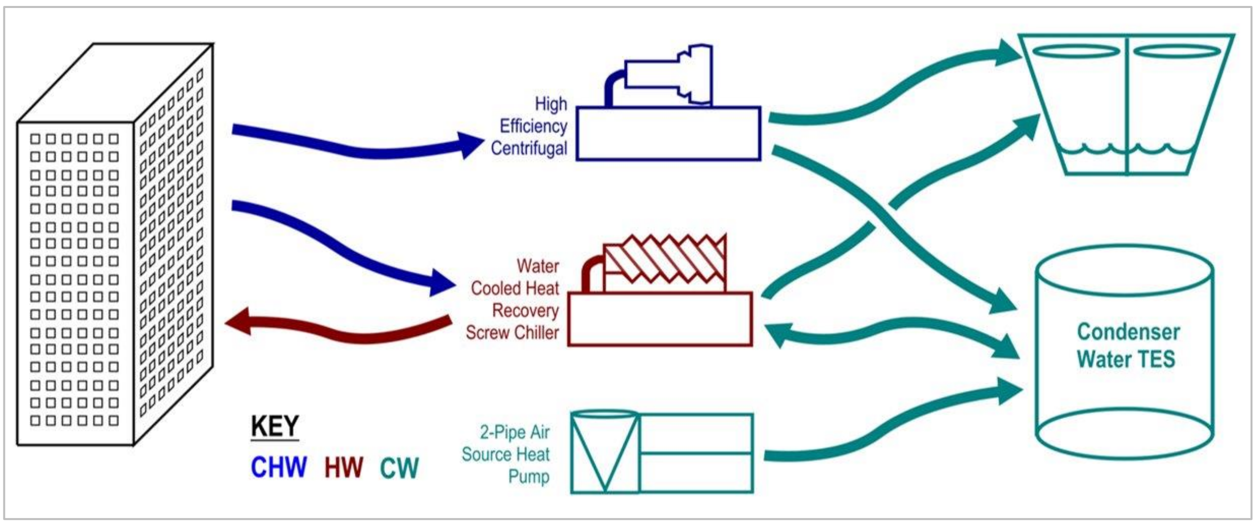


Figure 11: TIER Schematic
Source: (Gill 2021)

Water-cooled VRF with TES

Water-cooled VRF with TES (see Figure 12 for an example schematic) typically consists of VRF fan coils at each zone, water-cooled condensing units serving the fan coils, boilers or AWHPs to add heat to the tank, and fluid coolers, dry-coolers, or AWHPs to provide heat rejection.

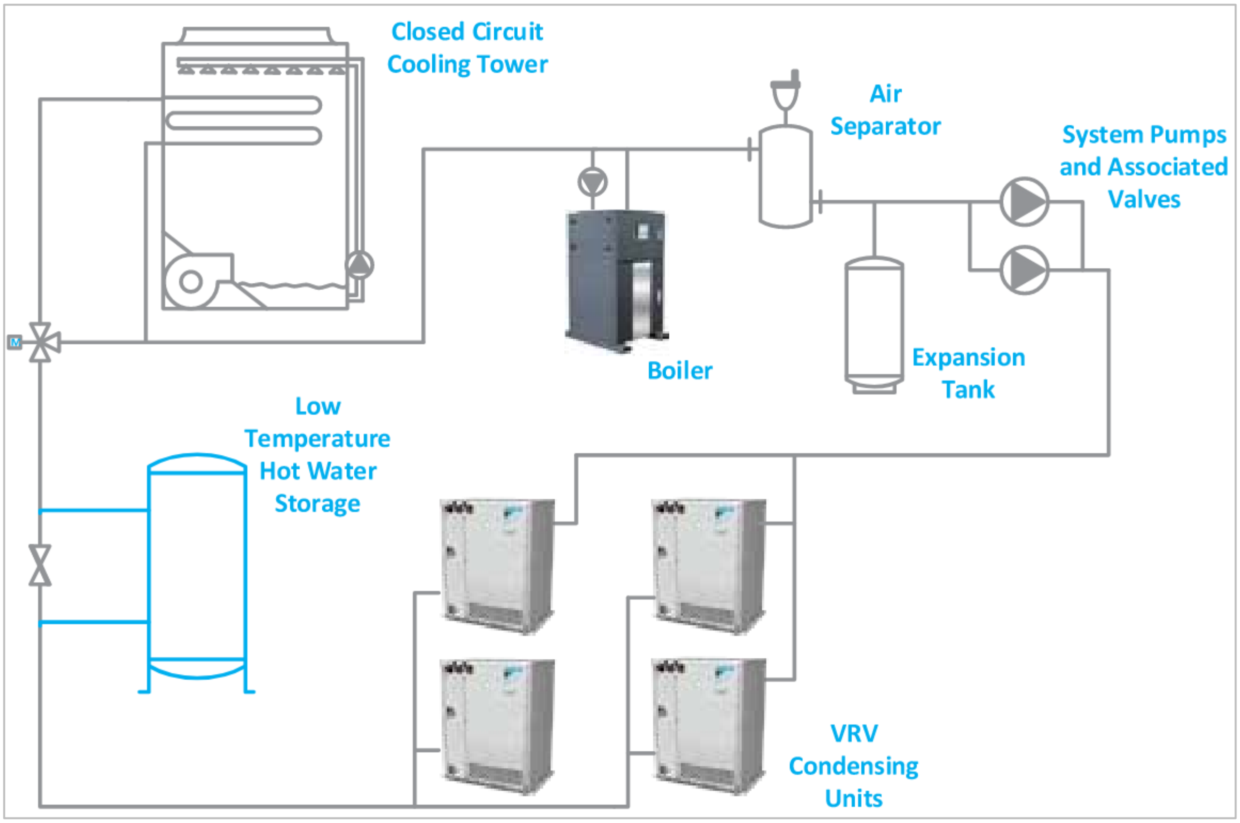


Figure 12: Water-Cooled VRF with TES

Source: Daikin, used with permission

Water-source heat pumps (WSHP) with TES

Water-source heat pumps (WSHP) with TES typically include water-source heat pumps at each zone served by a closed condenser water loop (CCW), boilers or AWHPs to provide heat, and AWHPs and/or cooling towers to provide heat rejection. Refer to Figure 13 and Figure 14 for schematics for this system type. Thousands of WSHP systems are in service throughout the state. Adding an additional thermal energy storage tank to this design is a minor tweak to the system, and simply adds some thermal buffer to the water loop.

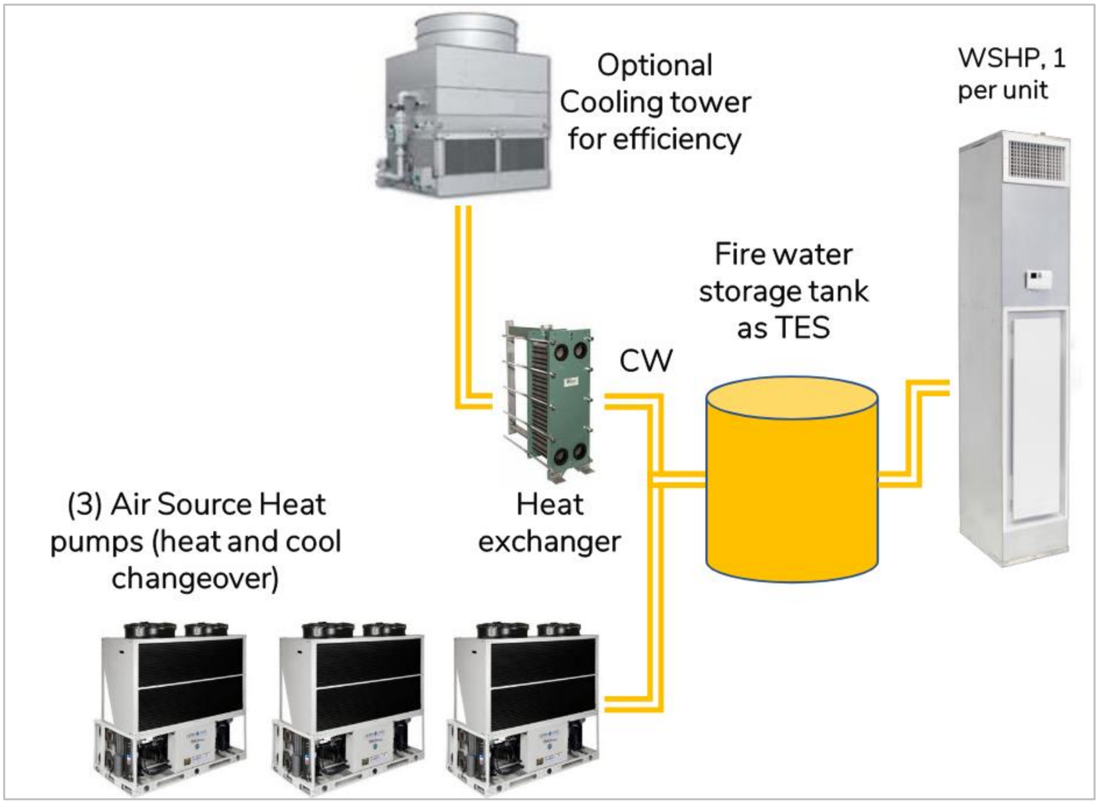


Figure 13: WSHP with TES Schematic

Source: Taylor Engineers

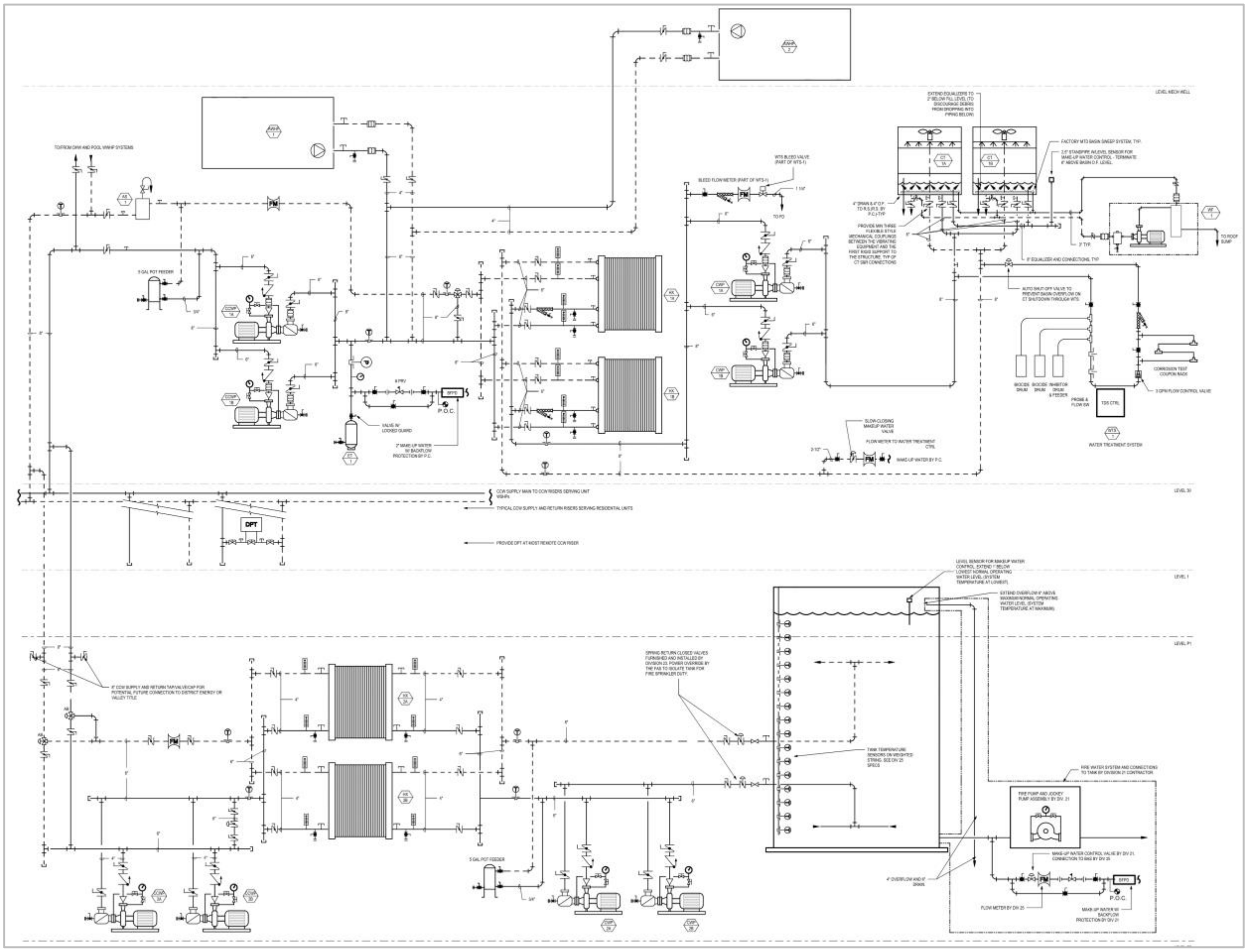


Figure 14: WSHP with TES Detailed Schematic

Source: Taylor Engineers

Note: This screenshot of a design drawing is high resolution and is intended to be viewed using the zoom function of PDF software. This guidance applies to all design drawings included in this report.

3.2.2.1 Understanding Condenser Water TIER

Condenser water TIER plants take heat rejected from cooling loads via high efficiency, low lift, centrifugal chillers and stores it in a TES tank at tepid temperatures between 60°F (16°C) and 80°F (27°C). Tank temperature excursions down to 40°F (4.4°C) are allowed on peak heating days to minimize tank size. When energy is needed for building heating, heat is extracted from the tank using water-to-water heat recovery chillers. In effect, the cooling chillers and heat recovery chillers are placed in a cascade configuration: the cooling chillers have a lift envelope of 40°F chilled water supply temperature to 80°F (27°C) condenser water leaving temperature, while the heat recovery chillers have a lift envelope of 60°F (16°C) evaporator supply temperature to the active hot water supply temperature setpoint, typically 110°F (43°C) to 140°F (60°C) for all-electric designs.

During most days in California's mild climate zones the energy recovered from cooling loads alone can satisfy heating loads. During the small fraction of the year when heat recovery alone cannot satisfy heating demand, trim ASHPs are used to charge the storage tank.

The schematics below show an example plant in a few typical modes of operation to illustrate the design concept. Flow paths for chilled water, condenser water, and hot water are traced in each.

Figure 15 illustrates a typical cold morning operation condition during which the TES tank discharges. All the red heat recovery chillers are in operation, supplying hot water to the building at 130°F (54°C) on the condenser side while extracting heat from the TES tank on the evaporator side. Any cooling loads that the building might have—e.g., due to 24/7 IT spaces, data centers, lab equipment, etc.—are concurrently addressed by a blue variable speed "cooling-only" machine. The condenser water rejected from this machine, which is 70°F (21°C) in this example, is then passed through the trim air source heat pumps, which act to boost the condenser water charging the top of the tank to 80°F (27°C). The amount of heat the blue cooling only chiller and the ASHPs are adding to the tank is less than the amount of heat the red heat recovery chillers are removing from the tank so on balance the tank is discharging (decreasing in temperature).

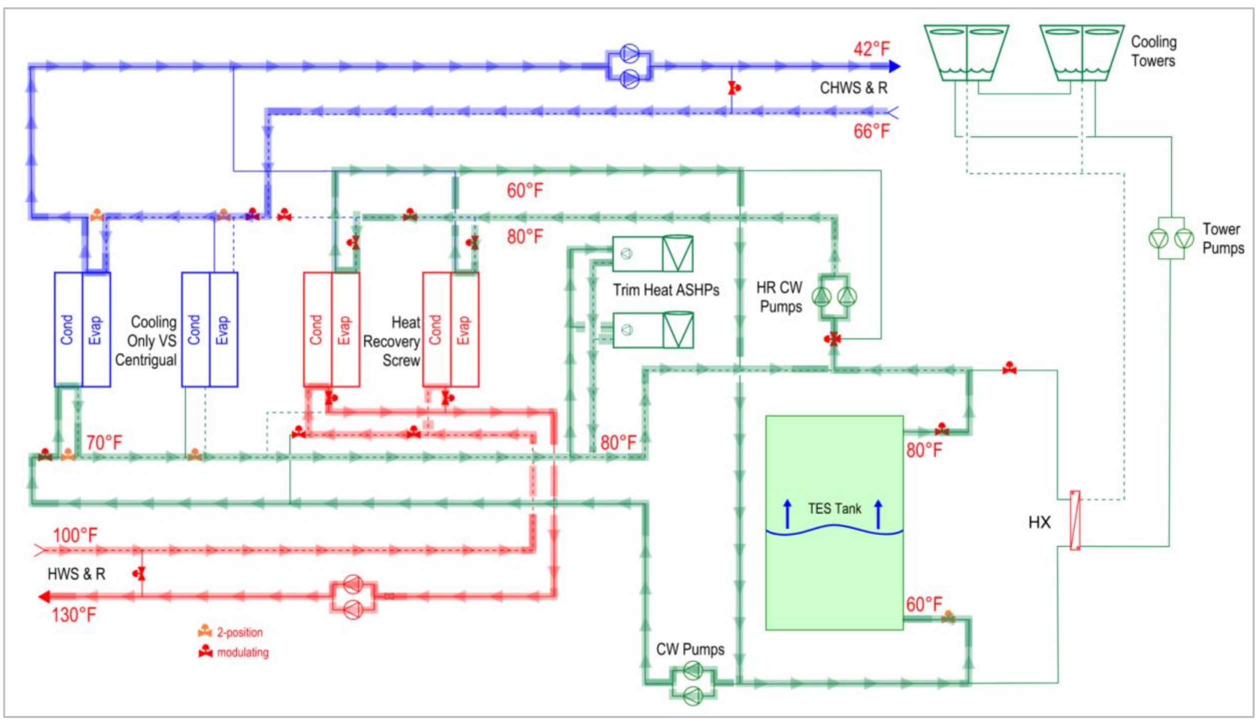


Figure 15: Cool Day Morning Operation of a Condenser Water TIER System

Later during the same day, when heating loads decrease and cooling loads increase, the net result is that the tank charges (increasing in temperature). During the example condition in

Figure 16, only one red heat recovery chiller is providing heating while drawing energy from the TES tank. Two-cooling only blue chillers are cooling the building in a series configuration while head pressure control on the condenser side is modulating flow through the cooling-only machines' condenser barrels to achieve the target condenser water leaving temperature of 80°F (27°C) needed to charge the tank. The air-source heat pumps are off because building automation system (BAS) logic has determined that heat rejection loads alone will be sufficient to charge the tank by the end of the business day, i.e., bring the tank up to an average temperature of about 80°F.

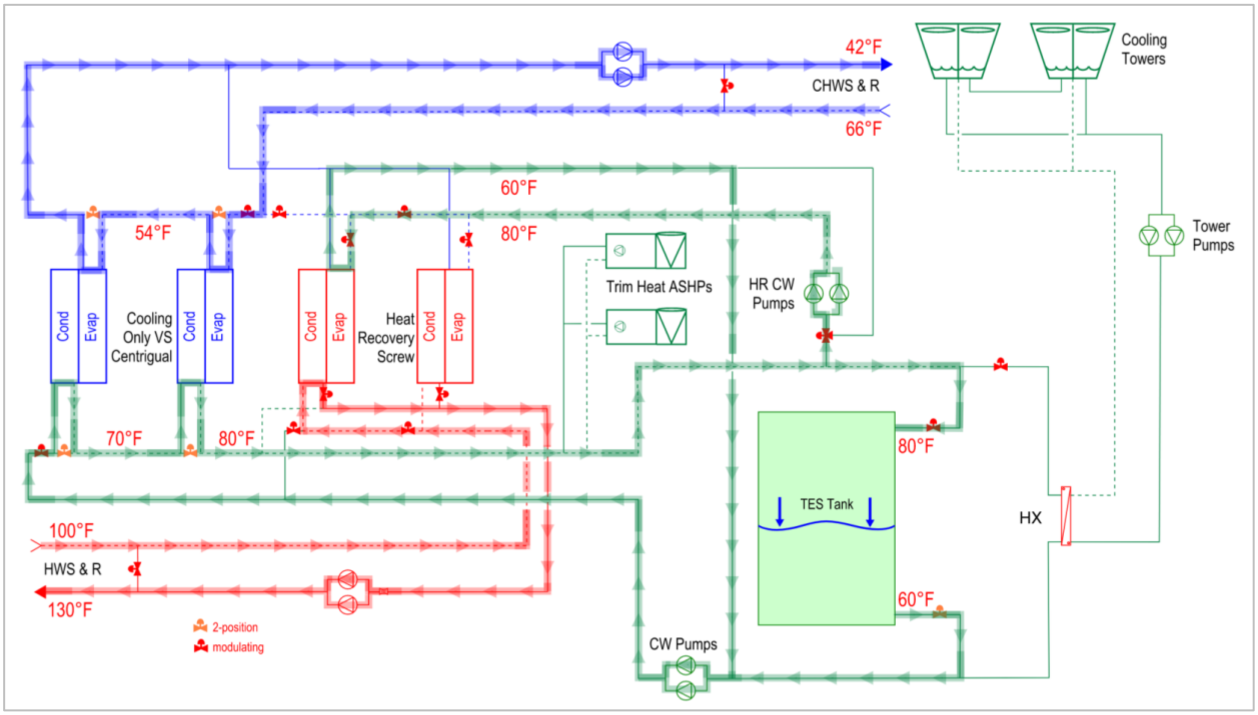


Figure 16: Cool Day Afternoon Operation of a Condenser Water TIER System

Figure 17 shows a high cooling load condition as might occur during the afternoon of a warm day. In this scenario, one of the red heat recovery chillers has been indexed into "cooling mode" and is connected on the evaporator side to the chilled water loop while rejecting heat at low lift to the condenser water loop. Any building heating loads are served by the one remaining heat recovery chiller indexed to the hot water loop. A mixing valve upstream of the heat recovery chiller evaporator inlets (shown in yellow) prevents water warmer than 80°F (27°C) from entering the heating heat recovery chiller's evaporator barrel as is required by many chiller manufacturers for continuous operation. Since the day is warm, morning heating loads were small, meaning the tank is already fully charged by early afternoon. Therefore, all excess heat is rejected through the cooling towers, which are isolated with a heat exchanger to prevent dirty tower water from entering the tank or the chilled or hot water loops.

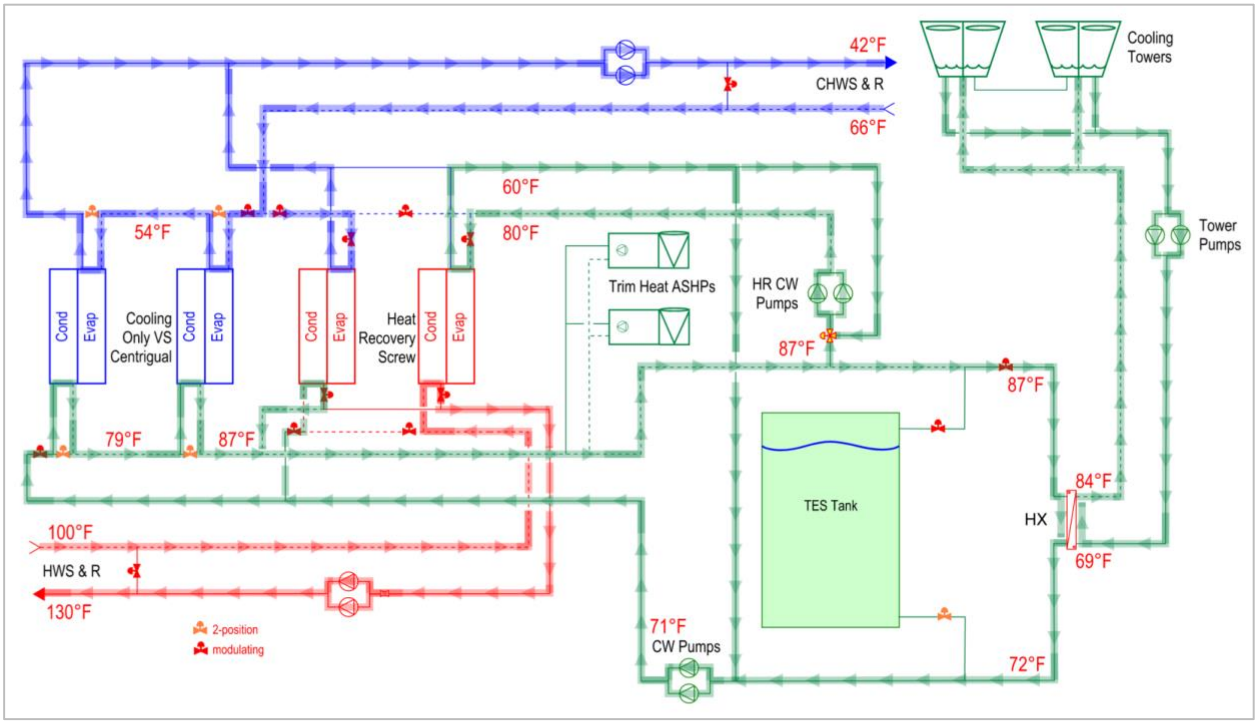


Figure 17: Warm Day Afternoon Operation of a Condenser Water TIER System

Figure 18, Figure 19, and Figure 20 are included to provide additional visual context regarding how CW TES fits into a building design. The purpose of including these figures is to show that while CW TES does take up space in the building, it can be effectively factored into the building design without becoming an overly prominent aspect of the building architecture. Note that other TIER projects have located the TES tank inside parking structures or basements.

Figure 18: Demonstration of TES Tank Size Relative to Building

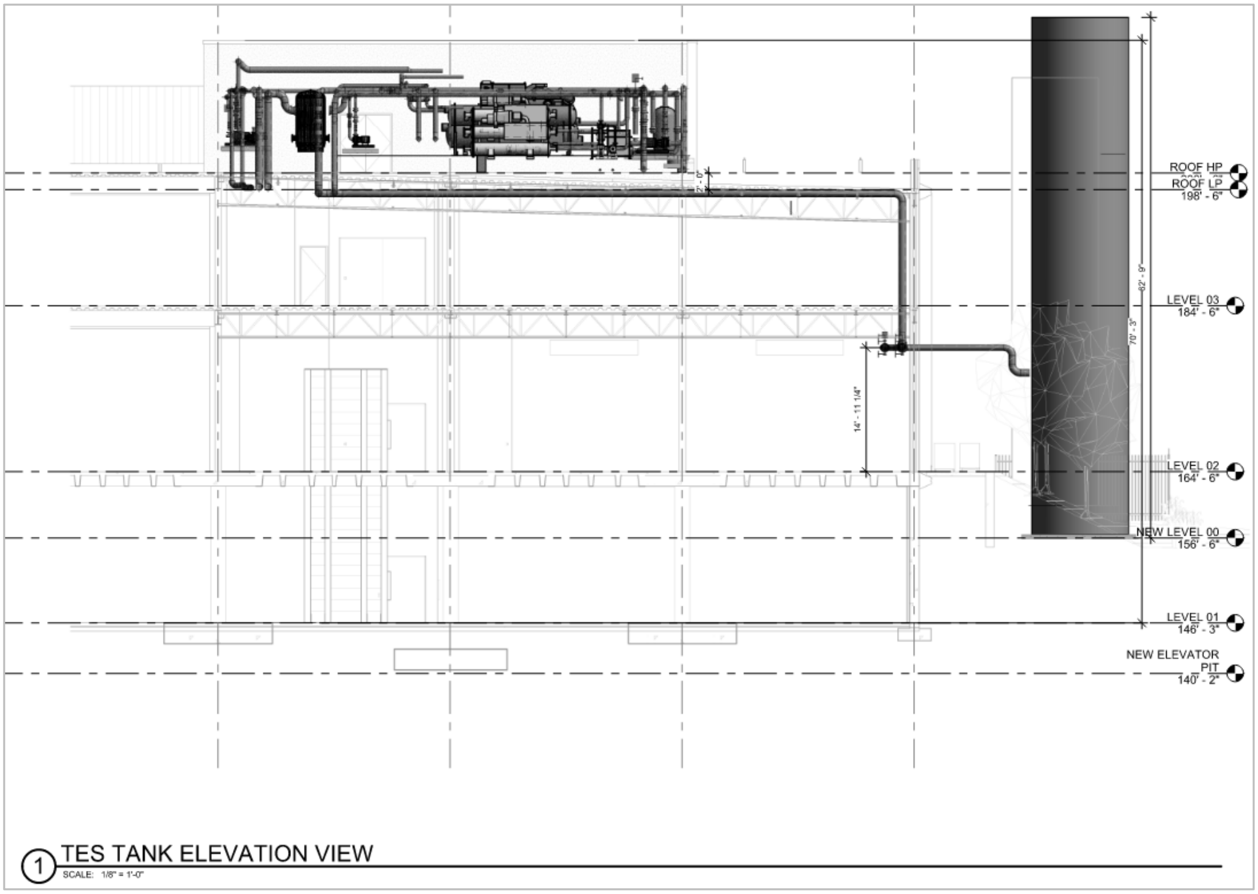


Figure 19: Schematic Showing TES Tank Elevation View

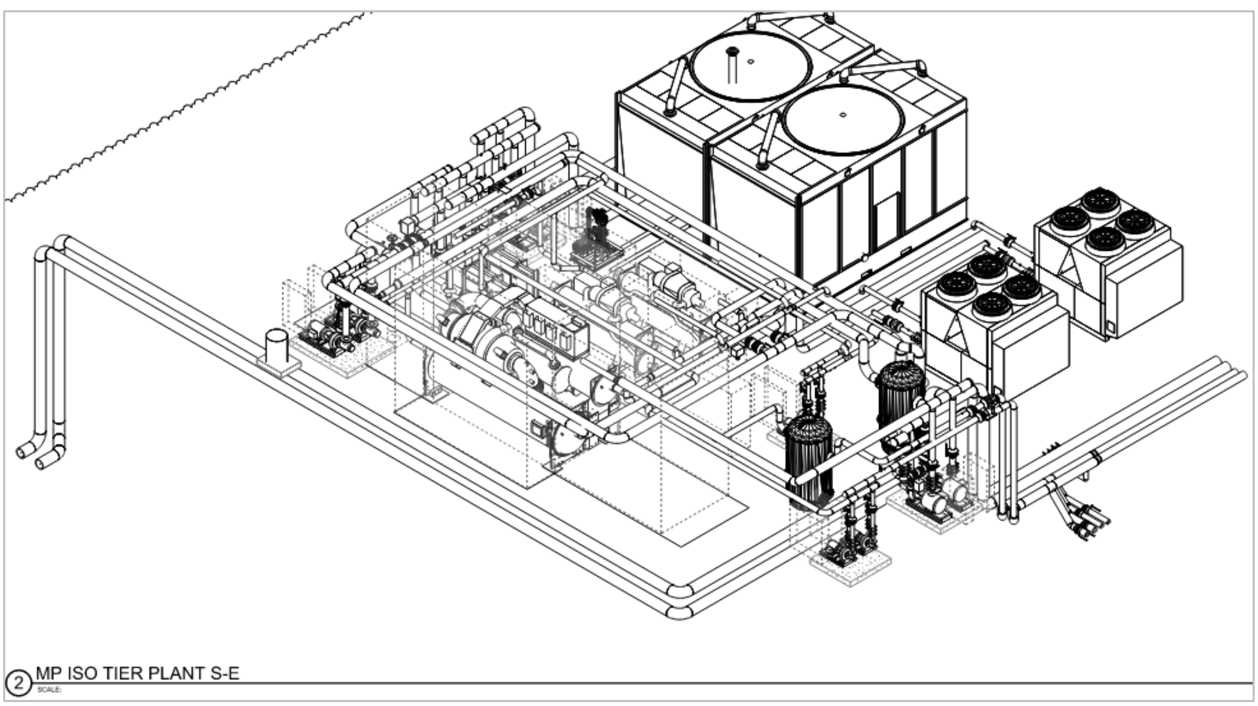


Figure 20: Schematic Showing TIER Plant Equipment

3.2.2.2 Service Hot Water Heat Recovery

Adding service hot water (SHW, a.k.a. domestic hot water or DHW) heat recovery to a building that uses condenser heat recovery for hot water space heating is straightforward and common. A heat exchanger (HX) is added upstream of the service hot water heater(s), also known as electric water heaters (EWH). The heating hot water (HHW) flow through the heat exchanger is modulated to preheat the domestic cold water (DCW) before it goes to the EWH. When the DCW flow switch indicates there is no DHW load then the control valve is closed. To the heating hot water system, the HX is just another HW load, like a VAV reheat coil. Note that the HHW system does not need to be sized for the capacity of the SHW HX. If the HHW system is at peak capacity serving space heating needs then the SHW HX valve can simply be shut, as the EWH is already sized to meet the entire SHW (DHW) load.

Figure 21 shows the control points for a typical SHW Heat Exchanger.

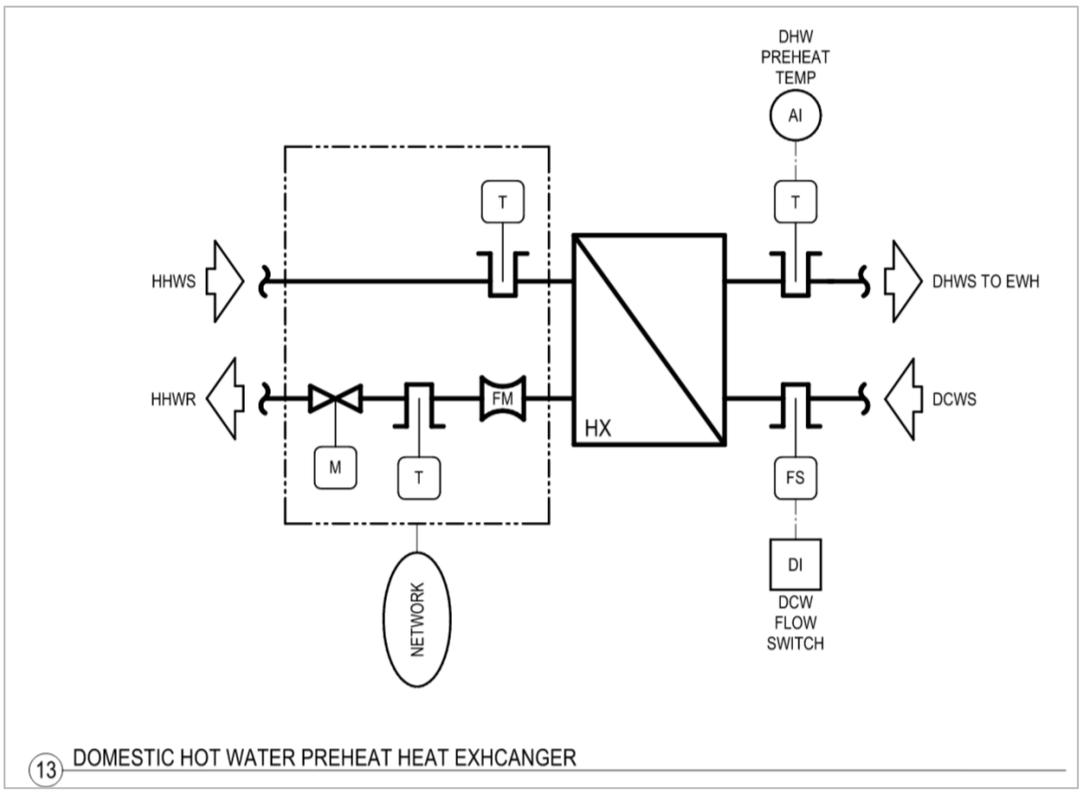


Figure 21: Control Schematic for SHW Heat Exchanger

Figure 22 shows the plumbing schedule for a Sunnyvale office building with SHW heat recovery. The schedule shows the electric water heaters (EWH) and the location of one of the EWH on level 1 (EWH-01-02). Figure 23 shows the HX schedule for the same building and the location of HX-2-1 corresponding to the EWH in Figure 22. The red lines in Figure 23 show the additional HW piping needed to serve this HX.

