Codes and Standards Enhancement (CASE) Initiative

2025 California Energy Code

Residential HVAC Performance

Residential HVAC
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Draft CASE Report

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Executive Summary

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

Email comments and suggestions to Kristin Heinemeier (kheinemeier@frontierenergy.com) and info@title24stakeholders.com by July 18, 2023 Comments will not be released for public review or will be anonymized if shared.

Introduction

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

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

The Statewide CASE Team gathered input from stakeholders to inform the proposal and associated analyses and justifications. Stakeholders also provided input on the code compliance and enforcement process. See Appendix F for a summary of stakeholder engagement.

The goal of this CASE Report is to present a cost effective code change proposal for Residential HVAC performance. The report contains pertinent information supporting the code change.

Proposal Description

Proposed Code Change

This CASE Report documents a set of proposals designed to ensure that residential HVAC systems perform efficiently and effectively, providing comfort and protecting the condition of the equipment. The six measures described here are mostly mandatory measures, with a few prescriptive measures and newly defined prescriptive alternatives. They generally apply to both single family and multifamily buildings, and to new construction as well as additions and alterations. The proposed measures include one new HERS measure and contain proposals to allow for remote verification in lieu of on-site verification.

Table 1 provides a summary of the measures. Every effort was made to simplify these measures, while adding rigor to some processes such as HVAC load calculations and refrigerant charge verifications. These measures reflect an increased emphasis on the design process, which is especially important with the increased interest in installing heat pumps.

Table 1: Summary of Code Change Proposal

Code Change Proposal	Brief Description
Design (Sizing, Equipment Selection, and Ducts/ Diffusers)	Require documentation of load calculations and system sizing; provide details on duct/diffuser design; minimum heating capacity—not including supplementary heating.
Design (Sizing, Equipment Selection, and Ducts/ Diffusers)	Require documentation of load calculations and system sizing, even for like-for-like replacements; provide details on duct/diffuser design; require use of average infiltration assumptions (or blower door test) and allow simplifying assumptions in some load calculations; minimum heating capacity—not including supplementary heating; and maximum equipment sizing limits (or ensure adequate airflow).
Supplementary Heating	Install and field verify controls that lock out supplementary heating above an outdoor temperature of 35°F; impose strip heating capacity limits.
Defrost	Set defrost delay timer optimally.
Crankcase Heating (CCH)	Mandatory: CCH may not run when compressor runs. Prescriptive: CCH energy below federal maximum; CCH has temperature controls; or install smart thermostat.
Refrigerant Charge Verification (RCV)	Require documentation when refrigerant weigh-in method used and allow remote verification.
Variable Capacity Systems	Modify fan efficacy test procedure; clarify definition of system airflow; compliance model revisions to account for distribution loss impacts of variable capacity systems.

Justification and Background

Design (Sizing, Equipment Selection, and Ducts/Diffusers)

Proper design of a residential HVAC system is the foundation for energy savings and effective operation over the life of the system, for new homes as well as additions or alterations. Sizing is sometimes a delicate balance between oversizing (which can be inefficient, uncomfortable, and prevent effective humidity control), and undersizing (which can result in excessive operation of heat pump backup strip heating, insufficient airflow to achieve whole home comfort, and inability to achieve thermostat set-points).

The requirements proposed here seek to provide load calculation and equipment selection guidance that is specific to California climates. This is achieved by putting more emphasis on design, by requiring that authorized calculations (already required—based on authorized algorithms found in or ACCA Manual J, ASHRAE Manuals, or the SMACNA Residential Comfort System Installation Standards Manual) be, and a duct and diffuser design be submitted, preventing undersizing of heat pump units (and avoiding excessive strip heating), avoiding upsized systems that have a steep energy penalty unless ducts are correspondingly upsized, and ensuring that variable capacity and multi speed systems can operate at sufficiently low capacities. The requirements propose to provide more rigor in the requirement to use and document authorized load calculations, and require a closer look at the impact of house infiltration on sizing. To reduce the time and cost for simple projects, allowance is made for simplification of the current procedures in many circumstances, although load calculations are explicitly now required even for like-for-like equipment replacements.

The benefits of these measures include avoiding the energy penalty from an upsized system in existing homes without correspondingly upsized ducts where cooling is dominant, and minimizing use of supplementary heating by avoiding undersizing the heat pump in homes where heating is dominant. It will also improve comfort by encouraging selection and location of diffusers to ensure adequate mixing. This measure will also result in significant improvements in electrical demand when strip heating is installed. By preventing oversizing, it will reduce wear and tear on a system and extend its life.

Supplementary Heating

Some heat pumps are installed with gas or electric backup or supplementary heating, depending upon climate, equipment sizing, and contractor experience. For the HVAC designer, supplementary heating can provide an added capacity cushion to maintain customer comfort and satisfaction. Supplementary heating should be used sparingly: electric resistance supplementary heating uses about three times as much electric energy as a heat pump compressor to provide a unit of heat, while a ”dual fuel” system that couples a heat pump along with a natural gas furnace as a backup heat source may result in more greenhouse gas emissions than a standard heat pump. With a well-designed heat pump system, supplementary heating should seldom operate in most California climates. To minimize energy consumption, controls are needed to ensure that the heat pump provides as much of the required heating as possible. The supplemental heating measure requires installation of controls that lock out the operation of the supplementary heating when temperatures are not severe and limit the capacity of electric resistance strip heating to the minimum needed for emergency or defrost operation. Because this control is so critical to avoiding the potential for significant energy waste with supplementary heating, HERS verification is proposed to be required. To assist in both installation and verification, manufacturers of heat pumps and third-party thermostats will be required to produce simple language instructions of how to configure their equipment to meet these requirements.

These measures will provide cost effective energy savings in most climate zones, by eliminating the use of either inefficient electric resistance strip heating or natural gas at times when the heat pump will provide comfort more efficiently and with fewer greenhouse gas emissions. They will also provide significant benefits to winter morning peak demands, through proper control and a limit on capacity. Possible comfort impacts may occur for those occupants who choose to implement a deep nighttime setback, by extending the amount of time needed to reach setpoint.

It is important to note that avoiding supplementary heating makes all the other performance measures proposed here even more important (e.g. sizing, defrost controls, and air distribution design).

Defrost

To remove ice from heat pump outdoor coils at times when outdoor temperatures are low and humidity is high enough, heat pump systems typically utilize a defrost cycle. In a defrost cycle, the system ”reverses,” essentially air conditioning the indoor space to warm up the outside coils (for ice removal), followed by a period of recovery, during which the system must reheat the space. Energy used for defrost is necessary, but does not contribute to useful heating, and can create comfort problems.

This measure will require that, when present, the manufacturer’s defrost delay timer be set to a moderate value of no less than 90 minutes to extend the amount of time between defrost cycles.

This will reduce energy use by heat pumps by reducing the frequency of defrost cycles and the length of time the unit spends in defrost mode. The proposed control requirement will improve peak demand, as the conditions that are conducive to frost development coincide closely with winter morning peaks in California’s mild climates. The requirement can also improve comfort, as it will minimize unnecessary defrost operation. Reducing the frequency of defrost operation can also reduce wear and tear on a system and improve system life.

Crankcase Heating (CCH)

CCH is used in most heat pumps and air conditioners to prevent compressor damage by keeping the compressor warmer than the outdoor coils and casing[1]. Field monitoring studies have found that CCH can consume surprising amounts of energy on an annual basis, particularly in low load buildings or other applications where the compressor is off for much of the year. CCH that runs during mild conditions is particularly a problem in air conditioners, where the CCH can run all winter long.

This measure has two components: a mandatory measure and a prescriptive measure. The mandatory measure will ensure that CCH will not operate when the compressor is operating. The prescriptive measure reflects the fact that energy use with a poorly controlled CCH can be excessive and requires installation of an Occupant Controlled Smart Thermostat to reduce HVAC energy use, unless evidence is provided by the manufacturer that the CCH controls are efficient (rated off-mode power is less than that required by federal regulation or manufacturer documentation that the CCH is efficiently controlled), or that there is no CCH.

CCH energy is a “vampire” electrical load—silent and overlooked—but significant when totaled over time and across all California air conditioner and heat pump units. Especially in mild climates where systems are likely to be off for significant fraction of the year, CCH can represent a large fraction of the energy consumed over the year (studies have found situations where CCH represented about half of annual energy (for example, (McHugh 2022), (Dryden 2021), and (B. A. Wilcox 2018)). Better control can reduce this significantly. CCH operation does not represent a significant peak demand issue, since its use is not concentrated during either the summer or winter peak. It should have no effect on comfort. So long as the CCH is not disabled at times when it would be needed, it should not affect system life or maintenance requirements.

Refrigerant Charge Verification

Proper refrigerant charge is necessary for air conditioners and heat pumps to operate at peak performance in all climate zones. The primary methods of verification of refrigerant charge in Title 24 Part 6 currently include either testing the refrigerant temperatures and pressures with refrigerant gauges,or adding the correct amount of refrigerant by weight to an empty or partially charged system. For the former, a HERS Rater is required to visit the site to do independent testing. For the latter, a HERS Rater is required to visit the site to observe the weigh-in process.

[1] During off-cycles, the refrigerant will migrate to the coldest part of the system.

Challenges with ensuring proper refrigerant charge include inadequate training, out-of-calibration gauges, charging air conditioners when outdoor temperatures are too low, the time and cost for a HERS Rater to be at the site (along with logistical challenges of being there at the right moment during installation), concerns about the inaccuracy of the current requirements (researchers have suggested that current methods may have a 50 percent chance of misreporting appropriateness of charge), and the fact that modern systems are more complicated for which standard procedures are not appropriate. Since manufacturers take great pains to determine the optimum amount of charge, it would be preferred to use their recommended charge weight.

The proposed measure will extend verification requirements to heat pumps in all climate zones except 6 and 7. It retains existing methods but adds rigor to the weigh-in method while providing a remote verification option that should make the process easier and less expensive in most situations. It removes the description of the Field Indicator Display method of compliance, as there is no record that it has ever been used or indication that it is likely to be used in the future.

The revised procedures for charge verification will not affect energy savings or cost effectiveness in the climate zones where it is already required for both cooling-only systems and heat pumps. But energy savings for charge verification are higher for heat pumps than for cooling-only systems, and charge verification was found to be cost effective for heat pumps in most climate zones, even those where it was not cost effective for cooling-only systems. Adding increased rigor to the weigh-in method makes charge verification more accurate, only increasing energy savings, although these additional savings were not modeled. The allowance for remote verification may also lead to increased compliance rates for this measure. The HERS verification process may be a big contributor to non-compliance rates, due in part to the inconvenience and complexity of coordinating system startup with HERS Rater availability—which seems especially unwarranted when charge weigh-in is the only verification needed—and the requirement in some cases for homeowners to be present. Reducing the cost and inconvenience of this verification may actually improve compliance rates.

Variable Capacity and Zonally Controlled Systems

Variable Capacity and Multi Speed (VCMS) systems can provide much improved system efficiency which is reflected in the high SEER and HSPF ratings. However, for systems with ducts in vented attics without roof deck insulation, duct losses climb as the airflow rate declines, and the distribution efficiency can be greatly reduced. This effect is captured when systems are modeled using the VCHP-Detailed method in CBECC-Res but is not reflected in standard CBECC-Res modeling of VCMS systems. The proposed change to compliance models will account for reduced distribution efficiency at lower speeds and airflows. Zonally controlled systems would not be affected by this change since duct air velocity is maintained.

The proposed measure will require a change in the way that fan efficacy is measured during field verification and clarifies how system air flow is defined in zoned systems. It also proposes modifying the way that variable capacity systems are modeled in vented attics.

Scope of Code Change Proposal

Table 2 summarizes the scope of the proposed changes and which sections of Standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manuals, and compliance documents that would be modified as a result of the proposed change(s).

Table 2: Scope of Code Change Proposal

Measure	Type of Requirement	Mandatory	
Design (sizing, Equipment Selection, and Ducts/ Diffusers)	Applicable Climate Zones	All HVAC in all CZs, New Construction (NC), Additions (ADD), and Alterations (ALT)	
	Modified Section(s) of Title 24, Part 6	150.0(h) 1, 2, 5(new), 6(new); 150.2(a) 1E(new) and 2D(new) and 150.2(b) 1O(new), 2D(new), and 2E(new)	
	Modified Title 24, Part 6 Appendices	JA 2.2, and RA TBD(new)	
	Would Compliance Software Be Modified	Yes	
	Modified Compliance Document(s)	CF1R-PERF, CR1R-ALT-02, CF1R-NCB, CF2R-MCH-01-E, CF2R-TBD(new)	
Supplementary Heating	Applicable Climate Zones	Heat pumps in all CZs but 15; Not for small single family homes	
	Modified Section(s) of Title 24, Part 6	110.2(b)1, 110.2(b)2, 150.0(h)9(new), 150.0(h)10(new)	
	Modified Title 24, Part 6 Appendices	RA 3.4.TBD(new)	
	Would Compliance Software Be Modified	Yes	
	Modified Compliance Document(s)	CF2R-MCH-01-E, CF2R-MCH-TBD(new), CF3R-MCH-TBD(new)	
Defrost	Applicable Climate Zones	Heat pumps in all CZs; Not for small single family homes in CZs 5-10, 15	
	Modified Section(s) of Title 24, Part 6	150.0(h)7(new)	
	Modified Title 24, Part 6 Appendices	RA 3.4.TBD(new)	
	Would Compliance Software Be Modified	Yes	
	Modified Compliance Document(s)	CF2R-MCH-01-E, CF2R-MCH-TBD(new), CF3R-MCH-TBD(new)	
Crankcase Heating	Applicable Climate Zones	Heat pumps and AC in all CZs	Heat pumps and AC in all CZs
	Modified Section(s) of Title 24, Part 6	150.0(h)8(new)	150.1(c)7B(new)
	Modified Title 24, Part 6 Appendices	None	None
	Would Compliance Software Be Modified	Yes	
	Modified Compliance Document(s)	CF2R-MCH-01-E	CF2R-MCH-01-E

Measure	Type of Requirement	Mandatory
Refrigerant Charge Verification	Applicable Climate Zones	Heat Pumps. In ALT: all CZs; in NC: CZs 1-5, 8-16; Not for small single family homes
	Modified Section(s) of Title 24, Part 6	150.1(c)7A
	Modified Title 24, Part 6 Appendices	JA 6.1(eliminated), RA3.2.3, RA 3.2.4(eliminated)
	Would Compliance Software Be Modified	Yes
	Modified Compliance Document(s)	CF2R-MCH-25c, CF3R-MCH-25c, CF2R-MCH-25g (new), CF3R-MCH-25g (new), CF3R-MCH-25d(eliminated)
Variable Capacity and Zonally Controlled Systems	Applicable Climate Zones	Variable Capacity Systems in all CZs
	Modified Section(s) of Title 24, Part 6	150.0(m)13
	Modified Title 24, Part 6 Appendices	None
	Would Compliance Software Be Modified	Yes
	Modified Compliance Document(s)	None

Market Analysis and Regulatory Assessment

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. It then considered how the proposed standard may impact the market in general as well as individual market actors. Information was gathered about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, CEC staff, and a wide range of industry actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during a public stakeholder meeting that the Statewide CASE Team held on January 24, 2023 (California Statewide Codes & Standards Team 2023).

Currently, there are about 9,766,766 single family homes in California. 63,600 homes are built annually, most of which have HVAC systems. We assume that by 2026, 90 percent of new homes will be installing heat pumps. We assume that this fraction will increase to 100 percent within the next 30 years, due to a range of factors including local reach code requirements for electrification and current and expected tax incentives. The residential HVAC performance measures described in this report will be applicable to all of these homes, as described in the following sections.

Similarly,13 percent of HVAC replacements are currently gas to heat pump, and this fraction is expected to increase to 100 percent within the next 30 years, due to reach codes, tax incentives, and rebates from programs such as TECH Clean California. The following sections describe to how many homes these measures will apply.

The measures described here will have an impact on a number of market actors. HVAC system designers and system installers typically work for the same HVAC contracting firm. These firms range from small “mom and pop”, one-truck firms to large and sophisticated firms employing a hundred or more HVAC professionals. These contractors purchase equipment and supplies from distributors that are sometimes aligned with particular manufacturers. Many distributors have experienced staff that play an important role in educating designers and installers on the proper use of the products that they sell. Energy consultants provide services to designers to run compliance software and determine if the home complies with code and help prepare documents to submit to code officials. Plans checkers, who work for city or county jurisdictions, typically do a cursory review of submitted plans, primarily to determine whether required information is provided in the plan package. HERS Raters are independent consultants, hired by contractors to provide on-site testing and observations. It is possible that some of these roles may be modified as the market adjusts to the revised requirements in the 2025 version of Title 24, Part 6. For example, distributors or energy consultants may take on a bigger role in carrying out and documenting load calculations, system selection, duct/diffuser design, and blower door tests. When HERS Raters provide remote verification, they will be in much more of a quality-assurance rather than testing role.

Beyond the January 2023 Stakeholder meeting, the Statewide CASE Team met with several manufacturers and contractors during development of this proposal. A survey will be done of contractors to assess the prevalence of some of the issues described below and to estimate incremental costs. The team has reviewed data collected in the HERS Registry to ascertain rates of implementation of various processes and features.

Each measure was evaluated for market and technical feasibility, as described in Section 3.2. This included assessing:

- Under what conditions this measure was found to be technically feasible,
- Any conflicts with other building objectives and other codes that might conflict with the measure
- Availability of necessary products or technologies in the market
- Whether there are multiple manufacturers that currently provide the technology
- Whether changes would be required in the typical design strategy and which market actors would need to make revisions to their standard practice
- Whether there is enough market experience to predict product reliability, producer stability, and field performance
- The persistence of savings and any requirements for regular maintenance to achieve persistent savings
- Impacts on occupant comfort, aesthetics, etc., and any needs for mitigation

- Challenges associated with added field verification tests.

All proposed measures were found to be feasible and cost effective. This is described in Section 3.2. Some highlights of this assessment include:

- The importance of providing education to contractors on load calculations, sizing methods, and the importance of proper sizing.
- The importance of doing thoughtful duct and diffuser design, particularly with heat pumps which can cause uncomfortable drafts if poorly designed.
- Overcoming contractor and homeowner perceptions of effectiveness and the fact that supplementary heating should be minimized.
- The importance of ensuring that controls are configured correctly, the challenges this poses as systems are becoming more and more complicated, and the role that instructions from manufacturers can play.
- The role for advanced tools to collect and report system data for remote verification of the Refrigerant Charge Verification.

The Statewide CASE Team also analyzed the impacts of the measures on various parties such as builders, designers, owners and occupants, and on statewide employment. It evaluated the economic impacts on California businesses and on jobs. These, and other analyses of market impacts of the proposed measures, are described in Section 3.3.

Cost Effectiveness

The proposed code changes were found to be cost effective for all climate zones where it is proposed to be required. The benefit-to-cost (B/C) ratio over the 30-year period of analysis ranged, depending on the climate zone, from 1.0 (the threshold for inclusion in the proposal) to over 100 (for defrost in climate zone 16). See more details in Section 5.[2]

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

See Section 5 for the methodology, assumptions, and results of the cost-effectiveness analysis.

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

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

Table 3 through Table 7 present the estimated impacts of the proposed code change that would be realized statewide during the first 12 months that proposed requirement(s) are in effect.

First-year statewide energy impacts are represented by the following metrics: electricity savings in gigawatt-hours per year (GWh/yr), peak electrical demand reduction in megawatts (MW), natural gas savings in million therms per year (million therms/yr), source energy savings in millions of kilo British thermal units per year (million kBtu/yr), and Long-term Systemwide Cost (LSC) savings in millions of 2026 present value dollars per year (million 2026 PV$/yr). See Section 6.1 for more details on the first-year statewide impacts. Section 4.2 contains details on the per-unit energy savings.

Avoided GHG emissions are measured in metric tons of carbon dioxide equivalent (metric tons CO2e). Assumptions used in developing the GHG savings are provided in 6.2 and Appendix D of this report. The monetary value of avoided GHG emissions is included in the LSC hourly factors provided by CEC and is thus included in the cost-effectiveness analysis.

The energy savings from these measures are very significant. Statewide savings are estimated to be over $100M for new construction and additions and over $360M for alterations. The highest performing measures include CCH and design measures in alterations and supplementary heating control measure in new construction and additions. Statewide source energy savings exceed 150 MBtu for alterations and are almost 40 MBtu for new construction and additions. Over 15 MW of demand savings are estimated.

The proposed measures are not expected to have any impacts on water use or water quality, excluding impacts that occur at power plants.

In addition to the emissions reductions noted in Table 3 through Table 7, the Statewide CASE Team calculated impacts on GHG emissions for these measures associated with embodied carbon. These measures reduce GHG emissions by almost 30 thousand metric tons CO2e due to embodied carbon impacts. See Appendix D for details on the methodology. These measure(s) do not have additional reductions from embodied carbon.

Table 3: Summary of Impacts for Residential HVAC Performance: Design

Category	Metric	New Construction & Additions	Alterations
Cost Effectiveness	Benefit-Cost Ratio Range (varies by climate zone and building type)	100.00 - 1000.00	1.09 - 1000.00
Statewide Impacts During First Year	Electricity Savings (GWh)	0.02	84.04
	Peak Electrical Demand Reduction (MW)	0.01	0.12
	Natural Gas Savings (Million Therms)	0.00	0.00
	Source Energy Savings (Million kBtu)	0.04	63.50
	LSC Electricity Savings (Million 2026 PV$)	$0.14	$66.00
	LSC Gas Savings (Million 2026 PV$)	$0.00	$0.00
	Total LSC Savings (Million 2026 PV$)	$0.14	$66.00
	Avoided GHG Emissions (Metric Tons CO_2e)	3	3,354
	Monetary Value of Avoided GHG Emissions ($)	$361	$413,002
	On-site Indoor Water Savings (Gallons)	N/A	N/A
	On-site Outdoor Water Savings (Gallons)	N/A	N/A
	Embedded Electricity in Water Savings (kWh)	0.00	0.00
Per Home Impacts During First Year	Electricity Savings (kWh)	0.37	139.01
	Peak Electrical Demand Reduction (W)	0.11	0.20
	Natural Gas Savings (kBtu)	0.00	0.00
	Source Energy Savings (kBtu)	0.76	105.04
	LSC Savings (2026 PV$)	$2.38	$109.17
	Avoided GHG Emissions (kg CO_2e)	0.05	5.55
	On-site Indoor Water Savings (Gallons)	N/A	N/A
	On-site Outdoor Water Savings (Gallons)	N/A	N/A
	Embedded Electricity in Water Savings (kWh)	0	0

Table 4: Summary of Impacts for Residential HVAC Performance: Supplementary Heating

Category	Metric	New Construction & Additions	Alterations
Cost Effectiveness	Benefit-Cost Ratio Range (varies by climate zone and building type)	0.00 - 20.59	0.82 - 17.65
Statewide Impacts During First Year	Electricity Savings (GWh)	7.45	6.19
	Peak Electrical Demand Reduction (MW)	6.92	0.00
	Natural Gas Savings (Million Therms)	0.00	0.00
	Source Energy Savings (Million kBtu)	22.63	18.09
	LSC Electricity Savings (Million 2026 PV$)	$57.32	$46.98
	LSC Gas Savings (Million 2026 PV$)	$0.00	$0.00
	Total LSC Savings (Million 2026 PV$)	$57.32	$46.98
	Avoided GHG Emissions (Metric Tons CO_2e)	1,198	957
	Monetary Value of Avoided GHG Emissions ($)	$147,482	$117,841
	On-site Indoor Water Savings (Gallons)	N/A	N/A
	On-site Outdoor Water Savings (Gallons)	N/A	N/A
	Embedded Electricity in Water Savings (kWh)	0.00	0.00
Per Home Impacts During First Year	Electricity Savings (kWh)	127.31	85.75
	Peak Electrical Demand Reduction (W)	118.46	0.00
	Natural Gas Savings (kBtu)	0.00	0.00
	Source Energy Savings (kBtu)	386.79	250.54
	LSC Savings (2026 PV$)	$979.50	$650.82
	Avoided GHG Emissions (kg CO_2e)	20.46	13.26
	On-site Indoor Water Savings (Gallons)	N/A	N/A
	On-site Outdoor Water Savings (Gallons)	N/A	N/A
	Embedded Electricity in Water Savings (kWh)	0.00	0.00

Table 5: Summary of Impacts for Residential HVAC Performance: Defrost

Category	Metric	New Construction & Additions	Alterations
Cost Effectiveness	Benefit-Cost Ratio Range (varies by climate zone and building type)	0.00 - 55.23	1.51 - 104.44
Statewide Impacts During First Year	Electricity Savings (GWh)	3.20	6.12
	Peak Electrical Demand Reduction (MW)	1.10	2.19
	Natural Gas Savings (Million Therms)	0.00	0.00
	Source Energy Savings (Million kBtu)	11.08	21.48
	LSC Electricity Savings (Million 2026 PV$)	$26.31	$50.74
	LSC Gas Savings (Million 2026 PV$)	$0.00	$0.00
	Total LSC Savings (Million 2026 PV$)	$26.31	$50.74
	Avoided GHG Emissions (Metric Tons CO2e)	582	1,137
	Monetary Value of Avoided GHG Emissions ($)	$71,662	$140,006
	On-site Indoor Water Savings (Gallons)	N/A	N/A
	On-site Outdoor Water Savings (Gallons)	N/A	N/A
	Embedded Electricity in Water Savings (kWh)	0.00	0.00
Per Home Impacts During First Year	Electricity Savings (kWh)	54.69	84.85
	Peak Electrical Demand Reduction (W)	18.85	30.39
	Natural Gas Savings (kBtu)	0.00	0.00
	Source Energy Savings (kBtu)	189.35	297.50
	LSC Savings (2026 PV$)	$449.63	$702.87
	Avoided GHG Emissions (kg CO2e)	9.94	15.75
	On-site Indoor Water Savings (Gallons)	N/A	N/A
	On-site Outdoor Water Savings (Gallons)	N/A	N/A
	Embedded Electricity in Water Savings (kWh)	0.00	0.00

Table 6: Summary of Impacts for Residential HVAC Performance: Crankcase Heating

Category	Metric	New Construction & Additions	Alterations
Cost Effectiveness	Benefit-Cost Ratio Range (varies by climate zone and building type)	10.26 - 43.74	10.66 - 103.90
Statewide Impacts During First Year	Electricity Savings (GWh)	12.92	269.22
	Peak Electrical Demand Reduction (MW)	0.78	17.09
	Natural Gas Savings (Million Therms)	0.00	0.00
	Source Energy Savings (Million kBtu)	15.83	344.67
	LSC Electricity Savings (Million 2026 PV$)	$80.97	$1,703.64
	LSC Gas Savings (Million 2026 PV$)	$0.00	$0.00
	Total LSC Savings (Million 2026 PV$)	$80.97	$1,703.64
	Avoided GHG Emissions (Metric Tons CO_2e)	847	18,214
	Monetary Value of Avoided GHG Emissions ($)	$104,260	$2,243,000
	On-site Indoor Water Savings (Gallons)	N/A	N/A
	On-site Outdoor Water Savings (Gallons)	N/A	N/A
	Embedded Electricity in Water Savings (kWh)	0.00	0.00
Per Home Impacts During First Year	Electricity Savings (kWh)	198.65	445.32
	Peak Electrical Demand Reduction (W)	12.09	28.27
	Natural Gas Savings (kBtu)	0.00	0.00
	Source Energy Savings (kBtu)	243.53	570.12
	LSC Savings (2026 PV$)	$1,245.27	$2,817.99
	Avoided GHG Emissions (kg CO_2e)	13.02	30.13
	On-site Indoor Water Savings (Gallons)	N/A	N/A
	On-site Outdoor Water Savings (Gallons)	N/A	N/A
	Embedded Electricity in Water Savings (kWh)	0.00	0.00

Table 7: Summary of Impacts for Residential HVAC Performance: Refrigerant Charge Verification

Category	Metric	New Construction & Additions	Alterations
Cost Effectiveness	Benefit-Cost Ratio Range (varies by climate zone and building type)	0.00 - 4.92	0.00 - 9.64
Statewide Impacts During First Year	Electricity Savings (GWh)	0.64	3.05
	Peak Electrical Demand Reduction (MW)	0.18	0.61
	Natural Gas Savings (Million Therms)	0.00	0.00
	Source Energy Savings (Million kBtu)	1.87	6.22
	LSC Electricity Savings (Million 2026 PV$)	$5.24	$21.86
	LSC Gas Savings (Million 2026 PV$)	$0.00	$0.00
	Total LSC Savings (Million 2026 PV$)	$5.24	$21.86
	Avoided GHG Emissions (Metric Tons CO2e)	99	345
	Monetary Value of Avoided GHG Emissions ($)	$12,167	$42,441
	On-site Indoor Water Savings (Gallons)	N/A	N/A
	On-site Outdoor Water Savings (Gallons)	N/A	N/A
	Embedded Electricity in Water Savings (kWh)	0.00	0.00
Per Home Impacts During First Year	Electricity Savings (kWh)	84.15	136.24
	Peak Electrical Demand Reduction (W)	24.54	27.06
	Natural Gas Savings (kBtu)	0.00	0.00
	Source Energy Savings (kBtu)	245.82	277.75
	LSC Savings (2026 PV$)	$688.01	$976.29
	Avoided GHG Emissions (kg CO2e)	12.97	15.39
	On-site Indoor Water Savings (Gallons)	N/A	N/A
	On-site Outdoor Water Savings (Gallons)	N/A	N/A
	Embedded Electricity in Water Savings (kWh)	0.00	0.00

Compliance and Enforcement

Overview of Compliance Process

The compliance process is described in Section 2.5.1. Impacts that the proposed measure would have on market actors is described in Section 2.5.2 and Appendix E. The Statewide CASE Team worked with stakeholders to develop a recommended compliance and enforcement process and to identify the impacts this process would have on various market actors.

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

1. Load calculations were previously required, although there was no requirement to submit them or verify that they were completed. The proposed measures include a requirement that a report from the load calculations be submitted with the Certificate of Compliance. Notably, load calculations would now be required even for like-for-like system replacements.
2. At the same time, simplifications of the load calculation process are allowed in some circumstances.
3. A schematic diagram and room-by-room description of duct and diffusers will be required on the system plans submitted to the enforcement agency.
4. Sizing limits are provided, as a modification to the ACCA Manual S limits that are often used.
5. Manufacturers' documents will be needed to ascertain whether or not a heat pump or air conditioner's CCH meets requirements.
6. Supplementary heating (strip heaters or furnace backup) will have to be locked out above a certain outdoor air temperature, and this control will have to be configured correctly (requiring manufacturers to provide succinct instructions) and HERS verified.
7. Refrigerant charge weigh-in can be HERS-verified remotely for the first time, with a requirement to upload evidence or documentation of system characteristics and the weigh-in process.
8. The process for testing airflow and efficacy are clarified for variable speed systems serving zoned systems.

Field Verification and Diagnostic Testing

The proposed measures include one new HERS verification, and provide an alternative verification for one existing HERS measure.

The Supplementary Heating Control and Defrost measures require field verification. Since each manufacturer controls their equipment in different ways, the manufacturer is required, for both cases, to provide the installer with succinct and readily-accessible instructions for the proper configuration. The HERS verification will consist of obtaining these instructions and field-verifying that they were followed.

The Refrigerant Charge Verification measure provides a new option for remote verification of the proper weigh-in of refrigerant charge. Although it will be much more convenient for the contractor to not require a HERS Rater to be present during the charge, the verification includes a bit more rigor than previously required, including submission of evidence or documentation of the factors that are required for proper charge weigh-in.

Addressing Energy Equity and Environmental Justice

The Statewide CASE Team recognizes, acknowledges, and accounts for a history of prejudice and inequality in disproportionately impacted populations (DIPs) and the role this history plays in the environmental justice issues that persist today. DIPs refers to populations throughout California that most suffer from a combination of economic, health, and environmental burdens. These burdens include poverty, high unemployment, air and water pollution, presence of hazardous wastes, as well as high incidence of asthma and heart disease. DIPs also incorporate race, class, and gender since these intersecting identity factors affect how people frame issues, interpret, and experience the world.[3] While the term disadvantaged communities (DACs) is often used in the energy industry and state agencies, the Statewide CASE Team chose to use terminology that is more acceptable to and less stigmatizing for those it seeks to describe (DC Fiscal Policy Institute 2017).

Including impacted communities in the decision-making process, ensuring that the benefits and burdens of the energy sector are evenly distributed, and facing ith the unjust legacies of the past all serve as critical steps to achieving energy equity. Recognizing the importance of engaging DIPs and gathering their input to inform the code change process and proposed measures, the Statewide CASE Team is working to build relationships with community-based organizations (CBOs) to facilitate meaningful engagement. A participatory approach allows individuals to address problems, develop innovative ideas, and bring forth a different perspective. Please reach out to Marissa Lerner (mlerner@energy-solution.com) for further engagement.

[3] Environmental disparities have been shown to be associated with unequal harmful environmental exposure correlated with race/ethnicity, gender, and socioeconomic status. For example, chronic diseases, such as respiratory diseases, cardiovascular disease, and cancer, associated with environmental exposure have been shown to occur in higher rates in the LGBTQ+ population than in the cisgender, heterosexual population (Goldsmith and Bell 2021). Socioeconomic inequities, climate, energy, and other inequities are inextricably linked and often mutually reinforcing.

1. Introduction

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

For this report, the Statewide CASE Team is requesting input on availability of systems on the market with various:

1. *Manufacturer recommended variable capacity charging modes and tests.*
2. *Crankcase heater control algorithms.*
3. *Defrost control algorithms.*

Email comments and suggestions to Kristin Heinemeier (kheinemeier@frontierenergy.com) and info@title24stakeholders.com by July 18, 2023. Comments will not be released for public review or will be anonymized if shared.

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

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

The goal of this CASE Report is to present a code change proposal for residential HVAC performance. The report contains pertinent information supporting the proposed code change.

When developing the code change proposal and associated technical information presented in this report, the Statewide CASE Team worked with many industry stakeholders including individual HVAC manufacturers, contractors, and distributors, TECH program managers, and HERS Raters. The proposal incorporates feedback received during a public stakeholder workshop that the Statewide CASE Team held on January 24, 2023 (California Statewide Codes & Standards Team 2023).

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

- Section 2 – Measure Description provides a description of the six measures and their background. This section also presents a detailed description of how this code change is accomplished in the various sections and documents that make up the Title 24, Part 6 Standards.
- Section 3 – Market Analysis includes a review of the current market structure. It describes the feasibility issues associated with the code change, including whether the proposed measure overlaps or conflicts with other portions of the building standards, such as fire, seismic, and other safety standards, and whether technical, compliance, or enforceability challenges exist.
- Section 4 – Energy Savings presents the per-unit energy, demand reduction, and Long-term Systemwide Cost savings associated with the proposed code change. This section also describes the methodology that the Statewide CASE Team used to estimate per-unit energy, demand reduction, and Long-term Systemwide Cost savings.
- Section 5 – Cost and Cost Effectiveness presents the lifecycle cost and cost-effectiveness analysis. This includes a discussion of the materials and labor required to implement the measure and a quantification of the incremental cost. It also includes estimates of incremental maintenance costs, i.e., equipment lifetime and various periodic costs associated with replacement and maintenance during the period of analysis.
- Section 6 – First-Year Statewide Impacts presents the statewide energy savings and environmental impacts of the proposed code change for the first year after the 2025 code takes effect. This includes the amount of energy that would be saved by California building owners and tenants and impacts (increases or reductions) on material with emphasis placed on any materials that are considered toxic. Statewide water consumption impacts are also reported in this section.

- Section 7 – Addressing Energy Equity and Environmental Justice presents the potential impacts of proposed code changes on disproportionately impacted populations (DIPs), as well as a summary of research and engagement methods.
- Section 8 – Proposed Revisions to Code Language concludes the report with specific recommendations with ~~strikeout~~ (deletions) and <u>underlined</u> (additions) language for the Standards, Reference Appendices, and Alternative Calculation Method (ACM) Reference Manual. Generalized proposed revisions to sections are included for the Compliance Manual and compliance forms.
- Section 9 – Bibliography presents the resources that the Statewide CASE Team used when developing this report.
- Appendix A: Statewide Savings Methodology presents the methodology and assumptions used to calculate statewide energy impacts.
- Appendix B: Embedded Electricity in Water Methodology presents the methodology and assumptions used to calculate the electricity embedded in water use (e.g., electricity used to draw, move, or treat water) and the energy savings resulting from reduced water use.
- Appendix C: California Building Energy Code Compliance (CBECC) Software Specification presents relevant proposed changes to the compliance software (if any).
- Appendix D: Environmental Analysis presents the methodologies and assumptions used to calculate impacts on GHG emissions and water use and quality.
- Appendix E: Discussion of Impacts of Compliance Process on Market Actors presents how the recommended compliance process could impact identified market actors.
- Appendix F: Summary of Stakeholder Engagement documents the efforts made to engage and collaborate with market actors and experts.
- Appendix G: Energy Cost Savings in Nominal Dollars presents LSC savings over the period of analysis in nominal dollars.
- Appendix H: Description of Existing Building Prototype provides background information on the existing building prototype used for energy savings analysis.

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

2. Measure Description

2.1 Proposed Code Change

This CASE Report documents a set of proposals designed to ensure that residential HVAC systems perform efficiently and effectively, providing comfort and protecting the condition of the equipment. The six measures described here are mostly mandatory measures, with a few prescriptive measures and newly defined prescriptive alternatives. They generally apply to both single family and multifamily buildings, and to new construction as well as additions and alterations. The proposed measures include one new HERS measure and contain proposals to allow for remote verification in lieu of on-site verification for an existing HERS measure.

Table 8 provides a summary of the measures. Every effort was made to simplify these measures, while adding rigor to some processes such as HVAC load calculations and refrigerant charge verifications. These measures reflect an increased emphasis on the design process, which is especially important with the increased interest in installing heat pumps.

