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2025 California Energy Code

Technical Measure Report

Nonresidential HVAC Heat Pump Baseline Measures

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EXECUTIVE SUMMARY

Introduction

The California Energy Commission (CEC) sponsored this code change proposal for two nonresidential heating, ventilating, and air conditioning (HVAC) heat pump baseline measures. This report proposes specific energy efficiency actions that would result in further reductions of wasteful, uneconomic, inefficient, or unnecessary consumption of energy in the state of California. The code change proposal, or "measure", described in this report is provided for consideration and possible inclusion in the California Energy Code (also known as the Energy Code, or Building Energy Efficiency Standards, or Title 24 Part 6).

Code Change Descriptions

Two code changes are being proposed:

1. For nonresidential alterations, the heat pump rooftop unit (RTU) baseline measure requires that alterations to existing retail and grocery, school, office and financial institution, and library buildings install packaged single zone heat pump RTUs as specified when replacing or adding single zone packaged RTUs with rated cooling capacity less than 65,000 Btu/h. Exceptions are proposed for the following building types and climate zones:
    a. climate zone 16 for all buildings, and
    b. climate zones 1, 2 and 14 for retail and grocery buildings,
    c. climate zones 1, 2 and 14 for office and financial institution buildings,
    d. climate zone 2 for libraries.

   Beyond the performance path, a separate prescriptive option exists for gas furnace RTUs. To enhance flexibility, the analysis incorporates gas furnace RTUs with efficiency upgrades as an alternative compliance approach for mixed-fuel buildings, provided their lifecycle cost savings equal or surpass the savings from replacing the existing single zone packaged RTU with a heat pump RTU (see Section 5.1 for details). An exception to the heat pump requirement is proposed for any building that requires a new main service panel or a service transformer to comply with the heat pump baseline requirement.

2. For nonresidential newly constructed buildings, the multizone heat pump baseline measure proposal requires for prescriptive compliance that multizone systems in office and school buildings install specified equipment:
    a. Offices, financial institutions, and libraries must use one of the following:
        i. A variable refrigerant flow (VRF) heat pump system with a dedicated outside air system (DOAS) with air side heat recovery or energy recovery that meets the outside air ventilation requirements of the zones served by the system.

ii. Air-to-water heat pumps (AWHP) provide heating hot water to a four-pipe fan coil (FPFC) system and are sized to 50 percent of the design heating load. Electric boilers may supplement the AWHPs but they must have a capacity less than or equal to 50 percent of the design heating load. A DOAS with air side heat recovery must be used to meet the outside air requirements of the zones served by the system.

iii. Any system that uses an AWHP that supplies all of the heating for the building with demand control ventilation (DCV) for all zones, and airside heat recovery for all air distribution systems for all zones in the building.

b. Schools must use AWHPs that provide heat to a four-pipe fan coil (FPFC) system. Electric boilers may supplement the AWHPs but they must have a capacity less than or equal to 50 percent of the design heating load. A DOAS with air side heat recovery must be used to meet the outside air requirements of the zones served by the system.

Scope of Work

The nonresidential HVAC heat pump baseline measures will modify the following Energy Code sections, reference appendices and supporting documents listed in Table 1. In the "Regulation Type(s)" column, "M" indicates the proposed measures are mandatory requirements, "Ps" indicates prescriptive requirements, and "Pm" indicates requirements in the performance modeling approach.

Table 1: Code Change Scope of Work

Energy Code Section(s)	Regulation Type(s): M, Ps, or Pm	Reference Appendices	Modeling Tools	Forms	Other Supporting Documents
Section 140.4(a)	Ps + Pm	N/A	CBECC, EnergyPlus	NRCC, LMCC-MCH, LMCC-PRF	Compliance manual + ACM reference manual
Section 141.0(b)2C	Ps + Pm	N/A	CBECC, EnergyPlus	NRCC, LMCC-MCH, LMCC-PRF	Compliance manual + ACM reference manual

Compliance and Enforcement

The proposed measure is straightforward from a compliance and permit standpoint. However, as there would be a shift in design practice and the use of some different HVAC systems, a greater emphasis would be required on commissioning, particularly with verification of control sequences.

Market Assessment

The report provides an assessment of product availability, incremental cost, potential market size, and potential economic and fiscal impacts to the state – including potential impacts on the creation or elimination of jobs in the state. Overall, incorporating heat pumps in building HVAC applications is a mature design practice; widening its adoption with the proposed measures will further increase design and construction practices using heat pumps and create a demand for both product inventory and workforce training. The growth in jobs and businesses will boost the California economy and bring financial benefits. Individual businesses focused only on fuel heating products can be impacted, but the proposal is not expected to affect the entire market adversely. Single-zone heat pump RTUs are a mature product that is commonly available in the marketplace. Smaller single-zone heat pumps have been required since the adoption of the 2022 Energy Code update cycle for new construction, demonstrating that manufacturers can meet increased demand. Manufacturers and retailers have signaled a steadily increasing demand for heat pumps due to policy shifts and market conditions (Global Market Insights, 2023).

Cost-effectiveness

Cost and savings life cycle analysis was performed for heat pump baselines in alterations and for multizone heating systems in newly constructed nonresidential buildings. Heat pump baseline measures were shown to be cost effective in most climate zones for alterations and cost effective in all climate zones for multizone space heating applications in newly constructed buildings.

Requiring that supplemental electric boilers are sized at most to 50 percent of the design load allows the AWHPs to be sized down to 50 percent of the design load, thus saving on cost. This sizing approach was included in the energy and cost-effectiveness analysis.

Statewide Energy Impacts

Table 2 and Table 3 summarize the estimated statewide energy and greenhouse gas (GHG) emissions savings for the first year that the proposed measure is implemented. The tables highlight the first-year energy savings, with a notable total reduction of 389,160 million Btu in source energy and a present value (PV$) savings of $220.14 million in long-term system cost (LSC), emphasizing the immediate and long-term economic and environmental benefits of the measures. While this measure will increase statewide electricity use, it will also reduce natural gas use, which results in net source energy savings and energy cost savings statewide.

Table 2: Estimated Statewide Energy Savings

	First Year Statewide Electricity Savings (GWh)	First Year Statewide Power Demand Reduction (MW)	First Year Statewide Natural Gas Savings (Million Therms)	First Year Statewide LSC Savings (PV Million $)	First Year Statewide Source Energy Savings (Million Btu)
Heat Pump RTU Alterations	(16.5)	(5.8)	2.48	28.70	138,780
Multizone Heating Systems (Newly Constructed Buildings)	4.35	(0.66)	2.73	191.44	250,380
TOTAL	(12.15)	(6.46)	5.21	220.14	389,160

Table 3: Estimated Statewide Greenhouse Gas Emission Savings

	First Year Statewide GHG Emission Savings (MT CO_2e/year)
Heat Pump RTU Alterations	10,361
Multizone Heating Systems (Newly Constructed Buildings)	15,140
TOTAL	**25,501**

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ACRONYMS

Acronym	Definition
ACM	Alternate Calculation Method
AGIC	Avoided Gas Infrastructure Costs
AWHP	Air-to-Water Heat Pump
BCR	Benefit-Cost Ratio
BCZ	Building Climate Zone
BEM	Building Energy Modeling
Btu	British Thermal Units
CBECC	California Building Energy Code Compliance software
CBECC-Res	California Building Energy Code Compliance software for single-family buildings
CEC	California Energy Commission
CO	Carbon Monoxide
CPUC	California Public Utilities Commission
CSS	Commercial Saturation Survey
CZ	California Climate Zone
DCV	Demand Control Ventilation
DOAS	Dedicated Outdoor Air System
EIR	Environmental Impact Report
EUL	Effective Useful Life
FCZ	Forecast Climate Zone
FPFC	Four-Pipe Fan Coil
GHG	Greenhouse Gas

Acronym	Definition
GPM	Gallons Per Minute
GWh	Gigawatt-Hour
HVAC	Heating, Ventilation and Air Conditioning
IEA	International Energy Agency
kBTU	Thousands of British Thermal Units
kWh	Kilowatt-Hour
LSC	Long-term System Cost (30-year $)
MTCO2e	Metric Tons of Carbon Dioxide Equivalent
MW	Megawatt
PLR	Part Load Ratio
PV$	Present Value Dollars
PVAV	Packaged Variable Air Volume
RTU	Roof Top Unit
VAV	Variable Air Volume
VRF	Variable Refrigerant Flow

1. Introduction

This report proposes specific energy efficiency actions that could result in further reductions of wasteful, uneconomic, inefficient, or unnecessary consumption of energy in the state of California. The code change proposal, or "measure", described in this report is provided by the California Energy Commission (CEC) for consideration and possible inclusion in the California Energy Code (also known as the Energy Code, or Building Energy Efficiency Standards, or Title 24 Part 6). This measure will be considered and may be modified as part of a comprehensive regulatory package proposed and adopted by the CEC. The Energy Code must be found to be technically feasible and cost-effective as a whole.

Consistent with California Law (Public Resources Code 25402(b)(3)), an energy efficiency measure is cost-effective if the life-cycle value of the energy savings exceeds the life-cycle cost of the measure. When this occurs the life-cycle Benefit-Cost Ratio (BCR) is 1.0 or greater, when amortized over the economic life of the structure. BCR is calculated by dividing the total dollar energy savings benefit of the measure by the total dollar cost of the measure, over a period of analysis of 30 years.

To calculate benefit, Long-term System Cost (LSC) is used to determine the dollar value of energy efficiency measures in the Energy Code. LSC hourly factors help the state account for long-term benefits associated with policies needed to meet the statewide climate actions goals – such as 100% renewable generation, proliferation of electric transportation, and drastic reductions in fossil fuel combustion occurring in buildings. Today's energy costs do not adequately account for these long-term values to California's energy system. LSC hourly factors weigh the long-term value of each hour differently, where times of peak demand are more valuable, and times of off-peak demand are less valuable. LSC hourly factors are not utility rates or energy rate forecasts. LSC is not a predicted utility bill. These LSC hourly factors are used to convert predicted site energy use – an output common to building energy modeling (BEM) software – to 30-year present value for California's energy system.

Energy savings for proposed measures are estimated using both LSC hourly factors and CEC-established model prototypes. Large sets of survey data are used to create prototypes that act as averaged representations of common building types in California. These prototypes are created for use in BEM software to provide accuracy and consistency amongst energy models that are used to determine energy savings for the state. CEC-developed prototypes and LSC hourly factors are published by the CEC ahead of each code cycle integral to research versions of CEC's reference Energy Code compliance software (CBECC-Res and CBECC). For this reason, CBECC-Res and CBECC are the CEC-recommended BEM software tool when assessing energy savings of proposed measures.

To calculate cost, first costs and ongoing maintenance costs must be assessed for proposed measures and accounted for over a period of analysis of 30 years. In the

BCR, both the benefits and the costs are assessed incrementally, meaning in comparison to the latest adopted version of the Energy Code.

Similar to LSC hourly factors, the CEC develops and publishes conversion factors for source energy, and for GHG Emissions for each code cycle. These three sets of hourly factors are published on CEC's website and formatted to be accessible and usable in combination with broadly available BEM tools.

2. Rooftop Units in Alterations

2.1 Measure Description

The heat pump roof top units (RTU) in alterations baseline measure proposes a change to Section 141.0(b)2C of Title 24 Part 6. As part of the proposed baseline change, existing single-zone RTUs with gas furnaces and direct expansion (DX) cooling systems with rated cooling capacities less than 65,000 Btu/h serving spaces in the following building types must be replaced with heat pump RTUs:

- Retail and grocery
- School
- Office and Financial Institution
- Library

Building owners, engineers, and contractors have multiple paths to compliance with the heat pump requirement. The proposed regulation includes specific alternative options (prescriptive pathways) and exempts buildings needing new main service panels or transformers due to the upgrade. The proposed single-zone RTUs with gas furnace systems have been specified at the minimum equipment efficiency ratings required by the federal appliance efficiency standards with additional measures to achieve the same energy performance as the heat pump RTU.

This measure provides 30-Year Long-Term System Cost (LSC) savings and cost-effectively increases the stringency of the Energy Code. It encourages the installation of efficient heat pumps reducing fossil fuel consumption and supporting California's 2045 carbon neutrality goal. It also contributes to the state's economic and environmental health.

This measure reduces "the wasteful, uneconomic, inefficient, or unnecessary consumption of energy" consistent with Public Resources Code 25402. The measure also has a co-benefit of decarbonizing buildings by reducing source and on-site emissions associated with nonresidential space conditioning systems.

Measure Modifications to Energy Code Documents

This section provides descriptions of how the proposed measure will affect each Energy Code document.

Energy Code Change Summary

Currently, alterations to packaged single zone RTUs are not required to be heat pumps; packaged heat pump RTUs are only required for newly constructed buildings. This measure proposes revising Section 141.0(b)2C to require that alterations in existing retail and grocery, school, office and financial institution and library buildings install packaged single zone heat pump RTUs as specified when replacing or adding single zone packaged RTUs. Exceptions are proposed for the following buildings and climate zones:

1. climate zone 16 for all buildings,
2. climate zones 1, 2 and 14 for retail and grocery,
3. climate zones 1, 2 and 14 for office and financial institution, and
4. climate zone 2 for libraries.

The requirement applies only to RTUs with cooling capacity <65,000 Btu/hr. An alternative prescriptive option is provided for gas furnace RTUs (in addition to the performance path, which is always available) for added flexibility.

Gas furnace RTUs can prescriptively comply by being installed with additional efficiency measures to achieve equal or better LSC than the heat pump RTU baseline. Additional components for installation with gas furnace RTUs are an economizer, economizer with demand control ventilation (DCV), or economizer with variable speed fan controls. These components can be either field installed retrofit options without impacting the manufacturer warranty or factory-assembled options. Specifying these system component options gives contractors and engineers flexibility in adding efficiency measures to gas furnace RTUs with minimum federal appliance standards efficiency. The component options vary based on climate zones and building types and were based on LSC analysis results.

For existing buildings located in climates where the winter design dry bulb temperatures can fall below 35°F, new or replacement heat pump RTUs will likely require adding electric resistance heating or gas heating (in climate zone 16) to maintain thermal comfort when the heat pump heating capacity is largely reduced and during defrost control mode. Depending on the existing building electrical system infrastructure, service and/or distribution panels and feeder upgrades may be required. An exception is proposed for buildings that require a service upgrade that involves a new main service panel or service transformer to comply with the heat pump requirement.

2.1.1.1 Reference Appendices Change Summary

No changes to the Reference Appendices are required for the proposed code measure.

Compliance Manuals Change Summary

The Nonresidential section of the Energy Code Compliance Manual will be revised to include a description of the heat pump RTU alterations requirement, indicating when it applies. The section will describe how either a heat pump RTU or a gas furnace RTU with DX cooling and required efficiency measures can meet the requirement. Additionally, the compliance manual section will explain how variable speed fan controls can be integrated with single-stage units, offering improved efficiency and comfort by adjusting fan speed based on space conditioning needs.

ACM Reference Manuals Change Summary

The Alternative Compliance Method (ACM) Reference Manual will be modified to set the standard design system to be a heat pump when single zone RTUs are added to or replaced on existing buildings. The heat pump RTU requirement would apply to spaces in school, retail and grocery, office and financial institution and library buildings that do not include covered processes in most climate zones. The standard design will match the federal minimum efficiency standards requirements for heat pump RTUs.

Projects that specify single zone furnace RTUs with DX cooling and with appropriate efficiency measures may comply but would be compared against the heat pump RTU standard design in most climate zones. Replacements in school buildings in climate zone 16, office and financial institution buildings in climate zones 1, 2, 14 and 16, retail and grocery buildings in climate zones 1, 2, 14 and 16, and library buildings in climate zones 2 and 16 instead would have a single zone packaged RTU system with a gas furnace and DX cooling as the Standard Design.

Compliance Forms Change Summary

The structure and layout of both the prescriptive (NRCC-MCH-E, LMCC-MCH-E) and performance (NRCC-PRF, LMCC-PRF) certificates of compliance will not need to be modified. The HVAC unit will be documented in the existing HVAC table. The prescriptive form (NRCC-MCH) ruleset will need to be modified to restrict the HVAC system type selection as prescribed by the proposed measure. The structure, layout, and ruleset of the certificate of installation (NRCI-MCH-E) will not need to be modified to accommodate the proposed measure. No certificates of acceptance or verification will need to be modified as there are no new acceptance or HERS requirements associated with the proposed measure.

Measure Context

Comparable Model Code or Standard

Not applicable.

Conflicts with Other Regulations or Certifications

Not applicable.

Compliance and Enforcement

The proposed measure will result in minimal increase to the demands of compliance officials. The primary incremental work will be in reviewing permit applications to verify installed equipment.

2.2 Market and Economic Analysis

For the proposed measure, this section provides an assessment of product availability, incremental cost, potential market size, and potential economic and fiscal impacts to the state, including potential impacts on the creation or elimination of jobs in the state.

For the 2025 code cycle, NORESCO used the IMPLAN model software, along with economic and construction information from published sources, and professional judgement to develop estimates of the economic impacts associated with each of the proposed code changes. IMPLAN estimates jobs created as a function of incoming cash flow in different sectors of the economy, due to revisions to 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, indirect employment, from the requirements for raw materials to the manufacturing plant, and induced employment. Induced employment can be considered as jobs created in the state's economy to increased purchasing power from the jobs added directly. Effectively, 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 and no supply constraints. Due to these assumptions, the model 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 market information. Although measure authors are 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, NORESCO applies conservative assumptions regarding the likely economic benefits associated with the proposed code changes. By following this approach, the economic impacts presented in this report represent a lower-bound estimates of the actual benefits expected with the proposed code changes.

Adoption of these code change proposals would result in modest yet positive economic impacts through the additional direct spending by those in the commercial building industry, architects, energy consultants, and building inspectors.

2.2.1 Market Structure and Availability

All major HVAC manufacturers produce single zone packaged heat pump RTUs in the less than 65,000 Btu/h capacity range. Some of them have units intended as replacement for gas-heating RTUs, which have the same footprint and are designed to work with the existing roof curb. Nationally, there is a trend towards heat pumps in newly constructed building projects, and the market is adapting to meet the demand. One market study (Global Market Insights, 2023) predicted an annual growth rate of 8% for the North American heat pump market over the next decade. It is likely that the increase in required heat pump units in California will increase manufacturing at a healthy pace.

2.2.2 Design and Construction Practices

Construction practice involves removing the existing unit and replacing it with a heat pump packaged RTU. While some manufacturers have heat pump models that can use the existing roof curb, there is a chance that a new roof curb adaptor will need to be installed, which would add to the project cost. However, when replacing with new gas furnace RTUs, roof curb adapters are also common to be included.

Projects in temperate coastal climates will usually not need defrost, but projects in inland valleys and the mountains, where the winter design dry bulb temperatures fall below 35°F, will likely need defrost. Best practice includes supplemental electric resistance heating to be available when the unit is in a defrost mode and when the heat pump heating capacity is reduced. For heating operation, with the exception of climate zone 16, the hours of supplemental heating operation are minimal in nonresidential units, due to the internal loads and that operation is normally limited to the hours of morning warm-up from the night setback.

Adding supplemental electric resistance heaters can require electrical service upgrades to accommodate the new or replacement heat pump units, which can range from utilizing existing panel spare breakers to adding or retrofitting electrical distribution panels or even building service upgrades that involves a transformer, new meter, new feeder and/or main switchboard. For existing buildings that require utility service upgrade with a new utility transformer to comply with the heat pump requirement, an exception has been provided to the heat pump requirement.

2.2.3 Impacts on Market Actors

Because the measure impacts existing buildings, it will not have an impact on builders or developers of newly constructed buildings. Though not currently required, building owners and designers could prepare for future retrofit requirements for heat pump RTUs by providing adequate electrical capacity for future replacements, and a contingency for supplemental electric resistance heating. Contractors, equipment distributors, and retailers will experience a demand increase on skill sets, knowledge, demand on stock volumes, post-install training, and commissioning needs on heat pump RTU replacement. Building officials, building permit inspectors, and certificate technicians, will also require more skillset and knowledge training when inspecting and certifying new heat pump installations. There are no disproportionate impacts on disadvantaged communities.

2.2.4 Impacts on Jobs and Businesses

According to IEA (International Energy Agency, 2022), shortages of qualified installers call for large-scale worker training and incorporating heat pumps into existing certifications for heating technicians. IEA predicts global employment in heat pump supply will triple to over 1.3 million workers by 2030 with 15 percent of the new jobs created in North America. The biggest growth will be in installation jobs followed by maintenance and manufacturing. A similar trend is expected in California. Jobs may shift from manufacturers and distributors focused on gas furnace RTUs exclusively to companies manufacturing and distributing of heat pump RTUs.

The IMPLAN software tool was used to estimate the impacts of the heat pump alterations measure on the commercial construction market. The heat pump alterations measure has a wide impact on existing buildings. With an expected useful life of 15 years, it is assumed that on average 1/15 the existing stock of single rooftop HVAC units will be replaced every year. For applicable building types – small office, retail, school, and library – and the applicable climate zones there are 71.63 million square feet of existing building construction impacted annually in the state. A weighted-average first cost savings of $0.79/ft^2$ was applied. Table 4 shows an estimate of the impact that the central heat pump measure will have on commercial buildings in California. The economic impact analysis calculates the total present value of incremental compliance costs across a span of 30 years. The impacts listed in the tables below pertain to the first year of the standards' implementation.

Table 4: HP Alterations Commercial Construction Economic Impacts

Impact Type	Employment (Jobs Created)	Labor Income	Value Added	Output
Direct Effect	54.6	$4,342,845	$6,538,589	$14,147,518
Indirect Effect	31.8	$2,510,358	$4,309,730	$7,545,133
Induced Effect	28.9	$1,969,348	$3,526,097	$5,612,232
Total Effect	**115.3**	**$8,822,551**	**$14,374,416**	**$27,304,883**

For the impact of building designers and energy consultants, the specification of the heat pump is assumed to have no significant impact. However, for projects wishing to use the alternate gas compliance option, which requires additional measures such as demand control ventilation or variable speed fan control, it is assumed that 20 percent of alterations projects will use the gas compliance option, and that this will incur an extra two hours average design time. Table 5 shows the resulting estimate of economic impact on the market for building designers and energy consultants as a result of this measure.