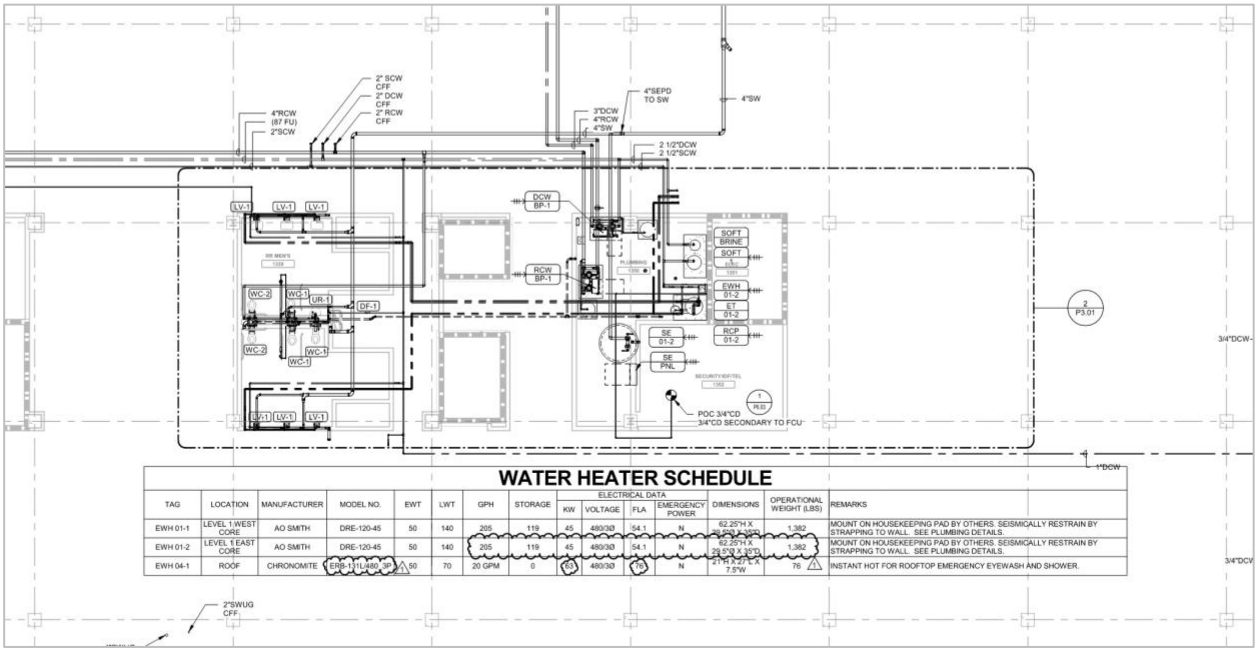


Figure 22: Typical Plumbing Drawings Showing EWH Location and Schedule

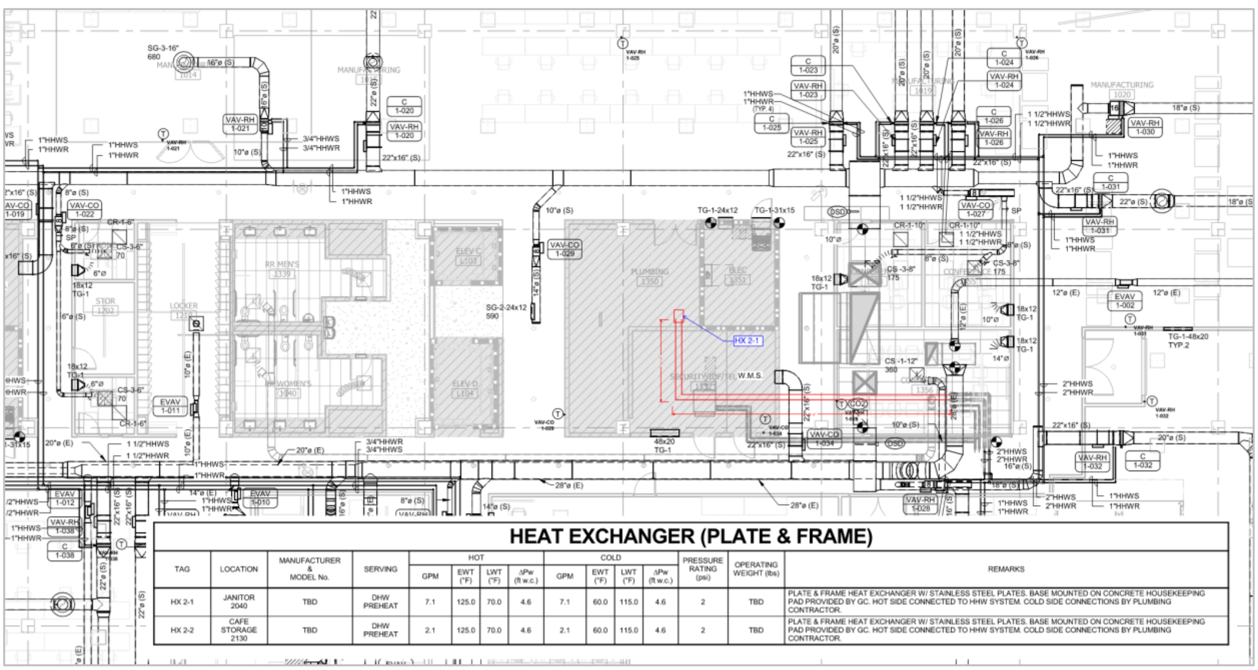
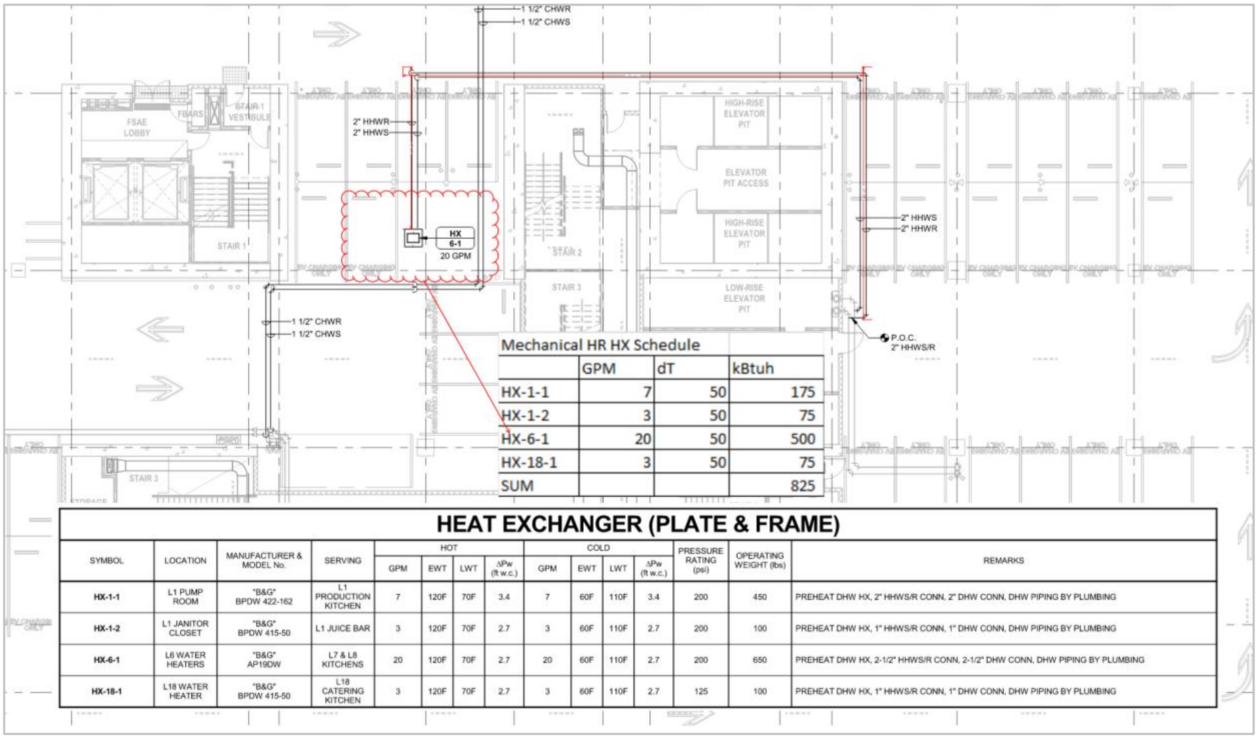


Figure 23: Typical Mechanical Drawings Showing DHW HX Incremental Piping and Equipment Schedule

Figure 24, Figure 25, and Figure 26 are from a large office building “A” in San Jose. This building has several 4-pipe AWHPs that use their condenser heat recovery for space heating and SHW preheat. Building “A” has a peak cooling capacity of 2,000 tons, a peak heating capacity of about 10,000 kBtuh. It also has two kitchens with a total SHW load of 1,600 kBtuh, and HX’s with a SHW preheat capacity of 800 kBtuh, i.e., the ability to use heat recovery to meet 50 percent of the peak SHW load. Figure 24 shows the incremental piping needed to serve one of the HX. Figure 25 shows the location of three of the EWHs. Figure 26 shows the incremental piping needed to serve another HX. Incremental piping from these and other HXs were averaged to arrive at an average incremental cost for SHW HR.



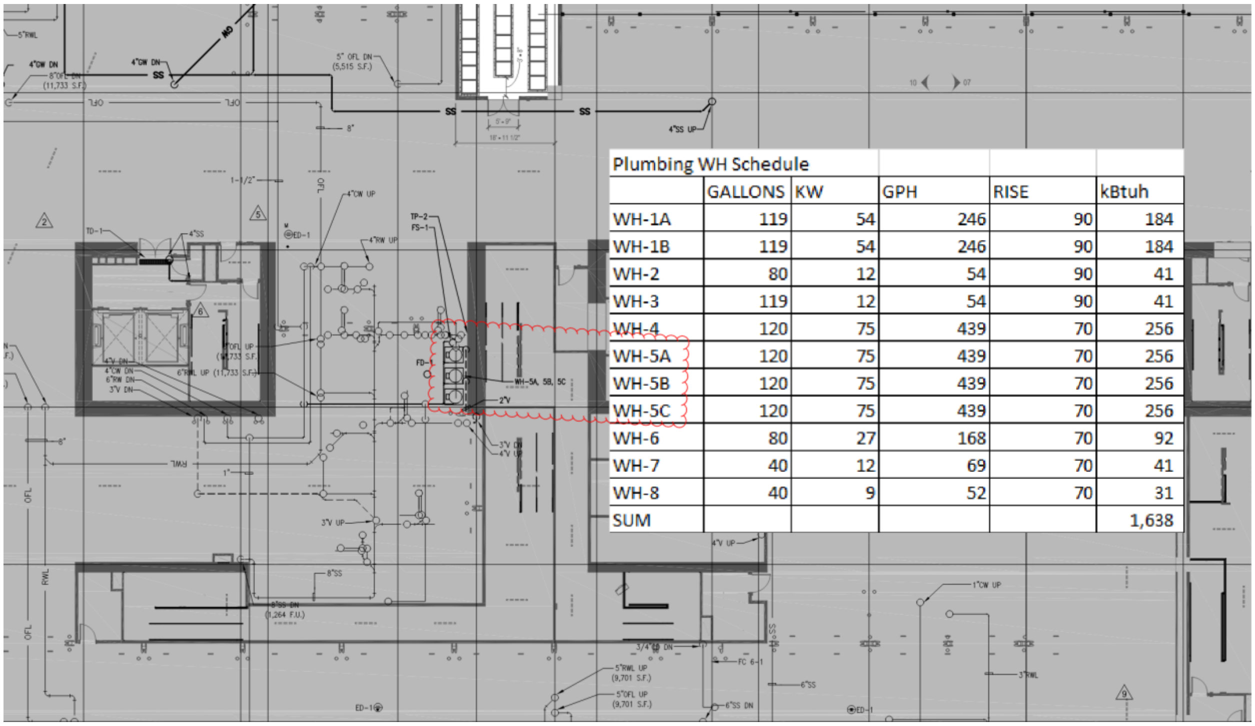
Mechanical HR HX Schedule

	GPM	dT	kBtuh
HX-1-1	7	50	175
HX-1-2	3	50	75
HX-6-1	20	50	500
HX-18-1	3	50	75
SUM			825

HEAT EXCHANGER (PLATE & FRAME)

SYMBOL	LOCATION	MANUFACTURER & MODEL No.	SERVING	HOT				COLD				PRESSURE RATING (psi)	OPERATING WEIGHT (lbs)	REMARKS
				GPM	EWT	LWT	ΔPw (ft w.c.)	GPM	EWT	LWT	ΔPw (ft w.c.)			
HX-1-1	L1 PUMP ROOM	"B&G" BPDW 422-162	L1 PRODUCTION KITCHEN	7	120F	70F	3.4	7	60F	110F	3.4	200	450	PREHEAT DHW HX, 2" HHWS/R CONN, 2" DHW CONN, DHW PIPING BY PLUMBING
HX-1-2	L1 JANITOR CLOSET	"B&G" BPDW 415-50	L1 JUICE BAR	3	120F	70F	2.7	3	60F	110F	2.7	200	100	PREHEAT DHW HX, 1" HHWS/R CONN, 1" DHW CONN, DHW PIPING BY PLUMBING
HX-6-1	L6 WATER HEATERS	"B&G" AP19DW	L7 & L8 KITCHENS	20	120F	70F	2.7	20	60F	110F	2.7	200	650	PREHEAT DHW HX, 2-1/2" HHWS/R CONN, 2-1/2" DHW CONN, DHW PIPING BY PLUMBING
HX-18-1	L18 WATER HEATER	"B&G" BPDW 415-50	L18 CATERING KITCHEN	3	120F	70F	2.7	3	60F	110F	2.7	125	100	PREHEAT DHW HX, 1" HHWS/R CONN, 1" DHW CONN, DHW PIPING BY PLUMBING

Figure 24: San Jose Building "A" Mechanical Drawing Level 6



Plumbing WH Schedule

	GALLONS	KW	GPH	RISE	kBtuh
WH-1A	119	54	246	90	184
WH-1B	119	54	246	90	184
WH-2	80	12	54	90	41
WH-3	119	12	54	90	41
WH-4	120	75	439	70	256
WH-5A	120	75	439	70	256
WH-5B	120	75	439	70	256
WH-5C	120	75	439	70	256
WH-6	80	27	168	70	92
WH-7	40	12	69	70	41
WH-8	40	9	52	70	31
SUM					1,638

Figure 25: San Jose Building "A" Plumbing Drawing Level 6

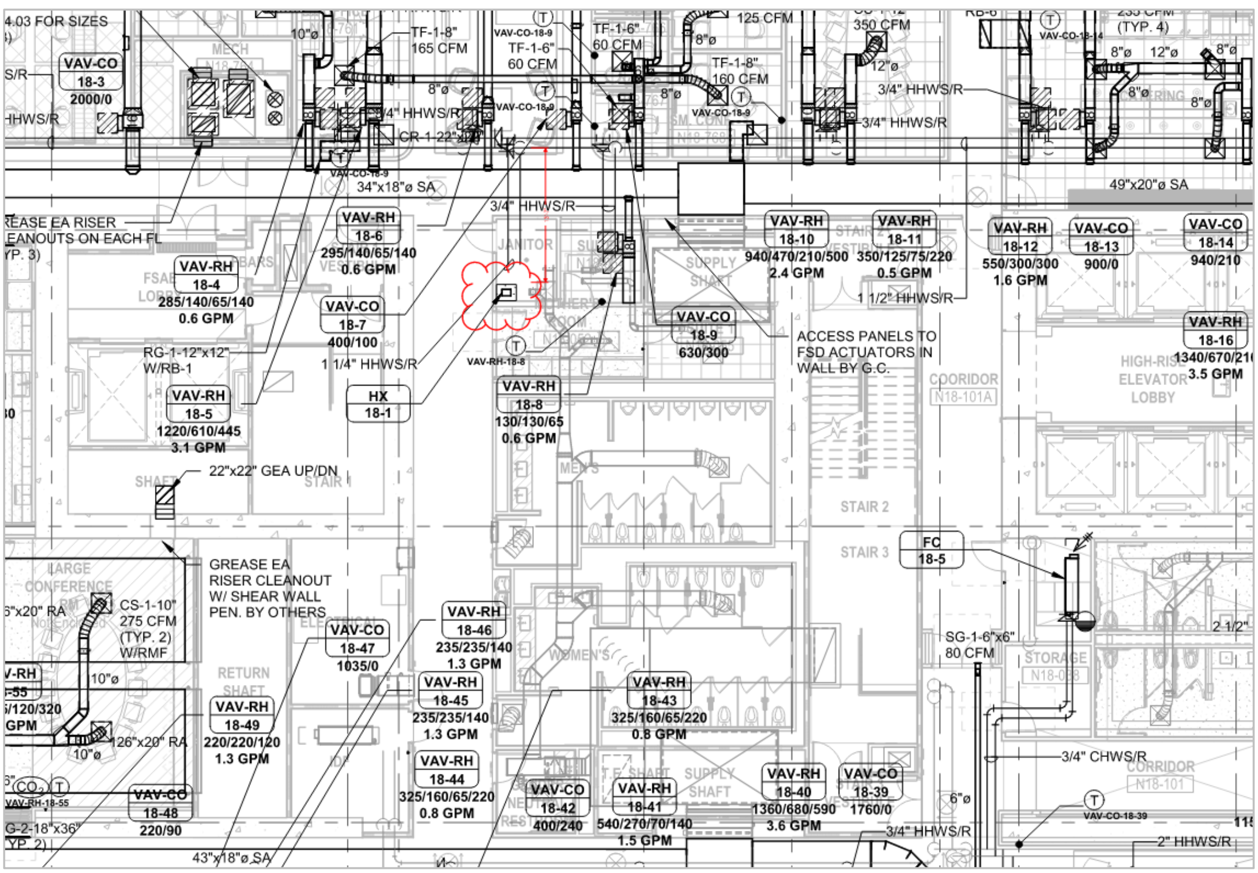


Figure 26: San Jose Building "A" Mechanical Drawing Level 18

3.2.3 Market Impacts and Economic Assessments

3.2.3.1 Impact on Builders

Builders of residential and commercial structures are directly impacted by many of the measures proposed by the Statewide CASE Team for the 2025 code cycle. It is within the normal practices of these businesses to adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training to remain compliant with changes to design practices and building codes.

California's construction industry comprises approximately 93,000 business establishments and 943,000 employees (see Table 64). For 2022, total estimated payroll will be about $78 billion. Nearly 72,000 of these business establishments and 473,000 employees are engaged in the residential building sector, while another 17,600 establishments and 369,000 employees focus on the commercial sector. The remainder of establishments and employees work in industrial, utilities, infrastructure, and other heavy construction roles (the industrial sector).

Table 64: California Construction Industry, Establishments, Employment, and Payroll in 2022 (Estimated)

Building Type	Construction Sectors	Establishments	Employment	Annual Payroll (Billions $)
Residential	**All**	**71,889**	**472,974**	**31.2**
Residential	Building Construction Contractors	27,948	130,580	9.8
Residential	Foundation, Structure, and Building Exterior	7,891	83,575	5.0
Residential	Building Equipment Contractors	18,108	125,559	8.5
Residential	Building Finishing Contractors	17,942	133,260	8.0
Commercial	**All**	**17,621**	**368,810**	**35.0**
Commercial	Building Construction Contractors	4,919	83,028	9.0
Commercial	Foundation, Structure, and Building Exterior	2,194	59,110	5.0
Commercial	Building Equipment Contractors	6,039	139,442	13.5
Commercial	Building Finishing Contractors	4,469	87,230	7.4
Industrial, Utilities, Infrastructure, & Other (Industrial+)	**All**	**4,206**	**101,002**	**11.4**
Industrial+	Building Construction	288	3,995	0.4
Industrial+	Utility System Construction	1,761	50,126	5.5
Industrial+	Land Subdivision	907	6,550	1.0
Industrial+	Highway, Street, and Bridge Construction	799	28,726	3.1
Industrial+	Other Heavy Construction	451	11,605	1.4

Source: (State of California Employment Development Department 2022)

The proposed change to hydronic space heating designs would likely affect commercial builders but would not impact firms that focus on construction and retrofit of industrial buildings, utility systems, public infrastructure, or other heavy construction. The effects on the residential and commercial building industry would not be felt by all firms and workers, but rather would be concentrated in specific industry subsectors. Table 65 shows the commercial building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report. As noted above, this proposal includes requirements for heat recovery and thermal energy storage which will impact electrical and mechanical contractors. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 2.2.4 Economic Impacts.

Table 65: Specific Subsectors of the California Commercial Building Industry Impacted by Proposed Change to Code/Standard by Subsector in 2022 (Estimated)

Construction Subsector	Establishments	Employment	Annual Payroll (Billions $)
Other Nonresidential Exterior contractors	277	3,006	0.2
Nonresidential Electrical Contractors	3,137	74,277	7.0
Nonresidential plumbing & HVAC contractors	2,346	55,572	5.5

Source: (State of California Employment Development Department 2022)

3.2.3.2 Impact on Building Designers and Energy Consultants

Adjusting design practices to comply with changing building codes is within the normal practices of building designers. Building codes (including Title 24, Part 6) are typically updated on a three-year revision cycle, and building designers and energy consultants engage in continuing education and training to remain compliant with changes to design practices and building codes.

In the coming years, all-electric space heating is expected to become the default option for most buildings. This proposal seeks to ensure that heat recovery and thermal energy storage are included in designs when appropriate. The current default approach to space heating in large nonresidential buildings essentially amounts to a simple load calculation to determine the design day heating loads and then a corresponding gas boiler selection (typically with some oversizing) with capacity to meet this heating load. This proposal argues that for all-electric designs, this approach (except with swapping out 2-pipe air to water heat pumps for the gas boiler) is insufficient. AWHPs consume too much real estate in the building and are also not particularly efficient options by themselves. In the absence of this measure, over time, it is probable that industry to conclude that heat recovery and TES are essential elements to an all-electric space heating designs. This measure essentially seeks to accelerate the adoption of these cost-effective and efficient aspects into all-electric hydronic space heating designs. The Statewide CASE Team intends to work with the market leaders to ensure that these best practices are widely disseminated throughout the HVAC designer community in California.

Businesses that focus on residential, commercial, institutional, and industrial building design are contained within the Architectural Services sector (North American Industry Classification System 541310). Table 66 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The proposed code changes would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for Hydronic Heat Recovery and Thermal Energy Storage to affect firms that focus on nonresidential construction.

There is not a North American Industry Classification System (NAICS)[14] code specific to energy consultants. Instead, businesses that focus on consulting related to building energy efficiency are contained in the Building Inspection Services sector (NAICS 541350), which is comprised of firms primarily engaged in the physical inspection of residential and nonresidential buildings.[15] It is not possible to determine which business establishments within the Building Inspection Services sector are focused on energy efficiency consulting. The information shown in Table 66Table 9 provides an upper bound indication of the size of this sector in California.

Table 66: California Building Designer and Energy Consultant Sectors in 2022 (Estimated)

Sector	Establishments	Employment	Annual Payroll (Millions $)
Architectural Services [a]	4,134	31,478	3,623.3
Building Inspection Services [b]	1,035	3,567	280.7

Source: (State of California Employment Development Department 2022)

a. Architectural Services (NAICS 541310) comprises private-sector establishments primarily engaged in planning and designing residential, institutional, leisure, commercial, and industrial buildings and structures.

b. Building Inspection Services (NAICS 541350) comprises private-sector establishments primarily engaged in providing building (residential & nonresidential) inspection services encompassing all aspects of the building structure and component systems, including energy efficiency inspection services.

[14] NAICS is the standard used by federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS was development jointly by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadistica y Geografia, to allow for a high level of comparability in business statistics among the North American countries. NAICS replaced the Standard Industrial Classification (SIC) system in 1997.

[15] Establishments in this sector include businesses primarily engaged in evaluating a building's structure and component systems and includes energy efficiency inspection services and home inspection services. This sector does not include establishments primarily engaged in providing inspections for pests, hazardous wastes or other environmental contaminates, nor does it include state and local government entities that focus on building or energy code compliance/enforcement of building codes and regulations.

3.2.3.3 Impact on Occupational Safety and Health

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

3.2.3.4 Impact on Building Owners and Occupants

Commercial Buildings

The commercial building sector includes a wide array of building types, including offices, restaurants and lodging, retail, and mixed-use establishments, and warehouses (including refrigerated) (Kenney M 2019). Energy use by occupants of commercial buildings also varies considerably, with electricity used primarily for lighting, space cooling and conditioning, and refrigeration, while natural gas is used primarily for water heating and space heating. According to information published in the 2019 California Energy Efficiency Action Plan, there is more than 7.5 billion square feet of commercial floor space in California consuming 19 percent of California's total annual energy use (Kenney M 2019). The diversity of building and business types within this sector creates a challenge for disseminating information on energy and water efficiency solutions, as does the variability in sophistication of building owners and the relationships between building owners and occupants.

Estimating Impacts

Building owners and occupants would benefit from lower energy bills. As discussed in Section 2.2.4.1, when building occupants save on energy bills, they tend to spend it elsewhere in the economy thereby creating jobs and economic growth for the California economy. The Statewide CASE Team does not expect the proposed code change for the 2025 code cycle to impact building owners or occupants adversely.

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

The Statewide CASE Team anticipates the proposed change would have minimal material impact on California component retailers. All measures being proposed at Section 140.4(r) are achievable with existing commercially available equipment. Water storage tanks, for example, are commonly used for many applications such as data center makeup water storage. AWHP sales are poised to sharply increase in the coming years as all-electric reach codes expand. Our measure would encourage a portion of those units to be 4-pipe rather than 2-pipe, which would have a negligible impact on

AWHP manufacturers, since it's common for the same manufacturer to produce both styles. Impact on Building Inspectors

Table 67 shows employment and payroll information for state and local government agencies in which many inspectors of residential and commercial buildings are employed. Building inspectors participate in continuing education and training to stay current on all aspects of building regulations, including energy efficiency. The Statewide CASE Team, therefore, anticipates the proposed change would have no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections.

Table 67: Employment in California State and Government Agencies with Building Inspectors in 2022 (Estimated)

Sector	Govt.	Establishments	Employment	Annual Payroll (Million $)
Administration of Housing Programs[a]	State	18	265	29.0
	Local	38	3,060	248.6
Urban and Rural Development Admin[b]	State	38	764	71.3
	Local	52	2,481	211.5

Source: (State of California Employment Development Department 2022)

Administration of Housing Programs (NAICS 925110) comprises government establishments primarily engaged in the administration and planning of housing programs, including building codes and standards, housing authorities, and housing programs, planning, and development.

a. Urban and Rural Development Administration (NAICS 925120) comprises government establishments primarily engaged in the administration and planning of the development of urban and rural areas. Included in this industry are government zoning boards and commissions.

3.2.3.6 Impact on Statewide Employment

As described in Sections 3.2.3.1 through 0, the Statewide CASE Team does not anticipate significant employment or financial impacts to any particular sector of the California economy. This is not to say that the proposed change would not have modest impacts on employment in California. In Section 3.2.4, the Statewide CASE Team estimated the proposed change in Hydronic Heat Recovery and Thermal Energy Storage would affect statewide employment and economic output directly and indirectly through its impact on builders, designers, and energy consultants, and building inspectors. In addition, the Statewide CASE Team estimated how energy savings associated with the proposed change in Hydronic Heat Recovery and Thermal Energy Storage would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

3.2.4 Economic Impacts

For the 2025 code cycle, the Statewide CASE Team used the IMPLAN model software[16], along with economic information from published sources, and professional judgement to develop estimates of the economic impacts associated with each of the proposed code changes. Conceptually, IMPLAN estimates jobs created as a function of incoming cash flow in different sectors of the economy, due to implementing a code or a standard. The jobs created are typically categorized into direct, indirect, and induced employment. For example, cash flow into a manufacturing plant captures direct employment (jobs created in the manufacturing plant), indirect employment (jobs created in the sectors that provide raw materials to the manufacturing plant) and induced employment (jobs created in the larger economy due to purchasing habits of people newly employed in the manufacturing plant). Eventually, IMPLAN computes the total number of jobs created due to a code. The assumptions of IMPLAN include constant returns to scale, fixed input structure, industry homogeneity, no supply constraints, fixed technology, and constant byproduct coefficients. The model is also static in nature and is a simplification of how jobs are created in the macro-economy.

The economic impacts developed for this report are only estimates and are based on limited and to some extent speculative information. The IMPLAN model provides a relatively simple representation of the California economy and, though the Statewide CASE Team is confident that the direction and approximate magnitude of the estimated economic impacts are reasonable, it is important to understand that the IMPLAN model is a simplification of extremely complex actions and interactions of individual, businesses, and other organizations as they respond to changes in energy efficiency codes. In all aspects of this economic analysis, the CASE Authors rely on conservative assumptions regarding the likely economic benefits associated with the proposed code change. By following this approach, the economic impacts presented below represent lower bound estimates of the actual benefits associated with this proposed code change.

Adoption of this code change proposal[17] would result in relatively modest economic impacts through the additional direct spending by those in the commercial building industry, architects, energy consultants, and building inspectors. The Statewide CASE Team does not anticipate that money saved by commercial building owners or other organizations affected by the proposed 2025 code cycle regulations would result in additional spending by those businesses.

[16] IMPLAN employs economic data and advanced economic impact modeling to estimate economic impacts for interventions like changes to the California Title 24, Part 6 code. For more information on the IMPLAN modeling process, see www.IMPLAN.com.

[18] 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.

Table 68: Estimated Impact that Adoption of the Proposed Measure would have on the California Commercial Construction Sector

Type of Economic Impact	Employment (Jobs)	Labor Income (Million)	Total Value Added (Million)	Output (Million)
Direct Effects (Additional spending by Commercial Builders)	136.4	$10.6	$12.2	$20.9
Indirect Effect (Additional spending by firms supporting Commercial Builders)	33.4	$2.9	$4.5	$8.3
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	56.7	$3.9	$6.9	$11.0
Total Economic Impacts	**226.5**	**$17.4**	**$23.7**	**$40.2**

Source: CASE Team analysis of data from the IMPLAN modeling software. (IMPLAN Group LLC 2020)

Table 69: Estimated Impact that Adoption of the Proposed Measure would have on the California Building Designers and Energy Consultants Sectors

Type of Economic Impact	Employment (Jobs)	Labor Income (Million)	Total Value Added (Million)	Output (Million)
Direct Effects (Additional spending by Building Designers & Energy Consultants)	3.7	0.4	0.4	0.6
Indirect Effect (Additional spending by firms supporting Bldg. Designers & Energy Consultants)	1.5	0.1	0.2	0.3
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	2.2	0.2	0.3	0.4
Total Economic Impacts	**7.4**	**0.7**	**0.8**	**1.3**

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

3.2.4.1 Creation or Elimination of Jobs

The Statewide CASE Team does not anticipate that the measures proposed for the 2025 code cycle regulation 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, the estimates of economic impacts discussed in Section 3.2.4 would lead to modest changes in employment of existing jobs.

3.2.4.2 Creation or Elimination of Businesses in California

As stated in Section 3.2.4.1, the Statewide CASE Team’s proposed change would not result in economic disruption to any sector of the California economy. The proposed change represents a modest change to the design strategy to provide space heating in nonresidential buildings, which would not excessively burden or competitively disadvantage California businesses – nor would it necessarily lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not foresee any new businesses being created, nor does the Statewide CASE Team think any existing businesses would be eliminated due to the proposed code changes.

3.2.4.3 Competitive Advantages or Disadvantages for Businesses in California

The proposed code changes would apply to all businesses incorporated in California, regardless of whether the business is located inside or outside of the state.[18] Therefore, the Statewide CASE Team does not anticipate that these measures proposed for the 2025 code cycle regulation would have an adverse effect on the competitiveness of California businesses. Likewise, the Statewide CASE Team does not anticipate businesses located outside of California would be advantaged or disadvantaged.

3.2.4.4 Increase or Decrease of Investments in the State of California

The Statewide CASE Team analyzed national data on corporate profits and capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI).[19] As Table 70 shows, between 2017 and 2021, NPDI as a percentage of corporate profits ranged from a low of 18 in 2020 due to the worldwide economic slowdowns associated with the COVID 19 pandemic to a high of 35 percent in 2019, with an average of 26 percent. While only an approximation of the proportion of business income used for net capital investment, the Statewide CASE Team believes it provides a reasonable estimate of the proportion of proprietor income that would be reinvested by business owners into expanding their capital stock.

Table 70: 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)
2017	518.473	1882.460	28
2018	636.846	1977.478	32
2019	690.865	1952.432	35
2020	343.620	1908.433	18
2021	506.331	2619.977	19
5-Year Average	**539.227**	**2068.156**	**26**

Source: (Federal Reserve Economic Data, FRED 2022)

[18] 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.

[19] 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.

The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed measure would lead to significant change (increase or decrease) in investment, directly or indirectly, in any affected sectors of California's economy. Nevertheless, the Statewide CASE Team can derive 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 proprietor income, which was used a conservative estimate of corporate profits, a portion of which would likely be allocated to net business investment.[20]

3.2.4.5 Incentives for Innovation in Products, Materials, or Processes

The HVAC industry is trending toward all-electric space heating designs. The purpose of this measure is to support this trend by further solidifying the notion that all-electric hydronic systems should be designed with appropriate amounts of thermal energy storage and hydronic heat recovery to maximize efficiency and limit upfront costs. This measure is expected to drive innovation in the nonresidential HVAC industry.

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

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

Cost of Enforcement

Cost to the State: State government already has budget for code development, education, and compliance enforcement. While state government will be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, these activities are already covered by existing state budgets. The costs to state government are small when compared to the overall costs savings and policy benefits associated with the code change proposals. The proposed code change is expected to impact state buildings in an equal manner to all other nonresidential buildings. This proposal has been found to be cost-effective.

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 re-training 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

[20] 26 percent of proprietor income was assumed to be allocated to net business investment; see Table 12.

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 3.1.5 and Appendix E, 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.

3.2.4.7 Impacts on Specific Persons

While the objective of any of the Statewide CASE Team's proposal is to promote energy efficiency, the Statewide CASE Team recognizes that there is the potential that a proposed code change may result in unintended consequences. This code change proposal is not expected to impact specific persons. Refer to Section 3.6 for more details addressing energy equity and environmental justice.

3.2.5 Fiscal Impacts

3.2.5.1 Mandates on Local Agencies or School Districts

There are no relevant mandates to local agencies or school districts.

3.2.5.2 Costs to Local Agencies or School Districts

There are no costs to local agencies or school districts.

3.2.5.3 Costs or Savings to Any State Agency

There are no costs or savings to any state agencies.

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

There are no added non-discretionary costs or savings to local agencies.

3.2.5.5 Costs or Savings in Federal Funding to the State

There are no costs or savings to federal funding to the state.

3.3 Energy Savings

The Statewide CASE Team gathered stakeholder input to inform the energy savings analysis. We researched manufacturer product literature for heat recovery and thermal energy storage equipment to inform technical efficiency and capacity assumptions in the analysis. See Appendix F for a summary of stakeholder engagement.

Energy savings benefits may have potential to disproportionately impact DIPs. Refer to Section 2.6 for more details addressing energy equity and environmental justice.

3.3.1 Energy Savings Methodology

3.3.1.1 Key Assumptions for Energy Savings Analysis

Simultaneous Cooling and Heating

The purpose of this measure is to ensure hydronic heat recovery occurs when significant overlapping cooling and heating loads are present. Heating loads can be either space heating hydronics or domestic hot water. To demonstrate energy savings, the Hospital prototype was used since it includes significant overlapping cooling and heating loads were modeled.

The base case for this measure is an all-electric building whose heating loads are entirely satisfied with air-to-water heat pumps (AWHPs). This was chosen to reflect local jurisdictions requiring all-electric designs via reach codes. Currently, the prototypes that use hydronic heating are served by gas boilers. The standard design prototypes were modified within CBECC to replace the gas boilers with the CBECC AWHP object. These modified models became the base case for this measure.

The measure case was modified to replace 30 percent of the AWHP equipment with 4-pipe dedicated heat recovery chillers to satisfy the overlapping cooling and heating loads. As a result of the conversion of 30 percent of the AWHPs to DRHCs, the WCC system was able to be downsized as well.

To produce initial results, the all-electric baseline prototype load profiles were exported from CBECC and then modified in Excel to model a dedicated heat recovery chiller system. Since heat recovery chillers are most appropriate for buildings with large overlapping cooling and heating loads, this measure is tailored for buildings with this characteristic.

Thermal Energy Storage

Many large buildings have low overlapping cooling and heating loads, making chilled water to hot water heat recovery chiller units impractical. However, the buildings may still have a significant peak heating load, necessitating a large AWHP system if the building is all-electric. These buildings are good candidates for thermal energy storage of day-before cooling waste heat for the next morning warm-up heating needs. This allows the building to downsize the AWHP capacity.

This measure's base case, similar to the simultaneous cooling and heating measure, consists of an all-electric building fully satisfied with AWHPs supplying hot water. The impacted prototypes include large office, medium office, and secondary school, and hotel.

We modeled this measure using condenser water (CW) TES (in essence, the TIER system), which provides several EE benefits. CW TES systems operate the AWHP and

DHRC in low-lift conditions. In the TIER system, the AWHP is configured to deliver CW temperatures (drawing heat from ambient air at design heating conditions, which is typically 30 °F in most California climates) and the heat recovery chiller operates between CW and HW temperatures. The more limited operating envelopes increase efficiency due to the compressor not having to work as hard as it would if the AWHP were configured to deliver HW temperatures, or the heat recovery chiller operated between CHW and HW temperature ranges.

The measure case was modeled outside of CBECC (and EnergyPlus) according to detailed specification prepared by Taylor Engineers in a memo to the Oakland Building Department. This memo is reproduced in Appendix H. The all-electric baseline prototype IDF files were exported from CBECC and then post-processed according to the Taylor Engineers specification.

Heat Recovery for Service Water Heating

Energy savings for this measure were calculated by first simulating the Large Office prototype in CBECC in all 16 climate zones. The airside economizer in this model was disabled to accurately represent all potential condenser heat available for heat recovery. The peak heating, cooling, and SHW loads were then exported to Excel, along with the hourly load profile PLR (part load ratio) for CHW load, HW load, and SHW load.

Excel was then used to post-process the results on an 8760 hourly basis. Adjustable inputs were added to the spreadsheet for process cooling loads (e.g., a data center). This represents the $Cooling_{HL}$ referenced in the proposed language. An adjustable process SHW load was also added (e.g., kitchen, laundry, fitness center, etc.). This represents the SHW_{cap} referenced in the proposed language. The adjustable process the peak heating/cooling loads and the process inputs for $Cooling_{HL}$ and SHW_{cap} were then scaled to represent the different thresholds for simultaneous heat recovery in 140.4r(1) and for SHW heat recovery in 140.4r(3). The spreadsheet also includes adjustable values for heat recovery chiller capacity and SHW heat recovery capacity, representing the minimum capacity for each as specified in the proposed language. A fixed process cooling PLR of 0.5 was assumed. This is conservative and consistent with the ACM load profile for computer rooms, which is 0.25 for 25 percent of the time, 0.5 for 25 percent of the time, 0.75 for 25 percent of the time and 1.0 for 25 percent of the time (average of 62 percent). The SHW PLR from the prototype models was used for the process SHW_{cap} PLR.

For each hour the scaled cooling load from the model and the scaled process cooling load were added to determine the total hourly cooling load. A fixed water-to-water heat recovery chiller COP of 4.5 was assumed to approximate the chiller waste heat. The cooling load plus chiller waste heat represents the available condenser heat rejection available for heat recovery. The model then compares the available heat rejection, the current HHW load and the heat recovery chiller capacity and takes the smallest of these

3 to determine how much heat is recovered in that hour for HHW. The HHW energy savings for that hour are then calculated by assuming a fixed COP of 4.5 for the heat recovery chiller versus a fixed COP of 3.3 for a baseline AWHP.

The spreadsheet also accounts for the fact that a 4-pipe AWHP heat recovery chiller is less efficient in cooling-only mode than a 2-pipe AWHP in cooling-only mode. The hourly PLR is compared to the fraction of chiller capacity that is 2-pipe vs 4-pipe. Whatever capacity the 2-pipe cannot satisfy must be met by the 4-pipe. The energy penalty for running the 4-pipe in cooling only mode is then calculated based on a fixed COP for 2-pipe of 4.5 and a fixed COP for 4-pipe of 3.5. Net KW savings are then multiplied by the electric rate in that climate for that hour to determine the hourly $ savings.