Table 8: Summary of Proposed Code Changes

Measure	Type	Applicable to	Brief Description
Design (Sizing, Equipment Selection, and Ducts/ Diffusers)	Mandatory	All HVAC in all CZs, New Construction (NC)	Require documentation of load calculations and system sizing; provide details on duct/diffuser design; minimum heating capacity—not including supplementary heating.
Design (Sizing, Equipment Selection, and Ducts/ Diffusers)	Mandatory	All HVAC in all CZs, Additions (ADD) and Alterations (ALT)	Require documentation of load calculations and system sizing, even for like-for-like replacements; provide details on duct/diffuser design; require use of average infiltration assumptions (or blower door test) and allow simplifying assumptions in some load calculations; minimum heating capacity—not including supplementary heating; and maximum equipment sizing limits (or ensure adequate airflow).
Supple-mentary Heating	Mandatory	Heat pumps in all CZs but 15; Not for small single family homes	Install and field verify controls that lock out supplementary heating above a certain outdoor temperature; impose strip heating capacity limits.
Defrost	Mandatory	Heat pumps in all CZs; Not for small single family homes in CZs 5-10, 15	Set defrost delay timer optimally.

Measure	Type	Applicable to	Brief Description
Crankcase Heating (CCH)	Mandatory	Heat pumps and AC in all CZs	CCH may not run when compressor runs.
	Prescriptive	Heat pumps and AC in all CZs	CCH energy below federal maximum; CCH has temperature controls; or install smart thermostat.
Refrigerant Charge Verification (RCV)	Prescriptive	Heat pumps. In ALT: all CZs; in NC: CZs 1-5, 8-16; Not for small single family homes	Require documentation when refrigerant weigh-in method used and allow remote verification.
Variable Capacity Systems	Mandatory	Variable Capacity Systems in all CZs	Modify fan efficacy test procedure; clarify definition of system airflow; compliance model revisions to account for distribution loss impacts of variable capacity systems.

2.2 Justification and Background Information

2.2.1 Justification

2.2.1.1 Design (Sizing, Equipment Selection, and Ducts/Diffusers)

Proper design of a residential HVAC system is the foundation for energy savings and effective operation over the life of the system, for new homes as well as additions or alterations. Sizing is sometimes a delicate balance between oversizing (which can be inefficient, uncomfortable, and prevent effective humidity control), and undersizing (which can result in excessive operation of heat pump backup strip heating, insufficient airflow to achieve whole home comfort, and inability to achieve thermostat set-points).

The requirements proposed here seek to provide load calculation and equipment selection guidance that is specific to California climates. This is achieved by putting more emphasis on design, by requiring that authorized calculations (already required—based on authorized algorithms found in or ACCA Manual J, ASHRAE Manuals, or the SMACNA Residential Comfort System Installation Standards Manual) be, and a duct and diffuser design be submitted, preventing undersizing of heat pump units (and avoiding excessive strip heating), avoiding upsized systems that have a steep energy penalty unless ducts are correspondingly upsized, and ensuring that variable capacity and multi speed systems can operate at sufficiently low capacities. The requirements propose to provide more rigor in the requirement to use and document authorized load calculations, and require a closer look at the impact of house infiltration on sizing. To reduce the time and cost for simple projects, allowance is made for simplification of the current procedures in many circumstances, although load calculations are explicitly now required even for like-for-like equipment replacements.

The benefits of these measures include avoiding the energy penalty from an upsized system in existing homes without correspondingly upsized ducts where cooling is dominant, and minimizing use of supplementary heating by avoiding undersizing the heat pump in homes where heating is dominant. It will also improve comfort by encouraging selection and location of diffusers to ensure adequate mixing. This measure will also result in significant improvements in electrical demand when strip heating is installed. By preventing oversizing, it will reduce wear and tear on a system and extend its life.

2.2.1.2 Supplementary Heating

Some heat pumps are installed with gas or electric backup or supplementary heating, depending upon climate, equipment sizing, and contractor experience. For the HVAC designer, supplementary heating can provide an added capacity cushion to maintain customer comfort and satisfaction. Supplementary heating should be used sparingly: electric resistance supplementary heating uses about three times as much electric energy as a heat pump compressor to provide a unit of heat, while a ”dual fuel” system that couples a heat pump along with a natural gas furnace as a backup heat source may result in more greenhouse gas emissions than a standard heat pump. With a well-designed heat pump system, supplementary heating should seldom operate in most California climates. To minimize energy consumption, controls are needed to ensure that the heat pump provides as much of the required heating as possible. The supplemental heating measure requires installation of controls that lock out the operation of the supplementary heating when temperatures are not severe and limit the capacity of electric resistance strip heating to the minimum needed for emergency or defrost operation. Because this control is so critical to avoiding the potential for significant energy waste with supplementary heating, HERS verification is proposed to be required. To assist in both installation and verification, manufacturers of heat pumps and third-party thermostats will be required to produce simple language instructions of how to configure their equipment to meet these requirements.

These measures will provide cost effective energy savings in most climate zones, by eliminating the use of either inefficient electric resistance strip heating or natural gas at times when the heat pump will provide comfort more efficiently and with fewer greenhouse gas emissions. They will also provide significant benefits to winter morning peak demands, through proper control and a limit on capacity. Possible comfort impacts may occur for those occupants who choose to implement a deep nighttime setback, by extending the amount of time needed to reach setpoint.

It is important to note that avoiding supplementary heating makes all the other performance measures proposed here even more important (e.g. sizing, defrost controls, and air distribution design).

2.2.1.3 Defrost

To remove ice from heat pump outdoor coils at times when outdoor temperatures are low and humidity is high enough, heat pump systems typically utilize a defrost cycle. In a defrost cycle, the system ”reverses,” essentially air conditioning the indoor space to warm up the outside coils (for ice removal), followed by a period of recovery, during which the system must reheat the space. Energy used for defrost is necessary, but does not contribute to useful heating, and can create comfort problems.

This measure will require that, when present, the manufacturer’s defrost delay timer be set to a moderate value of no less than 90 minutes to extend the amount of time between defrost cycles.

This will reduce energy use by heat pumps by reducing the frequency of defrost cycles and the length of time the unit spends in defrost mode. The proposed control requirement will improve peak demand, as the conditions that are conducive to frost development coincide closely with winter morning peaks in California’s mild climates. The requirement can also improve comfort, as it will minimize unnecessary defrost operation. Reducing the frequency of defrost operation can also reduce wear and tear on a system and improve system life.

2.2.1.4 Crankcase Heating

Crankcase heating (CCH) is used in most heat pumps and air conditioners to prevent compressor damage by keeping the compressor warmer than the outdoor coils and casing[4]. Field monitoring studies have found that CCH can consume surprising amounts of energy on an annual basis, particularly in low load buildings or other applications where the compressor is off for much of the year. CCH that runs during mild conditions is particularly a problem in air conditioners, where the CCH can run all winter long.

This measure has two components: a mandatory measure and a prescriptive measure. The mandatory measure will ensure that CCH will not operate when the compressor is operating. The prescriptive measure reflects the fact that energy use with a poorly controlled CCH can be excessive and requires installation of an Occupant Controlled Smart Thermostat to reduce HVAC energy use, unless evidence is provided by the manufacturer that the CCH controls are efficient (rated off-mode power is less than that required by federal regulation or manufacturer documentation that the CCH is efficiently controlled), or that there is no CCH.

CCH energy is a “vampire” electrical load—silent and overlooked—but significant when totaled over time and across all California air conditioner and heat pump units. Especially in mild climates where systems are likely to be off for significant fraction of the year, CCH can represent a large fraction of the energy consumed over the year

[4] During off-cycles, the refrigerant will migrate to the coldest part of the system.

(studies have found situations where CCH represented about half of annual energy (for example, (McHugh 2022), (Dryden 2021), and (B. A. Wilcox 2018)). Better control can reduce this significantly. CCH operation does not represent a significant peak demand issue, since its use is not concentrated during either the summer or winter peak. It should have no effect on comfort. So long as the CCH is not disabled at times when it would be needed, it should not affect system life or maintenance requirements.

2.2.1.5 Refrigerant Charge Verification

Proper refrigerant charge is necessary for air conditioners and heat pumps to operate at peak performance in all climate zones. The primary methods of verification of refrigerant charge in Title 24 Part 6 currently include either testing the refrigerant temperatures and pressures with refrigerant gauges, or adding the correct amount of refrigerant by weight to an empty or partially charged system. For the former, a HERS Rater is required to visit the site to do independent testing. For the latter, a HERS Rater is required to visit the site to observe the weigh-in process.

Challenges with ensuring proper refrigerant charge include inadequate training, out-of-calibration gauges, charging air conditioners when outdoor temperatures are too low, the time and cost for a HERS Rater to be at the site (along with logistical challenges of being there at the right moment during installation), concerns about the inaccuracy of the current requirements (researchers have suggested that current methods may have a 50 percent chance of misreporting appropriateness of charge), and the fact that modern systems are more complicated for which standard procedures are not appropriate. Since manufacturers take great pains to determine the optimum amount of charge, it would be preferred to use their recommended charge weight.

The proposed measure will extend verification requirements to heat pumps in all climate zones except 6 and 7. It retains existing methods but adds rigor to the weigh-in method while providing a remote verification option that should make the process easier and less expensive in most situations. It removes the description of the Field Indicator Display method of compliance, as there is no record that it has ever been used or indication that it is likely to be used in the future.

The revised procedures for charge verification will not affect energy savings or cost effectiveness in the climate zones where it is already required for both cooling-only systems and heat pumps. But energy savings for charge verification are higher for heat pumps than for cooling-only systems, and charge verification was found to be cost effective for heat pumps in most climate zones, even those where it was not cost effective for cooling-only systems. Adding increased rigor to the weigh-in method makes charge verification more accurate, only increasing energy savings, although these additional savings were not modeled. The allowance for remote verification may also lead to increased compliance rates for this measure. The HERS verification process may be a big contributor to non-compliance rates, due in part to the inconvenience and complexity of coordinating system startup with HERS Rater availability—which seems especially unwarranted when charge weigh-in is the only verification needed—and the requirement in some cases for homeowners to be present. Reducing the cost and inconvenience of this verification may actually improve compliance rates.

2.2.1.6 Variable Capacity and Zonally Controlled Systems

Variable Capacity and Multi Speed (VCMS) systems can provide much improved system efficiency which is reflected in the high SEER and HSPF ratings. However, for systems with ducts in vented attics without roof deck insulation, duct losses climb as the airflow rate declines, and the distribution efficiency can be greatly reduced. This effect is captured when systems are modeled using the VCHP-Detailed method in CBECC-Res but is not reflected in standard CBECC-Res modeling of VCMS systems. The proposed change to compliance models will account for reduced distribution efficiency at lower speeds and airflows. Zonally controlled systems would not be affected by this change since duct air velocity is maintained.

The proposed measure will require a change in the way that fan efficacy is measured during field verification and clarifies how system air flow is defined in zoned systems. It also proposes modifying the way that variable capacity systems are modeled in vented attics.

2.2.2 Background Information

2.2.2.1 Design (Sizing, Equipment Selection, and Ducts/Diffusers)

Design includes selecting the right type of system for the application (building characteristics and climate); sizing the unit and system optimally; sizing and positioning ducts and diffusers to provide well-mixed conditioned air without drafts; and selecting features that will improve performance. Sizing must find a balance between oversizing and undersizing.

In section 150.0(h) of the standards, Title 24 Part 6 currently requires that cooling and heating loads be determined using a method based on the ASHRAE Handbook, the SMACNA Residential Comfort System Installation Standards Manual, or ACCA Manual J.

ACCA Manual J is the decades old load calculation with continual support by Air Conditioning Contractor of America (ACCA, Manual J—Residential Load Calculation 2016). The SMACNA Manual and ASHRAE Handbooks also provide algorithms that are authorized to be used in load calculation. Algorithms provided in the these sources can be embedded in commercial software or can be used in manual calculations.

Title 24, Part 6, 150.0(h) also notes that the system must meet a minimum heating capacity adequate to meet the minimum requirements of the California Building Code (CBC). It specifies that the load calculations shall be based on an indoor temperature of 68°F for heating and 75°F for cooling, and on outdoor design conditions selected from Reference Joint Appendix JA2.2 (which is based on data from the ASHRAE Climatic Data from 1982 for Region X—Including California). It says that “The outdoor design temperatures for heating shall be no lower than the Heating Winter Median of Extremes values. The outdoor design temperatures for cooling shall be no greater than the 1.0 percent Cooling Dry Bulb and Mean Coincident Wet Bulb values.”

The California Green Code, Title 24, Part 11, Section 4.507.2, states that heating and air conditioning systems shall be sized, designed and have their equipment selected using ACCA Manuals J, D, and S, although there is no indication it has been followed consistently.   However, there is no specific requirement in Title 24, Part 6 to follow Manual S for system selection (ACCA, Manual S—Residential Equipment Selection 2014). For heat pumps, Manual S calls for sizing the heat pump to satisfy cooling loads regardless of climate zone, and to make up any shortfall in heating capacity with strip heating. It should be noted that Manual S is currently being revised, and it is expected that a new version will be available before the 2025 revisions to Title 24 Part 6 are adopted. The Statewide CASE Team provided comments to ACCA to ensure that it is the most informed basis from which to define California sizing requirements.

The California Mechanical Code requires that residential ducts be sized according to ACCA Manual D (or other approved methods).

Typical sizing methods allow for a number of implicit and explicit safety factors that fairly consistently result in oversized systems:

- Using the most severe outdoor temperatures for sizing
- Assuming the worst regarding building infiltration
- Using authorized load calculation methods, many of which are known to oversize by approximately 20 percent in some situations
- Using Manual S, which allows for a safety factor in the selected system size
- Using all these to identify a “good” size, and then rounding up to the next larger system.

These combine to result in a very oversized system. It should be remembered that oversizing a system is not the “safe” solution, as an oversized system can have as many comfort problems as an undersized system. And if an oversized unit is not accommodated by installing upsized ductwork, there can be a steep energy penalty.

The mandatory measures proposed in this section include the following:

Requirements related to load calculations:

- The design temperatures to be used in the authorized load calculations are proposed to be based on updated 2021 ASHRAE Region X weather data, and to be based on the 1 percent heating value, rather than the more severe “Heating Winter Median of Extremes” values, because the latter leads to oversized systems. Indoor temperature assumptions are not proposed to be changed.
- Accurate load calculations are important, but they can be time consuming. This proposal addresses this concern by allowing simplifying assumptions for the inputs to authorized load calculations in some circumstances. For example, in a simple like-for-like HVAC replacement (replacing with the same type of system and the same or smaller size), designers would be allowed to make assumptions such as a square home, and only general window locations. These simplifying assumptions are designed based on an analysis of the sensitivity of authorized load calculation outputs to different inputs. These assumptions would not be allowed for installation of heat pumps with electric resistance strip heaters, where sizing is more critical in managing the system’s annual energy usage.
- One authorized load calculation input that is more critical than often assumed is the envelope infiltration leakage. It is common for designers to use this input to ensure a “safety factor” by assuming high leakage, resulting in a larger system. This is not a desired practice, so the proposed requirements here will allow designers to upsize the unit based on a leaky envelope only if they establish through “blower door” infiltration measurements that it is in fact leaky. Otherwise, they will be required to assume no greater than “average” leakage and disclose to the homeowner that the leakage was not measured.
- This measure proposes to require that the output of an authorized load calculation, (and inputs and a description of the calculation if a load calculation software tool is not used) including design conditions, be submitted with a CF-1R to the local jurisdiction for plan review.
- Like-for-like equipment replacements, or “box-swaps” have been allowed in the past without load calculations. However, it is clear that many existing systems were poorly sized to start with, and changes to the home over time make any sizing estimates in the past irrelevant. Load calculations will be required even for this application.

Requirements related to System Selection:

- It is proposed that systems selected must meet ACCA Manual S limits, with the following modifications:
    - Minimum sizes:

        - For heating-only systems and heat pumps, the heating capacity (not including any supplementary heating) must be at least as large as the design heating load.
    - Maximum sizes:
        - For cooling-only systems, or heat pumps where the design cooling load is greater than the design heating load (cooling-dominated application):
            - The cooling capacity cannot be more than 6,000 Btuh larger than the design cooling load, and the heating capacity cannot be more than 12,000 Btuh larger than the design heating load.
            - For multi- and variable-speed systems, the *lowest speed* cooling capacity cannot be more than 80 percent of the design cooling load.
        - For heat pumps where the design heating load is greater than the design cooling load (heating-dominated application):
            - For multi- and variable speed systems, the *lowest speed* heating capacity cannot be more than 80 percent of the design heating load.
        - These maximum capacity limits are waived if system airflow is verified to be at least 350 cfm/ton. Since this is already a requirement for new construction, these maximum limits do not apply to new construction. The limits are also waived if the design cooling load is more than 12,000 Btuh larger than the design heating load, since it may then be unavoidable to oversize the heating capacity.
- Undersizing of heating systems is disallowed to prevent the common practice of downsizing a heat pump and making up for the lack of capacity with inefficient strip heating or fossil fuel use. There are no proposed restrictions on undersizing air conditioners.
- This proposal is more lenient about oversizing systems, particularly in heating dominated applications, and where the duct system is appropriately sized. This reflects research that found that, in heating dominated applications or in situations where the ducts are correspondingly upsized, there is little energy penalty for installing an oversized system (Domanski, Henderson and Payne 2014). In cooling dominated applications, however, they found about a 7 percent energy penalty if a system is oversized by 20 percent, and ducts are not correspondingly upsized. In cooling-dominated applications, it will likely be impossible to avoid somewhat oversizing the heating, so the proposed measure

allows oversizing of cooling capacity by up to 6,000 Btuh and heating capacity by up to 12,000 Btuh. In these cooling-dominated applications.

Designers can choose to oversize the system in excess of these limits, however, so long as they verify that the system airflow is sufficient, in some cases requiring duct modifications. Agiain, since new construction is already required to verify sufficient airflow, these limits are not required for new constructin.

In the small fraction of applications that are extremely cooling-dominated—defined as having cooling loads that exceed heating loads by more than 12,000 Btuh—it may be impossible to adequately limit heating oversizing. In these applications, system designers can also waive the limits described above.

- The limits above relate to the capacity of a single-speed system, or the maximum capacity of a multi- or variable-speed system. For multi- and variable-speed systems, the degree to which the system can "turn down" to operate at a lower capacity is also important to its overall performance. The proposed limits for the maximum allowed lowest speed capacity require that the system be able to turn down to 80 percent of the design cooling load for cooling dominated applications or 80 percent of the design heating load for heating dominated applications. Again, the designer can choose to waive these limits so long as the ducts are appropriately sized for the system's nominal capacity, and in extremely cooling-dominated applications.
- The measure also refers to requirements from Manual S-2023, for other limits on heat pumps and cooling-only systems, and for heating-only systems.

Requirements related to ducts and diffusers:

- Duct size and diffuser type and location are important for providing comfort. This is especially critical for heat pumps, where the supplied air is at a much lower temperature than that supplied by a furnace (typically about 100°F vs. 130°F for a furnace). Diffusers are rated by the manufacturer with a certain "throw." This defines the distance from the diffuser to a point where air velocity has been reduced to 50 feet per minute, where it is suitable to be introduced into the occupied zone. A well designed and placed diffuser will have a throw that is well matched to the room size. These factors are described in ASHRAE Handbook of Fundamentals, Chapter 20.

  The proposed measure will not require designers to design the ducts and diffusers well, but will require that they look at the manufacturer specs of the diffusers that they will employ, and show the manufacturer throw and room geometry. It is proposed that these factors be required to be included on the plans with at least a schematic diagram and room-by room information. If a designer has given some thought to the design of the system, this should take very little incremental time.

The benefits of these required measures depend on whether the home is cooling or heating dominated. With cooling dominated applications, the primary benefit is from avoiding the energy penalty from an oversized system without correspondingly upsized ducts. This penalty is expected to vary from about 5 percent for a ten percent oversized system to over 20 percent for a one hundred percent oversized system (Domanski, Henderson and Payne 2014). With heating dominated applications, the primary benefit is from avoiding undersizing the heat pump and requiring excessive amounts of supplementary heating, from either electric resistance strip heating or furnace operation (in a dual fuel system).

This measure will also have a big impact on peak demand when strip heating is installed. A strip heater on an undersized heat pump attempting to warm up a home on a cold winter morning will have a very significant increased demand. It will also have an impact on comfort, since it avoids excessive oversizing that threatens comfort due to short-cycling (never staying at the setpoint for long) and difficulty in controlling humidity. Oversizing that causes the system to cycle frequently can cause more wear and tear on a system and reduce its life.

2.2.2.2 Supplementary Heating

Most heat pump space conditioning systems utilize supplementary heating to ensure that the capacity is always sufficient to provide comfort to occupants. This backup heating can be either an electric resistance strip heater or a natural gas furnace. While this may be necessary in some very cold climates, interviews with contractors throughout California have found that with a well-designed system, it is not necessary in most residential applications. Even in Colder climate zones within California, the use of heat pumps designed with improved capacity at lower temperatures can avoid the need for suppolemental heating.

Electric resistance heating uses about three times as much energy as the heat pump compressor to provide heat, and electric heat has been disallowed as a primary source of heating in California for decades. When designers choose to install electric resistance heating backup with heat pumps, its use must be carefully controlled to avoid excessive energy use, particularly on cold winter mornings when occupants want their system to warm up rapidly.

“Dual fuel” systems that use a heat pump along with a natural gas furnace are sometimes installed as a retrofit (making replacement of the air handler unnecessary and often avoiding the need for installing a 220V circuit to the air handler) or a new system where the heat pump and furnace can be matched by the manufacturer. These systems are sometimes selected because they don’t require replacement of the air handler, or because homeowners believe that the heat pump is not a mature technology, and they are anxious about relying upon it to provide comfort for their families. With a well-designed system, it is possible that the furnace will seldom operate. To minimize the use of fossil fuels, controls should be installed to ensure that the heat pump provides as much of the heating as possible.

The requirements that are currently in Section 110.2(b)2 of Title 24, Part 6 related to strip heating specify that strip heating shall have controls that prevent strip heater operation when the heating load can be met by the heat pump alone. They also state that the strip heater must have controls in which “the cut-on temperature for compression heating is higher than the cut-on temperature for supplementary heating, and the cut-off temperature for compression heating is higher than the cut-off temperature for supplementary heating.” Exceptions are provided for defrost, and for recovery from setback so long as controls “preclude the unnecessary operation” of the strip heater. These requirements are difficult to interpret and impossible to enforce consistently. Supplementary heating in the form of a backup natural gas furnace is not addressed.

In its Performance Tested Comfort Systems (PTCS) program, Bonneville Power Administration requires that auxiliary strip heat must be controlled in such a manner that it does not engage when the outdoor air temperature is above 35°F, except when supplemental heating is required during a defrost cycle or when emergency heating is required during a refrigeration cycle failure (Burke 2019).

The mandatory measures proposed in this section, applicable for all climate zones except 15, and not for ADUs, include the following:

- Both electric resistance strip heating and furnaces in dual-fuel systems are required to have controls that are capable of locking out the supplementary heating whenever the outdoor air temperature is above 32°F. The temperature selection was made to provide optimal solutions for both very cold climate zones that have a very low design temperature, and more mild climates where the control should be more stringent.

  This type of control can typically be carried out by a thermostat (either from the OEM or a third-party manufacturer) that has access to an outdoor air temperature sensor or some other way of accessing local weather information (e.g., a smart thermostat). It can also be carried out by OEM or third-party controls on the outdoor unit. In either case, the measure requires that the controls be wired correctly, setpoints be set appropriately, and any other configurations such as dip-switches or thermostat installation settings be correct. This is important since heat pumps (especially dual fuel) are more complicated than conventional systems, and there may be installers who are not aware of the importance of these settings or trained in how to set them.

- Properly configured controls are required not only to ensure optimal performance, but also to avoid the potential for very high energy use and high winter morning peak demands. HERS verification of this configuration is required. Because it is difficult for both installers and HERS Raters to identify the proper way to configure systems, simple language easily accessible instructions for configuring the system to meet these requirements will be required to be provided by the manufacturer of either the heat pump or the thermostat (particularly important if a third-party thermostat is used). Interviews with contractors indicated that controls for heat pumps (and especially for control of supplementary heating) are more complex than conventional systems, and that many contractors are not aware of the importance of configuring controls correctly. As the state and the entire HVAC industry moves toward electrification of heating end uses rapidly, it is essential that heat pumps are installed correctly.
- A second requirement sets a limit on the capacity of a strip heater. This will prevent excessive energy use if for some reason the controls are not adequate. It will also minimize the peak demand impact of strip heaters on cold winter mornings. The limit is based on either the difference between the heating capacity at the design temperature and the heating design load, or 2.7 kw per nominal ton, whichever is greater. The first metric is a common way of sizing a heat pump, based upon the balance point. If the heat pump is sized according to the limits described in Section 2.2.1.1, however, this will be a very small number. The second metric is an amount of heating designed to mildly temper air delivered during transient defrost operation, without carrying the entire heating load of the home during defrost[5]. This approach will allow for indoor temperature to be maintained during the defrost cycle.

Implementing the proposed modifications in Title 24, Part 6 will provide cost effective energy savings in all climate zones but 15 by eliminating the use of either inefficient electric resistance strip heating or natural gas at times when the heat pump will provide comfort more efficiently and with fewer greenhouse gas emissions. It will also provide significant benefits to winter morning peak demands, through proper control and a limit on capacity.

Possible comfort impacts may occur for those occupants who choose to implement a deep nighttime setback. Extending the time needed to reach setpoint can occur, and occupants may choose to modify the nighttime setback strategy. The strip heater capacity limit may result in brief periods of cooler-than desired supply air during defrost cycles, but these will be brief and the capacity of the heat pump will soon be available to provide the necessary heating.

[5] Power required to heat air from 50°F just to 72°F at about 390 cfm/ton.

It is important to note that avoiding supplementary heating makes all the other performance measures proposed here even more important. It reinforces the importance of adequate attention to sizing, air distribution design, and defrost controls, for example.

2.2.2.3 Defrost

A defrost cycle removes ice from the heat pump outdoor refrigerant coil when outdoor temperatures are low and relative humidity high enough. In heating operation, the outdoor coil of a heat pump is significantly colder than the ambient temperature as the evaporator needs a temperature difference to extract heat from the outdoor air. When the outdoor dry bulb temperature is low enough to cause below freezing coil air temperatures, frost build up on the outdoor coil is common. This affects the heat transfer capacity of the outdoor coils, and lower the airflow through the coils, further reducing the evaporator temperature and heat transfer capacity. In extreme situations, the airflow can be reduced to such an extent that the system will no longer be able to operate due to low refrigerant pressure controls.

To prevent this, systems typically utilize a defrost cycle. During periods where frosting is likely (normally outdoor air temperatures in the mid thirties to mid forties), the system reverses operation and pulls heat from indoors and rejects the heat to the outdoor coil. In heating mode, this is essentially air conditioning the indoor space to warm up the outside coils, followed by a period of recovery, during which the system must reheat the space. Since providing cooling during already cold conditions can be uncomfortable, most systems compensate by running supplementary strip heat to temper the air.

There is not a lot that can be done to reduce the energy consumed for defrosting, but a good control algorithm can ensure that it runs as infrequently and as quickly as possible, to just prevent frost. Many systems use both temperature and time controls to initiate and to terminate the cycle. For example, some systems initiate the defrost mode only after a specified amount of time has elapsed after conditions become conducive to frost, based on outdoor air temperature or an outdoor coil temperature. The defrost mode itself can be terminated after a set amount of time, or when conditions are no longer conducive. The only user-configurable parameter of most defrost cycles is the “delay time,” or the amount of time that must elapse before initiating the defrost mode. Typical settings are 30, 60, 90, or 120 minutes, and the longer the delay, the less energy will used on defrost. This delay time is typically configured through use of a dip-switch or jumper on the control board of the outdoor unit.

Some higher-end systems utilize more advanced controls, including sensing temperatures at different points in the coil, or sensing any increasing resistance to airflow across the coil. Some systems disable the inside blower so that cold air is not blown on occupants. This may affect the amount of time the system has to stay in defrost mode. The energy used during these advanced defrost cycles is part of the federally regulated performance rating of a heat pump or air conditioner (AHRI 2023), so any requirements on these controls would be preempted, and are not proposed in this CASE Report. Since this feature is seldom advertised or considered a differentiator, lack of information can be a market barrier, and it is reasonable for code to address this.

The only mention of defrost in Title 24, Part 6 is to clarify that supplemental heating can be provided during a defrost cycle. There is no mention of controls that can minimize the energy used during these cycles by ensuring that they run as infrequently as possible and continue only as long as needed to eliminate coil icing.

The mandatory measure proposed in this section include the following:

- This measure requires the installer to set the defrost delay timer—if it exists—to a value of no less than 90 minutes. Many contractors have found that 120 minutes is adequate in most California climates, and 90 minutes is a safe and efficient setting. This would be required for all climate zones, but for homes less than 500 sqft it would be required only for climate zones 1-4, 11-14, and 16.
- The measure also requires the manufacturer to provide simple instructions for how to configure this timer. Proper settings are required to be HERS verified.

This new proposed requirement will reduce energy use by heat pumps by reducing the frequency of defrost cycles and the length of time the unit spends in defrost mode. Energy impacts can be estimated from analysis of fraction of time in a defrost cycle that the system is in defrost mode vs. delay mode. Energy use by the heat pump is fairly constant during both delay and defrost. The strip heater should only operate during the defrost mode, when it must both address current heating loads as well as make up for the cooling effect of the heat pump—with a very low coefficient of performance of 1.0. If the delay time is increased from 45 minutes (midway between the 30 and 60 minute settings that are common in some systems) to 90 minutes (the limit recommended by this measure), energy used for defrost will be reduced by about 25 percent[6].

The proposed control requirement will impact peak demand, as the conditions that are conducive to frost development coincide closely with winter morning peaks. The requirement can also have comfort implications, as it will minimize unnecessary defrost

[6] Assumes that the system energy consumption divided by heating load (E/L) is about 0.33 during the defrost delay (as expected for heat pump compressor operation), and is 2.33 during defrost operation (heat pump still runs in cooling mode with a COP of 3, and strip heating both meets heating load and removes an equivalent amount of cooling, each with a COP of 1). Assuming 12 minutes of defrost operation per cycle, going from a delay of 45 minutes to 90 minutes decreases the percent time in defrost from 21 percent to 12 percent per cycle. The average cycle E/L is reduced from 0.75 to 0.57: a 25 percent reduction.

operation. Reducing the frequency of defrost operation can also reduce wear and tear on a system and improve system life.

2.2.2.4 Crankcase Heating

CCH is used in most heat pumps and air conditioners to keep the compressor warmer than the outdoor coils and casing. This prevents the migration of liquid refrigerant into the compressor, which could cause severe damage on startup. CCH only needs to run when the compressor is off to ensure that upon startup refrigerant has not accumulated in the compressor. A variety of superior technologies exist, including compressors that inherently do not require CCH, and controls that operate CCH only as needed. Poorly controlled CCH is particularly a problem in air conditioners, where the CCH can run all winter long.

Field monitoring studies have found that CCH can consume surprising amounts of energy on an annual basis, particularly in low load buildings or other applications where the compressor is off for much of the year. For one monitored project, CCH in apartments consumed 900-2300 kWh/year, or almost half of the total annual HVAC load (McHugh 2022). CCH at each apartment at a housing complex in California represented a fixed load of about 100 Watts, consuming about 900 kWh/year or half of the average systems' energy use (Dryden 2021). Researchers studying a research house in central California found CCH was roughly half of the system's annual cooling energy usage (B. A. Wilcox 2018).

DOE regulates OFF mode power, including CCH, for residential air conditioners and heat pumps (DOE n.d.). The test method provided in AHRI Standard 210/240 (AHRI 2023) describes how the Off-mode Power Consumption (referred to as $P_{w,off}$) is to be established in a test lab. The method of test includes measuring power consumed by a heat pump or air conditioner when the unit is connected to its main power source but is neither providing cooling nor heating to the building it serves. Hence it includes the CCH, but also components such as controllers and indicators. The final metric is the average of the off-mode power per compressor, measured under conditions simulating the heating (P1) and shoulder (P2) seasons. These values are adjusted for the type of controls and for whether or not compressors are single- or multi-stage.

DOE efficiency standards require that, for systems with a cooling capacity of less than 3 tons, $P_{w,off}$ be no greater than 30W for air conditioners and 33W for heat pumps, and for larger systems, it must be no greater than 10W/ton for air conditioners and 11W/ton for heat pumps.

Regulations related to off-mode power consumption do not, however, address *on-mode* consumption. Most features that affect energy use are included in efficiency ratings and tests, and therefore cannot be included in Title 24, Part 6 requirements due to concerns about preemption. However, the federal test standard does not require that a CCH be present during those tests (per AHRI 210/240 Appendix G. Unit Configuration for Standard Efficiency Determination – Normative), and hence federal regulation is silent on energy use by CCH when the system is in on-mode. This means that Title 24, Part 6 is not prohibited by preemption concerns from regulating how the CCH is controlled when the system is operating.

It is impossible to identify in the field whether or not a unit has a CCH and how it is controlled.

Two CCH requirements are proposed here, one mandatory and the other prescriptive.

- The mandatory requirement states that CCH for heat pumps or air conditioners may not run continuously when the compressor is operating. Since this refers to on-mode operation, it is not in violation of preemption requirements.
- The prescriptive requirement reflects the fact that energy use with a poorly controlled CCH can be excessive and requires compensating efficiency measures when CCH without better controls are used. It states that unless the installer provides manufacturer documentation that the equipment does not have CCH, the designer must specify an Occupant Controlled Smart Thermostat, per JA5.

  Alternatively, the designer may provide manufacturer documentation showing that CCH control includes either thermostatic control (disabling CCH above a fixed outdoor temperature no higher than 55°F or differential temperature between crankcase and evaporator or condenser) or Positive Temperature Coefficient Control, and provide manufacturer's intermediate values "P1" and "P2" that are used in calculating the reported Pw,off values, per AHRI 210/240, to allow accurate modeling of connected power and control.

    - The prescriptive requirement does not apply if Pw,off values are below the federal efficiency standard limits, provide manufacturer's intermediate values "P1" and "P2" that are used in calculating the reported Pw,off values, per AHRI 210/240, to allow accurate modeling of connected CCH power and control.

CCH energy is a "vampire" electrical load: silent and overlooked, but significant. This is especially true in mild climates where systems are likely to be off for a significant fraction of the year. CCH can represent a large fraction of the energy consumed over the year. CCH operation does not represent a significant peak demand issue, since its use should not coincide with either the summer or winter peak (although avoiding operation when the compressor is running would provide more savings during peak periods). It should have no effect on comfort. So long as the CCH is not disabled at times when it would be needed, it should not affect system life or maintenance requirements.

2.2.2.5 Refrigerant Charge Verification

Proper refrigerant charge is necessary for air conditioners and heat pumps in all Climate Zones to operate at peak performance. Installers must ensure that a new system has the proper amount of charge before completing an installation, and this has been required beginning with the 2001, Title 24, Part 6 standards. With the increasing use of heat pumps, incorrect charge affects heating as well as cooling performance.

The primary methods of verification of refrigerant charge in Title 24, Part 6 currently include testing the refrigerant temperatures and pressures with refrigerant gauges, or adding the correct amount of refrigerant by weight to an empty or partially charged system. For the former, a HERS Rater is required to visit the site to do independent testing. For the latter, a HERS Rater is required to visit the site to observe the weigh-in process.

An alternative to refrigerant charge verification using a “fault indicator display” or FID has been allowed. As of this date no manufacturers have stepped forward with a device that meets the specifications listed in the Joint Appendices Section JA6.1. Measuring the temperature difference (“split”) between supply and return air streams is a component of the current FID specification, and an improved method was proposed in the 2019 Quality HVAC CASE Report as an alternative to charge verification but was not adopted due to concerns with its accuracy (Heinemeier 2020).

Challenges with ensuring proper refrigerant charge include:

- Inadequate technician training
- Difficulty in coordinating the HERS visit with the contractor refrigerant charge activity, and narrow window of opportunity for verification leading to non-compliance
- Some of the charging processes are lengthy (such as system evacuation), and it is impractical for a HERS Rater to be present to observe them
- Varying manufacturer charge test specifications and refrigerant weigh-in information provided
- Some variable capacity systems cannot use the standard charging protocol due to their inability to set compressor speed and/or do not provide charge ports
- Challenges with winter charge verification when the outdoor temperature is lower than 55°F such as manufacturer prohibitions against restricting outdoor unit airflow, and lack of follow-up when verification is deferred until outdoor temperatures rise
- Inadequate evacuation and leak detection due to improperly maintained vacuum pumps or limited time for evacuation
- Out-of-calibration gauges or scales

- Concerns about the accuracy of the current requirements
- Lack of charge verification where sampling is allowed

Modern HVAC systems are more complicated, and the “standard procedures” (charge testing procedures in Reference Residential Appendix Section RA3.2.2 Title 24, Part 6, 2022) are less appropriate, and manufacturers take great pains to determine the optimum amount of charge. It would be preferred to use their recommended charge weight, although the current weigh-in method lacks rigor and lacks a confirming performance test to ensure that the system is truly ready to operate efficiently. It is possible to weigh in the correct amount of charge but have systems still not perform properly due to other faults, such as low indoor coil airflow or line restrictions.

There are currently two primary methods allowed for verifying that the right amount is added: testing the performance of the system (subcooling for TXVs or superheat for fixed metering devices—the “standard” procedure), or observing that the installer added the required amount by weight (the “weigh-in” procedure). In both cases, a HERS Rater must travel to the site and perform their own tests or observe the installers adjustments. Sampling is allowed for the standard procedure, but not for the weigh-in procedure. To address situations where the outdoor conditions are not conducive to a charge test when the system is installed in winter, allowances are provided for modifying the test protocol or allowing for tentative approval pending future testing during the summer.

In RA3.2, the current weigh-in method requires that the installer confirm—and that the HERS Rater observe—a number of factors:

- The system is evacuated to 500 microns or less and, when isolated, rises no more than 300 microns over five minutes.
- The system is brazed with dry nitrogen in the lines and indoor coil.
- For weigh-in charge adjustment: The installer adds or removes the correct amount of charge, including adjustments for the diameter and extra length of the lineset, indoor coil (adjustments provided by manufacturer), and liquid line filter drier.
- For weigh-in of total charge: the installer adds or removes the correct amount of charge, based on lineset, indoor coil, filter dryer, and standard label charge.