Table 5: HP Alterations Building Designers / Energy Consultants Economic Impacts

Impact Type	Employment (Jobs Created)	Labor Income	Value Added	Output
Direct Effect	1.9	$213,580	$211,441	$334,203
Indirect Effect	0.8	$63,593	$88,382	$142,277
Induced Effect	1.2	$79,700	$142,726	$227,169
Total Effect	**3.9**	**$356,873**	**$442,549**	**$703,649**

Finally, for building inspectors, an estimated average incremental time required to verify the heat pump installation, including electrical panel details, is one hour. This was applied to the entire project dataset. Projects using the gas compliance option may also require a slight increase in review time. Table 6 shows the effect that the measure is expected to have on building inspectors in the state.

Table 6: HP Alterations Building Inspectors Economic Impacts

Impact Type	Employment (Jobs Created)	Labor Income	Value Added	Output
Direct Effect	1.2	$135,039	$160,140	$194,602
Indirect Effect	0.2	$12,506	$19,478	$33,925
Induced Effect	0.6	$42,474	$76,084	$121,102
Total Effect	**2.0**	**$190,019**	**$255,702**	**$349,628**

2.2.5 Economic and Fiscal Impacts

LSC savings of heat pumps in alterations indicate that over long-term (30-year analysis period), heat pumps will save energy cost to the building owners and avoid the pricing volatility of natural gas. The growth in jobs and businesses will also boost the California economy and bring financial benefits.

2.2.6 Cost of Compliance and Enforcement

The proposed measure is straightforward from a compliance and permit standpoint. However, as there would be a shift in design and construction practice, there will be training needed for successful implementation. The California state government already has budgeted for code development, education, and compliance support. 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 state budgets. The costs to state government are small when compared to the overall costs savings and policy benefits associated with this proposal.

2.3 Energy Savings and Cost-effectiveness

This section provides a summary of energy savings estimates, costs, and overall cost-effectiveness analysis for the proposed measures. Energy savings, costs, and cost effectiveness of proposed measures are assessed incrementally, meaning in comparison to the latest adopted version of the Energy Code. Best available data is used and references to those data sources are provided to clearly substantiate energy savings, costs, and cost effectiveness.

Consistent with California Law (Public Resources Code 25402(b)(3)), an energy efficiency measure is cost-effective if the life-cycle value of the energy savings exceeds the life-cycle cost of the measure. This occurs when the life-cycle Benefit-Cost Ratio (BCR) is 1.0 or greater, when amortized over the economic life of the structure. BCR is calculated by dividing the total dollar energy savings benefit of the measure by the total dollar cost of the measure, over a period of analysis of 30 years.

To calculate benefit, Long-term System Cost (LSC) is used to determine the dollar value of energy efficiency measures in the Energy Code. LSC hourly factors help the state account for long-term benefits associated with policies needed to meet the statewide climate actions goals – such as 100 percent renewable generation, proliferation of electric transportation, and drastic reductions in fossil fuel combustion occurring in buildings. Today's utility rates do not adequately account for these long-term values to California's energy system. LSC hourly factors weigh the long-term value of each hour differently, where times of peak demand are more valuable, and times off-peak demand are less valuable. LSC hourly factors are not utility rates or energy rate forecasts. LSC is not a predicted utility bill.

LSC hourly conversion factors are developed and published by the CEC for each code cycle. These LSC hourly factors are used to convert predicted site energy use – an output common to building energy modeling (BEM) software – to 30-year present value to California's energy system.

Energy cost savings for proposed measures are estimated using LSC hourly factors and are based on CEC-established model prototypes. Large sets of survey data are used to create prototypes that act as averaged representations of common building types in California. These prototypes are created for use in BEM software to provide accuracy and consistency amongst energy models that are used to determine energy savings for the state.

Similar to LSC hourly factors, the CEC develops and publishes conversion factors for Source Energy, and for GHG Emissions for each code cycle. These three sets of hourly factors are published on CEC's website and formatted to be accessible and usable in combination with broadly available BEM tools.

2.3.1 Energy Savings Methodology

CEC-developed prototypes and LSC hourly factors are published by the CEC ahead of each code cycle integral to research versions of CEC's reference Energy Code compliance software (CBECC-Res and CBECC). For this reason, CBECC-Res and CBECC are the CEC-recommended BEM software tool when assessing energy savings of proposed measures.

Replacement of single zone gas furnace RTUs with single zone heat pump RTUs were evaluated for the following four CEC-developed prototypes: Small Office, Medium Retail, Small School and Library buildings. Under the 2022 Energy Code (2022 Title 24) the prescriptive and performance standards baselines for these buildings are single zone gas furnace RTUs with DX cooling. Unit sizes that were evaluated were < 65,000 Btu/h in the prototype models. According to the California Commercial Saturation Survey (CSS) (CPUC, 2014) report, Table 9-3 and Table 9-14, 53 percent of the commercial HVAC units are packaged single zone units, and small units with rated capacity less than 65,000 Btu/h account for 83 percent of HVAC units with DX cooling surveyed.

The existing building stock constructed in the year 2000 was selected for analysis. It is expected that buildings constructed in the year 2000 will show lower LSC savings for this measure compared to older buildings because newer buildings typically include improved efficiency features through renovations and replacements, resulting in reduced heating and cooling load and cost-effectiveness conclusions that can more universally apply to all existing building RTU replacements.

The existing building prototype envelopes are assumed to comply with the 2006 Title 24 prescriptive requirements. With the wide adoption of Light Emitting Diode (LED) technologies, it is expected that the interior lighting has been retrofitted to meet the 2016 Title 24 prescriptive requirement with daylighting controls, where applicable. This expectation is based on CSS (CPUC, 2014) data that surveyed average Lighting Power Density (LPD) for various business types. 2016 Title 24 requirements for LPDs are lower than the 2014 CSS surveyed data but are higher than the newly constructed buildings standard specified by the 2022 Energy Code.

All prototype building models were first created in CBECC 2025 and then modeled in EnergyPlus (version 9.4) with parametric simulations on various energy efficiency measures in all 16 California climate zones.

The heat pump RTUs modeled have supplemental electric resistance heaters except climate zone 16 where dual-fuel heat pumps with supplemental gas furnaces were modeled. Supplemental heaters are used when the heat pump is in defrost mode or when the outdoor air temperatures are low. Climate zone 16 is heating dominated and a large amount of winter heating need is expected to be met by the supplemental heaters, therefore dual-fuel heat pumps are applied to reduce the winter electric heating demand and associated LSC penalty.

To add flexibility, gas furnace RTUs with efficiency improvement measures were also analyzed and become the alternate prescriptive mixed-fuel compliance option if associated LSC savings are equal to or greater than the heat pump RTU replacement (Refer to Section 5.1 for proposed code language). The efficiency measures analyzed are the following:

- Adding economizer control even for units with cooling capacity <54,000 Btuh to utilize free cooling provided by outside air,
- Adding demand-controlled ventilation to reduce RTU cooling and heating needs when outside air condition requires conditioning,
- Reducing supply fan speed during ventilation mode.

2.3.2 Energy Savings Results

Table 7 lists the four prototypes used for the heat pump RTU alteration analysis.

Table 7: Prototype(s) Used for Energy, Cost, and Environmental Analysis

Prototype ID	Occupancy Type (Residential, Retail, Office, etc.)	Floor Area (ft^2)	Number of Stories	Statewide Floor Area (Million ft^2)
Prototype 1	Small Office	5,502	1	228
Prototype 2	Medium Retail	24,563	1	535
Prototype 3	Small School	24,413	1	313
Prototype 4	Library	25,992	1	59

Table 8 through Table 11 below list the LSC savings over a 30-Year period of analysis for each prototype. Supplemental electric resistance heaters were modeled in all climate zones except climate zone 16, where a dual-fuel heat pump was modeled for all prototypes to provide supplemental heating using a gas furnace instead.

Overall results show LSC savings for heat pump RTUs compared to gas furnace RTUs in the majority of the climate zones for the prototypes modeled. Installation of minimum efficiency dual fuel heat pumps in climate zone 16 did not result in an LSC savings for any building type. Installation of heat pump RTUs also did not result in an LSC savings in climate zones 1, 2, and 14 for retail and grocery; in climate zones 2 and 14 for office; and in climate zone 2 for the library building type. Electricity LSC savings (in present value $/sf) for all building types and climate zones are mostly negative, meaning heat pumps consume more electricity and result in a higher electricity LSC compared to gas furnace RTUs. Only in climate zones with small heating needs, such as climate zone 15 for example, the electricity LSC savings become positive because the increase in heat pump heating electricity consumption due to compressor operation is relatively small and is offset by the heat pump fan LSC savings. Note that minimally code-compliant heat pump units have a smaller fan power allowance compared to gas furnace RTUs as specified by Title 24, Part 6 Table 140.4-A, so using a heat pump in place of a unit with a gas furnace will result in fan energy savings. Natural gas cost savings always occur and more than offset the additional electricity LSC costs in most building types and climate zones.

Table 12 through Table 15 below also show Source Energy savings for the measure. Electricity source energy savings are all negative and are always offset by the natural gas source energy savings to result in a net positive source energy savings.

Table 8: Small Office LSC Savings Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity LSC Savings (PV$/sf)	30-Year Natural Gas LSC Savings (PV$/sf)	30-Year Total Energy LSC Savings (PV$/sf)
1	(7.05)	7.20	0.15
2	(3.92)	3.81	(0.11)
3	(2.64)	2.96	0.32
4	(1.99)	2.50	0.51
5	(2.60)	2.82	0.22
6	(0.30)	0.81	0.50
7	(0.01)	0.56	0.55
8	(0.35)	0.85	0.51
9	(0.49)	1.02	0.54
10	(1.06)	1.50	0.44
11	(4.04)	4.30	0.27
12	(3.58)	3.70	0.12
13	(2.83)	3.03	0.20
14	(3.96)	3.93	(0.03)
15	0.03	0.49	0.52
16	(12.17)	9.87	(2.30)

Table 9: Medium Retail LSC Savings Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity LSC Savings (PV$/sf)	30-Year Natural Gas LSC Savings (PV$/sf)	30-Year Total Energy LSC Savings (PV$/sf)
1	(3.39)	3.13	(0.25)
2	(1.77)	1.68	(0.09)
3	(1.30)	1.43	0.13
4	(0.92)	1.16	0.24
5	(1.18)	1.26	0.07
6	(0.14)	0.49	0.35
7	0.07	0.34	0.41
8	(0.13)	0.48	0.35
9	(0.33)	0.66	0.33
10	(0.50)	0.77	0.27
11	(2.20)	2.23	0.03
12	(1.72)	1.73	0.01
13	(1.24)	1.33	0.09
14	(2.17)	2.08	(0.10)
15	0.10	0.30	0.40
16	(5.53)	4.58	(0.95)

Table 10: Small School LSC Savings Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity LSC Savings (PV$/sf)	30-Year Natural Gas LSC Savings (PV$/sf)	30-Year Total Energy LSC Savings (PV$/sf)
1	(9.70)	10.13	0.43
2	(6.50)	6.62	0.12
3	(4.65)	5.14	0.49
4	(3.45)	4.37	0.92
5	(4.20)	4.64	0.44
6	(1.33)	2.03	0.69
7	(0.84)	1.54	0.70
8	(1.21)	1.89	0.68
9	(1.59)	2.50	0.92
10	(1.99)	2.67	0.68
11	(5.85)	6.65	0.80
12	(5.47)	6.09	0.62
13	(4.47)	5.13	0.67
14	(5.29)	5.69	0.40
15	(0.47)	1.03	0.56
16	(13.43)	11.78	(1.65)

Table 11: Library LSC Savings Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity LSC Savings (PV$/sf)	30-Year Natural Gas LSC Savings (PV$/sf)	30-Year Total Energy LSC Savings (PV$/sf)
1	(5.15)	5.30	0.15
2	(3.72)	3.67	(0.05)
3	(2.28)	2.62	0.34
4	(1.80)	2.32	0.52
5	(2.37)	2.65	0.28
6	(0.56)	1.11	0.55
7	(0.19)	0.78	0.59
8	(0.59)	1.16	0.56
9	(0.92)	1.50	0.58
10	(1.13)	1.61	0.48
11	(3.57)	3.86	0.30
12	(3.36)	3.52	0.16
13	(2.60)	2.86	0.25
14	(3.62)	3.62	0.00
15	(0.02)	0.55	0.53
16	(9.52)	7.37	(2.14)

Table 12: Small Office Source Energy Savings Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity Source Savings (kBtu/sf)	30-Year Natural Gas Source Savings (kBtu/sf)	30-Year Total Energy Source Savings (kBtu/sf)
1	(2.83)	11.33	8.51
2	(1.82)	5.71	3.89
3	(1.21)	4.47	3.26
4	(1.05)	3.75	2.70
5	(1.26)	4.29	3.02
6	(0.24)	1.17	0.93
7	(0.12)	0.80	0.68
8	(0.28)	1.23	0.95
9	(0.37)	1.48	1.12
10	(0.61)	2.18	1.56
11	(2.04)	6.36	4.32
12	(1.77)	5.47	3.70
13	(1.43)	4.46	3.03
14	(2.01)	5.71	3.70
15	(0.12)	0.70	0.58
16	(4.83)	14.88	10.05

Table 13: Medium Retail Source Energy Savings Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity Source Savings (kBtu/sf)	30-Year Natural Gas Source Savings (kBtu/sf)	30-Year Total Energy Source Savings (kBtu/sf)
1	(1.32)	4.89	3.58
2	(0.80)	2.53	1.73
3	(0.57)	2.17	1.60
4	(0.47)	1.75	1.28
5	(0.56)	1.92	1.36
6	(0.14)	0.71	0.57
7	(0.07)	0.49	0.42
8	(0.15)	0.69	0.54
9	(0.24)	0.96	0.72
10	(0.31)	1.11	0.81
11	(1.06)	3.31	2.25
12	(0.81)	2.57	1.75
13	(0.62)	1.96	1.34
14	(1.07)	3.04	1.97
15	(0.06)	0.43	0.37
16	(2.17)	6.88	4.71

Table 14: Small School Source Energy Savings Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity Source Savings (kBtu/sf)	30-Year Natural Gas Source Savings (kBtu/sf)	30-Year Total Energy Source Savings (kBtu/sf)
1	(3.38)	16.07	12.69
2	(2.58)	10.09	7.52
3	(1.79)	7.89	6.09
4	(1.57)	6.63	5.07
5	(1.75)	7.20	5.45
6	(0.68)	3.00	2.31
7	(0.49)	2.24	1.75
8	(0.67)	2.76	2.10
9	(0.87)	3.68	2.81
10	(1.00)	3.90	2.90
11	(2.69)	9.89	7.20
12	(2.46)	9.11	6.65
13	(2.03)	7.60	5.56
14	(2.51)	8.36	5.85
15	(0.36)	1.48	1.12
16	(4.87)	17.86	12.99

Table 15: Library Source Energy Savings Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity Source Savings (kBtu/sf)	30-Year Natural Gas Source Savings (kBtu/sf)	30-Year Total Energy Source Savings (kBtu/sf)
1	(2.13)	8.27	6.14
2	(1.71)	5.55	3.84
3	(1.05)	3.96	2.91
4	(0.95)	3.50	2.54
5	(1.16)	4.06	2.91
6	(0.36)	1.63	1.27
7	(0.21)	1.12	0.91
8	(0.40)	1.68	1.28
9	(0.55)	2.19	1.64
10	(0.64)	2.34	1.70
11	(1.82)	5.73	3.91
12	(1.66)	5.23	3.57
13	(1.33)	4.21	2.88
14	(1.85)	5.29	3.44
15	(0.15)	0.80	0.65
16	(3.86)	11.08	7.22

2.3.3 Incremental First Cost

For the heat pump alterations measure, costs were gathered for packaged single zone heat pump RTU with nominal capacity of 3 tons, 4 tons, and 5 tons. Larger-capacity systems that use multiple stages were not in the scope of the analysis. Equipment costs were taken from distributor cost estimates for multiple manufacturers. These costs were compared against recent studies conducted by other contractors for codes and standards research in California. For the distributor costs, an incremental cost was used if the heat pump had a similar make and model gas-heating counterpart.

Table 16: Heat Pump RTU Alterations – Incremental Equipment First Cost

System Size	Gas Furnace RTU Cost	Heat Pump RTU Cost	Incremental Cost
2 ton	$3,600	$3,600	$0
3 ton	$8,000	$6,300	($1,700)
4 ton	$9,000	$7,100	($1,900)
5 ton	$9,800	$7,400	($2,400)

1. Note: Distributor estimate includes economizer for all system sizes, outside air hood for 2 ton unit, and roof curb

A second estimate was obtained from a national distributor of commercial HVAC equipment. The second estimate showed an incremental cost for heat pumps of $100 per ton. However, when the required Low NOx burner was added to the gas furnace RTU system cost, the net incremental cost for the heat pumps was negative $50 per ton. These two cost sources were averaged to derive an incremental cost savings of $221 per ton for the heat pump unit.

For existing buildings located in the inland valleys and the mountains, where the winter design dry bulb temperatures fall below 35°F, new or replacement heat pump RTUs will likely require adding electric resistance heaters to maintain thermal comfort during the defrost cycle and when heat pump heating capacity is reduced at low outdoor air temperatures. Depending on the existing building electrical system infrastructure, adding electric resistance heaters can involve electrical system upgrades ranging from adding a breaker to an existing panel, retrofitting an existing electrical distribution panel, adding a new distribution panel, to utility service upgrade that involves a new main service panel or utility service transformer. The current incremental cost estimate includes scenarios from adding a breaker to retrofitting a building electrical distribution panel ($4,200 - $6,000 for a 100 Amp 277/480V 3-phase panel upgrade).

The heat pump RTUs and gas furnace RTUs have an expected useful life of 15 years (Hiller, 2000); for a 30-year period of analysis one RTU heat pump replacement was assumed at a discounted cost valuation after 15 years. For this analysis, the cost of the replacement heat pump RTU and the cost of a replacement air conditioner with furnace RTU are the same costs as present value costs for new equipment but discounted to reflect the 15-year useful life cycle. CEC staff used a discount rate of

3% applied to both the proposed heat pump RTU and to the gas furnace RTU replacement costs.

2.3.4 Incremental Maintenance Costs

The expected life of equipment is determined from the 2015 ASHRAE Handbook of Fundamentals (American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2015). Maintenance costs for the heat pump over its expected life are expected to be comparable to the gas furnace. The heat pump has additional components of the solenoid reversing valve and electric resistance heat, which require little to no maintenance, and the system has the significant avoided maintenance cost of the gas burners and coils. There may be a slight reduction in maintenance costs for the heat pump due to the avoided cost of cleaning the burners or inspecting the ignition.

Cost Effectiveness

Cost-effectiveness analysis is required to determine the economic impact of proposed measures over a 30-year period of analysis. This analysis must consider and include incremental energy savings for all impacted energy sources (electricity and natural gas), incremental first costs, and incremental maintenance costs over a 30-year period of analysis. Design costs and incremental costs associated with code compliance are not included in this analysis.

For purposes of the California Energy Code, a measure is cost-effective if the life-cycle value of the energy savings exceeds the life-cycle cost of the measure. This occurs when the life-cycle Benefit-Cost Ratio (BCR) is equal to or greater than 1.0. BCR is calculated by dividing the total present value LSC benefits by the total present value incremental measure costs.

Tables below summarize the cost-effectiveness analysis results for four prototypes. Note BCR is labeled "Infinite" if the present value (PV) of the total incremental measure cost is negative, i.e., it is lower than the gas furnace RTU baseline. BCR is labeled as "N/A" if the LSC savings of the heat pump RTUs is less than (a.k.a. no benefit) from the gas furnace RTU.

Table 17: Cost-effectiveness Summary – Small Office

Climate Zone	Benefit: Total Incremental LSC Savings (PV$)	Cost: Total Incremental First Costs and Maintenance Costs (PV$)	Benefit-Cost Ratio (BCR[1])
1	$825	$978	0.8
2	($605)	($1,654)	N/A
3	$1,761	($4,296)	Infinite
4	$2,806	($4,654)	Infinite
5	$1,210	($1,296)	Infinite
6	$2,751	($5,012)	Infinite
7	$3,026	($4,654)	Infinite
8	$2,806	($5,369)	Infinite
9	$2,971	($5,727)	Infinite
10	$2,421	($5,012)	Infinite
11	$1,486	($2,012)	Infinite
12	$660	($1,654)	Infinite
13	$1,100	($2,012)	Infinite
14	($165)	($2,012)	N/A
15	$2,861	($6,085)	Infinite
16	($12,655)	($961)	N/A

Footnotes to Table:

1. BCR is Infinite if the PV of the total incremental first costs and maintenance costs is negative, and BCR is N/A if the PV of the total incremental LSC savings is negative.

Table 18: Cost-effectiveness Summary – Medium Retail

Climate Zone	Benefit: Total Incremental LSC Savings (PV$)	Cost: Total Incremental First Costs and Maintenance Costs (PV$)	Benefit-Cost Ratio (BCR[1])
1	($6,125)	($9,866)	N/A
2	($2,205)	($11,888)	N/A
3	$3,185	($18,614)	Infinite
4	$5,880	($19,688)	Infinite
5	$1,715	($12,130)	Infinite
6	$8,575	($21,478)	Infinite
7	$10,045	($21,836)	Infinite
8	$8,575	($22,552)	Infinite
9	$8,085	($22,552)	Infinite
10	$6,615	($20,762)	Infinite
11	$735	($14,394)	Infinite
12	$245	($12,246)	Infinite
13	$2,205	($13,320)	Infinite
14	($2,450)	($12,962)	N/A
15	$9,800	($23,984)	Infinite
16	($23,520)	($4,065)	N/A

Footnotes to Table:

1. BCR is Infinite if the PV of the total incremental first costs and maintenance costs is negative, and BCR is N/A if the PV of the total incremental LSC savings is negative.

Table 19: Cost-effectiveness Summary – Small School

Climate Zone	Benefit: Total Incremental LSC Savings (PV$)	Cost: Total Incremental First Costs and Maintenance Costs (PV$)	Benefit-Cost Ratio (BCR[1])
1	$9,765	($7,466)	Infinite
2	$2,441	($11,510)	Infinite
3	$12,207	($20,762)	Infinite
4	$21,972	($23,626)	Infinite
5	$9,765	($10,078)	Infinite
6	$17,089	($23,626)	Infinite
7	$17,089	($27,921)	Infinite
8	$17,089	($26,847)	Infinite
9	$21,972	($26,490)	Infinite
10	$17,089	($27,563)	Infinite
11	$19,530	($11,858)	Infinite
12	$14,648	($13,647)	Infinite
13	$17,089	($11,858)	Infinite
14	$9,765	($16,511)	Infinite
15	$14,648	($29,711)	Infinite
16	($39,061)	($4,730)	N/A

Footnotes to Table:

1. BCR is Infinite if the PV of the total incremental first costs and maintenance costs is negative, and BCR is N/A if the PV of the total incremental LSC savings is negative.