The heat recovered for HHW is then subtracted from the condenser heat available to determine the remaining heat available for SHW heat recovery. This is then compared to the SHW load in that hour to determine the amount of SHW heat recovery in that hour. The SHW energy savings for that hour are then calculated by assuming a fixed COP of 4.5 for the heat recovery chiller versus a fixed COP of 1.0 for a baseline electric water heater. These KW savings are then multiplied by the electric rate in that climate for that hour to determine the hourly dollar savings.

Note that this analysis is highly conservative because it does not take credit for cooling energy savings, only heating energy savings. It assumes that if the air economizer were enabled there would be no simultaneous heating and cooling. This is obviously not always true, particularly if there is a significant SHW load or if there is a data center without a direct air economizer or the data center is not operated at elevated supply and return temperatures (e.g., 75 SAT, 95 RAT). A more accurate analysis would take credit for cooling savings by also determining the Cooling PLR with the economizer enabled and comparing this to the calculated heat recovery. The smaller of the current required cooling and the current heat recovery would be free cooling load, since the HR chiller energy is already accounted for as part of the incremental heating energy savings. This free cooling load would be compared to the energy a 2-pipe AWHP would use to meet this load to determine the free cooling KW savings. Since the B/C ratio is already > 1 in all climates it was not necessary to capture the cooling energy savings.

Incremental cost functions for heat recovery chiller capacity and SHW heat recovery capacity on a per kBtuh basis were developed based on the Incremental Costs in Section 3.4.3. These cost functions were then applied to the adjustable values for heat recovery chiller capacity and SHW heat recovery capacity to determine the total incremental cost for the current spreadsheet assumptions. These are compared to the total $ savings to determine the B/C ratio for the current spreadsheet assumptions. The adjustable variables in the spreadsheet were then run through a wide range of parametric analysis to demonstrate cost-effectiveness under a wide range of assumptions for building loads, process loads, HR chiller sizing, and SHW sizing.

3.3.1.2 Energy Savings Methodology per Prototypical Building

The Statewide CASE Team measured per unit energy savings expected from the proposed code changes in several ways in order to quantify key impacts. First, savings are calculated by fuel type. Electricity savings are measured in terms of both energy usage and peak demand reduction. Natural gas savings are quantified in terms of energy usage. Second, the Statewide CASE Team calculated Source Energy Savings. Source Energy represents the total amount of raw fuel required to operate a building. In addition to all energy used from on-site production, source energy incorporates all transmission, delivery, and production losses. The hourly Source Energy values provided by CEC are proportional to GHG emissions. Finally, the Statewide CASE Team calculated Long-term Systemwide Cost (LSC) savings, formerly known as Time Dependent Value (TDV) Energy Cost Savings. LSC savings are calculated using hourly energy cost metrics for both electricity and natural gas provided by the CEC. These LSC hourly factors are projected over the 30-year life of the building. The LSC hourly factors incorporate the hourly cost of marginal generation, transmission and distribution, fuel, capacity, losses, and cap-and-trade-based CO2 emissions. More information on Source Energy and LSC hourly factors is available in the March 2020 CEC Staff Workshop on Energy Code Compliance Metrics and the July 2022 CEC Staff Workshop on Energy Code Accounting for the 2025 Building Energy Efficiency Standards.

The CEC directed the Statewide CASE Team to model the energy impacts using specific prototypical building models that represent typical building geometries for different types of buildings (California Energy Commission 2022). The prototype buildings that the Statewide CASE Team used in the analysis are presented in Table 71.

Table 71: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name	Number of Stories	Floor Area (Square Feet)	Description
Hospital	5	241,501	5-Story Hospital plus basement. Source: DOE Standard 90.1 Hospital prototype and scorecard. The prototype contains Title 24, Part 6, minimally compliant envelope features and lighting. For HVAC systems, the AIA guidelines recommended using VAV systems wherever possible.
OfficeLarge	12	498,589	12 story + 1 basement office building with 5 zones and a ceiling plenum on each floor. WWR-0.40.
SchoolLarge	2	210,866	High school with WWR of 35% and SRR 1.4%

The Statewide CASE Team estimated LSC energy, source energy, electricity, natural gas, peak demand, and GHG impacts by simulating the proposed code change in EnergyPlus using prototypical buildings and rulesets from the 2025 Research Version of the California Building Energy Code Compliance (CBECC) software.

CBECC generates two models based on user inputs: the Standard Design and the Proposed Design. The Standard Design represents the geometry of the prototypical building and a design that uses a set of features that result in a lifecycle energy budget and Source energy budget that is minimally compliant with 2022 Title 24, Part 6 code requirements. Features used in the Standard Design are described in the 2022 Nonresidential ACM Reference Manual. The Proposed Design represents the same geometry as the Standard Design, but it assumes the energy features that the software user describes with user inputs. To develop savings estimates for the proposed code changes, the Statewide CASE Team created a Standard Design for each prototypical building representing compliance with 2022 code and then modified the space heating system to convert it from a natural gas boiler to an electric AWHP sized to meet peak design loads. This system represents the baseline conditions against which the measures were compared. For this measure, the standard design uses a 2-pipe AWHP because our baseline condition is assumed to be a design minimally complying with the code in a local jurisdiction that has adopted an all-electric energy code.

The Proposed Design was identical to the Standard Design in all ways except for the revisions that represent the proposed changes to the code. This measure contains two subcategories: heat recovery with or without thermal energy storage in the proposed design. Most prototypes would fall under the category of requiring thermal energy storage, so their proposed design configurations included heat recovery and thermal energy storage. The Hospital prototype would comply without thermal energy storage, so it was modified to only include hydronic heat recovery. The changes between the standard and proposed designs are further described in Section 3.3.1.1.

CBECC calculates whole-building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/y) and therms per year (Therms/yr). It then applies the 2025 LSC hourly factors to calculate lifecycle energy use in kilo British thermal units per year (kBtu/y), Source Energy factors to calculate Source Energy Use in kilo British thermal units per year (kBtu/y), and hourly GHG emissions factors to calculate annual GHG emissions in metric tons of carbon dioxide emissions equivalent (MT or “tonnes” CO_2e/y) (California Energy Commission 2022). CBECC also generates LSC savings values measured in 2026 present value dollars (2026 PV$) and nominal dollars. CBECC also calculates annual peak electricity demand measured in kilowatts (kW).

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

Per-unit energy impacts for nonresidential buildings are presented in savings per square foot. Annual energy, GHG, and peak demand impacts for each prototype building were translated into impacts per square foot by dividing by the floor area of the prototype building. This step allows for an easier comparison of savings across different building types and enables a calculation of statewide savings using the construction forecast that is published in terms of floor area by building type.

3.3.1.3 Statewide Energy Savings Methodology

The per-unit energy impacts were extrapolated to statewide impacts using the statewide construction forecasts that the CEC provided. The statewide construction forecasts estimate new construction/additions that would occur in 2026, the first year that the 2025 Title 24, Part 6 requirements are in effect. They also estimate the amount of total existing building stock in 2026, which the Statewide CASE Team used to approximate savings from building alterations (California Energy Commission 2022). The construction forecast provides construction (new construction/additions and existing building stock) by building type and climate zone, as shown in Appendix A.

Appendix A presents additional information about the methodology and assumptions used to calculate statewide energy impacts.

3.3.2 Per-Unit Energy Impacts Results

Energy savings and peak demand reductions per unit are presented in Table 72 through Table 75. This measure would only apply to new construction/additions, not alterations. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. Per-unit savings for the first year are expected to range from 0.17 to 1.10 kWh/y depending upon climate zone. Demand reductions are expected to range between 0.00 kW and 0.21 kW depending on climate zone.

Table 72: First Year Electricity Savings (kWh) Per Square Foot – Simultaneous Cooling and Heating

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
Hospital	0.94	0.89	0.78	0.98	0.83	0.74	0.66	0.73	0.74	0.74	0.74	0.85	0.72	0.91	0.55	1.10

Table 73: First Year Peak Demand Reduction (W) Per Square Foot – Simultaneous Cooling and Heating

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
Hospital	0.15	0.14	0.09	0.17	0.14	0.13	0.12	0.16	0.15	0.12	0.12	0.13	0.09	0.20	0.12	0.17

Table 74: First Year Source Energy Savings (kBtu) Per Square Foot – Simultaneous Cooling and Heating

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
Hospital	2.15	2.17	1.66	2.34	1.89	1.68	1.47	1.62	1.63	1.67	1.85	1.96	1.63	2.57	1.23	2.76

Table 75: First Year LSC Energy Savings ($) Per Square Foot – Simultaneous Cooling and Heating

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
Hospital	5.96	5.77	4.69	5.97	5.28	4.62	3.93	4.56	4.54	4.52	4.56	5.09	4.25	5.91	3.42	7.15

Table 76: First Year Electricity Savings (kWh) Per Square Foot – Thermal Energy Storage

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
OfficeLarge	0.34	0.47	0.17	0.49	0.27	0.26	0.28	0.31	0.27	0.28	0.46	0.46	0.41	0.68	0.31	0.94

Table 77: First Year Peak Demand Reduction (W) Per Square Foot – Thermal Energy Storage

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
OfficeLarge	0.09	0.10	0.04	0.11	0.07	0.01	0.00	0.02	0.02	0.04	0.14	0.12	0.09	0.21	0.02	0.23

Table 78: First Year Source Energy Savings (kBtu) Per Square Foot – Thermal Energy Storage

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
OfficeLarge	1.04	1.31	0.45	1.32	0.68	0.21	0.19	0.31	0.33	0.39	1.37	1.17	0.94	2.03	0.41	2.59

Table 79: First Year LSC Energy Savings ($) Per Square Foot – Thermal Energy Storage

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
OfficeLarge	2.39	3.04	1.02	3.08	1.69	1.21	1.24	1.46	1.35	1.47	3.02	2.82	2.45	4.55	1.67	6.43

Table 80: First Year Electricity Savings (kWh) Per Square Foot – Heat Recovery for Service Water Heating

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
OfficeLarge	0.19	0.17	0.17	0.15	0.16	0.17	0.18	0.17	0.17	0.17	0.15	0.16	0.15	0.15	0.17	0.13

Table 81: First Year Source Energy Savings (kBtu) Per Square Foot – Heat Recovery for Service Water Heating

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
OfficeLarge	0.21	0.17	0.18	0.16	0.16	0.18	0.19	0.18	0.17	0.18	0.16	0.17	0.16	0.18	0.19	0.14

Table 82: First Year LSC Energy Savings ($) Per Square Foot – Heat Recovery for Service Water Heating

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
OfficeLarge	0.91	0.78	0.78	0.73	0.76	0.83	0.87	0.83	0.80	0.80	0.70	0.76	0.73	0.76	0.83	0.61

3.4 Cost and Cost Effectiveness

3.4.1 Energy Cost Savings Methodology

Energy cost savings were calculated by applying the LSC hourly factors to the energy savings estimates that were derived using the methodology described in Section 2.3.1. LSC hourly factors are a normalized metric to calculate energy cost savings that accounts for the variable cost of electricity and natural gas for each hour of the year, along with how costs are expected to change over the period of analysis. In this case, the period of analysis used is 30 years.

The CEC requested energy cost savings over the 30-year period of analysis in both 2026 present value dollars (2026 PV$) and nominal dollars. The cost effectiveness analysis uses energy cost values in 2026 PV$. Costs and cost-effectiveness using and 2026 PV$ are presented in Section 2.4 of this report. CEC uses results in nominal dollars to complete the Economic and Fiscal Impacts Statement (From 399) for the entire package of proposed change to Title 24, Part 6. Appendix G presents energy cost savings results in nominal dollars.

3.4.2 Energy Cost Savings Results

Per-unit energy cost savings for newly constructed buildings that are realized over the 30-year period of analysis are presented 2026 precent value dollars (2026 PV$) in Table 83 through Table 85.

The LSC hourly factors methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. This measure is expected to have an impact on heating peak demand, as well as potentially on cooling peak demand depending on how the thermal energy storage tank is configured.

Any time code changes impact cost, there is potential to disproportionately impact DIPs. Refer to Section 3.6 for more details addressing energy equity and environmental justice.

Table 83: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions – Hospital (Simultaneous Cooling and Heating)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	5.96	0.00	5.96
2	5.77	0.00	5.77
3	4.69	0.00	4.69
4	5.97	0.00	5.97
5	5.28	0.00	5.28

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
6	4.62	0.00	4.62
7	3.93	0.00	3.93
8	4.56	0.00	4.56
9	4.54	0.00	4.54
10	4.52	0.00	4.52
11	4.56	0.00	4.56
12	5.09	0.00	5.09
13	4.25	0.00	4.25
14	5.91	0.00	5.91
15	3.42	0.00	3.42
16	7.15	0.00	7.15

[a] "NA" refers to the fact that the CEC forecasts 0 square feet of construction activity in this climate zone for this building type in 2026.

Table 84: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions – Large Office (Thermal Energy Storage)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	NA	NA	NA
2	NA	NA	NA
3	1.02	0.00	1.02
4	3.08	0.00	3.08
5	NA	NA	NA
6	1.21	0.00	1.21
7	1.24	0.00	1.24
8	1.46	0.00	1.46
9	1.35	0.00	1.35
10	1.47	0.00	1.47
11	3.02	0.00	3.02
12	2.82	0.00	2.82
13	NA	NA	NA
14	4.55	0.00	4.55
15	1.67	0.00	1.67
16	6.43	0.00	6.43

Table 85: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions – Large Office (Heat Recovery for Service Water Heating)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	NA	NA	NA
2	NA	NA	NA
3	0.78	0.00	0.78
4	0.73	0.00	0.73
5	NA	NA	NA
6	0.83	0.00	0.83
7	0.87	0.00	0.87
8	0.83	0.00	0.83
9	0.80	0.00	0.80
10	0.80	0.00	0.80
11	0.70	0.00	0.70
12	0.76	0.00	0.76
13	NA	NA	NA
14	0.76	0.00	0.76
15	0.83	0.00	0.83
16	0.61	0.00	0.61

3.4.3 Incremental First Cost

3.4.3.1 Simultaneous Heat Recovery

The incremental cost for simultaneous heat recovery was determined by starting with an all-electric design without heat recovery and upgrading the design to include heat recovery. A typical all-electric central plant without heat recovery consists of all 2-pipe air to water heat pumps (AWHP, sometimes labeled ATWHP, and sometimes more generally referred to as air source heat pumps or ASHP). 2-pipe AWHPs can provide chilled water or hot water, but not at the same time. In cooling mode, heat is rejected to the ambient air. In heating mode, heat is extracted from ambient air. 4-pipe AWHPs can provide both heating and cooling at the same time by recovering condenser waste heat. The net heat that is not recovered is rejected to ambient air.

Figure 27 shows a typical plant with a combination of 2-pipe and 4-pipe AWHPs. These AWHPs all have a cooling capacity of approximately 130 tons. The two pipes leaving the 2-pipe AWHPs have four control valves such that when the 2-pipe AWHP is needed for cooling it is connected to the CHW system and when the 2-pipe AWHP is needed for heating it is connected to the HW system. The 4-pipe AWHPs do not have these control valves as they are always connected to both the CHW and HW system.

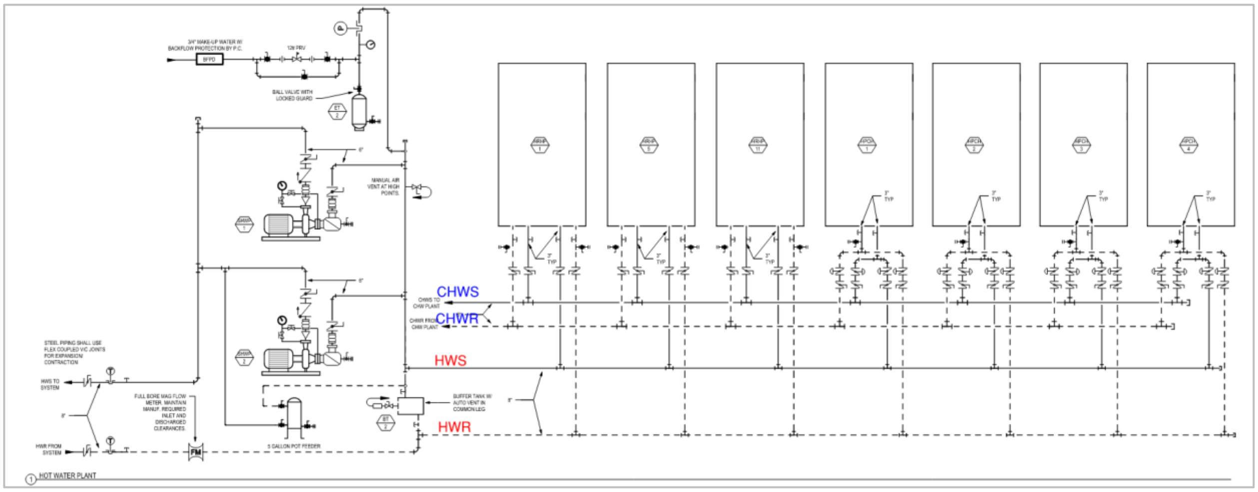


Figure 27: Typical CHW/HW Plant with 2-Pipe and 4-Pipe AWHPs

The incremental cost of simultaneous heat recovery is the additional cost to upgrade one 2-pipe AWHP to a 4-pipe AWHP. A Bay Area mechanical contractor provided the full incremental cost to upgrade one of the 130-ton AWHP in this plant from a 2-pipe AWHP to a 4-pipe AWHP. As shown in Table 86, the 4-pipe AWHP costs $65,000 more than the 2-pipe and has slightly higher maintenance, but the 4-pipe is less expensive to install and has a lower controls cost, mostly because it does not require the 4-way control valves. The net result is an incremental cost of $565/ton of heat recovery capacity.

Table 86: Incremental First Cost and Maintenance Cost for 4-pipe vs 2-pipe AWHP

Parameter	Value
Representative AWHP capacity (tons)	130
Incremental equipment cost ($/ton)	$500
Incremental equipment cost ($/AWHP)	$65,000
Incremental piping ($/AWHP)	($15,000)
Incremental piping ($/ton)	($115)
Incremental controls ($/AWHP)	($17,500)
Incremental controls ($/ton)	($135)
Incremental maintenance cost ($/yr/AWHP)	$250
Incremental maintenance cost ($/yr/ton)	$1.92
NPV multiplier for annual maintenance	19.6
NPV of annual maintenance $/ton	$38

Parameter	Value
Expected life of AWHP (years)	20
Replacement cost multiplier	0.55
Incremental replacement cost ($/ton)	$277
Net incremental cost for 4-pipe ($/AWHP)	$73,389
Net incremental cost for 4-pipe ($/ton)	$565
HR Chiller capacity in prototype (tons)	368
Incremental cost for prototype ($)	$207,977

3.4.3.2 Thermal Energy Storage (TES)

Condenser water Time Independent Energy Recovery (TIER) is a form of TES that uses condenser water for thermal storage. It was bid as an alternate system design option versus AWHPs on four recent Bay Area new construction projects. See Table 87 and Appendix I for a reproduction of a technical memo developed by Taylor Engineers comparing several all-electric hydronic design options, including TIER. Pricing was provided by each individual project's General Contractor and thus represents the total net cost to the owner. In all cases TIER costs less than the base case all-electric design.

Table 87: TIER Plant Incremental Cost Savings

Location	Santa Clara	Sunnyvale	San Jose	Oakland
Stories	3	3	6	27
Building area (ft2)	314,000	1,100,000	1,022,981	718,000
CHWcap (tons)	780	2,660	1,800	1,200
SHWcap (kBtuh)	307	N/A	553	N/A
Hwcap (kBtuh)	5,000	18,986	11,896	10,215
Tank capacity (kBtu)	12,125	45,807	**	34,436
Tank capacity (gallons)	35,000	141,000	**	53,000
Tank doubles as fire water storage?	No	Yes	Yes	Yes
First Cost Savings ($)	*	1,500,000	6,725,003	2,200,000
First cost savings ($/ft2)	*	$ 1.36	$ 6.57	$ 3.06

*For the Santa Clara site, TIER was the base bid. The GC indicated that AWHPs was a net cost add but did not provide a hard bid, i.e., TIER was lower cost. The owner opted for TIER since it was lower cost, lower energy use, and lower maintenance.

**Tank size TBD.

Table 88: Detailed Pricing for TIER vs AWHP - San Jose Site

All-In System Costs (options)	ASHPs - Heating Only $	ASHPs - Heating Only $/sf	ASHP/ Chilled Water $	ASHP/ Chilled Water $/sf	TIER Plant $	TIER Plant $/sf
General Conditions	481,226	$0.47	481,226	$0.47	481,226	$0.47
Staking	5,000	$0.00	5,000	$0.00	5,000	$0.00
Concrete	0	$0.00	0	$0.00	156,741	$0.15
Rebar	0	$0.00	0	$0.00	37,425	$0.04
Structural Steel	500,000	$0.49	500,000	$0.49	210,000	$0.21
Misc. Metal	75,000	$0.07	75,000	$0.07	32,000	$0.03
Below Grade Waterproofing	0	$0.00	0	$0.00	5,000	$0.00
Signage	1,000	$0.00	1,000	$0.00	1,000	$0.00
Fire Sprinklers	0	$0.00	0	$0.00	26,600	$0.03
Plumbing	320,000	$0.31	320,000	$0.31	320,000	$0.31
HVAC	17,791,154	$17.39	17,199,508	$16.81	11,118,477	$10.87
Electrical	3,000,000	$2.93	3,000,000	$2.93	3,028,623	$2.96
Design	320,327	$0.31	320,327	$0.31	320,327	$0.31
Subtotal	22,493,707	$21.99	21,902,061	$21.41	15,742,419	$15.39
Contingency	1,124,685	$1.10	1,095,103	$1.07	787,121	$0.77
SDI	236,184	$0.23	229,972	$0.22	165,295	$0.16
Fee	703,710	$0.69	685,201	$0.67	492,498	$0.48
Total	24,558,286	$24.01	23,912,336	$23.38	17,187,333	$16.80

3.4.3.3 Incremental Cost for SHW Heat Recovery

Bay Area equipment reps, mechanical contractors, controls contractors and service contractors provided incremental cost data to add SHW heat recovery on a $/kBtuh of HR capacity basis, shown in Table 89.

Table 89: Pricing for SWH Heat Recovery

Parameter	Value
HX 2-1 gpm	7.1
HX dT	55
HX kbtuh	195
Pipe size	1”
Pipe cost ($/LF)	$111
LF of pipe mech	104
LF of pipe plumbing	20
LF of pipe	124

Parameter	Value
Cost of piping	$13,764
Cost of HX	$6,540
Install cost of HX, excluding piping above	$1,200
Incremental controls per HX (see pts and SOO below)	$6,500
Incremental annual maintenance cost per HX	$0
Maintenance multiplier	19.60
NPV of maintenance	$0
Incremental cost	$28,004
Incremental cost $/kBtuh of HR capacity	$143

3.4.4 Incremental Maintenance and Replacement Costs

Incremental maintenance cost is the incremental cost of replacing the equipment or parts of the equipment, as well as periodic maintenance required to keep the equipment operating relative to current practices over the 30-year period of analysis. The present value of equipment maintenance costs (or savings) was calculated using a three percent discount rate (d), which is consistent with the discount rate used when developing the 2025 LSC hourly factors. The present value of maintenance costs that occurs in the n^{th} year is calculated as follows:

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

The incremental maintenance and replacement costs for Simultaneous Heat Recovery were provided by a Bay Area mechanical and service contractor and are listed in Table 86.

For heat recovery with TES, maintenance and replacement costs are expected to be lower for the proposed case because there are fewer AWHPs to maintain and replace. Incremental maintenance costs for this measure were not quantified. This aspect is not needed to demonstrate cost-effectiveness since the proposed case has lower first costs, lower energy costs and lower maintenance/replacement costs than the base case.

3.4.5 Cost Effectiveness

This measure proposes a prescriptive requirement for builders who have chosen to pursue an all-electric design. As such, a cost analysis is required to demonstrate that the measure is cost effective over the 30-year period of analysis.

The CEC establishes the procedures for calculating cost effectiveness. The Statewide CASE Team collaborated with CEC staff to confirm that the methodology in this report is consistent with their guidelines, including which costs were included in the analysis. The incremental first cost and incremental maintenance costs over the 30-year period of analysis were included. The LSC savings from electricity savings were also included in the evaluation. Design costs were not included nor were the incremental costs of code compliance verification.

According to the CEC's definitions, a measure is cost effective if the benefit-to-cost (B/C) ratio is greater than 1.0. The B/C ratio is calculated by dividing the cost benefits realized over 30 years by the total incremental costs, which includes maintenance costs for 30 years. The B/C ratio was calculated using 2026 PV costs and cost savings.

Results of the per-unit cost-effectiveness analyses are presented in Table 90 for new construction/addition for the condition of heat recovery without thermal energy storage (represented by the hospital prototype). Results of the per-unit cost-effectiveness analyses are presented in Table 91 for new construction/addition for the condition of heat recovery with thermal energy storage (represented by the large office prototype). The B/C ratio is infinite (implying immediate payback) due to the fact that the incremental first cost is negative relative to the baseline design without heat recovery or thermal energy storage. Table 92 shows the cost-effectiveness for heat recovery for service hot water.

Table 90: 30-Year Cost-Effectiveness Summary Per Square Foot – New Construction/Additions – Hospital (Simultaneous Cooling and Heating)

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	5.96	0.41	14.39
2	5.77	0.41	13.93
3	4.69	0.41	11.32
4	5.97	0.41	14.43
5	5.28	0.41	12.74
6	4.62	0.41	11.16
7	3.93	0.41	9.48
8	4.56	0.41	11.01
9	4.54	0.41	10.96
10	4.52	0.41	10.91
11	4.56	0.41	11.01
12	5.09	0.41	12.29
13	4.25	0.41	10.26
14	5.91	0.41	14.27
15	3.42	0.41	8.25
16	7.15	0.41	17.26
Total	4.76	0.41	11.49

a. **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC Savings over the period of analysis (California Energy Commission 2022). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) three percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

Table 91: 30-Year Cost-Effectiveness Summary Per Square Foot – New Construction/Additions – Large Office (Thermal Energy Storage)

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	-	(3.66)	-
2	-	(3.66)	-
3	0.71	(3.66)	Infinite
4	2.09	(3.66)	Infinite
5	-	(3.66)	-
6	0.66	(3.66)	Infinite
7	0.63	(3.66)	Infinite
8	0.85	(3.66)	Infinite
9	0.76	(3.66)	Infinite
10	0.37	(3.66)	Infinite
11	0.87	(3.66)	Infinite
12	0.48	(3.66)	Infinite
13	-	(3.66)	-
14	1.66	(3.66)	Infinite
15	0.08	(3.66)	Infinite
16	2.11	(3.66)	Infinite
Total	0.78	(3.66)	Infinite

a. **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC Savings over the period of analysis (California Energy Commission 2022). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

b. Costs: Total Incremental Present Valued Costs: Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) three percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

Table 92: 30-Year Cost-Effectiveness Summary Per Square Foot – New Construction/Additions – Large Office (Heat Recovery for Service Water Heating)

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	-	0.29	-
2	-	0.28	-
3	0.78	0.27	2.87
4	0.73	0.32	2.32
5	-	0.27	-
6	0.83	0.25	3.36
7	0.87	0.23	3.80
8	0.83	0.24	3.39
9	0.80	0.25	3.20
10	0.80	0.26	3.11
11	0.70	0.29	2.41
12	0.76	0.28	2.73
13	-	0.28	-
14	0.76	0.28	2.73
15	0.83	0.25	3.27
16	0.61	0.29	2.11
Total	0.80	0.29	2.94

a. **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC Savings over the period of analysis (California Energy Commission 2022). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) three percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

3.5 First-Year Statewide Impacts

3.5.1 Statewide Energy and Energy Cost Savings

The Statewide CASE Team calculated the first-year statewide savings for new construction and additions by multiplying the per-unit savings, which are presented in Section 2.3.2, by assumptions about the percentage of newly constructed buildings that would be impacted by the proposed code. The statewide new construction forecast for

2026 is presented in Appendix A, as are the Statewide CASE Team's assumptions about the percentage of new construction that would be impacted by the proposal (by climate zone and building type).

The first-year energy impacts represent the first-year annual savings from all buildings that were completed in 2026. The 30-year energy cost savings represent the energy cost savings over the entire 30-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

Table 93, Table 94, and Table 95 present the first-year statewide energy and energy cost savings from newly constructed buildings and additionsTable 93 by climate zone.

Table 93: Statewide Energy and Energy Cost Impacts – New Construction and Additions – Hospital – Simultaneous Cooling and Heating

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026	First-Year[a] 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 Energy Cost Savings (Million 2026 PV$)
1	8,817	0.01	0.00	0	0.02	$0.05
2	52,380	0.05	0.01	0	0.11	$0.30
3	252,480	0.20	0.02	0	0.42	$1.18
4	130,740	0.13	0.02	0	0.31	$0.78
5	23,916	0.02	0.00	0	0.05	$0.13
6	98,550	0.07	0.01	0	0.17	$0.46
7	164,700	0.11	0.02	0	0.24	$0.65
8	132,360	0.10	0.02	0	0.21	$0.60
9	236,820	0.17	0.04	0	0.38	$1.07
10	243,840	0.18	0.03	0	0.41	$1.10
11	43,770	0.03	0.01	0	0.08	$0.20
12	247,590	0.21	0.03	0	0.48	$1.26
13	81,870	0.06	0.01	0	0.13	$0.35
14	42,510	0.04	0.01	0	0.11	$0.25
15	34,500	0.02	0.00	0	0.04	$0.12
16	14,439	0.02	0.00	0	0.04	$0.10
Total	1,809,282	1.41	0.24	0	3.21	$8.61

a. First-year savings from all buildings completed statewide in 2026.

Table 94: Statewide Energy and Energy Cost Impacts – New Construction and Additions - Large Office – Thermal Energy Storage

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026	First-Year[a] 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 Energy Cost Savings (Million 2026 PV$)
1	0	0.00	0.00	0	0.00	$0.00
2	0	0.00	0.00	0	0.00	$0.00
3	970,200	0.16	0.04	0	0.43	$0.99
4	473,400	0.23	0.05	0	0.63	$1.46
5	0	0.00	0.00	0	0.00	$0.00
6	426,600	0.11	0.00	0	0.09	$0.52
7	247,500	0.07	0.00	0	0.05	$0.31
8	686,400	0.21	0.01	0	0.21	$1.01
9	1,245,600	0.34	0.03	0	0.42	$1.68
10	117,480	0.03	0.00	0	0.05	$0.17
11	32,640	0.01	0.00	0	0.04	$0.10
12	172,410	0.08	0.02	0	0.20	$0.49
13	0	0.00	0.00	0	0.00	$0.00
14	60,060	0.04	0.01	0	0.12	$0.27
15	3,909	0.00	0.00	0	0.00	$0.01
16	14,985	0.01	0.00	0	0.04	$0.10
Total	4,451,184	1.31	0.18	0	2.27	$7.09

a. First-year savings from all buildings completed statewide in 2026.

Table 95: Statewide Energy and Energy Cost Impacts – New Construction and Additions - Large Office – Heat Recovery for Service Water Heating

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026	First-Year[a] 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 Energy Cost Savings (Million 2026 PV$)
1	0	0.00	0.00	0	0.00	$0.00
2	0	0.00	0.00	0	0.00	$0.00
3	970,200	0.16	0.01	0	0.17	$0.76
4	473,400	0.07	0.00	0	0.07	$0.35
5	0	0.00	0.00	0	0.00	$0.00
6	426,600	0.07	0.00	0	0.08	$0.35
7	247,500	0.04	0.00	0	0.05	$0.22
8	686,400	0.12	0.00	0	0.12	$0.57
9	1,245,600	0.21	0.00	0	0.21	$1.00
10	117,480	0.02	0.00	0	0.02	$0.09
11	32,640	0.00	0.00	0	0.01	$0.02
12	172,410	0.03	0.00	0	0.03	$0.13
13	0	0.00	0.00	0	0.00	$0.00
14	60,060	0.01	0.00	0	0.01	$0.05
15	3,909	0.00	0.00	0	0.00	$0.00
16	14,985	0.00	0.00	0	0.00	$0.01
Total	4,451,184	0.74	0.01	0	0.78	$3.54

a. First-year savings from all buildings completed statewide in 2026.

3.5.2 Statewide Greenhouse Gas (GHG) Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions associated with energy consumption using the hourly GHG emissions factors that CEC developed along with the 2025 LSC hourly factors and an assumed cost of $123.15 per metric tons of carbon dioxide equivalent emissions (metric tons CO2e).

The 2025 LSC hourly factors used in the lifecycle cost-effectiveness analysis include the monetary value of avoided GHG emissions based on a proxy for permit costs (not social costs).[21] The Cost-Effectiveness Analysis presented in Section 3.42.4 of this

[21] The permit cost of carbon is equivalent to the market value of a unit of GHG emissions in the California Cap-and-Trade program, while social cost of carbon is an estimate of the total economic value of damage done per unit of GHG emissions. Social costs tend to be greater than permit costs. See more on the Cap-and-Trade Program on the California Air Resources Board website: https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program.

report does not include the cost savings from avoided GHG emissions. To demonstrate the cost savings of avoided GHG emissions, the Statewide CASE Team disaggregated the value of avoided GHG emissions from the other economic impacts. The authors used the same monetary values that are used in the LSC hourly factors.

Table 96Table 96 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 233 (metric tons CO2e) would be avoided.

Table 96: First-Year Statewide GHG Emissions Impacts

Measure	Electricity Savings[a] (GWh/yr)	Reduced GHG Emissions from Electricity Savings[a] (Metric Tons CO2e)	Natural Gas Savings[a] (Million Therms/yr)	Reduced GHG Emissions from Natural Gas Savings[a] (Metric Tons CO2e)	Total Reduced GHG Emissions[b] (Metric Ton CO2e)	Total Monetary Value of Reduced GHG Emissions[c] ($)
Simultaneous cooling and heating	1.41	170	0	0	170	20,892
Thermal Energy Storage	1.31	120	0	0	120	14,821
Heat Recovery for Service Water Heating	0.74	41	0	0	41	5,053
TOTAL	3.46	331	0.00	0.00	331	40,766

a. First-year savings from all buildings completed statewide in 2026.
b. GHG emissions savings were calculated using hourly GHG emissions factors are published alongside the in the LSC hourly factors and Source Energy factors by CEC here: https://www.energy.ca.gov/files/2025-energy-code-hourly-factors
c. The monetary value of avoided GHG emissions is based on a proxy for permit costs (not social costs) derived from the 2022 TDV Update Model published by CEC here: https://www.energy.ca.gov/files/tdv-2022-update-model

3.5.3 Statewide Water Use Impacts

Systems configured to reject heat to a thermal energy storage tank instead of a cooling tower will likely experience water savings due to the reduced runtime hours of the cooling towers. The Statewide CASE Team quantified this impact per prototype building. Since energy use of the proposed design was calculated using spreadsheet-based calculation instead of EnergyPlus, water use was also calculated in a spreadsheet and was estimated based on the energy rejected through the cooling tower. The methodology included multiplying the heat rejection energy by 970 Btu/lb of water, then converting this to volume using the conversion factor of 8.33 gallons/lb. In this calculation, it was assumed that the cooling tower operated at three cycles of concentration, which resulted in two-thirds of the water being evaporated and one-third being bled by the system. The water consumption in the baseline design was automatically calculated by EnergyPlus. The water savings for large office are shown in Table 97.

Table 97: Water Savings for Heat Recovery + Thermal Energy Storage Measure – Large Office

Climate Zone	Baseline Design (2-pipe AWHP) Water Consumption (gal)	Proposed Design (HR+TES) Water Consumption (gal)	Water Savings (gal)	Water Savings per square foot (gal/sf)	Water Savings (%)
1	135,347	26,188	109,159	0.22	81%
2	1,241,864	961,236	280,628	0.56	23%
3	613,215	384,963	228,252	0.46	37%
4	1,885,924	1,473,273	412,651	0.83	22%
5	795,456	547,209	248,247	0.50	31%
6	1,443,901	1,166,211	277,690	0.56	19%
7	1,549,401	1,176,116	373,285	0.75	24%
8	2,328,133	1,936,345	391,788	0.79	17%
9	2,230,099	1,807,783	422,316	0.85	19%
10	2,616,637	2,136,918	479,719	0.96	18%
11	2,581,298	1,899,646	681,652	1.37	26%
12	1,831,528	1,385,399	446,129	0.89	24%
13	2,706,587	1,990,151	716,436	1.44	26%
14	2,418,528	1,916,540	501,988	1.01	21%
15	4,910,731	3,505,169	1,405,562	2.82	29%
16	912,126	707,007	205,119	0.41	22%

3.5.4 Statewide Material Impacts

This measure is expected to result in small changes to materials. The simultaneous cooling and heating measure (140.4(k)9) would result in a minor change in hydronic equipment configuration. The Thermal Energy Storage measure (140.4(k)10) would result in additional thermal energy storage equipment specification which would be offset by reduced AWHP equipment specifications. Material impacts have not been quantified.

3.5.5 Other Non-Energy Impacts

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

3.6 Addressing Energy Equity and Environmental Justice

The Statewide CASE Team recognizes, acknowledges, and accounts for a history of prejudice and inequality in disproportionately impacted populations (DIPs) and the role this history plays in the environmental justice issues that persist today. DIPs refer to the populations throughout California that most suffer from a combination of economic, health, and environmental burdens. These burdens include poverty, high unemployment, air and water pollution, presence of hazardous wastes, as well as high incidence of asthma and heart disease. DIPs also incorporate race, class, and gender since these intersecting identity factors affect how people frame issues, interpret, and experience the world.[22] While the term disadvantaged communities (DACs) is often used in the energy industry and state agencies, the Statewide CASE Team chose to use terminology that is more acceptable to and less stigmatizing for those it seeks to describe (DC Fiscal Policy Institute 2017).

Including impacted communities in the decision-making process, ensuring that the benefits and burdens of the energy sector are evenly distributed, and facing the unjust legacies of the past serve as critical steps to achieving energy equity. To minimize the risk of perpetuating inequity, code change proposals are being developed with intentional consideration of the unintended consequences of proposals on DIPs.