Charge verification is currently required in only Climate Zones 2 and 8-15, because it was not found to be cost effective for cooling-only systems in other climate zones. Credit is given for charge verification with application of a “Compressor Efficiency Multiplier” within the CBECC-Res compliance software: 0.90 without verification, and 0.96 with verification. This reflects both the reduction in performance possible if the system is poorly charged and the probability that the system will end up properly charged with and without verification.

A third method of verification is currently offered in Title 24, Part 6: Field Indicator Display (FID). This was added as a placeholder to allow manufacturers to propose other methods to comply, although its definition is very thoroughly described. This method has never been utilized, and as written, it is not likely to be used. There is also more general language that allows anyone to propose a new method to the Energy Commission for approval as an acceptable alternative.

The accuracy of the standard procedure has been questioned. Researchers at Purdue University evaluated the charge testing procedure in Title 24, Part 6 (among other diagnostic methods), and found that it can lead to false alarm rates on the order of 50 percent (Yuill, Cheung and Braun 2014). Using refrigerant gauges in the standard procedure provides opportunities for both refrigerant release (a significant greenhouse gas problem), and introduction of moisture and other noncondensibles into the system, (a threat to performance and equipment life). Modern systems are more complicated, making the standard method less appropriate, and the performance charts provided for the standard method do not apply to variable capacity systems.

At the same time, technologies have emerged that allow contractors to collect, record, and report information about installation and adjustment processes and the results of tests. At the most basic level, almost all field installers have a smart phone capable of taking time-stamped photographs of instrument gauge readings. For more advanced documentation, Visual Service (visualservice.com), for example, allows the installer to use any Bluetooth-enabled instruments to take measurements (such as refrigerant canister weight, and air flow and temperature measurements) and record the readings. Reports specific to code compliance can be created and securely transmitted to a HERS Rater. These types of solutions make it possible to get robust validation of contractor activities without the expense of a HERS Rater traveling to the site.

This CASE Report proposal provides a set of code changes that would shift focus from charge testing to verified weigh-in, while adding more rigor to the weigh-in method. At the same time, it provides an option that would allow HERS Raters to verify weigh-in remotely, with electronic documentation uploaded by installers. The proposed measure retains existing methods but adds rigor to the weigh-in method while providing a remote verification option that should make the process easier and less expensive in most situations.

Charge verification has greater savings for heat pumps than for cooling-only systems, because heat pumps operate year round. The analysis done for this report found that it is cost effective for heat pumps in all climate zones except 6 and 7. The Compressor Efficiency Multiplier within CBECC-Res for verified and unverified systems is not proposed to be changed.

The prescriptive measures proposed in this section include the following:

- Refrigerant charge verification is proposed to be required for heat pumps in CZs 1-5 and 8-16. It will not be required for ADUs.

  Exception: Pre-charged systems that have a line set length within 5’ and a coil size within 10 percent of the manufacturer’s defauls.
- Systems for which charge cannot be adjusted may not use compression or flare fittings.

Modifications to the Charge Verification options include:

- Standard Charge Verification Procedure:
  - Current procedure including winter setup and tentative approval with return visit.
  - Not allowed for variable capacity systems, although variable capacity systems may follow manufacturer charge verification test method.
- Weigh-In Charging Verification Procedure:
  - Document system was brazed with dry nitrogen in the lines and indoor coil, and type of fittings used.
  - Document system was evacuated to 500 microns or less and, when isolated, rose no more than 300 microns over five minutes prior to weighing-in refrigerant (in-person verification, vacuum gauge photographs, or electronic instrument records).
  - Document assumptions for weigh-in adjustment or total charge weigh in (estimate geometry, line set assumed by manufacturer, excess line set length, adjustment for indoor coil(s) as recommended by manufacturer, filter dryer) and resulting total or added/removed refrigerant weight required per manufacturer’s requirements.
  - Document weight actually added or recovered (in-person verification, before and after scale photographs, or electronic instrument records).

  Exception: Vacuum documentation is not required if verification or documentation is provided that no fittings (other than the fitting to the compressor) are compression or flare fittings (in-person verification, photographs).
  - Weigh-in Procedure can be observed by HERS Rater in person or verified remotely through review of submitted documentation.

It is also proposed to remove any mention of the FID approach from Title 24, Part 6.

The revised procedures for charge verification will not affect energy savings or cost effectiveness in the climate zones where it is already required for both cooling-only systems and heat pumps. In the climate zones where charge verification was not previously found to be cost effective for cooling-only systems—1, 3-7, and 16—charge verification was not required. But energy savings for charge verification is higher for heat pumps than cooling-only systems, and charge verification was found to be cost effective for heat pumps in all climate zones, even those where it was not cost effective for cooling-only systems.

Although it is not modeled, it is expected that the revised procedures will make charge verification more accurate, due to the increased rigor for the weigh-in method. The allowance for remote verification may also lead to increased compliance rates. A properly charged system will provide comfort more reliably. A system that is poorly charged or contains noncondensibles due to an improper evacuation will have a reduced system life and require maintenance or replacement prematurely.

Other solutions such as automated Fault Detection and Diagnosis (FDD) were also considered. A measure to allow long-term FDD to be substituted for charge verification was considered for the 2022 Title 24 Part 6 code cycle, but it was problematic because it is difficult to ascertain in a fair and robust way that a particular tool is reliable enough. These considerations are documented in the CASE Report developed at that time (Heinemeier 2020). The current proposal is a step in this direction, by allowing installers to make use of advanced tools to make their own diagnoses.

2.2.2.6 Variable Capacity Systems

Variable capacity (VC) heat pumps and air conditioners, including those with two-speed and variable speed compressors and fans, can provide much improved system efficiency, which is accounted for in high efficiency ratings. However, for systems with ducts in vented attics without roof deck insulation, conduction losses increase as the airflow rate declines, and the distribution efficiency can be greatly reduced. This effect is captured by compliance software when systems are modeled using the “VCHP-Detailed” option (only available for cold-climate heat pumps that are NEEP listed) but is not reflected in standard CBECC-Res modeling of VCMS systems. The proposed change to compliance software will account for reduced distribution efficiency of all variable capacity systems while operating at lower speeds and airflows in response to the reduced instantaneous building loads as modeled. Zonally controlled systems would not be affected by this change since duct air velocity is maintained. This change will have little or no impact on systems with ducts in vented high performance attics (prescriptively required in Climate Zones 4 and 8-16) or where ducts are located in conditioned space.

Fan efficacy testing measures the fan power consumed per cfm of system airflow. This can be no more than 0.58 W/cfm for heat pumps or 0.45 W/cfm for furnaces. This metric is used to confirm that the fan energy of a system is not excessive, although it has a more important purpose of ensuring that the airflow of the system is adequate. Airflow and fan efficacy testing is done for VCMS systems at maximum speed.

A current exception to fan efficacy verification for zonally controlled systems allows efficacy verification to be conducted with all zones calling (zone dampers open) if a variable capacity system is installed. However, this overlooks the efficacy penalty if a single zone is calling for high speed fan and not all dampers are open, which can result in much reduced airflow and increased fan energy.

Title 24, Part 6 Section 150.0(m)13C requires zonally controlled systems to deliver through the air handler fan in every zonal control mode 350 cfm per ton of nominal cooling capacity. Taken literally, this would require each air handler used in a multi-split DX or multizone hydronic system to deliver 350 cfm per ton. This oversight can be overcome by including an exception stating if one compressor serves multiple air handlers that the sum of measured air handler airflows must meet or exceed 350 cfm/ton.

The mandatory measures proposed in this section include the following:

- For all Variable Capacity/Zoned Systems, airflow and efficacy testing must be done with only a single zone calling, not with all zone dampers open. This will ensure that when the system is only serving a single zone it will continue to operate efficiently. To pass this test will require that systems coordinate fan speed with the number of zones calling. Such products are available from major manufacturers.
- For systems with individual compressors serving multiple air handlers, the *sum* of airflows measured at all air handlers must be at least 350 cfm per ton of nominal compressor capacity.
- For non-zonally controlled VCMS systems with attic ducts, performance (airflow, distribution efficiency, and duct loss) will be calculated by compliance software as a function of instantaneous building load.

A current exception to fan efficacy verification for zonally controlled systems allows efficacy verification to be conducted with all zones calling if a variable capacity system is installed. A modification to this exception will require efficacy to be tested when only one zone is calling to verify that controls adequately reduce fan speed under this condition. This code change acknowledges that that there is currently no requirement that fan and compressor speed be coordinated with the number of zones calling, which can result in watts per cfm far exceeding the allowed 0.45 or 0.58 values.

2.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manuals, and compliance forms would be modified by the proposed change.[7] See Section 8 of this report for detailed proposed revisions to code language.

2.3.1 Specific Purpose and Necessity of Proposed Code Changes

Each proposed change to language in Title 24, Part 1 and Part 6 as well as the reference appendices to Part 6 are described below. See Section 8.2 of this report for marked-up code language.

2.3.1.1 Design (Sizing, Equipment Selection, and Ducts/Diffusers)

Section: 10-103 – Permit, Certificate, Informational, and Enforcement Requirements for Designers, Installers, Builders, Manufacturers and Suppliers.

Specific Purpose: The specific purpose is to require that the load calculation report be submitted with the Certificate of Compliance, and that submitted building plans must include at least a schematic diagram and room-by-room duct and diffuser design information.

Necessity: These changes are necessary to ensure that sizing and design items are developed by designers and documented for installers.

Section: 150.0(h)1 – Mandatory Features and Devices, Space-Conditioning Equipment, Building Cooling and Heating Loads.

Specific Purpose: The specific purpose is to require that the load calculation report be submitted with the Certificate of Compliance.

Necessity: These changes are necessary to ensure that These changes are necessary to ensure that sizing and design items are developed by designers and documented for installers.

Section: 150.0(h)2 – Mandatory Features and Devices, Space-Conditioning equipment, Design Conditions.

Specific Purpose: The specific purpose is to change the outdoor design condition to be used for sizing heating systems, and to utilize the most up to date weather data.

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

Necessity: This change is necessary to ensure that sizing assumptions are optimal for year-round operation.

Section: 150.0(h)5 – Mandatory Features and Devices, Space-Conditioning Equipment, Duct Design (NEW)

Specific Purpose: The specific purpose is to require that submitted building plans must include at least a schematic diagram and room-by-room duct and diffuser design information.

Necessity: This change is necessary to ensure designers have designed air distribution system to provide adequate mixing and minimize drafts.

Section: 150.0(h)6 – Mandatory Features and Devices, Space-Conditioning Equipment, System Selection (NEW)

Specific Purpose: The specific purpose is to provide guidance on how to use authorized load calculation in sizing, and the requirements for submittal of sizing calculations, primarily for new construction. It provides minimum capacity limit for heating, not including any supplementary heating and states that there is no maximum limit for new construction.

Necessity: This change is necessary to ensure designers have avoided situations where system performance may be degraded due to undersizing.

Section: 150.2(a)1E and 2D – Energy Efficiency Standards for Additions and Alterations to Existing Single family Residential Buildings – Additions: Prescriptive and Performance (NEW)

Specific Purpose: The specific purpose is to modify 150.0(h)1 requirements for load calculations in additions: It allows simplifying assumptions for small additions (except HP with strip), clarifies that room-by-room loads are not required, and requires "average" leakage or measurement with disclosure.

Necessity: This change is necessary to simplify the load calculation process in some situations, and to prevent the practice of assuming a leaky envelope to justify a larger system.

Section: 150.2(b)1O and 2D – Energy Efficiency Standards for Additions and Alterations to Existing Single family Residential Buildings – Alterations: Prescriptive and Performance (NEW)

Specific Purpose: The specific purpose is to modify 150.0(h)1 requirements for load calculations in alterations: It clarifies that it is still required for like-for-like, allows simplifying assumptions for like-for-like (except HP with strip), clarifies that room-by-room loads are not required, and requires "average" leakage or measurement with disclosure.

Necessity: This change is necessary to require load calculations even when a system is being swapped out for another similar system, simplify the load calculation process in some situations, and to prevent the practice of assuming a leaky envelope to justify a larger system.

Section: 150.2(b)2E – Energy Efficiency Standards for Additions and Alterations to Existing Single family Residential Buildings – Alterations: Prescriptive and Performance (NEW)

Specific Purpose: The specific purpose is provide an exception to that room-by-room duct information is not required when ducts are not replaced or added, in an alteration.

Necessity: This change is necessary to avoid complicating the design process when ducts are not modified.

Section: Joint Appendix 2.2: California Design Location Data, Table 2-3- Design Day Data for California Cities

Specific Purpose: The specific purpose is update the design data with more recent 2021 AS?HRAE design temperature data.

Necessity: This change is necessary to update design data

Section: Residential Appendix TBD – Simplifying Load Calculation Input Assumptions (NEW)

Specific Purpose: The specific purpose is provide simplifying assumptions allowed for load calculations in some circumstances.

Necessity: This change is to simplify the load calculation process.

2.3.1.2 Supplementary Heating

Section: 110.2(b) – Mandatory Requirements for Space-Conditioning Equipment, Controls for Heat Pumps with Supplementary Heaters (renamed).

Specific Purpose: Changes to this section will identify required controls that will lock out supplementary heating above a certain temperature and define a maximum capacity for electric strip heating. They will require that manufacturers of heat pumps and/or thermostats will provide simple instructions on how to configure their equipment to meet these requirements, and that the controls be configured correctly. It will provide a maximum capacity limit on electric resistance strip heaters.

Necessity: These changes are necessary to ensure that supplementary heating is not used when it is not needed.

Section: 150.0(h)9 – Mandatory Features and Devices, Space-Conditioning Equipment, Supplementary Heating Control Configuration (NEW)

Specific Purpose: The specific purpose is to require HERS verification that heat pumps are capable and configured to do lockout supplementary heating above a certain OAT, as required in 110.2(b)

Necessity: These changes are necessary to ensure that supplementary heating is not used when it is not needed.

Section: Residential Appendix TBD: Procedure for Verification of Configuration of Space Conditioning System Controls. (NEW)

Specific Purpose: The specific purpose is to provide procedures for verification supplementary heating control configuration.

Necessity: These changes are necessary to provide guidance to HERS Raters on how to confirm proper configuration of system controls.

2.3.1.3 Defrost

Section: 150.0(h)7 – Mandatory Features and Devices, Space-Conditioning Equipment, Defrost (NEW)

Specific Purpose: The specific purpose is to require that defrost delay timers shall be set optimally, and that manufacturers of space conditioning systems will provide simple instructions on how to configure their equipment to meet these requirements, and that the controls be HERS verified.

Necessity: These changes are necessary to ensure that defrost modes are engaged less frequently.

Section: Residential Appendix TBD: Procedure for Verification of Configuration of Space Conditioning System Controls. (NEW)

Specific Purpose: The specific purpose is to provide procedures for verification of defrost delay timer configuration.

Necessity: These changes are necessary to provide guidance to HERS Raters on how to confirm proper configuration of system controls.

2.3.1.4 Crankcase Heating (CCH)

Section: 150.0(h)8 – Mandatory Features and Devices, Space-Conditioning Equipment, Crankcase Heating (NEW)

Specific Purpose: The specific purpose is to require that documentation is provided to installer that there is no CCH or that it does not run when compressor is on.

Necessity: These changes are necessary to ensure that heat pumps and AC systems are operating to minimize electrical energy usage.

Section: 150.1(c)7B – Performance and Prescriptive Compliance Approaches for Single family Residential Buildings, Prescriptive Standards/Component Packages, Space Heating and Space Cooling, Crankcase Heating (NEW)

Specific Purpose: The specific purpose is to provide options and exceptions for CCH.

Necessity: These changes are necessary to ensure that heat pumps and AC systems are operating to minimize electrical energy usage.

2.3.1.5 Refrigerant Charge Verification

Section: 150.1(c)7A– Performance and Prescriptive Compliance Approaches for Single family Residential Buildings. Space heating and space cooling. Refrigerant Charge.

Specific Purpose: Changes to this section include removing the FID option, adding a stipulation that systems may use a method recommended by manufacturer, adding an exception that pre-charged systems with line set and coil sizes close to manufacturer's defaults are not required to do RCV, and modifying Table 150.1-A to show climate zones where RCV is required.

Necessity: These changes will clean up the code by removing a major section that is no longer needed, provide exceptions to reflect the technical limitations of charge verification procedures, and note which climate zones RCV is required for AC and HP.

Section: Joint Appendix 6.1: Fault Indicator Display (FID)

Specific Purpose: This appendix, which includes all the detailed requirements for the FID method of charge verification, is removed in its entirety. This method has never been utilized, and with advances in technology, it is no longer expected to be used.

Necessity: This change will clean up the code by removing a major section that is no longer needed.

Section: RA3.2.3 Weigh-In Charging Procedure

Specific Purpose: This section is changed to apply to heat pumps, provide an exception from vacuum verification when better fittings are used, and provide a new section describing the requirements for remote verification of the weigh-in procedure.

Necessity: These changes are required to describe the enhanced requirements for documentation and relaxed requirements to allow remote verification.

Section: RA3.4.2 Fault Indicator Display (FID) Verification Procedure

Specific Purpose: This section, which requires field verification for FID charging procedure, is removed in its entirety. This method has never been utilized, and with advances in technology, it is no longer expected to be used.

Necessity: This change will clean up the code by removing a major section that is no longer needed.

2.3.1.6 Variable Capacity Systems

Section: 150.0(m)13C & D

Specific Purpose: The specific purpose is to modify Exception 1 to Section 150.0(m)13C to require that fan efficacy tests effectively address zonally controlled variable capacity systems. This may be accomplished by eliminating or slightly modifying the current exception that applies to these systems.

Necessity: These changes are necessary to ensure that these systems perform at required efficacy levels in all modes.

2.3.2 Specific Purpose and Necessity of Changes to the Residential ACM Reference Manual

2.3.2.1 Design (Sizing, Equipment Selection, and Ducts/Diffusers)

Section 2.4.1 Heating Subsystems and 2.4.6 Cooling Subsystems of the Single Family ACM Reference Manual would be revised to clarify the approach to sizing for the Standard and Proposed Designs.

2.3.2.2 Supplementary Heating

Section 2.4.1 Heating Subsystems of the Single Family ACM Reference Manual would be revised to define how supplementary heating is controlled in the software.

2.3.2.3 Defrost

Section 2.4.1 Heating Subsystems of the Single Family ACM Reference Manual would be revised to incorporate details on how defrost is modeled in the software.

2.3.2.4 Crankcase Heating

Section 2.4.1 Heating Subsystems of the Single Family ACM Reference Manual would be revised to incorporate details on how CCH is modeled in the software.

2.3.2.5 Refrigerant Charge Verification

Section 2.4.7 Verified Refrigerant Charge of Fault Indicator Display of the Residential ACM Reference Manual currently describes how credit is calculated when charge is verified to be correct. It estimates impacts by establishing a Compressor Efficiency Multiplier (CEM) which is used in compliance performance calculations to degrade the efficiency of a compressor to 90 percent of the rated efficiency when charge is not verified as correct but is increased to 96 percent of the rated efficiency when it is verified as correct. This would be expanded to include a specific CEM for heating. References to the fault indicator display option would also be deleted.

Additionally, Appendix G – Algorithms would be updated to specify the details of how the CEM is applied in the equations that calculate efficiency.

2.3.2.6 Variable Capacity Systems

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

2.3.3 Summary of Changes to the Residential Compliance Manual

The following information will be added or revised in the Residential Compliance Manual:

2.3.3.1 Design (Sizing, Equipment Selection, and Ducts/Diffusers)

- Revise Sections 4.2 and 4.3 of the Residential Compliance Manual to provide the sizing limits for Heating and Cooling systems, respectively, for new construction, additions, and alterations. This includes exceptions for existing homes where airflow is verified to be at least 350 cfm/ton.
- Provide specific requirements for submitting authorized load calculation inputs and/or outputs in the permit application package.
- Describe the simplifying assumptions that are allowed to the authorized load calculation inputs in some cases.
- Describe requirement to assume only “average” envelope leakage.
- Clarify that load calculations are now required even for like-for-like replacements.
- Clarify that room-by-room loads are not required.
- Provide the specific requirements for including at least schematic diagrams and room-by-room duct and diffuser information, except when ducts are not replace or modified.

2.3.3.2 Supplementary Heating

- Describe the requirement to lockout supplementary heating on heat pumps, including obtaining instructions from manufacturer and configuring controls.
- Describe requirements to confirm that variable and multispeed systems installed with third-party thermostats must be configured correctly, including obtaining instructions from manufacturers an configuring controls.

2.3.3.3 Defrost

- Describe the requirements for the defrost delay timer, including obtaining instructions from manufacturer and configuring controls.

2.3.3.4 Crankcase Heating

- Describe what manufacturer documentation can be used to ascertain whether CCH mandatory requirement that the CCH is off when compressor is on are met
- Describe prescriptive options and how to provide the necessary information.

2.3.3.5 Refrigerant Charge Verification

- Describe the new procedure for remote verification of weigh-in.
- Describe new exceptions from RCV requirements.

2.3.3.6 Variable Capacity Systems

- Add a discussion of VCMS and duct losses to the Residential Compliance Manual.

2.3.4 Summary of Changes to Compliance Forms

The proposed code changes would modify the compliance forms, as listed below.

2.3.4.1 Design (Sizing, Equipment Selection, and Ducts/Diffusers)

- CF1R-PERF, ALT-02, and NCB: Add requirements for load calculation report to be submitted and plans to include at least a schematic diagram and room-by-room duct and diffuser information.
- CF2R-MCH-01-E, Section I: Remove capacity information.
- CF2R-MCH-TBD: New form to show system selection information including loads and capacities.

2.3.4.2 Supplementary Heating

- CF2R-MCH-01-E, Section H: Add space to record that supplementary heating controls (controls capability, provided instructions, configuration of controls) and capacity for strip heaters meet requirements.
- CF2R-MCH-01-E, Section H: Add space to record that variable and multi speed systems installed with third-party thermostats meets requirements (instructions provided and system configured).
- CF2R-MCH-01-E, Section N: Add HERS test required for configuration of space Conditioning System Controls (Supplementary Heating Lockout).
- CF2R-MCH-TBD: New form to document configuration of space Conditioning System Controls (Supplementary Heating Lockout).
- CF3R-MCH-TBD: New form to verify configuration of space Conditioning System Controls (Supplementary Heating Lockout).

2.3.4.3 Defrost

- CF2R-MCH-01-E, Section H: Add space to record that defrost delay timer setting meets requirements (instructions provided, timer configured).
- CF2R-MCH-01-E, Section N: Add HERS test required for configuration of space Conditioning System Controls (Defrost Delay Timer).
- CF2R-MCH-TBD: New form to document configuration of space Conditioning System Controls (Defrost Delay Timer).
- CF3R-MCH-TBD: New form to verify configuration of space Conditioning System Controls (Defrost Delay Timer).

2.3.4.4 Crankcase Heating

- CF2R-MCH-01-E, Section D: Add space to record prescriptive CCH option chosen, P1 and P2 values provided by manufacturer, and that manufacturer documentation confirms.

- CF2R-MCH-01-E, Section H: Add space to record that CCH does not operate when compressor is operating (per manufacturer documents).

2.3.4.5 Refrigerant Charge Verification

- CF2R-MCH-25c (Documentation of Weigh-In): Modified to reflect exception for verification of vacuum when better fittings are used.
- CF3R-MCH-25c (Observation of Weigh-In): Modified to reflect exception for verification of vacuum when better fittings are used.
- CF2R-MCH-25g (Remote Documentation of Weigh-In): New form to include documentation requirements for remote weigh-in, and reflecting exception for verification of vacuum when better fittings are used.
- CF3R-MCH-25g (Remote Verification of Weigh-In): New form to include documentation verification for remote weigh-in, and reflect exception for verification of vacuum when better fittings are used.
- CF3R-MCH-25d (FID): Eliminate form for Refrigerant Charge FID Option.

2.3.4.6 Variable Capacity Systems

The proposed code change would not modify the Compliance Forms.

2.4 Regulatory Context

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

2.4.1.1 Design (Sizing, Equipment Selection, and Ducts/Diffusers)

The California Green Code, Title 24, Part 11, Section 4.507.2, states that heating and air conditioning systems shall be sized, designed and have their equipment selected using ACCA Manuals J, D, and S. The CEC should consider modifying requirements in Title 24, Part 11 requirements to agree with the requirements proposed here for Title 24, Part 6.

The California Mechanical Code requires that residential ducts be sized according to ACCA Manual D (or other approved methods). This is consistent with the requirements proposed here.

2.4.1.2 Supplementary Heating

This proposal is not relevant to other parts of the California Building Standards Code (https://www.dgs.ca.gov/BSC/Codes). Changes outside of Title 24, Part 6 are not needed.

2.4.1.3 Defrost

This proposal is not relevant to other parts of the California Building Standards Code (https://www.dgs.ca.gov/BSC/Codes). Changes outside of Title 24, Part 6 are not needed.

2.4.1.4 Crankcase Heating

This proposal is not relevant to other parts of the California Building Standards Code (https://www.dgs.ca.gov/BSC/Codes). Changes outside of Title 24, Part 6 are not needed.

2.4.1.5 Refrigerant Charge Verification

This proposal is not relevant to other parts of the California Building Standards Code (https://www.dgs.ca.gov/BSC/Codes). Changes outside of Title 24, Part 6 are not needed.

2.4.1.6 Variable Capacity Systems

This proposal is not relevant to other parts of the California Building Standards Code (https://www.dgs.ca.gov/BSC/Codes). Changes outside of Title 24, Part 6 are not needed.

2.4.2 Duplication or Conflicts with Federal Laws and Regulations

2.4.2.1 Design (Sizing, Equipment Selection, and Ducts/Diffusers)

There are no relevant federal laws or regulations.

2.4.2.2 Supplementary Heating

There are no relevant federal laws or regulations.

2.4.2.3 Defrost

There are no relevant federal laws or regulations.

2.4.2.4 Crankcase Heating

DOE regulates (DOE n.d.) OFF mode power, including CCH, for residential air conditioners and heat pumps. The test method provided in AHRI Standard 210/240 (AHRI 2023) describes how the Off-mode Power Consumption (referred to as $P_{w,off}$) is to be established in a test lab. Regulations related to off-mode power consumption do not, however, address *on-mode* consumption. On-mode performance is generally included other efficiency ratings and tests and hence are regulated. However, the standard does not require that a CCH be present during those tests (per AHRI 210/240 Appendix G. Unit Configuration for Standard Efficiency Determination – Normative), and hence federal regulation is silent on energy use by CCH when the system is in on-mode. This means that Title 24, Part 6 is not prohibited by preemption concerns from regulating how the CCH is controlled when the system is operating.

2.4.2.5 Refrigerant Charge Verification

There are no relevant federal laws or regulations.

2.4.2.6 Variable Capacity Systems

There are no relevant federal laws or regulations.

2.4.3 Difference From Existing Model Codes and Industry Standards

2.4.3.1 Design (Sizing, Equipment Selection, and Ducts/Diffusers)

Right sizing is a part of national programs such as ENERGY STAR® and the International Energy Conservation Code (IECC).

2.4.3.2 Supplementary Heating

There are no relevant industry standards or model codes.

2.4.3.3 Defrost

There are no relevant industry standards or model codes.

2.4.3.4 Crankcase Heating

There are no relevant industry standards or model codes.

2.4.3.5 Refrigerant Charge Verification

There are no relevant industry standards or model codes.

2.4.3.6 Variable Capacity Systems

There are no relevant industry standards or model codes.

2.5 Compliance and Enforcement

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

2.5.1 Compliance Activities during Phases of Project

Table 9: Full Summary of Measures

(Bold black indicates a required activity; bold green indicates a relaxed requirement. HL= Heating Load; HC=Heating Capacity at Design Temperature; CL= Total Cooling Load; CC=Total Cooling Capacity at Design Temperature)

1. *If Addition or Alteration:*
    a. **Assume no more than "average" envelope leakage** (*or* ***do blower door test to establish envelope leakage***)
    b. *If like-for-like replacement or small addition and not a heat pump with strip heater:* **May use simplifying assumptions in load calculation**
2. **Include load calculation report or calculation inputs, outputs, and description with CF1R,** *(unless like-for-like or downsized replacement of properly sized system)*
3. **Include diagram and information on ducts/diffusers on plans**
4. **Select suitable unit:**
    a. HC must be ≥ HL
    b. *If CL is between HL and HL+12000, and airflow ≤ 350cfm/ton*:
        i. CC must be ≤ CL + 6000
        ii. HC must be ≤ HL+12000
        iii. *If variable capacity or multi speed:* Turns down to below 80 percent
    c. CCH off when compressor on
    d. *Prescriptive*: **Install Occupant Controlled Smart Thermostat** (*or CCH has better control*)
    e. *If strip heater:* Limit on capacity
5. *If strip heater or dual fuel:* **Install controls that lock out supplementary heating above 35°F**
6. **Set defrost delay timer**
7. *Prescriptive: If air conditioner in certain climates or heat pump in all climates, verify refrigerant weigh-in* (*or, if not variable capacity, standard charge test*): **Document weigh-in parameters, may upload documentation** (*or have* ***in-person verification***)
8. *If variable capacity and zoned system:* **Modified fan efficacy test procedure**

Table 10: Sample Paths for Common Projects

(*Assuming: single speed, not extremely cooling dominated application, no supplementary heating.)*

Replace AC/Furnace with Heat Pump	**Like-for-Like AC/Furnace Replacement**

• Assume “average” envelope leakage
• ~~Use simplifying assumptions in load calc~~
• Include load calc report w**ith** CF1R
• Include duct/diffuser **info** on p**lans**
• Select suitable unit:
  o HC ≥ HL
  o If CL > HL:
  CC ≤ CL+6000 and HC ≤ HL+12000
  o CCH well controlled
• Set defrost delay timer
• In most climates: Upload documentation of refrigerant weigh-in
	• Assume “average” envelope leakage
	• Use simplifying assumptions in load calc
	• Include load calc report w**ith** CF1R
	• Include duct/diffuser **info** on p**lans**
	• Select suitable unit:
	  o HC ≥ HL
	  o ~~If CL > HL:~~
	  CC ≤ CL+6000 ~~and HC ≤ HL+12000~~
	  o CCH well controlled
	• ~~Set defrost delay timer~~
	• In certain climates: Upload documentation of refrigerant weigh-in

New Construction with Heat Pump	**New Construction with AC/Furnace**

• ~~Assume “average” envelope leakage~~
• ~~Use simplifying assumptions in load calc~~
• Include load calc report with CF1R
• Include duct/diffuser info on plans
• Select suitable unit:
  o HC ≥ HL
  o If CL > HL:
  CC ≤ CL+6000 and HC ≤ HL+12000
  o CCH well controlled
• Set defrost delay timer
• In most climates: Upload documentation of refrigerant weigh-in
	• ~~Assume “average” envelope leakage~~
	• ~~Use simplifying assumptions in load calc~~
	• Include load calc report with CF1R
	• Include duct/diffuser info on plans
	• Select suitable unit:
	  o HC ≥ HL
	  o ~~If CL > HL:~~
	  CC ≤ CL+6000 ~~and HC ≤ HL+12000~~
	  o CCH well controlled
	• ~~Set defrost delay timer~~
	• In certain climates: Upload documentation of refrigerant weigh-in

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

Design Phase:

- The system designer will complete authorized load calculations for new construction, additions, and alterations. In some cases of alterations and additions, these calculations can make use of simplifying assumptions [TBD].
- For existing homes, when a heat pump with strip heating is installed, or when the designer does not choose to assume an envelope leakage of no greater than average envelope leakage, the installer will do a blower door test to establish the

expected leakage, which will be included in the authorized load calculation inputs.

- The designer will generate an authorized load calculation report, (or a description of the inputs, outputs, and calculation method for non-software calculations).
- The designer will design the distribution system and prepare a room-by-room list of ducts and diffusers.
- The designer will select a system to be installed, following the requirements proposed here. If the designer chooses to oversize the system (or in situations where heat pump cooling loads are significantly greater than heating loads and it is impossible to meet limits for both cooling and heating capacity simultaneously), the designer will ensure that the system provides 350 cfm/ nominal system ton. This may require duct modifications.
- If the designer chooses to include supplementary heating system, they ensure that it meets capacity limits (if electric resistance strip heating) and specify a thermostat or other controls that use either an outdoor air temperature sensor or an internet weather feed to lock out supplementary heating.
- The designer selects a system that has CCH controls that meet the mandatory and (if desired) prescriptive requirements. This may include specifying installation of an OCST.
- If the designer is selecting a variable capacity system combined with zoning they must specify one of the systems that integrate compressor and fan speed with zonal control.

Permit Application Phase:

- The designer will submit authorized load calculation report, (or a description of the inputs, outputs, and calculation method for non-software calculations), selected system details, and duct/diffuser list or diagram on a CF1R to the local jurisdiction for plan review.
- The designer or energy consultant will include all choices in their compliance run.

Construction Phase:

- If necessary, the installer will make duct modifications to ensure that the system provides 350 cfm/nominal system ton.
- The installer will obtain instructions for configuring supplementary heating lockout, setting defrost delay timer, and configuring variable or multispeed systems with third-party thermostats.
- The designer will obtain manufacturers documentation of CCH characteristics, if desired, or install an OCST.If supplementary heating is used, the installer will ensure that outdoor temperature lockout control is configured correctly.

- If used, the installer will set the defrost delay timer to be ≥ 90 minutes.
- For variable or multispeed systems with third-party thermostats, the installer will configure the system to ensure that the capacity varies.
- In certain climate zones 1for cooling only or heat pump systems, the installer will select a method of Refrigerant Charge Verification.
- If a Standard Charge Verification is used, the installer will use existing methods to charge the system.
- If a remote Charge Weigh-in Verification is used, the installer will document all weigh-in parameters, document the vacuum reached and maintained, and document scale readings before and after weighing in the charge. These can be documented via photographs, or via electronic instrument records. A CF2R form will be provided to record all assumptions.
- For Variable Capacity/Zoned Systems, the installer will provide and install a system that complies with the specifications.

Inspection Phase:

- No changes to building inspection process.
- HERS verification of proper configuration of the supplementary heating control and defrost delay timer settings will be required.
- If a Standard Charge Verification is used, and when sampled, a HERS Rater will travel to the site and conduct an independent test, as before.
- If an in-person Charge Weigh-in Verification is used, the installer will ensure that a HERS Rater will be at the site when the charge is weighed in, as before.
- If a remote Charge Weigh-in Verification is used, the installer will upload all documentation to a HERS Rater, who will verify it remotely.

2.5.2 Discussion of Compliance and Enforcement Processes

Design Phase:

- Authorized load calculations are already required, so requirements to do this are not new. However, many designers have not done these required calculations in the past, so they will need training and support to do them. It is possible that more consultants will emerge who can do the calculations for designers. There are also distributors who provide these calculations as a service to their contractor customers.
- For those who already do authorized load calculations, they may find that simplifying assumptions make their jobs easier than before.

- Industry experts report that most HVAC installers also are not trained in how to do a blower door test. While it is not strictly required, it may be a good option for many projects. Again, training will be required, or consultants may begin offering this as a discrete service
- Designing or inventorying existing ducts and diffusers and indicating them on a system schematic may require additional work on the part of the designer. They may require training, although this is an already an important part of system design and this would be a welcome change in the industry, and a critical change when heat pump installation is more ubiquitous.
- While load calculations have been required for some time, designers have never been instructed on what to do with that information. For the first time, Title 24 Part 6 will put requirements on the systems they can select. This should not require any additional time, however, beyond what is already required.
- If the designer chooses to include supplementary heating system, ensuring that it meets capacity limits and specifying a thermostat or other controls that lock it out should not take extra time or expertise.
- In the short run, it may be difficult for designers to identify available system that have adequate CCH controls, because this information is sometimes difficult to find. Outreach to manufacturers would help to make this information more available.

Permit Application Phase:

- Submitting the authorized load calculation report, and duct/diffuser schematic diagram with the CF1R to the local jurisdiction for plan review will not take much time, once the design has been established in the design phase. Care must be taken to ensure that all the information that is needed on design choices is available at this stage of project development.
- It is not expected that Plan Checkers will require much additional time to review submissions to verify that requirements are met.

Construction Phase:

- If the designer chooses to oversize the system, the installer may have to make duct modifications. This will be additional work, but most installers know how to do this. This is already required, however, and is not a new requirement.
- Installers will be required to configure controls appropriately, which may require training. Manufactures will help in this by producing a succinct and readily accessible description of how to configure and verify the configuration of their equipment to meet these requirements.

- Charge Weigh-in Verification will require more documentation than previously, and one more test (temperature split). The added time for these can be more than compensated for if remote verification is used.
- Four manufacturers have been identified that provide systems that integrate control of the compressor and fan speed with the number of zones calling for heating or cooling to avoid over-pressurization of ducts, a decrease in airflow, and an increase in fan energy use. These systems are unlikely to impact the time required for installation compared to other zoned systems.

Inspection Phase:

- The documentation requirements for the remote Charge Weigh-in Verification option are provided in RA 3.2.3.3. The detailed procedure for submitting this documentation to HERS Raters will be developed by HERS Providers.
- HERS verification will be required for supplementary heating and defrost delay timer configurations. Because these are difficult for both installers and verifiers, simple instructions from manufacturers will be required.
- Verification of integrated variable capacity zoned systems will be simpler than methods required for other zoned systems. A test method to be developed in the Reference Appendices will require testing of airflow and efficacy when only one zone is calling, instead of every zonal control mode as is currently required for zoned systems, making the test no more time consuming than for single zone systems.

3. Market Analysis

3.1 Current Market Structure

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. It then considered how the proposed standard may impact the market in general as well as individual market actors. Information was gathered about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, CEC staff, and a wide range of industry actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during a public stakeholder meeting that the Statewide CASE Team held on January 24, 2023 (California Statewide Codes & Standards Team 2023).

Currently, there are about 9,023,257 existing single family homes in California and 65,022new homes are estimated to be built in 2026. These figures are based on forecasts provided by the CEC (see Appendix A for further details). The Statewide Case Team assumes that by 2026, 90 percent of new homes will be installing heat pumps. This fraction is expected to increase to 100 percent within the next 30 years, due to a range of factors including new code requirements, local reach code requirements for electrification and current and expected tax incentives. The residential HVAC performance measures described in this report will be applicable to all of these homes, as described in the following sections.