Table 20: Cost-effectiveness Summary - Library

Climate Zone	Benefit: Total Incremental LSC Savings (PV$)	Cost: Total Incremental First Costs and Maintenance Costs (PV$)	Benefit-Cost Ratio (BCR[1])
1	$1,950	($4,749)	Infinite
2	($650)	($7,013)	N/A
3	$4,419	($11,097)	Infinite
4	$6,758	($11,813)	Infinite
5	$3,639	($5,939)	Infinite
6	$7,148	($12,171)	Infinite
7	$7,668	($12,171)	Infinite
8	$7,278	($13,961)	Infinite
9	$7,538	($13,961)	Infinite
10	$6,239	($12,887)	Infinite
11	$3,899	($7,603)	Infinite
12	$2,080	($6,529)	Infinite
13	$3,249	($7,603)	Infinite
14	$39	($7,245)	Infinite
15	$6,888	($15,751)	Infinite
16	($27,814)	($2,439)	N/A

Footnotes to Table:

1. BCR is Infinite if the PV of the total incremental first costs and maintenance costs is negative, and BCR is N/A if the PV of the total incremental LSC savings is negative.

3. Multizone Heating Systems in Newly Constructed Buildings

3.1 Measure Description

The proposed change adds a new heat pump baseline prescriptive requirement for multizone heating systems in specific newly constructed nonresidential buildings. New code provisions will be added to Section 140.4(a) of the Title 24 Standards. The proposed heat pump baseline system has been verified to be cost-effective for medium and large office buildings and large school buildings. During the course of analysis, a performance standards complying option utilizing gas boilers and commonly used efficiency measures also was evaluated for each building.

The proposal establishes prescriptive requirements that offices that use multizone systems install either variable refrigerant flow (VRF) systems, or four-pipe fan coil (FPFC) systems served by air-to-water heat pumps (AWHP) for space heating, sized to 50 percent of the design heat capacity with a supplemental electric boiler providing the rest of the design heat capacity. A dedicated outdoor air system (DOAS) with air-side heat recovery provides all of the outdoor ventilation required for the buildings. Alternatively, offices may use an alternate air distribution system provided that heating is supplied entirely by the AWHP system, each zone includes demand-controlled ventilation (DCV) for all zones of the building, and each air distribution system includes air-side heat recovery for all zones served by the system. Schools may only use the FPFC with DOAS and heat recovery.

3.1.1 Measure Modifications to Energy Code Documents

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

Energy Code Change Summary

SECTION 140.4 –

Subsection 140.4(a)3: New section will set the prescriptive requirements for offices and schools which do not match the prerequisites of Subsection 140.4(a)2. Section 140.4(a)3 will require offices to choose between VRF, or an AWHP-based hot water loop that feeds FPFC units for conditioning. Ventilation in both cases will be provided by a DOAS with airside heat recovery. The performance and controls for equipment will be specified. Schools will be required to use FPFC with DOAS and heat recovery for space conditioning.

Reference Appendices Change Summary

Acceptance test procedures may be modified and workshopped during the 45 day rulemaking comment period to include test procedures for AWHP and DOAS systems to ensure that they conform to prescriptive requirements.

Compliance Manuals Change Summary

The Nonresidential Compliance Manual will be modified to include a detailed description of the prescriptive HVAC design for the affected building types. A key component of this section is outlining the integration and impact of thermal storage on the AWHP system. This section will cover sizing methods, control requirements, and relevant considerations. Additionally, the Manual will describe sizing and control requirements for the AWHP system itself, the specification of the electric resistance heater, terminal units, and DOAS system for ventilation.

ACM Reference Manuals Change Summary

Section 5.1 of the ACM Reference Manual would modify the rules for the HVAC system map to trigger the multizone heating systems for offices and schools which do not currently map to single zone heat pump systems. For schools and offices with a chilled water plant, this will be the AWHP with FPFC and DOAS. The standard design will include sizing and control specifications for design hot water supply temperature and temperature difference across terminal units matching the performance specifications that are prescriptively required. For offices without a chilled water plant, it will be the Variable Refrigerant Flow (VRF) system with DOAS. Sections 5.6, 5.7, and 5.8 will also be modified to accommodate performance and specifications to match the prescriptive requirements.

Compliance Forms Change Summary

The structure and layout of the prescriptive (NRCC-MCH-E, LMCC-MCH-E) and performance (NRCC-PRF, LMCC-PRF) certificates of compliance will not need to be modified. The HVAC unit will be documented in the existing HVAC table and DCV and heat recovery will be documented in the existing controls table. The prescriptive forms (NRCC-MCH, LMCC-MCH) ruleset will need to be modified to restrict the HVAC system type selection as prescribed by the proposed measure. The performance ruleset will be modified as described in Appendix D: CBECC Software Specification. The structure, layout, and ruleset of the certificate of installation (NRCI-MCH-E, LMCI-MCH-E) will not need to be modified to accommodate the proposed measure. A new compliance form, NRCAMCH23A, would likely be added to verify installation of the AWHP and may include test procedures to verify that the system can provide heated water at the design supply temperature to zones in heating. No modifications or additions to the NRCVs or LMCVs will be required.

Measure Context

Comparable Model Code or Standard

There are no comparable model codes or standards where AWHPs are required.

Conflicts with Other Regulations or Certifications

There are no conflicts with other regulatory requirements. There are compliance options for multizone-system gas-heating boilers and gas furnaces. Section 0 describes systems utilizing gas space heating boilers that met the LSC and Source Energy targets established by the heat pump baseline systems using the CEC prototypes.

Compliance and Enforcement

A key step in ensuring that the designed system operates according to the specifications is thorough commissioning. While commissioning is already required on nonresidential buildings with conditioned floor area of 10,000 square feet or greater, the AWHP and DOAS system have specific control strategies that must be followed to ensure proper performance. One key component will be a dedicated section outlining the integration and impact of thermal storage on the AWHP system. This section will cover sizing methods, control requirements, and relevant considerations.

3.2 Market and Economic Analysis

For the proposed measure, this section provides an assessment of product availability, incremental cost, potential market size, and potential economic and fiscal impacts to the state – including potential impacts on the creation or elimination of jobs in the state.

The IMPLAN economic forecast software was used to determine market impacts and industry job impacts. Refer to the description in Section 2.2, Market and Economic Analysis, for a description of how this tool was used with construction forecasts and energy and cost data from the measure proposal to determine economic impacts.

Adoption of these code change proposals will result in modest yet positive economic impacts through the additional direct spending by those in the commercial building industry, architects, energy consultants, and building inspectors.

3.2.1 Market Structure and Availability

AWHPs have been used on newly constructed building projects for all-electric or low-greenhouse gas (GHG) emission buildings. The technology is well-suited for hydronic design that utilizes chilled water coils and hot water for heating. There are three major manufacturers of modular AWHP systems, that range in capacity from 20 tons up to over 100 tons. These systems are highly configurable, and can operate in heating mode and cooling mode, and some models have heat recovery capability as well. Larger, non-modular systems are also available, such as the Trane Ascend ACX heat pump. The larger units have less adaptability than the modular units and slightly lower part-load performance, but their cost is considerably lower, at approximately $1,300 per nominal ton, compared to $3,000 per nominal ton for the modular units.

DOAS provide ventilation to the zones in this system design option. These systems are available from multiple manufacturers and have become increasingly popular in newly constructed nonresidential installations, with their use rising from 9 percent to 19 percent of buildings in the last decade (Energy Solutions, Red Car Analytics, 2022). The heat recovery and control options are a standard feature of these systems; moreover, at the airflow (capacities) specified, the systems typically include a variable speed drive, which allows test and balance (TAB) contractors to adjust and verify airflows and ensure good fan performance.

FPFC units are standard products used in nonresidential buildings. While they are less common than variable air volume terminal units (VAV boxes), their operation is well-understood and documented.

3.2.2 Design and Construction Practices

For large office and large school buildings, NORESCO conducted a series of interviews with subject matter experts in the area of heat pump-based multizone HVAC systems. The AWHP system design included the following best practices as gleaned from these interviews:

- System Sizing: the AWHP system must be sized for 50 percent or more of the design heating capacity, with the remaining capacity provided by a supplemental electric resistance boiler. Although the supplemental boiler has a relatively low efficiency (COP=1), the AWHP sized for 50% of the design heating load will typically cover over 90% of operating hours (see Figure 1).
- Design Hot Water Supply Temperature: the AWHP is limited to a maximum design hot water supply temperature of 130°F at winter design conditions. If possible, a heating setpoint of 105°F will provide good efficiency. Generally the system design can achieve an additional 1% efficiency with every degree drop in hot water supply temperature setpoint.
- Freeze Protection: in climates with winter design temperatures close to freezing, a small amount of glycol should be added to the hot water loop.
- Thermal Storage: additional thermal storage using indirect hot water tanks will help address morning warm-up needs when the COP of the heat pump will be at its lowest. The measure proposal uses an indirect buffer tank but does not include additional thermal storage.
- Buffer Tank: AWHP systems require a fluid volume in the hot water loop of 8 to 10 gallons per nominal ton to ensure stability and minimize short-cycling. Depending on the distribution system design, this will usually require some amount of thermal storage.
- Cooling: It is possible to use the AWHP for both heating and cooling. However, for spaces with significant cooling needs, a central chiller will have a much higher efficiency than a AWHP system in cooling mode. The proposed measure requires a two-pipe AWHP that provides heating only.

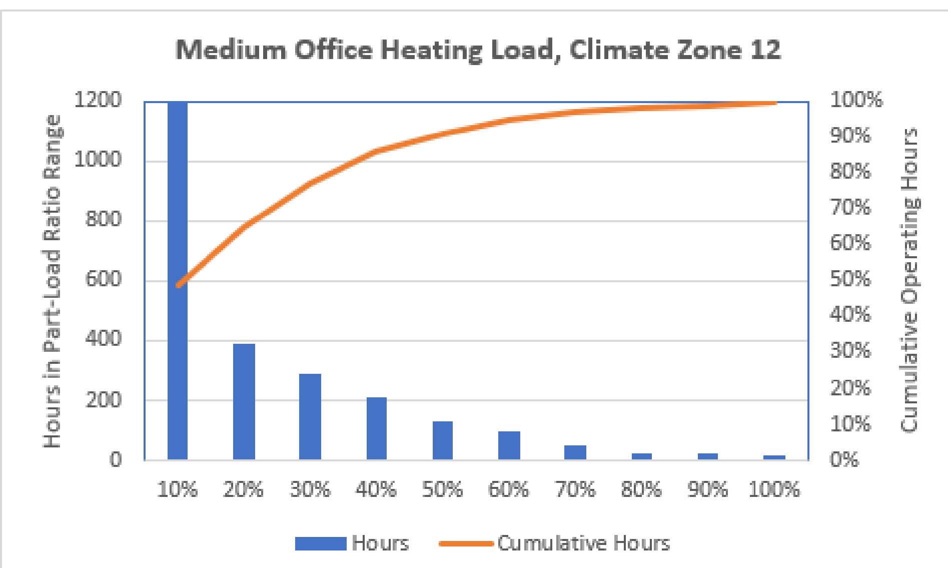

Figure 1: Heating Load Profile of Medium Office Prototype, Climate Zone 12

3.2.3 Impacts on Market Actors

The proposed measure will, in some cases, increase the first cost of the HVAC system by approximately 10%, whereas, in other cases, it may result in no cost increase at all. The measure is expected to have a positive net present value over the measure life. Operating costs are dependent on utility electricity prices.

No impacts are anticipated on disadvantaged communities. This measure impacts large office and large school buildings, and any additional first costs to building construction will not be transferred to building occupants. No changes were recommended to high-rise residential construction for this measure.

There are three manufacturers of modular AWHP systems, and at least two manufacturers of packaged products for nonresidential use. This measure would place market pressure for existing manufacturers to add products to their offerings and to make products available for the U.S. market. Currently, hydronic heat pumps have a sizeable market in Europe and Canada and are gaining traction in the United States (EHPA, 2023). Some manufacturers would be adversely affected, with gas boiler sales likely declining. However, the overall impact depends on policy measures in other jurisdictions. There are a small number of manufacturers of AWHPs that would directly benefit from this measure.

VRF systems have seen increasing demand in commercial applications, due to their relatively high efficiency, small footprint, and low maintenance requirements. Manufacturers include Daikin, Trane/Mitsubishi, Johnson Controls, Lennox and Toshiba/Carrier. Manufacturers will need to transition from R-410A to refrigerants with lower GWP by January 1, 2026 to meet California's environmental requirements. This measure also requires the use of DOAS systems for ventilation. DOAS systems are available from multiple manufacturers; their market penetration in commercial buildings has increased from 9 percent in 2012 to 19 percent in 2019 (Bulger, Dedicated Outdoor Air System Field Assessment Results, 2022). All of the system components included in the measure proposal are readily available from multiple manufacturers.

Distributors who do not currently carry AWHP systems would likely add those systems to their offering, once this measure is adopted. VRF systems are a mature product in the marketplace. Because the proposed measure would likely increase the frequency of VRF systems installations, there would be a greater demand for specialized contractors that install VRF systems.

While designers can use readily available products to comply with the proposed changes, they could benefit from training (such as that provided in the Nonresidential Compliance Manual) on system design details. Controls contractors will need to understand how control sequences work among the AWHP(s), supplemental heat, and dedicated outside air systems. This measure will provide an advantage to contractors who are already experienced installing hydronic systems. Code officials will need to verify system components and sizing, as the AWHP is typically only sized for 50% of the design heating load. Finally, acceptance test technicians would need training to have the skills needed for proper installation and verification of all system components. This measure will likely require documentation of an additional acceptance test for AWHP and its components.

3.2.4 Impacts on Jobs and Businesses

The proposed measure should increase opportunities for buildings to specify AWHP, VRF, and other systems that use electricity for space heating. Nationally, the commercial gas boiler market sales are forecast to increase at a compound annual growth rate of 5.9% over the next decade (Global Market Insights, 2023). This measure would likely dampen sales for gas boilers in the state but should not affect the market adversely.

This measure will likely lead to increased installations of AWHP and VRF units, and increased installation of FPFC and DOAS systems. Companies that manufacture these products will see increased demand over the next few code cycles. There will also be an increase in demand and jobs for design, installation, and training for the required systems. While there will be a gas option that complies with the new code requirements, there will likely be a reduction in statewide sales of gas boilers used for space heating. Distributors who do not adjust their inventory to include specified heat pump products could see their business impacted.

VRF systems usually require specialized contractors for installation. As this measure would result in increased use of VRF systems, businesses who do not provide training or who do not hire contractors with the required skills and experience would be impacted.

The IMPLAN software tool was used to develop estimates of the impact that the new construction measure for central heat pumps in multizone systems with have on the design, construction, and inspection segments of the market.

Inputs to the IMPLAN model include overall construction cost, the floor area of construction applicable to the measure, and the increase in first costs for the project. School construction costs were estimated at $450/sf, and medium office (mid-rise) and large office (high-rise) construction were assumed to be $646/sf and $759/sf, respectively (Statista, 2023). As shown in Table 21, the measure results in a modest increase in employment from the heat pump measure.

Table 21: Multizone Heat Pump Commercial Construction Economic Impacts

Impact Type	Employment	Labor Income	Value Added	Output
Direct Effect	100.6	$7,817,653	$9,034,749	$15,388,059
Indirect Effect	24.6	$2,129,578	$3,341,702	$6,153,963
Induced Effect	41.9	$2,856,317	$5,114,001	$8,139,561
Total Effect	**167.1**	**$12,803,549**	**$17,490,452**	**$29,681,583**

The measure will slightly increase demand on building designers and energy consultants, to handle the increased system complexity. The number of new buildings a year where the requirement will apply is 200 projects (assuming average building area matches prototype areas for medium office, large office and large school). An estimated increase in 100 person-hours of work per project will cover design and controls specification. This estimate is conservative as it does not include additional scope for commissioning new construction projects. Table 22 summarizes the anticipated impact of the multizone heat pump measure on the job market for building designers and energy consultants.

Table 22: Multizone Heat Pump Building Designers / Energy Consultants Economic Impacts

Impact Type	Employment	Labor Income	Value Added	Output
Direct Effect	9.7	$1,067,898	$1,057,206	$1,671,014
Indirect Effect	3.9	$317,967	$441,911	$711,386
Induced Effect	5.8	$398,500	$713,629	$1,135,844
Total Effect	**19.5**	**$1,784,365**	**$2,212,746**	**$3,518,243**

The economic impact to building inspectors, summarized in Table 23, is based on the assumption that each project will add 5 hours of inspection time, to verify that equipment, terminal unit components, and controls have been properly specified. This also allots time to verify that the air-to-water heat pump meets expected efficiency requirements.

Table 23: Multizone Heat Pump Building Inspectors Economic Impacts

Impact Type	Employment	Labor Income	Value Added	Output
Direct Effect	0.2	$26,938	$31,945	$38,819
Indirect Effect	0.0	$2,495	$3,886	$6,767
Induced Effect	0.1	$8,473	$15,177	$24,158
Total Effect	**19.5**	**$37,905**	**$51,008**	**$69,744**

3.2.5 Economic and Fiscal Impacts

The multizone heating system measure is expected to have a positive impact on manufacturers who sell heat pump equipment to the California market. Over time, the number of manufacturers who offer AWHP products in California will likely increase. The measure will also have a small, positive increase in contractors' commissioning work for the California market, given the increased requirements for commissioning system components. The multizone heating measure will shift focus away from sheet metal used for large distribution systems to hydronic piping.

3.2.6 Cost of Compliance and Enforcement

The proposed measure is straightforward from a compliance and permit standpoint. Compliance documentation for electric space heating systems will require specification of all required equipment and key control setpoints. At a minimum, documentation should include the following information for AWHP systems:

1. AWHP make and model, system capacity and rated COP
2. Design hot water supply temperature, and flow rate
3. DOAS make and model, design airflow, heat recovery effectiveness
4. DOAS supply air temperature control
5. FPFC Terminal Unit design airflow, and fan speed control
6. Sizing calculation for thermal storage, to ensure a minimum total hydronic loop volume of 8 gal per ton
7. Supplemental resistance heater rated capacity

VRF systems have been covered by the Title 24-2022 code, but designs should include documentation for:

1. VRF Outdoor Unit make and model, rated heating & cooling capacity, refrigerant charge (refrigerant type, factory charge), efficiency rating.
2. VRF Indoor Unit make and model, capacity, design airflow and fan speed control at three speeds (High/Medium/Low)
3. DOAS make and model, design airflow, heat recovery effectiveness
4. DOAS supply air temperature control

However, as there would be a shift in design practice, and the use of some different HVAC systems, a greater emphasis would be required on commissioning, particularly with verification of control sequences. The sizes of medium and large office buildings and large school buildings tend to be larger than other buildings, while at the same time the number of medium and large office and large school buildings tend to be small. For example, for approximately 40 million square feet of office space, and an average project size of 200,000 square feet, there are 200 new office buildings across all jurisdictions. By a similar approach, there are an estimated 40 to 50 large schools built in the state annually. This should not place significant additional burden on state and local government resources.

Training would leverage available materials from manufacturer guidelines and design elements derived for this proposal. Costs to deliver this training could range from $40,000 to $75,000 per project, depending on the medium of information delivery (brochure, online or in-person training, etc.).

3.3 Energy Savings and Cost-effectiveness

This section provides a summary of energy savings estimates, costs, and overall cost-effectiveness analysis for the proposed measure. Energy savings, costs, and cost effectiveness of proposed measures are assessed incrementally, meaning in comparison to the latest adopted version of the Energy Code. Best available data is used and references to those data sources are provided to substantiate energy savings, costs, and cost effectiveness.

Energy Savings Methodology

The energy savings methodology is described in section 2.3.1.

3.3.1 Energy Savings Results

For this measure, three prototypes were selected to calculate the 30-year present value of energy savings: the CEC's Medium Office, Large Office, and Large School prototypes. These prototypes were selected because they include natural gas boilers, are a high proportion of forecasted construction, and are not subject to significant process requirements (e.g., hospitals, and laboratories).

CBECC 2025.0.4 RV was used to generate the basic models, then EnergyPlus v9.4 was used to further refine the models.

Table 24: Prototype(s) Used for Energy, Cost, and Environmental Analysis

Prototype ID	Occupancy Type (Residential, Retail, Office, etc.)	Floor Area (ft^2)	Number of Stories	Statewide Floor Area (Million ft^2)
Medium Office	Office	53,628	3	13.31
Large Office	Office	498,589	12 (+ basement)	15.47
Large School	School	210,886	2	7.323

The analysis for the measure evaluated several heat pump-based options that would result in LSC and Source energy savings, and be cost effective. The resulting heat pump-based multizone system baselines were presented to stakeholders at two CEC workshops. Feedback from stakeholders resulted in the development of alternate system configurations that would achieve the LSC and source energy savings of the heat pump baselines. These system configurations are presented below:

1. Heat pump baseline.
2. Alternative prescriptive heat pump compliance option.
3. Gas equipment performance path option.

Heat pump baseline

The heat pump baseline compliance option includes system characteristics that result in LSC savings, Source energy savings, and are cost effective following the CEC methodology.

Medium Office Prototype. Under the 2022 Standards the Medium Office prototype currently uses a packaged variable-air-volume system with hot water reheat provided by a natural gas boiler. Cooling is provided by a DX system.

A VRF system combined with a DOAS that includes air-side heat recovery was selected as the proposed heat pump baseline HVAC system. The VRF fans were modeled as 3-speed with an energy consumption of 0.35 W/cfm at design conditions. The DOAS system was modeled with 0.77 W/cfm at design conditions. Air-side heat recovery was modeled at 60% sensible efficiency at 100% flow.

Large Office and Large School Prototypes. The Large Office and Large School prototypes include built-up variable-air-volume systems with chilled water and heating hot water coils at the air-handling unit (AHU) and hot water reheat at the zones. The heating hot water for the AHU and reheat coils is provided by a natural gas boiler. Chilled water is provided by a water-cooled chiller which rejects heat to a cooling tower.

A FPFC system with chilled water and hot water coils combined with a DOAS that includes air-side heat recovery was selected as the proposed heat pump baseline HVAC system. The same central plant as that used in the Large Office prototype was used in the FPFC system, except an AWHP with an electric resistance supplemental boiler was used instead of the natural gas boiler. To approximate the design guidelines from section 3.2.2, both AWHP and electric boiler was sized at 50% of the original prototype's heating design load. The FPFC fans were modeled with 3-speeds with an energy consumption of 0.35 W/cfm at design conditions. The DOAS system was modeled with 0.77 W/cfm at design conditions. Air-side heat recovery was modeled at 60% sensible efficiency at 100% flow.