The Statewide CASE Team recognizes the importance of engaging DIPs and gathering their input to inform the code change process and proposed measures. A participatory approach allows individuals to address problems, develop innovative ideas, and bring forth a different perspective. The Statewide CASE Team is working to build relationships with community-based organizations (CBOs) to facilitate meaningful engagement with stakeholders and gather feedback on the proposed measures. Please reach out to Bryan Boyce (bboyce@energy-solution.com), Nancy Metayer (nmetayer@energy-solution.com) and Marissa Lerner (mlerner@energy-solution.com) for further engagement.

3.6.1 Potential Impacts

The purpose of this code change is to guide mechanical designers toward efficient system configurations for all-electric designs in large buildings. Future revisions to the code language being proposed may target smaller buildings, but for this cycle, the Statewide CASE Team intends to only target the largest and most complex buildings

[22] Environmental disparities have been shown to be associated with unequal harmful environmental exposure correlated with race/ethnicity, gender, and socioeconomic status. For example, chronic diseases, such as respiratory diseases, cardiovascular disease, and cancer, associated with environmental exposure have been shown to occur in higher rates in the LGBTQ+ population than in the cisgender, heterosexual population (Goldsmith L 2022). Socioeconomic inequities, climate, energy, and other inequities are inextricably linked and often mutually reinforcing.

being constructed. The new requirements of thermal energy storage and heat recovery are complex and major changes to current practice, but because it only impacts large buildings, this will reduce the impact on DIPs since there are relatively few large buildings constructed. Furthermore, our analysis shows that inclusion of thermal energy storage reduces upfront construction costs (at the expense of a more complex system), which is a benefit to all practitioners, including DIPs.

Furthermore, the proposal only applies to buildings that are already pursuing all-electric space heating, so the requirements will only apply to the largest all-electric buildings in the state. This gives the Statewide CASE Team reason to believe that DIPs will not be adversely impacted by this measure. Furthermore, the requirements in this measure are cost-effective and with the inclusion of thermal energy storage, also reduce first costs.

Impacts may vary by building type. Offices of all sizes, for example, are expected to be used by all people equally and DIPs are not more or less likely to occupy office spaces than any other population. So, the proposed change is not expected to have an unequal impact on DIPs. The Statewide CASE Team identified schools and hotels as building types that may have disproportional impacts. These building types are discussed below.

3.6.2 Potential Disproportionately Impacted Populations

Proposed code changes to both small and large schools have the potential to disproportionately impact DIPs for those attending school and working at schools located in DIP’s communities. Proposed code changes that impact health, disaster preparedness, safety, and comfort especially all have the potential to disproportionately impact those who attend or work in schools. In addition, increased costs for building new schools or renovating schools can present challenges to jurisdictions with lower income populations where the tax base, funding, and budgets may be more constrained.

Proposed code changes to the hotel building type have the potential to disproportionately impact DIPs for those who work in the hospitality industry, use hotels as a means of temporary housing, or might use hotels for refuge during an extreme weather event (disaster preparedness). Proposed code changes that impact health, disaster preparedness especially have the potential to disproportionately impact those working or residing in hotels. While the costs may increase for this nonresidential building type, the burden of that cost is unlikely to disproportionately impact DIPs.

4. Electric Resistance Heating

4.1 Measure Description

4.1.1 Proposed Code Change

This measure proposes updates to prescriptive language limiting electric resistance for space heating at 140.4(g). The current ban on electric resistance heating is wide ranging and includes electric boilers, electric furnaces (except as backup for heat pumps) and electric resistance VAV reheat. There are currently six exceptions allowing various configurations that presumably don't consume much resistance electricity. The prescriptive ban on electric boilers and unitary furnaces would remain, but the code would be updated to allow electric resistance heat for spaces with decoupled ventilation, assuming certain energy efficient conditions are met. The proposal includes some editorial cleanup to the remainder of the exceptions to 140.4(g).

For additions, Exception 2 to 141.0(a) would be deleted. This exception allowed electric resistance heat for a narrow range of conditions, and our intent is to broaden its applicability. The requirements specified in the new exception to 140.4(g) that would ensure the existing building would not consume too much electric reheat energy would be preserved.

4.1.2 Justification and Background Information

4.1.2.1 Justification

Recent research conducted by the UC Berkeley Center for the Built Environment (CBE) has demonstrated a low rate of delivery of input boiler energy to useful heating at the occupied zone level (Raftery 2018). A study on an existing building put the fraction at 17 percent of input energy. It is likely that a newly constructed hydronic system with Title 24 compliant HVAC controls and a condensing boiler would perform better than an existing building with higher operating hours and a less efficient boiler. However, due to the significantly lower upfront costs and increasingly clean electric grid, electric resistance heating is appealing as an alternative to installing a hydronic system altogether, if the heating loads are small enough.

4.1.2.2 Background Information

Electric resistance heating has long been prescriptively banned in Section 140.4(g). However, recent research pointing to the inefficiencies in the hydronic system distribution network (Raftery 2018) and a steady shift toward cleaner electricity (spurred by utility renewables portfolio standards and legislation such as SB 32 and SB 100) have resulted in a need to revisit the tradeoff between hydronic and electric resistance

(ER) heating. Electric boilers retain the least attractive characteristics of hydronic heating (i.e., expensive piping networks and distribution losses which reduce efficiency) and deserve to remain prescriptively banned, however, airside electric resistance heating at the zone level can be a compelling alternative to hydronic heating systems. This is because the efficiency penalty of zone-level ER heating is less severe than a central ER boiler paired with the fact that ER zone heating is cheaper than hydronics. The inherent drawback to any resistance heating is the fact that the efficiency is capped at a 1.0 COP, which is easily surpassed by heat pumps. However, as demonstrated by UC Berkeley CBE research, a gas fired boiler hydronic space heating system falls well short of its traditionally assumed efficiency level for several reasons: the greater runtime hours of hydronic space heating systems than assumed, distribution system thermal losses when the building is economizing or in mechanical cooling mode, and poor gas boiler efficiency encountered in low part-load conditions. These factors are described in greater detail in Section 2.3.1.1 to support the Limit HWST energy savings but they are pertinent to this measure as well.

These significant downsides to hydronic systems present an opportunity to allow designers to bypass the need for a hydronic distribution system in favor of a zone-level ER heating system. The zone-level ER system option should only be pursued for sites with a relatively minimal heating load, otherwise the inefficient resistance heating (relative to heat pump hydronics) becomes too expensive to be justified. However, if heating loads can be sufficiently minimized, the lower upfront cost of the zone-level ER heating system design can be cost-effective. Adding an exception to 140.4(g) to allow zone-level ER heating with conditions to ensure low heating loads would provide a cost-effective all-electric space heating option for designers. Buildings could leverage a combination of hydronic and ER zones, since the requirement is intended to apply at the zone level. A building comprising VRF or some form of hydronic heat pumps (e.g., radiant AWHP, WSHP, TIER) in high heating load zones and then ER in low heating load zones could comply if all clauses are met.

4.1.2.3 Reducing Heating Loads

The proposed Exception 7 to Section 140.4(g) minimizes heating loads in several ways (the quotes are the actual proposed code language):

a) “the zone is not served by a hydronic heating system” – this eliminates the piping losses described in detail in Section 2.3.1.1.

b) “Each heating zone serves no more than one cooling zone and each cooling zone serves no more than one heating zone” – This one-to-one relationship between heating/cooling zones minimizes simultaneous heating/cooling and fighting, which can occur with large heating zones that overlap with multiple smaller cooling zones – e.g., a perimeter heating system with one zone per exposure or a radiant floor heating system with large zones.

c) “The primary airflow delivered to the zone at design heating conditions does not exceed the minimum required for ventilation.” This further minimizes reheat by requiring equipment like fan-powered boxes or radiant heat in perimeter zones. It effectively prohibits single duct VAV reheat boxes with electric resistance in perimeter zones because the primary airflow needed to be reheated to meet the peak heating load would exceed the ventilation minimum. A fan-powered VAV box, on the other hand, can deliver just the ventilation minimum while heating secondary/return air to meet the peak heating load. Note that this does not prohibit single duct VAV reheat boxes with electric resistance in interior zones because the peak heating load in interior zones can be satisfied by just reheating the minimum ventilation.

d) “All spaces with Note F in Table 120.1-A have occupant sensor ventilation controls meeting 120.1(d)5.A to G.” Figure 28 through Figure 31 include Table 120.1-A along with markup and commentary to illustrate the opacity of complying with occupied standby requirements. Note F designates the space types that are allowed to reduce ventilation to zero in occupied-standby mode. There are 28 space types in Table 120.1-A where occupied-standby ventilation is allowed. Section 120.1(d)5 requires occupied-standby ventilation where the lighting sections 130.1(c)5, 6 and 7 require occupancy sensors. These lighting sections effectively only require occupied standby in about 6 of the 28 space types where occupied standby is allowed (shaded pink in the Title 24 Table 120.1-A below). This clause would require occupied-standby in the other 22 space types where it is currently not required, including break rooms, coffee stations, bedroom/living room, barracks sleeping areas, lobbies/pre-function, large multipurpose rooms, public assembly spaces such as religious worship, courtrooms, and museums, malls, supermarkets, sports spectator areas, and entertainment stages (see yellow highlights below). We also expect that this clause will draw attention to the existing occupied standby requirement and thus improve compliance and enforcement for the six space types where it is already required.

e) “The zone does not have continuous exhaust makeup air or pressurization requirements that require an outdoor air rate greater than 0.15 cfm/ft2”. This excludes spaces like kitchens and labs that have outdoor air rates and thus high heating loads. Note that spaces with high exhaust rates like kitchens and labs do not necessarily require high outdoor air rates if there is a significant amount of transfer air available for exhaust makeup. We expect this will improve compliance and enforcement of the existing transfer air requirements in Sections 140.4(o) and 140.9(b)2.

TABLE 120.1-A– Minimum Ventilation Rates

Occupancy Category	Total Outdoor Air Rate[1] R_t (cfm/ft²)	Min Ventilation Air Rate for DCV R_a (cfm/ft²)	Air Class	Notes
Educational Facilities				
Daycare (through age 4)	0.21	0.15	2	
Daycare sickroom	0.15		3	
Classrooms (ages 5-8)	0.38	0.15	1	
Classrooms (age 9 -18)	0.38	0.15	1	
Lecture/postsecondary classroom	0.38	0.15	1	F
Lecture hall (fixed seats)	-	0.15	1	F
Art classroom	0.15		2	
Science laboratories	0.15		2	
University/college laboratories	0.15		2	
Wood/metal shop	0.15		2	
Computer lab	0.15		1	
Media center	0.15		1	A
Music/theater/dance	1.07	0.15	1	F
Multiuse assembly	0.5	0.15	1	F

PINK ones are required to have occ sensors in 130.1.c.5,6,7

130.1.c.5 just says "classrooms of any size". is a lecture hall a classroom or an assembly space?

YELLOW ones are NOT required to have occ sensors in 130.1.c.5,6,7

130.1.c.5 only requires for multipurpose rooms < 1,000 sf

Figure 28: Markup Illustrating Occupied Standby Requirements

Occupancy Category	Total Outdoor Airflow Rate[1] R_t cfm/ft^2	Min Ventilation Air Rate for DCV R_a (cfm/ft^2)	Air Class	Notes
Food and Beverage Service				
Restaurant dining rooms	0.5	0.15	2	
Cafeteria/fast-food dining	0.5	0.15	2	
Bars, cocktail lounges	0.5	0.2	2	
Kitchen (cooking)	0.15		2	
General				
Break rooms	0.5	0.15	1	F
Coffee Stations	0.5	0.15	1	F
Conference/meeting	0.5	0.15	1	F
Corridors	0.15		1	F
Occupiable storage rooms for liquids or gels	0.15		2	B
Hotels, Motels, Resorts, Dormitories				
Bedroom/living room	0.15		1	F
Barracks sleeping areas	0.15		1	F
Laundry rooms, central	0.15		2	
Laundry rooms within dwelling units	0.15		1	
Lobbies/pre-function	0.5	0.15	1	F
Multipurpose assembly	0.5		1	F
Office Buildings				
Breakrooms	0.5	0.15	1	
Main entry lobbies	0.5	0.15	1	F
Occupiable storage rooms for dry materials	0.15		1	
Office space	0.15		1	F
Reception areas	0.15		1	F
Telephone/data entry	0.15		1	F
Miscellaneous Spaces				
Bank vaults/safe deposit	0.15		2	F
Banks or bank lobbies	0.15		1	F
Computer (not printing)	0.15		1	F
Freezer and refrigerated spaces (<50oF)	-		2	E
General manufacturing (excludes heavy industrial and process using chemicals)	0.15		3	

130.1 only lists multipurpose < 1,000 sf

Figure 29: Markup Illustrating Occupied Standby Requirements

Occupancy Category	Total Outdoor Airflow Rate[1] R_t cfm/ft^2	Min Ventilation Air Rate for DCV R_a (cfm/ft^2)	Air Class	Notes
Pharmacy (prep. Area)	0.15		2	
Photo studios	0.15		1	
Shipping/receiving	0.15		2	B
Sorting, packing, light assembly	0.15		2	
Telephone closets	0.15		1	
Transportation waiting	0.5	0.15	1	F
Warehouses	0.15		2	B
All others	0.15		2	
Public Assembly Spaces				
Auditorium seating area	1.07	0.15	1	F
Places of religious worship	1.07	0.15	1	F
Courtrooms	0.19	0.15	1	F
Legislative chambers	0.19	0.15	1	F
Libraries (reading rooms and stack areas)	0.15		1	
Lobbies	0.5	0.15	1	F
Museums (children's)	0.25	0.15	1	
Museums/galleries	0.25	0.15	1	F
Residential				
Common corridors	0.15		1	F
Retail				
Sales (except as below)	0.25	0.2	2	
Mall common areas	0.25	0.15	1	F
Barbershop	0.4		2	
Beauty and nail salons	0.4		2	
Pet shops (animal areas)	0.25	0.15	2	
Supermarket	0.25	0.2	1	F
Coin-operated laundries	0.3		2	
Sports and Entertainment				
Gym, sports arena (play area)	0.5	0.15	2	E
Spectator areas	0.5	0.15	1	F
Swimming (pool)	0.15		2	C

Figure 30: Markup Illustrating Occupied Standby Requirements

Occupancy Category	Total Outdoor Airflow Rate[1] R_t cfm/ft²	Min Ventilation Air Rate for DCV R_a (cfm/ft²)	Air Class	Notes
Swimming (deck)	0.5	0.15	2	C
Disco/dance floors	1.5	0.15	2	F
Health club/aerobics room	0.15		2	
Health club/weight rooms	0.15		2	
Bowling alley (seating)	1.07	0.15	1	
Gambling casinos	0.68	0.15	1	
Game arcades	0.68	0.15	1	
Stages, studios	0.5	0.15	1	D, F

General footnotes for Table 120.1-A:

[1] R_t is determined as being the larger of the area method and the default per person method. The occupant density used in the default per person method is one half of the maximum occupant load assumed for egress purposes in the CBC.

Specific Notes:

A – For high-school and college libraries, the values shown for "Public Assembly Spaces – Libraries" shall be used.

B – Rate may not be sufficient where stored materials include those having potentially harmful emissions.

C – Rate does not allow for humidity control. "Deck area" refers to the area surrounding the pool that is capable of being wetted during pool use or when the pool is occupied. Deck area that is not expected to be wetted shall be designated as an occupancy category.

D – Rate does not include special exhaust for stage effects such as dry ice vapors and smoke.

E – Where combustion equipment is intended to be used on the playing surface or in the space, additional dilution ventilation, source control, or both shall be provided.

F – Ventilation air for this occupancy category shall be permitted to be reduced to zero when the space is in occupied-standby mode.

Figure 31: Markup Illustrating Occupied Standby Requirements

f) "All spaces with Rt ≥ 0.3 in Table 120.1-A have demand control ventilation meeting 120.1(d)4". This basically requires DCV in the same space types where DCV is required by section 120.1(d)3 but 120.1(d)3 has several exceptions, including systems with no economizer, no modulating OA control, and OA < 3,000 cfm. This clause removes the exceptions to DCV. Not only does this expand coverage of DCV but the Statewide CASE Team expects that tying it to the ER exception will also improve compliance and enforcement of the existing DCV requirements.

g) Computer room hot aisle air is transferred to the zone in heating. Computer room hot aisle air is “available” if there is a computer room with a design equipment load > 12 kW on the same floor and within 30 feet of the zone and > 50 percent of the heat from the computer room is not otherwise being recovered for space heating.…” Computer rooms are a tremendous and largely untapped sources of free heat for space heating. There are many ways to recover heat from computer rooms for space heat. One of the simplest and most efficient ways is to directly transfer air from the computer room hot aisle to spaces in heating. Title 24 requires hot/cold aisle containment for computer rooms over 10 kW. With containment the hot aisle air is typically 90-100°F, which is the perfect temperature for space heating.

Data centers, which are just very large computer rooms, always have office spaces that require heating. It is common to use a dual fan dual duct system in a data center to meet all the office heating needs but it is also common to have backup electric resistance heat to serve the office while the data center is being populated or when the data center is offline (e.g., during a major refresh). Figure 32 is from a data center office space that uses VAV boxes with electric resistance heat in the building interior. The perimeter uses fan powered boxes with secondary air ducted from the data center hot aisle and backup electric resistance heat. Figure 33 is the schematic from a data center office space that uses a dual fan dual duct system. The data center provides all the heat in normal operation but the hot deck air handler includes a backup electric resistance heating coil for periods when the data center is offline. The figures are meant to show where ER could be used and where computer room waste heat could satisfy a portion of the space heating load, thus offsetting the ER heating demand.

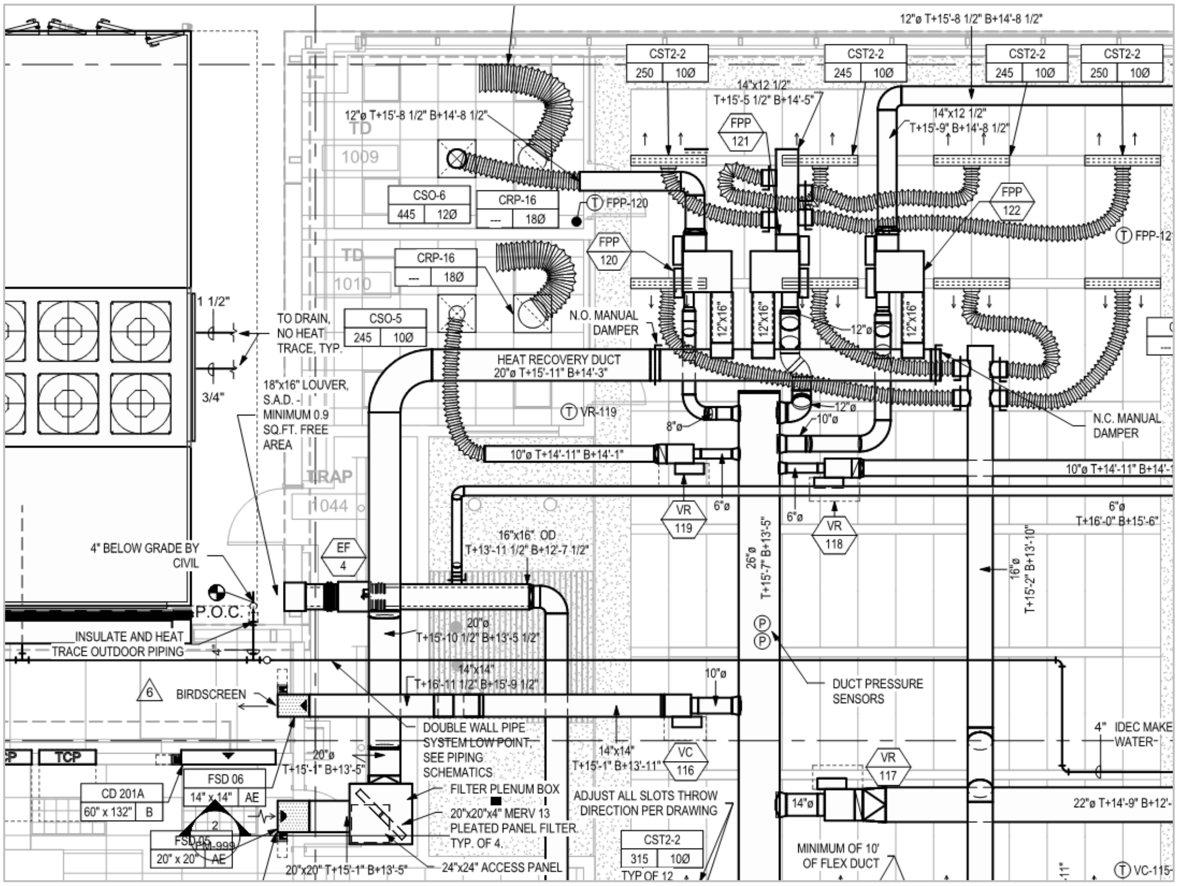


Figure 32: Data Center Office Space with Heat Recovery to Fan Powered Boxes

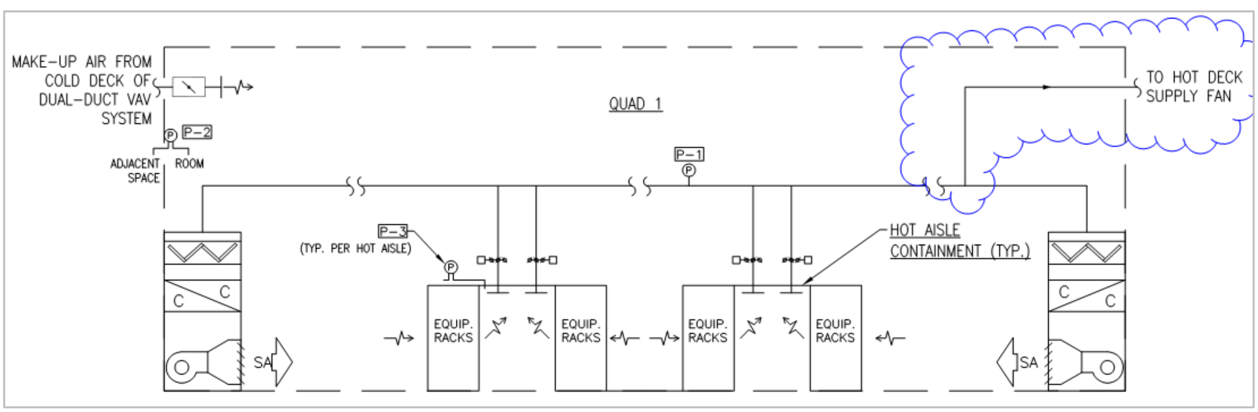


Figure 33: Data Center Dual Fan Dual Duct Heat Recovery Schematic

Just as all data centers have an office component, many offices and other commercial buildings have a computer room component that can satisfy a significant fraction of the office's space heating needs. An informal survey of 10 office buildings indicates that about half of them have computer rooms over 10 kW with available transfer air.

Figure 34 is a section of an office floor plan with an individual distribution frame (IDF) computer room. This computer room is served by a 6-ton (20 kW) fan coil. It is also served by a cooling-only VAV box to provide economizer cooling as required for computer rooms by Exception 2 to Section 140.9(a)1. The surrounding office spaces are served by VAV boxes with HW reheat.

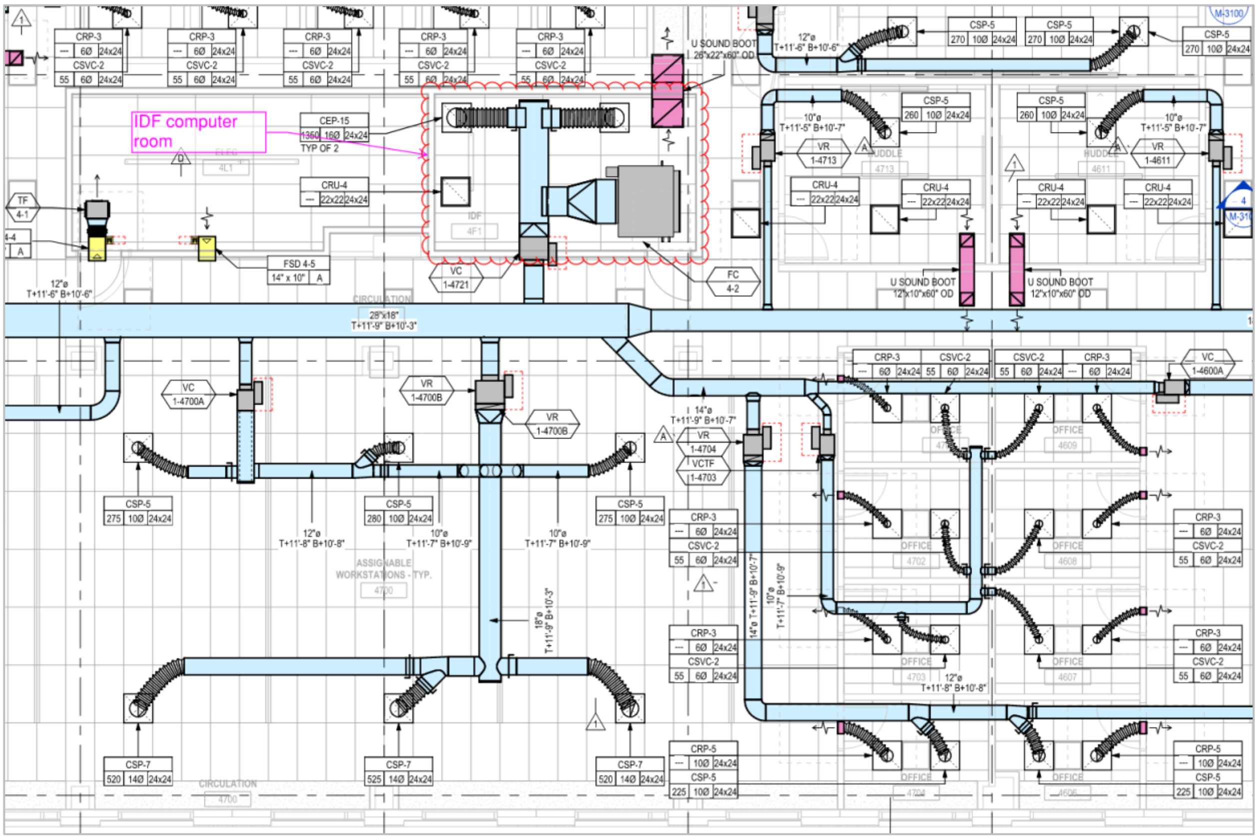


Figure 34: Office Computer Room Without Transfer Air

Figure 35 is the same office space converted to electric resistance heat. The interior reheat boxes are single duct electric reheat boxes. The perimeter boxes are changed to parallel fan powered boxes with electric heat. The fan boxes near the computer room draw their secondary air from the ceiling space of the computer room. The computer room ceiling space is connected to the computer room hot aisle by the return grille in the computer room ceiling. If the computer room load is low and there is minimal available transfer air, then the fan boxes simply pull return air through the computer room return air sound boot and modulate their electric resistance coils as needed. Note that one of the keys to heating with computer room transfer air is making sure the hot aisle stays hot, even at low load. In this case that is accomplished by locating the computer room VAV box and fan coil thermostats in the cold aisle and maintaining the cold aisle at 75°F (VAV box) and 78°F (fan coil). The fan coil speed is modulated to maintain the cold/hot aisle differential pressure at 0.01”. This ensures the computer servers do not pull the cold aisle air negative and minimizes bypass from cold to hot, thus keeping the air entering the servers cold and keeping the hot aisle hot.

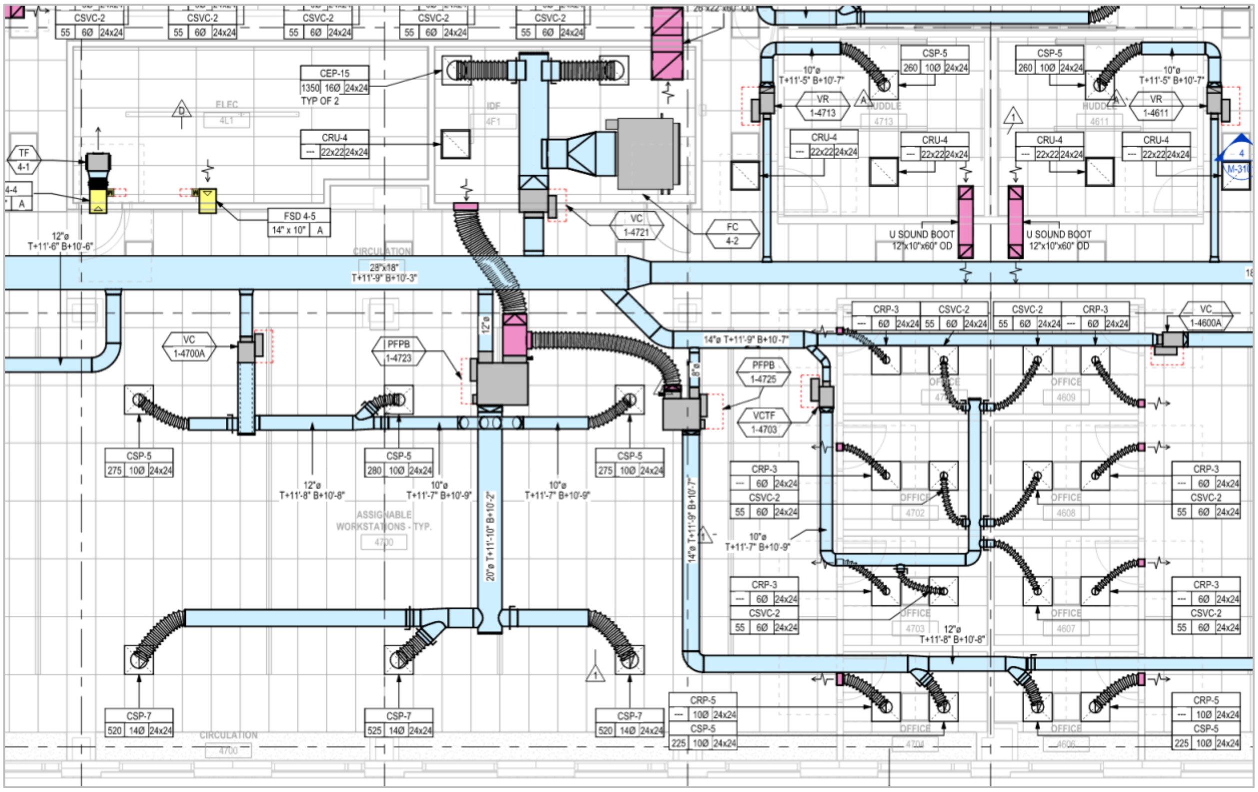


Figure 35: Office Computer Room with Transfer Air

Figure 36, Figure 37, and Figure 38 show typical office floor plans that include computer rooms over 10 kW. These figures also show the portions of those floor plans that have available transfer air and could be completely heated by the nearby computer rooms. As the figures indicate, significant amounts of floor plan space heating needs can be satisfied using available computer room waste heat.

Figure 36: Typical Office Computer Room

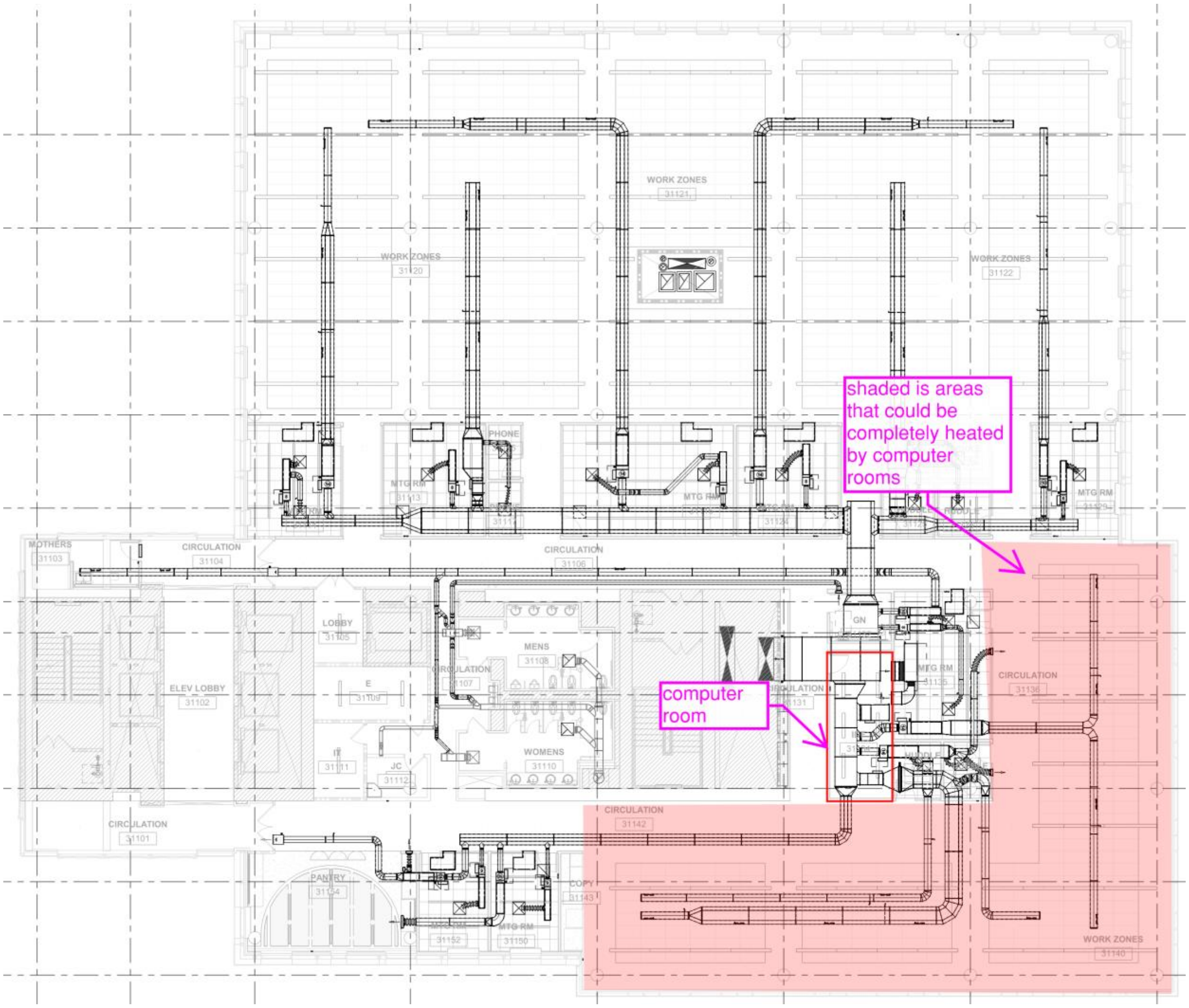


Figure 37: Typical Office Computer Room

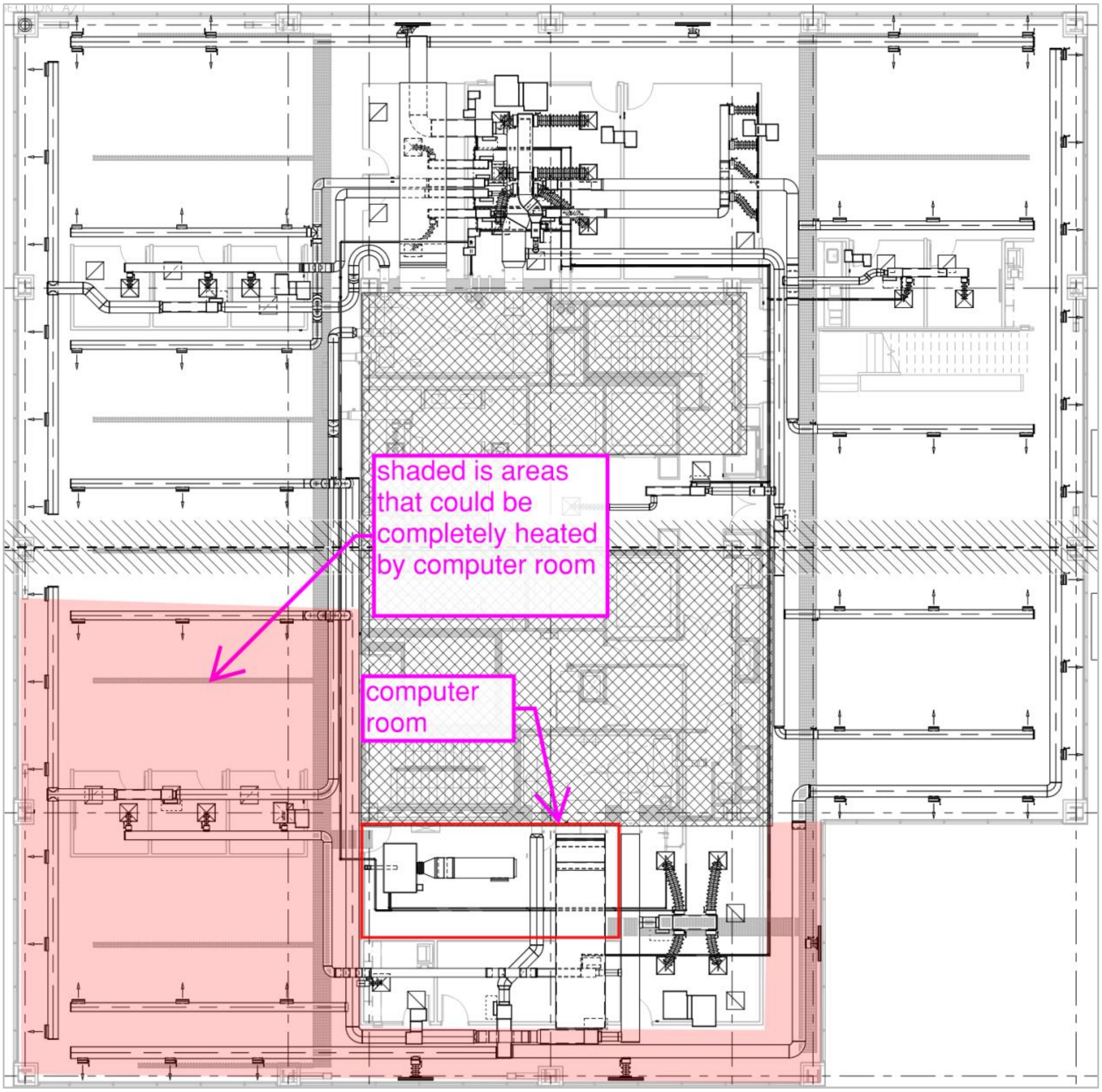


Figure 38: Typical Office Computer Room

4.1.2.4 True Energy Costs vs Modeled Energy Costs

As described below in sections 4.3 and 4.4, the proposed exception for electric resistance heating is lifecycle cost effective because the first cost savings are greater than the incremental lifecycle energy costs. The lifecycle energy costs of buildings with electric resistance are about 10 percent higher than buildings with either baseline system (gas boilers or AWHPs). It is important to recognize, however, that the analysis in sections 4.3 and 4.4 does not take credit for any of the following:

- reduced simultaneous heating/cooling and fighting (clause (b))
- increased use of occupied standby (clause (d))

- increased use of transfer air for kitchens, labs, and other high exhaust spaces (clause (e))
- increased use of demand-controlled ventilation (clause (f))
- increased use of computer room heat recovery (clause (g))

The analysis does not account for any of these because they are not readily modeled in the prototype models and because the proposal is already cost-effective.