The Statewide CASE Team estimates that 12.62 percent of HVAC replacements will install heat pumps in 2026 (see Appendix A for further details), and this fraction is expected to increase to 100 percent within the next 30 years, due to new code requirements, reach codes, tax incentives, and rebates from programs such as TECH Clean California. The following sections describe how many homes these measures will apply.

The measures described here will have an impact on a number of market actors. HVAC system designers and system installers typically work for the same HVAC contracting firm. These firms range from small “mom and pop”, one-truck firms to large and sophisticated firms employing a hundred or more HVAC professionals. These contractors purchase equipment and supplies from distributors that are sometimes aligned with particular manufacturers. Many distributors have experienced staff that play an important role in educating designers and installers on the proper use of the products that they sell. Energy consultants provide services to designers to run compliance software and determine if the home complies with code and help prepare documents to submit to code officials. Plans checkers, who work for city or county jurisdictions, typically do a cursory review of submitted plans, primarily to determine whether required information is provided in the plan package. HERS Raters are independent consultants, hired by contractors to provide on-site testing and observations. It is possible that some of these roles may be modified as the market adjusts to the revised requirements in the 2025 version of Title 24, Part 6. For example, distributors or energy consultants may take on a bigger role in carrying out and documenting load calculations, system selection, duct/diffuser design, and blower door tests. When HERS Raters provide remote verification, they will be in much more of a quality-assurance rather than testing role.

Beyond the January 2023 Stakeholder meeting, the Statewide CASE Team met with several manufacturers and contractors during development of this proposal. A survey will be done of contractors to assess the prevalence of some of the issues described below and to estimate incremental costs. The team has reviewed data collected in the HERS Registry to ascertain rates of implementation of various processes and features.

3.2 Technical Feasibility and Market Availability

3.2.1 Design (Sizing, Equipment Selection, and Ducts/Diffusers)

The measures described in this report respond to a number of current barriers to the market for HVAC systems. Investments made in efficient HVAC will be paid back over the life of the system in reduced energy bills, although new construction HVAC is still a very first-cost focused market. Sizing has direct implications on this first cost. While requiring a larger heat pump that will not have excessive strip heating comes at a higher first cost, it is partially offset by the cost of the strip heater itself. And encouraging designers not to specify a larger-than-needed system will have a lower first cost. Sizing also has an informational market barrier, as many contractors believe that undersizing can create comfort problems while overlooking the comfort problems created by oversizing. They can effectively convince homeowners to invest in a large system with the promise that it will provide better comfort, which is not necessarily true.

It will be important to educate contractors on this, so that they can effectively communicate to consumers as they are explaining why they may, for example, recommend replacing their current systems with a smaller unit. Conversely, the requirement that contractors must determine that an envelope is leaky before upsizing a system to accommodate those leaks is accompanied by a required disclaimer that they chose not to measure the leaks, and that the system may in fact be undersized. This of course could be counteracted by sealing leaks or measuring the infiltration rate.

Most systems installed in new construction, additions, and alterations are required to use authorized load calculations, but there is no way to definitively determine how many actually do it since it is not required to be documented. Interviews and surveys are being conducted with contractors to shed some light on this. A 2011 study of then-new construction found that 60 percent of systems were below the now-required 350 cfm/ton, and the median of these undersized duct systems were 20 percent undersized (Proctor, Chitwood and Wilcox 2011). These now represent a best case for existing buildings before that time, and we are assuming that 60 percent of existing homes will not meet the required 350 cfm/ton required to allow oversizing. We assume most designers of replacement systems will opt for not oversizing rather than doing ductwork modifications.

Products are readily available to ensure proper system design. Authorized load calculation software is available from multiple sources, including:

- Wrightsoft Right-J8
- Elite RHVAC
- Adtek Acculoads
- Florida Solar Energy Center's EnergyGauge (including Kwik Model)
- Carmelsoft HVAC ResLoad-J
- Avenir MJ8 Editions of HeatCAD and LoopCAD
- Cool Calc Manual J

While some software has been available for quite a long time, some of the software is new and responds to the need to make sizing quicker and more reliable. The blower door requirement should not be problematic as blower doors are standard diagnostic tools and are readily available in the market.

Changes in the design process will be required, although nothing is required that goes beyond the standard good practice for design. Authorized load calculations are already required, so this requirement is not new. However, many designers have not done these required calculations in the past, and designers have never been instructed on what to do with that information. For those who already do authorized load calculations, collecting inputs for load calculation can be time consuming, and many contractors may find that simplifying assumptions make their jobs easier than before. Training on how to do load calculations is offered by many entities, although more contractors may need to avail themselves of it. It is possible that consultants will emerge who can do the calculations for designers. In fact, there are already distributors who provide these calculations as a service to their contractor customers.

Time may be better spent measuring infiltration rates, although many contractors do not own blower doors or know how to do a test. This measure was designed to focus on the most important inputs in the load calculations, one of which is infiltration. While blower door testing is not strictly required, it may be a good option for many projects. Again, training will be required, or consultants may begin offering this as a discrete service.

Designing or inventorying existing ducts and diffusers may require additional work on the part of the designer. They may require training, although this is an important part of system design and this would be a welcome change in the industry. For the first time, Title 24, Part 6 will put requirements on the systems they can select. Simply adhering to different limits on the size they can select should not require much additional time, however.

After completing the design, submitting the authorized load calculation report (or a description of the inputs, outputs, and calculation method for non-software calculations), selected system details, and duct/diffuser list or diagram on a CF1R to the local jurisdiction for plan review will not take much more time. Care must be taken to ensure that all the information that is needed on design choices is available at this stage of project development. If the designer chooses to oversize the system, the installer may have to make duct modifications. This will be additional work, but most installers know how to do this.

This measure is feasible in any climate zone, although optimum sizing depends on climate zone. It can be more difficult to change system size for an alteration, although downsizing a system is not difficult. There should be very few situations where an existing system would be required to be upsized (for example, an undersized heat pump that had utilized excessive strip heating to meet load), which would hypothetically be more difficult in existing buildings.

As the market transitions from furnaces to heat pumps, it is critical to do proper air distribution design to avoid drafts and improve comfort. This measure can have an impact on comfort, since it avoids excessive oversizing that threatens comfort due to short-cycling (never staying at the setpoint for long) and difficulty in controlling humidity. Oversizing that causes the system to cycle frequently can cause more wear and tear on a system and reduce its life. There should be no degradation in performance over time due to these measures. However, in some situations downsizing a replacement system may uncover maintenance problems that had been masked by an oversized system and causing high energy bills. Addressing these uncovered problems could further improve performance.

3.2.2 Supplementary Heating

Contractor and homeowner perception of heat pump effectiveness is a barrier to the implementation of heat pumps. The outdated perception that heat pumps do not adequately heat a home is still prevalent[8]. This can make it difficult to “sell” a customer on the need to fuel switch, and/or forego or minimize the size or operation of a strip

[8] See, for example, New York Times, E. Shao. “As Heat Pumps Go Mainstream, A Big Question: Can They Handle Real Cold?” Feb 22, 2023,

heater. Although many contractors in California successfully avoid installing strip heaters, it will be important to disseminate case studies of installing systems without strip even in colder climate zones—both to contractors and homeowners. Most are not aware of cold-climate heat pumps that can be a very suitable solution in colder climates. Dual fuel can overcome market barriers of first cost, (by not requiring replacement of the air handler and possibly avoiding panel upgrades), and they overcome anxiety of new technologies and the perception that heat pumps are somehow not sufficient. These perceptions should be confronted head on, however, as they are truly outdated.

Interviews and a survey of contractors are being conducted to determine the percentage of heat pump systems are installed with supplementary heating currently. We expect that with the current CASE proposal requirements for sizing, the number will decrease this fraction. These are the heat pumps to which the supplementary heating measure would apply.

Properly configured controls are required not only to ensure optimal performance, but also to avoid the potential for very high energy use and winter morning peak demands. Therefore, manufacturers of heat pumps and thermostats will be required to produce a simple language one-page description of how to configure and verify the configuration of their equipment to meet these requirements. Interviews with contractors indicated that controls for heat pumps (and especially for control of supplementary heating) are more complex than conventional systems, and that many contractors are not aware of the importance of configuring controls correctly. As the state moves toward electrification of heating end uses rapidly, it is essential that heat pumps are installed correctly.

Heat pumps in all sizes and cold-climate heat pumps that can provide sufficient heating without supplementary heating are readily available on the market today, and new products are becoming available all the time. The controls to ensure that supplementary heating is not operated when unnecessary are also readily available: smart thermostats, proprietary thermostats for high-end and VC systems, proprietary controls on outdoor unit, and third-party controls on outdoor unit.

Installers throughout the state are prepared to implement the supplementary heating measure, although controls can be confusing and it can be difficult to ensure they are set optimally. Designers need to be able to ascertain whether or not a particular product has the required controls for locking out supplementary heating above a certain temperature. Manufacturers of heat pumps and thermostats can help in this by making this feature more prominent in their product literature. Meeting the strip heating capacity limit is not at all difficult. Configuring controls is where this measure becomes difficult, and training that focuses on this would be helpful. Manufacturers can also help on this front by prominently providing simple instructions for this. This could also be helped by resources, such as the Thermostat Support Sheets provided in the Performance Tested

Comfort Systems by Bonneville Power Administration, which describes how to set up a number of common thermostat models for use with heat pumps (Bonneville Power Administration 2020). Because heat pumps are relatively new for many contractors, it will be necessary at least in the short term to verify that they have configured controls properly, especially for heat pumps and dual fuel systems. It is possible that this verification could be conducted remotely with use of photographs.

The supplementary heating measure is appropriate in all climate zones. Possible comfort impacts may occur for those occupants who choose to implement a deep nighttime setback. Extending the time needed to reach setpoint can occur, and occupants may choose to modify the nighttime setback strategy. The strip heater capacity limit may result in brief periods of cooler-than desired supply air during defrost cycles, but these will be brief and the capacity of the heat pump will provide the necessary heating over time.

The persistence of savings from this measure should be good, unless a homeowner reprograms their thermostat, or a subsequent contractor resets the thermostat or outside controller. Persistence could be improved with an increase in awareness of the peak demand problem created by strip heating.

3.2.3 Defrost

Because defrost operation is not obvious to users, how the defrost is controlled is not a feature that is typically advertised or considered a differentiator. This is a market barrier that codes could overcome.

All heat pumps require a defrost mode. While some systems have advanced defrost control, most rely on a delay timer that can be set using a jumper or dip switch. The defrost measure would apply to these heat pumps. This measure does not apply to the small fraction of systems that utilize a more advanced defrost control mechanism. Typically, these more advanced controls are only available on the most high-end systems.

Most contractors aren't aware of the delay timer setting, or its importance for energy and demand. Setting delay timer properly is a simple task, but training may be necessary to raise awareness of this mode, and to encourage contractors to use optimal configuration.

The requirement can provide improved comfort as it will minimize unnecessary defrost operation. Reducing the frequency of defrost operation can also reduce wear and tear on a system and improve system life. The persistence of this measure should be good, unless a contractor resets the timer. Since it would be easier to change this setting in response to a comfort complaint than to take the time to diagnose underlying causes, this is a risk. This is another aspect that would benefit from installer training and awareness.

3.2.4 Crankcase Heating

CCH is a "vampire" electrical load that most people are not familiar with. It is seldom a feature that is advertised or considered a differentiator. Code requirements could help to overcome this market barrier.

It is estimated from a review of product literature that most heat pumps and air conditioners utilize active CCH. After discussions with manufacturers, we estimate that 50 percent of the CCHs in these systems have thermostatic or other more active controls, and that 5 percent of heat pump CCHs and 25 percent of air conditioner CCHs operate even when the compressor is off. The prescriptive measure would apply to the former, and the mandatory measure would apply to the latter. Many manufacturers pay some attention to this, since it's included in AHRI 210/240, but most manufacturers report exactly the minimum rating.

All that most contractors will have to do to comply with this measure is to install a system that meets mandatory and prescriptive requirements, and provide a copy of the manufacturer's literature describing it. In the short run, it may be difficult for designers to identify available system that have adequate CCH controls, because this information is sometimes difficult to find. Outreach to manufacturers would help to make this information more available.

This measure is feasible in all climate zones and for both heat pumps and air conditioners. It should have no effect on comfort, and so long as the CCH is not disabled at times when it would be needed, it should not affect system life or maintenance requirements. No evidence that leads to concerns about diminishment of savings over time.

3.2.5 Refrigerant Charge Verification

All manufacturers provide the information needed to weigh in the appropriate amount of refrigerant. Requirements for charging of Variable capacity systems varies by manufacturer. A manufacturer survey is being conducted to provide information on this. Some systems (minisplits) do not provide a charging port, making it impossible to do charge tests, and to adjust charge later other than total evacuation and weigh in which is time consuming in a maintenance call and not likely to be done.

Tools are available to record instrument readings and securely transmit a report. For example, Visual Service and measureQuick. Several manufacturers are developing more advanced ways to determine whether or not their systems have the appropriate amount of charge, although it is not clear how many of these are used for fine-tuning the charge for optimum performance versus indicating severely incorrect charge that leads to system malfunction.

Most installers have some familiarity with the existing methods for charging and verifying the charge of air conditioning systems and heat pumps. These verifications have been applied successfully for over a decade in certain climate zones. Because savings are higher for heat pumps, they will be required throughout the rest of the state, and we can anticipate the same level of awareness and ability. The current methods for weigh-in verification will require more documentation than previously. The weigh-in verification documentation must be by HERS Providers in accordance with requirements of the Standards.

A properly charged system will provide comfort more reliably, while a system that is poorly charged or contains noncondensibles due to an improper evacuation will have a reduced system life and require maintenance or replacement prematurely. Efforts taken during evacuation and better fittings will reduce the incidence of refrigerant line leakage, improving the persistence of savings from proper charge. The persistence of savings will be increased if large numbers of installers will be encouraged to use better quality fittings that can be expected to leak much less over the years than conventional flared fittings.

3.2.6 Change in Verification Procedures for Zonally Controlled Systems

- Through product literature and interviews with manufacturers, we estimate that very few systems installed in California are currently variable capacity, and even fewer of these are zoned systems. These are the systems to which the Variable Capacity requirements would apply.
- This code change was chosen to correct an oversight in the exception to the verification procedure which allows zonally controlled systems to be tested with all zone dampers open only if a variable speed compressor is installed. It is effectively not a new requirement but a modification to the existing verification procedure that has the consequence of meeting the intent of the original exception by introducing a new requirement that systems integrate fan/compressor speed with zonal control.
- There are no technical barriers to the proposed change. A market survey found that four major manufacturers, Trane, Carrier, Lennox, and Rheem advertise systems that include this capability. The costs for these systems is likely higher than for systems that do not integrate these functions.
- This code change proposal was presented at a stakeholder workshop and one builder was interviewed. The workshop did not produce any negative comments. The builder interview revealed that zonal control is more common than expected,

and high-performance variable capacity systems are being used to overcome compliance challenges. The cost barrier, if it exists, may be overcome by decreased lifecycle heating and cooling costs, improved comfort, and reduced noise from registers that deliver more than their rated airflow. Additional research is needed to identify potential cost barriers.

- The technical feasibility and need for this measure is clearly evident when one considers what would happen when one zone thermostat in a multizone system calls for the heating or cooling system to operate at maximum speed. The resulting high volume of air the variable speed (ECM) fan attempts to deliver to that single zone will result in low airflow, increased fan energy, and therefore poor efficacy. Greatly increased friction losses as the fan tries to force air through a single duct and register can result in excessive noise at the registers. The current exception that enables this condition aggravates the problem.
- This measure is technically feasible in all cases where variable capacity systems deliver heating and cooling to zonally controlled distribution systems. There are no conflicts with other code requirements, and it meets the intent of the requirement that single speed zonally controlled systems be tested in every control mode.
- A brief web search determined that systems that integrate system speed with zonal control are available from manufacturers including Trane, Carrier, Lennox, and Rheem. All have a California distribution network. Further investigation is needed to determine whether these products are locally warehoused and can meet potential market demand in a timely manner.
- The current demand for these systems by the design community is probably low due to lack of knowledge of their existence, cost concerns, and codes that do not require them. Increased demand and competition are likely to have a favorable impact on costs.
- This measure would not require a change in typical design strategy. Using components that are designed to work together from the same manufacturer may simplify equipment specifications.
- Individual systems that combine zone control and variable capacity are not in common use at present, although they are available, and by making information available to designers, builders, and contractors their prevalence is expected to increase. Four current manufacturers have invested in development of these systems and should be eager to help builders meet the new code requirements by adopting them.
- As with any code change that requires relatively new technology there is likely to be a learning curve for specifiers, distributors, contractors, and verifiers. The rapid adoption and product reliability of variable speed furnaces that are now

required to meet DOE standards, provides an example that there is sufficient market experience dealing with reliability and producer stability to support this technology.

- Energy savings for integrated zonally controlled variable capacity systems are primarily related to reduced fan energy and improved performance by not restricting air handler airflow. There is no reason to suspect that these savings would diminish over time, and they will persist to the end of life of the equipment. Maintenance requirements such as routine filter changes and replacement of failed damper motors are no different than for non-integrated systems.
- The proposed code change will not result in any adverse impacts. Integration of zone control and system speed will reduce noise and provide better comfort than systems lacking this feature. By reducing air velocity over the coil when fewer than all zones are calling for cooling will increase the latent cooling capacity.
- Field verifiers will need to be sufficiently knowledgeable about how to set zone thermostats to restrict operation to a single zone. The current requirement that single speed zoned systems be tested in every zonal control mode already requires that knowledge.

Current Market and Market Trends

- Compliance challenges, comfort demands, and incentive programs are increasing the adoption of variable capacity and multispeed VCMS
- Zonal control appears to be a more popular means of providing uniform temperatures than multiple systems
- Of the cold climate heat pumps in the NEEP database, 25,584 out of 38,641 units are variable capacity

Market Barriers

- The primary market barrier to improving airflow and efficacy of zonally controlled systems is the higher cost of systems that integrate zonal control and compressor/fan speed
- Personal communications with contractors suggest that building departments may not be enforcing efficacy testing, particularly measurement of fan watts

Technical Considerations

- Would represent only a minor modification to the way that airflow and efficacy tests are done for these systems
- CBECC-Res contains and applies algorithms that calculate duct loss as a function of airflow rate; VCMS systems can be identified using the existing Multi-speed Compressor check box

Technical Barriers and Potential Solutions

- To implement CBECC-Res modifications, a relationship between load, capacity, and airflow must be established that is representative of commonly used HVAC systems
- Data from available expanded performance tables is being reviewed for this purpose; additional data would improve accuracy

3.2.7 Airflow Verification for Systems with Multiple Air Handlers

Current code requires that air handlers in zonally controlled systems be verified to deliver at least 350 cfm per nominal ton of equipment capacity. For systems having multiple air handlers served from a single compressor, an exception is proposed that clarifies that the airflow requirement should use the sum of airflows from all air rather than 350 cfm per ton for each air handler. There are no technical or market-related issues or barriers to this correction in verification procedures.

3.2.8 Compliance Software Modification for Variable Capacity Systems with Attic Ducts

The 2022 version of CBECC-Res compliance software includes an optional method ("VCHP-Detailed") for evaluating variable capacity system performance. It meets the intent of a proposal introduced in a 2022 CASE Report to account for distribution efficiency impacts from reduced airflow in attic ducts but is limited to NEEP-listed cold climate heat pumps. The currently proposed software change will impact the performance credit for all variable capacity heat pumps and for furnace/air conditioner systems when ducts are installed in an uninsulated, vented attic. The result may be increased adoption of prescriptive requirements or other building efficiency improvements to offset the performance penalty, which will vary by climate zone and house design. There are no technical or market-related issues or technical barriers associated with this software change.

3.3 Market Impacts and Economic Assessments

3.3.1 Impact on Builders

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

California's construction industry comprises approximately 93,000 business establishments and 943,000 employees (see Table 11). For 2022, total estimated payroll will be about $78 billion. Nearly 72,000 of these business establishments and 473,000 employees are engaged in the residential building sector, while another 17,600 establishments and 369,000 employees focus on the commercial sector. The remainder of establishments and employees work in industrial, utilities, infrastructure, and other heavy construction roles (the industrial sector).

Table 11: California Construction Industry, Establishments, Employment, and Payroll in 2022 (Estimated)

Building Type	Construction Sectors	Establishments	Employment	Annual Payroll (Billions $)
Residential	**All**	**71,889**	**472,974**	**31.2**
Residential	Building Construction Contractors	27,948	130,580	9.8
Residential	Foundation, Structure, & Building Exterior	7,891	83,575	5.0
Residential	Building Equipment Contractors	18,108	125,559	8.5
Residential	Building Finishing Contractors	17,942	133,260	8.0

Source: (State of California n.d.)

The proposed change to residential HVAC performance measures would likely affect residential builders but would not impact firms that focus on construction and retrofit of commercial or industrial buildings, utility systems, public infrastructure, or other heavy construction. The effects on the residential and commercial building industry would not be felt by all firms and workers, but rather would be concentrated in specific industry subsectors. Table 12 shows the residential building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report. These building sectors employ contractors and builders involved in the design and installation of HVAC equipment which is impacted by the proposed changes.

The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 3.4 Economic Impacts.

Table 12: Specific Subsectors of the California Residential Building Industry by Subsector in 2022 (Estimated)

Residential Building Subsector	Establishments	Employment	Annual Payroll (Billions $)
New single family general contractors	12,671	58,367	4.4
New multifamily general contractors	421	6,344	0.7
New housing for-sale builders	189	3,969	0.5
Residential Remodelers	14,667	61,900	4.2
Residential plumbing and HVAC contractors	9,852	75,404	5.1

Source: (State of California n.d.)

3.3.2 Impact on Building Designers and Energy Consultants

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

Businesses that focus on residential, commercial, institutional, and industrial building design are contained within the Architectural Services sector (North American Industry Classification System 541310). Table 13 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The proposed code changes would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for residential HVAC performance measures to affect firms that focus on single family and multifamily construction.

There is not a North American Industry Classification System (NAICS)[9] code specific to energy consultants. Instead, businesses that focus on consulting related to building energy efficiency are contained in the Building Inspection Services sector (NAICS 541350), which is comprised of firms primarily engaged in the physical inspection of residential and nonresidential buildings.[10] It is not possible to determine which business establishments within the Building Inspection Services sector are focused on energy efficiency consulting. The information shown in Table 13 provides an upper bound indication of the size of this sector in California.

Table 13: California Building Designer and Energy Consultant Sectors in 2022 (Estimated)

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

Source: (State of California n.d.)

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

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

a. Architectural Services (NAICS 541310) comprises private-sector establishments primarily engaged in planning and designing residential, institutional, leisure, commercial, and industrial buildings and structures.
b. Building Inspection Services (NAICS 541350) comprises private-sector establishments primarily engaged in providing building (residential & nonresidential) inspection services encompassing all aspects of the building structure and component systems, including energy efficiency inspection services

3.3.3 Impact on Occupational Safety and Health

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

3.3.4 Impact on Building Owners and Occupants (Including Homeowners and Potential First-Time Homeowners)

According to data from the U.S. Census, American Community Survey (ACS), there were more than 14.5 million housing units in California in 2021 and nearly 13.3 million were occupied (see Table 14). Most housing units (nearly 9.42 million) were single family homes (either detached or attached), approximately 2 million homes were in buildings containing two to nine units, and 2.5 million homes were in multifamily buildings containing 10 or more units. The California Department of Revenue estimated that building permits for 67,300 single family and 54,900 multifamily homes will be issued in 2022, up from 66,000 single family and 53,500 multifamily permits issued in 2021.

Table 14: California Housing Characteristics in 2021[a]

Housing Measure	Estimate
Total housing units	14,512,281
Occupied housing units	13,291,541
Vacant housing units	1,220,740
Homeowner vacancy rate	0.7%
Rental vacancy rate	4.3%
Number of 1-unit, detached structures	8,388,099
Number of 1-unit, attached structures	1,030,372
Number of 2-unit structures	348,295
Number of 3- or 4-unit structures	783,663
Number of 5- to 9-unit structures	856,225
Number of 10- to 19-unit structures	740,126
Number of 20+ unit structures	1,828,547
Mobile home, RV, etc.	522,442

Sources: (United States Census Bureau n.d.), (Federal Reserve Economic Data (FRED) n.d.)

a. Total housing units as reported for 2021; all other housing measures estimated based on historical relationships

Table 15 shows the distribution of California homes by vintage. About 15 percent of California homes were built in 2000 or later and another 11 percent built between 1990 and 1999. The majority of California's existing housing stock (8.5 million homes – 59 percent of the total) were built between 1950 and 1989, a period of rapid population and economic growth in California. Finally, about 2.1 million homes in California were built before 1950. According to Kenney et al, 2019, more than half of California's existing multifamily buildings (those with five or more units) were constructed before 1978 when there were no building energy efficiency standards (Kenney 2019).

Table 15: Distribution of California Housing by Vintage in 2021 (Estimated)

Home Vintage	Units	Percent	Cumulative Percent
Built 2014 or later	348,296	2.4	2.4
Built 2010 to 2013	261,221	1.8	4.2
Built 2000 to 2009	1,581,839	10.9	15.1
Built 1990 to 1999	1,596,351	11.0	26.1
Built 1980 to 1989	2,191,354	15.1	41.2
Built 1970 to 1979	2,539,649	17.5	58.7
Built 1960 to 1969	1,915,621	13.2	71.9
Built 1950 to 1959	1,930,133	13.3	85.2
Built 1940 to 1949	841,712	5.8	91.0
Built 1939 or earlier	1,306,105	9.0	100.0
Total housing units	**14,512,281**	**100.0**	**–**

Sources: (United States Census Bureau n.d.)

Table 16 shows the distribution of owner- and renter-occupied housing by household income. Overall, about 55 percent of California housing is owner-occupied and the rate of owner-occupancy generally increases with household income. The owner-occupancy rate for households with an income below $50,000 is only 37 percent, whereas the owner occupancy rate is 71 percent for households earning $100,000 or more.

Table 16: Owner- and Renter-Occupied Housing Units in California by Income in 2021 (Estimated)

Household Income	Total	Owner Occupied	Renter Occupied
Less than $5,000	353,493	113,315	240,178
$5,000 to $9,999	254,304	74,939	179,366
$10,000 to $14,999	495,287	134,633	360,654
$15,000 to $19,999	412,498	144,064	268,435
$20,000 to $24,999	467,694	169,431	298,264
$25,000 to $34,999	906,996	355,968	551,028

Household Income	Total	Owner Occupied	Renter Occupied
$35,000 to $49,999	1,319,892	560,453	759,438
$50,000 to $74,999	2,036,560	990,769	1,045,791
$75,000 to $99,999	1,662,032	920,607	741,425
$100,000 to $149,999	2,307,889	1,490,247	817,642
$150,000 or more	3,074,895	2,337,651	737,244
Total Housing Units	**13,291,541**	**7,292,076**	**5,999,465**

Source: (United States Census Bureau n.d.)

Understanding the distribution of California residents by home type, home vintage, and household income is critical for developing meaningful estimates of the economic impacts associated with proposed code changes affecting residents. Many proposed code changes specifically target single family or multifamily residences and so the counts of housing units by building type shown in Table 14 through Table 16 provides the information necessary to quantify the magnitude of potential impacts. Likewise, impacts may differ for owners and renters, by home vintage, and by household income, information provided in Table 15 and Table 16.

3.3.4.1 Estimating Impacts

For California residents, the proposed code changes would result in lower energy bills. As discussed earlier, when homeowners or building occupants save on energy bills, they tend to spend it elsewhere thereby creating jobs and economic growth for the California economy. Energy cost savings can be particularly beneficial to low-income homeowners who typically spend a higher portion of their income on energy bills, often have trouble paying energy bills, and sometimes go without other necessities to save money for energy bills (Association, National Energy Assistance Directors 2011).

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

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

3.3.6 Impact on Building Inspectors

Table 17 shows employment and payroll information for state and local government agencies in which many inspectors of residential and commercial buildings are employed. Building inspectors participate in continuing education and training to stay current on all aspects of building regulations, including energy efficiency. The Statewide CASE Team, therefore, anticipates the proposed change would have no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections.

Table 17: Employment in California State and Government Agencies with Building Inspectors in 2022 (Estimated)

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

Source: (State of California, Employment Development Department n.d.)

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

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

3.3.7 Impact on Statewide Employment

As described in Sections 3.3.1 through 3.3.6, the Statewide CASE Team does not anticipate significant employment or financial impacts to any particular sector of the California economy. This is not to say that the proposed change would not have modest impacts on employment in California. In Section 3.4, the Statewide CASE Team estimated the proposed residential HVAC performance measures would affect statewide employment and economic output directly and indirectly through its impact on builders, designers and energy consultants, and building inspectors. In addition, the Statewide CASE Team estimated how energy savings associated with the proposed change in residential HVAC performance measures would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

3.4 Economic Impacts

For the 2025 code cycle, the Statewide CASE Team used the IMPLAN model software[11], along with economic information from published sources, and professional judgement to develop estimates of the economic impacts associated with each of the proposed code changes. Conceptually, IMPLAN estimates jobs created as a function of incoming cash flow in different sectors of the economy, due to implementing a code or a standard. The jobs created are typically categorized into direct, indirect, and induced employment. For example, cash flow into a manufacturing plant captures direct employment (jobs created in the manufacturing plant), indirect employment (jobs

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

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

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

Adoption of this code change proposal would result in relatively modest economic impacts through the additional direct spending by those in the residential building and remodeling industry, architects, energy consultants, and building inspectors, as well as indirectly as residents spend all or some of the money saved through lower utility bills on other economic activities.[12] There may also be some nonresidential customers that are impacted by this proposed code change; however, the Statewide CASE Team does not anticipate such impacts to be materially important to the building owner and would have measurable economic impacts.

[12] For example, for the lowest income group, we assume 100 percent of money saved through lower energy bills will be spent, while for the highest income group, we assume only 64 percent of additional income will be spent.

Table 18: Estimated Impact that Adoption of the Proposed Measure would have on the California Residential Construction Sector

Measure	Type of Economic Impact	Type of Economic Impact	Employment (Jobs)	Labor Income	Total Value Added
Design	**Direct Effects** (Additional spending by Residential Builders)	3,621.31	$272,483,786	$415,602,407	$891,207,716
	Indirect Effect (Additional spending by firms supporting Residential Builders)	2,218.22	$163,505,000	$279,374,059	$474,625,232
	Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	1,841.80	$125,360,661	$224,463,586	$357,263,064
Supplementary Heating	**Direct Effects** (Additional spending by Residential Builders)	48.95	$3,780,854	$5,152,679	$9,789,516
	Indirect Effect (Additional spending by firms supporting Residential Builders)	21.94	$1,632,600	$2,755,311	$4,678,743
	Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	22.54	$1,534,144	$2,746,847	$4,371,954
Defrost	**Direct Effects** (Additional spending by Residential Builders)	18.75	$1,460,868	$1,285,290	$2,433,050
	Indirect Effect (Additional spending by firms supporting Residential Builders)	5.43	$404,464	$682,307	$1,158,594
	Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	8.33	$566,802	$1,014,830	$1,615,229
Crankcase Heating (mandatory	**Direct Effects** (Additional spending by Residential Builders)	6.38	$481,618	$702,483	$1,496,605
	Indirect Effect (Additional spending by firms supporting Residential Builders)	3.71	$273,305	$466,718	$792,885
	Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	3.21	$218,150	$390,606	$621,700
Crankcase Heating (prescriptive)	**Direct Effects** (Additional spending by Residential Builders)	33.15	$2,494,732	$4,284,588	$8,941,103
	Indirect Effect (Additional spending by firms supporting Residential Builders)	21.78	$1,608,376	$2,741,459	$4,656,996
	Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	16.86	$1,147,743	$2,055,082	$3,270,931
Refrigerant Charge	**Direct Effects** (Additional spending by Residential Builders)	51.15	$3,894,558	$5,069,627	$10,580,061
	Indirect Effect (Additional spending by firms supporting Residential Builders)	25.77	$1,903,298	$3,244,172	$5,510,971
	Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	24.91	$1,695,478	$3,035,777	$4,831,830
All	**All**	**7,994**	**$584,446,437**	**$955,067,828**	**$1,787,846,180**

Source: CASE Team analysis of data from the IMPLAN modeling software.[13]

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

Table 19: Estimated Impact that Adoption of the Proposed Measure would have on the California Building Designers and Energy Consultants Sectors

Measure	Type of Economic Impact	Employment (Jobs)	Labor Income	Total Value Added	Output
Design	**Direct Effects** (Additional spending by Building Designers & Energy Consultants)	0.1	$10,792	$10,684	$16,887
	Indirect Effect (Additional spending by firms supporting Bldg. Designers & Energy Consultants)	0.0	$3,213	$4,466	$7,189
	Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	0.1	$4,027	$7,212	$11,479
Supplementary Heating	**Direct Effects** (Additional spending by Building Designers & Energy Consultants)	2.6	$284,963	$282,110	$445,902
	Indirect Effect (Additional spending by firms supporting Bldg. Designers & Energy Consultants)	1.0	$84,848	$117,922	$189,830
	Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	1.6	$106,338	$190,428	$303,094
Defrost	**Direct Effects** (Additional spending by Building Designers & Energy Consultants)	2.8	$303,398	$300,361	$474,749
	Indirect Effect (Additional spending by firms supporting Bldg. Designers & Energy Consultants)	1.1	$90,337	$125,550	$202,110
	Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	1.7	$113,217	$202,748	$322,702
Crankcase Heating (mandatory	**Direct Effects** (Additional spending by Building Designers & Energy Consultants)	0.2	$23,771	$23,533	$37,197
	Indirect Effect (Additional spending by firms supporting Bldg. Designers & Energy Consultants)	0.1	$7,078	$9,837	$15,835
	Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	0.1	$8,871	$15,885	$25,284
Crankcase Heating (prescriptive)	**Direct Effects** (Additional spending by Building Designers & Energy Consultants)	1.5	$169,796	$168,096	$265,691
	Indirect Effect (Additional spending by firms supporting Bldg. Designers & Energy Consultants)	0.6	$50,557	$70,264	$113,110
	Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	0.9	$63,362	$113,467	$180,599
Refrigerant Charge	**Direct Effects** (Additional spending by Building Designers & Energy Consultants)	0.4	$39,781	$39,383	$62,248
	Indirect Effect (Additional spending by firms supporting Bldg. Designers & Energy Consultants)	0.1	$11,845	$16,462	$26,500
	Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	0.2	$14,845	$26,584	$42,312
All	**All**	**15**	**$1,391,039**	**$1,724,992**	**$2,742,718**

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

Table 20: Estimated Impact that Adoption of the Proposed Measure would have on California Building Inspectors

Measure	Type of Economic Impact	Employment (Jobs)	Labor Income (Million)	Total Value Added (Million)	Output (Million)
Design	Direct Effects (Additional spending by Building Inspectors)	0.1	$13,612	$16,142	$19,616
	Indirect Effect (Additional spending by firms supporting Building Inspectors)	0.0	$1,261	$1,963	$3,420
	Induced Effect (Spending by employees of Building Inspection Bureaus and Departments)	0.1	$4,281	$7,669	$12,207
Supplementary Heating	Direct Effects (Additional spending by Building Inspectors)	3.2	$359,410	$426,217	$517,938
	Indirect Effect (Additional spending by firms supporting Building Inspectors)	0.4	$33,286	$51,843	$90,292
	Induced Effect (Spending by employees of Building Inspection Bureaus and Departments)	1.7	$113,046	$202,501	$322,316
Defrost	Direct Effects (Additional spending by Building Inspectors)	3.4	$382,662	$453,790	$551,445
	Indirect Effect (Additional spending by firms supporting Building Inspectors)	0.4	$35,439	$55,196	$96,134
	Induced Effect (Spending by employees of Building Inspection Bureaus and Departments)	1.8	$120,359	$215,601	$343,167
Crankcase Heating (mandatory	Direct Effects (Additional spending by Building Inspectors)	0.3	$29,982	$35,555	$43,206
	Indirect Effect (Additional spending by firms supporting Building Inspectors)	0.0	$2,777	$4,325	$7,532
	Induced Effect (Spending by employees of Building Inspection Bureaus and Departments)	0.1	$9,430	$16,892	$26,887
Crankcase Heating (prescriptive)	Direct Effects (Additional spending by Building Inspectors)	1.9	$214,155	$253,962	$308,614
	Indirect Effect (Additional spending by firms supporting Building Inspectors)	0.2	$19,833	$30,890	$53,801
	Induced Effect (Spending by employees of Building Inspection Bureaus and Departments)	1.0	$67,358	$120,660	$192,052
Refrigerant Charge	Direct Effects (Additional spending by Building Inspectors)	0.4	$50,174	$59,500	$72,305
	Indirect Effect (Additional spending by firms supporting Building Inspectors)	0.1	$4,647	$7,237	$12,605
	Induced Effect (Spending by employees of Building Inspection Bureaus and Departments)	0.2	$15,781	$28,269	$44,996
All	**All**	**$15**	**$1,477,493**	**$1,988,212**	**$2,718,533**

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

Table 21: Estimated Impact that Adoption of the Proposed Measure would have on Discretionary Spending by California Residents

Measure	Type of Economic Impact	Employment (Jobs)	Labor Income	Total Value Added	Output
Design	**Direct Effects (Additional spending by households)**	0.0	$0	$0	$0
	Indirect Effect (Purchases by businesses to meet additional household spending)	0.0	$0	$0	$0
	Induced Effect (Spending by employees of businesses experiencing "indirect" effects)	3,196.0	$217,698,525	$393,132,666	$625,225,200
Supplementary Heating	**Direct Effects (Additional spending by households)**	0.0	$0	$0	$0
	Indirect Effect (Purchases by businesses to meet additional household spending)	0.0	$0	$0	$0
	Induced Effect (Spending by employees of businesses experiencing "indirect" effects)	289.8	$19,737,789	$35,643,648	$56,686,479
Defrost	**Direct Effects (Additional spending by households)**	0.0	$0	$0	$0
	Indirect Effect (Purchases by businesses to meet additional household spending)	0.0	$0	$0	$0
	Induced Effect (Spending by employees of businesses experiencing "indirect" effects)	289.8	$19,742,259	$35,651,720	$56,699,317
Crankcase Heating (mandatory	**Direct Effects (Additional spending by households)**	0.0	$0	$0	$0
	Indirect Effect (Purchases by businesses to meet additional household spending)	0.0	$0	$0	$0
	Induced Effect (Spending by employees of businesses experiencing "indirect" effects)	329.8	$22,462,617	$40,564,301	$64,512,124
Crankcase Heating (prescriptive)	**Direct Effects (Additional spending by households)**	0.0	$0	$0	$0
	Indirect Effect (Purchases by businesses to meet additional household spending)	0.0	$0	$0	$0
	Induced Effect (Spending by employees of businesses experiencing "indirect" effects)	6,367.0	$433,687,820	$783,178,702	$1,245,541,527
Refrigerant Charge	**Direct Effects (Additional spending by households)**	0.0	$0	$0	$0
	Indirect Effect (Purchases by businesses to meet additional household spending)	0.0	$0	$0	$0
	Induced Effect (Spending by employees of businesses experiencing "indirect" effects)	825.4	$56,221,749	$101,528,505	$161,467,580
Total Economic Impacts		**11,298**	**$769,550,759**	**$1,389,699,542**	**$2,210,132,227**

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

3.4.1 Creation or Elimination of Jobs

The Statewide CASE Team does not anticipate that the measures proposed for the 2025 code cycle regulation would lead to the creation of new *types* of jobs or the elimination of *existing* types of jobs. In other words, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. Rather, the estimates of economic impacts discussed in Section 3.4 would lead to modest changes in employment of existing jobs.