The 2022 prescriptively compliant models (baseline models) and proposed models were simulated to produce outputs for all annual metrics: electricity consumption, natural gas consumption, weighted peak demand, LSC, Source energy, and GHG emissions.

Proposed heat pump baseline prescriptive compliance option models were compared with 2022 prescriptively compliant models and the resulting savings are presented in Table 25 through Table 30. Alterations were not included in the proposed update as these systems may have space requirements that are not suitable for existing buildings that currently use natural gas boilers.

Table 25: Medium Office Heat Pump Baseline LSC Savings Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity LSC Savings (PV$/sf)	30-Year Natural Gas LSC Savings (PV$/sf)	30-Year Total Energy LSC Savings (PV$/sf)
1	(4.41)	6.85	2.44
2	(1.85)	6.00	4.15
3	(3.76)	3.98	0.22
4	0.91	6.32	7.23
5	(3.57)	4.13	0.56
6	(1.15)	1.96	0.82
7	1.66	2.59	4.25
8	1.88	3.29	5.17
9	2.01	3.83	5.84
10	1.88	3.71	5.59
11	2.96	7.32	10.28
12	0.24	5.82	6.07
13	3.15	5.89	9.04
14	2.33	7.31	9.64
15	8.01	4.96	12.97
16	(3.28)	9.19	5.91

Table 26: Large Office Heat Pump Baseline LSC Savings Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity LSC Savings (PV$/sf)	30-Year Natural Gas LSC Savings (PV$/sf)	30-Year Total Energy LSC Savings (PV$/sf)
1	(1.11)	4.39	3.28
2	0.38	4.99	5.37
3	(2.11)	3.49	1.38
4	1.89	5.48	7.38
5	(2.17)	3.50	1.33
6	0.39	2.25	2.64
7	2.92	3.90	6.82
8	4.59	5.15	9.74
9	4.42	5.52	9.94
10	4.42	5.31	9.73
11	5.10	8.63	13.73
12	2.67	6.54	9.20
13	5.99	7.48	13.47
14	4.13	6.89	11.03
15	10.22	7.93	18.15
16	(0.90)	7.68	6.78

Table 27: Large School Heat Pump Baseline LSC Savings Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity LSC Savings (PV$/sf)	30-Year Natural Gas LSC Savings (PV$/sf)	30-Year Total Energy LSC Savings (PV$/sf)
1	(1.07)	5.82	4.75
2	0.24	4.90	5.13
3	(1.78)	4.36	2.57
4	0.80	4.77	5.57
5	(1.81)	4.11	2.30
6	0.09	2.69	2.77
7	0.45	4.15	4.59
8	1.41	4.64	6.05
9	1.35	4.96	6.31
10	2.10	4.50	6.60
11	2.25	7.30	9.55
12	1.21	6.76	7.97
13	2.04	6.15	8.19
14	2.25	4.83	7.08
15	4.35	4.38	8.73
16	(1.82)	6.71	4.89

Table 28: Medium Office Heat Pump Baseline Source Energy Savings Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity Source Savings (kBtu/sf)	30-Year Natural Gas Source Savings (kBtu/sf)	30-Year Total Energy Source Savings (kBtu/sf)
1	(0.97)	10.80	9.83
2	(0.43)	9.49	9.06
3	(0.80)	6.15	5.35
4	0.04	10.09	10.13
5	(0.77)	6.47	5.70
6	(0.45)	3.11	2.65
7	0.05	4.32	4.37
8	0.21	5.41	5.62
9	0.32	6.28	6.61
10	0.24	6.00	6.24
11	0.54	11.65	12.19
12	(0.00)	9.08	9.08
13	0.70	9.43	10.12
14	0.47	11.44	11.91
15	1.40	8.62	10.02
16	(0.93)	14.06	13.13

Table 29: Large Office Heat Pump Baseline Source Energy Savings Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity Source Savings (kBtu/sf)	30-Year Natural Gas Source Savings (kBtu/sf)	30-Year Total Energy Source Savings (kBtu/sf)
1	(0.03)	6.93	6.90
2	0.13	8.08	8.21
3	(0.42)	5.55	5.13
4	0.19	8.96	9.16
5	(0.48)	5.59	5.11
6	(0.14)	3.65	3.51
7	0.33	6.65	6.98
8	0.79	8.73	9.51
9	0.81	9.34	10.14
10	0.76	8.91	9.67
11	0.97	14.34	15.31
12	0.62	10.64	11.26
13	1.36	12.56	13.93
14	0.72	11.13	11.85
15	1.84	14.07	15.91
16	(0.42)	11.90	11.48

Table 30: Large School Heat Pump Baseline Source Energy Savings Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity Source Savings (kBtu/sf)	30-Year Natural Gas Source Savings (kBtu/sf)	30-Year Total Energy Source Savings (kBtu/sf)
1	(0.05)	9.32	9.28
2	(0.00)	7.81	7.81
3	(0.48)	6.83	6.35
4	(0.05)	7.59	7.54
5	(0.56)	6.53	5.97
6	(0.19)	4.25	4.06
7	(0.13)	6.66	6.53
8	0.02	7.39	7.41
9	0.03	7.91	7.94
10	0.33	7.14	7.47
11	0.44	11.50	11.94
12	0.23	10.64	10.87
13	0.34	9.68	10.02
14	0.37	7.45	7.82
15	0.73	7.13	7.85
16	(0.71)	10.30	9.59

Alternative prescriptive heat pump option

In response to stakeholder comments after presenting the initial analysis and system options at CEC workshops, alternative prescriptive heat pump options were created for the medium office and large office prototypes.

The proposed alternative systems used the same air-distribution systems as the original prototypes, except that an AWHP with an electric resistance supplemental boiler was used instead of the natural gas boiler. Additional measures were added such that LSC and Source savings were at least as high as the heat pump baseline systems. DCV was added to all zones. Air-side heat recovery with 60% sensible efficiency was added to all packaged variable-air-volume (PVAV) and VAV systems. The Medium Office prototype used parallel fan powered boxes in climate zone 16.

Alternative compliance option models need to perform at least as well as the heat pump baseline systems. Therefore, their LSC and Source results were compared with the proposed prescriptive heat pump baseline compliance results. Wherever the alternative compliance option has LSC and Source savings greater than or equal to the proposed prescriptive heat pump baseline, the alternative compliance option can be used for compliance. Alternative compliance option savings relative to the proposed 2025 heat pump baseline are presented in Table 31 through Table 34.

Table 31: Medium Office Alternative Prescriptive Heat Pump Option LSC Savings Relative to the Heat Pump Baseline Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity LSC Savings (PV$/sf)	30-Year Natural Gas LSC Savings (PV$/sf)	30-Year Total Energy LSC Savings (PV$/sf)
1	4.58	0.00	4.58
2	3.26	0.00	3.26
3	4.46	0.00	4.46
4	3.53	0.00	3.53
5	4.17	0.00	4.17
6	2.79	0.00	2.79
7	3.03	0.00	3.03
8	2.90	0.00	2.90
9	3.25	0.00	3.25
10	3.57	0.00	3.57
11	3.33	0.00	3.33
12	3.26	0.00	3.26
13	3.64	0.00	3.64
14	3.41	0.00	3.41
15	4.79	0.00	4.79
16	2.25	0.00	2.25

Table 32: Large Office Alternative Prescriptive Heat Pump Option LSC Savings Relative to the Heat Pump Baseline Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity LSC Savings (PV$/sf)	30-Year Natural Gas LSC Savings (PV$/sf)	30-Year Total Energy LSC Savings (PV$/sf)
1	3.86	0.00	3.86
2	2.16	0.00	2.16
3	3.43	0.00	3.43
4	2.05	0.00	2.05
5	3.21	0.00	3.21
6	1.43	0.00	1.43
7	1.43	0.00	1.43
8	0.80	0.00	0.80
9	1.34	0.00	1.34
10	1.35	0.00	1.35
11	1.78	0.00	1.78
12	1.79	0.00	1.79
13	1.34	0.00	1.34
14	1.64	0.00	1.64
15	1.13	0.00	1.13
16	1.15	0.00	1.15

Table 33: Medium Office Alternative Prescriptive Heat Pump Option Source Energy Savings Relative to the Heat Pump Baseline Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity Source Savings (kBtu/sf)	30-Year Natural Gas Source Savings (kBtu/sf)	30-Year Total Energy Source Savings (kBtu/sf)
1	0.96	0.00	0.96
2	0.86	0.00	0.86
3	1.01	0.00	1.01
4	0.90	0.00	0.90
5	1.04	0.00	1.04
6	0.91	0.00	0.91
7	0.95	0.00	0.95
8	1.01	0.00	1.01
9	1.05	0.00	1.05
10	1.13	0.00	1.13
11	0.69	0.00	0.69
12	0.77	0.00	0.77
13	0.89	0.00	0.89
14	0.74	0.00	0.74
15	1.46	0.00	1.46
16	0.04	0.00	0.04

Table 34: Large Office Alternative Prescriptive Heat Pump Option Source Energy Savings Relative to the Heat Pump Baseline Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity Source Savings (kBtu/sf)	30-Year Natural Gas Source Savings (kBtu/sf)	30-Year Total Energy Source Savings (kBtu/sf)
1	1.04	0.00	1.04
2	0.75	0.00	0.75
3	0.92	0.00	0.92
4	0.79	0.00	0.79
5	0.94	0.00	0.94
6	0.65	0.00	0.65
7	0.63	0.00	0.63
8	0.58	0.00	0.58
9	0.64	0.00	0.64
10	0.67	0.00	0.67
11	0.66	0.00	0.66
12	0.61	0.00	0.61
13	0.52	0.00	0.52
14	0.65	0.00	0.65
15	0.64	0.00	0.64
16	0.28	0.00	0.28

Gas equipment performance path options

The two previous sections (Sections 3.3.1.1 and 3.3.1.2) presented heat-pump based system options designed to be included in the prescriptive path. Numerous possible approaches to compliance could be accomplished using natural gas-only systems. The details of system design and components could be widely varying. Compliance for that range of gas-based systems would need to occur through the performance compliance path.

The following performance compliance approaches were explored:

Medium Office. This compliance option used a similar system as the proposed heat pump baseline system, except the VRF system was replaced with zonal fan coil units that used a split DX system for cooling and hot water for heating coils was supplied by a natural gas boiler.

Efficiency measures were added to meet or exceed the performance of the proposed VRF and DOAS baseline system. The DOAS capacity was increased to accommodate an economizer function. The economizer minimum outdoor air temperature was raised. DCV was applied to all zones. The efficiency of the airside heat recovery was increased and its setpoint was controlled on exhaust air temperature. In climate zone 1, window U-value was decreased, and SHGC was increased. (See Appendix D for values)

Large Office. For the Large Office prototype, the heat pump baseline system was modeled except the AWHP was replaced with a natural gas boiler hot-water plant was used with the FPFC with DOAS systems.

The DOAS capacity was increased to accommodate an economizer function. DCV was applied to all zones. The efficiency of the airside heat recovery in the heat pump baseline was increased. Window U-value was decreased for all climate zones, and high SHGC passive heating was included in climate zones 1, and 16.

Large School. For the Large School prototype, the heat pump baseline system was modeled except the AWHP was replaced with a natural gas boiler hot-water plant to serve the FPFC with DOAS systems.

Variable speed fans were modeled in the FPFC systems. DCV was applied to all zones. The efficiency of the airside heat recovery was increased. Lighting power was reduced for all zones. Window U-value was decreased for all climate zones, and SHGC was increased in climate zones 1 – 5, and 11 – 16.

The gas equipment performance compliance option models were compared with the proposed heat pump baseline models to verify that they achieve greater than or equal to LSC and Source energy savings compared to the heat pump baseline. The savings are presented in Table 36 through Table 40.

Table 35: Medium Office Gas Equipment Performance Compliance Option LSC Savings Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity LSC Savings (PV$/sf)	30-Year Natural Gas LSC Savings (PV$/sf)	30-Year Total Energy LSC Savings (PV$/sf)
1	4.00	(0.82)	3.18
2	4.69	(0.75)	3.94
3	3.66	(0.73)	2.92
4	5.97	(0.80)	5.17
5	3.25	(0.61)	2.64
6	2.44	(0.30)	2.14
7	3.08	(0.22)	2.86
8	3.67	(0.27)	3.41
9	4.24	(0.30)	3.94
10	4.57	(0.31)	4.27
11	7.21	(1.14)	6.07
12	5.42	(0.83)	4.59
13	6.41	(0.64)	5.76
14	7.59	(1.05)	6.54
15	7.70	(0.22)	7.48
16	8.54	(1.88)	6.65

Table 36: Large Office Gas Equipment Performance Compliance Option LSC Savings Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity LSC Savings (PV$/sf)	30-Year Natural Gas LSC Savings (PV$/sf)	30-Year Total Energy LSC Savings (PV$/sf)
1	3.05	(0.53)	2.52
2	2.79	(0.35)	2.44
3	2.31	(0.53)	1.78
4	3.38	(0.40)	2.98
5	2.19	(0.38)	1.82
6	1.62	(0.28)	1.34
7	1.75	(0.26)	1.49
8	1.89	(0.22)	1.67
9	2.06	(0.25)	1.82
10	2.08	(0.25)	1.83
11	3.99	(0.85)	3.14
12	3.02	(0.56)	2.47
13	2.94	(0.39)	2.54
14	4.21	(0.64)	3.57
15	2.78	(0.20)	2.58
16	5.07	(0.93)	4.14

Table 37: Large School Gas Equipment Performance Compliance Option LSC Savings Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity LSC Savings (PV$/sf)	30-Year Natural Gas LSC Savings (PV$/sf)	30-Year Total Energy LSC Savings (PV$/sf)
1	2.44	(0.66)	1.78
2	1.59	(0.41)	1.18
3	0.32	(0.31)	0.01
4	1.72	(0.41)	1.31
5	0.41	(0.29)	0.11
6	0.53	(0.10)	0.43
7	0.53	(0.08)	0.45
8	1.18	(0.17)	1.01
9	1.26	(0.27)	0.99
10	1.26	(0.25)	1.01
11	2.50	(0.86)	1.63
12	1.74	(0.64)	1.09
13	1.51	(0.52)	1.00
14	4.12	(1.11)	3.01
15	1.87	(0.25)	1.61
16	6.61	(1.18)	5.42

Table 38: Medium Office Gas Equipment Performance Compliance Option Source Energy Savings Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity Source Savings (kBtu/sf)	30-Year Natural Gas Source Savings (kBtu/sf)	30-Year Total Energy Source Savings (kBtu/sf)
1	1.57	(1.26)	0.31
2	1.63	(1.15)	0.48
3	1.19	(1.13)	0.06
4	1.78	(1.21)	0.56
5	1.11	(0.94)	0.17
6	0.69	(0.47)	0.22
7	0.76	(0.35)	0.42
8	0.96	(0.41)	0.55
9	1.12	(0.44)	0.67
10	1.18	(0.46)	0.73
11	2.25	(1.69)	0.56
12	1.75	(1.25)	0.50
13	1.83	(0.95)	0.88
14	2.31	(1.54)	0.77
15	1.68	(0.31)	1.37
16	2.89	(2.82)	0.07

Table 39: Large Office Gas Equipment Performance Compliance Option Source Energy Savings Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity Source Savings (kBtu/sf)	30-Year Natural Gas Source Savings (kBtu/sf)	30-Year Total Energy Source Savings (kBtu/sf)
1	1.26	(0.82)	0.43
2	1.09	(0.55)	0.54
3	0.88	(0.87)	0.01
4	1.21	(0.63)	0.58
5	0.86	(0.60)	0.25
6	0.55	(0.43)	0.12
7	0.53	(0.38)	0.15
8	0.57	(0.33)	0.24
9	0.62	(0.37)	0.25
10	0.64	(0.37)	0.28
11	1.49	(1.28)	0.21
12	1.09	(0.86)	0.23
13	0.97	(0.60)	0.38
14	1.62	(0.96)	0.66
15	0.72	(0.29)	0.43
16	2.16	(1.39)	0.77

Table 40: Large School Gas Equipment Performance Compliance Option Source Energy Savings Over 30-Year Period of Analysis

Climate Zone	30-Year Electricity Source Savings (kBtu/sf)	30-Year Natural Gas Source Savings (kBtu/sf)	30-Year Total Energy Source Savings (kBtu/sf)
1	1.25	(0.99)	0.26
2	0.99	(0.61)	0.38
3	0.46	(0.45)	0.01
4	0.97	(0.60)	0.37
5	0.47	(0.44)	0.03
6	0.21	(0.14)	0.07
7	0.19	(0.11)	0.08
8	0.38	(0.24)	0.14
9	0.46	(0.39)	0.07
10	0.42	(0.36)	0.06
11	1.41	(1.27)	0.14
12	1.08	(0.94)	0.13
13	0.91	(0.76)	0.15
14	1.77	(1.61)	0.17
15	0.53	(0.36)	0.16
16	2.83	(1.74)	1.09

3.3.2 Incremental First Cost

The cost methodology developed HVAC system costs from several resources, including direct distributor estimates, design project details, and RS Means Online. Dedicated outside air systems (DOAS) and variable refrigerant flow (VRF) system costs were developed from published research (Bulger, Analysis of Expanded Efficiency Parameters for Very High Efficiency DOAS, 2022). These system costs are both more accurate than RS Means and more applicable to California projects.

The AWHP equipment costs were gathered directly from distributors for two subclasses of equipment. The AWHP system is a two-pipe configuration and comes in a capacity range of 120 to 200 tons. The AWHP costs were generated with standard options and without a desuperheater (heat recovery).

Table 41: Material and Labor Cost Data Source

Cost Component	Value	Material Data Source	Labor Data Sources
Gas Boiler	Varies	Distributor Estimates; RS Means Online regression of cost with capacity	RS Means Online
Air-to-Water Heat Pump	$1280 per ton	Direct Distributor Quote (no superheater, no heat recovery)	RS Means Online
Water-Cooled Chiller	N/A	None – neutral cost	None – neutral cost
Condensate Line	$59.80 per ton	(Red Car Analytics, 2019)	(Red Car Analytics, 2019)
Ductwork	$24.60/ft Material $246.33/ft Labor	Recent CA design projects	Recent CA design projects
VAV Terminal Units	$5,000 each	Recent CA Bay Area large office design projects	Recent CA Bay Area large office design projects
Four-Pipe Fan Coil Units	$16,000 each	Recent CA Bay Area large office design projects	Recent CA Bay Area large office design projects
Hot Water Piping	$16.32/ft Material $40.33/ft Labor	Recent CA Bay Area large office design projects	Recent CA Bay Area large office design projects
Circulation Pump	Varies by HP	RS Means Online	RS Means Online
Supplemental Electric Boiler	$5161.1+$40.06/kW	RS Means Online	RS Means Online
Controls	$2.25/sf (Base; VRF) $2.5/sf (AWHP)	(Jingiuan Dove Feng, 2018) ; assume 11% increase for AWHP project due to increased number of control points, and custom programming (conservative estimate)	(Jingiuan Dove Feng, 2018)
Commissioning	60 hrs @ $160/hr loaded for base; 120 hrs @$160/hr loaded for proposed	Consultant estimates from Cx experience and interviews (conservative)	Consultant estimates from Cx experience and interviews (conservative)
PVAV Unit	Varies by Nominal Ton	RS Means Online	RS Means Online
VRF System	$1620/ton Material $722/ton Labor	(Red Car Analytics, 2019)	(Red Car Analytics, 2019)
VRF Indoor Units	$0.50/sf	(Red Car Analytics, 2019)	(Red Car Analytics, 2019)
DOAS Units	$8.14/cfm Material $1.87/cfm for Labor	(Red Car Analytics, 2019)	(Red Car Analytics, 2019)

System Sizing

System sizes for equipment (boiler, DOAS system, etc.) were taken from the auto-sized capacity requirements by climate zone for each model with the exception of the AWHP with electric resistance boiler, whose sizing is discussed in 3.2.2. Circulation pump sizes are based on the next larger standard motor size for the design flow, with the standard design pump power in W/GPM (gallons per minute) taken from the ACM Reference Manual.

For distribution systems, duct lengths and piping lengths were estimated by specifying a main duct run around the perimeter of each floor (20 to 30’ from the perimeter), and by assuming 30 ft of supply and return ductwork to each zone terminal unit of the Large Office prototype, and 50 ft of supply and return ductwork to each zone of the Large School prototype.

The terminal units were costed out using estimates for the number of thermal zones in the building. The Medium Office, Large Office, and Large School prototype buildings were defined with 30, 120, and 46 zones, respectively. Since the zone size is dependent on design, for the Large Office, a sensitivity analysis was done to determine the effect zoning can have on the system costs. Although four-pipe fan coil units cost more than VAV terminal units, the FPFC distribution system with the AWHP and DOAS delivers a lower life-cycle cost for the Large Office prototype than the VAV-reheat system for most zoning configurations.

In addition to the HVAC equipment, the newly constructed building project will incur costs for controls and for commissioning. The installed cost for the control system for an office building is approximately $2.25/sf (Jingiuan Dove Feng, 2018). It is assumed that the proposed AWHP system with DOAS, fan coil units and supplemental heating will carry a slightly higher cost, due to additional control points and complexity of programming. For the proposed case, the estimated controls cost is $2.50/sf, an incremental cost of $0.25/sf. Interviews with subject matter experts indicated that commissioning costs for the AWHP system design would be higher. This was accounted for by assuming an extra 100 hours of commissioning soft costs for the proposed system.

Incremental Maintenance Costs

The 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 period of analysis of 30 years. The present value of equipment and maintenance costs or savings is calculated using the following equation:

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

Where:
d = the discount rate of 3%
n = the number of periods of 30 years

Effective useful life (EUL) was determined from an ASHRAE publication (ASHRAE Research Project 1237-TRP, n.d.) with a comprehensive list of estimates on component useful life. Annual maintenance costs were developed by determining a labor estimate and a schedule associated with maintenance. The maintenance costs of FPFC units are expected to be significantly higher than the terminal unit in the 2022 base case, the VAV terminal unit. A DOAS may require additional labor to maintain, as it is not quite as common as other systems, and therefore, a conservative (high) estimate was used to determine maintenance costs for this system.