4.1.2.5 Other Benefits of Electric Resistance

It is also important to understand that the lifecycle cost analysis does not take credit for any of these other important benefits of electric resistance heat:

1) Prescriptive code benefits – The first cost savings of electric resistance will encourage many projects to switch from performance compliance to prescriptive compliance. This has many benefits because there are many valuable prescriptive requirements that are not properly accounted for in the performance compliance software, including:
    a. Prescriptive envelope – Many, if not most buildings that use the performance approach have too high a window-wall ratio to comply prescriptively. Theoretically, the software requires the design to compensate with improved HVAC and lighting. In practice, limitations of the software and enforcement mean that HVAC and lighting often do not compensate. Furthermore, envelope savings are more reliable and durable than HVAC and lighting savings, which require good design, good commissioning, and good long-term O&M.
    b. Window switches – HVAC interlocks for operable windows is a prescriptive requirement. The ACM Reference Manual does include a methodology for penalizing a project without the required switches, but the methodology is conservative and almost certainly underestimates the true benefit of the interlocks.
    c. PV and batteries are prescriptive requirements.
2) Refrigerant Leakage – Other electric heating options such as AWHPs or VRF require refrigerants which are powerful global warming gases. In addition to the environmental consequences, refrigerants can also pose significant health and safety risks, particularly VRF systems where a leak can result in dangerous levels of refrigerant in occupied spaces. Note that the lifecycle cost analysis also did not take credit for eliminating the cost of refrigerant monitoring systems.
3) Gas Leakage – Natural gas (methane) is also a powerful greenhouse gas.
4) Embodied Carbon – Electric resistance has a much smaller embodied carbon footprint compared to gas boilers, AWHPs, VRF, etc. Gas boilers, for example,

are large pieces of equipment and require lots of copper and steel piping throughout the building, pipe insulation, pumps, equipment bases, structural supports, expansion tanks, storage tanks, control valves, isolation valves, etc. AWHPs are much bigger than gas boilers. VRF also requires lots of piping and pipe insulation. As the electricity grid gets greener, the embodied carbon penalty for these other systems will only tilt the scales further in favor of electric resistance. Although not accounted for in the lifecycle analysis, material impacts are quantified and discussed in Section 4.5.4.

4.1.2.6 Impact on Other Title 24 Requirements

It is also important to recognize that the proposed exception for electric resistance does not allow a project to avoid the proposed requirements herein for condenser heat recovery and thermal energy storage or any other current or future requirements in Title 24, like the heat pump requirement for most single zone systems in most climate zones. The proposal is an exception to the electric resistance ban that allows electric resistance in some cases. It does not require electric resistance in any cases. If a project had enough process loads and enough simultaneous heating and cooling to trigger the condenser heat recovery requirement, or the project were large enough to trigger the TES requirement, then the project would need to include heat pumps (e.g., AWHP, WSHP, VRF).

4.1.2.7 Impact on Reach Codes

Another benefit of this proposal allowing electric resistance is that it may encourage additional jurisdictions in California to adopt all-electric reach codes. Currently, as demonstrated by the incremental costs for this measure (see section 0), going all-electric is significantly more expensive for many building types than gas heat (e.g., large office). Allowing electric resistance makes going all-electric the lowest cost option for many of these building types, rather than the most expensive option.

4.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manuals, and compliance forms would be modified by the proposed change.[23] See Section 5 of this report for detailed proposed revisions to code language.

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[23] Visit EnergyCodeAce.com for trainings, tools, and resources to help people understand existing code requirements.

4.1.3.1 Specific Purpose and Necessity of Proposed Code Changes

Each proposed change to language in Title 24, Part 1 and Part 6 as well as the reference appendices to Part 6 are described below. See Section 5.2 of this report for marked-up code language.

Section: 140.4(g) Exception 5

Specific Purpose: This exception is deleted because the new Exception 7 can be cost-effectively applied to any building that would have qualified to use Exception 5. Exception 7 is also more energy efficient than Exception 5.

Necessity: These changes are necessary to increase energy efficiency via cost-effective building design standards, as mandated by California Public Resources Code, Sections 25213 and 25402.

Section: 140.4(g) Exception 7

Specific Purpose: The specific purpose is to add an exception to the prescriptive ban on electric resistance heating. This exception would allow electric resistance heating at the zone level.

Necessity: These changes are necessary to increase energy efficiency via cost-effective building design standards, as mandated by California Public Resources Code, Sections 25213 and 25402.

Section: 141.0(a) Exception 2

Specific Purpose: The new Exception 7 to 140.4(g) provides a feasible and cost-effective option for additions that might use 141.0(a) Exception 2 and is more energy efficient than 141.0(a) Exception 2.

Necessity: These changes are necessary to increase energy efficiency via cost-effective building design standards, as mandated by California Public Resources Code, Sections 25213 and 25402.

4.1.3.2 Specific Purpose and Necessity of Changes to the Nonresidential ACM Reference Manual

The proposed code change would not modify the ACM Reference Manual.

4.1.3.3 Summary of Changes to the Nonresidential Compliance Manual

Chapter 4 (Section 4.7 HVAC System Requirements) of the Nonresidential Compliance Manual would need to be revised. This proposal to add an exception to 140.4(g) contains several specific conditions and triggers that must be met to ensure that space heating loads are absolutely minimized to allow electric resistance heating at the zone level. Additional clarification and several examples should be added to the compliance manual to explain these triggers and conditions in further detail than what is reasonable to include in the prescriptive code itself.

4.1.3.4 Summary of Changes to Compliance Forms

The proposed code change would not modify the compliance forms.

4.1.4 Regulatory Context

4.1.4.1 Determination of Inconsistency or Incompatibility with Existing State Laws and Regulations

There are no relevant state or local laws or regulations.

4.1.4.2 Duplication or Conflicts with Federal Laws and Regulations

There are no relevant federal laws or regulations.

4.1.4.3 Difference From Existing Model Codes and Industry Standards

There are no relevant industry standards or model codes.

4.1.5 Compliance and Enforcement

When developing this proposal, the Statewide CASE Team considered methods to streamline the compliance and enforcement process and how negative impacts on market actors who are involved in the process could be mitigated or reduced. This section describes how to comply with the proposed code change. It also describes the compliance verification process. Appendix E presents how the proposed changes could impact various market actors.

The compliance verification activities related to this measure that need to occur during each phase of the project are described below:

- **Design Phase:** A designer would be able to comply with code using zone-level ER heating prescriptively were this measure to be enacted. In the past, the designer would have had to pursue the performance path. Adding this exception would simplify the compliance process by enabling more buildings to comply prescriptively.
- **Permit Application Phase:** No changes are anticipated as a result of this measure.
- **Construction Phase:** Construction would be simpler for buildings installing zone-level ER heating as compared to those with hydronic distribution systems. The electrical system impacts would be relatively minimal.

- **Inspection Phase:** Inspecting for correctly installed HVAC controls would be imperative for realizing the system efficiency that makes this design choice cost-effective. However, these and other prescriptive requirements are already familiar measures for building inspectors and no changes are anticipated as a result of this measure.

4.2 Market Analysis

4.2.1 Current Market Structure

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. It then considered how the proposed standard may impact the market in general as well as individual market actors. Information was gathered about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, CEC staff, and a wide range of industry actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during a public stakeholder meeting that the Statewide CASE Team held on February 27, 2023.

Currently, very few nonresidential buildings are constructed in California with ER heating due to the prescriptive ban at 140.4(g).

4.2.2 Technical Feasibility and Market Availability

The use of zone-level ER for space heating is technically feasible but has been prescriptively limited for quite some time. Decades ago, this ban made sense due to the high carbon intensity of the electric grid and less sophisticated HVAC controls capable of limiting heating demand. However, these former challenges for ER heating have been mitigated by progress in recent years. Today, it is possible to design a system with very low heating loads if the prescriptive code were to be followed along with some additional EE strategies that are included in this measure. These criteria include the low prescriptive window-wall ratios, prohibiting hot water piping, minimizing ventilation loads with CO_2 and occupant sensing ventilation resets, heat recovery from computer rooms, and largely eliminating reheat by using parallel fan-powered boxes (FPB) or other systems that decouple heating and primary air. All of the above listed strategies are technically feasible and widely implemented in nonresidential buildings.

4.2.3 Market Impacts and Economic Assessments

4.2.3.1 Impact on Builders

Builders of residential and commercial structures are directly impacted by many of the measures proposed by the Statewide CASE Team for the 2025 code cycle. It is within the normal practices of these businesses to adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

California's construction industry comprises approximately 93,000 business establishments and 943,000 employees (see Table 98). For 2022, total estimated payroll will be about $78 billion. Nearly 72,000 of these business establishments and 473,000 employees are engaged in the residential building sector, while another 17,600 establishments and 369,000 employees focus on the commercial sector. The remainder of establishments and employees work in industrial, utilities, infrastructure, and other heavy construction roles (the industrial sector).

Table 98: California Construction Industry, Establishments, Employment, and Payroll in 2022 (Estimated)

Building Type	Construction Sectors	Establishments	Employment	Annual Payroll (Billions $)
Residential	**All**	**71,889**	**472,974**	**31.2**
Residential	Building Construction Contractors	27,948	130,580	9.8
Residential	Foundation, Structure, & Building Exterior	7,891	83,575	5.0
Residential	Building Equipment Contractors	18,108	125,559	8.5
Residential	Building Finishing Contractors	17,942	133,260	8.0
Commercial	**All**	**17,621**	**368,810**	**35.0**
Commercial	Building Construction Contractors	4,919	83,028	9.0
Commercial	Foundation, Structure, & Building Exterior	2,194	59,110	5.0
Commercial	Building Equipment Contractors	6,039	139,442	13.5
Commercial	Building Finishing Contractors	4,469	87,230	7.4
Industrial, Utilities, Infrastructure, & Other (Industrial+)	**All**	**4,206**	**101,002**	**11.4**
Industrial+	Building Construction	288	3,995	0.4
Industrial+	Utility System Construction	1,761	50,126	5.5
Industrial+	Land Subdivision	907	6,550	1.0
Industrial+	Highway, Street, and Bridge Construction	799	28,726	3.1
Industrial+	Other Heavy Construction	451	11,605	1.4

Source: (State of California Employment Development Department 2022)

The proposed change to the prescriptive ban to electric resistance heating would likely affect commercial builders but would not impact firms that focus on construction and retrofit of industrial buildings, utility systems, public infrastructure, or other heavy construction. The effects on the residential and commercial building industry would not be felt by all firms and workers, but rather would be concentrated in specific industry subsectors. Table 99 shows the commercial building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report. Electrical, plumbing, and HVAC contractors would be slightly impacted by a potential shift away from hydronic to ER-based space heating designs. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 4.2.4 Economic Impacts.

Table 99: Specific Subsectors of the California Commercial Building Industry Impacted by Proposed Change to Code/Standard by Subsector in 2022 (Estimated)

Construction Subsector	Establishments	Employment	Annual Payroll (Billions $)
Nonresidential Electrical Contractors	3,137	74,277	7.0
Nonresidential plumbing & HVAC contractors	2,346	55,572	5.5

Source: (State of California Quarterly Census of Employment and Wages 2010)

4.2.3.2 Impact on Building Designers and Energy Consultants

Adjusting design practices to comply with changing building codes is within the normal practices of building designers. Building codes (including Title 24, Part 6) are typically updated on a three-year revision cycle, and building designers and energy consultants engage in continuing education and training to remain compliant with changes to design practices and building codes.

The market will benefit from this exception being added to the prescriptive code due to the wider number of all-electric space heating options available. The designer will have more flexible options to prescriptive comply with the code. The building owner will have an additional cost-effective and cheaper up-front cost option to choose from. Energy consultants will also benefit from the added all-electric space heating option.

Businesses that focus on residential, commercial, institutional, and industrial building design are contained within the Architectural Services sector (NAICS 541310). Table 100 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The proposed code changes would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for the added exception to the ban on ER heating to affect firms that focus on nonresidential construction.

There is not a North American Industry Classification System (NAICS)[24] code specific to energy consultants. Instead, businesses that focus on consulting related to building energy efficiency are contained in the Building Inspection Services sector (NAICS 541350), which is comprised of firms primarily engaged in the physical inspection of residential and nonresidential buildings.[25] It is not possible to determine which business establishments within the Building Inspection Services sector are focused on energy efficiency consulting. The information shown in Table 100 provides an upper bound indication of the size of this sector in California.

Table 100: California Building Designer and Energy Consultant Sectors in 2022 (Estimated)

Sector	Establishments	Employment	Annual Payroll (Millions $)
Architectural Services [a]	4,134	31,478	3,623.3
Building Inspection Services [b]	1,035	3,567	280.7

Source: (State of California Employment Development Department 2022)

a. Architectural Services (NAICS 541310) comprises private-sector establishments primarily engaged in planning and designing residential, institutional, leisure, commercial, and industrial buildings and structures.

b. Building Inspection Services (NAICS 541350) comprises private-sector establishments primarily engaged in providing building (residential & nonresidential) inspection services encompassing all aspects of the building structure and component systems, including energy efficiency inspection services.

4.2.3.3 Impact on Occupational Safety and Health

The proposed code change does not alter any existing federal, state, or local regulations pertaining to safety and health, including rules enforced by the California Division of Occupational Safety and Health (DOSH). All existing health and safety rules would remain in place. Complying with the proposed code change is not anticipated to

[24] NAICS is the standard used by federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS was development jointly by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadistica y Geografia, to allow for a high level of comparability in business statistics among the North American countries. NAICS replaced the Standard Industrial Classification (SIC) system in 1997.

[25] Establishments in this sector include businesses primarily engaged in evaluating a building's structure and component systems and includes energy efficiency inspection services and home inspection services. This sector does not include establishments primarily engaged in providing inspections for pests, hazardous wastes or other environmental contaminates, nor does it include state and local government entities that focus on building or energy code compliance/enforcement of building codes and regulations.

have adverse impacts on the safety or health of occupants or those involved with the construction, commissioning, and maintenance of the building.

4.2.3.4 Impact on Building Owners and Occupants

Commercial Buildings

The commercial building sector includes a wide array of building types, including offices, restaurants and lodging, retail, and mixed-use establishments, and warehouses (including refrigerated) (Kenney M 2019). Energy use by occupants of commercial buildings also varies considerably, with electricity used primarily for lighting, space cooling and conditioning, and refrigeration, while natural gas is used primarily for water heating and space heating. According to information published in the 2019 California Energy Efficiency Action Plan, there is more than 7.5 billion square feet of commercial floor space in California consuming 19 percent of California's total annual energy use (Kenney M 2019). The diversity of building and business types within this sector creates a challenge for disseminating information on energy and water efficiency solutions, as does the variability in sophistication of building owners and the relationships between building owners and occupants.

Estimating Impacts

Building owners and occupants would benefit from lower energy bills. As discussed in Section 2.2.4.1, when building occupants save on energy bills, they tend to spend it elsewhere in the economy thereby creating jobs and economic growth for the California economy. The Statewide CASE Team does not expect the proposed code change for the 2025 code cycle to impact building owners or occupants adversely.

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

The Statewide CASE Team anticipates the proposed change would have no material impact on California component retailers.

4.2.3.6 Impact on Building Inspectors

Table 101 shows employment and payroll information for state and local government agencies in which many inspectors of residential and commercial buildings are employed. Building inspectors participate in continuing education and training to stay current on all aspects of building regulations, including energy efficiency. The Statewide CASE Team, therefore, anticipates the proposed change would have no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections.

Table 101: Employment in California State and Government Agencies with Building Inspectors in 2022 (Estimated)

Sector	Govt.	Establishments	Employment	Annual Payroll (Million $)
Administration of Housing Programs[a]	State	18	265	29.0
	Local	38	3,060	248.6
Urban and Rural Development Admin[b]	State	38	764	71.3
	Local	52	2,481	211.5

Source: (State of California Quarterly Census of Employment and Wages 2010)

a. Administration of Housing Programs (NAICS 925110) comprises government establishments primarily engaged in the administration and planning of housing programs, including building codes and standards, housing authorities, and housing programs, planning, and development.

b. Urban and Rural Development Administration (NAICS 925120) comprises government establishments primarily engaged in the administration and planning of the development of urban and rural areas. Included in this industry are government zoning boards and commissions.

4.2.3.7 Impact on Statewide Employment

As described in Sections 4.2.3.1 through 4.2.3.6, the Statewide CASE Team does not anticipate significant employment or financial impacts to any particular sector of the California economy. This is not to say that the proposed change would not have modest impacts on employment in California. In Section 4.2.4, the Statewide CASE Team estimated the proposed change in the exceptions to the prescriptive ban on electric resistance heating would affect statewide employment and economic output directly and indirectly through its impact on builders, designers, and energy consultants, and building inspectors. In addition, the Statewide CASE Team estimated how energy savings associated with the proposed change in the exceptions to the prescriptive ban on electric resistance heating would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

4.2.4 Economic Impacts

For the 2025 code cycle, the Statewide CASE Team used the IMPLAN model software[26], along with economic information from published sources, and professional judgement to develop estimates of the economic impacts associated with each of the proposed code changes. Conceptually, IMPLAN estimates jobs created as a function of incoming cash flow in different sectors of the economy, due to implementing a code or a standard. The jobs created are typically categorized into direct, indirect, and induced employment. For example, cash flow into a manufacturing plant captures direct

[26] IMPLAN employs economic data and advanced economic impact modeling to estimate economic impacts for interventions like changes to the California Title 24, Part 6 code. For more information on the IMPLAN modeling process, see www.IMPLAN.com.

employment (jobs created in the manufacturing plant), indirect employment (jobs created in the sectors that provide raw materials to the manufacturing plant) and induced employment (jobs created in the larger economy due to purchasing habits of people newly employed in the manufacturing plant). Eventually, IMPLAN computes the total number of jobs created due to a code. The assumptions of IMPLAN include constant returns to scale, fixed input structure, industry homogeneity, no supply constraints, fixed technology, and constant byproduct coefficients. The model is also static in nature and is a simplification of how jobs are created in the macro-economy.

The economic impacts developed for this report are only estimates and are based on limited and to some extent speculative information. The IMPLAN model provides a relatively simple representation of the California economy and, though the Statewide CASE Team is confident that the direction and approximate magnitude of the estimated economic impacts are reasonable, it is important to understand that the IMPLAN model is a simplification of extremely complex actions and interactions of individual, businesses, and other organizations as they respond to changes in energy efficiency codes. In all aspects of this economic analysis, the CASE Authors rely on conservative assumptions regarding the likely economic benefits associated with the proposed code change. By following this approach, the economic impacts presented below represent lower bound estimates of the actual benefits associated with this proposed code change. Adoption of this code change proposal would result in relatively modest economic impacts through the additional direct spending by those in the commercial building industry, architects, energy consultants, and building inspectors. The Statewide CASE Team does not anticipate that money saved by commercial building owners or other organizations affected by the proposed 2025 code cycle regulations would result in additional spending by those businesses.

Table 102: Estimated Impact that Adoption of the Proposed Measure would have on the California Commercial Construction Sector

Type of Economic Impact	Employment (Jobs)	Labor Income (Million)	Total Value Added (Million)	Output (Million)
Direct Effects (Additional spending by Commercial Builders)	164.3	$12.8	$14.8	$25.1
Indirect Effect (Additional spending by firms supporting Commercial Builders)	40.2	$3.5	$5.5	$10.0
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	68.3	$4.7	$8.4	$13.3
Total Economic Impacts	**272.9**	**$20.9**	**$28.6**	**$48.5**

Source: CASE Team analysis of data from the IMPLAN modeling software (IMPLAN Group LLC 2020).

4.2.4.1 Creation or Elimination of Jobs

The Statewide CASE Team does not anticipate that the measures proposed for the 2025 code cycle regulation 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, the estimates of economic impacts discussed in Section 4.2.4 would lead to modest changes in employment of existing jobs.

4.2.4.2 Creation or Elimination of Businesses in California

As stated in Section 4.2.4.1, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. The proposed change represents a modest change to options available to nonresidential building designers to prescriptively provide space heating, which would not excessively burden or competitively disadvantage California businesses – nor would it necessarily lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not foresee any new businesses being created, nor does the Statewide CASE Team think any existing businesses would be eliminated due to the proposed code changes.

4.2.4.3 Competitive Advantages or Disadvantages for Businesses in California

The proposed code changes would apply to all businesses incorporated in California, regardless of whether the business is located inside or outside of the state (IMPLAN Group LLC 2020). Therefore, the Statewide CASE Team does not anticipate that these measures proposed for the 2025 code cycle regulation would have an adverse effect on the competitiveness of California businesses. Likewise, the Statewide CASE Team does not anticipate businesses located outside of California would be advantaged or disadvantaged.

4.2.4.4 Increase or Decrease of Investments in the State of California

The Statewide CASE Team analyzed national data on corporate profits and capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI).[27] As Table 103 shows, between 2017 and 2021, NPDI as a percentage of corporate profits ranged from a low of 18 in 2020 due to the worldwide economic slowdowns associated with the COVID 19 pandemic to a high of 35 percent in 2019, with an average of 26 percent. While only an approximation of the proportion of business income used for net capital investment, the Statewide CASE

[27] 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.

Team believes it provides a reasonable estimate of the proportion of proprietor income that would be reinvested by business owners into expanding their capital stock.

Table 103: 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)
2017	518.473	1882.460	28
2018	636.846	1977.478	32
2019	690.865	1952.432	35
2020	343.620	1908.433	18
2021	506.331	2619.977	19
5-Year Average	**539.227**	***2068.156***	**26**

Source: (Federal Reserve Economic Data, FRED 2022)

The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed measure would lead to significant change (increase or decrease) in investment, directly or indirectly, in any affected sectors of California's economy. Nevertheless, the Statewide CASE Team is able to derive 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 proprietor income, which was used conservative estimate of corporate profits, a portion of which is assumed to be allocated to net business investment.[28]

4.2.4.5 Incentives for Innovation in Products, Materials, or Processes

This proposal is not expected to drive, lead to, or incentivize innovation in building materials, components, or processes, nor is it expected to stifle innovation.

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

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

Cost of Enforcement

Cost to the State: State government already has budget for code development, education, and compliance enforcement. While state government will be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements,

[28] 26 percent of proprietor income was assumed to be allocated to net business investment; see Table 12.

these activities are already covered by existing state budgets. The costs to state government are small when compared to the overall costs savings and policy benefits associated with the code change proposals. As a nonresidential measure, there may be impacts to state buildings (new construction/additions or alterations), but the Statewide CASE Team's analysis has found that the proposed code changes are cost effective.

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 re-training 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 2.1.5 and Appendix E, 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.

4.2.4.7 Impacts on Specific Persons

While the objective of any of the Statewide CASE Team's proposal is to promote energy efficiency, the Statewide CASE Team recognizes that there is the potential that a proposed code change may result in unintended consequences. This proposal would not impact any specific group or groups of persons differently from impacts to persons generally. Refer to Section 2.6 for more details addressing energy equity and environmental justice.

4.2.5 Fiscal Impacts

4.2.5.1 Mandates on Local Agencies or School Districts

There are no relevant mandates to local agencies or school districts.

4.2.5.2 Costs to Local Agencies or School Districts

There are no costs to local agencies or school districts.

4.2.5.3 Costs or Savings to Any State Agency

There are no costs or savings to any state agencies.

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

There are no added non-discretionary costs or savings to local agencies.

4.2.5.5 Costs or Savings in Federal Funding to the State

There are no costs or savings to federal funding to the state.

4.3 Energy Savings

The code change proposal would not modify the stringency of the existing California Energy Code, so there would be no savings on a per-unit basis. Section 4.3 of the CASE Report, which typically presents the methodology, assumptions, and results of the per-unit energy impacts, has been truncated for this proposal. The Statewide CASE Team completed an analysis of a prescriptively complying standard design (with piping distribution losses added) with an ER heating system meeting all conditions included in the added exception. The baseline was developed for both a natural gas boiler and an electric 2-pipe AWHP system.

The Statewide CASE Team gathered stakeholder input to inform the energy savings analysis. See Appendix F for a summary of stakeholder engagement.

Energy savings benefits may have potential to disproportionately impact DIPs. Refer to Section 4.6 for more details addressing energy equity and environmental justice.

4.3.1 Energy Savings Methodology

4.3.1.1 Key Assumptions for Energy Savings Analysis

Electric resistance has long been disallowed by the prescriptive code at 140.4(g). Recent Center for the Built Environment research has indicated that approximately 20 percent of the input boiler energy is delivered to zone heating. This research points to the potential for zone-level electric resistance heating, which would avoid the low-efficiency boilers (when in part load) and distribution system losses (when the building is in economizing or cooling mode).

The modeled prototypes include those with hydronic space heating. This includes Large Office, Medium Office, Large School, and Hospital.

For this measure, the base case is a CBECC model for each of the applicable prototypes with a gas boiler for space heating. Pipe losses were included in the baseline system according to heat loss estimates developed with CBE research. In addition, the HWST was modified to 130°F to align with the HWST limit measure.

The measure case is altered such that the gas boiler (and associated distribution loses) is removed from the model and each zone’s hourly heating demand is assumed to be satisfied by a 1.0 COP electric resistance heater.

4.3.1.2 Energy Savings Methodology per Prototypical Building

The Statewide CASE Team measured per unit energy savings expected from the proposed code changes in several ways in order to quantify key impacts. First, savings are calculated by fuel type. Electricity savings are measured in terms of both energy usage and peak demand reduction. Natural gas savings are quantified in terms of energy usage. Second, the Statewide CASE Team calculated Source Energy Savings. Source Energy represents the total amount of raw fuel required to operate a building. In addition to all energy used from on-site production, source energy incorporates all transmission, delivery, and production losses. The hourly Source Energy values provided by CEC are proportional to GHG emissions. Finally, the Statewide CASE Team calculated LSC Savings, formerly known as Time Dependent Value (TDV) Energy Cost Savings. LSC Savings are calculated using hourly energy cost metrics for both electricity and natural gas provided by the CEC. These LSC hourly factors are projected over the 30-year life of the building. The LSC hourly factors incorporate the hourly cost of marginal generation, transmission and distribution, fuel, capacity, losses, and cap-and-trade-based CO2 emissions. More information on Source Energy and LSC hourly factors is available in the March 2020 CEC Staff Workshop on Energy Code Compliance Metrics and the July 2022 CEC Staff Workshop on Energy Code Accounting for the 2025 Building Energy Efficiency Standards.

The CEC directed the Statewide CASE Team to model the energy impacts using specific prototypical building models that represent typical building geometries for different types of buildings (California Energy Commission 2022). The prototype buildings that the Statewide CASE Team used in the analysis are presented in Table 104.

Table 104: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name	Number of Stories	Floor Area (Square Feet)	Description
Hospital	5	241,501	5-Story Hospital plus basement. Source: DOE Standard 90.1 Hospital prototype and scorecard. The prototype contains Title 24, Part 6, minimally compliant envelope features and lighting. For HVAC systems, the AIA guidelines recommended using VAV systems wherever possible.
HotelSmall	4	42,554	4 story Hotel with 77 guest rooms. WWR-11%
OfficeLarge	12	498,589	12 story + 1 basement office building with 5 zones and a ceiling plenum on each floor. WWR-0.40.
OfficeMedium	3	53,628	3 story office building with 5 zones and a ceiling plenum on each floor. WWR-0.33
SchoolLarge	2	210,866	High school with WWR of 35% and SRR 1.4%

The Statewide CASE Team estimated LSC energy, source energy, electricity, natural gas, peak demand, and GHG impacts by simulating the proposed code change in EnergyPlus using prototypical buildings and rulesets from the 2025 Research Version of the California Building Energy Code Compliance (CBECC) software.

CBECC generates two models based on user inputs: the Standard Design and the Proposed Design.[29] The Standard Design represents the geometry of the prototypical building and a design that uses a set of features that result in a LSC energy budget and source energy budget that is minimally compliant with 2022 Title 24, Part 6 code requirements. Features used in the Standard Design are described in the 2022 Nonresidential ACM Reference Manual. The Proposed Design represents the same geometry as the Standard Design, but it assumes the energy features that the software user describes with user inputs. To develop savings estimates for the proposed code changes, the Statewide CASE Team created a Standard Design and Proposed Design for each prototypical building with the Standard Design representing compliance with 2022 code and the Proposed Design representing compliance with the proposed requirements. Comparing the energy impacts of the Standard Design to the Proposed Design reveals the impacts of the proposed code change relative to a building that is minimally compliant with the 2022 Title 24, Part 6 requirements.

There is an existing Title 24, Part 6 requirement that covers the building system in question and applies to both new construction/additions and alterations, so the Standard Design is minimally compliant with the 2022 Title 24 requirements. The standard design space heating system was modified from the default gas boiler space heating system to a 2-pipe AWHP system in CBECC. For both standard design fuel types, the HWST was set to 130°F.

CBECC calculates whole-building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/y) and therms per year (Therms/yr). It then applies the 2025 LSC hourly factors to calculate LSC energy use in kilo British thermal units per year (kBtu/y), Source Energy factors to calculate Source Energy Use in kilo British thermal units per year (kBtu/y), and hourly GHG emissions factors to calculate annual GHG emissions in metric tons of carbon dioxide emissions equivalent (MT or “tonnes” CO2e/y) (California Energy Commission 2022). CBECC also generates LSC Savings values measured in 2026 present value dollars (2026 PV$) and nominal dollars. CBECC also calculates annual peak electricity demand measured in kilowatts (kW).

[29] CBECC-Res creates a third model, the Reference Design, that represents a building similar to the Proposed Design, but with construction and equipment parameters that are minimally compliant with the 2006 International Energy Conservation Code (IECC). The Statewide CASE Team did not use the Reference Design for energy impacts evaluations.

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

Per-unit energy impacts for nonresidential buildings are presented in savings per square foot. Annual energy, GHG, and peak demand impacts for each prototype building were translated into impacts per square foot by dividing by the floor area of the prototype building. This step allows for an easier comparison of savings across different building types and enables a calculation of statewide savings using the construction forecast that is published in terms of floor area by building type.

4.3.1.3 Statewide Energy Savings Methodology

The per-unit energy impacts were extrapolated to statewide impacts using the statewide construction forecasts that the CEC provided. The statewide construction forecasts estimate new construction/additions that would occur in 2026, the first year that the 2025 Title 24, Part 6 requirements are in effect. They also estimate the amount of total existing building stock in 2026, which the Statewide CASE Team used to approximate savings from building alterations (California Energy Commission 2022). The construction forecast provides construction (new construction/additions and existing building stock) by building type and climate zone, as shown in Appendix A. Appendix A presents additional information about the methodology and assumptions used to calculate statewide energy impacts.

4.3.2 Per-Unit Energy Impacts Results

Energy savings and peak demand reductions per unit are presented in Table 105 through Table 113. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. For the scenario comparing a gas boiler-powered hydronic system to the ER heating system, per-unit savings for the first year are expected to range from -2.05 to -0.56 kWh/y and 2.50 to 10.82 therms/y depending upon climate zone. Demand increases are expected to range between -0.39 and -0.10 kW depending on climate zone. Keep in mind that this version of the analysis is fuel substitution, so large natural gas and negative electric “savings” are expected. For the scenario comparing an electric AWHP hydronic system to the ER heating system, per-unit savings for the first year are expected to range from -0.50 to -0.29 kWh/y depending upon climate zone. Demand increases are expected to range between -0.11 and -0.03 kW depending on climate zone.

Table 105: First Year Electricity Savings (kWh) Per Square Foot – Electric Resistance Heating (Gas Baseline)

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
OfficeLarge	(1.34)	(1.29)	(1.12)	(1.32)	(1.12)	(0.62)	(0.56)	(0.68)	(0.73)	(0.79)	(1.33)	(1.15)	(1.01)	(1.36)	(0.62)	(2.05)
OfficeMedium	(1.33)	(1.03)	(0.79)	(0.97)	(0.76)	(0.30)	(0.26)	(0.33)	(0.36)	(0.46)	(1.07)	(0.90)	(0.72)	(1.07)	(0.25)	(1.90)

Table 106: First Year Peak Demand Reduction (W) Per Square Foot – Electric Resistance Heating (Gas Baseline)

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
OfficeLarge	(0.24)	(0.25)	(0.24)	(0.29)	(0.23)	(0.13)	(0.10)	(0.16)	(0.18)	(0.19)	(0.33)	(0.28)	(0.26)	(0.34)	(0.16)	(0.39)
OfficeMedium	(0.26)	(0.22)	(0.19)	(0.22)	(0.21)	(0.07)	(0.06)	(0.09)	(0.11)	(0.13)	(0.26)	(0.22)	(0.21)	(0.26)	(0.09)	(0.30)

Table 107: First Year Natural Gas Savings (kBtu) Per Square Foot – Electric Resistance Heating (Gas Baseline)

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
OfficeLarge	10.43	8.49	7.71	8.07	7.84	3.52	2.95	3.54	3.91	4.16	7.35	7.01	5.63	7.30	2.22	10.74
OfficeMedium	11.79	8.55	7.15	7.63	7.23	3.00	2.58	3.01	3.53	3.57	7.69	7.44	6.02	7.56	2.20	11.63

Table 108: First Year Source Energy Savings (kBtu) Per Square Foot – Electric Resistance Heating (Gas Baseline)

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
OfficeLarge	6.26	4.24	3.86	3.59	4.15	1.40	1.21	1.11	1.38	1.54	2.58	3.10	2.23	2.48	0.28	4.04
OfficeMedium	7.57	4.96	4.46	4.51	4.89	1.94	1.84	2.02	2.24	2.15	3.92	4.21	3.46	4.18	1.24	6.19

Table 109: First Year LSC Energy Savings ($) Per Square Foot – Electric Resistance Heating (Gas Baseline)

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
OfficeLarge	(2.75)	(3.57)	(3.07)	(3.73)	(2.76)	(2.00)	(1.63)	(2.38)	(2.48)	(2.65)	(4.34)	(3.34)	(3.20)	(4.56)	(2.74)	(7.19)
OfficeMedium	(2.40)	(2.18)	(1.57)	(1.94)	(0.96)	(0.24)	(0.00)	(0.45)	(0.38)	(0.98)	(2.61)	(1.63)	(1.36)	(2.55)	(0.50)	(5.88)

Table 110: First Year Electricity Savings (kWh) Per Square Foot – Electric Resistance Heating (AWHP Baseline)

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
OfficeLarge	(0.32)	(0.35)	(0.46)	(0.35)	(0.37)	(0.35)	(0.32)	(0.39)	(0.40)	(0.43)	(0.50)	(0.38)	(0.40)	(0.36)	(0.44)	(0.29)
OfficeMedium	(0.11)	(0.02)	(0.17)	(0.00)	(0.07)	(0.06)	(0.06)	(0.08)	(0.05)	(0.13)	(0.18)	(0.04)	(0.05)	(0.02)	(0.07)	(0.13)

Table 111: First Year Peak Demand Reduction (W) Per Square Foot – Electric Resistance Heating (AWHP Baseline)

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
OfficeLarge	(0.06)	(0.06)	(0.11)	(0.07)	(0.07)	(0.07)	(0.06)	(0.09)	(0.10)	(0.10)	(0.09)	(0.07)	(0.09)	(0.04)	(0.10)	(0.03)
OfficeMedium	(0.06)	(0.04)	(0.07)	(0.02)	(0.06)	(0.02)	(0.02)	(0.04)	(0.06)	(0.06)	(0.04)	(0.02)	(0.06)	(0.04)	(0.04)	(0.04)

Table 112: First Year Source Energy Savings (kBtu) Per Square Foot – Electric Resistance Heating (AWHP Baseline)

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
OfficeLarge	(0.70)	(0.67)	(1.15)	(0.76)	(0.86)	(0.85)	(0.71)	(0.93)	(0.95)	(1.02)	(1.08)	(0.80)	(0.86)	(0.63)	(1.02)	(0.51)
OfficeMedium	(0.39)	(0.12)	(0.62)	(0.14)	(0.33)	(0.27)	(0.20)	(0.32)	(0.23)	(0.47)	(0.45)	(0.24)	(0.32)	(0.19)	(0.32)	(0.39)

Table 113: First Year LSC Energy Savings ($) Per Square Foot – Electric Resistance Heating (AWHP Baseline)

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
OfficeLarge	(2.00)	(2.13)	(3.11)	(2.18)	(2.33)	(2.32)	(2.02)	(2.58)	(2.66)	(2.79)	(3.06)	(2.32)	2.47)	(2.09)	(2.80)	(1.67)
OfficeMedium	(0.86)	(0.31)	(1.44)	(0.16)	(0.54)	(0.49)	(0.39)	(0.62)	(0.47)	(0.99)	(1.16)	(0.39)	(0.58)	(0.26)	(0.62)	(0.83)

4.4 Cost and Cost Effectiveness

4.4.1 Energy Cost Savings Methodology

Energy cost savings were calculated by applying the LSC hourly factors to the energy savings estimates that were derived using the methodology described in Section 2.3.1. LSC hourly factors are a normalized metric to calculate energy cost savings that accounts for the variable cost of electricity and natural gas for each hour of the year, along with how costs are expected to change over the period of analysis. In this case, the period of analysis used is 30 years.