3.4.2 Creation or Elimination of Businesses in California

As stated in Section 0, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. The proposed change represents a modest change to residential HVAC design and installation, which would not excessively burden or competitively disadvantage California businesses – nor would it necessarily lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not foresee any new businesses being created, nor does the Statewide CASE Team think any existing businesses would be eliminated due to the proposed code changes.

3.4.3 Competitive Advantages or Disadvantages for Businesses in California

The proposed code changes would apply to all businesses incorporated in California, regardless of whether the business is located inside or outside of the state.[14] Therefore, the Statewide CASE Team does not anticipate that these measures proposed for the 2025 code cycle regulation would have an adverse effect on the competitiveness of California businesses. Likewise, the Statewide CASE Team does not anticipate businesses located outside of California would be advantaged or disadvantaged.

3.4.4 Increase or Decrease of Investments in the State of California

The Statewide CASE Team analyzed national data on corporate profits and capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI).[15] As Table 22 shows, between 2017 and 2021, NPDI as a percentage of corporate profits ranged from a low of 18 in 2020 due to the worldwide economic slowdowns associated with the COVID 19 pandemic to a high of 35 percent in 2019, with an average of 26 percent. While only an approximation of the proportion of

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

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

business income used for net capital investment, the Statewide CASE Team believes it provides a reasonable estimate of the proportion of proprietor income that would be reinvested by business owners into expanding their capital stock.

Table 22: Net Domestic Private Investment and Corporate Profits, U.S.

Year	Net Domestic Private Investment by Businesses, Billions of Dollars	Corporate Profits After Taxes, Billions of Dollars	Ratio of Net Private Investment to Corporate Profits (Percent)
2017	518.473	1882.460	28
2018	636.846	1977.478	32
2019	690.865	1952.432	35
2020	343.620	1908.433	18
2021	506.331	2619.977	19
5-Year Average	**-**	**-**	**26**

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

The Statewide CASE Team estimates that the sum of proposed code changes in this report will increase in investment in California:

Change in Proprietor Income * 0.26 = $85,464,898.00

The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed measure would lead to significant change (increase or decrease) in investment, directly or indirectly, in any affected sectors of California's economy. Nevertheless, the Statewide CASE Team is able to derive a reasonable estimate of the change in investment by California businesses based on the estimated change in economic activity associated with the proposed measure and its expected effect on proprietor income, which we use a conservative estimate of corporate profits, a portion of which we assume will be allocated to net business investment.[16]

3.4.5 Incentives for Innovation in Products, Materials, or Processes

There have been no identified emerging trends within the affected industry affected by these proposed regulations.

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

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

[16] 26 percent of proprietor income was assumed to be allocated to net business investment; see Table 22.

3.4.6.1 Cost of Enforcement

Cost to the State: State government already has budget for code development, education, and compliance enforcement. While state government will be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, these activities are already covered by existing state budgets. The costs to state government are small when compared to the overall costs savings and policy benefits associated with the code change proposals.

Cost to Local Governments: All proposed code changes to Title 24, Part 6 would result in changes to compliance determinations. Local governments would need to train building department staff on the revised Title 24, Part 6 Standards. While this re-training is an expense to local governments, it is not a new cost associated with the 2025 code change cycle. The building code is updated on a triennial basis, and local governments plan and budget for retraining every time the code is updated. There are numerous resources available to local governments to support compliance training that can help mitigate the cost of retraining, including tools, training and resources provided by the IOU Codes and Standards program (such as Energy Code Ace). As noted in Section 2.5 and Appendix E, the Statewide CASE Team considered how the proposed code change might impact various market actors involved in the compliance and enforcement process and aimed to minimize negative impacts on local governments.

3.4.7 Impacts on Specific Persons

While the objective of any of the Statewide CASE Team's proposal is to promote energy efficiency, the Statewide CASE Team recognizes that there is the potential that a proposed code change may result in unintended consequences. There are no anticipated impacts to any specific group or groups of persons (i.e., persons of a specific protected class, persons eligible to participate in affordable housing programs, renters, commuters, etc.) that would differ from impacts to persons generally. Refer to Section 7 for more details addressing energy equity and environmental justice.

3.5 Fiscal Impacts

3.5.1 Mandates on Local Agencies or School Districts

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

3.5.2 Costs to Local Agencies or School Districts

There are no costs to local agencies or school districts.

3.5.3 Costs or Savings to Any State Agency

There are no costs or savings to any state agencies.

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

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

3.5.5 Costs or Savings in Federal Funding to the State

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

4. Energy Savings

The Statewide CASE Team gathered stakeholder input to inform the energy savings analysis. For example, interviews with contractors helped to determine typical practices for sizing. Discussions with manufacturers helped to identify typical CCH configurations. A review of data in the HERS Registry also identified typical sizing practices. Refer to Appendix F for a summary of stakeholder engagement.

Energy savings benefits may have potential to disproportionately impact DIPs. Refer to Section 7 for more details addressing energy equity and environmental justice.

This section covers all measures that would modify the stringency of the existing California Energy Code. The variable capacity system measure would not modify the stringency of the code, so there would be no savings on a per-unit basis and therefore it is not reported on in this section.

Sections 4, 5, and a provide results for single family buildings. While the code change proposals also apply to multifamily buildings, the energy impacts are not captured in this report but will be included in the Final CASE Report.

4.1 Energy Savings Methodology

4.1.1 Key Assumptions for Energy Savings Analysis

The energy savings analysis relies on results of California Building Energy Code Compliance (CBECC) software simulations, specifically the 2025 research version of CBECC-Res, to estimate energy use for single family prototype buildings (California Energy Commission n.d.). The Statewide CASE Team simulated the energy impacts in every climate zone and applied the climate-zone specific Long-term System Cost (LSC) hourly factors when calculating energy cost impacts. The Statewide CASE Team evaluated various scenarios comparing the energy impacts and cost effectiveness across prototypes and climate zones. This process, in parallel with stakeholder outreach and market and technical research, informed the ultimate proposals that are made in this report.

4.1.2 Energy Savings Methodology per Prototypical Building

The Statewide CASE Team measured per unit energy savings expected from the proposed code changes in several ways in order to quantify key impacts. First, savings are calculated by fuel type. Electricity savings are measured in terms of both energy usage and peak demand reduction. Natural gas savings are quantified in terms of energy usage. Second, the Statewide CASE Team calculated Source Energy Savings. Source Energy represents the total amount of raw fuel required to operate a building. In addition to all energy used from on-site production, source energy incorporates all transmission, delivery, and production losses. The hourly source energy values provided by CEC are strongly correlated with GHG emissions.[17] Finally, the Statewide CASE Team calculated Long-term Systemwide Cost (LSC) Savings, formerly known as Time Dependent Valuation (TDV) Energy Cost Savings. LSC Savings are calculated using hourly LSC factors for both electricity and natural gas provided by the CEC. These LSC hourly factors are projected over the 30-year life of the building and incorporate the hourly cost of marginal generation, transmission and distribution, fuel, capacity, losses, and cap-and-trade-based CO2 emissions.[12]

The CEC directed the Statewide CASE Team to model the energy impacts using specific prototypical building models that represent typical building geometries for different types of buildings (California Energy Commission 2022). The prototype buildings that the Statewide CASE Team used in the analysis are presented in Table 23.

Energy savings are calculated using three new construction prototypes, a 500 square foot small home, a single story 2,100 square foot home, and a two-story 2,700 square foot home. Statewide results are weighted 2 percent for the 500 square foot prototype, 42 percent for the 2,100 square foot prototype and 56 percent for the 2,700 square foot prototype. Energy savings and overall impacts are similar across the 2,100 and 2,700 square foot prototypes. In this report where individual prototype results are presented, results of the 2,100 and 2,700 square foot prototypes are presented as a weighted average based on the statewide distribution due. Results are separately presented for the 500 square foot single family new construction prototype since the impacts in some cases differ significantly for the smaller prototype. See Appendix A for further details on how the weighting was derived. Energy savings for alterations are calculated based on a single 1,665 square foot existing home prototype.

Additional details on the 2,100 and 2,700 square foot single family prototypes can be found in the Single family Residential Alternative Calculation Method (ACM) Approval Manual (California Energy Commission 2022). The 500 square foot single family prototype is a new prototype being evaluated in this code cycle to reflect recent trends in California construction of a greater number of accessory dwelling units and small homes (Bay Area Council Economic Institute n.d.) (UC Berkeley Center for Community Innovation 2021). The single family existing building prototype reflects the prototype developed during the 2022 code cycle as part of the Residential Energy Savings and Process Improvements for Additions and Alterations CASE Report (Statewide CASE Team 2020) and was developed based on the alteration prototypes described in the ACM Approval Manual (California Energy Commission 2022). See Appendix H for further details on the existing home prototype.

[17] See Hourly Factors for Source Energy, Long-term Systemwide Cost, and Greenhouse Gas Emissions at https://www.energy.ca.gov/files/2025-energy-code-hourly-factors

Table 23: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name	Number of Stories	Floor Area (Square Feet)	Description
One-Story Single Family (2,100 ft^2)	1	2,100	Single story 3-bedroom house with attached garage, 9-ft ceilings, vented attic and steep-sloped roof.
Two-Story Single Family (2,700 ft^2)	2	2,700	Two-story 4-bedroom house with attached garage, 9-ft ceilings, 1-ft between floors, vented attic and steep-sloped roof.
Small Single Family (500 ft^2)	1	500	Detached single story 1-bedroom small home, 9-ft ceilings.
Single Family Existing Building (1,665 ft^2)	1	1,665	Single story 3-bedroom existing home, no attached garage, 8-ft ceilings, vented attic and steep-sloped roof.

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

CBECC-Res generates two models based on user inputs: the Standard Design and the Proposed Design.[18] The Standard Design represents the geometry of the prototypical building and a design that uses a set of features that result in a LSC budget and Source Energy budget that is minimally compliant with 2022 Title 24, Part 6 code requirements. Features used in the Standard Design are described in the 2022 Single family Residential ACM Reference Manual. The Proposed Design represents the same geometry as the Standard Design, but it assumes the energy features that the software user describes with user inputs. To develop savings estimates for the proposed code changes, the Statewide CASE Team created a Standard Design and Proposed Design for each prototypical building with the Standard Design representing compliance with 2022 code and the Proposed Design representing compliance with the proposed requirements. Comparing the energy impacts of the Standard Design to the Proposed Design reveals the impacts of the proposed code change relative to a building that is either minimally compliant with the 2022 Title 24, Part 6 requirements or that follows industry typical practices.

For most of the residential HVAC performance measures, there is an existing Title 24, Part 6 requirement that covers the building system in question and applies to both new construction/ additions and alterations, so the Standard Design is minimally compliant with the 2022 Title 24 requirements.

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

For other measures, there are no existing requirements in Title 24, Part 6 that cover the building system in question. The Statewide CASE Team modified the Standard Design so that it calculated energy impacts of the most common current design practice, or industry standard practice for both new Construction/additions and alterations.

Table 24 presents precisely which parameters were modified and what values were used in the Standard Design and Proposed Design. CBECC-Res was used to model energy impacts in most instances; however, for some measures post-processing of CBECC output was necessary as there was no direct way to evaluate the measure directly in CBECC-Res.

For the design measure, heating dominated and cooling dominated climate zones were identified using the auto sizing function in CBECC-Res. The 500 square foot, 2100 square foot, and 2700 square foot prototypes were all modeled with a Furnace/AC combo with both heating and cooling sizing factors set to 1, where sizing factor refers to the factor multiplied by the heating and cooling load calculated by the software. It was determined that the systems with a higher cooling capacity than heating capacity were cooling dominated climate zones and that the climate zones with higher heating capacities were heating dominated climate zones. For the heating dominated climate zones, the impact of undersizing for heat pump heating was directly evaluated in CBECC-Res. With insufficient compressor capacity the model applies backup electric resistance heating to make up the difference. When systems are right sized compressor use increases but electric resistance energy use decreases. For new construction there are no proposed limits on cooling capacity and therefore the proposed requirements don't impact system sizing in cooling dominated climates. For alterations, the impacts of compressor oversizing or undersizing on cooling energy use are not well considered in CBECC-Res. As a result, a NIST study that documented the impacts of oversizing (Domanski, Henderson and Payne 2014) was relied on to reflect expected energy use of a typical home. That study identified that oversizing only results in an energy penalty in cooling-dominated climates and where ducts are not correspondingly upsized. They found that the penalty was about seven percent when units were 20 percent oversized.

The supplementary heating measure also could not directly be evaluated within CBECC-Res as there is no way to directly limit backup supplementary heating. This was accomplished through post-processing the hourly data. Whenever supplementing heating was operating and temperatures were above 35°F, backup heating was assumed to not be allowed to operate. This was accomplished by converting any supplementary heating energy use during these time periods to zero. The energy delivered during that timestep from supplementary heating was then converted to heat pump compressor energy use using an average coefficient of performance (COP) based on the calculated COP of the heat pump for that timestep. The peak demand impacts were not evaluated but will be estimated for the Final CASE Report. The impacts on comfort were also not evaluated.

This measure has a small impact if a fixed thermostat setpoint is applied and the heat pump is appropriately sized for the heating load. The thermostat setpoint used for heat pumps in CBECC-Res is a fixed setpoint of 68°F. Savings were also estimated in the case of a setback thermostat as the value of this measure is much greater during morning warm up periods. A variable setpoint was evaluated with a setback to 65°F from 11pm to 7am and 68°F at all other times. Savings for this measure are presented as an average between the fixed setpoint and setback thermostat results.

The defrost measure savings were based on the existing approach to calculate defrost energy that is currently applied in CBECC-Res and its simulation engine, the California Simulation Engine (CSE). was modeled by adjusting the percent reduction to the heat pump capacity that CBEC-Res assumes while the system is in defrost mode. The software accounts for defrost by assuming a variable percent reduction to the heat pump's capacity in the range of outdoor temperatures from 47°F to 17°F. The percent reduction is dependent upon a linear equation that is based on a 10 percent capacity reduction at 35°F and a zero percent capacity reduction at 17°F. This reduction can be adjusted in the CSE by inputting a different capacity at 35°F. In order to achieve a 25 percent reduction to the model's defrost energy (described in section 2.2.2.3), the input for the capacity at 35°F was changed to assume a 7.5 percent capacity reduction instead of a 10 percent reduction at 35°F.

The assumptions for CCH capacity align with the current DOE allowances for crankcase heaters on residential heat pumps, as reflected in the test standard (AHRI 2023). The capacity and the control logic for the CCH are simulated by editing inputs in CSE. To evaluate the mandatory measure proposal, the heater was simulated to operate continuously in the basecase and to be turned off whenever the compressor was operating for the proposed case. The prescriptive measure proposal analysis was layered on top of this control scheme and the heater was turned off whenever outdoor air temperature was above 55°F in the proposed case.

Refrigerant charge verification is handled by CBECC-Res for space cooling by altering the EER used in the simulation and applying a six percent degradation. With charge verification the EER is multiplied by 0.96 and without charge verification the EER is multiplied by 0.90. The impacts on performance during heating operation are not as large as in cooling operation. Heat pumps are typically equipped with a suction line accumulator which accumulates liquid refrigerant to prevent it from entering the compressor. When the heat pump operates in heating mode it is common for liquid refrigerant to be stored in the accumulator. The accumulator and liquid refrigerant stored in it can partially compensate for incorrect refrigerant charge in heating mode. It is estimated that the heating impact of low refrigerant charge is on average 67% of the cooling impact. To simulate the impact for heating the HSPF was multiplied by 0.90 without charge verification and 0.94 with charge verification.

Table 24: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change

Measure	Climate Zone	HVAC System Type	Standard Design Parameter Value	Proposed Design Parameter Value
Design	Cooling Dominated CZs 2-15 (alterations only)	Heat pump. Savings will be the same for AC.	Oversized, modeled as right sized for cooling (1.0 sizing factor) but with a 7.3% energy penalty imposed, based on NIST study (Domanski, Henderson and Payne 2014).	Right sized for cooling (1.0 sizing factor).
	Heating Dominated CZs 1 & 16 (new construction & alterations)	Heat pump only.	Undersized, modeled in CBECC with Heating sizing factor 0.9, resulting in additional strip heating use.	Right sized for heating (1.0 sizing factor).
Supple-mentary Heat	All CZs	Heat pump only.	Right sized for heating or cooling, whichever is larger (1.0 sizing factor). Evaluated both with fixed and setback thermostat setpoints.	Strip heating is disabled when outdoor air > max (25°F, local heating design temperature) except during defrost. Evaluated both with fixed and setback thermostat setpoints. Savings presented as an average of these 2 thermostat cases.
Defrost	All CZs	Heat pump only.	CBECC-RES defrost assumptions (capacity at 35°F degraded by 10%)	Standard Design with capacity at 35°F degraded by 7.5%
Crankcase Heating (Mandatory)	All CZs	Heat pump. (AC analysis to be included in the Final CASE Report).	33W for 3-ton and below or 11W/ton above 3-ton. On continuously, no control.	33W for 3-ton and below or 11W/ton above 3-ton. Off when compressor is operating.
Crankcase Heating (Prescriptive)	All CZs	Heat pump. Savings will be the same for AC and are applied to all systems.	33W for 3-ton and below or 11W/ton above 3-ton. Off when compressor is operating.	33W for 3-ton and below or 11W/ton above 3-ton Off above 55°F OAT and when compressor is operating.
Charge Verification, Heat Pumps	CZ 1,3-7,16	Heat pump only.	No charge verification. Heat pump HSPF multiplied by 0.90.	Charge verification. Heat pump HSPF multiplied by 0.94.

CBECC-Res calculates whole-building energy consumption for every hour of the year and outputs annual totals measured in kilowatt-hours per year (kWh/yr) and therms per year (therms/yr). It then applies the 2025 LSC hourly factors to calculate Long-term Systemwide Cost in 2026 present value dollars (2026 PV$), Source Energy hourly factors to calculate Source Energy Use in kilo British thermal units per year (kBtu/yr), and hourly GHG emissions factors to calculate annual GHG emissions in metric tons of carbon dioxide emissions equivalent per year (metric tons or “tonnes” of CO_2e/yr). CBECC-Res also calculates annual peak electricity demand measured in kilowatts (kW).

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

Per unit energy impacts for single family buildings are presented in savings per prototype building. As described in Section a, the Statewide CASE Team developed a weighted average savings of the prototypes to calculate statewide savings.

4.1.3 Statewide Energy Savings Methodology

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

4.2 Per-Unit Energy Impacts Results

Energy savings and peak demand reductions per unit are presented in the following sections. Savings are presented for all of the single family prototypes, both new construction and alterations. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates.

4.2.1 Design (Sizing, Equipment Selection, and Ducts/Diffusers)

Energy savings and peak demand reductions per unit are presented in Table 25 through Table 28. There are no natural gas savings for this measure. Climate Zones 1 and 16 are the two climate zones that are considered "heating dominated": that is, the homes modeled in their representative cities have a larger heating load than cooling load. These were modeled to comply with the requirement that heating could not be undersized.

Climate zones 2-15 are considered "cooling dominated" and were modeled to comply with the requirement that cooling cannot be extremely oversized unless ducts are correspondingly upsized. Because the measure for cooling-dominated applications has an exception for homes where airflow is at least 350 cfm/ton, which is a mandatory requirement for new construction, savings were not calculated for the new construction prototypes. In addition, demand reduction savings were not calculated for the cooling dominated alterations cases.

Per-unit savings for the first year are expected to range from 6 to 33 kwh/yr for the weighted 2100/2700 prototype, 6 to 15 for the small home, and 5 to 652 for alterations. Demand reductions are expected to range from 2 to 8 Watts for the weighted 2100/2700 prototype, 2 to 4 Watts for the small home, and 12 to 13 Watts for alterations. Source savings are expected to range from 3 to 105 kBtu for the weighted 2100/2700 prototype, 20 to 45 for the small home, and 5 to 447 for alterations. The first year long-term system cost savings per unit range from $28 to $269 for the weighted 2100/2700 prototype, $45 to $120 for the small home, and $5 to $447 for alterations.

Table 25: First Year Electricity Savings (kWh) Per Home – Design

Climate Zone	2,100/2,700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	33	6	51
2	N/A	N/A	38
3	N/A	N/A	8
4	N/A	N/A	155
5	N/A	N/A	5
6	N/A	N/A	53
7	N/A	N/A	74
8	N/A	N/A	135
9	N/A	N/A	127
10	N/A	N/A	182
11	N/A	N/A	254
12	N/A	N/A	112
13	N/A	N/A	317
14	N/A	N/A	222
15	N/A	N/A	652
16	6	15	59

Table 26: First Year Peak Demand Reduction (kW) Per Home – Design

Climate Zone	2,100/2,700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	0.008	0.002	0.013
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	0.002	0.004	0.012

Table 27: First Year Source Energy Savings (kBtu) Per Home – Design

Climate Zone	2,100/2,700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	105	20	167
2	N/A	N/A	30
3	N/A	N/A	7
4	N/A	N/A	111
5	N/A	N/A	5
6	N/A	N/A	34
7	N/A	N/A	50
8	N/A	N/A	94
9	N/A	N/A	94
10	N/A	N/A	122
11	N/A	N/A	198
12	N/A	N/A	102
13	N/A	N/A	250
14	N/A	N/A	143
15	N/A	N/A	447
16	3	45	167

Table 28: First Year Long-term System Cost Savings (2026 PV$) Per Home – Design

Climate Zone	2,100/2,700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	$269	$45	$416
2	N/A	N/A	$30
3	N/A	N/A	$7
4	N/A	N/A	$111
5	N/A	N/A	$5
6	N/A	N/A	$34
7	N/A	N/A	$50
8	N/A	N/A	$94
9	N/A	N/A	$94
10	N/A	N/A	$122
11	N/A	N/A	$198
12	N/A	N/A	$102
13	N/A	N/A	$250
14	N/A	N/A	$143
15	N/A	N/A	$447
16	$28	$120	$433

4.2.2 Supplementary Heating

Energy savings per unit are presented in Table 29 through Table 32. Peak demand reductions are still being calculated for this measure. There are no natural gas savings for this measure. This measure does not apply too small single family homes or heat pumps in CZ 15. Per-unit savings for the first year are expected to range from 31 to 424 kwh/yr for the weighted 2100/2700 prototype and 27 to 376 for alterations. Source savings are expected to range from 100 to 1,025 kBtu for the weighted 2100/2700 prototype and 90 to 856 for alterations. The first year long-term system cost savings per unit range from $215 to $3,061 for the weighted 2100/2700 prototype and $191 to $2,648 for alterations.

Table 29: First Year Electricity Savings (kWh) Per Home – Supplementary Heating

Climate Zone	2,100/2,700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	424	N/A	376
2	241	N/A	137
3	135	N/A	129
4	175	N/A	91
5	138	N/A	140
6	36	N/A	32
7	31	N/A	27
8	38	N/A	56
9	54	N/A	62
10	54	N/A	55
11	157	N/A	103
12	190	N/A	122
13	109	N/A	85
14	224	N/A	155
15	N/A	N/A	N/A
16	303	N/A	245

Table 30: First Year Peak Demand Reduction (kW) Per Home – Supplementary Heating

Climate Zone	2,100/2,700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	N/A	N/A	N/A
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	N/A	N/A	N/A

Table 31: First Year Source Energy Savings (kBtu) Per Home – Supplementary Heating

Climate Zone	2,100/2,700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	1,025	N/A	856
2	696	N/A	370
3	448	N/A	366
4	463	N/A	230
5	431	N/A	372
6	134	N/A	116
7	100	N/A	90
8	138	N/A	189
9	200	N/A	209
10	192	N/A	179
11	486	N/A	287
12	562	N/A	329
13	364	N/A	256
14	693	N/A	454
15	N/A	N/A	N/A
16	789	N/A	626

Table 32: First Year Long-term System Cost Savings (2026 PV$) Per Home – Supplementary Heating

Climate Zone	2,100/2,700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	$3,061	N/A	$2,648
2	$1,853	N/A	$1,023
3	$1,096	N/A	$978
4	$1,294	N/A	$662
5	$1,099	N/A	$1,038
6	$289	N/A	$253
7	$215	N/A	$191
8	$299	N/A	$440
9	$435	N/A	$491
10	$436	N/A	$441
11	$1,229	N/A	$777
12	$1,475	N/A	$915
13	$880	N/A	$658
14	$1,700	N/A	$1,156
15	N/A	N/A	N/A
16	$2,186	N/A	$1,744

4.2.3 Defrost

Energy savings and peak demand reductions per unit are presented in Table 33 through Table 36. There are no natural gas savings for this measure. This measure is not applicable to small homes in CZs 5-10 and CZ 15. Per-unit savings for the first year are expected to range from 3 to 147 kwh/yr for the weighted 2100/2700 prototype, 3 to 21 for the small home, and 4 to 288 for alterations. Demand savings are expected to range from 0 to 40 Watts for the weighted 2100/2700 prototype, 1 to 6 Watts for the small home, and 0 to 79 Watts for alterations. Source savings are expected to range from 10 to 482 kBtu for the weighted 2100/2700 prototype, 15 to 70 for the small home, and 17 to 799 for alterations. The first year long-term system cost savings per unit range from $24 to $1,215 for the weighted 2100/2700 prototype, $25 to $170 for the small home, and $33 and $2298 for alterations.

Table 33: First Year Electricity Savings (kWh) Per Home – Defrost

Climate Zone	2,100/2,700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	147	21	253
2	100	8	156
3	36	3	70
4	84	8	143
5	41	N/A	87
6	3	N/A	4
7	3	N/A	5
8	8	N/A	24
9	16	N/A	41
10	19	N/A	47
11	80	6	165
12	83	7	167
13	61	6	124
14	92	9	204
15	6	N/A	18
16	142	14	288

Table 34: First Year Peak Demand Reduction (kW) Per Home – Defrost

Climate Zone	2,100/2,700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	0.040	0.006	0.068
2	0.028	0.003	0.047
3	0.015	0.001	0.027
4	0.026	0.003	0.047
5	0.018	N/A	0.036
6	0.001	N/A	0.002
7	0.000	N/A	0.000
8	0.003	N/A	0.010
9	0.007	N/A	0.017
10	0.010	N/A	0.027
11	0.023	0.002	0.046
12	0.028	0.003	0.055
13	0.022	0.003	0.044
14	0.037	0.004	0.080
15	0.004	N/A	0.011
16	0.039	0.005	0.079

Table 35: First Year Source Energy Savings (kBtu) Per Home – Defrost

Climate Zone	2,100/2,700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	482	70	783
2	339	25	516
3	143	15	266
4	279	30	466
5	143	N/A	300
6	24	N/A	17
7	10	N/A	17
8	49	N/A	100
9	73	N/A	166
10	73	N/A	183
11	279	25	566
12	279	25	566
13	220	20	433
14	328	35	699
15	24	N/A	83
16	401	40	799

Table 36: First Year Long-term System Cost Savings (2026 PV$) Per Home – Defrost

Climate Zone	2,100/2,700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	$1,215	$170	$2,048
2	$820	$65	$1,265
3	$325	$25	$616
4	$667	$60	$1,149
5	$359	N/A	$716
6	$24	N/A	$33
7	$24	N/A	$33
8	$49	N/A	$216
9	$147	N/A	$366
10	$171	N/A	$416
11	$646	$55	$1,315
12	$681	$60	$1,349
13	$513	$50	$1,016
14	$768	$75	$1,665
15	$63	N/A	$183
16	$1,138	$115	$2,298

4.2.4 Crankcase Heating

Energy savings and peak demand reductions per unit are presented in Table 37 through Table 40 for the mandatory CCH measure. Savings for the prescriptive measure are not included, because they accrue from the installation of an OCST, which has already been identified as cost effective. There are no natural gas savings for this measure. Per-unit savings for the first year are expected to range from 4 to 53 kwh/yr for the weighted 2100/2700 prototype, 2 to 46 for the small home, and 12 to 95 for alterations. Demand savings are expected to range from 1 to 11 Watts for the weighted 2100/2700 prototype, 1 to 6 Watts for the small home, and 1 to 16 Watts for alterations. Source savings are expected to range from 0 to 143 kBtu for the weighted 2100/2700 prototype, 5 to 65 for the small home, and 17 to 150 for alterations. The first year long-term system cost savings per unit range from $35 to $405 for the weighted 2100/2700 prototype, $15 to $300 for the small home, and $83 to $599 for alterations.

Table 37: First Year Electricity Savings (kWh) Per Home – Crankcase Heating

Climate Zone	2,100/2,700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	51	23	54
2	21	7	35
3	11	3	21
4	25	16	49
5	10	2	20
6	4	5	12
7	4	8	15
8	10	20	28
9	12	18	29
10	15	21	37
11	33	26	69
12	22	16	49
13	33	31	69
14	34	28	69
15	53	46	95
16	44	24	75

Table 38: First Year Peak Demand Reduction (kW) Per Home – Crankcase Heating

Climate Zone	2,100/2,700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	0.011	0.006	0.012
2	0.006	0.002	0.009
3	0.004	0.001	0.007
4	0.007	0.003	0.009
5	0.003	0.001	0.006
6	0.001	0.001	0.002
7	0.001	0.001	0.001
8	0.001	0.001	0.004
9	0.002	0.001	0.005
10	0.002	0.001	0.005
11	0.006	0.003	0.011
12	0.006	0.002	0.011
13	0.006	0.003	0.010
14	0.007	0.003	0.014
15	0.003	0.002	0.005
16	0.010	0.004	0.016

Table 39: First Year Source Energy Savings (kBtu) Per Home – Crankcase Heating

Climate Zone	2,100/2,700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	143	65	133
2	59	20	100
3	35	15	67
4	70	40	117
5	24	10	67
6	14	5	17
7	0	10	17
8	24	25	50
9	24	20	50
10	38	25	67
11	84	40	150
12	59	30	117
13	63	45	117
14	84	45	150
15	63	50	100
16	133	55	200

Table 40: First Year Long-term System Cost Savings (2026 PV$) Per Home – Crankcase Heating

Climate Zone	2,100/2,700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	$405	$175	$400
2	$178	$55	$283
3	$105	$30	$166
4	$202	$145	$383
5	$70	$15	$150
6	$38	$40	$83
7	$35	$80	$133
8	$73	$140	$200
9	$98	$130	$216
10	$108	$150	$266
11	$265	$205	$516
12	$181	$140	$383
13	$265	$230	$516
14	$265	$205	$500
15	$352	$300	$599
16	$359	$175	$566

4.2.5 Refrigerant Charge Verification

Energy savings and peak demand reductions per unit are presented in Table 41 through Table 44. The tables compare the proposed design of heat pump HVAC systems with a HSPF value of 94 percent of the prescriptive 2022 HSPF value with refrigerant charge verification and the standard design of heat pump HVAC systems with a HSPF value of 90 percent and no refrigerant charge verification. There are no natural gas savings for this measure. Per-unit savings for the first year are expected to range from 38 to 148 kwh/yr for the weighted 2100/2700 prototype, and 87 to 487 for alterations. Demand savings are expected to range from 15 to 34 Watts for the weighted 2100/2700 prototype, and to 72 Watts for alterations. Source savings are expected to range from 133 to 387 kBtu for the weighted 2100/2700 prototype, and 100 to 799 for alterations. The first year long-term system cost savings per unit range from $321 to $1,166 for the weighted 2100/2700 prototype, and $466 to $4,595 for alterations.

Table 41: First Year Electricity Savings (kWh) Per Home – Refrigerant Charge

Climate Zone	2,100/2,700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	131	N/A	217
2	N/A	N/A	N/A
3	46	N/A	101N/A
4	86	N/A	288
5	38	N/A	87
6	N/A	N/A	74
7	N/A	N/A	94
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	148	N/A	322

Table 42: First Year Peak Demand Reduction (kW) Per Home – Refrigerant Charge

Climate Zone	2,100/2,700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	0.029	N/A	0.048
2	N/A	N/A	N/A
3	0.019	N/A	N/A
4	0.025	N/A	0.045
5	0.015	N/A	0.030
6	N/A	N/A	0.008
7	N/A	N/A	0.004
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	0.034	N/A	0.067

Table 43: First Year Source Energy Savings (kBtu) Per Home – Refrigerant Charge

Climate Zone	2,100/2,700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	359	N/A	583
2	N/A	N/A	N/A
3	157	N/A	N/A
4	258	N/A	500
5	133	N/A	250
6	N/A	N/A	100
7	N/A	N/A	100
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	387	N/A	799

Table 44: First Year Long-term System Cost Savings (2026 PV$) Per Home – Refrigerant Charge

Climate Zone	2,100/2,700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	$1,019	N/A	$1,665
2	N/A	N/A	N/A
3	$422	N/A	N/A
4	$691	N/A	$1,948
5	$321	N/A	$699
6	N/A	N/A	$466
7	N/A	N/A	$566
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	$1,166	N/A	$2,431

5. Cost and Cost Effectiveness

This section covers all measures that would modify the stringency of the existing California Energy Code. The variable capacity system measure would not modify the stringency of the code, so there would be no savings on a per-unit basis and therefore it is not reported on in this section.

5.1 Energy Cost Savings Methodology

Energy cost savings were calculated by applying the LSC hourly factors to the energy savings estimates that were derived using the methodology described in Section 4.1. LSC hourly factors are a normalized metric to calculate energy cost savings that accounts for the variable cost of electricity and natural gas for each hour of the year, along with how costs are expected to change over the 30-year period of analysis.

The CEC requested LSC savings over the 30-year period of analysis in both 2026 present value dollars (2026 PV$) and nominal dollars. The cost effectiveness analysis uses LSC values in 2026 PV$. Costs and cost effectiveness using and 2026 PV$ are presented in Section 4 of this report. CEC uses results in nominal dollars to complete the Economic and Fiscal Impacts Statement (From 399) for the entire package of proposed change to Title 24, Part 6. Appendix G presents LSC savings results in nominal dollars.

Incremental first costs and costs over time were established through interviews with manufacturers and contractors, searching for costs from online sources, and a survey of contractors. These are listed in Section 5.3.

5.2 Energy Cost Savings Results

Per-unit energy cost savings for newly constructed buildings, additions, and alterations in terms of LSC savings realized over the 30-year period of analysis are presented in 2026 present value dollars (2026 PV$) for each measure in the following subsections. The LSC methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. When a code change impacts cost, there is potential to disproportionately impact DIPs. Refer to Section 7 for more details addressing energy equity and environmental justice.

Energy savings for alterations are greater than that for new construction in all cases due to the higher heating and cooling loads in existing buildings.

5.2.1 Design (Sizing, Equipment Selection, and Ducts/Diffusers)

LSC savings per-unit are presented in Table 45 through Table 47. Per-unit cost savings are expected to range from $28 to $269 for the weighted 2100/2700 prototype, $45 to $120 for the small home, and $5 to $474 for alterations.

Table 45: 2026 PV Long-term Systemwide Cost Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – Design – 2100/2700 Weighted Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	$269	$0	$269
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	$28	$0	$28

Table 46: 2026 PV Long-term Systemwide Cost Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – Design – 500 ft² Small Home Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	$45	$0	$45
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	$120	$0	$120

Table 47: 2026 PV Long-term Systemwide Cost Savings Over 30-Year Period of Analysis – Per Home – Alterations – Design – 1665 ft² Existing Home Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	$416	$0	$416
2	$30	$0	$30
3	$7	$0	$7
4	$111	$0	$111
5	$5	$0	$5
6	$34	$0	$34
7	$50	$0	$50
8	$94	$0	$94
9	$94	$0	$94
10	$122	$0	$122
11	$198	$0	$198
12	$102	$0	$102
13	$250	$0	$250
14	$143	$0	$143
15	$447	$0	$447
16	$433	$0	$433

5.2.2 Supplementary Heating

LSC savings per-unit are presented in

Table 48 through Table 49. Per-unit cost savings are expected to range from $215 to $3,061 for the weighted 2100/2700 prototype and $191 to $2,648 for alterations. This measure is not applicable to small homes.