Table 42: Annual Maintenance Costs and EUL

Equipment	Annual Maintenance Cost ($/EA)	EUL (years)
PVAV	$500	20
VRF	$400	20
Boiler	$500	25
AWHP	$300	15
Pump	$50	20
FPFC	$180	20
VAV Terminal Unit	$45	20
DOAS	$1,000	20
Built-up AHU (Note 1)	$250	20

Replacement costs for units occur at the end of their service life, applying a discount rate of 3% following CEC standard procedures. There is no assumed increase or decrease in equipment costs, other than the time-discounting. For the built-up air handling unit, since the entire unit is custom and may not be replaced in its entirety, an estimate of $1.10/cfm of airflow covers replacement of interior components of the system (fan motors, fans, coils).

Commissioning is integral to proper operation of any large HVAC system with many components. This is considered a first cost, with no assumed continuous commissioning.

Maintenance costs were estimated for each major equipment in the design, from estimating labor hours typically required to perform preventive maintenance tasks. FPFC units are expected to require significantly more time for maintenance than VAV terminal units, with the added zonal fan and filter.

For the built-up air handling units, industry estimates for replacement of major components – coils, fans, etc. - were included as the replacement estimate of $1.11 per cfm of supply airflow. For other equipment, replacement costs are the discounted cost of new equipment at the end of its service life.

Cost Effectiveness

Cost-effectiveness analysis is required to determine the economic impact of proposed measures over a 30-year period of analysis. This analysis must consider and include incremental energy savings for all impacted energy sources (electricity and natural gas), incremental first costs, and incremental maintenance costs over a 30-year period of analysis. Design costs and incremental costs associated with code compliance are not included in this analysis.

For purposes of the California Energy Code, a measure is cost-effective when the life-cycle value of the energy savings exceeds the life-cycle cost of the measure. When this occurs the life-cycle Benefit-Cost Ratio (BCR) is equal to or greater than 1.0. BCR is calculated by dividing the total present value cost benefits by the total present value costs.

All proposed prescriptive heat pump baselines were found to be cost effective- in all climate zones. BCR results are presented in Table 43 through Table 45.

Table 43: Medium Office Cost-effectiveness Summary

Climate Zone	Benefit: Total Incremental LSC Savings and Other Savings (PV$/sf)	Cost: Total Incremental First Costs and Maintenance Costs (PV$/sf)	Benefit-Cost Ratio (BCR)
CZ 1	2.44	(1.49)	Infinite
CZ 2	4.15	(0.26)	Infinite
CZ 3	0.22	(0.31)	Infinite
CZ 4	7.23	(0.06)	Infinite
CZ 5	0.56	(0.62)	Infinite
CZ 6	0.82	0.10	8.0
CZ 7	4.25	0.20	21.4
CZ 8	5.17	0.38	13.6
CZ 9	5.84	0.34	17.4
CZ 10	5.59	0.59	9.5
CZ 11	10.28	0.28	36.9
CZ 12	6.07	(0.00)	Infinite
CZ 13	9.04	0.05	197.2
CZ 14	9.64	0.90	10.8
CZ 15	12.97	0.74	17.6
CZ 16	5.91	1.35	4.4

Table 44: Large Office Cost-effectiveness Summary

Climate Zone	Benefit: Total Incremental LSC Savings and Other Savings (PV$/sf)	Cost: Total Incremental First Costs and Maintenance Costs (PV$/sf)	Benefit-Cost Ratio (BCR)
CZ 1	3.28	0.02	203.5
CZ 2	5.37	(0.10)	Infinite
CZ 3	1.38	(0.29)	Infinite
CZ 4	7.38	(0.14)	Infinite
CZ 5	1.33	(0.15)	Infinite
CZ 6	2.64	(0.44)	Infinite
CZ 7	6.82	(0.53)	Infinite
CZ 8	9.74	(0.48)	Infinite
CZ 9	9.94	(0.54)	Infinite
CZ 10	9.73	(0.41)	Infinite
CZ 11	13.73	(0.34)	Infinite
CZ 12	9.20	(0.15)	Infinite
CZ 13	13.47	(0.41)	Infinite
CZ 14	11.03	(0.50)	Infinite
CZ 15	18.15	(0.75)	Infinite
CZ 16	6.78	(0.64)	Infinite

Table 45: Large School Cost-effectiveness Summary

Climate Zone	Benefit: Total Incremental LSC Savings and Other Savings (PV$/sf)	Cost: Total Incremental First Costs and Maintenance Costs (PV$/sf)	Benefit-Cost Ratio (BCR)
CZ 1	4.75	2.30	2.1
CZ 2	5.13	2.22	2.3
CZ 3	2.57	1.86	1.4
CZ 4	5.57	2.14	2.6
CZ 5	2.30	2.06	1.1
CZ 6	2.77	1.44	1.9
CZ 7	4.59	1.42	3.2
CZ 8	6.05	1.69	3.6
CZ 9	6.31	1.54	4.1
CZ 10	6.60	1.64	4.0
CZ 11	9.55	1.87	5.1
CZ 12	7.97	2.05	3.9
CZ 13	8.19	1.80	4.5
CZ 14	7.08	1.80	3.9
CZ 15	8.73	1.19	7.3
CZ 16	4.89	1.64	3.0

4. STATEWIDE IMPACTS

This section provides the first-year statewide savings of the proposed measure. This analysis is to help determine the overall value of the proposed measure to the State of California, and is not used to determine cost effectiveness of the proposed measure. To assist with this analysis a statewide newly constructed buildings forecast was developed by the CEC for 2026, which is presented in more detail in *Appendix A: Statewide Savings Methodology*. The first-year energy impacts represent the first-year annual savings from all buildings forecasted to be completed in 2026.

4.1 Statewide Savings

To assist with this analysis a statewide existing construction database was developed by the CEC for 2026, which is presented in more detail in *Appendix A: Statewide Savings Methodology*. The first year energy impacts represent the -first year- annual savings from both new and existing buildings construction data estimated in 2026.

For the heat pump RTU alteration sub-measure, savings were estimated for the prototypes in corresponding climate zones where the prescriptive requirement applies (refer to section 5 for prescriptive requirement). Additionally, given the life-expectancy (average 15 years) of the RTU equipment, the heat pump RTU alteration is expected to cover 1/15th of the existing building installations. Therefore, only 1/15th of the existing building floor area (for applicable prototypes and climate zones) was used to scale the unit savings to statewide savings.

For the Multizone Heating System sub-measure, the heat pump baseline was used to calculate savings.

Table 46: Estimated Statewide Savings

	First Year Statewide Electricity Savings (GWh)	First Year Statewide Power Demand Reduction (MW)	First Year Statewide Natural Gas Savings (Million Therms)	First Year Statewide LSC Savings (PV Million $)	First Year Statewide Source Energy Savings (Million Btu)
Heat Pump RTU Alterations	(16.5)	(5.8)	2.48	28.70	138,780
Multizone Heating Systems (Newly Constructed Buildings)	4.35	(0.66)	2.73	191.44	250,380
TOTAL	(12.15)	(6.46)	5.21	220.14	389,160

4.2 Statewide Greenhouse Gas Emissions Savings

Statewide greenhouse gas emissions savings are listed below for each measure using hourly GHG emissions factors published by CEC.

Table 47: Estimated Statewide Greenhouse Gas Emissions Savings

	First Year Statewide GHG Emission Savings (MT CO_2e/year)
Heat Pump RTU Alterations	10,361
Multizone Heating Systems (Newly Constructed Buildings)	15,140
TOTAL	**25,501**

4.3 Statewide Water Savings

No on-site water impacts are associated with the proposed measure.

4.4 Other Non-Energy Impacts

Flue gas products vented from the mixed-fuel products contain nitrogen oxides and may contain particulates (PM2.5), sulfur dioxide and carbon dioxide. Large amounts of flue gas vented outdoors can negatively impact local and regional air quality. Nitrogen oxides particularly are chief causes of concern attributing to ground-level ozone, respiratory problems, smog, and global warming etc. In California, South Coast Air Quality Management District (SCAQMD) set forth ultra-low NOx requirements for heating equipment to improve air quality. The adoption of heat pumps for new and replacement installations of rooftop unit will completely eliminate associated NOx emissions. Heat pumps today use refrigerants such as R-410A, which have low toxicity and do not propagate flames but have greenhouse warming potentials greater than 750. To address the problem of global warming, industry is moving towards refrigerants such as R-32 and R-454B, which are classified as A2L refrigerants, with low flammability and low toxicity. Industry has regulations regarding safe refrigerant use, and as the heat pumps are located outdoors, the systems should pose limited risk when installed according to manufacturer guidelines.

The 2022 California Building Code (CBC, 2022) requires carbon monoxide (CO) detection in group I-2, I-4, R occupancies and in classrooms in group E occupancies in newly constructed buildings or alterations when served by fuel burning appliances. Dwelling units, sleeping units and classrooms will require CO monitoring when replacing with new fuel-burning appliances, including outdoor fuel-burning equipment, are installed (Division of State Architects, 2021). In existing buildings, leaky ductwork combined with malfunctioning flues can cause combustion products leaking into the indoor environment. CO build up can cause headaches and dizziness to nausea and unconsciousness depending on the doses and exposure time. The adoption of heat pump baselines for new or replacement rooftop units eliminates associated indoor pollution and health and safety risks. The proposal also reduces risks from indoor pollution associated with combustion emissions from gas boilers in building mechanical rooms.

5. PROPOSED CODE LANGUAGE

This section provides a complete description of language change recommendations for the Title 24 Part 6 on the heat pump measures and summarizes changes to the Reference Appendices, and any other impacted supporting documents.

5.1 Energy Code (Title 24, Part 6)

This section provides a complete description of language change recommendations for the Title 24 Part 6 on the heat pump baseline measures and summarizes changes to the Reference Appendices, and other impacted supporting documents.

The following shows proposed changes to the 2022 Energy Code sections. Underlines (new language) and strikethroughs (deletions) show edits to code language.

SECTION 140.4 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

A building complies with this section by being designed with and having constructed and installed a space-conditioning system that meets the applicable prescriptive requirements of Subsections (a) through (q).

(a) **Sizing, Equipment Selection, and Type.**

1. …

~~**EXCEPTION to Section 140.4(a)2:** Systems utilizing recovered heat for space heating.~~

3. **Multizone Office and School Heat Pump Systems.** Multizone space conditioning systems in office buildings, school buildings, and libraries shall meet the following requirements or shall meet the performance compliance requirements of Section 140.1.

   A. **Office buildings**. Office buildings, financial institutions, and libraries shall use space conditioning systems complying with one of the following requirements.

      i. The space conditioning system shall be a variable refrigerant flow (VRF) heat pump system with a dedicated outdoor air system (DOAS) providing ventilation to all zones served by the space conditioning system. Indoor fans shall meet the requirements of Section 140.4(a)3D. The DOAS shall comply with Section 140.4(a)3E; or

      ii. The space conditioning system shall be four-pipe fan coil (FPFC) terminal units with a DOAS providing ventilation to all zones served by the space conditioning system. The FPFC hot water coils shall be supplied by an air-to-water heat pump (AWHP) space heating hot water loop which complies with Section 140.4(a)3C. The DOAS shall comply with Section 140.4(a)3E; or

iii. The space conditioning system shall utilize heating supplied through a hot water loop served by an AWHP which complies with Section 140.4(a)3C. Ventilation systems shall include DCV in all zones. All air systems shall be equipped with a heat recovery system in compliance with Section 140.4(q). A second stage terminal heating system complying with Section 140.4(a)3F shall be used in climate zone 16.

B. **School buildings**. The space conditioning system shall be FPFC terminal units with a DOAS providing ventilation to all zones served by the space conditioning system. The FPFC hot water coils shall be supplied by an air-to-water heat pump (AWHP) space heating hot water loop served by an AWHP which complies with Section 140.4(a)3C. The DOAS shall comply with Section 140.4(a)3E.

C. **AWHP space-heating hot water loop**. Air-source heat pumps used for space heating hot water shall have a rated heating COP of not less than 3.29 when the outdoor air temperature is 47°F dry-bulb and 43°F wet-bulb, at a leaving water temperature not less than the design supply water temperature of the hot water loop. If chilled water produced by an AWHP is used for space-cooling, it shall only be used when the AWHP is simultaneously supplying space-heating hot water equal to the AWHP's space-heating hot water demand. The loop fluid volume shall not be less than 8 gallons per nominal ton of heating capacity of the loop. Supplemental heating shall be an electric resistance boiler with a capacity not greater than 50% of the design hot water loop heating capacity.

D. **Indoor fans**. Indoor fans shall have an energy consumption at design airflow of not greater than 0.35 W/cfm, shall have no fewer than three speeds, and shall turn off when there is no demand for heating or cooling in the space. At 66 percent air flow the power draw shall be no more than 51 percent of the fan power at full fan speed and shall be at 33 percent air flow the power draw is no more than 12 percent of the fan power at full fan speed.

E. **DOAS**. DOAS shall comply with Section 140.4(p), shall be equipped with a heat recovery system in compliance with Section 140.4(q), and shall have a maximum fan energy consumption at design airflow of 0.77 W/cfm. If heating coils on the DOAS are included, they shall be hydronic heating coils utilizing the AWHP space-heating hot water loop. If cooling coils are included on the DOAS, they shall be hydronic cooling coils utilizing space -cooling chilled water.

EXCEPTION to 140.4(a)3E: If an AWHP space-heating hot water loop is not included in the design, or space-cooling chilled water is not included in the design, DOAS heating and cooling shall be supplied by heat pump coils.

F. **Second Stage Terminal Heating System.** Second Stage Terminal Heating System shall be parallel fan powered boxes, or single zone systems that use only recirculated air from the zone or plenums as supply air when in heating mode. The systems shall use hydronic coils supplied by the AWHP heating hot water loop. Fans shall cycle on only when there is a demand for heating and shall have a fan power not greater than 0.3 W/cfm. Systems providing ventilation air shall be set to their minimum position when there is a demand for heating.

(c) **Fan systems**. Each fan system moving air into, out of or between conditioned spaces or circulating air for the purpose of conditioning air within a space shall meet the requirements of Items 1, 2 and 3 below.

1. Fan power budget. For each fan system that includes at least one fan or fan array with fan electrical input power ≥ 1 kW, fan system electrical input power (Fan $kW_{design,system}$) determined per Section 140.4(c)1(B) at the fan system design airflow shall not exceed Fan kW_{budget} as calculated per Section 140.4(c)1(A).

EXCEPTION to 140.4(c)1: Systems whose fan power is specified in Section 140.4(3).

SECTION 141.0 – ADDITIONS, ALTERATIONS, AND REPAIRS TO EXISTING NONRESIDENTIAL, AND HOTEL/MOTEL BUILDINGS, TO EXISTING OUTDOOR LIGHTING, AND TO INTERNALLY AND EXTERNALLY ILLUMINATED SIGNS

(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 and meet the following:

i. Additional Fan Power Allowances are available when determining the Fan Power Budget (Fan kWbudget) as specified in Table 141.0-D. These values can be added to the Fan Power Allowance values in Tables 140.4-A and Table 140.4-B.

TABLE 141.0-D: ADDITIONAL FAN POWER ALLOWANCES

Airflow	Multizone VAV Systems[1] ≤5,000 cfm	Multizone VAV Systems[1] >5,000 and ≤10,000 cfm	Multizone VAV Systems[1] >10,000 cfm	All Other Fan Systems ≤5,000 cfm	All Other Fan Systems >5,000 and ≤10,000 cfm	All Other Fan Systems >10,000 cfm
Supply Fan System Additional Allowance	0.135	0.114	0.105	0.139	0.12	0.107
Supply Fan System Additional Allowance In	0.033	0.033	0.043	0.000	0.000	0.000
Exhaust/ Relief/ Return/ Transfer Fan System Additional	0.07	0.061	0.054	0.07	0.062	0.055

Airflow	Multizone VAV Systems[1] ≤5,000 cfm	Multizone VAV Systems[1] >5,000 and ≤10,000 cfm	Multizone VAV Systems[1] >10,000 cfm	All Other Fan Systems ≤5,000 cfm	All Other Fan Systems >5,000 and ≤10,000 cfm	All Other Fan Systems >10,000 cfm
Exhaust/ Relief/ Return/ Transfer Fan System Additional Allowance In Unit with	0.016	0.017	0.022	0.000	0.000	0.000

Footnotes to Table 141.0-D:

See FAN SYSTEM, MULTIZONE VARIABLE AIR VOLUME (VAV) in definitions for "Multizone" to be classified as a multizone VAV system.

ii. New or replacement single zone packaged direct expansion (DX) rooftop systems with rated cooling capacity less than 65,000 Btu/hr shall meet the applicable requirements in Table 141.0-E-1 or shall meet the performance compliance requirements of Section 141.0(b)3.

Air conditioners with furnaces complying with Table 141.0-E-1 using variable speed fan and controls shall be designed to vary the indoor fan air flow rate as a function of the load and shall have a minimum of two stages of fan control. The minimum speed at stage 1 shall be set for ventilation only mode and shall be the greater of 50% or the minimum fan speed required to meet the minimum ventilation airflow rate. When the indoor fan is operating at 50% speed, it shall draw no more than 30% of the power at full fan speed.

iii. Systems are required to follow Section 140.4(e) with the exception:

1. SZAC1, 2, 3 and SZHP1 in Table 141.0-E-1 with rated cooling capacity less than 65,000 Btu/hr are required to have an economizer, and
2. All other single packaged air-cooled unitary air conditioners and heat pumps with rated cooling capacity equal to or greater than 54,000 Btu/hr are required to have an economizer.

Table 141.0-E-1 – NEW OR REPLACEMENT SINGLE ZONE AIR CONDITIONER OR HEAT PUMP REQUIREMENT

Building Area Type	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Retail and grocery	NR	NR	SZHP or SZAC 1	SZHP or SZAC 1	SZHP or SZAC 1	SZHP or SZAC 1	SZHP or SZAC 1	SZHP or SZAC 1	SZHP or SZAC 1	SZHP or SZAC 1	SZHP or SZAC 1	SZHP or SZAC 1	SZHP or SZAC 1	NR	SZHP or SZAC 3	NR
School	SZHP or SZAC 2	SZHP or SZAC 2	SZHP or SZAC 2	SZHP or SZAC 2	SZHP or SZAC 1	SZHP or SZAC 1	SZHP or SZAC 2	SZHP or SZAC 1	SZHP or SZAC 2	SZHP or SZAC 2	SZHP or SZAC 2	SZHP or SZAC 2	SZHP or SZAC 2	SZHP or SZAC 2	SZHP or SZAC 2	NR
Office, financial institution	NR	NR	SZHP or SZAC 1	SZHP or SZAC 1	SZHP or SZAC 1	SZHP or SZAC 1	SZHP or SZAC 1	SZHP or SZAC 1	SZHP or SZAC 1	SZHP or SZAC 1	SZHP or SZAC 2	SZHP or SZAC 1	SZHP or SZAC 1	NR	SZHP or SZAC 2	NR
Library	SZHP or SZAC 1	NR	SZHP or SZAC 1	SZHP or SZAC 1	SZHP or SZAC 1	SZHP or SZAC 1	SZHP or SZAC 1	SZHP or SZAC 2	SZHP or SZAC 2	SZHP or SZAC 2	SZHP or SZAC 2	SZHP or SZAC 2	SZHP or SZAC 2	SZHP or SZAC 2	SZHP or SZAC 2	NR

Footnotes to Table 141.0-E01

- SZHP – Single Zone Heat Pump
- SZAC – Single Zone Air Conditioner with furnace
- SZAC1 – Single Zone Air Conditioner with furnace + Economizer
- SZAC2 – Single Zone Air Conditioner with furnace + Economizer + Demand Controlled Ventilation
- SZAC3 – Single Zone Air Conditioner with furnace + Economizer + Variable Frequency Drive
- NR – No Requirement

Exception 1 to Section 141.0(b)2C: Section 140.4(a)2 shall not apply to new or replacement space conditioning systems or components. Section 140.4(a)3 shall not apply to new or replacement space conditioning systems or components.

Exception 2 to Section 141.0(b)2C: Subsection (b)2C does not apply to replacement of electric reheat of equivalent or lower capacity electric resistance space heaters, when natural gas is not available.

Exception 3 to Section 141.0(b)2C: Section 140.4(n) is not applicable to ~~new or replacement space conditioning systems.~~ existing operable wall or roof openings without interlock controls.

Exception 4 to Section 141.0(b)2Cii: ~~Section 140.4(e) is applicable to systems, other than single package air-cooled commercial unitary air conditioners and heat pumps, with cooling capacity less than 54,000 Btu/h~~. Section 141.0(b)2Cii is not applicable if the alteration exceeds the existing main service panel or service transformer capacity. An electrical load calculation shall be submitted by a registered professional engineer in accordance with Article 220 of California Electrical Code.

5.2 Reference Appendices

There are no proposed changes to the Reference Appendices. The prescriptive requirements are fully defined in the Standards language revisions, and the performance approach is defined in proposed revisions to the ACM Reference Manual.

5.3 Compliance Manuals

For the Compliance Manual, the Nonresidential sections will be revised with a description of the heat pump change, and examples of how a heat pump alteration can meet the requirements, and an example of how a rooftop DX unit with gas heating can comply with appropriate efficiency measures. The edits will also discuss when supplemental heating is required for defrost.

The edits will also provide a description of complying AWHP systems in newly constructed buildings using the proposed prescriptive systems. Language will be developed when the measure has been marked for inclusion in the 2025 Standards after Rulemaking proceedings.

5.4 ACM Reference Manual

The following revisions will implement the changes to the baseline system for heat pump alterations and for applicable building types with multizone space heating. The change also includes new performance curves for the AWHP, documented in the ACM Appendix and CBECC compliance software.