The CEC requested energy cost savings over the 30-year period of analysis in both 2026 present value dollars (2026 PV$) and nominal dollars. The cost effectiveness analysis uses energy cost values in 2026 PV$. Costs and cost-effectiveness using and 2026 PV$ are presented in Section 4.4 of this report. CEC uses results in nominal dollars to complete the Economic and Fiscal Impacts Statement (From 399) for the entire package of proposed change to Title 24, Part 6. Appendix G presents energy cost savings results in nominal dollars.

The methodology for additions and alterations was the same as for new construction. This is a conservative estimate as it assumed the perfect operation of HVAC controls and an efficient envelope in the baseline system.

4.4.2 Energy Cost Savings Results

Per-unit energy cost savings for newly constructed buildings, additions, and alterations that are realized over the 30-year period of analysis are presented 2026 precent value dollars (2026 PV$) in Table 114 through Table 122.

The LSC hourly factors methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. This measure has the potential to increase winter morning peak electric demand, particularly if a natural gas boiler is in the Baseline. Summer afternoon/evening peak impacts are expected to be minimal.

Any time code changes impact cost, there is potential to disproportionately impact DIPs. Refer to Section 4.6 for more details addressing energy equity and environmental justice.

Table 114: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions – OfficeLarge – Electric Resistance Heating (Gas Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	NA[a]	NA	NA
2	NA	NA	NA
3	(7.44)	4.36	(3.07)
4	(8.39)	4.66	(3.73)
5	NA	NA	NA
6	(4.05)	2.05	(2.00)
7	(3.38)	1.75	(1.63)
8	(4.50)	2.12	(2.38)
9	(4.80)	2.32	(2.48)
10	(5.14)	2.49	(2.65)
11	(8.71)	4.37	(4.34)
12	(7.43)	4.10	(3.34)
13	NA	NA	NA
14	(8.95)	4.39	(4.56)
15	(4.12)	1.38	(2.74)
16	(13.44)	6.25	(7.19)

[a] "NA" refers to the fact that the CEC forecasts 0 square feet of construction activity in this climate zone for this building type in 2026.

Table 115: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions–OfficeMedium – Electric Resistance Heating (Gas Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	(9.04)	6.64	(2.40)
2	(7.10)	4.92	(2.18)
3	(5.68)	4.11	(1.57)
4	(6.41)	4.47	(1.94)
5	(5.06)	4.10	(0.96)
6	(2.01)	1.77	(0.24)
7	(1.56)	1.56	(0.00)
8	(2.28)	1.83	(0.45)
9	(2.51)	2.13	(0.38)
10	(3.14)	2.16	(0.98)
11	(7.22)	4.61	(2.61)
12	(6.05)	4.42	(1.63)
13	(4.99)	3.63	(1.36)
14	(7.15)	4.60	(2.55)
15	(1.87)	1.37	(0.50)
16	(12.70)	6.82	(5.88)

[a] "NA" refers to the fact that the CEC forecasts 0 square feet of construction activity in this climate zone for this building type in 2026.

Table 116: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions–All Prototypes – Electric Resistance Heating (Gas Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	(9.04)	6.64	(2.40)
2	(7.10)	4.92	(2.18)
3	(6.91)	4.29	(2.62)
4	(7.75)	4.60	(3.15)
5	(5.06)	4.10	(0.96)
6	(3.12)	1.92	(1.20)
7	(2.48)	1.65	(0.83)
8	(3.57)	2.00	(1.57)
9	(3.80)	2.24	(1.57)
10	(3.64)	2.24	(1.40)
11	(7.65)	4.54	(3.11)
12	(6.28)	4.36	(1.92)
13	(4.99)	3.63	(1.36)
14	(7.80)	4.52	(3.28)
15	(1.98)	1.37	(0.60)
16	(12.94)	6.64	(6.31)

[a] "NA" refers to the fact that the CEC forecasts 0 square feet of construction activity in this climate zone for this building type in 2026.

Table 117: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations– OfficeLarge – Electric Resistance Heating (Gas Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	(8.50)	5.75	(2.75)
2	(8.35)	4.78	(3.57)
3	(7.44)	4.36	(3.07)
4	(8.39)	4.66	(3.73)
5	(7.16)	4.40	(2.76)
6	(4.05)	2.05	(2.00)
7	(3.38)	1.75	(1.63)
8	(4.50)	2.12	(2.38)
9	(4.80)	2.32	(2.48)
10	(5.14)	2.49	(2.65)
11	(8.71)	4.37	(4.34)
12	(7.43)	4.10	(3.34)
13	(6.58)	3.37	(3.20)
14	(8.95)	4.39	(4.56)
15	(4.12)	1.38	(2.74)
16	(13.44)	6.25	(7.19)

Table 118: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations–OfficeMedium – Electric Resistance Heating (Gas Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	(9.04)	6.64	(2.40)
2	(7.10)	4.92	(2.18)
3	(5.68)	4.11	(1.57)
4	(6.41)	4.47	(1.94)
5	(5.06)	4.10	(0.96)
6	(2.01)	1.77	(0.24)
7	(1.56)	1.56	(0.00)
8	(2.28)	1.83	(0.45)
9	(2.51)	2.13	(0.38)
10	(3.14)	2.16	(0.98)
11	(7.22)	4.61	(2.61)
12	(6.05)	4.42	(1.63)
13	(4.99)	3.63	(1.36)
14	(7.15)	4.60	(2.55)
15	(1.87)	1.37	(0.50)
16	(12.70)	6.82	(5.88)

Table 119: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations–All Prototypes – Electric Resistance Heating (Gas Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	(5.88)	4.31	(1.57)
2	(5.44)	3.70	(1.74)
3	(5.57)	3.50	(2.07)
4	(6.30)	3.78	(2.52)
5	(3.99)	3.10	(0.88)
6	(2.84)	1.64	(1.20)
7	(2.18)	1.36	(0.82)
8	(3.30)	1.73	(1.57)
9	(3.64)	1.93	(1.71)
10	(3.10)	1.76	(1.34)
11	(4.73)	2.92	(1.81)
12	(5.14)	3.30	(1.83)
13	(3.28)	2.16	(1.12)
14	(6.52)	3.55	(2.98)
15	(1.90)	1.02	(0.87)
16	(9.55)	4.76	(4.80)

Table 120: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions–OfficeLarge – Electric Resistance Heating (AWHP Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	NA	NA	NA
2	NA	NA	NA
3	(3.11)	0.00	(3.11)
4	(2.18)	0.00	(2.18)
5	NA	NA	NA
6	(2.32)	0.00	(2.32)
7	(2.02)	0.00	(2.02)
8	(2.58)	0.00	(2.58)
9	(2.66)	0.00	(2.66)
10	(2.79)	0.00	(2.79)
11	(3.06)	0.00	(3.06)
12	(2.32)	0.00	(2.32)
13	NA	NA	NA
14	(2.09)	0.00	(2.09)
15	(2.80)	0.00	(2.80)
16	(1.67)	0.00	(1.67)

Table 121: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions –OfficeMedium – Electric Resistance Heating (AWHP Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	(0.86)	0.00	(0.86)
2	(0.31)	0.00	(0.31)
3	(1.44)	0.00	(1.44)
4	(0.16)	0.00	(0.16)
5	(0.54)	0.00	(0.54)
6	(0.49)	0.00	(0.49)
7	(0.39)	0.00	(0.39)
8	(0.62)	0.00	(0.62)
9	(0.47)	0.00	(0.47)
10	(0.99)	0.00	(0.99)
11	(1.16)	0.00	(1.16)
12	(0.39)	0.00	(0.39)
13	(0.58)	0.00	(0.58)
14	0.26	0.00	0.26
15	(0.62)	0.00	(0.62)
16	0.83	0.00	0.83

Table 122: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction and Additions –All Prototypes – Electric Resistance Heating (AWHP Baseline)

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	(0.86)	0.00	(0.86)
2	(0.31)	0.00	(0.31)
3	(2.61)	0.00	(2.61)
4	(1.54)	0.00	(1.54)
5	(0.54)	0.00	(0.54)
6	(1.48)	0.00	(1.48)
7	(1.21)	0.00	(1.21)
8	(1.76)	0.00	(1.76)
9	(1.71)	0.00	(1.71)
10	(1.44)	0.00	(1.44)
11	(1.71)	0.00	(1.71)
12	(0.72)	0.00	(0.72)
13	(0.58)	0.00	(0.58)
14	(0.60)	0.00	(0.60)
15	(0.73)	0.00	(0.73)
16	0.01	0.00	0.01

4.4.3 Incremental First Cost

A real 40,000 ft2 Bay Area office building that was recently built has a VAV HW reheat system served by a gas boiler. The piping was designed for a design HWST of 160°F. To account for the proposed maximum HWST of 130°F, the Gas Baseline design was slightly modified to include larger pumps and piping needed for 130°F HWST. To develop the AWHP baseline the Statewide CASE Team redesigned the mechanical system with an AWHP instead of a boiler and then redesigned it with fan-powered VAV boxes with electric resistance heat, instead of hydronic heating. Thus, there were 3 full designs: Gas Baseline, AWHP Baseline and Electric Resistance.

Contractor pricing for the mechanical equipment for each case was solicited from Bay Area HVAC equipment representatives. Pricing was provided for boilers, AWHPs, HW reheat boxes, fan power boxes with electric resistance, and single duct VAV boxes with electric resistance (interior zones can meet the criteria without fan boxes). Incremental pricing for a complete installation was then solicited from Bay Area mechanical and electrical contractors. This pricing includes all miscellaneous costs associated with a hydronic system such as expansion tanks and water treatment. It also includes a sound boot on the inlet of each of the fan-powered boxes. It also included the cost for the electrical contractor to power the AWHP and each of the fan-powered boxes. Detailed incremental costs are shown in Table 123 through Table 126.

Table 123: Building Data for ER Heating Measure Costing

Metric	Data	Source (if applicable)
Area (ft2)	40,000	Real Building Drawings
Peak load (Btuh/ft2)	18	Real Building Drawings
Peak load (Btuh)	720,000	Real Building Drawings
Total zones	53	Real Building Drawings
Interior zones	16	Real Building Drawings
Avg ft2/box	754.72	Real Building Drawings
Discount rate for annual costs	3%	MeasureSET
Study period (years)	30	MeasureSET
PV multiplier	19.60	calculation

Table 124: Gas Hydronic Baseline Cost Data

Baseline: Gas Boiler serving HW Reheat Boxes	Data	Source (if applicable)
Avg cost/reheat box	$345	Bay Area equip. rep.
Cost of reheat boxes	$18,282	Bay Area equip. rep.
Mech installation cost for typical HW reheat box ($/box)	$5,000	Bay Area mech. Contractor
Mech installation cost for reheat boxes ($)	$265,000	Calculation
Boiler cost - installed ($/Btuh)	0.1	Bay Area equip. reps
Boiler cost - installed ($)	$72,000	Calculation
HW piping cost $/ft2 (does not include box piping)	5.68	Bay Area mech. Contractor
HW piping cost $ (does not include box piping)	$227,200	Calculation
Pump cost $/gpm installed	170.5	Bay Area equip. reps
Gpm	86	Calculation
Pump cost $	$14,663	Calculation
Misc. hydronics cost $ (ET, TES, WTS, etc.)	$30,000	Bay Area mech. Contractor
Boiler/HW incremental controls $	$15,000	Bay Area mech. Contractor
Gas service to building and to boiler	$20,000	Bay Area mech. Contractor
Plumbing for boiler $ (MUW, drain, etc.)	$10,000	Bay Area mech. Contractor
Structural/arch for boiler (pad, roof screen, mech room, etc.)	0	Bay Area mech. Contractor
Annual maintenance for HW system, incl boiler ($/yr)	$1,000	Bay Area service Contractor
Other first costs	$12,500	Bay Area mech. Contractor
Total first cost	$684,645	Calculation
Total annual costs	$1,000	Bay Area service Contractor
PV of annual	$19,600	Calculation
Boiler expected life (years)	30	ASHRAE database
Boiler replacement cost	0	Calculation
NPV	$704,246	Calculation
Savings/ft2 vs Gas Baseline	$5.91	Calculation

Table 125: Electric (AWHP) Hydronic Baseline Cost Data

Baseline: AWHP serving HW Reheat Boxes	Data	Source (if applicable)
Avg cost/reheat box	$345	Bay Area equip. rep.
Cost of reheat boxes	$18,282	Bay Area equip. rep.
Mech installation cost for typical HW reheat box ($/box)	$5,000	Bay Area mech. Contractor
Mech installation cost for reheat boxes ($)	$265,000	Calculation
AWHP cost - installed ($/Btuh)	$0.28	Bay Area mech. Contractor
AWHP cost - installed ($)	$201,600	Calculation
HW piping cost $/ft2 (does not include box piping)	$5.68	Bay Area mech. Contractor
HW piping cost $ (does not include box piping)	$227,200	Calculation
Pump cost $/gpm installed	$171	Bay Area equip. reps
Gpm	86	calculated
Pump cost $	$14,663	calculated
Misc. hydronics cost $ (ET, TES, WTS, etc.)	$30,000	Bay Area mech. Contractor
AWHP/HW incremental controls $	$15,000	Bay Area mech. Contractor
Electrical service to AWHP	$30,280	Bay Area elec. Contractor
Plumbing for AWHP $ (MUW, drain, etc.)	$10,000	Bay Area mech. Contractor
Structural/arch for AWHP (pad, roof screen, mech room, etc.)	0	Bay Area mech. Contractor
Annual maintenance for HW system, incl AWHP ($/year)	$1,000	Bay Area service Contractor
Other first costs	$12,500	Bay Area mech. Contractor
Total first cost	$824,525	Calculated
Total annual costs	$1,000	Calculated
PV of annual	$19,600	Calculated
AWHP expected life (years)	20	ASHRAE database
AWHP replacement cost	$111,621	Calculated
NPV	$955,747	Calculated

Table 126: ER Heating Proposed Design Cost Data

Proposed: Electric Resistance Heat	Data	Source (if applicable)
Interior zones	16	Real Building Drawings
Perimeter zones	37	Real Building Drawings
Single duct avg cost/box	$1,033	Bay Area equip. rep.
Fan box avg cost/box	$1,789	Bay Area equip. rep.
Cost of electric resistance boxes (SD + FPB)	$82,721	Calculated
Mechanical installation cost of typical single duct box with electric resistance ($/box)	$2,000	Bay Area mech. Contractor
Mechanical installation cost of typical FPB with electric resistance ($/box)	$3,000	Bay Area mech. Contractor
Mechanical installation cost for boxes	$143,000	Calculated
Electrical service to FPBs	$1,820	Bay Area elec. Contractor
Electrical install for boxes	$96,460	Calculated
Unit price of filter change for FPB ($/box)	150	Bay Area mech. Contractor
Sound boot per box ($/box)	1,000	Bay Area mech. Contractor
Percent of FPB with sound boots	100%	Conservative estimate
Sound boot cost	$37,000	Calculated
Total first cost	$359,181	Calculated
Total annual costs	$5,550	Calculated
PV of annual	$108,782	Calculated
NPV	$467,963	Calculated
Savings/ft2 vs AWHP baseline	$12.19	Calculated

4.4.4 Incremental Maintenance and Replacement Costs

Incremental maintenance cost was provided by Bay Area service contractors based on the three designs described above and is included in the table above. Surprisingly, the electric resistance case has the highest maintenance cost, even though it has no central heating plant equipment and no moving parts in the heating system. The high maintenance cost for the Electric Resistance measure is for filter replacements as Title 24 requires filters in fan powered boxes. There are other types of electric resistance heating systems that would comply with the proposal and not require filter changes, such as baseboard radiators or radiant panels.

The only replacement cost included in the analysis is for replacement of the AWHP after 20 years. All other equipment has an expected life of 30 years or longer.

4.4.5 Cost Effectiveness

This measure proposes a prescriptive option. As such, a cost analysis is required to demonstrate that the measure is cost effective over the 30-year period of analysis.

The CEC establishes the procedures for calculating cost effectiveness. The Statewide CASE Team collaborated with CEC staff to confirm that the methodology in this report is consistent with their guidelines, including which costs were included in the analysis. The incremental first cost and incremental maintenance costs over the 30-year period of analysis were included. The LSC Savings from electricity and natural gas savings were also included in the evaluation. Design costs were not included nor were the incremental costs of code compliance verification.

According to the CEC's definitions, a measure is cost effective if the benefit-to-cost (B/C) ratio is greater than 1.0. The B/C ratio is calculated by dividing the cost benefits realized over 30 years by the total incremental costs, which includes maintenance costs for 30 years. The B/C ratio was calculated using 2026 PV costs and cost savings.

Results of the per-unit cost-effectiveness analyses are presented in Table 127 and Table 128 for new construction/additions and alterations, respectively. Results are shown for the condition with a gas boiler in the baseline.

The proposed measure saves money over the 30-year period of analysis relative to the existing conditions. The proposed code change is cost effective in every climate zone except for CZ16.

Table 127: 30-Year Cost-Effectiveness Summary Per Square Foot – New Construction/Additions and Alterations – Gas Baseline

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	(2.40)	(6.73)	2.81
2	(2.18)	(6.73)	3.08
3	(2.62)	(6.73)	2.57
4	(3.15)	(6.73)	2.14
5	(0.96)	(6.73)	7.02
6	(1.20)	(6.73)	5.63
7	(0.83)	(6.73)	8.15
8	(1.57)	(6.73)	4.29
9	(1.57)	(6.73)	4.30
10	(1.40)	(6.73)	4.81
11	(3.11)	(6.73)	2.17
12	(1.92)	(6.73)	3.51
13	(1.36)	(6.73)	4.95
14	(3.28)	(6.73)	2.05
15	(0.60)	(6.73)	11.20
16	(6.31)	(6.73)	1.07

a. **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC Savings over the period of analysis (California Energy Commission 2022, 51-53) (California Energy Commission 2022). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) three percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

c. Values only apply to Alterations, as the construction forecasts projects no new construction large office in the given climate zones in 2026.

Table 128: 30-Year Cost-Effectiveness Summary Per Square Foot – New Construction/Additions and Alterations – AWHP Baseline

Climate Zone	Benefits LSC Savings + Other PV Savings[a] (2026 PV$)	Costs Total Incremental PV Costs[b] (2026 PV$)	Benefit-to-Cost Ratio
1	(0.86)	(9.75)	11.28
2	(0.31)	(9.75)	31.90
3	(2.61)	(9.75)	3.73
4	(1.54)	(9.75)	6.35
5	(0.54)	(9.75)	17.98
6	(1.48)	(9.75)	6.60
7	(1.21)	(9.75)	8.04
8	(1.76)	(9.75)	5.53
9	(1.71)	(9.75)	5.69
10	(1.44)	(9.75)	6.77
11	(1.71)	(9.75)	5.72
12	(0.72)	(9.75)	13.59
13	(0.58)	(9.75)	16.94
14	(0.60)	(9.75)	16.26
15	(0.73)	(9.75)	13.44
16	0.01	(9.75)	infinite

a. **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC Savings over the period of analysis (California Energy Commission 2022, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of the CASE analysis period.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) three percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the Benefit-to-Cost ratio is infinite.

c. Values only apply to Alterations, as the construction forecasts projects no new construction large office in the given climate zones in 2026.

4.5 First-Year Statewide Impacts

4.5.1 Statewide Energy and Energy Cost Savings

The Statewide CASE Team calculated the first-year statewide savings for new construction and additions by multiplying the per-unit savings, which are presented in Section 2.3.2, by assumptions about the percentage of newly constructed buildings that would be impacted by the proposed code. The statewide new construction forecast for 2026 is presented in Appendix A, as are the Statewide CASE Team's assumptions about the percentage of new construction that would be impacted by the proposal (by climate zone and building type). The Statewide CASE Team used the same savings methodology for alterations.

The first-year energy impacts represent the first-year annual savings from all buildings that were completed in 2026. The 30-year energy cost savings represent the energy cost savings over the entire 30-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

The tables below presents the first-year statewide energy and energy cost savings from newly constructed buildings and additions for the gas baseline (Table 129) and the electric baseline (Table 130Table 130) by climate zone. Table 131 and Table 131 presents first-year statewide savings from new construction, additions, and alterations for the two baselines.

While a statewide analysis is crucial to understanding broader effects of code change proposals, there is potential to disproportionately impact DIPs that needs to be considered. Refer to Section 4.6 for more details addressing energy equity and environmental justice.

Table 129: Statewide Energy and Energy Cost Impacts – New Construction and Additions (Gas Baseline)

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Million Square Feet)	First-Year[a] 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 Energy Cost Savings (Million 2026 PV$)
1	9,114	(0.01)	(0.00)	0.00	0.07	($0.02)
2	33,327	(0.03)	(0.01)	0.00	0.17	($0.07)
3	322,420	(0.33)	(0.07)	0.02	1.30	($0.85)
4	162,554	(0.20)	(0.04)	0.01	0.63	($0.51)
5	25,935	(0.02)	(0.01)	0.00	0.13	($0.02)
6	183,610	(0.09)	(0.02)	0.01	0.30	($0.22)
7	114,072	(0.05)	(0.01)	0.00	0.17	($0.09)
8	275,380	(0.15)	(0.04)	0.01	0.41	($0.43)
9	513,520	(0.29)	(0.08)	0.02	0.90	($0.80)
10	109,592	(0.06)	(0.02)	0.00	0.22	($0.15)
11	26,411	(0.03)	(0.01)	0.00	0.09	($0.08)
12	236,159	(0.22)	(0.06)	0.02	0.95	($0.45)
13	41,013	(0.03)	(0.01)	0.00	0.14	($0.06)
14	38,388	(0.05)	(0.01)	0.00	0.14	($0.13)
15	19,315	(0.01)	(0.00)	0.00	0.02	($0.01)
16	10,637	(0.02)	(0.00)	0.00	0.06	($0.07)
Total	2,121,447	(1.58)	(0.38)	0.11	5.70	($3.98)

a. First-year savings from all buildings completed statewide in 2026.

Table 130: Statewide Energy and Energy Cost Impacts – New Construction and Additions (AWHP Baseline)

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Million Square Feet)	First-Year[a] 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 Energy Cost Savings (Million 2026 PV$)
1	3,906	(0.00)	(0.00)	0.00	(0.00)	($0.00)
2	14,283	(0.00)	(0.00)	0.00	(0.00)	($0.00)
3	138,180	(0.05)	(0.01)	0.00	(0.14)	($0.36)
4	69,666	(0.02)	(0.00)	0.00	(0.04)	($0.11)
5	11,115	(0.00)	(0.00)	0.00	(0.00)	($0.01)
6	78,690	(0.02)	(0.00)	0.00	(0.05)	($0.12)
7	48,888	(0.01)	(0.00)	0.00	(0.02)	($0.06)
8	118,020	(0.03)	(0.01)	0.00	(0.08)	($0.21)
9	220,080	(0.05)	(0.02)	0.00	(0.14)	($0.38)
10	46,968	(0.01)	(0.00)	0.00	(0.03)	($0.07)
11	11,319	(0.00)	(0.00)	0.00	(0.01)	($0.02)
12	101,211	(0.01)	(0.00)	0.00	(0.03)	($0.07)
13	17,577	(0.00)	(0.00)	0.00	(0.01)	($0.01)
14	16,452	(0.00)	0.00	0.00	(0.00)	($0.01)
15	8,278	(0.00)	(0.00)	0.00	(0.00)	($0.01)
16	4,559	(0.00)	0.00	0.00	0.00	$0.00
Total	909,191	(0.21)	(0.06)	0.00	(0.55)	($1.43)

a. First-year savings from all buildings completed statewide in 2026.

Table 131: Statewide Energy and Energy Cost Impacts – New Construction, Additions, and Alterations (Gas Baseline)

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 Energy Cost Savings (PV$ Million)
New Construction & Additions	(1.6)	(0.4)	0.1	5.7	(4.0)
Alterations	(12.9)	(3.0)	0.9	41.7	(35.0)
Total	(14.5)	(3.4)	1.0	47.4	(39.0)

Table 132: Statewide Energy and Energy Cost Impacts – New Construction, Additions, and Alterations (AWHP Baseline)

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 Energy Cost Savings (PV$ Million)
New Construction & Additions	(0.2)	(0.1)	0.0	(0.6)	(1.0)
Alterations	0	0	0	0	0
Total	(0.2)	(0.1)	0.0	(0.6)	(1.0)

a. First-year savings from all alterations completed statewide in 2026.

4.5.2 Statewide Greenhouse Gas (GHG) Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions associated with energy consumption using the hourly GHG emissions factors that CEC developed along with the 2025 LSC hourly factors and an assumed cost of $123.15 per metric tons of carbon dioxide equivalent emissions (metric tons CO2e).

The 2025 LSC hourly factors used in the lifecycle cost-effectiveness analysis include the monetary value of avoided GHG emissions based on a proxy for permit costs (not social costs).[30] The Cost-Effectiveness Analysis presented in Section 2.4 of this report does not include the cost savings from avoided GHG emissions. To demonstrate the

[30] The permit cost of carbon is equivalent to the market value of a unit of GHG emissions in the California Cap-and-Trade program, while social cost of carbon is an estimate of the total economic value of damage done per unit of GHG emissions. Social costs tend to be greater than permit costs. See more on the Cap-and-Trade Program on the California Air Resources Board website: https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program.

cost savings of avoided GHG emissions, the Statewide CASE Team disaggregated the value of avoided GHG emissions from the other economic impacts. The authors used the same monetary values that are used in the LSC hourly factors.

Table 133 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 386 (metric tons CO2e) would be avoided.

Table 133: First-Year Statewide GHG Emissions Impacts

Measure	Electricity Savings[a] (GWh/yr)	Reduced GHG Emissions from Electricity Savings[a] (Metric Tons CO2e)	Natural Gas Savings[a] (Million Therms/yr)	Reduced GHG Emissions from Natural Gas Savings[a] (Metric Tons CO2e)	Total Reduced GHG Emissions[b] (Metric Ton CO2e)	Total Monetary Value of Reduced GHG Emissions[c] ($)
Gas boiler to ER heat	(14)	(2,107)	0.97	5,291	3,183	392,036
AWHP to ER heat	(0.21)	(31)	0.0	0	(31)	(3,758)
Total	(14.49)	(2,138)	0.97	5,291	3,152	388,278

a. First-year savings from all buildings completed statewide in 2026.

b. GHG emissions savings were calculated using hourly GHG emissions factors are published alongside the in the LSC hourly factors and Source Energy factors by CEC here: https://www.energy.ca.gov/files/2025-energy-code-hourly-factors

c. The monetary value of avoided GHG emissions is based on a proxy for permit costs (not social costs) derived from the 2022 TDV Update Model published by CEC here: https://www.energy.ca.gov/files/tdv-2022-update-model

4.5.3 Statewide Water Use Impacts

The proposed code change will not result in water savings.

4.5.4 Statewide Material Impacts

The proposed code change is expected to result in significant material impacts. We can expect a reduction in hydronic distribution system pipe materials as well as avoided boiler or AWHP equipment materials if building designers choose to pursue electric resistance heating instead of hydronic systems. Material impacts are being quantified and will be ready in time for the final CASE Report.

4.5.5 Other Non-Energy Impacts

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

4.6 Addressing Energy Equity and Environmental Justice

The Statewide CASE Team recognizes, acknowledges, and accounts for a history of prejudice and inequality in disproportionately impacted populations (DIPs) and the role this history plays in the environmental justice issues that persist today. DIPs refer to the populations throughout California that most suffer from a combination of economic, health, and environmental burdens. These burdens include poverty, high unemployment, air and water pollution, presence of hazardous wastes, as well as high incidence of asthma and heart disease. DIPs also incorporate race, class, and gender since these intersecting identity factors affect how people frame issues, interpret, and experience the world.[31] While the term disadvantaged communities (DACs) is often used in the energy industry and state agencies, the Statewide CASE Team chose to use terminology that is more acceptable to and less stigmatizing for those it seeks to describe (DC Fiscal Policy Institute 2017).

Including impacted communities in the decision-making process, ensuring that the benefits and burdens of the energy sector are evenly distributed, and facing the unjust legacies of the past serve as critical steps to achieving energy equity. To minimize the risk of perpetuating inequity, code change proposals are being developed with intentional consideration of the unintended consequences of proposals on DIPs.

The Statewide CASE Team recognizes the importance of engaging DIPs and gathering their input to inform the code change process and proposed measures. A participatory approach allows individuals to address problems, develop innovative ideas, and bring forth a different perspective. The Statewide CASE Team is working to build relationships with community-based organizations (CBOs) to facilitate meaningful engagement with stakeholders and gather feedback on the proposed measures. Please reach out to Bryan Boyce (bboyce@energy-solution.com), Nancy Metayer (nmetayer@energy-solution.com) and Marissa Lerner (mlerner@energy-solution.com) for further engagement.

4.6.1 Potential Impacts

As noted throughout this proposal, this proposal is cost-effective and in addition the initial cost costs for an electric resistance heating system is expected to be lower than compared to a hydronic system. The system being described in this measure is also simpler than a hydronic space heating system. The proposal is likely to induce projects

[31] Environmental disparities have been shown to be associated with unequal harmful environmental exposure correlated with race/ethnicity, gender, and socioeconomic status. For example, chronic diseases, such as respiratory diseases, cardiovascular disease, and cancer, associated with environmental exposure have been shown to occur in higher rates in the LGBTQ+ population than in the cisgender, heterosexual population (Goldsmith L 2022). Socioeconomic inequities, climate, energy, and other inequities are inextricably linked and often mutually reinforcing.

to select electric heating systems instead of natural gas boiler-based systems, which would result in a decrease in on-site pollution emissions, which will benefit all building occupants including DIPs. The cumulative effect of these factors leads the Statewide CASE Team to conclude that the measure will not adversely impact DIPs and if anything, will likely benefit them.

Impacts may vary by building type. Offices of all sizes, for example, are expected to be used by all people equally and DIPs are not more or less likely to occupy office spaces than any other population. So, the proposed change is not expected to have an unequal impact on DIPs. The Statewide CASE Team identified schools and hotels as building types that may have disproportional impacts. These building types are discussed below.

4.6.2 Potential Disproportionately Impacted Populations

A conceivable adverse impact to DIPs would be the potential for increased electricity consumption over the lifetime of the building. Up-front costs, natural gas emissions, and system complexity are all anticipated to be reduced because of this proposal. Furthermore, this measure does not particularly target DIPs relative to other groups. It is for these reasons that the Statewide CASE Team is not anticipating adverse impacts to DIPs.

Proposed code changes to both small and large schools have the potential to disproportionately impact populations for those attending school and working at schools located in DIP communities. Proposed code changes that impact health, disaster preparedness, safety, and comfort especially all have the potential to disproportionately impact those who attend or work in schools. In addition, increased costs for building new schools or renovating schools can present challenges to jurisdictions with lower income populations where the tax base, funding, and budgets may be more constrained.

Proposed code changes to the hotel building type have the potential to disproportionately impact DIPs for those who work in the hospitality industry, use hotels as a means of temporary housing, or might use hotels for refuge during an extreme weather event (disaster preparedness). Proposed code changes that impact health, disaster preparedness especially have the potential to disproportionately impact those working or residing in hotels. While the costs may increase for this nonresidential building type, the burden of that cost is unlikely to impact DIPs.

5. Proposed Revisions to Code Language

5.1 Guide to Markup Language

The proposed changes to the standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2022 documents are marked with red underlining (new language) and ~~strikethroughs~~ (deletions).

5.2 Standards

SECTION 120.2 – REQUIRED CONTROLS FOR SPACE-CONDITIONING SYSTEMS

(l) HVAC Hot Water Temperature. Zones that use hot water for space heating shall be designed for a hot water supply temperature of no greater than 130°F.

SECTION 140.4 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

(g) Electric resistance heating. Electric resistance heating systems shall not be used for space heating.

Exception 1 to Section 140.4(g): Where an electric resistance heating system supplements a heating system in which at least 60 percent of the annual heating energy requirement is supplied by site-solar or recovered energy.

Exception 2 to Section 140.4(g): Where an electric resistance heating system supplements a heat pump heating system, and the heating capacity of the heat pump is more than 75 percent of the design heating load calculated in accordance with Section 140.4(a) at the design outdoor temperature specified in Section 140.4(b)4.

Exception 3 to Section 140.4(g): Where the total capacity of all electric resistance heating systems serving the entire building is less than 10 percent of the total design output capacity of all heating equipment serving the entire building.

Exception 4 to Section 140.4(g): Where the total capacity of all electric resistance heating systems serving the entire building, excluding those allowed under Exception 2, is no more than 3 kW.

~~**Exception 5 to Section 140.4(g):** Where an electric resistance heating system serves an entire building that is not a hotel/motel building; and has a conditioned floor area no greater than 5,000 square feet; and has no mechanical cooling; and is in an area where natural gas is not currently available.~~

Exception 6 to Section 140.4(g): Heating systems serving as emergency backup to gas or heat pump heating equipment.

Exception 7 to Section 140.4(g): in zones complying with the following:

(a) the zone is not served by a hydronic heating system

(b) each heating zone serves no more than one cooling zone and each cooling zone serves no more than one heating zone

(c) the primary airflow delivered to the zone at design heating conditions does not exceed the minimum required for ventilation

(d) the zone does not have continuous exhaust makeup air or pressurization requirements that require an outdoor air rate greater than 0.15 cfm/ft2.

(e) All spaces with Note F in Table 120.1-A have occupant sensor ventilation controls meeting 120.1(d)5.A to G

(f) All spaces with R_t ≥ 0.3 in Table 120.1-A have demand control ventilation meeting 120.1(d)4

(g) for zones on the same floor as, and within 30 feet of, a computer room with a design equipment load > 12 kW and at least 50% of the heat from the computer room at design conditions is not otherwise being recovered for space heating (e.g., condenser heat recovery), hot aisle air from the computer room shall be transferred to the zone in heating.

The transfer system shall be sized for at least:

1. 50% of the design equipment load of the computer room, or
2. 50% of the design heating load of the zone

(h) has the capability to detect failure of the heater in the ON position. Capabilities include manual reset thermal cutout or discharge air temperature sensor with associated fault detection logic.

….

(r) Condenser Heat Recovery

1. Simultaneous Condenser Heat Recovery is required for buildings with electric heat (not gas boilers) that meet either A or B:

A. $Cooling_{HL}$ + 0.1*$Cooling_{LL}$ ≥ 200 tons and SHW_{cap} + $Heating_{cap}$ ≥ 2000 kBtuh, or

B. $Cooling_{cap}$ ≥ 300 tons and SHW_{cap} + 0.1*$Heating_{cap}$ ≥ 600 kBtuh

- $Cooling_{cap}$ = design capacity of all mechanical cooling systems
- $Cooling_{HL}$ = design capacity of all mechanical cooling systems serving spaces with a design equipment power density > 5 watts/ft2 and < 40% outdoor air at design airflow, i.e., high load spaces.

· $Cooling_{LL}$ = $Cooling_{cap}$ - $Cooling_{HL}$. If the design includes capacity for future cooling systems, then assume 20% of future systems serve high load spaces.

· SHW_{cap} = design capacity of all service hot water (SHW) systems, excluding systems expected to operate less than 5 hours/week, such as instant-hot for emergency eyewash.

· $Heating_{cap}$ = design capacity of all space heating systems

The heat recovery system shall have a heating COP of at least 3.5 at design conditions and shall be capable of transferring the lesser of the following from spaces in cooling to spaces in heating:

· 50% of the peak heat rejection of the cooling system

· 50% of (SHW_{cap} + $Heating_{cap}$)

EXCEPTION 1 to Section 140.4(r)1: Buildings that include thermal energy storage meeting 140.4(r)2

EXCEPTION 2 to Section 140.4(r)1: Laboratory buildings with exhaust air heat recovery systems meeting 140.9(c)6.

2. Thermal Energy Storage is required for buildings with electric heat (not gas boilers) that meet both A and B:

A. $Cooling_{cap}$ ≥ 800 tons

B. SHW_{cap} + $Heating_{cap}$ ≥ 4,000 kBtuh

The thermal energy storage systems shall include both:

1. a condenser water storage tank, or other means, capable of storing 2 hours times (SHW_{cap} + $Heating_{cap}$), and
2. water-to-water chillers or other means of heat recovery to extract heat from the storage system in heating and reject heat to the storage system in cooling.

3. Heat Recovery for Service Water Heating.

If the building is required to have simultaneous condenser heat recovery by 140.4(r)1 or thermal energy storage by 140.4(r)2 and SHW_{cap} ≥ 500 kBtuh then the heat recovery system shall also heat or preheat the service hot water. The heat recovery system shall have the capacity to transfer the smaller of:

· 30% of the peak heat rejection of the cooling system

· 30% of SHW_{cap}

EXCEPTION 1 to Section 140.4(r): Buildings with a computer room heat recovery system capable of meeting 60% of the design space heating load.

SECTION 141.0 – ADDITIONS, ALTERATIONS, AND REPAIRS TO EXISTING NONRESIDENTIAL

(a) Additions

~~**Exception 2 to Section 141.0(a):** Where an existing system with electric reheat is expanded by adding variable air volume (VAV) boxes to serve an addition, total electric reheat capacity may be expanded so that the total capacity does not exceed 150 percent of the existing installed electric heating capacity in any one permit, and the system need not comply with Section 140.4(g). Additional electric reheat capacity in excess of 150 percent of the existing installed electric heating capacity may be added subject to the requirements of Section 140.4(g).~~

(b) Alterations

2. Prescriptive approach.

C. New or Replacement Space-Conditioning Systems or Components other than new or replacement space-conditioning system ducts shall meet the requirements of Section 140.4 applicable to the systems or components being altered.

Exception 6 to Section 141.0(b)2C: Exception 7 to Section 140.4(g) (allowing electric resistance heating) only applies to spaces meeting the prescriptive envelope requirements in section 140.3 and systems meeting the exhaust air heat recovery requirements in section 140.4(g).