Table 48: 2026 PV Long-term Systemwide Cost Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – Supplementary Heating – 2100/2700 Weighted Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	$3,061	$0	$3,061
2	$1,853	$0	$1,853
3	$1,096	$0	$1,096
4	$1,294	$0	$1,294
5	$1,099	$0	$1,099
6	$289	$0	$289
7	$215	$0	$215
8	$299	$0	$299
9	$435	$0	$435
10	$436	$0	$436
11	$1,229	$0	$1,229
12	$1,475	$0	$1,475
13	$880	$0	$880
14	$1,700	$0	$1,700
15	N/A	N/A	N/A
16	$2,186	$0	$2,186

Table 49: 2026 PV Long-term Systemwide Cost Savings Over 30-Year Period of Analysis – Per Home – Alterations – Supplementary Heating – 1665 ft^2 Existing Home Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	$2,648	$0	$2,648
2	$1,023	$0	$1,023
3	$978	$0	$978
4	$662	$0	$662
5	$1,038	$0	$1,038
6	$253	$0	$253
7	$191	$0	$191
8	$440	$0	$440
9	$491	$0	$491
10	$441	$0	$441
11	$777	$0	$777
12	$915	$0	$915
13	$658	$0	$658
14	$1,156	$0	$1,156
15	N/A	N/A	N/A
16	$1,744	$0	$1,744

5.2.3 Defrost

LSC savings per-unit are presented in Table 50 through Table 52. Per-unit cost savings are expected to range from $24 to $1,215 for the weighted 2100/2700 prototype, $25 to $170 for the small home, and $183 to $2,298 for alterations.

Table 50: 2026 PV Long-term Systemwide Cost Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – Defrost – 2100/2700 Weighted Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	$1,215	$0	$1,215
2	$820	$0	$820
3	$325	$0	$325
4	$667	$0	$667
5	$359	$0	$359
6	$24	$0	$24
7	$24	$0	$24
8	$49	$0	$49
9	$147	$0	$147
10	$171	$0	$171
11	$646	$0	$646
12	$681	$0	$681
13	$513	$0	$513
14	$768	$0	$768
15	$63	$0	$63
16	$1,138	$0	$1,138

Table 51: 2026 PV Long-term Systemwide Cost Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – Defrost – 500 ft^2 Small Home Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	$170	$0	$170
2	$65	$0	$65
3	$25	$0	$25
4	$60	$0	$60
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	$55	$0	$55
12	$60	$0	$60
13	$50	$0	$50
14	$75	$0	$75
15	N/A	N/A	N/A
16	$115	$0	$115

Table 52: 2026 PV Long-term Systemwide Cost Savings Over 30-Year Period of Analysis – Per Home – Alterations – Defrost – 1665 ft^2 Existing Home Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	$2,048	$0	$2,048
2	$1,265	$0	$1,265
3	$616	$0	$616
4	$1,149	$0	$1,149
5	$716	$0	$716
6	$33	$0	$33
7	$33	$0	$33
8	$216	$0	$216
9	$366	$0	$366
10	$416	$0	$416
11	$1,315	$0	$1,315
12	$1,349	$0	$1,349
13	$1,016	$0	$1,016
14	$1,665	$0	$1,665
15	$183	$0	$183
16	$2,298	$0	$2,298

5.2.4 Crankcase Heating

LSC savings per-unit for the mandatory measure are presented in Table 53 through Table 55, and savings for the prescriptive measure are presented in Table 56 through Table 58. For the mandatory measure, per-unit cost savings are expected to range from $35 to $405 for the weighted 2100/2700 prototype, $15 to $300 for the small home, and $83 to $599 for alterations. For the prescriptive measure, per-unit cost savings are expected to range from $527 to $2,031 for the weighted 2100/2700 prototype, $535 to $1,605 for the small home, and $533 to $5,195 for alterations.

Table 53: 2026 PV Long-term Systemwide Cost Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – Crankcase Heating, Mandatory – 2100/2700 Weighted Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	$405	$0	$405
2	$178	$0	$178
3	$105	$0	$105
4	$202	$0	$202
5	$70	$0	$70
6	$38	$0	$38
7	$35	$0	$35
8	$73	$0	$73
9	$98	$0	$98
10	$108	$0	$108
11	$265	$0	$265
12	$181	$0	$181
13	$265	$0	$265
14	$265	$0	$265
15	$352	$0	$352
16	$359	$0	$359

Table 54: 2026 PV Long-term Systemwide Cost Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – Crankcase Heating, Mandatory – 500 ft^2 Small Home Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	$175	$0	$175
2	$55	$0	$55
3	$30	$0	$30
4	$145	$0	$145
5	$15	$0	$15
6	$40	$0	$40
7	$80	$0	$80
8	$140	$0	$140
9	$130	$0	$130
10	$150	$0	$150
11	$205	$0	$205
12	$140	$0	$140
13	$230	$0	$230
14	$205	$0	$205
15	$300	$0	$300
16	$175	$0	$175
16	$175	$0	$175

Table 55: 2026 PV Long-term Systemwide Cost Savings Over 30-Year Period of Analysis – Per Home – Alterations – Crankcase Heating, Mandatory – 1665 ft^2 Existing Home Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	$400	$0	$400
2	$283	$0	$283
3	$166	$0	$166
4	$383	$0	$383
5	$150	$0	$150
6	$83	$0	$83
7	$133	$0	$133
8	$200	$0	$200
9	$216	$0	$216
10	$266	$0	$266
11	$516	$0	$516
12	$383	$0	$383
13	$516	$0	$516
14	$500	$0	$500
15	$599	$0	$599
16	$566	$0	$566
16	$400	$0	$400

Table 56: 2026 PV Long-term Systemwide Cost Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – Crankcase Heating, Prescriptive – 2100/2700 Weighted Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	$527	$0	$527
2	$872	$0	$872
3	$1,159	$0	$1,159
4	$1,009	$0	$1,009
5	$1,099	$0	$1,099
6	$1,710	$0	$1,710
7	$1,748	$0	$1,748
8	$1,487	$0	$1,487
9	$1,403	$0	$1,403
10	$1,396	$0	$1,396
11	$1,180	$0	$1,180
12	$1,117	$0	$1,117
13	$1,176	$0	$1,176
14	$1,120	$0	$1,120
15	$2,031	$0	$2,031
16	$803	$0	$803

Table 57: 2026 PV Long-term Systemwide Cost Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – Crankcase Heating, Prescriptive – 500 ft^2 Small Home Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	$535	$0	$535
2	$795	$0	$795
3	$1,105	$0	$1,105
4	$925	$0	$925
5	$1,030	$0	$1,030
6	$1,605	$0	$1,605
7	$1,595	$0	$1,595
8	$1,385	$0	$1,385
9	$1,305	$0	$1,305
10	$1,255	$0	$1,255
11	$1,000	$0	$1,000
12	$1,020	$0	$1,020
13	$1,015	$0	$1,015
14	$1,015	$0	$1,015
15	$1,335	$0	$1,335
16	$765	$0	$765

Table 58: 2026 PV Long-term Systemwide Cost Savings Over 30-Year Period of Analysis – Per Home – Alterations – Crankcase Heating, Prescriptive – 1665 ft^2 Existing Home Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	$533	$0	$533
2	$1,848	$0	$1,848
3	$2,048	$0	$2,048
4	$2,131	$0	$2,131
5	$1,981	$0	$1,981
6	$3,130	$0	$3,130
7	$3,097	$0	$3,097
8	$3,213	$0	$3,213
9	$3,080	$0	$3,080
10	$3,380	$0	$3,380
11	$2,980	$0	$2,980
12	$2,531	$0	$2,531
13	$2,831	$0	$2,831
14	$2,547	$0	$2,547
15	$5,195	$0	$5,195
16	$1,548	$0	$1,548

5.2.5 Refrigerant Charge Verification

LSC savings per-unit are presented in Table 59 through Table 60. Per-unit cost savings are expected to range from $321 to $1,166 for the weighted 2100/2700 prototype and $466 to $4,595 for alterations. This measure is not applicable to small homes.

Table 59: 2026 PV Long-term Systemwide Cost Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – Refrigerant Charge – 2100/2700 Weighted Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	$1,019	$0	$1,019
2	N/A	N/A	N/A
3	$422	$0	$422
4	$691	$0	$691
5	$321	$0	$321
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	$1,166	$0	$1,166

Table 60: 2026 PV Long-term Systemwide Cost Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – Refrigerant Charge - Prescriptive – 1665 ft^2 Existing Home Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	$1,665	$0	$1,665
2	N/A	N/A	N/A
3	$849N/A	N/A	$849N/A
4	$1,948	$0	$1,948
5	$699	$0	$699
6	$466	$0	$466
7	$566	$0	$566
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	$2,431	$0	$2,431

5.3 Incremental First Cost

Incremental costs reflect the difference between the Standard Design and the Proposed Design as described in Table 24 for each measure. Table 61 describes the cost estimates for each measure evaluated.

The hourly rate of $88 per hour is based on 2022 RS Means residential labor rates for sheet metal workers and includes a weighted average City Cost Index of 1.3 for labor in California.

Table 61: Summary of Measure Incremental First Cost

Measure	Climate Zone	HVAC System Type	Cost
Design	Cooling Dominated CZs 2-15	Heat pump for alterations. Savings will be the same for AC.	$1,676/ton reduction in equipment cost. ¼ hour for designer to include authorized load calculation/duct design on CF1R. $88/hour = $22 increase.
	Heating Dominated CZs 1 & 16	Heat pump only.	$1,676/ton increase. ¼ hour for designer to include authorized load calculation/duct design on CF1R. $88/hour = $22 increase. $590 decrease from eliminating supplemental electric resistance heating.
Supplementary Heat	All CZs	Heat pump only.	Cost for smart thermostat or OA sensor. Assume $225 smart - $75 programmable = $150 increase.
Defrost	All CZs	Heat pump only.	Cost for technician time to set delay timer, estimated at ¼ hour. $88/hour = $22 increase.
Crankcase Heating (Mandatory)	All CZs	Heat pump & AC.	$15 increase for controls.
Crankcase Heating (Prescriptive)	All CZs	Heat pump & AC.	$50 increase for controls.
Charge Verification, Heat Pumps	CZ 1,3-5,16	Heat pump only.	$100 for HERS verification, increase. 15 min for contractor to document assumptions and readings, complete form, upload. $88/hour = $22 increase. 15 min for contractor to do capacity test. $88/hour = $22 increase.

Heat pump equipment costs for the design measure were collected from four on-line HVAC equipment vendors, an HVAC distributor, and a major California production home HVAC contractor. The different sources provide different perspectives and were compared to provide a level of consistency between equipment component costs and the full installed costs that would be realized by a production builder. The distributor and on-line cost estimates are indicative of equipment-only cost impacts, while the HVAC contractor costs represent "typical" full installed costs to the builder. There is of course a degree of variability in these costs based on building design, local economic environment, and other factors.

On-line heat pump costs for indoor and outdoor components were collected in January 2023 from four different suppliers (Supply House, HVAC Direct, AC Wholesalers, and Budget Heating) for minimum efficiency split system heat pumps ranging in size from 2 to 5 ton nominal capacity. Since a focus of this CASE study is on heat pump sizing, the key cost parameter is the incremental cost for an incremental ton of capacity. The data collected from the on-line vendors was used to compute incremental costs for an added ton of capacity from a 2, 3, and 4 ton reference point. From the four on-line sources, the average cost of a ton of capacity was $569 (ranging from $602 for the 2-3 ton increment, from $617 for the 3-4 ton increment, and from $487 for the 4-5 ton increment). The cost data points from the HVAC distributor confirmed these findings with an average cost per ton of $541 for a one ton increment (ranging from $646 for the 2-3 ton increment and from $436 for the 3-4 ton increment). Variability in pricing is to be expected between different manufacturers.

Production builder installed HVAC costs are the most definitive costs as they represent the full cost of equipment and associated installation impacts, such as labor and miscellaneous costs. The HVAC contractor provided recent "typical" production home HVAC costs for 3 and 4 ton split system heat pumps. These costs are presented in Table 62. The cost for a ton of capacity was $1,676. In addition, costs are provided for typical strip heat installed costs[19] (both electrician labor, strip heat element, and electrical components) which was found to be $590 for a typically sized system.

Table 62: Production Builder Installed HVAC System Costs

Case	Installed Cost
Nominal 3 ton minimum efficiency heat pump install	$10,788
Nominal 4 ton minimum efficiency heat pump install	$12,464
Installed cost for 8-10 kW RH strip	$590

[19] Note: strip heat labor costs are estimated at $450. Material costs total $140, but are included in heat pump installed costs.

Labor costs for design, defrost, and refrigerant charge verification are estimates of the time required for these tasks, taken from interviews with contractors. The incremental cost for control of CCH are based on the cost of third-party controls and estimates of the components required to provide similar functionality, reduced by about 40 percent if they are provided by an OEM.

5.4 Incremental Maintenance and Replacement Costs

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

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

Heat pumps and air conditioners have an estimated useful life of 15 years based on the Database for Energy Efficient Resources (DEER) (California Public Utilities Commission 2021b). The proposed measures are assumed to replace the HVAC equipment at year 15. The incremental measure costs described in Table 61 are also assessed at year 15, (with the exception of costs for the two CCH measures, because it is expected that innovation will result in this being business as usual at time of later replacement). The present values of these incremental replacement costs are calculated according to the equation above and added to the incremental first cost.

There is no difference in regular maintenance between the proposed measures and the baseline and as a result no incremental maintenance costs are assessed.

5.5 Cost Effectiveness

These measures propose a set of mandatory and primary prescriptive requirements. As such, a cost analysis is required to demonstrate that the measure is cost effective over the 30-year period of analysis.

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

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

Similar to what was presented in Section 5.2, in this section results are presented for the weighted 2,100 and 2,700 square foot and 500 square foot single family new construction prototypes and the 1,665 square foot alteration prototype. Energy savings for alterations are greater than that for new construction in all cases due to the higher heating and cooling loads in existing buildings. The incremental costs for this measure are estimated to be roughly equivalent for new construction and alterations; therefore, cost effectiveness is generally improved for alterations as a result of higher heating and cooling loads.

5.5.1 Design (Sizing, Equipment Selection, and Ducts/Diffusers)

a. Results of the per-unit cost-effectiveness analyses are presented in Table 63 through **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC savings over the period of analysis (California Energy Commission 2022, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.
b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis if PV of proposed costs is greater than PV of current costs. Costs are discounted at a real (inflation-adjusted) three percent rate. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

Table 65Table 66. As before, results for the new-construction prototypes are only shown for the heating-dominated climate zones, because the measure for cooling-dominated climate zones is only applicable to existing buildings. For both the weighted 2100/2700 prototype and the small home, the measure was cost effective in both Climate Zones 1 and 16 (benefit to cost ratio was essentially infinite, as the first costs were reduced). For alterations, the measure was cost effective in all sixteen climate zones, and in Climate Zones 2-15 the benefit to cost ratio was infinite.

Table 63: 30-Year Cost-Effectiveness Summary Per Home – New Construction/Additions – Design – 2100/2700 Weighted Prototype

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	$269	-$156	infinite
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	$28	-$64	infinite

a. **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC savings over the period of analysis(California Energy Commission 2022, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

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

Table 64: 30-Year Cost-Effectiveness Summary Per Home – New Construction/Additions – Design – 500 ft² Small Home Prototype

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	$45	-$468	infinite
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	$120	-$454	infinite

c. **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC savings over the period of analysis (California Energy Commission 2022, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

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

Table 65: 30-Year Cost-Effectiveness Summary Per Home – Alterations – Design – Existing Home Prototype

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	$416	$109	3.83
2	$30	-$1,912	infinite
3	$7	-$1,496	infinite
4	$111	-$1,835	infinite
5	$5	-$1,568	infinite
6	$34	-$1,572	infinite
7	$50	-$1,555	infinite
8	$94	-$1,782	infinite
9	$94	-$1,815	infinite
10	$122	-$2,056	infinite
11	$198	-$2,248	infinite
12	$102	-$1,935	infinite
13	$250	-$2,106	infinite
14	$143	-$1,919	infinite
15	$447	-$2,878	infinite
16	$433	$398	1.19

a. **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC savings over the period of analysis (California Energy Commission 2022, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

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

5.5.2 Supplementary Heating

Results of the per-unit cost-effectiveness analyses are presented in Table 66 through Table 67. For the weighted 2100/2700 new construction prototype and for alterations, the measure was cost effective in all climate zones except 15, where this measure isn't applicable. This measure is not applicable for small homes because it is not cost effective in almost all climate zones.

Table 66: 30-Year Cost-Effectiveness Summary Per Home – New Construction/Additions – Supplementary Heating – 2100/2700 Weighted Prototype

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	$3,061	$150	20.41
2	$1,853	$150	12.35
3	$1,096	$150	7.31
4	$1,294	$150	8.63
5	$1,099	$150	7.33
6	$289	$150	1.93
7	$215	$150	1.43
8	$299	$150	2.00
9	$435	$150	2.90
10	$436	$150	2.91
11	$1,229	$150	8.19
12	$1,475	$150	9.84
13	$880	$150	5.87
14	$1,700	$150	11.34
15	N/A	N/A	N/A
16	$2,186	$150	14.57

a. **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC savings over the period of analysis (California Energy Commission 2022, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

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

Table 67: 30-Year Cost-Effectiveness Summary Per Home – Alterations – Supplementary Heating – Existing Home Prototype

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	$2,648	$150	17.65
2	$1,023	$150	6.82
3	$978	$150	6.52
4	$662	$150	4.41
5	$1,038	$150	6.92
6	$253	$150	1.68
7	$191	$150	1.27
8	$440	$150	2.94
9	$491	$150	3.27
10	$441	$150	2.94
11	$777	$150	5.18
12	$915	$150	6.10
13	$658	$150	4.39
14	$1,156	$150	7.71
15	N/A	N/A	N/A
16	$1,744	$150	11.63

a. **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC savings over the period of analysis (California Energy Commission 2022, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

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

5.5.3 Defrost

a. Results of the per-unit cost-effectiveness analyses are presented in Table 68 through **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC savings over the period of analysis (California Energy Commission 2022, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

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

Table 70. For the weighted 2100/2700 new construction prototype and for alterations, the measure was cost effective in all climate zones. For the small home, the measure was cost effective in Climate Zones 1-4, 11-14, and 16, but not cost effective in Climate Zones 5-10, and 15, where it is not required.

Table 68: 30-Year Cost-Effectiveness Summary Per Home – New Construction/Additions – Defrost – 2100/2700 Weighted Prototype

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	$1,215	$22	55.21
2	$820	$22	37.28
3	$325	$22	14.75
4	$667	$22	30.30
5	$359	$22	16.34
6	$24	$22	1.11
7	$24	$22	1.11
8	$49	$22	2.22
9	$147	$22	6.66
10	$171	$22	7.77
11	$646	$22	29.35
12	$681	$22	30.93
13	$513	$22	23.32
14	$768	$22	34.90
15	$63	$22	2.86
16	$1,138	$22	51.72

a. **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC savings over the period of analysis (California Energy Commission 2022, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

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

Table 69: 30-Year Cost-Effectiveness Summary Per Home – New Construction/Additions – Defrost – 500 ft^2 Small Home Prototype

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	$170	$22	7.73
2	$65	$22	2.95
3	$25	$22	1.14
4	$60	$22	2.73
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	$55	$22	2.50
12	$60	$22	2.73
13	$50	$22	2.27
14	$75	$22	3.41
15	N/A	N/A	N/A
16	$115	$22	5.23

c. **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC savings over the period of analysis (California Energy Commission 2022, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

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

Table 70: 30-Year Cost-Effectiveness Summary Per Home – Alterations – Defrost – Existing Home Prototype

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	$2,048	$22	93.09
2	$1,265	$22	57.52
3	$616	$22	28.00
4	$1,149	$22	52.22
5	$716	$22	32.54
6	$33	$22	1.51
7	$33	$22	1.51
8	$216	$22	9.84
9	$366	$22	16.65
10	$416	$22	18.92
11	$1,315	$22	59.79
12	$1,349	$22	61.30
13	$1,016	$22	46.17
14	$1,665	$22	75.68
15	$183	$22	8.32
16	$2,298	$22	104.44

a. **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC savings over the period of analysis (California Energy Commission 2022, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

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

5.5.4 Crankcase Heating

a. Results of the per-unit cost-effectiveness analyses are presented for the mandatory measure in Table 71 through Table 73, and for the prescriptive measure in Table 74 through **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC savings over the period of analysis (California Energy Commission 2022, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

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

Table 76. Both the mandatory and prescriptive measures were cost effective in both new construction prototypes and in alterations, in all climate zones.

Table 71: 30-Year Cost-Effectiveness Summary Per Home – New Construction/Additions – Crankcase Heating, Mandatory – 2100/2700 Weighted Prototype

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	$405	$15	26.99
2	$178	$15	11.87
3	$105	$15	6.98
4	$202	$15	13.49
5	$70	$15	4.65
6	$38	$15	2.56
7	$35	$15	2.33
8	$73	$15	4.89
9	$98	$15	6.51
10	$108	$15	7.21
11	$265	$15	17.68
12	$181	$15	12.10
13	$265	$15	17.68
14	$265	$15	17.68
15	$352	$15	23.50
16	$359	$15	23.96

a. **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC savings over the period of analysis (California Energy Commission 2022, 51-53), (California Energy Commission 2022, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

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

Table 72: 30-Year Cost-Effectiveness Summary Per Home – New Construction/Additions – Crankcase Heating, Mandatory – 500 ft^2 Small Home Prototype

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	$175	$15	11.67
2	$55	$15	3.67
3	$30	$15	2.00
4	$145	$15	9.67
5	$15	$15	1.00
6	$40	$15	2.67
7	$80	$15	5.33
8	$140	$15	9.33
9	$130	$15	8.67
10	$150	$15	10.00
11	$205	$15	13.67
12	$140	$15	9.33
13	$230	$15	15.33
14	$205	$15	13.67
15	$300	$15	20.00
16	$175	$15	11.67

a. **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC savings over the period of analysis (California Energy Commission 2022, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

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

Table 73: 30-Year Cost-Effectiveness Summary Per Home – Alterations – Crankcase Heating, Mandatory – Existing Home Prototype

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	$400	$15	26.64
2	$283	$15	18.87
3	$166	$15	11.10
4	$383	$15	25.53
5	$150	$15	9.99
6	$83	$15	5.55
7	$133	$15	8.88
8	$200	$15	13.32
9	$216	$15	14.43
10	$266	$15	17.76
11	$516	$15	34.41
12	$383	$15	25.53
13	$516	$15	34.41
14	$500	$15	33.30
15	$599	$15	39.96
16	$566	$15	37.74

a. **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC savings over the period of analysis (California Energy Commission 2022, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

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

Table 74: 30-Year Cost-Effectiveness Summary Per Home – New Construction/Additions – Crankcase Heating, Prescriptive – 2100/2700 Weighted Prototype

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	$527	$50	10.54
2	$872	$50	17.45
3	$1,159	$50	23.17
4	$1,009	$50	20.17
5	$1,099	$50	21.99
6	$1,710	$50	34.20
7	$1,748	$50	34.97
8	$1,487	$50	29.73
9	$1,403	$50	28.06
10	$1,396	$50	27.92
11	$1,180	$50	23.59
12	$1,117	$50	22.34
13	$1,176	$50	23.52
14	$1,120	$50	22.41
15	$2,031	$50	40.62
16	$803	$50	16.05

a. **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC savings over the period of analysis (California Energy Commission 2022, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

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

Table 75: 30-Year Cost-Effectiveness Summary Per Home – New Construction/Additions – Crankcase Heating, Prescriptive – 500 ft^2 Small Home Prototype

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	$535	$50	10.70
2	$795	$50	15.90
3	$1,105	$50	22.10
4	$925	$50	18.50
5	$1,030	$50	20.60
6	$1,605	$50	32.10
7	$1,595	$50	31.90
8	$1,385	$50	27.70
9	$1,305	$50	26.10
10	$1,255	$50	25.10
11	$1,000	$50	20.00
12	$1,020	$50	20.40
13	$1,015	$50	20.30
14	$1,015	$50	20.30
15	$1,335	$50	26.70
16	$765	$50	15.30

c. **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC savings over the period of analysis (California Energy Commission 2022, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

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

Table 76: 30-Year Cost-Effectiveness Summary Per Home – Alterations – Crankcase Heating, Prescriptive – Existing Home Prototype

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	$533	$50	10.66
2	$1,848	$50	36.96
3	$2,048	$50	40.96
4	$2,131	$50	42.62
5	$1,981	$50	39.63
6	$3,130	$50	62.60
7	$3,097	$50	61.94
8	$3,213	$50	64.27
9	$3,080	$50	61.61
10	$3,380	$50	67.60
11	$2,980	$50	59.61
12	$2,531	$50	50.62
13	$2,831	$50	56.61
14	$2,547	$50	50.95
15	$5,195	$50	103.90
16	$1,548	$50	30.97

a. **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC savings over the period of analysis (California Energy Commission 2022, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

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

5.5.5 Refrigerant Charge Verification

Results of the per-unit cost-effectiveness analyses are presented in Table 77 through Table 78. For the weighted 2100/2700 prototype, the measure was found to be cost effective in all climate zones except 6 and 7. The measure was not found to be cost effective in any climate zone for the small home prototype. For alterations, the measure was found to be cost effective in all climate zones.

Table 77: 30-Year Cost-Effectiveness Summary Per Home – New Construction/Additions – Refrigerant Charge – 2100/2700 Weighted Prototype

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	$1,019	$252	4.04
2	N/A	N/A	N/A
3	$422	$252	1.67
4	$691	$252	2.74
5	$321	$252	1.27
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	$1,166	$252	4.62

a. **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC savings over the period of analysis (California Energy Commission 2022, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

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

Table 78: 30-Year Cost-Effectiveness Summary Per Home – Alterations – Refrigerant Charge – Existing Home Prototype

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	$1,665	$252	6.60
2	N/A	N/A	N/A
3	$849	$252	3.37
4	$1,948	$252	7.72
5	$699	$252	2.77
6	$466	$252	1.85
7	$566	$252	2.24
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	$2,431	$252	9.64

a. **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC savings over the period of analysis (California Energy Commission 2022, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

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

6. First-Year Statewide Impacts

This section covers all measures that would modify the stringency of the existing California Energy Code. The variable capacity system measure would not modify the stringency of the code, so there would be no savings on a per-unit basis and therefore it is not reported on in this section.

6.1 Statewide Energy and Energy Cost Savings

The Statewide CASE Team calculated the first-year statewide savings for new construction and additions by multiplying the per-unit savings, which are presented in Section 4.2, by assumptions about the percentage of newly constructed buildings that would be impacted by the proposed code. The statewide new construction forecast for 2026 is presented in Appendix A, as are the Statewide CASE Team's assumptions about the percentage of new construction that would be impacted by the proposal (by climate zone and building type).

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

While a statewide analysis is crucial to understanding broader effects of code change proposals, there is potential to disproportionately impact DIPs that needs to be considered. Refer to Section 7 for more details addressing energy equity and environmental justice.

6.1.1 Design (Sizing, Equipment Selection, and Ducts/Diffusers)

The tables below present the first-year statewide energy and energy cost savings from newly constructed buildings and additions (Table 79) and alterations (Table 80) by climate zone. Table 81 presents first-year statewide savings from new construction, additions, and alterations.

Table 79: Statewide Energy and Energy Cost Impacts – New Construction and Additions – Design

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Buildings)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
1	323	0.01	0.00	N/A	0.03	$0.08
2	N/A	N/A	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A	N/A	N/A
12	N/A	N/A	N/A	N/A	N/A	N/A
13	N/A	N/A	N/A	N/A	N/A	N/A
14	N/A	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A
16	1,743	0.01	0.00	N/A	0.01	$0.06
Total	**58,520**	**0.02**	**0.01**	**N/A**	**0.04**	**$0.14**

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

Table 80: Statewide Energy and Energy Cost Impacts – Alterations – Design

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Buildings)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
1	2,992	0.15	0.04	N/A	0.50	$1.25
2	17,720	0.68	N/A	N/A	0.54	$0.54
3	64,834	0.51	N/A	N/A	0.47	$0.47
4	33,155	5.15	N/A	N/A	3.67	$3.67
5	6,485	0.03	N/A	N/A	0.03	$0.03
6	39,636	2.10	N/A	N/A	1.35	$1.35
7	32,957	2.45	N/A	N/A	1.64	$1.64
8	61,752	8.32	N/A	N/A	5.78	$5.78
9	83,365	10.55	N/A	N/A	7.80	$7.80
10	71,160	12.95	N/A	N/A	8.65	$8.65
11	22,365	5.69	N/A	N/A	4.43	$4.43
12	87,919	9.85	N/A	N/A	8.98	$8.98
13	42,314	13.41	N/A	N/A	10.59	$10.59
14	16,523	3.67	N/A	N/A	2.37	$2.37
15	11,845	7.72	N/A	N/A	5.30	$5.30
16	6,529	0.38	0.08	N/A	1.09	$2.83
Total	**601,550**	**83.62**	**0.12**	**-**	**63.19**	**$65.67**

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

Table 81: Statewide Energy and Energy Cost Impacts – New Construction, Additions, and Alterations – Design

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
New Construction & Additions	0.0	0.0	N/A	0.0	$0.14
Alterations	83.6	0.1	-	63.2	$65.67
Total	**83.6**	**0.1**	**-**	**63.2**	**$65.81**

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

6.1.2 Supplementary Heating

The tables below present the first-year statewide energy and energy cost savings from newly constructed buildings and additions (Table 82) and alterations (Table 83) by climate zone. Table 84 presents first-year statewide savings from new construction, additions, and alterations.

Table 82: Statewide Energy and Energy Cost Impacts – New Construction and Additions – Supplementary Heating

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Buildings)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
1	317	0.13	N/A	N/A	0.32	$0.96
2	1,641	0.40	N/A	N/A	1.13	$3.00
3	2,677	0.36	N/A	N/A	1.18	$2.87
4	2,372	0.42	N/A	N/A	1.09	$3.04
5	543	0.07	N/A	N/A	0.23	$0.58
6	1,516	0.05	N/A	N/A	0.20	$0.44
7	1,648	0.05	N/A	N/A	0.17	$0.35
8	3,672	0.14	N/A	N/A	0.51	$1.10
9	3,780	0.21	N/A	N/A	0.76	$1.65
10	7,012	0.38	N/A	N/A	1.35	$3.07
11	5,151	0.81	N/A	N/A	2.49	$6.31
12	12,826	2.44	N/A	N/A	7.14	$18.75
13	6,401	0.70	N/A	N/A	2.33	$5.63
14	3,298	0.74	N/A	N/A	2.28	$5.59
15	N/A	N/A	N/A	N/A	N/A	N/A
16	1,708	0.52	N/A	N/A	1.34	$3.71
Total	**54,562**	**7.42**	**6.84**	**-**	**22.51**	**$57.05**

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

Table 83: Statewide Energy and Energy Cost Impacts – Alterations – Supplementary Heating

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Buildings)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
1	359	0.14	N/A	N/A	0.31	$0.95
2	2,126	0.29	N/A	N/A	0.79	$2.17
3	7,780	1.01	N/A	N/A	2.84	$7.61
4	3,979	0.36	N/A	N/A	0.92	$2.63
5	778	0.11	N/A	N/A	0.29	$0.81
6	4,756	0.15	N/A	N/A	0.55	$1.20
7	3,955	0.11	N/A	N/A	0.36	$0.76
8	7,410	0.42	N/A	N/A	1.40	$3.26
9	10,004	0.62	N/A	N/A	2.09	$4.91
10	8,539	0.47	N/A	N/A	1.53	$3.77
11	2,684	0.28	N/A	N/A	0.77	$2.08
12	10,550	1.29	N/A	N/A	3.47	$9.65
13	5,078	0.43	N/A	N/A	1.30	$3.34
14	1,983	0.31	N/A	N/A	0.90	$2.29
15	N/A	N/A	N/A	N/A	N/A	N/A
16	783	0.19	N/A	N/A	0.49	$1.37
Total	**70,765**	**6.17**	**N/A**	**N/A**	**18.01**	**$46.81**

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

Table 84: Statewide Energy and Energy Cost Impacts – New Construction, Additions, and Alterations – Supplementary Heating

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
New Construction & Additions	7.5	6.9	N/A	22.6	$57.05
Alterations	6.2	0	N/A	18.1	$46.81
Total	**13.6**	**6.9**	**N/A**	**40.7**	**$103.86**

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

6.1.3 Defrost

The tables below present the first-year statewide energy and energy cost savings from newly constructed buildings and additions (Table 85) and alterations (Table 86) by climate zone. Table 87 presents first-year statewide savings from new construction, additions, and alterations.

Table 85: Statewide Energy and Energy Cost Impacts – New Construction and Additions – Defrost

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Buildings)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
1	323	0.05	0.01	N/A	0.15	$0.38
2	1,675	0.16	0.05	N/A	0.55	$1.33
3	2,732	0.10	0.04	N/A	0.38	$0.86
4	2,420	0.20	0.06	N/A	0.66	$1.57
5	543	0.02	0.01	N/A	0.08	$0.19
6	1,516	0.00	0.00	N/A	0.04	$0.04
7	1,648	0.01	0.00	N/A	0.01	$0.04
8	3,672	0.03	0.01	N/A	0.18	$0.18
9	3,780	0.06	0.03	N/A	0.28	$0.55
10	7,012	0.13	0.07	N/A	0.51	$1.20
11	5,256	0.41	0.12	N/A	1.43	$3.32
12	13,088	1.07	0.36	N/A	3.57	$8.71
13	6,531	0.39	0.14	N/A	1.41	$3.29
14	3,365	0.30	0.12	N/A	1.08	$2.53
15	2,787	0.02	0.01	N/A	0.07	$0.18
16	1,743	0.24	0.07	N/A	0.68	$1.93
Total	**58,092**	**3.20**	**1.10**	**N/A**	**11.08**	**$26.31**

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

Table 86: Statewide Energy and Energy Cost Impacts – Alterations – Defrost

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Buildings)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
1	359	0.09	0.02	N/A	0.28	$0.74
2	2,126	0.33	0.10	N/A	1.10	$2.69
3	7,780	0.54	0.21	N/A	2.07	$4.79
4	3,979	0.57	0.19	N/A	1.85	$4.57
5	778	0.07	0.03	N/A	0.23	$0.56
6	4,756	0.02	0.01	N/A	0.08	$0.16
7	3,955	0.02	0.00	N/A	0.07	$0.13
8	7,410	0.18	0.07	N/A	0.74	$1.60
9	10,004	0.41	0.17	N/A	1.67	$3.66
10	8,539	0.40	0.23	N/A	1.56	$3.55
11	2,684	0.44	0.12	N/A	1.52	$3.53
12	10,550	1.76	0.58	N/A	5.97	$14.23
13	5,078	0.63	0.22	N/A	2.20	$5.16
14	1,983	0.40	0.16	N/A	1.39	$3.30
15	1,421	0.03	0.02	N/A	0.12	$0.26
16	783	0.23	0.06	N/A	0.63	$1.80
Total	**72,186**	**6.12**	**2.19**	**N/A**	**21.48**	**$50.74**

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

Table 87: Statewide Energy and Energy Cost Impacts – New Construction, Additions, and Alterations – Defrost

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
New Construction & Additions	3.2	1.1	N/A	11.1	$26.31
Alterations	6.1	2.2	N/A	21.5	$50.74
Total	**9.3**	**3.3**	**N/A**	**32.6**	**$77.05**

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

6.1.4 Crankcase Heating

The tables below present the first-year statewide energy and energy cost savings from newly constructed buildings and additions (Table 88) and alterations (Table 89) by climate zone. Table 90 presents first-year statewide savings from new construction, additions, and alterations. Statewide results are presented for both the mandatory and prescriptive CCH measures combined.

Table 88: Statewide Energy and Energy Cost Impacts – New Construction and Additions – Crankcase Heating Mandatory

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Buildings)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
1	25	0.00	0.00	N/A	0.00	$0.01
2	130	0.00	0.00	N/A	0.01	$0.02
3	212	0.00	0.00	N/A	0.01	$0.02
4	188	0.00	0.00	N/A	0.01	$0.04
5	43	0.00	0.00	N/A	0.00	$0.00
6	120	0.00	0.00	N/A	0.00	$0.00
7	131	0.00	0.00	N/A	0.00	$0.00
8	291	0.00	0.00	N/A	0.01	$0.02
9	300	0.00	0.00	N/A	0.01	$0.03
10	557	0.01	0.00	N/A	0.02	$0.06
11	409	0.01	0.00	N/A	0.03	$0.11
12	1,018	0.02	0.01	N/A	0.06	$0.18
13	508	0.02	0.00	N/A	0.03	$0.13
14	262	0.01	0.00	N/A	0.02	$0.07
15	221	0.01	0.00	N/A	0.01	$0.08
16	136	0.01	0.00	N/A	0.02	$0.05
Total	**4,552**	**0.11**	**0.02**	**N/A**	**0.25**	**$0.83**

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

Table 89: Statewide Energy and Energy Cost Impacts – Alterations – Crankcase Heating Mandatory

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Buildings)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
1	678	0.04	0.01	N/A	0.09	$0.27
2	4,014	0.14	0.04	N/A	0.40	$1.14
3	14,685	0.31	0.11	N/A	0.98	$2.45
4	7,510	0.37	0.07	N/A	0.88	$2.88
5	1,469	0.03	0.01	N/A	0.10	$0.22
6	8,978	0.11	0.01	N/A	0.15	$0.75
7	7,465	0.11	0.01	N/A	0.12	$0.99
8	13,987	0.39	0.05	N/A	0.70	$2.79
9	18,882	0.55	0.09	N/A	0.94	$4.09
10	16,118	0.59	0.08	N/A	1.07	$4.29
11	5,066	0.35	0.06	N/A	0.76	$2.61
12	19,914	0.98	0.22	N/A	2.32	$7.63
13	9,584	0.66	0.10	N/A	1.12	$4.95
14	3,743	0.26	0.05	N/A	0.56	$1.87
15	2,683	0.25	0.01	N/A	0.27	$1.61
16	1,479	0.11	0.02	N/A	0.30	$0.84
Total	**136,251**	**5.26**	**0.93**	**N/A**	**10.75**	**$39.37**

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

Table 90: Statewide Energy and Energy Cost Impacts – New Construction, Additions, and Alterations – Crankcase Heating Mandatory

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
New Construction & Additions	0.1	0.0	N/A	0.2	$0.83
Alterations	5.3	0.9	N/A	10.8	$39.37
Total	**5.4**	**0.9**	**N/A**	**5.4**	**0.9**

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

Table 91: Statewide Energy and Energy Cost Impacts – New Construction and Additions – Crankcase Heating Prescriptive

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Buildings)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
1	180	0.02	0.00	N/A	0.01	$0.09
2	931	0.14	0.01	N/A	0.14	$0.81
3	1,518	0.29	0.02	N/A	0.34	$1.74
4	1,345	0.21	0.01	N/A	0.24	$1.33
5	308	0.05	0.00	N/A	0.07	$0.34
6	860	0.22	0.02	N/A	0.32	$1.45
7	935	0.25	0.02	N/A	0.39	$1.61
8	2,082	0.48	0.03	N/A	0.63	$3.04
9	2,143	0.47	0.03	N/A	0.63	$2.96
10	3,975	0.85	0.05	N/A	1.08	$5.47
11	2,920	0.56	0.03	N/A	0.60	$3.42
12	7,271	1.29	0.07	N/A	1.37	$7.99
13	3,629	0.69	0.04	N/A	0.83	$4.23
14	1,870	0.33	0.02	N/A	0.38	$2.07
15	1,580	0.50	0.03	N/A	0.74	$3.18
16	969	0.12	0.01	N/A	0.14	$0.76
Total	**32,511**	**6.46**	**0.39**	**N/A**	**7.92**	**$40.48**

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

Table 92: Statewide Energy and Energy Cost Impacts – Alterations – Crankcase Heating Prescriptive

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Buildings)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
1	1,503	0.14	0.01	N/A	0.13	$0.80
2	8,905	2.81	0.12	N/A	2.82	$16.46
3	32,579	11.03	0.60	N/A	12.48	$66.72
4	16,660	5.65	0.33	N/A	6.10	$35.51
5	3,259	1.04	0.05	N/A	1.19	$6.46
6	19,917	9.49	0.85	N/A	13.93	$62.34
7	16,561	7.87	0.72	N/A	12.13	$51.29
8	31,030	15.48	1.11	N/A	21.70	$99.71
9	41,891	20.25	1.14	N/A	27.20	$129.03
10	35,758	18.90	1.14	N/A	25.01	$120.86
11	11,238	5.38	0.30	N/A	6.17	$33.49
12	44,179	17.92	1.05	N/A	19.86	$111.81
13	21,263	9.69	0.55	N/A	11.68	$60.18
14	8,303	3.37	0.19	N/A	3.87	$21.15
15	5,952	4.77	0.33	N/A	7.14	$30.92
16	3,281	0.81	0.07	N/A	0.93	$5.08
Total	**302,279**	**134.61**	**8.55**	**N/A**	**172.34**	**$851.82**

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

Table 93: Statewide Energy and Energy Cost Impacts – New Construction, Additions, and Alterations – Crankcase Heating Prescriptive

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
New Construction & Additions	6.5	0.4	N/A	7.9	$40.48
Alterations	134.6	8.5	N/A	172.3	$851.82
Total	**141.1**	**8.9**	**N/A**	**180.3**	**$892.30**

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

6.1.5 Refrigerant Charge Verification

The tables below present the first-year statewide energy and energy cost savings from newly constructed buildings and additions (Table 94) and alterations (Table 95) by climate zone. Table 96 presents first-year statewide savings from new construction, additions, and alterations.