5.1.3 HVAC System Map

ACM Reference Manual Table 3: System Descriptions

System Type	Description	Detail
System 1 – RAC	Residential air conditioner	Single-phase single zone system with constant volume fan, no economizer, direct expansion cooling, and gas furnace heating.
System 2 – RESERVED		
System 3a – SZAC	Packaged single zone air conditioner	Single-phase single zone system with constant-volume fan, direct expansion cooling, and gas furnace heating.
System 3b – SZHP	Packaged single zone heat pump	Single-phase single zone system with constant-volume fan, direct expansion heat pump cooling and heating, and electric resistance supplemental heating.
System 3c – SZDFHP	Packaged single zone dual-fuel heat pump	Single zone system with constant-volume fan, direct expansion heat pump cooling and heating, and gas supplemental heating.
System 4 – Reserved		
System 5 – PVAV	Packaged VAV	Multizone packaged system with variable-volume fan, direct expansion cooling, gas furnace heating, and hot water reheat terminal units served by a central gas boiler.
System 6 – VAV	Built-up VAV	Multizone 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 7a – SZVAVAC	Packaged single zone variable-air-	Single zone system with variable-air-volume fan, direct expansion variable speed drive

System Type	Description	Detail
	volume air conditioner	cooling, and gas furnace heating. Minimum fan speed ratio of 0.2 for laboratory spaces and 0.5 for all other spaces. Integrated economizer for standard design cooling capacities ≥ 33 kBtu/h.
System 7b – SZVAVHP	Packaged single zone variable-air-volume heat pump	Single zone system with variable-air-volume fan, direct expansion heat pump cooling and heating, and electric resistance supplemental heating.
System 7c – SZVAVDFHP	Packaged single zone variable-air-volume dual-fuel heat pump	Single zone system with variable-air volume fan, direct expansion heat pump cooling and heating, and gas supplemental heating.
System 8 – RESERVED		
System 9 – HEATVENT	Heating and ventilation only	Single zone system with a constant volume fan and gas furnace heating.
System 10 – CRAH	Computer room air handler	Single zone built-up system with variable-volume fan, chilled water cooling provided by a central water-cooled chiller and cooling tower, and no heating.
System 11 – CRAC	Computer room air conditioner	Single zone packaged system with variable volume fan, direct expansion cooling, and no heating
System 12 – Reserved		
System 13a – BKITCHMAU	Built-up kitchen	Built-up single zone makeup air unit with dedicated exhaust

System Type	Description	Detail
	makeup air unit	fan, chilled water cooling, and hot water heating.
System 13b – PKITCHMAU	Packaged kitchen makeup air unit	Packaged single zone makeup air unit with dedicated exhaust fan, direct expansion cooling, and gas furnace heating.
System 14 – AWHP+FPFC+DOAS	Air-to-water heat pump with four pipe fan coil units and DOAS	Zonal four pipe fan coil units with three speed fans and DOAS with heat recovery providing ventilation. Chilled water cooling provided by a central water-cooled chiller and cooling tower, and space heating hot water provided by a non-modular AWHP with supplemental electric resistance boiler.
System 15 – VRF+DOAS	VRF system with DOAS	Zonal VRF units with three speed fans and DOAS with heat recovery providing ventilation.

5.6.5 Variable Refrigerant Flow (VRF) Zone Systems (Indoor Units)

INDOOR UNIT TYPE

Applicability: VRF.

Definition: Ducted or Unducted.

Units: List – Ducted, Unducted.

Input Restrictions: None.

Standard Design: For healthcare facilities, same as the Proposed Design. For System 15, Ducted. For all other cases, not applicable.

DESIGN SUPPLY AIR TEMPERATURE (COOLING)

Applicability: VRF.

Definition: Design SAT in cooling for the zone.

Units: Deg F.

Input Restrictions: As Designed.

Standard Design: For healthcare facilities, same as the Proposed Design. For System 15, 55°F. For all other cases, not applicable.

DESIGN SUPPLY AIR TEMPERATURE (HEATING)

Applicability: VRF.

Definition: Design SAT in heating for the zone.

Units: Deg F.

Input Restrictions: As Designed.

Standard Design: For healthcare facilities, same as the Proposed Design. <u>For System 15, 95°F.</u> For all other cases, not applicable.

NET COOLING CAPACITY

Applicability: VRF.

Definition: Net cooling capacity of the zone system (one system if count>1), which includes all cooling to the zone but excludes any fan motor heat.

Units: Btu/h.

Input Restrictions: None.

Standard Design: For healthcare facilities, same as the Proposed Design with adjustment to account for Standard Design fan heat. <u>For System 15, auto-sized by compliance software.</u> For all other cases, not applicable.

NET HEATING CAPACITY

Applicability: VRF.

Definition: Net heating capacity of the zone system (one system if count>1), which includes all cooling to the zone but excludes any fan motor heat.

Units: Btu/h.

Input Restrictions: None.

Standard Design: For healthcare facilities, same as the Proposed Design with adjustment to account for Standard Design fan heat. <u>For System 15, auto-sized by compliance software.</u> For all other cases, not applicable.

SUPPLY FAN CAPACITY FOR COOLING

Applicability: VRF.

Definition: The supply fan flow rate when the zone requires cooling.

Units: cfm (for each mode).

Input Restrictions: Not applicable. The cooling airflow is set to be the same as the system design airflow.

Standard Design: For healthcare facilities, same as the Proposed Design. <u>For System 15, auto-sized by compliance software.</u> For all other cases, not applicable.

SUPPLY FAN CAPACITY FOR HEATING

Applicability: VRF.

Definition: The supply fan flow rate when the zone requires heating.

Units: cfm (for each mode).

Input Restrictions: Not applicable. The heating airflow is set to be the same as the system design airflow.

Standard Design: For healthcare facilities, same as the Proposed Design. For System 15, auto-sized by compliance software. For all other cases, not applicable.

SUPPLY FAN CAPACITY FOR DEADBAND

Applicability: VRF.

Definition: Identify the supply fan airflow rate in deadband (floating) mode.

Units: cfm (for each mode).

Input Restrictions:

If the fan control is set to Continuous:

If a multi-speed or variable speed fan is defined for the VRF fan coil, this will be set to the minimum fan flow. Otherwise, it is set to the design airflow.

If the fan control is set to Cycling: 0 cfm.

Standard Design: For healthcare facilities, same as the Proposed Design. For System 15, 0 cfm. For all other cases, not applicable.

SUPPLY TEMP CONTROL

Applicability: VRF.

Definition: The method of controlling the system supply air temperature.

Units: List (Constant, reset by outside air, reset by demand).

Input Restrictions: No Supply Air Temperature Control.

Standard Design: ~~Not applicable.~~ For System 15, No Supply Air Temperature Control.

AUXILIARY POWER WHEN ON

Applicability: VRF.

Definition: The parasitic electrical energy use of the zone terminal unit when either terminal unit coil is operating.

Units: Watts or Btu/h.

Input Restrictions: None.

Standard Design: For healthcare facilities, same as the Proposed Design. For System 15, 0 Btu/h. For all other cases, not applicable.

Auxiliary Power When Off

Applicability: VRF.

Definition: The parasitic electrical energy use of the zone terminal unit when the terminal unit coils are off.

Units: Watts or Btu/h.

Input Restrictions: None.

Standard Design: For healthcare facilities, same as the Proposed Design. For System 15, 0 Btu/h. For all other cases, not applicable.

Supply Fan Airflow Capacity Control

Applicability: VRF.

Definition: The supply fan airflow shall be capable of specifying one (constant volume), two-, three-, or variable speed control and power relationships for each fan unit.

Units: List: Subset of fan capacity control options: constant volume, two speed, three-speed, and variable speed.

Input Restrictions: As designed. Minimum airflow capacity to be no less than 50% flow.

Standard Design: For healthcare facilities, same as the Proposed Design. For System 14 and 15 indoor fans, three-speed, cycling. For all other cases, not applicable.

5.7.2 System Controls

Air Handler Fan Cycling

Applicability: All fan systems.

Definition: This building descriptor indicates whether the system supply fan operates continuously or cycles with building loads when the HVAC schedule indicates the building is occupied. (See night cycle control input for fan operation during unoccupied hours.) The fan systems in most commercial buildings operate continuously.

Units: List continuous or cycles with loads.

Input Restrictions: As designed if the HVAC system serves zones with a dedicated outside air source for ventilation; otherwise, continuous.

Standard Design: For healthcare facilities, same as the Proposed Design. For ~~all others~~ System 1, 14, and 15, cycles with loads ~~for hotel/motel guestroom systems~~; continuous for all other standard design system types.

5.7.3 Fan and Duct Systems

Fan Control Method

Applicability: All fan systems with supply or relief fans or both.

Definition: A description of how the supply (and return/relief) fan(s) are controlled.

The options include:

Constant volume
Variable-flow, inlet, or discharge dampers
Variable-flow, inlet guide vanes
Variable-flow, variable speed drive (VSD)
Variable-flow, variable pitch blades
Two-speed
Three-speed

For variable speed fans, the fan control method determines which part-load performance curve to use.

Units: List (see above).

Input Restrictions: As designed. The user shall not be able to select VSD with static pressure reset if the building does not have DDC controls to the zone level.

Standard Design: For healthcare facilities, same as the Proposed Design. Based on the prescribed system type. Refer to the HVAC System Map in 5.1.2.

FAN POWER INDEX

Applicability: Fan systems that use the power-per-unit-flow method.

Definition: The fan power (at the motor) per unit of flow.

Units: W/cfm.

Input Restrictions: As designed or specified in the manufacturers' literature.

Standard Design: For healthcare facilities with total system fan power greater than or equal to 1 kW and the system is not DOAS, power-per-unit-flow allowance based on the components in the proposed system according to 140.4(c)1 of the Energy Code.. For healthcare facilities with DOAS and total system fan power less than 1 kW, 1.0 W/CFM. For all others health care facilities, same as Proposed Design.

For all other buildings:

System 1 – RAC (Residential Air Conditioner) : 0.45 W/CFM

System 10 – CRAC and System 11 – CRAH systems: 0.58 W/CFM.

System 14 – AWHP+FPFC+DOAS and System 15 – VRF+DOAS:

Indoor unit fans: 0.35 W/cfm

DOAS supply fan: 0.626 W/cfm

DOAS return fan: 0.144 W/cfm

Other systems: The fan electrical power input of the standard design will be based on which components are present in the given HVAC system type, and what the prescriptive fan power budget allows for each airflow range.

The standard design fan input electrical power will be determined by the system type and airflow range described in the table below:

Table 48: Total System Fan Power Allowance, in W/cfm by System Type

System No.	≤ 5,000 cfm	> 5,000 cfm; ≤ 10,000 cfm	> 10,000 cfm
3a – SZAC	0.802	0.780	0.748
3b – SZHP (no furnace)	0.744	0.720	0.676
3c – SZDFHP (with furnace)	0.802	0.780	0.748
7a – SZVAVAC	0.802	0.780	0.748
7b – SZVAVHP	0.744	0.720	0.676
7c – SZVAVDFHP (with furnace)	0.802	0.780	0.748
5 – PVAV	1.000	1.022	0.964
6 – VAV	0.977	1.013	0.947
9 – HEATVENT	0.616	0.620	0.605

Source: California Energy Commission

Standard Design: Existing Buildings: Same as proposed if existing and unaltered; otherwise use newly constructed buildings values with the following additional credits (includes supply and return/relief/exhaust):

Table 49: Additional System Fan Power Allowance, in W/cfm by System Type

System No.	≤ 5,000 cfm	> 5,000 cfm; ≤ 10,000 cfm	> 10,000 cfm
MZ-VAV (Systems 5 and 6)	0.205	0.174	0.159
All other (Systems 1, 3, 7, and 9)	0.209	0.182	0.162

Source: California Energy Commission

MULTI-SPEED FAN POWER RATIO

Applicability: Two- and Three-speed fans.

Definition: The ratio of part-load power to full-load power at the given fan flow.

Units: Unitless.

Input Restrictions: Not input. Same as Standard Design

Standard Design:

Two-speed fans: 30 percent power at 50 percent flow

Three-speed fans: 51 percent power at 66 percent flow, 12 percent power at 33 percent flow

5.7.4 Outdoor Air Controls and Economizers

Air Side Economizers

ECONOMIZER CONTROL TYPE

Applicability: All systems with an air-side economizer

Definition: An air-side economizer increases outside air ventilation during periods when system cooling loads can be reduced from increased outside air flow. The control types include:

No economizer.

Fixed dry-bulb. The economizer is enabled when the temperature of the outside air is equal to or lower than temperature fixed setpoint (e.g., 75°F).

Differential dry-bulb. The economizer is enabled when the temperature of the outside air is lower than the return air temperature.

Differential enthalpy. The economizer is enabled when the enthalpy of the outside air is lower than the return air enthalpy.

Differential dry-bulb and enthalpy. The system shifts to 100 percent outside air or the maximum outside air position needed to maintain the cooling SAT setpoint, when the outside air dry-bulb is less than the return air dry-bulb AND the outside air enthalpy is less than the return air enthalpy. This control option requires additional sensors.

Units: List (see above)

Input Restrictions: As designed

Standard Design: The control should be no economizer when the standard design net cooling capacity is less than 33,000 Btu/h, the system type is System 14 or 15, and when the standard design cooling system is not a computer room air handling unit

(CRAH). Otherwise, the standard design shall assume an integrated fixed dry-bulb economizer.

An exception is that economizers shall not be modeled for systems serving multifamily dwelling units or hotel/motel guestroom occupancies. An exception for systems serving healthcare facilities with Standard Design net cooling capacity less than 54,000 Btu/h where ventilation is provided by a DOAS with heat recovery.

DOAS with heat recovery serving healthcare facilities shall assume having a fixed dry-bulb economizer.

ECONOMIZER LOW TEMPERATURE LOCKOUT

Applicability: Systems with air-side economizers

Definition: A feature that permits the lockout of economizer operation (return to minimum outside air position) when the outside air temperature is below the lockout setpoint.

Units: Degrees Fahrenheit (F°)

Input Restrictions: As designed

Standard Design: For healthcare facilities, System 14, and System 15 DOAS with heat recovery, 55 °F. For all others, 45 °F

HEAT RECOVERY ECONOMIZER LOCKOUT

Applicability: All systems with airside heat recovery.

Definition: A flag to indicate whether or not the heat recovery is bypassed when economizer is enabled.

Units: Boolean.

Input Restrictions: As designed.

Standard Design: For healthcare facilities heat recovery, energy recovery bypass during economizer operation.

For System 14 and 15 DOAS with heat recovery, bypass when within economizer limits.

For all others, heat recovery bypass during economizer operation for HVAC systems impacted based on requirements in 140.4(q). Not applicable for all systems.

Standard Design: Existing Buildings: The economizer is disabled for HVAC systems impacted based on requirements in 140.4(q). Not applicable for all systems.

5.7.6 Heating Systems

General

HEATING SOURCE

Applicability: All systems that provide heating.

Definition: The source of heating for the heating coils. The choices are:

Hot water
Electric resistance
Electric heat pump
Gas furnace
Oil furnace
VRF

Units: List (see above).

Input Restrictions: As designed. Electric heat pumps may have an additional coil to be used as supplemental heat. See section below. Electric resistance heating system shall not be used for healthcare facilities space heating unless it meets one of the exceptions to Section 140.4(g) in the Energy Code.
Standard Design: For healthcare facilities, same as the Proposed Design. For all others, based on the prescribed system type. Refer to the HVAC system map in Chapter 5.1.2 HVAC System Map.

Standard Design: Existing Building: Same as proposed if unaltered. Alterations of single zone systems in office buildings, library buildings, financial institution buildings, and school buildings, where: the existing system type is a SZAC or SZHP, and the existing system nominal rated capacity is 65,000 Btu/h or less: the Standard Design shall be a heat pump for the climate zones specified in the table below.

Table 5-XXX Standard Design Climate Zone (CZ) Applicability for Single Zone System Alterations

Building Type	Standard Design Heat Pump (SZHP) (Note 1)	Standard Design Packaged Unit with Furnace (SZAC)
Retail, Grocery	CZ 3-13, 15	CZ 1, 2, 14, 16
School	CZ 1-15	CZ 16
Office, Financial Institution	CZ 3-13, 15	CZ 1, 2, 14, 16
Library	CZ 1, 3-15	CZ 2, 16

Note 1. Alterations of existing units with zero heating capacity used for cooling-only of interior spaces shall have a standard design system with zero heating capacity if the proposed system has zero heating capacity.

5.8.1 ~~Boilers~~ Hydronic System Heating Equipment

AWHP Rated Heating Capacity

Applicability: All AWHPs.

Definition: The heating capacity of the AWHP at rated conditions.

Units: Btu/h.

Input Restrictions: As designed.

Standard Design: Sized to 50 percent of the load at heating design conditions.

Standard Design: Existing Buildings: Same as proposed if unaltered; same as newly constructed buildings rules if altered or replacement.

AWHP Capacity Ratio Curves

Applicability: All AWHPs.

Definition: A curve or group of curves that varies the heating capacity of an AWHP as a function of evaporator conditions and condenser conditions.

Multipass:

$$EIR_{FT} = a + b(t_{hwr}) + c(t_{hwr})^2 + d(t_{owb}) + e(t_{owb})^2 + f(t_{hwr})(t_{owb})$$

Non-modular:

$$EIR_{FT} = a + b(t_{hwr}) + c(t_{hwr})^2 + d(t_{odb}) + e(t_{odb})^2 + f(t_{hwr})(t_{odb})$$

Where:

t_{hwr} — The hot water return temperature (°C)
t_{wdb} — The outside air wet-bulb temperature (°C)
t_{odb} — The outside air dry-bulb temperature (°C)

Units: Data structure.

Input Restrictions: Curve coefficients are prescribed in Appendix 5.7 given the AWHP type.

Standard Design: Use Non-modular curves specified in Appendix 5.7.

Appendix 5.7 AWHP Capacity Ratio Curve Parameters

Non-modular:

- Coefficient1 Constant: 0.859622974323302
- Coefficient2 x: 0.0389784557561991
- Coefficient3 x**2: 2.23382607607476E-05
- Coefficient4 y: -0.00196106447039671
- Coefficient5 y**2: -1.45713290410259E-05
- Coefficient6 x*y: -0.000203963618262175
- Minimum Value of x: -20
- Maximum Value of x: 100
- Minimum Value of y: 0
- Maximum Value of y: 100

AWHP Supplemental Boiler Rated Heating Capacity

Applicability: All AWHPs.

Definition: The heating capacity of the AWHP's integral tank element at rated conditions.

Units: Btu/h.

Input Restrictions: As designed.

Standard Design: Sized to 50 percent of the full heating design load at design conditions.

Standard Design: Existing Buildings: Same as proposed if unaltered; same as newly constructed buildings rules if altered or replacement.

AWHP RATED HEATING COP

Applicability: All AWHPs.

Definition: The heating efficiency of the AWHP at rated full-load conditions.

Units: COP.

Input Restrictions: As designed.

Standard Design: 3.29.

Standard Design: Existing Buildings: Same as proposed if unaltered; same as newly constructed buildings rules if altered or replacement.

AWHP COP RATIO CURVES

Applicability: All AWHPs.

Definition: A curve or group of curves that varies the heating efficiency of an AWHP as a function of evaporator conditions and condenser conditions.

Multipass:

$$EIR_{FT} = a + b(t_{hwr}) + c(t_{hwr})^2 + d(t_{owb}) + e(t_{owb})^2 + f(t_{hwr})(t_{owb})$$

Non-modular:

$$EIR_{FT} = a + b(t_{hwr}) + c(t_{hwr})^2 + d(t_{odb}) + e(t_{odb})^2 + f(t_{hwr})(t_{odb})$$

Where:

t_{hwr} — The hot water return temperature (°C)
t_{wdb} — The outside air wet-bulb temperature (°C)
t_{odb} — The outside air dry-bulb temperature (°C)

Units: Data structure.

Input Restrictions: Curve coefficients are prescribed in Appendix 5.7 given the AWHP type.

Standard Design: Use Non-modular curves specified in Appendix 5.7.

APPENDIX 5.7 AWHP EFFICIENCY ADJUSTMENT CURVE PARAMETERS

Non-modular:

- Coefficient1 Constant: 2.04325912137322
- Coefficient2 x: 0.0429320957027846
- Coefficient3 x**2: 3.28091237393946E-05
- Coefficient4 y: -0.0443703179351673
- Coefficient5 y**2: 0.00036139084649448
- Coefficient6 x*y: -0.000609596588481613
- Minimum Value of x: -20
- Maximum Value of x: 100
- Minimum Value of y: 0
- Maximum Value of y: 100

AWHP Rated Inlet Air Drybulb

Applicability: All AWHPs.

Definition: The dry-bulb temperature at rated full-load conditions.

Units: Degrees Fahrenheit (°F).

Input Restrictions: As designed.

Standard Design: 47°F.

Standard Design: Existing Buildings: Same as proposed if unaltered; same as newly constructed buildings rules if altered or replacement.

AWHP Rated Inlet Water Temperature

Applicability: All AWHPs.

Definition: The condenser inlet water temperature at rated full-load conditions.

Units: Degrees Fahrenheit (°F).

Input Restrictions: As designed.

Standard Design: 105°F.

Standard Design: Existing Buildings: Same as proposed if unaltered; same as newly constructed buildings rules if altered or replacement.

AWHP Minimum Outdoor Temperature for Compressor Operation

Applicability: All AWHPs.

Definition: The minimum outdoor air temperature where the compressor operates.

Units: Degrees Fahrenheit (°F).

Input Restrictions: As designed.

Standard Design: 40°F.

Standard Design: Existing Buildings: Same as proposed if unaltered; same as newly constructed buildings rules if altered or replacement.

AWHP COMPRESSOR LOCATION

Applicability: AWHP.

Definition: The location of the AWHP compressor.

Units: List zone, outdoors.

Input Restrictions: As designed

Standard Design: outdoors.

Standard Design: Existing Buildings: Same as proposed if water heater is existing.

AWHP COMPRESSOR SETPOINT

Applicability: AWHP.

Definition: The setpoint for the AWHP coil compressor.

Units: Degrees Fahrenheit (°F).

Input Restrictions: Not Input. Hot Water Supply Temperature + 2.5°F.

Standard Design: 107.5°F.

Standard Design: Existing Buildings: Same as proposed if water heater is existing.

AWHP STORAGE VOLUME

Applicability: AWHP.

Definition: The volume of a storage water heater.

Units: Gallons.

Input Restrictions: As designed.

Standard Design: The volume of the standard design is 8 gallons per ton of heating capacity.

AWHP TANK LOCATION

Applicability: All thermal energy storage systems.

Definition: The location of the AWHP tank.

Units: List zone, outdoors, or underground.

Input Restrictions: As designed.

Standard Design: For healthcare facilities, same as the Proposed Design. For System 14, outdoors. For all others, not applicable.

AWHP TANK HEATING ELEMENT SETPOINT

Applicability: AWHP.

Definition: The setpoint for the AWHP supplemental electric boiler.

Units: Degrees Fahrenheit (°F).

Input Restrictions: Not Input. Hot Water Supply Temperature – 3.0°F.

Standard Design: 102.0°F.

Standard Design: Existing Buildings: Same as proposed if water heater is existing.

AWHP Tank Heating Element Deadband

Applicability: AWHP.

Definition: The deadband for the AWHP supplemental electric boiler setpoint.

Units: Degrees Fahrenheit (°F).

Input Restrictions: Not Input. Same as Standard Design

Standard Design: 0.5°F.

Standard Design: Existing Buildings: Same as proposed if water heater is existing.

Hot Water Supply Temperature

Applicability: All boilers and AWHPs.