5.3 Reference Appendices

NA7.5.14 Thermal Energy Storage (TES) Systems

- Add choices for condenser water and hot water energy storage
- Add criteria to collect information for AWHP and HR chiller performance data
- Add to functional testing for TES used in heating load shifting mode

5.4 ACM Reference Manual

5. Nonresidential Building Descriptors Reference

5.1 Overview

…

5.1.2 HVAC System Map

Table 2: HVAC System Map

The systems currently mapped to System 6 will be divided into System 6A, 6B and 6C. 6A is for systems in jurisdictions without all-electric reach codes. 6B is for systems in jurisdictions with all-electric reach codes that do NOT meet the following criteria. 6C is for systems in jurisdictions with all-electric reach codes that meet the following criteria:

A. Design capacity of all mechanical cooling systems ≥ 800 tons, and
B. SHW_{cap} + $Heating_{cap}$ ≥ 4,000 kBtuh, where

SHW_{cap} = design capacity of all service hot water (SHW) systems, excluding systems expected to operate less than 5 hours/week, such as instant hot for emergency eyewash.

$Heating_{cap}$ = design capacity of all space heating systems

Table 3: System Descriptions

System Type	Description	Detail
System 6A – VAV	Built-up VAV	Multi-zone built-up system with variable volume fan, chilled water cooling provided by a central water cooled chiller and cooling tower, and hot water heating provided by central gas boiler.
System 6B – VAV	All-Electric Built-up VAV	Multi-zone built-up system with variable volume fan, chilled water cooling provided by a central water cooled chiller and cooling tower, and hot water heating provided by ~~central gas boiler~~ air-water heat pumps (AWHPs).
System 6C – VAV	All-Electric Built-up VAV with Heat Recovery and Thermal Energy Storage	Multi-zone built-up system with variable volume fan, chilled water cooling provided by a central ~~water cooled chiller and cooling tower, and hot water heating provided by central gas boiler.~~ TES plant with a condenser water storage tank with capacity per 140.4(r).2, water-water Heat Recovery chiller(s) sized to meet peak heating load, standard water-cooled chiller(s) sized to meet remaining peak load not met by HR chillers, 2 pipe AWHP(s) to recharge CW tank and sized to meet 25% of peak heating load.

5.8 HVAC Primary Systems

5.8.1 Boilers

…

HOT WATER SUPPLY TEMPERATURE
Applicability: All boilers.
Definition: The temperature of the water produced by the boiler and supplied to the hot water loop.
Units: Degrees Fahrenheit (°F).
Input Restrictions: ~~As designed.~~ ≤ 130°F.
Standard Design: ~~For healthcare facilities, same as the Proposed Design. For all others,~~ Use ~~180~~130°F for standard design boiler.
HOT WATER TEMPERATURE DIFFERENCE
Applicability: All boilers.
Definition: The difference between the temperature of the water returning to the boiler from the hot water loop and the temperature of the water supplied to the loop.
Units: Degrees Fahrenheit (°F).
Input Restrictions: As designed.
Standard Design: ~~For healthcare facilities, same as the Proposed Design. For all others,~~ Use ~~40~~25°F for standard design boiler.
HOT WATER SUPPLY TEMPERATURE RESET
Applicability: All boilers.
Definition: Variation of the hot water supply temperature with outdoor air temperature.
Units: Degrees Fahrenheit (°F).
Input Restrictions: As designed (not allowed for non-condensing boilers).
Standard Design: ~~For healthcare facilities, same as the Proposed Design. For all others,~~ the hot water supply temperature is fixed at ~~160~~ 130°F.

5.5 Compliance Forms

Certificate of Compliance

NRCC-MCH-01-E

- Add field to confirm 130 F HWST
- Fields for capacity, setpoints, other performance data of thermal energy storage, AWHP, and HR chiller equipment
- Space heating system coefficient of performance (including fields to verify 110.2 hydronic heat pump ratings), both component COP and entire system COP
- Fields to confirm compliance with clauses in newly proposed exception to 140.4(g)

Certificate of Installation

2022-NRCI-MCH-E

Modifications expected to add air to water heat pump, heat recovery chiller, thermal energy storage equipment (add fields for items such as model number, rated performance, capacity).

Certificate of Acceptance

NRCA-MCH-15-A Thermal Energy Storage

- Need to modify this form so that it can be used to confirm thermal energy storage applicability to space heating in addition to or instead of space cooling. The current description is based on TES that complements space cooling only (MacCracken 2020).
- Base modifications off of changes to NA7.5.14 Thermal Energy Storage

Certificate (CSU 2019)of Verification

No changes anticipated

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Appendix A: Statewide Savings Methodology

The Statewide CASE Team estimated statewide impacts for the first year by multiplying per-unit savings estimates by statewide construction forecasts that the CEC provided (California Energy Commission Housing and Commercial Construction Data - Excel 2022, California Energy Commission 2022). The CEC provided the construction estimates on March 27, 2023.

To calculate first-year statewide savings, the Statewide CASE Team multiplied the per-unit savings by statewide construction estimates for the first year the standards will be in effect (2026). The nonresidential new construction forecast is presented in Table 134 and nonresidential existing statewide building stock is presented in Source: (California Energy Commission 2022)

Table 135. The projected nonresidential new construction that will be impacted by the proposed code change in 2026 is presented in Table 134. The projected nonresidential existing statewide building stock that will be impacted by the proposed code change as a result of alterations in 2026 is presented in Source: (California Energy Commission 2022)

Table 135. This section describes how the Statewide CASE Team developed these estimates.

The CEC Building Standards Office provided the nonresidential construction forecast, which is available for public review on the CEC's website: https://www.energy.ca.gov/media/3538.

The construction forecast presents the total floorspace of newly constructed buildings in 2026 by building type and climate zone. The building types included in the CECs' forecast are summarized in Table 134.

The Statewide CASE Team made assumptions about the percentage of newly constructed floorspace that would be impacted by the proposed code change. Table 136 presents the assumed percentage of floorspace that would be impacted by the proposed code change by building type. If a proposed code change does not apply to a specific building type, it is assumed that zero percent of the floorspace would be impacted by the proposal. If the assumed percentage is non-zero, but less than 100 percent, it is an indication that some but not all buildings would be impacted by the proposal. The Statewide CASE Team assumed that impacted floor area does not vary by climate zone.

The three measures presented in this CASE Report are to some extent mutually exclusive. For example, a site cannot install both a hydronic space heating and zone-level electric resistance space heating system. So, the percentage of the construction forecast for each measure was estimated to account for this. In terms of the percentage of the building stock pursuing all-electric space heating designs, the Statewide CASE

Team followed the data indicated by jurisdictions that have passed all-electric reach codes (by analyzing localreachcodes.com and associating each jurisdiction that passed an all-electric reach code with its population). This led us to estimate 30 percent of the state is living in an all-electric region. This assumption is surely very conservative since it is done in 2023 and these measures wouldn't take effect until 2026. To factor in the momentum toward all-electric, the Statewide CASE Team added 10 percent of the floor area to all-electric measures.

Regarding the building types themselves, the focus was on the prototypes that include a gas boiler. These are the large office, medium office, large school, hospital, and hotel prototypes. The presence of the gas boiler in the prototype indicated that the building would be a candidate for the measures presented in this proposal.

Table 134: Estimated New Nonresidential Construction in 2026 (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 CZs
Large Office	0.0000	0.0000	3.2340	1.5780	0.0000	1.4220	0.8250	2.2880	4.1520	0.3916	0.1088	0.5747	0.0000	0.2002	0.0130	0.0500	14.8373
Medium Office	0.1302	0.4761	1.3720	0.7442	0.3705	1.2010	0.8046	1.6460	3.1840	1.1740	0.2685	2.7990	0.5859	0.3482	0.2629	0.1020	15.4691
Small Office	0.0131	0.4369	0.1869	0.0202	0.0642	0.1481	0.2339	0.1594	0.3600	0.4167	0.0933	0.5443	0.3852	0.0440	0.1051	0.0331	3.2445
Large Retail	0.0000	0.0000	1.0970	0.5497	0.1491	0.6978	0.3746	0.8316	1.6640	0.6327	0.2997	1.3030	0.3564	0.1442	0.1803	0.0555	8.3356
Medium Retail	0.0842	0.3480	0.7947	0.4459	0.0857	0.6027	0.2856	0.8641	1.4240	0.8224	0.1420	0.6274	0.3790	0.1800	0.1242	0.0812	7.2912
Strip Mall	0.0011	0.1543	0.5040	0.2256	0.0074	0.5629	0.4878	0.9855	1.0650	1.3450	0.0716	0.5928	0.3253	0.3206	0.1001	0.0602	6.8093
Mixed-use Retail	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Large School	0.0065	0.1273	0.8761	0.4418	0.0364	0.5941	0.6084	0.9052	1.4210	0.8535	0.3545	1.1520	0.6149	0.1661	0.0857	0.0681	8.3116
Small School	0.0665	0.2698	0.4566	0.2294	0.1395	0.3155	0.2944	0.3516	0.6581	0.3481	0.0988	0.7763	0.3025	0.1070	0.0373	0.0449	4.4963
Non-refrigerated Warehouse	0.0618	0.3672	2.1600	1.1180	0.1776	1.3630	0.7108	1.9480	3.0100	1.3600	0.6315	2.8440	0.8203	0.3618	0.3673	0.1381	17.4394
Hotel	0.0363	0.2154	1.0330	0.5306	0.1095	0.5527	0.4822	0.7835	1.1830	0.5716	0.1534	0.8029	0.2557	0.1375	0.1248	0.0440	7.0160
Assembly	0.0103	0.3935	1.5830	0.5574	0.0587	0.7868	0.7991	1.4310	1.8240	1.1440	0.1669	1.4140	0.3043	0.2453	0.1180	0.0843	10.9206
Hospital	0.0294	0.1746	0.8416	0.4358	0.0797	0.3285	0.5490	0.4412	0.7894	0.8128	0.1459	0.8253	0.2729	0.1417	0.1150	0.0481	6.0309
Laboratory	0.0008	0.0531	0.6313	0.3632	0.0208	0.0733	0.0527	0.1017	0.1214	0.0623	0.0084	0.0500	0.0097	0.0106	0.0061	0.0035	1.5688
Restaurant	0.0139	0.0826	0.3269	0.1667	0.0340	0.3365	0.2036	0.4933	0.8189	0.4129	0.0710	0.3135	0.1414	0.1015	0.0474	0.0296	3.5937
Enclosed Parking Garage	0.0002	0.0091	1.8300	1.2450	0.0046	2.5850	0.7059	2.2650	1.5270	0.0505	0.0016	0.0412	0.0030	0.0152	0.0037	0.0072	10.2942
Open Parking Garage	0.0023	0.1182	2.4740	1.6820	0.0589	3.6480	1.2010	3.1970	2.1550	0.6535	0.0205	0.5323	0.0384	0.1965	0.0477	0.0937	16.1191
Grocery	0.0069	0.0451	0.1048	0.0618	0.0119	0.0465	0.0172	0.0519	0.0915	0.0494	0.0089	0.0388	0.0228	0.0108	0.0076	0.0060	0.5817
Refrigerated Warehouse	0.0000	0.0000	0.0610	0.0507	0.0143	0.0220	0.0000	0.0068	0.0132	0.0387	0.0000	0.0685	0.1181	0.0076	0.0079	0.0052	0.4141
Controlled-environment Horticulture	0.0927	0.0775	0.3197	0.0399	0.2021	0.2578	0.0015	0.0234	0.0261	0.2780	0.3027	0.3053	0.0901	0.0108	0.0480	0.0047	2.0801
Vehicle Service	0.0019	0.0775	0.5473	0.3582	0.0291	0.5513	0.3416	0.7989	1.8090	0.5735	0.0215	0.3892	0.2476	0.1954	0.0567	0.0491	6.0478
Manufacturing	0.0056	0.1329	0.4035	0.1914	0.0599	0.1284	0.0889	0.1075	0.0950	0.1144	0.0604	0.1555	0.0206	0.0245	0.0174	0.0126	1.6184
Unassigned	0.0000	0.0000	0.0003	0.4212	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0008	0.0000	0.0000	0.0000	0.0000	0.4222
TOTAL	0.5642	3.6596	28.8186	14.6616	1.7490	19.0753	11.1696	25.5077	35.0225	13.2170	3.1162	17.9702	5.3753	3.4208	1.9175	1.2355	186.4807

Source: (California Energy Commission 2022)

Table 135: Estimated Existing Floorspace in 2026 (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 CZs
Large Office	0.1275	3.1020	139.8000	72.3500	1.8320	99.5400	72.7100	162.6000	303.1000	58.4800	2.6080	78.6100	9.2640	20.2700	4.4340	4.6630	1,033.4905
Medium Office	3.3790	30.9900	78.7900	42.2800	13.3200	47.8100	43.8700	59.1100	86.3400	66.6900	16.9400	101.7000	25.1800	13.3300	10.2500	4.0630	644.0420
Small Office	4.1780	12.7500	22.1900	11.3300	7.5040	13.2200	8.5160	13.2800	20.8800	24.4300	10.6000	43.9400	21.4700	4.9870	6.1810	2.6760	228.1320
Large Retail	1.0020	8.6650	58.6800	26.9000	4.2000	31.9600	25.3400	43.4600	66.5300	53.3100	11.4000	58.1600	22.5100	10.9100	9.4020	3.2070	435.6360
Medium Retail	1.1760	13.1100	44.5200	25.7400	5.4330	44.2700	34.6600	66.7200	108.2000	66.8900	10.3700	60.5000	24.1500	15.5300	8.7690	5.1700	535.2080
Strip Mall	3.3360	9.8420	37.4200	18.4300	5.0950	40.2300	28.2900	55.7600	83.7000	66.9200	12.2500	48.3700	24.1800	15.2700	8.6960	4.5910	462.3800
Mixed-use Retail	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Large School	0.7589	8.0200	34.8300	13.9500	2.0710	28.3700	22.5400	42.9100	73.5800	56.0100	10.1300	53.3800	26.4100	12.0600	7.6210	3.5890	396.2299
Small School	2.2300	11.1300	25.5700	9.9790	6.0600	25.6900	14.9600	34.4400	54.3100	33.0300	13.5000	42.0800	23.4400	8.7200	4.2510	3.6450	313.0350
Non-refrigerated Warehouse	3.3300	20.2200	108.3000	53.4300	9.8020	89.9800	51.4800	128.4000	207.3000	182.7000	33.7300	148.3000	51.0800	38.8700	29.0500	11.6300	1,167.6020
Hotel	1.7710	10.5200	48.1000	24.7300	5.0110	30.4900	32.6600	41.9700	66.0100	37.0900	7.2180	40.5300	13.0800	8.0060	5.8760	2.4390	375.5010
Assembly	4.3280	18.1800	91.3400	45.0600	6.5940	57.2500	40.9000	89.1400	120.2000	91.7500	16.3500	69.7200	30.1300	18.9500	11.8300	6.4390	718.1610
Hospital	1.8660	11.0900	48.3300	24.6700	5.0550	28.2500	27.1500	40.7700	69.8800	39.6000	11.1100	53.1800	22.4900	8.8020	5.0340	3.2340	400.5110
Laboratory	0.1782	4.0100	36.9300	28.0600	1.5310	12.2100	17.1900	15.6100	19.3100	10.8100	0.6790	12.1400	4.3960	1.7230	0.3870	0.5716	165.7358
Restaurant	0.6087	3.6160	14.7200	7.4940	1.5460	16.4600	10.7300	23.7800	40.0000	32.4100	3.5150	16.9500	7.7420	6.8590	3.4530	1.8970	191.7807
Enclosed Parking Garage	0.0170	0.5432	40.7100	30.9400	0.2988	29.1500	20.6700	58.4100	72.5300	2.6730	0.3450	3.0900	0.4883	0.8543	0.1666	0.4343	261.3205
Open Parking Garage	0.2193	7.0240	55.0300	41.8200	3.8640	41.1400	35.1700	82.4400	102.4000	34.5700	4.4610	39.9600	6.3140	11.0500	2.1550	5.6160	473.2333
Grocery	0.0960	1.7000	5.8690	3.5640	0.7523	3.4150	2.0820	4.0080	6.9510	4.0180	0.6502	3.7370	1.4500	0.9323	0.5386	0.3846	40.1480
Refrigerated Warehouse	0.0047	0.4556	0.9104	0.2123	0.3863	0.4566	0.0233	0.4213	0.7865	0.6521	0.2629	2.1460	3.9070	0.1842	0.1939	0.1444	11.1476
Controlled-environment Horticulture	0.6988	0.4569	2.6200	1.0720	6.3270	8.2640	1.0720	0.7413	1.5990	3.6090	2.5130	4.5330	5.3600	0.4681	0.6443	0.2349	40.2133
Vehicle Service	0.9073	6.1840	33.6500	15.9800	2.9710	33.7300	23.0800	49.5200	81.7800	56.5400	6.2960	38.3200	18.2400	15.0900	6.1800	3.5430	392.0113
Manufacturing	4.1050	16.8900	61.9300	79.5500	5.5900	73.3300	33.2700	122.7000	168.1000	49.5800	12.8600	57.0100	25.9700	16.9800	5.1460	9.2730	742.2840
Unassigned	0.3582	6.5750	9.0250	6.3180	0.2196	2.5750	0.7716	3.7780	7.8680	2.5510	3.3670	14.3500	2.9350	0.7699	0.4029	1.0260	62.8902
TOTAL	34.8095	208.2030	1,150.3344	636.6293	96.1428	807.1406	605.3749	1,240.7386	1,905.9045	1,004.1331	193.3021	1,020.3830	371.7292	239.2368	131.8425	82.9918	9,728.8962

Source: (California Energy Commission 2022)

Table 136: Percentage of Nonresidential Floorspace Impacted by Proposed Code Change in 2026, by Building Type

Building Type	New Construction Impacted (Percent Square Footage) *(Measure 1/ Measure 2/ Measure 3[b])*	Existing Building Stock (Alterations) Impacted (Percent Square Footage)[a] *(Measure 1/ Measure 2/ Measure 3[b])*
Large Office	90%/30%/10%	70%/10%/30%
Medium Office	90%/30%/10%	70%/10%/30%
Small Office	0%	0%
Large Retail	0%	0%
Medium Retail	0%	0%
Strip Mall	0%	0%
Mixed-use Retail	0%	0%
Large School	90%/30%/10%	70%/10%/30%
Small School	0%	0%
Non-refrigerated Warehouse	0%	0%
Hotel	90%/30%/10%	70%/10%/30%
Assembly	0%	0%
Hospital	90%/30%/10%	70%/10%/30%
Laboratory	0%	0%
Restaurant	0%	0%
Enclosed Parking Garage	0%	0%
Open Parking Garage	0%	0%
Grocery	0%	0%
Refrigerated Warehouse	0%	0%
Controlled-environment Horticulture	0%	0%
Vehicle Service	0%	0%
Manufacturing	0%	0%
Unassigned	0%	0%

a. The percentages shown in the table indicate the breakout within the three measures. The Statewide CASE Team estimated that 1/30th of the existing building stock will be impacted in 2026 based on 30 year measure life.

b. 1. Limit HWST, 2. Condenser heat recovery, 3. Electric resistance heating.

Appendix B: Embedded Electricity in Water Methodology

The Statewide CASE Team assumed the following embedded electricity in water values: 5,440 kWh/million gallons of water for indoor water use and 3,280 kWh/million gallons for outdoor water use (SBW Consulting, Inc. 2022). Embedded electricity use for indoor water use includes electricity used for water extraction, conveyance, treatment to potable quality, water distribution, wastewater collection, and wastewater treatment. Embedded electricity for outdoor water use includes all energy uses upstream of the customer; it does not include wastewater collection or wastewater treatment. The embedded electricity values do not include on-site energy consumption associated with water usage such as is the energy required for water heating or on-site pumping. On-site energy impacts are accounted for in the energy savings estimates presented in Section 2.3 of this report.

These embedded electricity values were derived from research conducted for CPUC Rulemaking 13-12-011. The CPUC study aimed to quantify the embedded electricity savings associated with IOU incentive programs that result in water savings, and the findings represent the most up-to-date research by the CPUC on embedded energy in water throughout California (Commission, Water/Energy Cost-Effectiveness Analysis: Errata to the Revised Final Report 2015a); (Commission, Water/Energy Cost-Effectiveness Analysis: Revised Final Report 2015b) This study resulted in the Water-Energy (W-E) Calculator 1.0, which was updated in February 2022 to Version 2.0 (SBW Consulting, Inc. 2022). The CPUC analysis was limited to evaluating the embedded electricity in water and does not include embedded natural gas in water. For this reason, this CASE Report does not include estimates of embedded natural gas savings associated with water reductions, though the embedded electricity values can be assumed to have the same associated emissions factors as grid-demanded electricity in general.

Appendix C: California Building Energy Code Compliance (CBECC) Software Specification

The purpose of this appendix is to present proposed revisions to CBECC for commercial buildings (CBECC) along with the supporting documentation that the CEC staff and the technical support contractors would need to approve and implement the software revisions.

This CASE Report recommends changes to prescriptive and mandatory code language that would result in changes to the ACM Reference Manual in several cases. The summary of the ACM Reference Manual changes is provided in the bulleted list below. See Section 5.4 for marked up language for the ACM Reference Manual.

- Measure 1 would result in a mandatory HWST limit of 130°F, which is below the current ACM Reference Manual setpoint of 160°F.
- Add a section describing 4-pipe dedicated heat recovery chiller and water-to-water heat pump objects to the ACM reference manual.
- Enhance the thermal energy storage object and ensure it can be configured to provide space heating, and also reflect different efficiency performance depending on if the TES tank uses ice, condenser water, or hot water.

Electric resistance reheat capabilities are already in the ACM Reference Manual.

As of May 2023, the Statewide CASE Team is reviewing the potential modifications to the compliance software associated with the measures in this proposal with the CEC Software Tools Unit and CBECC developers.

Appendix D: Environmental Analysis

Potential Significant Environmental Effect of Proposal

The CEC is the lead agency under the California Environmental Quality Act (CEQA) for the 2025 Energy Code and must evaluate any potential significant environmental effects resulting from the proposed standards. A “significant effect on the environment” is “a substantial adverse change in the physical conditions which exist in the area affected by the proposed project.” (Cal. Code Regs., tit. 14, § 15002(g).)

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 determined that the proposal will not result in a significant effect on the environment.

Direct Environmental Impacts

Direct Environmental Benefits

Various aspects of this proposal are expected to result in energy savings, water savings, and GHG emission reductions. In addition, for the electric resistance heating measure, material reductions (e.g., natural gas boilers or packaged air to water heat pumps, piping for hot water distribution) are anticipated from a shift to electric resistance zone heating, which would result in embodied carbon emissions reductions. These benefits are further quantified throughout the body of this report.

Direct Adverse Environmental Impacts

This proposal is not expected to result in direct adverse environmental impacts, apart from the expected increase in electric load that may occur from the electric resistance heating measure. However, as discussed in this report, this increase in electric load is ideally minimized through the list of clauses that are being proposed to accompany the looser restriction on electric resistance heating. Further, nonresidential buildings prescriptively complying with code are going to be constructed with solar PV and battery storage, which should offset the increase in electric load from resistance heating.

Indirect Environmental Impacts

The measures in this proposal are not expected to result in indirect environmental benefits or adverse impacts.

Mitigation Measures

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

Water Use and Water Quality Impacts Methodology

The Statewide CASE Team anticipates water savings from the addition of thermal energy storage tanks in buildings. The reason for this is because unless it is fully charged, the TES tank receives waste heat instead of the cooling tower. The reduction in runtime hours of the cooling tower results in water savings due to the reduction in water evaporation and associated reduction in blowdown.

Embodied Carbon in Materials

Accounting for embodied carbon emissions is important for understanding the full picture of a proposed code change's environmental impacts. The embodied carbon in materials analysis accounts specifically for emissions produced during the "cradle-to-gate" phase: emissions produced from material extraction, manufacturing, and transportation. Understanding these emissions ensures the proposed measure considers these early stages of materials production and manufacturing instead of emissions reductions from energy efficiency alone.

The Statewide CASE Team calculated emissions impacts associated with embodied carbon from the change in materials as a result of the proposed measures. The calculation builds off the materials impacts outlined in 2.5.4, 0, and 4.5.4, see these sections for more details on the materials impact analysis.

After calculating the materials impacts, the Statewide CASE Team applied average embodied carbon emissions for each material. The embodied carbon emissions are based on industry-wide environmental product declarations (EPDs).[32, 33] These industry-wide EPDs provide global warming potential (GWP) values per weight of specific materials.[34] The Statewide CASE Team chose the industry-wide average for GWP values in the EPDs because the materials accounted for in the statewide calculation will have a range of embodied carbon; i.e. some materials like concrete have a wide range of embodied carbon depending on the manufacturer's processes, source of the materials, etc. The Statewide CASE Team assumes that most building projects will not specify low embodied carbon products. Therefore, an average is appropriate for a statewide estimate.

First year statewide impacts per material (in pounds) were multiplied by the GWP impacts for each material. This provides the total statewide embodied carbon impact for each material. If a material's use is increased, then there is an increase in embodied carbon impacts (additional emissions). If a material's use is decreased, then there is a decrease in embodied carbon impacts (emissions reduced). The total emissions reductions from this measure are the total GHG emissions reductions from the Statewide Greenhouse Gas Emissions Reductions measure sections (Sections 2.5.2, 3.5.2, and 4.5.2) combined with emissions reductions (or additional emissions) from embodied carbon in the Statewide Material Impacts measure sections (Sections 2.5.4, 0, and 4.5.4).

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[32] EPDs are documents which disclose a variety of environmental impacts, including embodied carbon emissions. These documents are based on lifecycle assessments on specific products and materials. Industry-wide EPDs disclose environmental impacts for one product for all (or most) manufacturers in a specified area and are often developed through the coordination of multiple manufacturers and/or associations. A manufacturer specific EPD only examines one product from one manufacturer. Therefore, an industry-wide EPD discloses all the environmental impacts from the entire industry (for a specific product/material) but a manufacturer specific EPD only factors one manufacturer.

[33] An industry wide EPD was not used for mercury, lead, copper, plastics, and refrigerants. Global warming potential values of mercury, lead and copper are based on data provided in a lifecycle assessment (LCA) conducted by Yale University in 2014. The GWP value for plastic is based on a LCA conducted by Franklin Associates, which capture roughly 59% of the U.S.' total production of PVC and HDPE production. The GWP values for refrigerants are based on data provided by the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report.

[34] GWP values for concrete and wood were in units of kg CO2 equivalent by volume of the material rather than by weight. An average density of each material was used to convert volume to weight.

Appendix E: Discussion of Impacts of Compliance Process on Market Actors

This appendix discusses how the recommended compliance process, which is described in Sections 2.1.5, 3.1.5, and 4.1.5, could impact various market actors. Table 137 identifies the market actors who will play a role in complying with the proposed change, the tasks for which they are responsible, how the proposed code change could impact their existing workflow, and ways negative impacts could be mitigated. The information contained in Table 137 is a summary of key feedback the Statewide CASE Team received when speaking to market actors about the compliance implications of the proposed code changes. Appendix F summarizes the stakeholder engagement that the Statewide CASE Team conducted when developing and refining the code change proposal, including gathering information on the compliance process.

Each of the proposed measures will impact the building construction industry in some fashion. The measure to limit HWST will cause mechanical designers to specify larger diameter pipes or different coils. This change is minor. The condenser heat recovery and thermal energy storage measure may present new strategies and requirements to mechanical designers and architects. The measure would impact only large buildings, so relatively few projects will be impacted, but for projects that qualify, it is the case that the new system requirements may be difficult to implement without workforce training in the runup to the new code taking effect. Integrating heat recovery and thermal energy storage for space heating is not exceedingly common practice as of 2023, however, manufacturers are rapidly developing new options. Architects may appreciate the additional roof space available by the reduction in air source heat pump equipment needed as a result of the measure, but they may also need to newly integrate thermal energy storage tanks into building designs. The electric resistance heating measure would likely be simpler than current hydronic options and welcomed by the building industry.

Table 137 identifies the market actors who will play a role in complying with the proposed change, the tasks for which they will be responsible, their objectives in completing the tasks, how the proposed code change could impact their existing workflow, and ways negative impacts could be mitigated.

Table 137: Roles of Market Actors in the Proposed Compliance Process

Market Actor	Task(s) in current compliance process relating to the CASE measure	How will the proposed measure impact the current task(s) or workflow?	How will the proposed code change impact compliance and enforcement?	Opportunities to minimize negative impacts of compliance requirement
HVAC Designer	• Coordinate with architect and building owner to choose system type • Develop layout, sizing, setpoints, and controls sequences for mechanical system	• Limit HWST: Designer would need to ensure that distribution system is sized to handle 130 F or lower HWST for hydronic systems • HR + TES: Designer may need to factor in new concepts to their design workflow, including hydronic heat recovery equipment and thermal energy storage.	• Modification to NCCC-MCH anticipated as a result of Limit HWST and HR+TES measures. • Designer may need to be educated on new strategies to incorporate TES into space heating systems	• Incorporate HR+TES sequences into ASHRAE Guideline 36 to alleviate controls development complexity on designer • Training classes through ASHRAE (local chapters) and local utilities for HR+TES design strategies
Architect	• Develop building function, layout, etc.	• Reduction in AWHP footprint frees up roof space • Additional TES tank space needs • ER Heating option frees up boiler, pipe distribution network, but requires a prescriptive envelope	• Work with mechanical designer	• Workforce education and training for new space heating requirements
ATT	• Completes NA7.5	• NA7.5.14 proposed changes to TES testing	• Improve compliance with new TES measure for space heating	• ATT training to ensure tests are conducted properly for new requirements

Appendix F: Summary of Stakeholder Engagement

Collaborating with stakeholders that might be impacted by proposed changes is a critical aspect of the Statewide CASE Team's efforts. The Statewide CASE Team aims to work with interested parties to identify and address issues associated with the proposed code changes so that the proposals presented to the CEC in this Draft CASE Report are generally supported. Public stakeholders provide valuable feedback on draft analyses and help identify and address challenges to adoption including cost effectiveness, market barriers, technical barriers, compliance and enforcement challenges, or potential impacts on human health or the environment. Some stakeholders also provide data that the Statewide CASE Team uses to support analyses.

This appendix summarizes the stakeholder engagement that the Statewide CASE Team conducted when developing and refining the recommendations presented in this report.

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 stakeholder 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 provide transparency in what the Statewide CASE Team is considering for code change proposals, during these meetings the Statewide CASE Team asks for feedback on:

1) Proposed code changes
2) Draft code language
3) Draft assumptions and results for analyses
4) Data to support assumptions
5) Compliance and enforcement, and
6) Technical and market feasibility

The Statewide CASE Team hosted two stakeholder meetings for Space Heating via webinar described in Table 138. Please see below for dates and links to event pages on Title24Stakeholders.com. Materials from each meeting such as slide presentations, proposal summaries with code language, and meeting notes, are included in the bibliography section of this report.

Table 138: Utility-Sponsored Stakeholder Meetings

Meeting Name	Meeting Date	Event Page from Title24stakeholders.com
First Round of Nonresidential HVAC Space Heating Utility-Sponsored Stakeholder Meeting	Monday, February 27, 2023	https://title24stakeholders.com/event/hvac-controls-and-space-heating-utility-sponsored-stakeholder-meeting/
Second Round of Nonresidential HVAC Space Heating Utility-Sponsored Stakeholder Meeting	TBD (Spring 2023)	TBD

The first round of utility-sponsored stakeholder meetings occurred from January to February 2023 and were important for providing transparency and an early forum for stakeholders to offer feedback on measures being pursued by the Statewide CASE Team. The objectives of the first round of stakeholder meetings were to solicit input on the scope of the 2025 code cycle proposals; request data and feedback on the specific approaches, assumptions, and methodologies for the energy impacts and cost-effectiveness analyses; and understand potential technical and market barriers. The Statewide CASE Team also presented initial draft code language for stakeholders to review.

The second round of utility-sponsored stakeholder meetings occurred from April to May 2023 and provided updated details on proposed code changes. The second round of meetings introduced early results of energy, cost-effectiveness, and incremental cost analyses, and solicited feedback on refined draft code language.

Utility-sponsored stakeholder meetings were open to the public. For each stakeholder meeting, two promotional emails were distributed from info@title24stakeholders.com One email was sent to the entire Title 24 Stakeholders listserv, totaling over 3,000 individuals, and a second email was sent to a targeted list of individuals on the listserv depending on their subscription preferences. The Title 24 Stakeholders' website listserv is an opt-in service and includes individuals from a wide variety of industries and trades, including manufacturers, advocacy groups, local government, and building and energy professionals. Each meeting was posted on the Title 24 Stakeholders' LinkedIn page (and cross-promoted on the CEC LinkedIn page) two weeks before each meeting to reach out to individuals and larger organizations and channels outside of the listserv. The Statewide CASE Team conducted extensive personal outreach to stakeholders identified in initial work plans who had not yet opted into the listserv. Exported webinar meeting data captured attendance numbers and individual comments, and recorded outcomes of live attendee polls to 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 139. Market actors helped the Statewide CASE Team understand various aspects of standard practice in the construction industry, provide a sounding board for the viability of different aspects of the code change proposals, and provide technical data used for the analysis. Table 139 provides a snapshot of the organizations that were consulted. Note that this is not an exhaustive list.

Table 139: Engaged Stakeholders

Organization/Individual Name	Market Role
Center for the Built Environment, UC Berkeley	Researcher
ASHRAE 90.1 MSC	Model code development
California Hydronics	HVAC Distributor
Norman S Wright	HVAC Distributor
Nyle	HVAC Manufacturer
Glumac	HVAC Designer
NRDC	Energy Efficiency Advocate
Larson Energy Research	Researcher
Appropriate Designs	HVAC Designer

Engagement with DIPs

Stakeholder outreach did not specifically target DIPs.

Appendix G: Energy Cost Savings in Nominal Dollars

The CEC requested energy cost savings over the 30-year period of analysis in both 2026 present value dollars (2026 PV$) and nominal dollars. The cost effectiveness analysis uses energy cost values in 2026 PV$. Costs and cost effectiveness 2026 PV$ are presented in Sections 2.4, 3.4, and 4.4 of this report. This appendix presents energy cost savings in nominal dollars.

Table 140: Nominal LSC Over 30-Year Period of Analysis – Per Square Foot – New Construction, Additions, and Alterations – Limit HWST (Gas Baseline)

Prototype	CZ 1	CZ 2	CZ 3	CZ	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
HighRiseMixedUse	2.48	1.72	1.96	1.56	1.76	1.28	1.20	0.99	1.08	1.03	1.37	1.50	1.27	1.40	0.64	1.96
Hospital	11.65	11.16	10.76	10.80	10.82	9.75	9.66	10.00	9.81	9.96	10.59	10.68	10.23	10.06	9.38	11.65
HotelSmall	5.04	4.08	4.04	3.77	4.02	2.50	2.32	2.29	2.50	2.60	3.22	3.57	2.83	3.17	1.50	4.30
OfficeLarge	6.04	4.59	4.74	4.29	4.44	2.77	2.50	2.43	2.60	2.64	3.97	3.96	3.24	3.92	1.58	5.58
OfficeMedium	6.21	4.60	4.64	4.09	4.33	2.42	2.26	2.10	2.44	2.37	4.10	4.14	3.35	4.07	1.65	5.78

Table 141: Nominal LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction, Additions, and Alterations – Limit HWST (AWHP Baseline)

Prototype	CZ 1	CZ 2	CZ 3	CZ	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
HighRiseMixedUse	0.63	0.47	0.50	0.39	0.45	0.30	0.26	0.23	0.26	0.25	0.35	0.37	0.31	0.35	0.16	0.50
Hospital	5.80	5.49	5.22	5.04	5.16	4.29	4.40	4.47	4.40	4.48	4.89	5.00	4.69	4.50	4.05	4.58
HotelSmall	1.60	1.28	1.22	1.12	1.19	0.64	0.68	0.60	0.68	0.68	0.99	1.07	0.87	0.98	0.42	1.40
OfficeLarge	1.78	1.51	1.41	1.35	1.37	0.68	0.73	0.67	0.73	0.76	1.27	1.21	1.00	1.27	0.45	1.85
OfficeMedium	2.02	1.52	1.32	1.28	1.26	0.60	0.67	0.59	0.67	0.66	1.29	1.26	1.04	1.28	0.44	1.95

Table 142: Nominal LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction – Simultaneous Cooling and Heating

Prototype	CZ 1	CZ 2	CZ 3	CZ	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Hospital	13.45	13.03	10.59	13.49	11.91	10.43	8.86	10.29	10.25	10.19	10.30	11.49	9.59	13.33	7.72	16.13

Table 143: Nominal LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction – Thermal Energy Storage

Prototype	CZ 1	CZ 2	CZ 3	CZ	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
OfficeLarge	-	-	2.30	6.96	-	2.73	2.80	3.31	3.05	3.32	6.82	6.37	-	10.26	3.76	14.51

Table 144: Nominal LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction – Heat Recovery for Service Water Heating

Prototype	CZ 1	CZ 2	CZ 3	CZ	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
OfficeLarge			1.77	1.65		1.86	1.97	1.86	1.80	1.81	1.59	1.73		1.71	1.87	1.37

Table 145: Nominal LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction – ER Heating (Gas Baseline)

Prototype	CZ 1	CZ 2	CZ 3	CZ	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
OfficeLarge	(4.72)	(6.81)	(5.80)	(7.21)	(5.09)	(3.98)	(3.22)	(4.81)	(4.99)	(5.34)	(8.67)	(6.47)	(6.35)	(9.15)	(5.83)	(14.61)
OfficeMedium	(3.68)	(3.65)	(2.46)	(3.21)	(1.10)	(0.09)	0.39	(0.55)	(0.31)	(1.66)	(4.69)	(2.53)	(2.13)	(4.56)	(0.76)	(11.49)

Table 146: Nominal LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction – ER Heating (AWHP Baseline)

Prototype	CZ 1	CZ 2	CZ 3	CZ	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
OfficeLarge	(4.51)	(4.81)	(7.02)	(4.93)	(5.25)	(5.23)	(4.55)	(5.83)	(6.02)	(6.30)	(6.90)	(5.25)	(5.58)	(4.71)	(6.33)	(3.76)
OfficeMedium	(1.95)	(0.69)	(3.25)	(0.37)	(1.22)	(1.09)	(0.87)	(1.41)	(1.07)	(2.23)	(2.62)	(0.88)	(1.30)	0.58	(1.40)	1.88

Appendix H: TIER Compliance Modeling Procedure Memorandum

The following memorandum was developed by Taylor Engineers to support an exceptional methods modeling procedure in order to achieve Title 24 compliance for a project using the Time Independent Energy Recovery (TIER) system design. This methodology formed the basis for the Statewide CASE Team's methodology for modeling the thermal energy storage and heat recovery measure.