Table 94: Statewide Energy and Energy Cost Impacts – New Construction & Additions – Refrigerant Charge

Climate Zone	Statewide Alterations Impacted by Proposed Change in 2026 (Homes)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
1	317	0.04	0.01	N/A	0.11	$0.32
2	N/A	N/A	N/A	N/A	N/A	N/A
3	2,677	0.12	0.05	N/A	0.42	$1.12
4	2,372	0.20	0.06	N/A	0.62	$1.65
5	543	0.02	0.01	N/A	0.07	$0.17
6	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A	N/A	N/A
12	N/A	N/A	N/A	N/A	N/A	N/A
13	N/A	N/A	N/A	N/A	N/A	N/A
14	N/A	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A
16	1,708	0.25	0.06	N/A	0.66	$1.98
Total	**7,617**	**0.64**	**0.18**	N/A	**1.87**	**$5.24**

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

Table 95: Statewide Energy and Energy Cost Impacts – Alterations – Refrigerant Charge

Climate Zone	Statewide Alterations Impacted by Proposed Change in 2026 (Homes)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
1	359	0.08	0.02	N/A	0.21	$0.60
2	N/A	N/A	N/A	N/A	N/A	N/A
3	7,780	0.79	0.28	N/A	2.33	$6.61
4	3,979	1.14	0.18	N/A	1.99	$7.75
5	778	0.07	0.02	N/A	0.19	$0.54
6	4,756	0.35	0.04	N/A	0.48	$2.22
7	3,955	0.37	0.02	N/A	0.40	$2.24
8	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A	N/A	N/A
12	N/A	N/A	N/A	N/A	N/A	N/A
13	N/A	N/A	N/A	N/A	N/A	N/A
14	N/A	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A
16	783	0.25	0.05	N/A	0.63	$1.90
Total	**22,391**	**3.05**	**0.61**	**N/A**	**6.22**	**$21.86**

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

Table 96: Statewide Energy and Energy Cost Impacts – New Construction, Additions, and Alterations – Refrigerant Charge

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
New Construction & Additions	0.6	0.2	N/A	1.9	$5.24
Alterations	3.1	0.6	N/A	6.2	$21.86
Total	**3.7**	**0.8**	N/A	**8.1**	**$27.10**

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

6.2 Statewide Greenhouse Gas (GHG) Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions associated with energy consumption using the hourly GHG emissions factors that CEC developed along with the 2025 LSC hourly factors and an assumed cost of $123.15 per metric ton of carbon dioxide equivalent emissions (metric tons CO2e). (California Energy Commission 2020)

The monetary value of avoided GHG emissions is based on a proxy for permit costs (not social costs).[20] The Cost-Effectiveness Analysis presented in Section 5 of this report does not include the cost savings from avoided GHG emissions. To demonstrate the cost savings of avoided GHG emissions, the Statewide CASE Team disaggregated the value of avoided GHG emissions from the other economic impacts.

Table 97 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of about 30,000 metric tons CO2e would be avoided.

Table 97: First-Year Statewide GHG Emissions Impacts

Measure	Electricity Savings[a] (GWh/yr)	Reduced GHG Emissions from Electricity Savings (Metric Tons CO2e)	Natural Gas Savings[a] (Million Therms/yr)	Reduced GHG Emissions from Natural Gas Savings (Metric Tons CO2e)	Total Reduced GHG Emissions[b] (Metric Ton CO2e)	Total Monetary Value of Reduced GHG Emissions[c] ($)
Design	84	3,340	N/A	N/A	3,340	$411,308
Supplementary Heating	14	2,144	N/A	N/A	2,144	$264,002
Defrost	9	1,719	N/A	N/A	1,719	$211,665
Crankcase Heating (mandatory	5	603	N/A	N/A	603	$74,251
Crankcase Heating (prescriptive)	141	9,530	N/A	N/A	9,530	$1,173,630
Refrigerant Charge	4	443	N/A	N/A	443	$54,608
TOTAL	**257**	**17779**	**N/A**	**N/A**	**17779**	**$2,189,464**

a. First-year savings from all applicable newly constructed buildings, additions, and alterations completed statewide in 2026.

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

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

[20] The permit cost of carbon is equivalent to the market value of a unit of GHG emissions in the California Cap-and-Trade program, while social cost of carbon is an estimate of the total economic value of damage done per unit of GHG emissions. Social costs tend to be greater than permit costs. See more on the Cap-and-Trade Program on the California Air Resources Board website.

6.3 Statewide Water Use Impacts

The proposed code change will not result in water savings.

6.4 Statewide Material Impacts

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

6.5 Other Non-Energy Impacts

The proposed code change will not result in any other non-energy impacts.

7. Addressing Energy Equity and Environmental Justice

The Statewide CASE Team assessed the potential impacts of the proposed measure, and based on a preliminary review, the measure is unlikely to have significant impacts on energy equity or environmental justice, therefore reducing the impacts of disparities in DIPs. The Statewide CASE Team does not recommend further research or action at this time.

The Statewide CASE Team is still in the process of investigating the potential impacts of the proposed code changes on DIPs. Final results of this research will be incorporated into the Final CASE Report.

This section covers all the code change proposals presented in this report.

The Statewide CASE Team recognizes, acknowledges, and accounts for a history of prejudice and inequality in disproportionately impacted populations (DIPs) and the role this history plays in the environmental justice issues that persist today. DIPs refer to populations throughout California that most suffer from a combination of economic, health, and environmental burdens. These burdens include poverty, high unemployment, air and water pollution, presence of hazardous wastes, as well as high incidence of asthma and heart disease. DIPs also incorporate race, class, and gender since these intersecting identity factors affect how people frame issues, interpret, and experience the world.[21] While the term disadvantaged communities (DACs) is often used in the energy industry and state agencies, the Statewide CASE Team chose to use terminology that is more acceptable to and less stigmatizing for those it seeks to describe (DC Fiscal Policy Institute 2017).

Including impacted communities in the decision-making process, ensuring that the benefits and burdens of the energy sector are evenly distributed, and grappling with the unjust legacies of the past all serve as critical steps to achieving energy equity.

The Statewide CASE Team assessed the potential impacts of the proposed measures, and based on a preliminary review, the measures are unlikely to have significant impacts on energy equity or environmental justice, therefore reducing the impacts of disparities in DIPs. The Statewide CASE Team does not recommend further research or

[21] Environmental disparities have been shown to be associated with unequal harmful environmental exposure correlated with race/ethnicity, gender, and socioeconomic status. For example, chronic diseases, such as respiratory diseases, cardiovascular disease, and cancer, associated with environmental exposure have been shown to occur in higher rates in the LGBTQ+ population than in the cisgender, heterosexual population (Goldsmith & Bell, 2021). Socioeconomic inequities, climate, energy, and other inequities are inextricably linked and often mutually reinforcing.

action at this time. This research is still in process and more details will be available in the Final CASE Report.

8. Proposed Revisions to Code Language

8.1 Guide to Markup Language

The proposed changes to the standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2022 documents are marked with red underlining (new language) and ~~strikethroughs~~ (deletions).

8.2 Standards

10-103 – PERMIT, CERTIFICATE, INFORMATIONAL, AND ENFORCEMENT REQUIREMENTS FOR DESIGNERS, INSTALLERS, BUILDERS, MANUFACTURERS, AND SUPPLIERS

(a) Documentation.

2. **Application for a building permit**. Each application for a building permit subject to Part 6 shall contain at least one copy of the documents specified in Section 10-103(a)2A, 10-103(a)2B, and 10-103(a)2C.

A. For all newly constructed buildings, additions, alterations, or repairs regulated by Part 6 the applicant shall submit the applicable Certificate(s) of Compliance to the enforcement agency for approval. The certificate(s) shall conform to the requirements of Section 10-103(a)1, and shall be approved by the local enforcement agency, in accordance with all applicable requirements of Section 10-103(d) by stamp or authorized signature prior to issuance of a building permit. A copy of the Certificate(s) of Compliance shall be included with the documentation the builder provides to the building owner at occupancy as specified in Section 10-103(b)

For alterations to existing residential buildings for which HERS field verification is required, and when the enforcement agency does not require building design plans to be submitted with the application for a building permit, the applicable Certificate of Compliance documentation specified in 10-103(a)1 is not required to be approved by the enforcement agency prior to issuance of a building permit, but shall be approved by the enforcement agency prior to final inspection of the dwelling unit, and shall be made available to the enforcement agency for all applicable inspections, or made available for viewing on an approved data registry.

When the enforcement agency requires building design plans to be submitted with the application for a building permit, the applicable Certificate of Compliance documents shall be incorporated into the building design plans. When Section 10-103(a)1 requires document registration, the certificate(s) that are incorporated into the building design plans shall be copies of the registered Certificate of Compliance documents from a HERS provider data registry, or a data registry approved by the Commission.

Per 150.0(h)1ii, for residential buildings, a report on load calculations (detailed report from load calculation software, or documentation of inputs, outputs, and algorithms used when custom calculations are done) must also be submitted with the Certificate of Compliance.

B. When the enforcement agency requires building design plans and specifications to be submitted with the application for a building permit, the plans shall conform to the specifications for the features, materials, components, and manufactured devices identified on the Certificate(s) of Compliance, and shall conform to all other applicable requirements of Part 6. Plans and specifications shall be submitted to the enforcement agency for any other feature, material, component, or manufactured device that Part 6 requires be indicated on the building design plans and specifications. Plans and specifications submitted with each application for a building permit for Nonresidential buildings, High-rise Residential buildings and Hotels and Motels shall provide acceptance requirements for code compliance of each feature, material, component or manufactured device when acceptance requirements are required under Part 6. Plans and specifications for Nonresidential buildings, High-rise Residential buildings and Hotels and Motels shall require, and indicate with a prominent note on the plans, that within 90 days after the Enforcement Agency issues a permanent final occupancy permit, record drawings be provided to the building owner. Per 150.0(h)5, when plans are required to be submitted to the enforcement agency, they must include the following:

   i. a schematic duct layout diagram showing supply register locations, return grill locations, duct sizes of all ducts and plenums and target airflows at each register.
   ii. equipment specifications with design total system airflow and corresponding design total external static pressure for each air handler
   iii. supply register information, including register size, type, design static pressure drop, throw distance{s) and noise criteria
   iv. return grill information, including grilled size, type, design static pressure drop and noise criteria
   v. return filter information, including filter type, dimensions, thickness, static pressure drop at design airflow, and MERV rating.

For all buildings, if the specification for a building design feature, material, component, or manufactured device is changed before final construction or installation, such that the building may no longer comply with Part 6 the building must be brought back into compliance, and so indicated on amended plans, specifications, and Certificate(s) of Compliance that shall be submitted to the enforcement agency for approval. Such characteristics shall include the efficiency (or other characteristic regulated by Part 6) of each building design feature, material, component, or device.

C. The enforcement agency shall have the authority to require submittal of any supportive documentation that was used to generate the Certificate(s) of Compliance, including but not limited to the electronic input file for the compliance software tool that was used to generate performance method Certificate(s) of Compliance; or any other supportive documentation that is necessary to demonstrate that the building design conforms to the requirements of Part 6.

SECTION 110.2 – MANDATORY REQUIREMENTS FOR SPACE-CONDITIONING EQUIPMENT

(b): Controls for heat pumps with supplementary ~~electric resistance~~ heaters.

1. Heat pumps with supplementary ~~electric resistance~~ heaters shall have controls that use either an outdoor air temperature sensor or an internet weather service to lock out

supplementary heating above an outdoor air temperature of no greater than 35°F. Either the thermostat or heat pump manufacturer shall provide the installer with succinct and readily-accessible instructions for the proper configuration and verification of configuration of these controls.

Note that this is also the limit for the changeover temperature of a dual-fuel heat pump.

~~1. That prevent supplementary heater operation when the heating load can be met by the heat pump alone; and~~

~~2. In which the cut-on temperature for compression heating is higher than the cut-on temperature for supplementary heating, and the cut-off temperature for compression heating is higher than the cut-off temperature for supplementary heating.~~

Exception 1 to Section 110.2(b)1: The controls may allow supplementary heater operation during ~~A.~~ ~~D~~defrost; and for emergency operation.

~~B. Transient periods such as start-ups and following room thermostat setpoint advance, if the controls provide preferential rate control, intelligent recovery, staging, ramping or another control mechanism designed to preclude the unnecessary operation of supplementary heating.~~

Exception 2 to Section 110.2(b)1: Room air-conditioner heat pumps.

2. When electric resistance strip heating is used, capacity is limited to the maximum of the difference between the heat heating capacity at the heating design temperature and the heating design load, and 2.7 kw per nominal ton (for defrost).

SECTION 150.0 – MANDATORY FEATURES AND DEVICES

(h) Space-conditioning equipment.

1. **Building cooling and heating loads**.

i. Building heating and cooling loads shall be determined using a method based on any one of the following:

A. The ASHRAE Handbook, Equipment Volume, Applications Volume and Fundamentals Volume; or

B. ~~The~~ SMACNA Residential Comfort System Installation Standards Manual; or

C. ~~The~~ ACCA Manual J.

~~The cooling and heating loads are two of the criteria that shall be used for equipment sizing and selection.~~

~~**NOTE**: Heating systems are required to have a minimum heating capacity adequate to meet the minimum requirements of the CBC. The furnace output capacity and other specifications are published in the Commission's directory of certified equipment or other directories approved by the Commission.~~

ii. Load calculations must be submitted along with the Certificate of Compliance for approval by the enforcement agency. These must include the following information: design city, indoor and outdoor design temperatures, winter heating loads for each zone/system, Sensible and latent summer cooling loads for each zone/system, load calculation software name and version. If load calculations use custom calculations based on the resources above, the report must also show all detailed algorithms, inputs and outputs. Load calculations used for a duct design shall be done on a room-by-room basis, but load calculations solely for system sizing are not required to be done on a room-by-room basis.

2. **Design conditions.** For the purpose of sizing the space- conditioning (HVAC) system, the indoor design temperatures shall be 68°F for heating and 75°F for cooling. Outdoor design conditions shall be selected from Reference Joint Appendix JA2, which is based on data from the ASHRAE 2021 Climatic Data for Region X. The outdoor design temperatures for heating shall be no lower than the 99.0 percent Heating Dry Bulb~~Heating Winter Median of Extremes~~ values. The outdoor design temperatures for cooling shall be no greater than the 1.0 percent Cooling Dry Bulb and Mean Coincident Wet Bulb values.

[…]

5. **Duct design.** When plans are required to be submitted to the enforcement agency, they must include the following:

   i. a schematic duct layout diagram showing supply register locations, return grill locations, duct sizes of all ducts and plenums and target airflows at each register.
   ii. equipment specifications with design total system airflow and corresponding design total external static pressure for each air handler
   iii. supply register information, including register size, type, design static pressure drop, throw distance{s) and noise criteria
   iv. return grill information, including grilled size, type, design static pressure drop and noise criteria
   v. return filter information, including filter type, dimensions, thickness, static pressure drop at design airflow, and MERV rating.

6. **System selection.**

   A. The cooling and heating loads are two of the criteria that shall be used for equipment sizing and selection.

   B. For each zone or system added or modified, the following must be provided: equipment type, design total airflow and corresponding total external static pressure drop for all air handlers, design heating capacity, design sensible and latent cooling capacities, winter heating loads, summer cooling loads, capacity to load sizing ratios, and efficiencies.

   C. Heating-only systems shall be sized based on ACCA Manual S-2023, Table N2.5.

   D. Heat pumps and cooling-only systems shall be sized based on ACCA Manual S-2023, substituting these limits (where referenced, the load shall be calculated at the relevant design condition):

      i. **Minimum:**

         a. **Heating Capacity**: Heating systems are required to have a heating capacity adequate to meet the minimum requirements of the CBC. Section 150.0(h)1v clarifies that for heat pumps, this refers to the capacity of the heat pump itself, not including any supplementary heating provided.

         b. **Cooling Capacity:** There is no limit on the minimum capacity**.**

      ii. **Maximum**: For new construction, there is no limit on the maximum heating or cooling capacity.

7. **Defrost**. If a heat pump is equipped with a defrost delay timer, either the thermostat or heat pump manufacturer shall provide the installer with succinct and readily-accessible instructions for the proper configuration of the defrost delay timer setting. The delay timer must be set to greater than or equal to 90 minutes. The proper setting shall be verified by a HERS Rater according to the procedures specified in Reference Residential Appendix Section RA 3.4.TBD.

8. **Crankcase heating**. If an air conditioner or heat pump is equipped with crankcase heating, the crankcase heater shall be controlled to not operate when the compressor is operating. Documentation from the manufacturer that either the unit does not have crankcase heating or that it is controlled to not operate when the compressor is operating shall be provided to the installer.

9. **Supplementary heating control configuration**. For systems with electric resistance or furnace supplementary heating, the presence and proper configuration of controls that lock out supplementary heating (as required per 110.2(b)1) shall be field verified, according to procedures provided in RA 3.4.TBD.

10. **Capacity variation with third-party thermostats**. When third-party thermostats are used with variable or multi-speed systems, the space conditioning system and thermostat together shall be capable of—and configured to—deliver all functionality necessary to provide proper modulation. To accomplish this, either the thermostat or space conditioning equipment manufacturer shall provide the installer with succinct and readily-accessible instructions for the proper configuration of these controls.

[…]

(m) Air-distribution and ventilation system ducts, plenums and fans.

13. **Space conditioning system airflow rate and fan efficacy**. Space conditioning systems that utilize forced air ducts to supply cooling to an occupiable space shall:

B. **Single zone central forced air systems**. Demonstrate in every control mode, airflow greater than or equal to 350 cfm per ton of nominal cooling capacity through the return grilles, and an air-handling unit fan efficiency less than or equal to 350 CFM per ton of nominal cooling capacity through the return grilles, and an air-handling unit fan efficacy less than or equal to the maximum W/CFM specified in Subsections i or ii below. The airflow rate and fan efficacy requirements in this section shall be confirmed by field verification and diagnostic testing in accordance with the procedures given in Reference Residential Appendix RA3.3.

i. 0.45 W/CFM for gas furnace air-handling units.

ii. 0.58 W/CFM for air-handling units that are not gas furnaces.

C. **Zonally controlled central forced air systems**. Zonally controlled central forced air cooling systems shall be capable of simultaneously delivering, in every zonal control mode, an airflow from the dwelling, through the air handler fan and delivered to the dwelling, of greater than or equal to 350 cfm per ton of nominal cooling capacity, and operating at an air-handling unit fan efficacy of less than or equal to the maximum W/CFM specified in Subsections i or ii below. The airflow rate and fan efficacy requirements in this section shall be confirmed by field verification and diagnostic testing in accordance with the applicable procedures specified in Reference Residential Appendix RA3.3.

i. 0.45 W/CFM for gas furnace air-handling units.

ii. 0.58 W/CFM for air-handling units that are not gas furnaces.

D. Small duct high velocity forced air systems. Demonstrate, in every control mode, airflow greater than or equal to 250 CFM per ton of nominal cooling capacity through the return grilles, and an air-handling unit fan efficacy less than or equal to 0.62 W/CFM as confirmed by field verification and diagnostic testing in accordance with the procedures given in Reference Residential Appendix RA3.3.

Exception 1 to Section 150.0(m)13B and D: Standard ducted systems (without zoning dampers) may comply by meeting the applicable requirements in Table 150.0-B or 150.0-C as confirmed by field verification and diagnostic testing in accordance with the procedures in Reference Residential Appendix Sections RA3.1.4.4 and RA3.1.4.5. The design clean-filter pressure drop requirements specified by Section 150.0(m)12Div for the system air filter(s) shall conform to the requirements given in Tables 150.0-B and 150.0-C.

Exception 2 to Section 150.0(m)13B and D: Multispeed compressor systems or variable speed compressor systems shall verify air flow (cfm/ton) and fan efficacy (Watt/cfm) for system operation at the maximum compressor speed and the maximum air handler fan speed.

Exception 3 to Section 150.0(m)13B: Gas furnace air-handling units manufactured prior to July 3, 2019 shall comply with a fan efficacy value less than or equal to 0.58 w/cfm as confirmed by field verification and diagnostic testing in accordance with the procedures given in Reference Residential Appendix RA3.3.

Exception 1 to Section 150.0(m)13C: Multispeed or variable speed compressor systems~~, or single speed compressor systems that utilize the performance compliance approach,~~ shall incorporate controls that vary fan speed with respect to the number of zones calling and shall demonstrate compliance with the airflow (cfm/ton) and fan efficacy (Watt/cfm) requirements of Section 150.0(m)13C by operating the system at maximum compressor capacity and system fan speed with all zones calling for conditioning, rather than in every zonal control mode.

Exception 2 to Section 150.0(m)13C: Zonally controlled forced air heat pump systems utilizing a single compressor to serve multiple air handlers shall demonstrate compliance with the airflow (cfm/ton) and fan efficacy (Watt/cfm) requirements of Section 150.0(m)13C using the sum of airflows and Watt/cfm of all air handlers.

Exception ~~2~~3 to Section 150.0(m)13C: Gas furnace air-handling units manufactured prior to July 3, 2019 shall comply with a fan efficacy value less than or equal to 0.58 w/cfm as confirmed by field verification and diagnostic testing in accordance with the procedures given in Reference Residential Appendix RA3.3.

SECTION 150.1 – PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES FOR SINGLE FAMILY RESIDENTIAL BUILDINGS

(c) Prescriptive standards/component packages

7. **Space heating and space cooling**.

   All space heating and space cooling equipment shall comply with minimum Appliance Efficiency Regulations as specified in Sections 110.0 through 110.2 and meet all applicable requirements of Sections 150.0 and 150.1(c)7A.

A. **Refrigerant charge.** When refrigerant charge verification ~~or fault indicator display~~ is shown as required by Table 150.1-A, the system shall comply with either Section 150.1(c)7Ai or 150.1(c)7Aii:

i. air-cooled air conditioners and air-source heat pumps, including but not limited to ducted split systems, ducted packaged systems, small duct high velocity systems, and mini-split systems, shall comply with subsections a, b and c, unless the system is of a type that cannot be verified using the specified procedures:

…

c. The installer shall charge the system according to manufacturer's specifications. Refrigerant charge shall be verified according to one of the following options, as applicable:

I. The installer and rater shall perform the standard charge procedure as specified by Reference Residential Appendix Section RA3.2.2, or an approved alternative procedure as specified by Section RA1; or

~~II. The system shall be equipped with a fault indicator display (FID) device that meets the specifications of Reference Joint Appendix JA6. The installer shall verify the refrigerant charge and FID device in accordance with the procedures in Reference Residential Appendix Section RA3.4.2. The HERS Rater shall verify FID device in accordance with the procedures in Section RA3.4.2; or~~

II~~III~~. The installer shall perform the weigh-in charging procedure as specified by Reference Residential Appendix Section RA3.2.3.1 provided the system is of a type that can be verified using the Section RA3.2.2 standard charge verification procedure and Section RA3.3 airflow rate verification procedure or approved alternatives in Section RA1. The HERS Rater shall verify the charge using Sections RA3.2.2 and RA3.3 or approved alternatives in Section RA1.

Exception 1 to Section 150.1(c)7Aic: When the outdoor temperature is less than 55°F and the installer utilizes the weigh-in charging procedure in Reference Residential Appendix Section RA3.2.3.1 to verify the refrigerant charge, the installer may elect to utilize the HERS Rater verification procedure in Reference Residential Appendix Section RA3.2.3.2. If the HERS Rater verification procedure in Section RA3.2.3.2 is used for compliance, the system's thermostat shall conform to the specifications in Section 110.12. Ducted systems shall comply with minimum system airflow rate requirement in Section 150.1(c)7Aib.

ii. Air-cooled air conditioners and air-source heat pumps, including but not limited to ducted split systems, ducted packaged systems, small duct high velocity systems and mini-split systems, which are of a type that cannot ~~comply~~ be verified using the specified procedures, with the requirements of Section 150.1(c)7Ai shall comply with Subsections a and b, as applicable.

a. The installer shall confirm the refrigerant charge using the weigh-in charging procedure specified in Reference Residential Appendix Section RA3.2.3.1, as verified by a HERS Rater according to the procedures specified in Reference Residential Appendix Section RA3.2.3.2; and
b. Systems that utilize forced air ducts shall comply with the minimum system airflow rate requirement in Section 150.1(c)7Aib provided the system is of a type that can be verified using the procedures in Section RA3.3 or an approved alternative procedure in Section RA1.

Exception 1 to Section 150.1(c)7A: Packaged systems for which the manufacturer has verified correct system refrigerant charge prior to shipment from the factory are not required to have refrigerant charge confirmed through field verification and diagnostic testing. The installer of these packaged systems shall certify on the Certificate of Installation that the packaged system was pre-charged at the factory and has not been altered in a way that would affect the charge. Ducted systems shall comply with minimum system airflow rate requirements in Section 150.1(c)7Aib, provided that the system is of a type that can be verified using the procedure specified in Section RA3.3 or an approved alternative in Section RA1.

Exception 2 to Section 150.1(c)7A: Systems certified by installer to be pre-charged with a line set length within 5' and a coil size within 10% of the manufacturer's defaults are not required to have refrigerant charge verification.

Exception 3 to Section 150.1(c)7A: Systems may use a method recommended by the manufacturer.

B. **Crankcase heating.** For air conditioners and heat pumps, unless the installer provides manufacturer documentation that the equipment does not have crankcase heating (CCH), one of the following must be met:

i. Installer shall provide manufacturer documentation showing that CCH control includes either thermostatic control (disabling CCH above a fixed setpoint no higher than 55°F or differential temperature between crankcase and evaporator or condenser) or Positive Temperature Coefficient Control. Installer must also provide manufacturer's intermediate values "P1" and "P2" that are used in calculating the reported $P_{w,off}$ values, per AHRI 210/240, to allow accurate modeling of connected power and control.

ii. Installer shall install an Occupant Controlled Smart Thermostat, per JA5.

Exception to Section 150.1(c)7B: These requirements do not apply if $P_{w,off}$ values are below the Federal Efficiency Standard limits and installer provides manufacturer's intermediate values "P1" and "P2" that are used in calculating the reported $P_{w,off}$ values, per AHRI 210/240.

Table 150.1-A COMPONENT PACKAGE – Single Family Standard Building Design

			Climate Zone															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
HVAC System	Space Heating	Refrigerant Charge Verification (for Heat Pumps)	REQ	REQ	REQ	REQ	REQ	NR	NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ
	Space Cooling	Refrigerant Charge Verification ~~or Fault Indicator Display~~	NR	REQ	NR	NR	NR	NR	NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	NR

SECTION 150.2 – ENERGY EFFICIENCY STANDARDS FOR ADDITIONS AND ALTERATIONS TO EXISTING SINGLE FAMILY RESIDENTIAL BUILDINGS

(a) Additions.

1. Prescriptive approach.

E. Load Calculations and System Capacity

i. **Load Calculations**: When doing load calculations as required in 150.0(h)1, for additions:

a) Simplifying assumptions described in RA[**TBD1**] are allowed for new systems serving an addition with a conditioned floor area of 144 square feet or less. Simplifying assumptions may not be used if the space conditioning systems is a heat pump with supplementary electric resistance heating.

b) Block loads (the total load for all rooms combined that are served by the central equipment) may be used for the purpose of system sizing.

c) The envelope leakage specified in the load calculation shall be no greater than "the default ACH value of "Average" from table 5A of ACCA Manual J, 8th Edition. A disclosure to the homeowner shall be provided that states that infiltration has a large impact on the load calculations, the infiltration for the home was not measures and subsequently, the equipment sizing may not be optimum, and additional infiltration reduction measures will improve comfort.

Exception to Section 150.2(a)1Eic: If leakage is established through field verification and diagnostic testing following procedures specified in Reference Residential Appendix RA3.8, the tested envelope leakage value may be used in the load calculations and no disclosure is required.

ii. System Capacity:

a) Minimum capacity limits are as described in 150.0(h)6A.

b) The maximum capacity depends on the relative sizes of the calculated heating and cooling design loads, and on the type of system and duct sizing.

1. In situations where airflow will be field verified to be at least 350 cfm/ton, there is no maximum capacity limit.
2. In situations where airflow will NOT be field verified to be at least 350 cfm/ton, the system capacities shall be no larger than indicated in Table 150.2-TBD.

Table 150.2-TBD: Maximum Heating and Cooling Capacity (HL = Design Heating Load; CL = Design Total Cooling Load)

System Type	**Maximum Heatng Capacity for Heating Only Systems**	**Maximum Heating Capacity for Heat Pumps when CL minus HL is:**		
		< 0	**0 – 12 kBtuh**	**> 12 kBtuh**
Single Speed System—Capacity	HL + 6 kBtuh	No maximum	HL + 12 kBtuh	No maximum
Variable or Multi Speed System—Maximum Capacity	HL + 6 kBtuh	No maximum	HL + 12 kBtuh	No maximum
Variable or Multi Speed System—Capacity at Lowest Speed	80% of HL	80% of HL	No maximum	No maximum
System Type	**Maximum Cooling Capacity for Cooling Only Systems**	**Maximum Cooling Capacity for Heat Pumps when CL minus HL is:**		
		< 0	**0 – 12 kBtuh**	**> 12 kBtuh**
Single Speed System—Capacity	CL + 6 kBtuh	No maximum	CL + 6 kBtuh	CL + 6 kBtuh
Variable or Multi Speed System—Maximum Capacity	CL + 6 kBtuh	No maximum	CL + 6 kBtuh	CL + 6 kBtuh
Variable or Multi Speed System—Capacity at Lowest Speed	80% of CL	No maximum	80% of CL	80% of CL

2. Performance approach.

D. Load Calculations and System Capacity

i. **Load Calculations**: When doing load calculations as required in 150.0(h)1, for additions:

a) Simplifying assumptions described in RA[**TBD1**] are allowed for new systems serving an addition with a conditioned floor area of 144 square feet or less. Simplifying assumptions may not be used if the space conditioning systems is a heat pump with supplementary electric resistance heating.

b) Block loads (the total load for all rooms combined that are served by the central equipment) may be used for the purpose of system sizing.

c) The envelope leakage specified in the load calculation shall be no greater than "the default ACH value of "Average" from table 5A of ACCA Manual J, 8th Edition. A disclosure to the homeowner shall be provided that states that infiltration has a large impact on the load calculations, the infiltration for the home was not measures and subsequently, the equipment sizing may not be optimum, and additional infiltration reduction measures will improve comfort.

Exception to Section 150.2(a)1Eic: If leakage is established through field verification and diagnostic testing following procedures specified in Reference Residential Appendix RA3.8, the tested envelope leakage value may be used in the load calculations and no disclosure is required.

ii. System Capacity:

a) Minimum capacity limits are as described in 150.0(h)6A.

b) The maximum capacity depends on the relative sizes of the calculated heating and cooling design loads, and on the type of system and duct sizing.

1. In situations where airflow will be field verified to be at least 350 cfm/ton, there is no maximum capacity limit.
2. In situations where airflow will NOT be field verified to be at least 350 cfm/ton, the system capacities shall be no larger than indicated in Table 150.2-TBD.

(b) Alterations.

1. Prescriptive approach.

O. Load Calculations and System Capacity

i. **Load Calculations:** When doing load calculations as required in 150.0(h)1, for alterations:

a) Simplifying assumptions described in RA[**TBD1**] are allowed for system replacements where the new equipment is the same type and is expected to be the same or lower capacity as the replaced equipment. Simplifying assumptions may not be used if the space conditioning systems is a heat pump with supplementary electric resistance heating.

b) Block loads (the total load for all rooms combined that are served by the central equipment) may be used for the purpose of system sizing.

c) The envelope leakage specified in the load calculation shall be no greater than "the default ACH value of "Average" from table 5A of ACCA Manual J, 8th Edition. A disclosure to the homeowner shall be provided that states that infiltration has a large impact on the load calculations, the infiltration for the home was not measures and subsequently, the equipment sizing may not be optimum, and additional infiltration reduction measures will improve comfort.

Exception to Section 150.2(b)1Oid: If leakage is established through field verification and diagnostic testing following procedures specified in Reference Residential Appendix RA3.8, the tested envelope leakage value may be used in the load calculations and no disclosure is required.

Note: Load calculations are required, even in the situation where the new equipment is the same type and is expected to be the same or lower capacity as the replaced system.

ii. System Capacity:

a) Minimum capacity limits are as described in 150.0(h)6A.

b) The maximum capacity depends on the relative sizes of the calculated heating and cooling design loads, and on the type of system and duct sizing.

1. Where airflow will be field verified to be at least 350 cfm/ton, there is no maximum capacity limit.
2. Where airflow will NOT be field verified to be at least 350 cfm/ton, the system capacities shall be no larger than indicated in Table 150.2-TBD.

2. Performance approach.

D. Load Calculations and System Capacity

iii. **Load Calculations:** When doing load calculations as required in 150.0(h)1, for alterations:

d) Simplifying assumptions described in RA[**TBD1**] are allowed for system replacements where the new equipment is the same type and is expected to be the same or lower capacity as the replaced equipment. Simplifying assumptions may not be used if the space conditioning systems is a heat pump with supplementary electric resistance heating.

e) Block loads (the total load for all rooms combined that are served by the central equipment) may be used for the purpose of system sizing.

f) The envelope leakage specified in the load calculation shall be no greater than "the default ACH value of "Average" from table 5A of ACCA Manual J, 8th Edition. A disclosure to the homeowner shall be provided that states that infiltration has a large impact on the load calculations, the infiltration for the home was not measures and subsequently, the equipment sizing may not be optimum, and additional infiltration reduction measures will improve comfort.

Exception to Section 150.2(b)1Oid: If leakage is established through field verification and diagnostic testing following procedures specified in Reference Residential Appendix RA3.8, the tested envelope leakage value may be used in the load calculations and no disclosure is required.

Note: Load calculations are required, even in the situation where the new equipment is the same type and is expected to be the same or lower capacity as the replaced system.

iv. **System Capacity:**

c) Minimum capacity limits are as described in 150.0(h)6A.

d) The maximum capacity depends on the relative sizes of the calculated heating and cooling design loads, and on the type of system and duct sizing.

3. Where airflow will be field verified to be at least 350 cfm/ton, there is no maximum capacity limit.

1. Where airflow will NOT be field verified to be at least 350 cfm/ton, the system capacities shall be no larger than indicated in Table 150.2-TBD.

8.3 Reference Appendices

~~JOINT APPENDIX 6.1 FAULT INDICATOR DISPLAY (FID)~~

(deleted in its entirety)

JOINT APPENDIX 2.2 CALIFORNIA DESIGN LOCATION DATA

Table 2-3 – Design Day Data for California Cities

[updated with data from http://ashrae-meteo.info/v2.0/places.php?continent=North%20America for 2021].

RESIDENTIAL APPENDIX 3.2.3 WEIGH-IN CHARGING PROCEDURE

This section specifies the weigh-in charging procedure in which the weight of the required refrigerant charge is determined by using the manufacturer's specifications for a standard refrigerant charge weight and taking into account adjustment factors such as deviations in refrigerant line length and diameter. The calculated weight of refrigerant is then installed using a refrigerant scale. RA3.2.3 provides two procedures: Section RA3.2.3.1 shall be used by the HVAC installer when the weigh-in procedure is required by the Standards for compliance. Section RA3.2.3.2 shall be used by the HERS Rater when the Standards specify use of the procedure for compliance, or specify it as an optional procedure for compliance. The weigh-in charging procedure is an acceptable method for demonstrating compliance at any outdoor temperature, however if the weigh-in charging procedure is used, HERS verification of compliance cannot use group sampling.