Definition: The temperature of the water produced by the boiler or AWHP and supplied to the hot water loop.

Units: Degrees Fahrenheit (°F).

Input Restrictions: As designed.

Standard Design: For healthcare facilities, same as the Proposed Design. If the Standard Design is an AWHP, then the design hot water supply temperature is 105°F. For all others, use 160°F if the standard design is a boiler.

Hot Water Temperature Difference

Applicability: All multizone space heating systems

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 System 14 it is 10°F. Use 40°F when the standard design is a gas 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 System 14, the hot water supply temperature is fixed (no reset). If the Standard Design is a gas boiler, the hot water supply temperature is fixed at 160 °F.

PUMP DESIGN HEAD

Applicability: All standard and proposed design pumps that use the detailed method.

Definition: The head of the pump at design flow conditions.

Units: ft of water.

Input Restrictions: As designed but subject to an input restriction. The user inputs of pump design head, impeller efficiency, and pump design flow shall be used to calculate the proposed brake horsepower. This shall be compared to the pump motor.

Horsepower for the next smaller motor size (MHPi-1) than the one specified by the user (MHPi).

The proposed pump design head shall be constrained so that the resulting brake horsepower is no smaller than 95 percent of the next smaller motor size:

$$design\ bhp_{prop} = \max\left[design\ bhp_{prop-user-head}, 0.95(MHP_{i-1})\right]$$

Where:

- $design\ bhp_{prop}$ — The brake horsepower used in the simulation
- $design\ bhp_{prop-user-head}$ — The brake horsepower resulting from the user input of design head
- MHP_i — The pump motor horsepower specified by the user
- i — The index into the standard motor size table for the user motor horsepower
- MHP_{i-1} — The motor horsepower for the next smaller motor size. For example, if the user-specified pump motor horsepower is 25, the next smaller motor size in the table above is 20

Since all other user inputs that affect the proposed design brake horsepower are not modified, the proposed design pump design head is adjusted in the same proportion as the pump brake horsepower in the equation above. If the user-entered pump design head results in a brake horsepower that is at least 95 percent of the horsepower of the next smaller motor size, no modification of the user input is required.

Standard Design: For healthcare facilities, same as the proposed design. For all others, for chilled water pumps:

$Head_{CHW}$ = (40 ft) + (0.03 ft/ton) x [chiller plant nominal capacity (tons)]

(not to exceed 100 ft)

For chilled water pumps serving FPFC systems: 1.2 x $Head_{CHW}$

For condenser water pumps: 45 ft

5.8.6 Variable Refrigerant Flow (VRF) Systems

Heat Recovery

Applicability: VRF.

Definition: Identification if heat recovery (refrigerant loop) is present.

Units: Boolean.

Input Restrictions: None (default : No).

Standard Design: For healthcare facilities, same as the Proposed Design. For System 15, Yes. For all others, not applicable.

Control Priority

Applicability: VRF.

Definition: A control parameter used to determine when outdoor unit is in heating or cooling.

Units: List: Master Thermostat Priority or Load Priority.

Input Restrictions: None.

Standard Design: For healthcare facilities, same as the Proposed Design. For System 15, Load Priority. For all others, not applicable.

Minimum Part-Load Ratio

Applicability: VRF.

Definition: The minimum part-load ratio for the heat pump. Below this ratio the unit will cycle to meet the load.

Units: Unitless.

Input Restrictions: 0.25 to 1.

Standard Design: For healthcare facilities, same as the Proposed Design. For System 15, 0.25. For all others, not applicable.

Rated EER

Applicability: VRF.

Definition: Full load cooling efficiency (Btu/h of net cooling output divided by the electrical energy consumption in Watts) per AHRI rating conditions.

Units: Btu/h-W.

Input Restrictions: As designed, the user-entered value must meet mandatory minimum requirements of the Appliance Standards for the applicable equipment type.

Standard Design: For healthcare facilities, and System 15 the minimum heating efficiency from the Energy Code for the applicable equipment type. For all others, not applicable.

Rated COP

Applicability: VRF.

Definition: Full load heating efficiency (net heating output divided by the electrical energy consumption, both in the same units) per AHRI rating conditions.

Units: None.

Input Restrictions: As designed, the user-entered value must meet mandatory minimum requirements of the Appliance Standards for the applicable equipment type.

Standard Design: For healthcare facilities, and System 15 the minimum heating efficiency from the Energy Code for the applicable equipment type. For all others, not applicable.

Equivalent Pipe Length

Applicability: VRF.

Definition: The equivalent pipe length between the farthest terminal unit and the condensing unit, including liquid refrigerant line length, fitting losses, and other losses.

Units: ft.

Input Restrictions: None.

Standard Design: For healthcare facilities, same as the Proposed Design. For System 15, 48 ft. For all others, not applicable.

Max Vertical Height

Applicability: VRF.

Definition: The vertical height difference between the highest or lowest terminal unit and outdoor unit.

Units: ft.

Input Restrictions: None.

Standard Design: For healthcare facilities, same as the Proposed Design. For System 15, 11 ft. For all others, not applicable.

Defrost Heat Source

Applicability: VRF.

Definition: The defrost heat source type.

Units: List – electric or gas.

Input Restrictions: None.

Standard Design: For healthcare facilities, same as the Proposed Design. For System 15, Electric. For all others, not applicable.

DEFROST CONTROL STRATEGY

Applicability: VRF.

Definition: The control method for enabling defrost.

Units: List – TimedCycle or OnDemand.

Input Restrictions: None.

Standard Design: For healthcare facilities, same as the Proposed Design. For System 15, OnDemand. For all others, not applicable.

MAX DEFROST TEMP

Applicability: VRF.

Definition: The maximum outdoor dry-bulb temperature at which defrost will occur.

Units: Deg F.

Input Restrictions: None.

Standard Design: For healthcare facilities, same as the Proposed Design. For System 15, 40°F. For all others, not applicable.

COMPRESSOR QUANTITY

Applicability: VRF.

Definition: The number of compressors represented by the unit.

Units: Unitless integer.

Input Restrictions: None.

Standard Design: For System 15, 1.

CRANKCASE HEATER CAPACITY

Applicability: VRF.

Definition: The capacity of the resistive heating element in or around the crank case of a compressor. The crank case heater operates only when the compressor is off.

Units: W.

Input Restrictions: The value is prescribed to be 10 W per ton (rated net cooling capacity).

Standard Design: ~~Not applicable.~~ For System 15, 0 W.

CRANKCASE HEATER SHUTOFF TEMPERATURE

Applicability: VRF.

Definition: The outdoor air dry-bulb temperature above which the crankcase heater is not permitted to operate.

Units: Deg F.

Input Restrictions: The value is prescribed to be 50°F.

Standard Design: ~~Not applicable.~~ For System 15, 40°F.

5.5 Compliance Forms

The prescriptive certificates of compliance (NRCC and LMCC-MCH) ruleset will be modified to restrict the HVAC system type as needed. This will not require any additional review from the plans examiner as the form will be doing all the work. The plans examiner will need to verify the proposed system type in the NRCC/LMCC matches the designed system type in the plan set. The performance certificate of compliance (NRCC and LMCC-PRF) will have its ruleset modified to adjust the baseline system type as needed. The layout of both the prescriptive and performance certificates of compliance will not need modification. The certificates of installation (NRCI and LMCI-MCH) will not need modification to the ruleset or the layout.

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APPENDICES

Appendix A: Statewide Savings Methodology

Estimated statewide energy savings for the first year that the Energy Code becomes in effect (2026) can be generated by multiplying the proposed measure's per unit savings by the provided statewide construction forecasts in this appendix.

The CEC has provided residential and nonresidential newly constructed building forecasts for 2026, broken out by building type and forecast climate zones (FCZ). This data can be converted from FCZ to building climate zones (BCZ) using the weighting factors presented in Table 50: . The CEC provided prototypes for all forecasted building types except for Controlled Environmental Horticulture, Grocery, Refrigerated Warehouse, Vehicle Service, Manufacturing and Miscellaneous. The Enclosed Parking Garage is included in the multifamily prototypes. Additionally, Table 53 provides more complete definitions of the various space types used in the forecast.

Updates to Appendix A, including updates to building start data, will be located on the 2025 Energy Code Pre-Rulemaking Docket 22-BSTD-01, https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=22-BSTD-01

Table 50: FCZ to BCZ Conversion Factors

Forecast zones (FCZ) along X-axis, building climate zones (BCZ) along Y-axis

Climat e Zone	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	17.90%	0.00%	13.51%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2	0.00%	0.00%	80.20%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3	0.00%	52.43%	6.28%	0.00%	3.64%	0.00%	52.26%	0.00%	0.00%	0.00%	0.00%
4	0.00%	30.39%	0.00%	0.00%	0.00%	0.00%	15.39%	0.00%	0.00%	0.00%	0.00%
5	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	32.33%	0.00%	0.18%	0.00%	0.00%
6	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	18.89%	61.19%	0.00%	0.00%
7	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
8	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	43.99%	0.00%	0.00%	0.00%
9	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	32.29%	37.22%	0.00%	0.00%
10	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	71.19%
11	0.42%	0.00%	0.00%	84.77%	22.07%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
12	0.00%	17.18%	0.00%	0.00%	72.61%	4.55%	0.00%	0.00%	0.00%	0.00%	0.00%
13	0.00%	0.00%	0.00%	0.00%	0.00%	94.81%	0.00%	0.00%	0.00%	78.49%	0.00%
14	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.51%	0.00%	12.10%	24.17%
15	3.18%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.10%
16	78.50%	0.00%	0.01%	15.23%	1.68%	0.64%	0.00%	0.33%	1.41%	9.41%	4.55%
Total	**100.00 %**	**100.00 %**	**100.00 %**	**100.00 %**	**100.00 %**	**100.00 %**	**100.00 %**	**100.00 %**	**100.00 %**	**100.00 %**	**100.00 %**

Table 50 (continued)

Climate Zone	11	12	13	14	15	16	17	18	19	20
1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.00%	0.00%	0.00%
3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
4	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
5	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
6	0.00%	6.60%	0.00%	0.00%	0.00%	17.18%	0.00%	0.00%	0.00%	0.00%
7	0.00%	62.81%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
8	0.00%	1.94%	0.00%	0.00%	0.00%	27.90%	0.00%	0.00%	0.00%	0.00%
9	0.00%	0.00%	0.00%	0.00%	0.00%	54.92%	99.35%	100.00%	0.00%	0.00%
10	86.11%	27.88%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
11	0.00%	0.00%	0.42%	0.00%	44.55%	0.00%	0.00%	0.00%	0.00%	0.00%
12	0.00%	0.00%	99.58%	100.00%	52.65%	0.00%	0.00%	0.00%	0.00%	0.00%
13	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
14	0.00%	0.66%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%
15	13.33%	0.12%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	99.98%	0.00%
16	0.56%	0.00%	0.00%	0.00%	2.61%	0.00%	0.65%	0.00%	0.00%	100.00%
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Table 51: Statewide Residential Units (2026)

Climate Zone	Single-Family Units	Multifamily Units
1	44,875	17,558
2	265,807	105,894
3	972,513	553,186
4	497,321	288,786
5	97,271	45,671
6	594,544	322,513
7	494,355	307,272
8	926,278	515,137
9	1,250,479	1,117,605
10	1,067,399	329,302
11	335,468	85,339
12	1,318,779	471,876
13	634,709	157,075
14	247,852	83,480
15	177,670	41,152
16	97,937	28,066
Total	9,023,257	4,469,912

Table 52: Statewide Residential Newly Constructed Buildings (2026)

Climate Zone	Single-Family Units	Multifamily Units
1	359	144
2	1,861	1,391
3	3,035	7,699
4	2,689	3,417
5	616	285
6	1,719	2,243
7	1,869	5,156
8	4,163	8,600
9	4,286	10,302
10	7,950	4,306
11	5,840	1,173
12	14,542	5,537
13	7,257	1,009
14	3,739	1,446
15	3,160	373
16	1,937	187
Total	65,022	53,268

Table 53: Statewide Nonresidential Newly Constructed Building Types

Forecast Building Types	Uses	Number of Stories	Floor Area (sf)
Assembly	Gatherings including, but not limited to: Arenas, Coliseums, Auditoriums, Transportation Terminals, Clubs and Lodges, Exhibition Halls, Funeral or Internment Facilities, Religious Buildings, Libraries, Museums, Theaters, Recreational and Exercise Facilities.	Any	Any
Controlled-environment Horticulture	Buildings with indoor conditioned spaces used for agriculture.	Any	Any
Hospital	Hospitals, Clinics, and Nursing Convalescent Facilities	Any	Any
Hotel	Hotels and Motels	Any	Any
Laboratory	Laboratories	Any	Any
Large Office	Offices, Banks and Financial Institutions, Government Services Buildings, Post Offices	≥ 5	Any
Medium Office	Offices, Banks and Financial Institutions, Government Services Buildings, Post Offices	2 - 4	Any
Small Office	Offices, Banks and Financial Institutions, Government Services Buildings, Post Offices	1	Any
Restaurant	Food and/or Beverage Service	Any	Any
Large Retail	Stores and Other Mercantile Buildings	Any	≥ 50k
Medium Retail	Stores and Other Mercantile Buildings	Any	< 50k
Grocery	Stores and Other Mercantile Buildings used for the sale of food items	Any	Any
Strip Mall Retail	Shopping Centers	Any	Any
Large School	Schools and Educational Facilities	Any	≥ 50k
Small School	Schools and Educational Facilities	Any	< 50k
Warehouse	Warehouses and Freight Terminals	Any	Any

Forecast Building Types	Uses	Number of Stories	Floor Area (sf)
Refrigerated Warehouse	Refrigerated Warehouses	Any	Any
Vehicle Service	Auto, Aircraft, Bus, Truck, Railroad, Boat, or any other Vehicle Servicing Facility	Any	Any
Manufacturing	Manufacturing Facilities	Any	Any
Enclosed Parking Garage	Parking Garages enclosed by walls and a roof with rooftop parking.	Any	Any
Open Parking Garage	Parking Garages that are open to the ambient environment. Parking lots with canopies are not considered Parking Garages.	Any	Any
Miscellaneous	Miscellaneous Non-Residential Buildings.	Any	Any

Table 54: Statewide Nonresidential Newly Constructed Buildings Distribution

Type of Nonresidential Space	Sub-measure 1	Sub-measure 2	Sub-measure 3
Assembly	20%	80%	80%
Controlled-environment Horticulture	20%	80%	80%
Hospital	20%	80%	80%
Hotel	20%	80%	80%
Laboratory	20%	80%	80%
Large Office	N/A	N/A	N/A
Medium Office	20%	80%	80%
Small Office	20%	80%	80%
Restaurant	N/A	N/A	N/A
Large Retail	20%	80%	80%
Medium Retail	20%	80%	80%
Grocery	20%	80%	80%
Strip Mall Retail	20%	80%	80%
Large School	20%	80%	80%
Small School	20%	80%	80%
Warehouse	20%	80%	80%
Refrigerated Warehouse	20%	80%	80%
Vehicle Service	N/A	N/A	N/A
Manufacturing	20%	80%	80%
Enclosed Parking Garage	20%	80%	80%
Open Parking Garage	N/A	N/A	N/A
Miscellaneous	20%	80%	80%

Table 55: Statewide Nonresidential Newly Constructed Buildings (2026 in Million ft²)

Space Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Large Office	0	0	3.234	1.578	0	1.422	0.825	2.288	4.152	0.3916	0.1088	0.5747	0	0.2002	0.01303	0.04995
Medium Office	0.1302	0.4761	1.372	0.7442	0.3705	1.201	0.8046	1.646	3.184	1.174	0.2685	2.799	0.5859	0.3482	0.2629	0.102
Small Office	0.01306	0.4369	0.1869	0.02019	0.06423	0.1481	0.2339	0.1594	0.36	0.4167	0.0933	0.5443	0.3852	0.04404	0.1051	0.03313
Large Retail	0	0	1.097	0.5497	0.1491	0.6978	0.3746	0.8316	1.664	0.6327	0.2997	1.303	0.3564	0.1442	0.1803	0.05547
Medium Retail	0.08421	0.348	0.7947	0.4459	0.08574	0.6027	0.2856	0.8641	1.424	0.8224	0.142	0.6274	0.379	0.18	0.1242	0.08122
Strip Mall	0.001146	0.1543	0.504	0.2256	0.007439	0.5629	0.4878	0.9855	1.065	1.345	0.07164	0.5928	0.3253	0.3206	0.1001	0.0602
Mixed-use Retail	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Large School	0.006476	0.1273	0.8761	0.4418	0.03636	0.5941	0.6084	0.9052	1.421	0.8535	0.3545	1.152	0.6149	0.1661	0.08573	0.0681
Small School	0.0665	0.2698	0.4566	0.2294	0.1395	0.3155	0.2944	0.3516	0.6581	0.3481	0.09881	0.7763	0.3025	0.107	0.03728	0.04489
Non-refrigerated Warehouse	0.06177	0.3672	2.16	1.118	0.1776	1.363	0.7108	1.948	3.01	1.36	0.6315	2.844	0.8203	0.3618	0.3673	0.1381
Hotel	0.03627	0.2154	1.033	0.5306	0.1095	0.5527	0.4822	0.7835	1.183	0.5716	0.1534	0.8029	0.2557	0.1375	0.1248	0.04395
Assembly	0.01028	0.3935	1.583	0.5574	0.05869	0.7868	0.7991	1.431	1.824	1.144	0.1669	1.414	0.3043	0.2453	0.118	0.08429
Hospital	0.02939	0.1746	0.8416	0.4358	0.07972	0.3285	0.549	0.4412	0.7894	0.8128	0.1459	0.8253	0.2729	0.1417	0.115	0.04813
Laboratory	0.000819	0.0531	0.6313	0.3632	0.02078	0.07327	0.05265	0.1017	0.1214	0.06227	0.008372	0.04996	0.009723	0.01063	0.006101	0.003518
Restaurant	0.0139	0.08256	0.3269	0.1667	0.03403	0.3365	0.2036	0.4933	0.8189	0.4129	0.07099	0.3135	0.1414	0.1015	0.04739	0.0296
Enclosed Parking Garage	0.000176	0.009137	1.83	1.245	0.004558	2.585	0.7059	2.265	1.527	0.05053	0.001585	0.04116	0.002972	0.0152	0.003691	0.007247
Open Parking Garage	0.002272	0.1182	2.474	1.682	0.05894	3.648	1.201	3.197	2.155	0.6535	0.0205	0.5323	0.03843	0.1965	0.04773	0.09372

Source: CEC

Table 55: (Continued, Non-Prototype Building Types)

Building Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Grocery	0.006871	0.04512	0.1048	0.06175	0.01187	0.04649	0.01716	0.0519	0.09145	0.0494	0.00891	0.03876	0.02276	0.01081	0.007629	0.006042
Refrigerated Warehouse	0	0	0.06098	0.05067	0.01431	0.02204	0	0.00683	0.01322	0.03874	0	0.06849	0.1181	0.007633	0.007893	0.00517
Controlled-environment Horticulture	0.09265	0.07749	0.3197	0.03986	0.2021	0.2578	0.001464	0.02342	0.02606	0.278	0.3027	0.3053	0.09011	0.01079	0.04796	0.004662
Vehicle Service	0.001921	0.07746	0.5473	0.3582	0.02914	0.5513	0.3416	0.7989	1.809	0.5735	0.02149	0.3892	0.2476	0.1954	0.05667	0.04908
Manufacturing	0.00564	0.1329	0.4035	0.1914	0.05985	0.1284	0.08885	0.1075	0.095	0.1144	0.06035	0.1555	0.02059	0.02453	0.01736	0.01262
Miscellaneous	0	0	0.000253	0.4212	0	0	0	0	0	0	0	0.000774	0	0	0	0

Table 56: Statewide Nonresidential Existing Construction (2026 in Million ft²)

Space Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Large Office	0.1275	3.102	139.8	72.35	1.832	99.54	72.71	162.6	303.1	58.48	2.608	78.61	9.264	20.27	4.434	4.663
Medium Office	3.379	30.99	78.79	42.28	13.32	47.81	43.87	59.11	86.34	66.69	16.94	101.7	25.18	13.33	10.25	4.063
Small Office	4.178	12.75	22.19	11.33	7.504	13.22	8.516	13.28	20.88	24.43	10.6	43.94	21.47	4.987	6.181	2.676
Large Retail	1.002	8.665	58.68	26.9	4.2	31.96	25.34	43.46	66.53	53.31	11.4	58.16	22.51	10.91	9.402	3.207
Medium Retail	1.176	13.11	44.52	25.74	5.433	44.27	34.66	66.72	108.2	66.89	10.37	60.5	24.15	15.53	8.769	5.17
Strip Mall	3.336	9.842	37.42	18.43	5.095	40.23	28.29	55.76	83.7	66.92	12.25	48.37	24.18	15.27	8.696	4.591
Mixed-use Retail	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Large School	0.7589	8.02	34.83	13.95	2.071	28.37	22.54	42.91	73.58	56.01	10.13	53.38	26.41	12.06	7.621	3.589
Small School	2.23	11.13	25.57	9.979	6.06	25.69	14.96	34.44	54.31	33.03	13.5	42.08	23.44	8.72	4.251	3.645
Non-refrigerated Warehouse	3.33	20.22	108.3	53.43	9.802	89.98	51.48	128.4	207.3	182.7	33.73	148.3	51.08	38.87	29.05	11.63
Hotel	1.771	10.52	48.1	24.73	5.011	30.49	32.66	41.97	66.01	37.09	7.218	40.53	13.08	8.006	5.876	2.439
Assembly	4.328	18.18	91.34	45.06	6.594	57.25	40.9	89.14	120.2	91.75	16.35	69.72	30.13	18.95	11.83	6.439
Hospital	1.866	11.09	48.33	24.67	5.055	28.25	27.15	40.77	69.88	39.6	11.11	53.18	22.49	8.802	5.034	3.234
Laboratory	0.1782	4.01	36.93	28.06	1.531	12.21	17.19	15.61	19.31	10.81	0.679	12.14	4.396	1.723	0.387	0.5716
Restaurant	0.6087	3.616	14.72	7.494	1.546	16.46	10.73	23.78	40	32.41	3.515	16.95	7.742	6.859	3.453	1.897
Enclosed Parking Garage	0.01696	0.5432	40.71	30.94	0.2988	29.15	20.67	58.41	72.53	2.673	0.345	3.09	0.4883	0.8543	0.1666	0.4343
Open Parking Garage	0.2193	7.024	55.03	41.82	3.864	41.14	35.17	82.44	102.4	34.57	4.461	39.96	6.314	11.05	2.155	5.616

Table 56: (Continued, Non-Prototype Building Types)

Building Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Grocery	0.09598	1.7	5.869	3.564	0.7523	3.415	2.082	4.008	6.951	4.018	0.6502	3.737	1.45	0.9323	0.5386	0.3846
Refrigerated Warehouse	0.004721	0.4556	0.9104	0.2123	0.3863	0.4566	0.02334	0.4213	0.7865	0.6521	0.2629	2.146	3.907	0.1842	0.1939	0.1444
Controlled-environment Horticulture	0.6988	0.4569	2.62	1.072	6.327	8.264	1.072	0.7413	1.599	3.609	2.513	4.533	5.36	0.4681	0.6443	0.2349
Vehicle Service	0.9073	6.184	33.65	15.98	2.971	33.73	23.08	49.52	81.78	56.54	6.296	38.32	18.24	15.09	6.18	3.543
Manufacturing	4.105	16.89	61.93	79.55	5.59	73.33	33.27	122.7	168.1	49.58	12.86	57.01	25.97	16.98	5.146	9.273
Miscellaneous	0.3582	6.575	9.025	6.318	0.2196	2.575	0.7716	3.778	7.868	2.551	3.367	14.35	2.935	0.7699	0.4029	1.026

Appendix B: Embedded Electricity in Water Methodology

No on-site water impacts associated with the proposed measure.