To:	City of Oakland Building Department
From:	Brandon Gill, Taylor Engineering
Subject:	TIER Plant Title 24 Exceptional Calculations Modeling Procedure
Date:	November 7, 2021

This memo provides a step-by-step summary of the spreadsheet modeling approach used for completing Time Independent Energy Recovery (TIER) plant Title 24 exceptional calculations and accompanies the submitted spreadsheet.

EnergyPlus Model Modifications

Make the following modifications to the EnergyPlus/CBECC-Com model:

1. Eliminate plant energy use, including chilled water and hot water systems, from the energy model by setting devices input ratings to near zero. I.e., set chiller rated input power to 0.001 kW, all pump heads to 0.001', cooling tower fan power to 0.001 kW, etc. This approach shifts the associated energy use from these devices, and their TDV, to the exceptional calculations.
2. Lock out the main AHU's (AH-1) airside economizer during all hours. The analysis requires knowing the *available* load for heat recovery during each hour. The economizer will be "enabled" and the CHW load reduced in Excel post-processing for certain hours when heat recovery is not required.

Spreadsheet Analysis

Conduct the spreadsheet analysis as follows:

1. Structure the spreadsheet as an 8,760 model, not a bin analysis.
2. Export the following parameters from EnergyPlus/CBECC-Com on an 8,760 basis.
    a. Ambient Dry Bulb
    b. Ambient Wet Bulb
    c. For the Main AHU
        i. Return Air Dry Bulb Temperature
        ii. Mixed Air Dry Bulb Temperature
        iii. Mixed Air Wet Bulb Temperature (or RH, or Dew Point)
        iv. Supply Air Dry Bulb Temperature

v. Supply Air Wet Bulb (or RH, or Dew Point)

d. Hot water loop heating load (btu/h)
e. Hot water supply temperature
f. Hot water return temperature
g. Hot water flow rate
h. Chilled water loop load (btu/h)
i. Chilled water loop supply temperature
j. Chilled water return temperature
k. Chilled water loop flow rate
l. Net closed condenser water loop load (from first floor water source chiller/heat pump and aux WCAC/WSHPs under C&S scope) (btu/h)
m. Closed condenser water loop load from each typical floor (btu/h)

3. Adjust chilled water loop load output from the energy model to account for economizing.
   a. If the TES tanks are <95 percent charged, do not adjust the chilled water loop load (in other words, keep the economizer locked out to maximize heat recovery).
   b. Else if, OAT > 75°F or OAT > RAT, do not adjust the chilled water loop load.
   c. Else, calculate mixed air enthalpy, outside air enthalpy, and supply air enthalpy from Enthalpy outputs. Calculate adjusted CHW load as the greatest of:
      i. (h_OAT – h_SAT)/(h_MAT – h_SAT)*(EnergyPlus CHW Load)
      ii. (OAT – SAT)/(MAT – SAT)*(EnergyPlus CHW Load)
      iii. 0 btu/h
4. Identify operating chillers, and loop index of evaporators and condensers per the table below. In the table below, the left subscript denotes the index of the evaporator, and the right subscript denotes the index of the condenser.

	Chilled Water Load (tons)				
Hot Water Load (kBtu/h)		**0 – 250**	**250 – 575**	**575 – 850**	**850+**
	0 – 2500	CH-1 $_{CHW-CW}$ HRC-1$_{CW-HW}$	CH-1 $_{CHW-CW}$ HRC-1$_{CW-HW}$ HRC-3 $_{CHW-CW}$	CH-1 $_{CHW-CW}$ HRC-1$_{CW-HW}$ HRC-2$_{CHW-CW}$ HRC-3 $_{CHW-CW}$	CH-1 $_{CHW-CW}$ HRC-1$_{CHW-HW}$ HRC-2$_{CHW-CW}$ HRC-3 $_{CHW-CW}$
	2500 – 5500	CH-1 $_{CHW-CW}$ HRC-1$_{CW-HW}$ HRC-2$_{CW-HW}$	CH-1 $_{CHW-CW}$ HRC-1$_{CW-HW}$ HRC-2$_{CW-HW}$	CH-1 HRC-1$_{CW-HW}$	—

			HRC-3 CHW-CW	HRC-2CHW-HW HRC-3 CHW-CW *Marginal condition that should not occur in practice, but may occur in the energy model	
	5500 – 7500	CH-1 CHW-CW HRC-1CW-HW HRC-3CW-HW	CH-1 HRC-1CW-HW HRC-3CHW-HW *Marginal condition that should not occur in practice, but may occur in the energy model	—	—
	7500+	CH-1 CHW-CW HRC-1CW-HW HRC-2CW-HW HRC-3CW-HW	—	—	—

5. Heating and cooling loads shall be split among operating devices per the following rules:
    a. For all chillers, CH-1 through HRC-3, with their evaporators indexed to the CHW loop, split adjusted CHW load proportionally to chiller nominal capacity.
    b. For any chillers, HRC-1 through HRC-3, with their evaporators indexed to the CHW loop and their condensers indexed to the HW loop, their heating output shall equal chiller cooling output + chiller compressor heat (chiller input energy) as calculated in subsequent steps.
    c. For any chillers, HRC-1 through HRC-3, with their evaporators indexed to the CW loop and their condensers indexed to the HW loop, their heating output shall equal current hourly heating load less the heating output of the chillers

covered by the chillers in the preceding clause. Where there are multiple such chillers, load shall be split proportionally to nominal chiller heating capacity.

6. Estimate the CWRT setpoint of chillers rejecting heat to the condenser water loop.
    a. If the CW storage tank is currently cycled through to 62°F at the top/44°F at the bottom, assume chillers have a CWRT setpoint of 62°F. (In practice the setpoint will either be 64°F or 60°F depending on whether the tank is charging or discharging, but at this point in the calculation we don't know that answer, and the error introduced by being off 2°F is small.)
    b. If the CW storage tank is currently cycled through to 82°F at the top/62°F at the bottom and not fully charged, assume chillers have a CWRT setpoint of 82°F. (In practice the setpoint will either be 84°F or 80°F depending on whether the tank is charging or discharging, but at this point in the calculation we don't know that answer, and the error introduced by being off 2°F is small.)
    c. If the tank is fully charged, assume chillers have a CWRT setpoint that resets from a maximum of current CHWST setpoint + 50°F at 700 tons of CHW load to a minimum of current CHWST setpoint + 20°F at 120 tons of CHW load.
7. Determine the CHWST of chillers with evaporators indexed to the chilled water loop.
    a. For CH-1, HRC-2, and HRC-3, CHWST setpoint will always equal the CHWST from the EnergyPlus file when indexed to the CHW loop.
    b. For HRC-1, CHWST setpoint shall equal (CHWST setpoint + CHWRT)/2 when indexed to the CHW loop (HRC-1 and HRC-2 evaporators are in series).
8. Determine the HWST setpoint of chillers with condensers indexed to the HW loop.
    a. For HRC-1 and HRC-3, HWST setpoint will always equal the HWST from the EnergyPlus file when indexed to the HW loop.
    b. For HRC-2, HWST setpoint shall equal (HWST setpoint + HWRT)/2 when indexed to the HW loop (HRC-1 and HRC-2 condensers are in series).
9. Estimate the CHWST setpoint of chillers with evaporators indexed to the condenser water loop.
    a. If the CW storage tank is currently cycled through to 62°F at the top/44°F at the bottom, HRC-2 and HRC-3 setpoint will equal 44°F and HRC-1 setpoint will equal 53°F.
    b. Otherwise, assume all chillers have a CHWST setpoint of 60°F.
10. Calculate power draw for chillers with condensers indexed to the CW loop given: current CHW load per chiller (see 5.a), CHWST and CWRT (see 6 and 7), full load chiller efficiency (see chiller table provided), and EnergyPlus chiller curves.
    a. The model in section 14.3.10 of the EnergyPlus Engineering Reference shall be used. This model is also used in CBECC-com.
    b. Normalize the chiller performance curves to the full load performance of the proposed design chillers.
11. Calculate power draw of chillers with condensers indexed to the HW loop.
    a. For chillers with evaporators indexed to the CHW loop and condensers indexed to the HW loop, follow the same procedure as in 10, albeit use HWST as CWRT in the curves.

b. For chillers with evaporators indexed to the CW loop, calculations are complicated by the fact that chiller models take evaporator load as an input to calculate chiller power. In this case, we instead know *condenser* load per the procedure in 5.c, so the process is iterative as follows:
    i. Guess that the chiller heating $COPh_0$ equals 4 for HRC-1 and -2, and 4.5 for HRC-3.
    ii. Using the heating load served by the chiller (see 5.c) and COPh, estimate evaporator load as Condenser Load - (Condenser Load)/COPh
    iii. Using the evaporator load estimate from the previous step, use the chiller model from 10 to estimate chiller power draw based on CHWST, HWST, full load chiller efficiency, and the Energy Plus chiller curves.
    iv. Calculate iteration 1 $COPh_1$ as (Evaporator load estimate + Chiller Power)/Chiller Power.
    v. Repeat 11.b.ii and 11.b.iii using $COPh_1$ to determine heat removed from the condenser loop via evaporators and chiller power.
    vi. This process could be continued until the power draw converges to within a couple percentage points, but our hunch is that this single iteration (which can be done easily in a spreadsheet without introducing circular references or VBA) is probably good enough.

12. Calculate excess heat dumped to the hot water loop that needs to be transferred to the CW loop.
    a. There may be rare occasions when all chillers have evaporators indexed to the CHW loop (near cooling design condition) but there is still a small amount of heating load so HRC-1's condenser is indexed to the hot water loop. The amount of heat rejected to the hot water loop may however exceed the hot water load. In these cases, that heat gets transferred to the CW loop by bleeding CW into the HW loop. So:
        i. Calculate excess hot water loop as the heat rejected from HRCs with condensers to the condenser water loop minus heating load from EnergyPlus. If this value is greater than zero, this heat shall be transferred to the CW loop.
13. Calculate the net heat added/removed from the condenser water loop without supplemental heat. This equals:
    a. Heat gain from chillers with condensers indexed to the condenser water loop.
    b. Plus excess heat from the hot water loop (see 12.a).
    c. Minus heat extracted by chillers with evaporators indexed to the condenser water loop.
    d. Plus net gain/removal from WSHPs and the lobby WC/WS chiller (see 2.l).
14. If heat is added to the condenser water loop, determine whether that heat should be added to the TES tanks or rejected via cooling towers:
    a. If the tanks are not full, and the hourly heat load is less than the remaining available storage capacity in the tanks, assume all energy is rejected to the TES tanks.
    b. If the tanks are not full, but the hourly head load exceeds the remaining available storage capacity in the tanks, the portion of the energy that can be

rejected to the tanks shall be. The remainder shall be rejected through the cooling towers.

   c. If the tanks are full, all energy is rejected through the cooling towers.

15. Determine whether the ASHPs operate during a given hour.
   a. If the net heat removal from the condenser water loop without supplemental heat exceeded 6 MBH during the previous hour, 4 MBH in each of the previous 2 consecutive hours, or 1.15 MBH in each of the previous 3 consecutive hours, run both ASHPs at full load.
   b. Otherwise, the ASHPs shall be off.
16. Determine the ASHP Supply Temperature Setpoint
   a. If the CW storage tank is currently cycled through to 62°F at the top/44°F at the bottom, ASHP Supply Temperature Setpoint shall be 77°F (minimum allowed by ASHP manufacturer).
   b. If the CW storage tank is currently cycled through to 82°F at the top/62°F at the bottom, ASHP Supply Temperature Setpoint shall be 84°F.
17. Calculate ASHP Capacity and Power
   a. ASHP capacity is primarily a function of outside air temperature and supply water temperature. Power is a function of the same variables and load. Since the model logic calls for running the ASHPs at full load, we can ignore load and just look at OAT and supply temperature.
   b. Use a lookup table from the manufacturer with outside air temperature and supply water temperature as inputs, and capacity and power as outputs, to determine power draw and output for each hour when the ASHPs are enabled.
18. Calculate Net Heat Addition/Removal from Storage Tanks and Adjust ASHP Power
   a. Net heat added/removed to/from the storage tanks equals the net heat gain to the condenser water loop without any supplemental heat (per 12) less heat rejected through the cooling towers (per 14) plus heat added by ASHPs (per 17).
   b. If both ASHPs do not need to run the full hour to finish charging the tank, multiply the ASHP capacity output and power draw for that hour by the fraction of the hour that they need to run to finish charging the tank.
19. Calculate Primary CWP-4A/B Flow/Power
   a. If the CW storage tank is currently cycled through to 62°F at the top/44°F at the bottom:
      i. Apply an 18°F delta-T to condenser heat rejection load from chillers with condensers indexed to the CW loop to determine flowrate. However, if the ASHPs are enabled, flowrate shall be no less than 880 GPM.
   b. If the CW storage tank is currently cycled through to 82°F at the top/62°F at the bottom and cooling towers are not enabled during this hour:
      i. Apply a 20°F delta-T to condenser heat rejection load from chillers with condensers indexed to the CW loop to determine flowrate. However, if the ASHPs are enabled, flowrate shall be no less than 785 GPM.
   c. If the CW storage tank is currently cycled through to 82°F at the top/62°F at the bottom and cooling towers are enabled during this hour:

i. Each enabled chiller with its condenser indexed to the condenser loop shall operate at design condenser water flow.
ii. Additionally, add flow for any excess heat dumped from the HW loop to the CW loop (see 12.a). Assume this heat is dumped with a 48°F delta-T for the purposes of calculating flow. (This is inherently conservative since delta-T will be even higher than HWST less design CWST (125°F-77°F) during most hours).

d. Calculate power assuming head varies as $(Flow)^{1.8}$, 80 percent pump efficiency, NEMA premium motor efficiency, 98 percent VFD efficiency.

20. Calculate Evaporator CWP-2A/B Flow/Power
    a. If the CW storage tank is currently cycled through to 62°F at the top/44°F at the bottom:
        i. Apply an 18°F delta-T to current evaporator load from chillers with evaporators indexed to the CW loop to determine flowrate.
    b. If the CW storage tank is currently cycled through to 82°F at the top/62°F at the bottom:
        i. Apply a 20°F delta-T to current evaporator load from chillers with evaporators indexed to the CW loop to determine flowrate.
    c. In neither scenario shall flowrate be less than 50 percent of the smallest heat recovery chiller's design evaporator flow.
    d. Calculate power assuming head varies as $(Flow)^{1.4}$, 80 percent pump efficiency, NEMA premium motor efficiency, 98 percent VFD efficiency.
21. Calculate Tank CWP-3A/B Flow/Power
    a. If the CW storage tank is currently cycled through to 62°F at the top/44°F at the bottom:
        i. Apply an 18°F delta-T to the net heat removal/addition from the storage tanks to determine flowrate.
    b. If the CW storage tank is currently cycled through to 82°F at the top/62°F at the bottom:
        i. Apply a 20°F delta-T to the net heat removal/addition from the storage tanks to determine flowrate.
    c. Calculate power assuming head varies as $(Flow)^{1.4}$, 75 percent pump efficiency, NEMA premium motor efficiency, 98 percent VFD efficiency.
22. Calculate Floor CWP Flow/Power
    a. Apply a 10°F delta-T to condenser water load from each floor to determine flowrate.
    b. Calculate power assuming there is a fixed 5 psi DP setpoint, but the remainder of design head varies as $(Flow)^{1.4}$, 72 percent pump efficiency, NEMA premium motor efficiency, and 98 percent VFD efficiency.
23. Calculate Cooling Tower CWP-1A/B Flow/Power
    a. Cooling tower pump flow equals Primary CWP Flow (see 19) when CWP-4A/B are enabled but shall be no less than 30 percent of design cooling tower flow.
    b. Calculate power assuming there is 15' of static head, but the remainder of design head varies as $(Flow)^{1.4}$, 80 percent pump efficiency, NEMA premium motor efficiency, and 98 percent VFD efficiency.

24. Calculate Cooling Tower Temps and Power
    a. Cooling tower leaving temperature shall be calculated as:
        i. When CWP-4A/B are on, CWRT setpoint (see 6.b), minus the delta-T resulting from the tower heat rejection load applied to the current CWP-4A/B flow, minus 2°F.
        ii. When CWP-4A/B are off but there is still tower heat rejection load due to floor auxiliary condenser water pumps, CWRT setpoint minus auxiliary load delta-T (10°F), minus 2°F.
        iii. These strategies assume a fixed HX approach of 2°F from the open CW loop to the closed CW loop, which is conservative. In practice, approach will decrease as flows decrease, but modeling those dynamics isn't justified.
    b. Cooling tower entering temperature shall be calculated as tower lower leaving temperature plus the delta-T resulting from the tower heat rejection load applied to the current CWP-1A/B flow.
    c. Using cooling tower flow from 23.a, tower entering and leaving temperatures, and ambient wet bulb, calculate cooling tower fan power using the CoolTools empirical model covered in Section 16.1.2.3 of the EnergyPlus Engineering Reference assuming both tower cells always run.
25. Calculate HWP Power
    a. Calculate power using HW flow from EnergyPlus. Assume head varies as $(\text{Flow})^{1.4}$, 78 percent pump efficiency, NEMA premium motor efficiency, and 98% VFD efficiency.
26. Calculate CHWP Power
    a. Calculate power using CHW flow from EnergyPlus, scaled linearly per the adjusted chilled water load from 3. Assume head varies as $(\text{Flow})^{1.4}$, 80 percent pump efficiency, NEMA premium motor efficiency, and 98 percent VFD efficiency.
27. Sum power from all end uses for the hour. Apply 2016 hourly TDV values to determine TDV from the TIER plant.

Limitations not elsewhere addressed

1. The above calculation method leaves the WSHPs and WS/WC lobby chiller in the EnergyPlus model. This means there is a disconnect between the condenser water loop temperatures that feed those devices in the model and the condenser water loop temperatures that they would see in practice per the TIER model. The implication of this omission is that these devices may be modeled as operating more or less efficient than they will in practice per the TIER model. Given the minor contribution of these loads, however, we believe this disconnect is acceptable.

Appendix I: Memo Discussing All-Electric Plant Options for a Large Office

The following narrative and sketches are reproduced from the bidding process for an actual project (the Oakland Site noted in Table 87 in Section 3.4.3.2). Three systems are described but the first one (All-Air All-Electric Plant) was not priced because it was expected that it would not comply with Title 24 for reasons discussed below. The intent of including this narrative is to illustrate the different hydronic all-electric design options available to large buildings. In addition, it is hoped that this narrative can further illustrate why heat recovery and thermal energy storage are such critical elements to all-electric designs in large buildings.

1. All-Air All-Electric Plant

For smaller buildings, an all-electric plant providing both heating and cooling can be provided using air-to-water, aka air-source, heat pump/chillers. They are available in two basic types:

- A 4-pipe version (commonly tagged ASHR) that can operate in 1) heating mode as an air-source heat pump, 2) cooling mode as an air-cooled chiller, and 3) simultaneous heating and cooling modes with partial or full heat recovery from the cooling system to the heating system. The ASHRs are piped separately to the hot water or chilled water distribution systems.
- A 2-pipe changeover version (commonly tagged ASHP) that can operate in either heating mode as an air-source heat pump, or cooling mode as an air-cooled chiller. These are piped with changeover piping to connect each ASHP to either the hot water or chilled water distribution systems.

The 4-pipe version is used when there are sufficient periods where both heating and cooling loads occur at the same time so energy can be recovered, but they cost 30 percent more than the 2-pipe version and are 10 to 15 percent less efficient when operating in either cooling mode or heating mode alone.

So a possibility for the Oakland Site would be to eliminate all of the chillers, cooling towers, and boilers and replace them with:

- Two (2) 4-pipe ASHRs, 120 tons and 1.1 MBH each. These units provide energy recovery when outdoor air temperature is between 60°F and 75°F and both mechanical cooling and heating occur simultaneously, and also assist with peak heating and peak cooling loads, and
- Six (6) 2-pipe changeover ASHPs, 160 tons and 1.4 MBH each. These provide the bulk of the heating and cooling loads.

This is likely the least expensive hydronic all-electric option. But it would be highly unlikely to comply with Title 24 Part 6 since the baseline in CBECC for large buildings is an all-variable speed water-cooled chiller plant (i.e., System 6 in the ACM Reference Manual), whereas this option would leverage air cooled chillers (when the ASHPs are in cooling mode). This all-air plant is not efficient enough to meet code for this building so it should not be budgeted. All-air source plants are an option for smaller low-rise buildings for which the baseline Title 24 HVAC system is a packaged air-cooled VAV system (i.e., System 5 in the ACM Reference Manual).

2. Hybrid All-Electric Plant

As noted above, in order to comply with Title 24 Part 6, the water-cooled variable speed chillers would need to be retained for at least most of the system cooling capacity. But it would be energy efficient to take advantage of the heat recovery from simultaneous heating and cooling that will occur during mild weather. So with this option, we have basically the same ASHP plant as Option 1 described above for heating but we retain the water-cooled plant. The difference is that the water-cooled plant can be reduced in size 20 percent due to the on-peak chilled water provided from the two heat recovery chillers.

Add:

- Two (2) 4-pipe Aermec NRP 1800 ASHRs, 120 tons and 1.1 MBH each.
- Six (6) 2-pipe Aermec NRB 2200HA heating-only ASHPs, ~1.4 MBH each.

Each ASHP and ASHR has internal primary pumps.

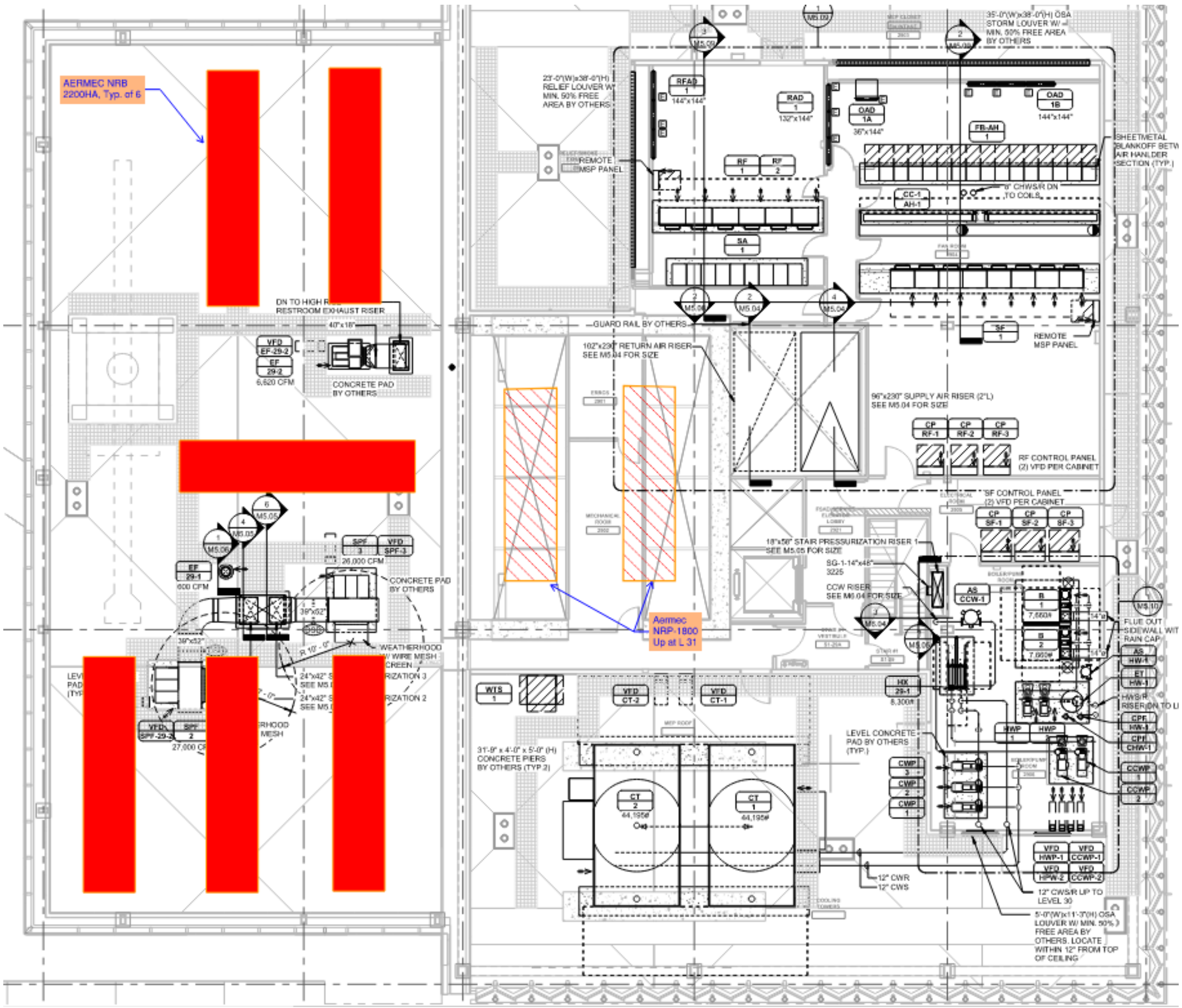
Revise the existing water-cooled plant design:

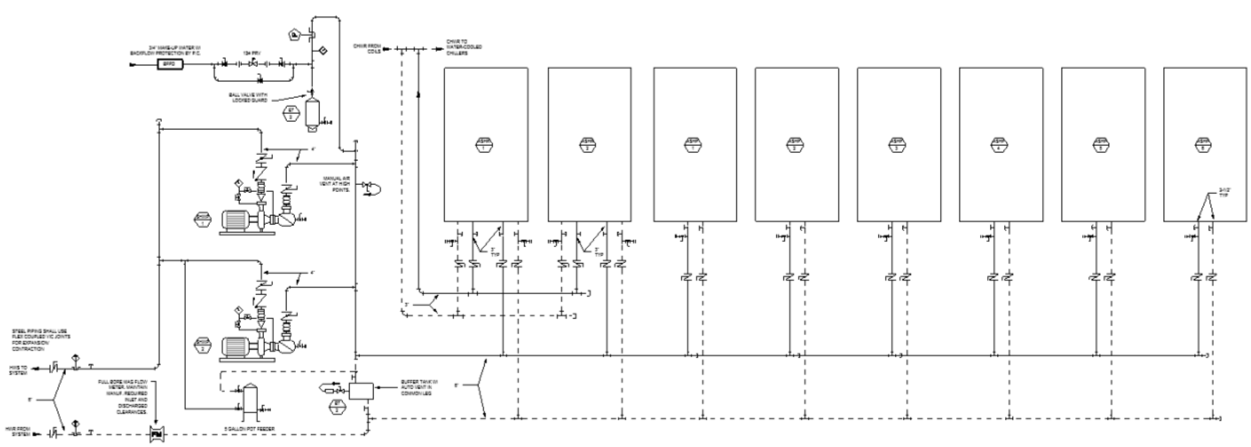
- Reduce chiller size from two at 600 tons to two at 480 tons. CHW pipe sizes remain the same.
- Reduce cooling tower from two at 1650 gpm to two at 1430 gpm. Tower pipe sizes remain the same.
- Reduce chiller CW pumps from two at 1100 gpm to two at 880 gpm. CW pipe sizes remain the same.

The heat recovery chillers are piped in series with the centrifugal chillers on the CHWR side so they can be base-loaded for heat recovery. Chilled water flow rate through the AHU coils and chillers and CHW pumps will stay the same as now shown.

The closed-loop condenser water (CCW) system for tenant and 1st floor WSHPs remains the same.

The roof plan and heat pump piping schematic are shown on the following pages.





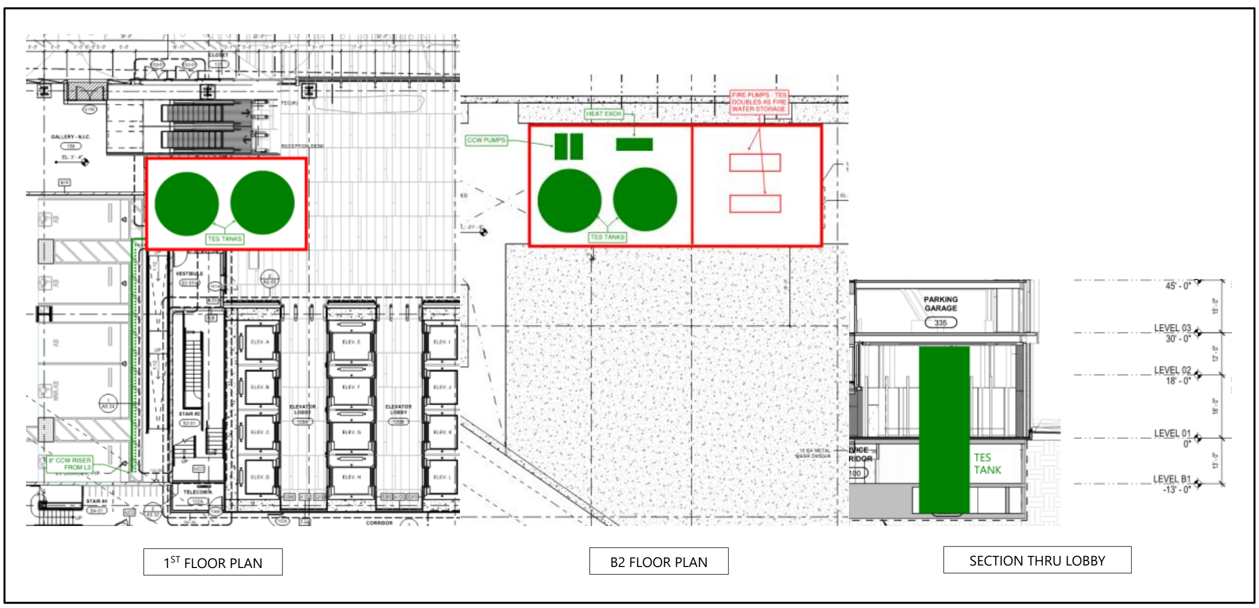
3. TIER Plant

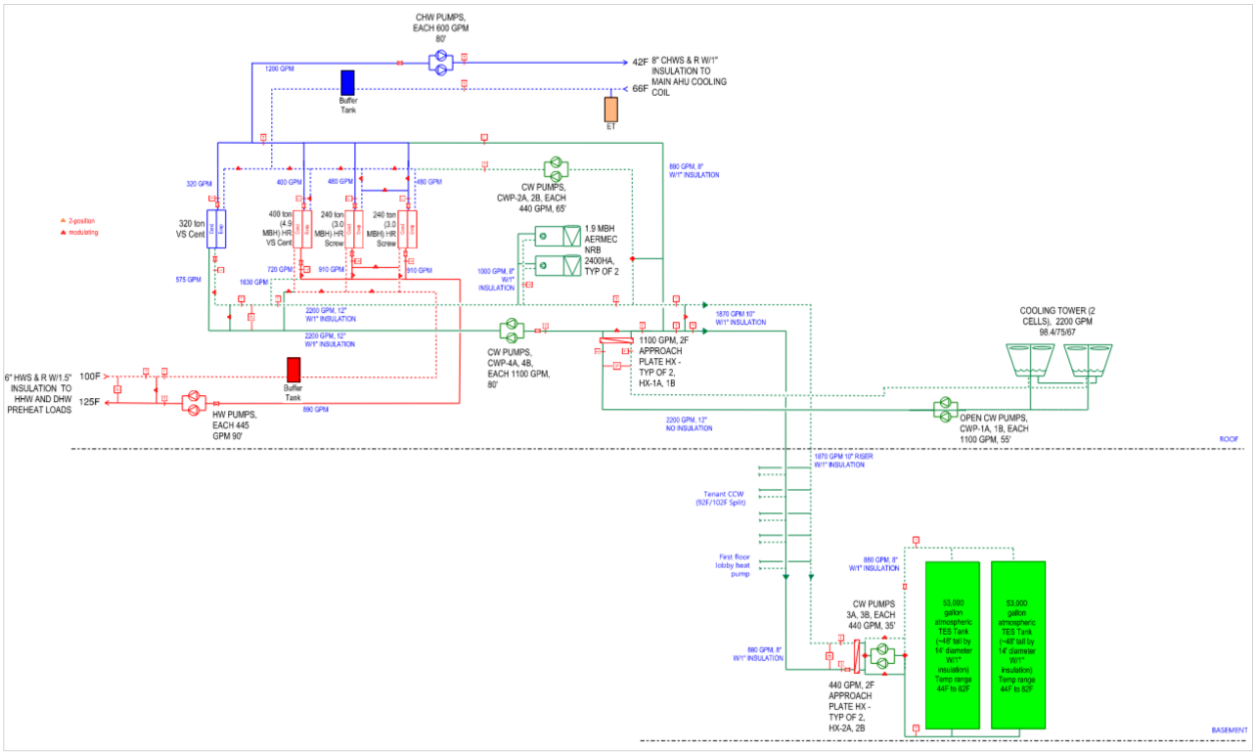
The third option is the Time Independent Energy Recovery plant described in this paper: https://taylorengineers.com/wp-content/uploads/2020/11/2020-12-29-TIER-Plant.pdf.

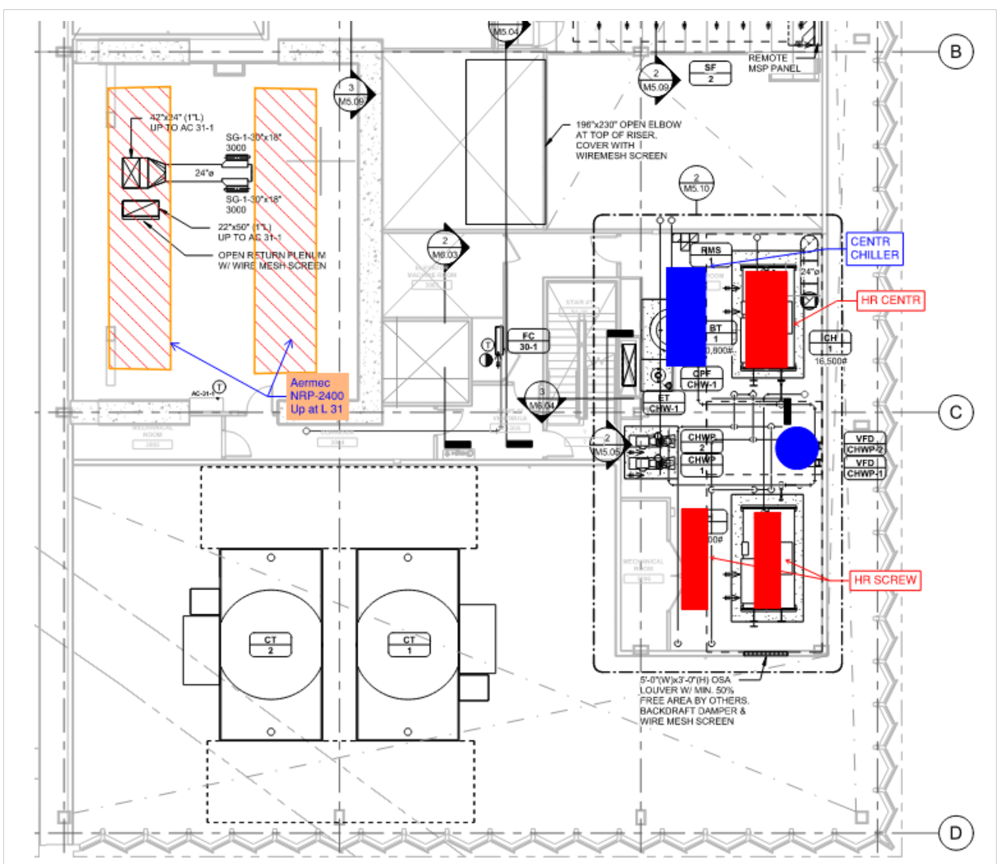
The plant layout along with equipment sizes are described below.

The CCW riser that is currently 8” increases to 10” and requires 1” insulation. CCW taps on each floor for future tenant WSHPs remain the same size but need 1” insulation due to possible cold CCW temperatures that may cause condensation. Future WSHPs will need head pressure control or other design elements to handle these low temperatures. After the tap to the 1st floor heat pump on L3, this riser reduces to 8” (now shown as 3”) and pipes over to the current CCW riser location with taps for future retail WSHPs, then 8” CCW is piped to the TES tanks. See the plans and schematic on the following pages.

The L29 boiler room will include another pair of CW pumps and another plate heat exchanger in lieu of the boilers. The L30 chiller room will be crowded with two additional chillers and needs to be rearranged but should fit – see plans on the following pages. The two ASHPs will be located over the elevator room on L31.




CHW PUMPS, EACH 600 GPM 80'
42F 8" CHWS & R W/1" INSULATION TO MAIN AHU COOLING COIL
66F
Buffer Tank
ET
CW PUMPS, CWP-2A, 2B, EACH 440 GPM, 65'
1.9 MBH AERMEC NRB 2400HA, TYP OF 2
320 ton VS Cent
COOLING TOWER (2 CELLS), 2200 GPM 98.4/75/67
CW PUMPS, CWP-4A, 4B, EACH 1100 GPM, 80'
1100 GPM, 2F APPROACH PLATE HX - TYP OF 2, HX-1A, 1B
6" HWS & R W/1.5" INSULATION TO HHW AND DHW PREHEAT LOADS
100F
125F
HW PUMPS, EACH 445 GPM 90'
OPEN CW PUMPS, CWP-1A, 1B, EACH 1100 GPM, 55'
CW PUMPS 3A, 3B, EACH 440 GPM, 35'
440 GPM, 2F APPROACH PLATE HX - TYP OF 2, HX-2A, 2B


REMOTE MSP PANEL
42"x24" (1"L) UP TO AC 31-1
SG-1-30"x18" 3000
22"x50" (1"L) UP TO AC 31-1
OPEN RETURN PLENUM W/ WIRE MESH SCREEN
196"x230" OPEN ELBOW AT TOP OF RISER, COVER WITH WIREMESH SCREEN
CENTR CHILLER
HR CENTR
HR SCREW
Aermec NRP-2400 Up at L 31
5'-0"(W)x3'-0"(H) OSA LOUVER W/ MIN. 50% FREE AREA BY OTHERS, BACKDRAFT DAMPER & WIRE MESH SCREEN
CT 1
CT 2
B
C
D

L30 PLAN