Appendix C: Environmental Impact Analysis

Greenhouse Gas Emissions Impacts Methodology

GHG emissions are calculated assuming the latest applicable GHG Emissions hourly factors published by the CEC and used by the CEC's reference code compliance software (CBECC-Res and CBECC).

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).)

NORESCO 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. While the proposed code change increases electricity use for heating, the affected buildings consume less energy overall. The code change is aligned with the 2025 Title 24 Standards as well as the state's long-term goals by better utilizing onsite renewable generation and battery storage systems These benefits are described throughout the body of this report.

A secondary benefit is the reduced reliance on natural gas, which will result in reduced methane leakage to the environment.

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 AWHP systems. However, this increase in electric load is addressed through specification of design conditions to ensure efficient heat pump operation and minimal use of electric resistance supplemental heating.

Indirect Environmental Impacts

The measures in this proposal are not expected to result in indirect environmental benefits or adverse impacts.

Mitigation Measures

NORESCO 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.)

One consideration for AWHPs and air conditioners and heat pumps in general is the refrigeration type used and the means of disposal at the end of the product's life. Fortunately, industry is transitioning to the use of low-GWP refrigerants, including R-32 and R-454B, which are much less harmful to the atmosphere. Currently, only a small fraction of refrigerant is reclaimed, as the process requires specialized equipment for testing the refrigerant's composition and ensuring that the purification has occurred properly. The mitigation measure therefore is twofold: accelerate the transition to low-GWP fuels, and incentivize facilities for reclamation of used refrigerants.

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 environmental impacts picture of a proposed code change. 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 because of the proposed measures. The calculation builds off the materials impacts outlined in 3.5.4, 4.5.4, and 5.5.4; 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).[30, 31] These industry-wide EPDs provide global warming potential (GWP) values per weight of specific materials.[32] 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 with additional emissions. If a material’s use is decreased, then there is a decrease in embodied carbon impacts and emissions are reduced. Table 154 presents estimated first-year GHG emissions impacts associated with embodied carbon.

Appendix D: CBECC Software Specification

Most systems, inputs, reports, and rules required for the measures already exist in CBECC. In addition to these, CBECC will need to incorporate the following:

AWHP

A new selection for the WtrHtr:HtPumpSubType

- Non-modular

When translating the Non-modular WtrHtr:HtPumpSubType to EnergyPlus the following specification shall be used:

- Evaporator Air Temperature Type for Curve Objects
  - DryBulbTemperature
- Heating Capacity Function of Temperature Curve
  - Coefficient1 Constant: 0.859622974323302
  - Coefficient2 x: 0.0389784557561991
  - Coefficient3 x**2: 2.23382607607476E-05
  - Coefficient4 y: -0.00196106447039671
  - Coefficient5 y**2: -1.45713290410259E-05
  - Coefficient6 x*y: -0.000203963618262175
  - Minimum Value of x: -20
  - Maximum Value of x: 100
  - Minimum Value of y: 0
  - Maximum Value of y: 100
- Heating COP Function of Temperature Curve
  - Coefficient1 Constant: 2.04325912137322
  - Coefficient2 x: 0.0429320957027846
  - Coefficient3 x**2: 3.28091237393946E-05
  - Coefficient4 y: -0.0443703179351673
  - Coefficient5 y**2: 0.00036139084649448

3-speed fans

A new Fan:CtrlMthd

- ThreeSpeed

When translating the ThreeSpeed Fan:CtrlMthd to EnergyPlus the following specification shall be used:

- Fan:SystemModel
  - Speed Control Method: Discrete
  - Electric Power Minimum Flow Rate Fraction: 0
  - Motor In Air Stream Fraction: 1
  - Design Power Sizing Method: TotalEfficiencyAndPressure
  - Number of Speeds: 3
  - Speed 1 Flow Fraction: 0.33

- Speed 1 Electric Power Fraction: 0.12
- Speed 2 Flow Fraction: 0.66
- Speed 2 Electric Power Fraction: 0.51
- Speed 3 Flow Fraction: 1
- Speed 3 Electric Power Fraction: 1

Exhaust air control of air-side heat recovery

A new HtRcvry:TempCtrl

- ExhaustTemperature

The following is a sample specification for controlling heat recovery on exhaust air temperature in EnergyPlus. This specification (or equivalent) shall be used:

```
Schedule:Constant,
   DOAS Neutral SAT Sch,    !- Name
   Temperature,             !- Schedule Type Limits Name
   22.77777778;             !- Hourly Value

SetpointManager:Scheduled,
   DOAS Neutral SAT,        !- Name
   Temperature,             !- Control Variable
   DOAS Neutral SAT Sch,    !- Schedule Name
   Bldg DOAS Supply Fan Outlet Node;  !- Setpoint Node or NodeList Name

EnergyManagementSystem:Actuator,
   DOAS_Pretreat_SAT_Setpt, !- Name
   DOAS Neutral SAT Sch,    !- Actuated Component Unique Name
   Schedule:Constant,       !- Actuated Component Type
   Schedule Value;          !- Actuated Component Control Type

EnergyManagementSystem:Sensor,
   DOAS_Return_Air_Temp,    !- Name
   Bldg DOAS Zone Mixer Outlet Node,  !- Output:Variable or Output:Meter Index Key
Name
   System Node Temperature; !- Output:Variable or Output:Meter Name

EnergyManagementSystem:Program,
   DOAS_Pretreat_SAT_Setpt_Setter,  !- Name

   IF DOAS_Return_Air_Temp > 22.7778,  !- Program Line 1
      SET DOAS_Pretreat_SAT_Setpt = 12.77777778,  !- Program Line 2
   ELSEIF DOAS_Return_Air_Temp < 22.7778,  !- A4
      SET DOAS_Pretreat_SAT_Setpt = 32.22222222,  !- A5
   ENDIF;                   !- A6
```

```
EnergyManagementSystem:ProgramCallingManager,
    DOAS_Pretreat_SAT_Setpt_Setter Mgr,  !- Name
    BeginTimestepBeforePredictor,  !- EnergyPlus Model Calling Point
    DOAS_Pretreat_SAT_Setpt_Setter;  !- Program Name 2
```

Large School Energy Model Data Inputs:

Base	FPFC+DOAS, AWHP Pkgd
Prescriptive baseline	Modular AWHP
Geometry:	Geometry:
* Floor area [sf] : 210,886	* Floor area [sf] : 210,886
* Stories Above Grade: 2	* Stories Above Grade: 2
* Stories Below Grade: 0	* Stories Below Grade: 0
* Floor to floor height (feet): 13 - 26	* Floor to floor height (feet): 13 - 26
* WWR: 34.5%	* WWR: 34.5%
* SRR: 1.42%	* SRR: 1.42%
Wall U-factor [Btu/h*ft2*°F]:	Wall U-factor [Btu/h*ft2*°F]:
* CZ 1,6,7 : 0.060	* CZ 1,6,7 : 0.060
* CZ 2,4,5, 8-16: 0.055	* CZ 2,4,5, 8-16: 0.055
* CZ 3: 0.071	* CZ 3: 0.071
Windows:	Windows:
* U-factor [Btu/h*ft2*°F]:	* U-factor [Btu/h*ft2*°F]:
* SHGC:	* SHGC:
- CZ 1-8,10,16: 0.36	- CZ 1-8,10,16: 0.36
- CZ 9, 11-15: 0.34	- CZ 9, 11-15: 0.34
* VT: 0.42	* VT: 0.42
Classroom:	Classroom:
* 0.6 W/sf	* 0.6 W/sf
Auditorium:	Auditorium:
* 0.7 W/sf	* 0.7 W/sf
Gym:	Gym:
* 0.5 W/sf	* 0.5 W/sf
Cafeteria:	Cafeteria:
* 0.45 W/sf	* 0.45 W/sf
Library:	Library:
* 0.8 W/sf	* 0.8 W/sf
Offices:	Offices:
* 0.6 W/sf	* 0.6 W/sf
* Daylighting controls: continuous to 10%	* Daylighting controls: continuous to 10%
Boiler:	Packaged AWHP:
* Natural gas	* 3.02 COP, air-to-water heat pump
- CZ 7 - 13, 15: 84% Et, non-condensing boiler	* 40 F coil cutoff temperature

- CZ 1 - 6, 14, 16: 90% Et, condensing boiler	* Sized for 50% of the prescriptive natural gas boiler capacity
* 180 F HW loop setpoint	* Electric resistance boiler backup
* 60 F HW loop delta T	* 100 F HW loop setpoint
	* 10 F HW loop delta T
Chiller:	* 10 gal/ton storage tank
*Water-cooled, centrifugal, variable speed	
- CZ 1: 0.6 kW/ton	Chiller:
- CZ 2 - 15: 0.585 kW/ton	*Water-cooled, centrifugal, variable speed
	- CZ 1: 0.6 kW/ton
Cooling tower:	- CZ 2 - 15: 0.585 kW/ton
*Open tower, axial, variable speed	
- CZ 1, 16: 42.1 gpm/hp	Cooling tower:
- CZ 2 - 15: 60 gpm/hp	*Open tower, axial, variable speed
	- CZ 1, 16: 42.1 gpm/hp
	- CZ 2 - 15: 60 gpm/hp
System:	System:
* VAV fan	* DOAS, constant volume
* HW reheat coils	* Four-pipe fan coils
* CZ 1,2, 4, 10 - 16: Heat recovery, plate, 60% ERR @ 100% flow	-Variable speed, variable flow
	* CZ 1,2, 4, 9 - 16: Heat recovery, plate, 60% ERR @ 100% flow
Electric Resistance, central water heater	Electric Resistance, central water heater
PV [kW]:	PV [kW]:
* CZ 1, 3, 5, 16: 267.9	* CZ 1, 3, 5, 16: 267.9
* CZ 2, 4, 6 - 14: 343.8	* CZ 2, 4, 6 - 14: 343.8
* CZ 15: 518.8	* CZ 15: 518.8
Battery [kWh]:	Battery [kWh]:
* CZ 1, 3, 5, 16: 560.0	* CZ 1, 3, 5, 16: 560.0
* CZ 2, 4, 6 - 14: 718.7	* CZ 2, 4, 6 - 14: 718.7
* CZ 15: 1,084.7	* CZ 15: 1,084.7

Large Office Energy Model Data Inputs:

2022 Prescriptive baseline	FPFC+DOAS, Pkgd AWHP
Geometry:	Geometry:
* Floor area [sf] : 53,628	* Floor area [sf] : 53,628
* Stories Above Grade: 3	* Stories Above Grade: 3
* Stories Above & Below Grade: 3	* Stories Above & Below Grade: 3
* Floor to floor height (feet): 13	* Floor to floor height (feet): 13
* WWR: 33%	* WWR: 33%
Wall U-factor [Btu/h*ft2*°F]:	Wall U-factor [Btu/h*ft2*°F]:
* CZ 1,6,7 : 0.060	* CZ 1,6,7 : 0.060
* CZ 2,4,5, 8-16: 0.055	* CZ 2,4,5, 8-16: 0.055
* CZ 3: 0.071	* CZ 3: 0.071
Windows:	Windows:
* U-factor [Btu/h*ft2*°F]:	* U-factor [Btu/h*ft2*°F]:
* SHGC:	* SHGC:
- CZ 1-8,10,16: 0.36	- CZ 1-8,10,16: 0.36
- CZ 9, 11-15: 0.34	- CZ 9, 11-15: 0.34
* VT: 0.42	* VT: 0.42
Office Area > 250 square feet:	Office Area > 250 square feet:
* 0.6 W/sf	* 0.6 W/sf
* Daylighting controls: continuous to 10%	* Daylighting controls: continuous to 10%
Boiler:	Packaged AWHP:
* Natural gas	* 3.02 COP, air-to-water heat pump
- CZ 7 - 13, 15: 84% Et, non-condensing boiler	* 40 F coil cutoff temperature
- CZ 1 - 6, 14, 16: 90% Et, condensing boiler	* Sized for 60% of the prescriptive natural gas boiler capacity
* 180 F HW loop setpoint	* Electric resistance boiler backup
* 40 F HW loop delta T	* 100 F HW loop setpoint
	* 10 F HW loop delta T
Chiller:	* 10 gal/ton storage tank
*Water-cooled, centrifugal, variable speed	
- CZ 1: 0.6 kW/ton	Chiller:
- CZ 2 - 15: 0.585 kW/ton	*Water-cooled, centrifugal, variable speed
	- CZ 1: 0.6 kW/ton
Cooling tower:	- CZ 2 - 15: 0.585 kW/ton
*Open tower, axial, variable speed	

- CZ 1, 16: 42.1 gpm/hp	Cooling tower:
- CZ 2 - 15: 60 gpm/hp	*Open tower, axial, variable speed
	- CZ 1, 16: 42.1 gpm/hp
	- CZ 2 - 15: 60 gpm/hp
System:	System:
* VAV fan	* DOAS, constant volume
* HW reheat coils	* Four-pipe fan coils
* CZ 1,2, 11 - 15: Heat recovery, plate, 60% ERR @ 100% flow	-Variable speed, variable flow
	* CZ 1,2, 4, 9 - 16: Heat recovery, plate, 60% ERR @ 100% flow
Electric Resistance, central water heater	Electric Resistance, central water heater
PV [kW]:	PV [kW]:
* CZ 1, 3, 5, 16: 1,291.5	* CZ 1, 3, 5, 16: 1,291.5
* CZ 2, 4, 6 - 14: 1,560.7	* CZ 2, 4, 6 - 14: 1,560.7
* CZ 15: 1,894.8	* CZ 15: 1,894.8
Battery [kWh]:	Battery [kWh]:
* "Basic" battery discharge scheme	* "Basic" battery discharge scheme
* CZ 1, 3, 5, 16: 2,425.8	* CZ 1, 3, 5, 16: 2,425.8
* CZ 2, 4, 6 - 14: 2,931.5	* CZ 2, 4, 6 - 14: 2,931.5
* CZ 15: 3,559.0	* CZ 15: 3,559.0

Medium Office Energy Model Data Inputs:

2022 Prescriptive baseline	VRF+DOAS
Geometry:	Geometry:
* Floor area [sf] : 53,628	* Floor area [sf] : 53,628
* Stories Above Grade: 3	* Stories Above Grade: 3
* Stories Above & Below Grade: 3	* Stories Above & Below Grade: 3
* Floor to floor height (feet): 13	* Floor to floor height (feet): 13
* WWR: 33%	* WWR: 33%
Wall U-factor [Btu/h*ft2*°F]:	Wall U-factor [Btu/h*ft2*°F]:
* CZ 1,6,7 : 0.060	* CZ 1,6,7 : 0.060
* CZ 2,4,5, 8-16: 0.055	* CZ 2,4,5, 8-16: 0.055
* CZ 3: 0.071	* CZ 3: 0.071
Windows:	Windows:
* U-factor [Btu/h*ft2*°F]:	* U-factor [Btu/h*ft2*°F]:
* SHGC:	* SHGC:
- CZ 1-8,10,16: 0.36	- CZ 1-8,10,16: 0.36
- CZ 9, 11-15: 0.34	- CZ 9, 11-15: 0.34

* VT: 0.42	* VT: 0.42
Office Area > 250 square feet:	Office Area > 250 square feet:
* 0.6 W/sf	* 0.6 W/sf
* Daylighting controls: continuous to 10%	* Daylighting controls: continuous to 10%
Boiler:	None
* 84% Et, natural gas, non-condensing boiler	
* 180 F HW loop setpoint	
* 40 F HW loop delta T	
System:	System:
* VAV fan	* DOAS, constant volume
* Packaged DX cooling coils	* VRF with Heat recovery
* HW reheat coils	* CZ 1,2, 11 - 16: Heat recovery, plate, 60% ERR @ 100% flow
Electric Resistance, central water heater	Electric Resistance, central water heater
CZ 1, 3, 5, 16: 138.9 kW	CZ 1, 3, 5, 16: 138.9 kW
CZ 2, 4, 6 - 14: 167.9 kW	CZ 2, 4, 6 - 14: 167.9 kW
CZ 15: 203.8 kW	CZ 15: 203.8 kW

Appendix E: AWHP Interview Summary

Interview Format with Subject Matter Experts

The interview followed the layout of the questions below, with allowed flexibility for the respondents to expand and elaborate on any of the questions as appropriate. All of the respondents were engineers experienced with some aspect of AWHP or VRF system design, energy modeling, and/or commissioning. Several were principals in their firms and some were also involved in either ASHRAE 90.1, Title 24, or IECC Standards activities. Respondent and company names were masked so that their feedback can be provided for this report.

Note that manufacturer representatives were also contacted to determine information on system options, costs, and applications.

Table 57: AWHP Interview Respondents

Name	Company	Time	Attendees
Respondent 1	Company 1	9/16/22. 11:30-12:00	John Arent, Bach Tsan
Respondent 2	Company 2	9/23/22	John Arent, Bach Tsan
Respondent 3	Company 3	9/23/22	John Arent, Bach Tsan
Respondent 4	Company 4	10/5/22 9:30-10:00	John Arent, Bach Tsan
Respondent 5	Company 5	10/12/22 9:30-10:00	John Arent, Bach Tsan
Respondent 6	Company 6	10/12/22 14:00-14:30	John Arent, Bach Tsan
Respondent 7	Company 7	10/18	John Arent
Respondent 8	Company 8	10/19	John Arent

General Questions

1. Have you designed a system that uses AWHPs or other non fossil-fuel based system for central heating?
    a. (If Yes) was the system installed in a commercial or HRR building? Was this a new

   b. (If No) Would you consider the design of such a system? What are the barriers and/or design challenges towards using AWHPs for central space heating?

Questions 2-4 if project uses this type of system

2. Were you able to use an off-the-shelf equipment for the project?
3. What design water supply temperature does the system provide?
4. Was supplemental heating used or needed? If yes, what type of heating?
5. What type of terminal units did you use? (VAV boxes, four-pipe fan coil, radiant heating, other)
6. What obstacles, if any, did you face at getting the AWHP system approved?
7. Are there any building conditions or constraints that would cause you to not specify AWHP for space heating?
8. General Discussion of System Costs and Wrap-Up

Key Takeaways

System Applicability:

AWHP applicable to new construction and retrofit projects. Common building types are large office and large school, with some health care, laboratory buildings, and hotel buildings. System constraints are primarily cost, and space and footprint required for larger buildings, when using the modular systems.

System Types:

There are two main types of systems: modular AWHPs and traditional AWHPs. The modular systems are lower in capacity (in the range of 15 tons to 50 tons), and supply relatively high hot water temperatures of approximately 130°F at ambient temperatures of 0°F. Examples of these are the Aermec or Multistack systems. They have excellent turndown for control. The drawbacks to these systems are their peak capacity range and their high system cost. Conventional heat pumps are much less expensive and have a much wider operating range (as much as 200 tons or greater) but are typically limited to hot water supply temperatures of 100°F at 0°F outside ambient.
For larger buildings, a cascade type system, described by Respondent 8 and Trane and mentioned by Respondent 3, can be used. This system configuration uses an AWHP as the primary space heating, with a supplemental water-water heat pump to maintain the required hot water temperature.

For smaller buildings, VRF systems (air-source or water-source) are another electric heating design option. For high-rise residential buildings, unit-by-unit water loop heat pump or floor-by-floor water-source VRF systems are a design option that requires minimal footprint inside the building.
Some level of freeze protection with glycol is normally required, even in the coastal areas. This will have a slight impact on efficiency levels of the heat pumps.

Supplemental Heating:

The designers are split on the need for supplemental heating in the temperate coastal climates. It is only needed typically for morning warm-up and for peak design heating conditions, less than 50 hours a year. The simplest options are a backup gas boiler or electric resistance boiler. More sophisticated options include a water-water heat pump, applicable to large buildings.

Terminal Units:

Different terminal units have been used with AWHP systems successfully. For a VAV-reheat system that is common in office buildings, specifying two-row coils instead of one-row coils is normally sufficient to deliver adequate discharge temperature at the diffusers. A manufacturer guide from Trane provides additional guidance. Fan coil units can also be used. Multiple designers have used radiant floor heating systems, which aligns well with the hot water delivery temperatures of AWHPs.

Thermal Storage:

Thermal energy storage was identified by nearly all respondents as a required element of a well-designed AWHP system for space heating. A number of energy storage techniques were identified: storage tanks, phase-change storage, radiant in-slab heating, and thermal piles in the foundation. A rule-of-thumb provided by Trane is to have 8 gallons per ton for an air-water heat pump system. The loop transit time is important for heat pumps when they reach conditions when defrost is needed.

Operation and Maintenance:

A few subject matter experts pointed out the challenge in applying complicated control strategies, especially from an operations and maintenance standpoint. An eye-opener was Respondent 5 describing how one project for a large-scale campus building took several months to commission. Respondent 6 described how, during a measurement and verification phase of the project for a net zero building, how they discovered a number of systems that weren’t working as described, resulting in a large deviation from expected energy use. The two-pipe system that Respondent 3 described would offer a simpler system to install and operate.

System Cost:

The modular AWHP systems are comparatively expensive, and several of the units would be required on larger projects. A precise estimate is still being investigated, but one respondent indicated a sixfold increase in system cost over a conventional system, not including the controls and commissioning. Respondent 6 developed a life-cycle cost estimate for a school project and a medical office building project, and the normalized first costs are shown below for the design options considered.