HVAC installers shall use the weigh-in charging procedure in accordance with the space conditioning system manufacturer's specifications.

Both the HVAC installer and the HERS Rater shall test the system airflow as specified by Standards Sections 150.1(c)7Aib and 150.2(b)1Fiia as applicable.

RA3.2.3.1 HVAC Installer - Weigh-In Charging Procedure

Split system air conditioners and heat pumps are shipped from the factory charged with a standard amount of refrigerant as indicated on the nameplate. The manufacturer-supplied refrigerant charge is expected to be the correct amount for the system based on a standard liquid line length and diameter. It is the responsibility of the HVAC installer to ensure that the charge is correct for each air conditioner and to adjust the charge based on liquid line dimensions that deviate from the manufacturer's standard line specification.

RA3.2.3.1.1 Procedure Options

There shall be two options for compliance using the weigh-in charging procedure:

RA3.2.3.1.1.1 Weigh-in Charge Adjustment

This option is applicable to a new system or existing system when a new outdoor unit is installed (with factory charge in outdoor unit). The HVAC installer shall weigh in lineset and indoor coil charge adjustment after evacuation of lineset and indoor coil. The documentation shall include the calculated charge adjustment for the lineset.

RA3.2.3.1.1.2 Weigh-in Total Charge

This option is applicable to all systems. The installer shall weigh in the total system charge after refrigerant recovery and evacuation of the entire system. The total system charge includes the nameplate charge for the outdoor unit and any adjustment for the lineset dimensions and indoor coil in accordance with the manufacturer's instructions. The documentation shall include the nameplate charge and the calculated lineset adjustment.

RA3.2.3.1.2 Minimum Qualifications for this Procedure

Persons who use this procedure to demonstrate compliance with Title 24, Part 6 shall be qualified to perform the following:

(a) Calculate the correct system charge based on the Manufacturer's standard charge and adjustments to the standard charge based on lineset dimensions and indoor coil.

(b) Obtain accurate refrigerant charge weight.

RA3.2.3.1.3 Instrumentation Specifications

[…]

RA3.2.3.1.4 Calibration

[…]

RA3.2.3.1.5 Weigh-in Procedure

The weigh-in procedure shall be performed in accordance with all manufacturer specifications to document and confirm:

(a) Liquid line filter drier has been installed if required per outdoor condensing unit manufacturer's instructions, and installed with the proper orientation with respect to refrigerant flow, if applicable.

(b) The system is braised with dry nitrogen in the lines and indoor coil.

(c) The system is evacuated to 500 microns or less and, when isolated, rises no more than 300 microns over five minutes.

(d) The lineset correction is calculated based on the length and diameter of the lineset.

(e) The indoor coil correction to refrigerant weight is used if it is supplied by the manufacturer.

(f) The amount of charge calculated for the lineset correction (and indoor coil correction if available) is added or removed, or the total charge based on the lineset, indoor coil, and standard label charge is installed.

The HVAC Installer shall certify on the Certificate of Installation that the manufacturer's specifications for these procedures have been met. This shall be verified either through on-site observation using procedures in RA 3.2.3.2 or remote4 verification using procedures in RA 3.2.3.3.

RA3.2.3.2 HERS Rater – Observation of Weigh-In Charging Procedure

When the Standards indicate this procedure is required, or is an option for compliance, the HERS Rater shall coordinate with the HVAC Installer to observe the weigh-in charging procedure.

HERS Rater shall observe and confirm:

(a) The system is evacuated to 500 microns or less and, when isolated, rises no more than 300 microns over five minutes.

(b) The lineset correction is calculated based on the length and diameter of the lineset, including the liquid line filter drier if required per outdoor condensing unit manufacturer instructions.

(c) The indoor coil correction to refrigerant weight is used if it is supplied by the manufacturer.

(d) The installer adds or removes the amount of charge calculated for the lineset correction or installs the total charge based on lineset, indoor coil, and standard label charge.

Exception to RA3.2.3.2: Vacuum verification is not required if on-site verification is provided that no fittings (other than the fitting to the compressor) are compression or flare fittings (in-person verification).

RA3.2.3.3 HERS Rater – Remote Verification of Weigh-In Charging Procedure

When the Standards indicate weigh-in verification is required, or is an option for compliance, the HVAC Installer shall collect and the HERS Rater shall coordinate with the installer to receive documentation of the weigh-in procedure. All documentation shall be transmitted to the HERS Rater, who shall review the documents and confirm that the adjustments and tests conform with the requirements of RA3.2.3.1.5.

This documentation shall consist of the following:

(a) Documentation that the system was evacuated to 500 microns or less and, when isolated, rose no more than 300 microns over five minutes (for example, vacuum gauge photographs, or electronic instrument records).

(b) Assumptions that were used to calculate the total charge or lineset correction based on the length and diameter of the lineset, including the liquid line filter drier if required per outdoor condensing unit manufacturer instructions (for example, estimated distance between units and vertical line lengths, line set assumed by manufacturer, excess line set length, adjustment for indoor coil(s) as recommended by manufacturer, filter dryer). The indoor coil correction to refrigerant weight if it is supplied by the manufacturer.

(c) The amount of charge calculated for the lineset correction or the total charge based on lineset, indoor coil, and standard label charge.

(d) The amount of charge added or removed (for example, before and after scale photographs, or electronic instrument records).

Exception to RA3.2.3.3: : Vacuum documentation is not required if remote documentation is provided that no fittings (other than the fitting to the compressor) are compression or flare fittings (in-person verification).

RA3.4 Field Verification of Installed HVAC System Components and Devices

- ~~RA3.4.2 Fault Indicator Display (FID) Verification Procedure~~
  - ~~RA3.4.2.1 Verification of installation of a FID with "self diagnostic reporting" functionality when outdoor air temperature is less than 55F~~
  - ~~RA3.4.2.2 Verification of Installation of a FID that does not have "self diagnostic reporting" functionality when outdoor air temperature is less than 55F~~
  - ~~RA3.4.2.3 Verification of Installation of a FID when the outdoor air temperature is equal to or greater than 55F~~

RESIDENTIAL APPENDIX [TBD1] SIMPLIFYING LOAD CALCULATION INPUT ASSUMPTIONS

Under circumstances described in 150.2(a)1E and 2D, and (b)1O and 2D, the following simplified load calculation input assumptions may be made.

		Sub-category	Simplification*	Notes		Sub-category	Simplification*	Notes
General		floor area	actual ± 5%	can simplify perimeter footprint		#bedrooms	actual	
		block load	"Yes"	room by room not required		ventilation	Equation 150.0-B "Exhaust Only"	
		design temps.	code required			occupants	# of bedrooms + 1	
		infiltration	"Average"					
Windows		area	actual	combined into one per direction		# panes	actual	
		orientation	actual	round to nearest 45 deg		frame type	actual	use predominant, if multiple
		tilt	"Vertical" for windows			exterior shade	ignore	
		overhangs	ignore unless > 1:1; on S/SW side	model if extension is greater than height above window		storm	ignore	
		U factor	default table	table 110.6-A		impact	ignore	
		SHGC	default table	table 110.6-B		structural	ignore	
		interior shade	"Closed Drapes"			skylight curb	ignore	
		tint	"Clear"					
Doors		area	actual			U factor	"Solid Wood"	
Floors		area/ slab	actual ± 10%			framing fraction	"15%"	
		type	actual	raised, slab, etc.		crawlspace wall R	vintage table	Table R3-50**
		covering	"100% Carpet"			crawlspace vented?	"Yes"	
		R-value	vintage table	Table R3-50**		crawlspace cond'd?	"No"	
Walls		area	actual ± 10%	avg height for vaulted ceilings		sheathing R value	vintage table	Table R3-50**
		type	actual	wood frame, brick, etc.		framing factor	"15%"	
		cavity R value	vintage table	Table R3-50**				
Ceiling		area	actual ± 10%			R value	vintage	Table R3-50**
		type	actual	below attic, cathedral, etc.		framing factor	"15%"	
		insulation type	"Fiberglass Batt"			truss type	"Wood"	
Roof		type	"Tile"			framing fraction	"15%"	
		attic?	"Yes"			radiant barrier?	"No"	
		color	"Dark"			vented	"Yes"	
		config.	actual	attic, cathedral, etc.		tile	4:12	
		deck insulation	"No"			cool roof	"No"	
		absorption	use default					
Ducts		R value	vintage table	Table R3-50**		leakage	10% total	
		location	actual	attic crawlspace etc.				

* Other inputs may be used in adequately documented.

**See 2016 Residential Compliance Manual Appendix B or 2016 Residential ACM Manual

RESIDENTIAL APPENDIX 3.4.TBD VERIFICATION OF SPACE CONDITIONING SYSTEM CONTROLS CONFIGURATION.

(a) **Defrost Delay Timer**. Section 150.0(h)7 requires that, when present, a heat pump's defrost delay timer be set at no less than 90 minutes. It requires that the heat pump or thermostat manufacturer provide the installer with succinct and readily-accessible instructions for the proper configuration of the defrost timer.

   i. Obtain from the installer the manufacturer's instructions for configuring defrost delay timer.

   ii. Identify where defrost delay timer is set: this could be a dip switch or jumper, typically configured on the outdoor unit.

   iii. Identify which setting will result in a defrost delay of no less than 90 minutes.

   iv. Inspect the defrost delay timer configuration and confirm that it is at the setting that will result in a defrost delay of no less than 90 minutes.

(b) **Supplementary Heating Control**. Section 110.2(b)1 requires that, when present, supplementary heaters (including electric resistance strip heaters and furnace backup) shall have controls that use either an outdoor air temperature sensor or an internet weather service to lock out supplementary heating above an outdoor air temperature of no greater than 35°F. It also requires that either the thermostat or heat pump manufacturer shall provide the installer with succinct and readily-accessible instructions for the proper configuration of these controls. If at time of testing the ambient temperature is 35°F or higher, conduct functional test in item (i), otherwise conduct construction inspection in item (ii).

   i. Functional Test

      1. Measure and Record outdoor temperature. Conduct test if outdoor temperature is greater than 35°F
      2. Measure and record indoor air temperature
      3. Record indoor air temperature displayed by thermostat (if available)
      4. Set to thermostat to heating mode
      5. Set heating setpoint temperature to 10 degrees above indoor temperature displayed by thermostat, if thermostat does not display indoor temperature, set thermostat setting to 10 degrees above measured indoor temperature.
      6. Record whether thermostat indicates supplementary heating is engaged.
      7. Measure amps of current to supplementary heating . Either by directly measuring current to supplementary heating elements or by measuring total current to indoor unit and subtract measured power to indoor unit with heating and cooling off but fan operating.
      8. If supplementary heating is on during step 7, the test has failed. Reconfigure HVAC system control settings for supplementary heat lock out at 35°F or less and retest util the system passes.

   ii. Construction inspection

      1. Obtain from the installer the manufacturer's instructions for configuring the supplementary heating lock-out control.

2. Identify where the supplementary heating lock-out is set: this could be on the thermostat, or a dip switch or jumper, configured on the indoor or outdoor unit's control board.
3. Inspect the thermostat programming or heat pump setting and confirm that it is configured to lockout supplementary heating above a temperature no greater than 35°F.
4. Measure and record outdoor temperature.
5. If thermostat or other control displays outdoor temperature as measured locally, confirm that displayed temperature is within 3°F of the measured temperature.
6. If thermostat uses internet weather service for ambient temperature, have thermostat display internet weather temperature and compare to internet temperature accessed by other means. Confirm displayed temperature is within 3°F of the internet temperature accessed by other means.

8.4 ACM Reference Manual

2.4 Building Mechanical Systems

2.4.1 Heating Subsystems

The heating subsystem describes the equipment that supplies heat to a space-conditioning system. Heating subsystems are categorized according to the types shown in **Error! Reference source not found.** and **Error! Reference source not found.**. A co nversion factor is used to convert heating seasonal performance factor (HSPF) to HSPF2 ratings for modeling. For split-system, small-duct high-velocity, and space-constrained equipment, the conversion factor is 0.85 to convert HSPF to HSPF2. For single-package equipment, the conversion factor is 0.84 to convert HSPF to HSPF2.

Furnace capacity is determined by the software as 200 percent of the heating load at the heating design temperature. Heat pump compressor size is determined by the software as the larger of the compressor size calculated for 110 percent of the cooling load, or the compressor with a 47°F rating that is 110 percent of the heating load (at the heating design temperature). If the maximum heat pump heating capacity is insufficient to meet the load, the unmet portion of the load will be met by backup heating. The exception is that backup heat is disabled when outdoor air temperature is above 35°F. Backup heat is provided by electric resistance in the Standard Design. In the Proposed Design backup heat is provided by electric resistance except in the case of dual fuel heat pumps where backup heat is provided by gas.

Heat pump CCH capacity is calculated as 33 Watts for systems with a capacity under 3 tons and 11 Watts per ton for systems with a capacity 3 tons or larger.

PROPOSED DESIGN

The user selects the type and supplies required inputs for the heating subsystem, including the appropriately rated heating efficiency. ~~Except for heat pumps, t~~The rated heating capacity is not used as a compliance variable by the compliance software.

~~When the proposed space-conditioning system is a heat pump, the user specifies the rated heating capacity at 47°F and 17°F for the heat-pump compressor. The capacity is used to determine the effect of backup electric resistance heat in the simulation. The specified capacities are listed on the CF1R for verification by a HERS Rater.~~

The CCH is assumed to operate whenever the compressor is not operating to provide heating or cooling. The user indicates whether the prescriptively required control is present that disables CCH operation at or above outdoor air temperatures of 55°F.

Standard Design

The standard design heating subsystem is a heat pump if the proposed water heating system is gas-fired in climate zones 3, 4, 13, and 14. Otherwise, the heating system is a gas-heating system.

When the standard design is a heat pump, the equipment used in the standard design building is an electric split-system heat pump with default ducts in the attic and a heating seasonal performance factor (HSPF) meeting the current *Appliance Efficiency Regulations* minimum efficiency for heat pumps. ~~The standard design heat-pump compressor size is determined by the software as the larger of the compressor size calculated for air-conditioning load, or the compressor with a 47°F rating that is 75 percent of the heating load (at the heating design temperature).~~

The CCH is assumed to operate whenever the compressor is not operating to provide heating or cooling and the outdoor air temperature is below 55°F.

When the standard design is a gas heating system, the equipment used in the standard design building is a gas furnace (or propane if natural gas is not available) with default ducts in the attic and an annual fuel utilization efficiency (AFUE) meeting the *Appliance Efficiency Regulations* minimum efficiency for central systems.

See Table 98: Standard Design Heating System for complete details on heating systems noted above.

Table 98: Standard Design Heating System

Proposed Design	Standard Design
Climate Zones 1–2, 5–12, and 15–16	80 percent AFUE central furnace, default duct
Climate Zones 3–4, and 13–14 (if the water heating system is not a gas-fired system)	80 percent AFUE central furnace, default duct

Proposed Design	Standard Design
Climate Zones 3–4, and 13–14 (if the water heating system is a gas-fired system)	8.2 HSPF or 7.5 HSPF2 central heat pump, ~~auto size capacity,~~ default duct

Source: California Energy Commission

Verification and Reporting

The proposed heating system type and rated efficiency are reported in the compliance documentation on the CF1R. ~~For heat pumps, which are supplemented by electric resistance backup heating, the HERS-verified rated heating capacity of each proposed heat pump is reported on the CF1R. Installed capacities must be equal to or larger than the capacities reported for modeled at 47° and 17° (RA 3.4.4.2).~~

[…]

2.4.6 Cooling Subsystems

The cooling subsystem describes the equipment that supplies cooling to a space-conditioning system.

Air conditioner compressor size is determined by the software as 110 percent of the cooling load. Air conditioner CCH capacity is calculated as 30 Watts for systems with a capacity under 3 tons and 10 Watts per ton for systems with a capacity 3 tons or larger. It is assumed to operate whenever the compressor is not operating to provide cooling and the outdoor air temperature is below 55°F.

Proposed Design

Cooling subsystems are categorized according to the types shown in **Error! Reference source not found.**. The user selects the type of cooling equipment and enters basic information to model the energy use of the equipment. Enter the cooling equipment type and additional information based on the equipment type and zoning, such as the SEER/SEER2 and EER/EER2. A conversion factor is used to convert EER to EER2 ratings for modeling. For all air conditioners the conversion factor is 0.96 to convert EER to EER2. A conversion factor is used to convert SEER to SEER2 ratings for modeling. For split-system equipment, the conversion factor is 0.95; for single-package equipment, the conversion factor is 0.96; for small-duct high-velocity equipment the conversion factor is 1.00; and for space-constrained equipment the conversion factor is 0.99 to convert SEER to SEER2. For some types of equipment, the user may also specify if the equipment has a multispeed compressor and if the system is zoned or not via checkboxes. For ducted cooling systems, the cooling airflow from the conditioned zone through the cooling coil is input as CFM per ton. The rated cooling capacity is not a compliance variable.

~~Until there is an approved compliance option for ductless heat pumps (ducted and ductless mini-split, multi-split, and variable-refrigerant-flow [VRF] systems), these systems are simulated as a minimum efficiency split-system equivalent to the standard design with default duct conditions.~~

See sections below for the details of specific inputs.

STANDARD DESIGN

The cooling system for the standard design building is a nonzonal control system, split-system ducted cooling system meeting the minimum requirements of the *Appliance Efficiency Regulations*. ~~The standard design system shall assume verified refrigerant charge in Climate Zones 2 and 8–15 for all systems.~~ Mandatory fan efficacy is assumed in all climate zones.

[…]

2.4.7 Verified Refrigerant Charge ~~or Fault Indicator Display~~

Proper refrigerant charge is necessary for electrically driven compressor air-conditioning and heat pump systems to operate at full capacity and efficiency. For cooling, s~~S~~oftware calculations set the cooling compressor efficiency multiplier to 0.90 to account for the effect of improper refrigerant charge or 0.96 for proper charge. For heating, software calculations set the heating compressor efficiency multiplier to 0.92 to account for the effect of improper refrigerant charge or 0.96 for proper charge.

PROPOSED DESIGN

The software allows the user to indicate if systems will have diagnostically tested refrigerant charge ~~or a field-verified fault indicator display (FID)~~. This allowance applies only to ducted split-systems and packaged air-conditioners and heat pumps. ~~Refrigerant charge verification is required by Section 150.1(c) and Table 150.1-A for the proposed cooling system type~~

STANDARD DESIGN

The standard design building is modeled with either diagnostically tested refrigerant charge ~~or a field-verified FID~~ for air conditioners if the building is in Climate Zone 2 or 8–15 and for heat pumps if the building is in Climate Zone 1-5 or 8-16. For heat pumps in buildings that are 500 square feet or less the standard design does not model diagnostically tested refrigerant charge.

VERIFICATION AND REPORTING

Refrigerant charge ~~or FID~~ requires field verification or diagnostic testing and is reported in the HERS-required verification listings on the CF1R. Details on refrigerant charge measurement are discussed in *Reference Residential Appendix RA3.2*. ~~Information on the requirements for FIDs is in *Reference Joint Appendix JA6.1*.~~

Appendix G – Algorithms

1.15 HVAC Equipment Models

1.15.2 Air-Source Heat Pump Model (Heating mode)

The air source heat pump model is based on methods presented in AHRI Standard 210/240-2008.

Primary model parameters. The following values characterize the ASHP and are constant for a given unit:

[…]

Fchgheat = Heating refrigerant charge factor, default = 0.92. For systems with a verified charge indicator light (Reference Residential Appendix RA3.4) or verified refrigerant charge (Reference Residential Appendix RA3), the factor shall be 0.96.

Estimation of unavailable model parameters.

COP47 = (0.3038073 × HSPF - 1.984475 × Cap17/Cap47 + 2.360116) x Fchgheat

COP17 = (0.2359355 × HSPF + 1.205568 × Cap17/Cap47 – 0.1660746) x Fchgheat

8.5 Compliance Forms

The following changes and additions to the Compliance Forms are proposed:

- Add to CF1R-PERF, CF1R ALT-02, and CF1R-NCB:
    - Remove the request to provide capacities for heat pumps.
    - Load calc software detailed report or documentation of custom calculations (inputs, outputs, algorithms) must be submitted (per Section 10-103, 150.0(h)1iv)
    - Plans must show at least a schematic diagram and room-by-room duct and diffuser information, including supply airflow, duct size, grille dimensions, and grille throw; and return airflow, duct size, grille dimensions, and net free area (per Section 10-103,150.0(h)5)
- New CF2R-MCH form to show system selection information, to include, for each zone or system added or modified:
    - equipment type, design total airflow and corresponding total external static pressure drop for all air handlers, design heating capacity, design sensible and latent cooling capacities, winter heating loads, summer cooling loads, capacity to load sizing ratios, and efficiencies

- a table to confirm that selected capacities are within limits.

- CF2R-MCH-01-E would be modified to include:
  - D. Installed Space Conditioning (SC) System Component Information
    - Add CCH prescriptive requirements per 150.1(c)7B, including space for which CCH Option:
    - Manufacturer documentation that CCH has “better” control (provide P1 and P2)
    - OCST
    - Pw,off is below federal limits (provide P1 and P2)
    - Manufacturer documentation that No CCH
  - H. Installed Heat Pump System – Split System Condensing Unit or Package Unit Equipment Information
    - Add spaces for:
      - supplementary heater control requirements, per 110.2(b)1:
        - controls capable of lock-out
        - manufacturer provided instructions for proper configuration
        - controls configured per description
        - strip heater capacity limit, per 110.2(b)2.
      - defrost control requirements, per 150.0(h)7:
        - manufacturer provided instructions for proper configuration
        - defrost delay timer set
      - CCH does not operate when compressor is operating, per150.0(h)8.
      - capacity variation with third-party thermostats, per 150.0(h)10:
        - manufacturer provided instructions for proper configuration.
        - space conditioning system and thermostat configured to provide a varying capacity.
  - I. Installed Heat Pump System – Efficiency and Performance Compliance Information
    - Remove capacity information, and refer to new CF2R-MCH with System Selection and Sizing informaion
  - N. HERS Verification Requirements for Space Conditioning Equipment
    - MCH-TBD Configuration of Space Conditioning System Controls, per 150.0(h)9.
- New CF2R-MCH-TBD: describing verification of Configuration of Space Conditioning System Controls
- New CF3R-MCH-TBD: describing verification of Configuration of Space Conditioning System Controls

- Modifications to CF2R-MCH-25c-Refrigerant Charge Verification – Weigh-In Observation Procedure:
    - Add additional fields to document weigh-in parameters.
    - Reflect exception to RA3.2.3.2 that vacuum verification is not required with better fittings.
- Modifications to CF3R-MCH-25c-Refrigerant Charge Verification – Weigh-In Observation:
    - Reflect exception to RA3.2.3.2 that vacuum documentation is not required with better fittings.
- New CF2R-MCH-25g-Refrigerant Charge Verification – Weigh-In Remote Verification Procedure:
    - Same as CF2R-MCH-25c-Refrigerant Charge Verification – Weigh-In Observation Procedure, except add description of documentation to be submitted.
- New CF3R-MCH-25g-Refrigerant Charge Verification – Weigh-In Remote Verification:
    - Same as CF3R-MCH-25c-Refrigerant Charge Verification – Weigh-In Observation, except add description of documentation submitted.
- Eliminate CF3R-MCH-25d Refrigerant Charge Verification - FID

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8.6 Residential Compliance Manual

4.2 HEATING EQUIPMENT

4.2.1 Mandatory Measures for Heating Equipment

4.2.1.3 Equipment Sizing

The Energy Standards ~~do not set limits on the sizing of heating equipment, but they do~~ require that heating loads be calculated for new heating systems, and that load calculations must be submitted along with the Certificate of Compliance for approval by the enforcement agency, including: design city, indoor and outdoor design temperatures, winter heating loads for each zone/system, Sensible and latent summer cooling loads for each zone/system, load calculation software name and version. If load calculations use custom calculations based on the resources above, the report must also show all detailed algorithms, inputs and outputs.

Oversized equipment typically operates less efficiently and can create comfort problems due to excessive cycling and improper airflow.

Acceptable load calculation procedures include methods described in the following publications:

1. *The ASHRAE Handbook – Equipment*
2. *The ASHRAE Handbook – Applications*

3. The ASHRAE Handbook – Fundamentals

4. The SMACNA Residential Comfort System Installation Manual

5. ACCA Manual J

The Energy Standards require that the outdoor design conditions for load calculations be selected from Reference Joint Appendix JA2 and that the indoor design temperature for heating load calculations be 68°F.

The outdoor design temperature must be no lower than the 99.0 percent Heating Dry Bulb "heating winter median of extremes," as listed in the Reference Joint 150.0(k).

If the actual city location for a project is not included in Reference Joint 150.0(k), or if the data given for a particular city do not match the conditions at the actual site as well as that given for another nearby city, consult the local building department for guidance.

The load calculations must be submitted with the compliance documentation when requested by the building department.

The load calculations may be prepared by 1) a mechanical engineer, 2) the mechanical contractor who is installing the equipment or 3) someone who is qualified to do so in the State of California according to Division 3 of the Business and Professions Code.

The Business and Professions Code does not prohibit an unlicensed person from preparing plans, drawings, or specifications for single family dwelling units of wood-frame construction not more than two stories and basement in height, or for certain buildings containing no more than four dwelling units of wood-frame construction not more than two stories and basement in height. However, licensure is required for apartment or condominium complexes.

The Energy Standards also state that heating system capacity must be within the following limits:

A. **Minimum**: Heating systems are required to have a heating capacity adequate to meet the minimum requirements of the CBC. Section 150.0(h)1v clarifies that for heat pumps, this refers to the capacity of the heat pump itself, not including any supplementary heating provided.

B. **Maximum**: The maximum heating capacity depends on the relative sizes of the calculated heating and cooling design loads, and on the type of system and duct sizing.
   1. For new construction, or for existing buildings where airflow will be field verified to be at least 350 cfm/ton: No maximum.
   2. For existing buildings where airflow will NOT be field verified to be at least 350 cfm/ton: Heating capacity shall be no larger than indicated in Table TBD1.

Table TBD1: Maximum Heating Capacity (HL = Design Heating Load; CL = Design Total Cooling Load)

System Type	**Maximum Heatng Capacity for Heating Only Systems**	**Maximum Heating Capacity for Heat Pumps when CL minus HL is:**		
		< 0	**0 – 12 kBtuh**	**> 12 kBtuh**
Single Speed System—Capacity	HL + 6 kBtuh	No maximum	HL + 12 kBtuh	No maximum
Variable or Multi Speed System—Maximum Capacity	HL + 6 kBtuh	No maximum	HL + 12 kBtuh	No maximum

Variable or Multi Speed System—Capacity at Lowest Speed	80% of HL	80% of HL	No maximum	No maximum

4.3 COOLING EQUIPMENT

4.3.1 Mandatory Measures for Cooling Equipment

4.3.1.4 Equipment Sizing

Similar to heating equipment, the Energy Standards do not set limits on the size of cooling equipment, but they do require that cooling loads be calculated for new cooling systems, and that load calculations must be submitted along with the Certificate of Compliance for approval by the enforcement agency, including: design city, indoor and outdoor design temperatures, winter heating loads for each zone/system, Sensible and latent summer cooling loads for each zone/system, load calculation software name and version. If load calculations use custom calculations based on the resources above, the report must also show all detailed algorithms, inputs and outputs.

Avoid oversizing the cooling components since oversizing may adversely affect the efficiency of the system. Ducts must be sized correctly, otherwise the system airflow rate may be restricted, adversely affecting the efficiency of the system and preventing the system from meeting the mandatory minimum airflow rate requirements.

The outdoor design conditions for load calculations must be selected from Reference Joint Appendix JA2, Table 2-3, using values no greater than the “1.0 percent cooling dry bulb” and “mean coincident wet bulb” values listed. The indoor design temperature for cooling load calculations must be 75°F. Acceptable load calculation procedures include methods described in:

1. *The ASHRAE Handbook – Equipment*
2. *The ASHRAE Handbook – Applications*
3. *The ASHRAE Handbook – Fundamentals*
4. The SMACNA Residential Comfort System Installation Manual.
5. *ACCA Manual J*

Cooling load calculations must be submitted with compliance documentation when requested by the building department. The load calculations may be prepared by 1) a mechanical engineer, 2) the mechanical contractor who is installing the equipment or 3) someone who is qualified to do so in the State of California according to Division 3 of the Business and Professions Code.

The Energy Standards also state that cooling system capacity must be within the following limits:

A. **Minimum**: No minimum.
B. **Maximum**: The maximum total cooling capacity depends on the relative sizes of the calculated heating and cooling design loads, and on the type of system and duct sizing.
   1. For new construction, or for existing buildings where airflow will be field verified to be at least 350 cfm/ton: No maximum.

3. For existing buildings where airflow will NOT be field verified to be at least 350 cfm/ton Heating capacity shall be no larger than indicated in Table TBD2.

Table TBD2: Maximum Cooling Capacity (HL = Design Heating Load; CL = Design Total Cooling Load)

System Type	**Maximum Cooling Capacity for Cooling Only Systems**	**Maximum Cooling Capacity for Heat Pumps when CL minus HL is:**		
		< 0	**0 – 12 kBtuh**	**> 12 kBtuh**
Single Speed System—Capacity	CL + 6 kBtuh	No maximum	CL + 6 kBtuh	CL + 6 kBtuh
Variable or Multi Speed System—Maximum Capacity	CL + 6 kBtuh	No maximum	CL + 6 kBtuh	CL + 6 kBtuh
Variable or Multi Speed System—Capacity at Lowest Speed	80% of CL	No maximum	80% of CL	80% of CL

To be added:

- Provide specific requirements for submitting authorized load calculation inputs and/or outputs in the permit application package.
- Describe the simplifying assumptions that are allowed to the authorized load calculation inputs in some cases.
- Describe requirement to assume only “average” envelope leakage.
- Clarify that load calculations are now required even for like-for-like replacements.
- Clarify that room-by-room loads are not required.
- Provide the specific requirements for including at least schematic diagrams and room-by-room duct and diffuser information, except when ducts are not replace or modified.
- Describe the requirement to lockout supplementary heating on heat pumps, including obtaining instructions from manufacturer and configuring controls.
- Describe requirements to confirm that variable and multispeed systems installed with third-party thermostats must be configured correctly, including obtaining instructions from manufacturers an configuring controls.
- Describe the requirements for the defrost delay timer, including obtaining instructions from manufacturer and configuring controls.

- Describe what manufacturer documentation can be used to ascertain whether CCH mandatory requirement that the CCH is off when compressor is on are met
- Describe prescriptive options and how to provide the necessary information.
- Describe the new procedure for remote verification of weigh-in.
- Describe new exceptions from RCV requirements.
- Add a discussion of VCMS and duct losses to the Residential Compliance Manual.

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Appendix A: Statewide Savings Methodology

The Statewide CASE Team estimated statewide impacts for the first year by multiplying per unit savings estimates by statewide construction forecasts that the CEC provided (California Energy Commission 2022). The CEC provided the construction estimates on March 27, 2023.

The Statewide CASE Team followed guidance provided in the CEC's New Measure Proposal Template (developed by the Energy Commission) to calculate statewide energy savings using the CEC's construction forecasts and assuming statewide weighting of 2 percent for the 500 square foot prototype, 42 percent for the 2,100 square foot prototype, and 56 percent for the 2,700 square foot prototype. In Sections 4 and 5 results are presented for a weighted average of the 2,100 square foot and 2,700 square foot new construction prototypes since results for each of these two prototypes individually are similar. With the exclusion of the 500 square foot prototype, savings results are weighted 43 percent for the 2100 square foot prototype and 57 percent for the 2700 square foot prototype (Section 4.2 of the CEC's New Measure Proposal Template).

The Statewide CASE Team did not make any changes to the CEC's construction estimates.

The Statewide CASE Team estimated statewide impacts for the first year by multiplying per unit savings estimates by the Energy Commission's statewide construction forecasts. The Statewide CASE Team made assumptions about the percentage of buildings in each climate zone that would be impacted by the proposed code change. **Error! Reference source not found.** Table 99 through Table 103 present the number of homes, both newly constructed and existing, that the Statewide CASE Team assumed will be impacted by each of the proposed code changes during the first year the 2025 code is in effect.

It is anticipated that the incremental costs for space conditioning heat pumps may fall over time as heat pump production volumes increase with increasing building electrification trends in California as well as the rest of the United States. Indications from an HVAC contractor surveyed as part of this CASE Report suggest that 2023 is shaping up to be somewhat of a transition as they had recently seen space conditioning heat pumps to be about 10 percent of their production home installations but expect to see that to increase to 25 percent by the end of 2023. Taking this into account and assuming that the CEC will be successful in establishing heat pumps as the prescriptive baseline for single family homes, it is projected that 90 percent of newly constructed homes will have heat pumps by 2026.

For new construction the design measure will impact 100 percent of all new homes in all climate zones. The supplementary heating, defrost, CCH, and refrigerant charge measures only apply to heat pumps and thus are estimated to impact 90 percent of new homes in the applicable climate zones and building types for each measure. For the cases where the proposal doesn’t apply to small homes 500 square feet and less the measure impact is reduced by 2 percent and will cover 98 percent of new homes for the measures that impact all HVAC systems or 88.2 percent of homes for the measures that impact heat pumps only. For the prescriptive measures, even if a project does not meet the new prescriptive performance requirements, they will need to trade this off in the performance approach with another energy efficiency measure that would provide the same level of savings.

For existing buildings, the impacted HVAC systems are assumed to have a lifetime of 15 years and therefore 6.7 percent of homes install replacement systems annually. The Residential Appliance Saturation Survey (RASS) data (DNV 2022) was used to estimate the number of homes that will install a central split ducted heat pump versus a gas furnace and air conditioner. The 2019 RASS survey indicated that 4 percent of single family homes have a primary central heat pump. This figure was 2 percent in both the 2003 and 2009 RASS surveys. Assuming that California achieves its goal of carbon neutrality by 2045, by that time all homes are expected to have heat pumps. Using these four datapoints an exponential trend curve was developed which estimated that in 2026 12.62 percent of homes will have a heat pump. Appling the 15 year replacement rate to this percentage results in 0.8 percent of homes that will install replacement heat pumps annually in 2026.

Table 99: Estimated New Construction and Existing Building Stock for Single Family Buildings by Climate Zone – Design

Building Climate Zone	Total Homes Completed in 2026 (New Construction) [A]	Percent of New Buildings Impacted by Proposal [B]	New Buildings Impacted by Proposal in 2026 C = A x B	Total Existing Homes in 2026 [D]	Percent of Existing Buildings Impacted by Proposal [E]	Buildings Impacted by Proposal in 2026 F = D x E
1	359	90%	323	44,875	0.80%	359
2	1,861	0%	0	265,807	7%	17729
3	3,035	0%	0	972,513	7%	64867
4	2,689	0%	0	497,321	7%	33171
5	616	0%	0	97,271	7%	6488
6	1,719	0%	0	594,544	7%	39656
7	1,869	0%	0	494,355	7%	32973
8	4,163	0%	0	926,278	7%	61783
9	4,286	0%	0	1,250,479	7%	83407
10	7,950	0%	0	1,067,399	7%	71196
11	5,840	0%	0	335,468	7%	22376
12	14,542	0%	0	1,318,779	7%	87963
13	7,257	0%	0	634,709	7%	42335
14	3,739	0%	0	247,852	7%	16532
15	3,160	0%	0	177,670	7%	11851
16	1,937	90%	1743	97,937	0.80%	783
TOTAL	**65,022**	**-**	**2,066**	**9,023,257**	**-**	**593,468**

Source: (California Energy Commission 2022)

Table 100: Estimated New Construction and Existing Building Stock for Single Family Buildings by Climate Zone – Supplemental Heating

Building Climate Zone	Total Homes Completed in 2026 (New Construction) [A]	Percent of New Buildings Impacted by Proposal [B]	New Buildings Impacted by Proposal in 2026 C = A x B	Total Existing Homes in 2026 [D]	Percent of Existing Buildings Impacted by Proposal [E]	Buildings Impacted by Proposal in 2026 F = D x E
1	359	88%	317	44,875	0.80%	359
2	1,861	88%	1641	265,807	0.80%	2126
3	3,035	88%	2677	972,513	0.80%	7780
4	2,689	88%	2372	497,321	0.80%	3979
5	616	88%	543	97,271	0.80%	778
6	1,719	88%	1516	594,544	0.80%	4756
7	1,869	88%	1648	494,355	0.80%	3955
8	4,163	88%	3672	926,278	0.80%	7410
9	4,286	88%	3780	1,250,479	0.80%	10004
10	7,950	88%	7012	1,067,399	0.80%	8539
11	5,840	88%	5151	335,468	0.80%	2684
12	14,542	88%	12826	1,318,779	0.80%	10550
13	7,257	88%	6401	634,709	0.80%	5078
14	3,739	88%	3298	247,852	0.80%	1983
15	3,160	0%	0	177,670	0.00%	0
16	1,937	88%	1708	97,937	0.80%	783
TOTAL	**65,022**	**-**	**54,562**	**9,023,257**	**-**	**70,765**

Source: (California Energy Commission 2022)

Table 101: Estimated New Construction and Existing Building Stock for Single Family Buildings by Climate Zone – Defrost

Building Climate Zone	Total Homes Completed in 2026 (New Construction) [A]	Percent of New Buildings Impacted by Proposal [B]	New Buildings Impacted by Proposal in 2026 C = A x B	Total Existing Homes in 2026 [D]	Percent of Existing Buildings Impacted by Proposal [E]	Buildings Impacted by Proposal in 2026 F = D x E
1	359	90%	323	44,875	0.8%	359
2	1,861	90%	1675	265,807	0.8%	2,126
3	3,035	90%	2732	972,513	0.8%	7,780
4	2,689	90%	2420	497,321	0.8%	3,979
5	616	88%	543	97,271	0.8%	778
6	1,719	88%	1516	594,544	0.8%	4,756
7	1,869	88%	1648	494,355	0.8%	3,955
8	4,163	88%	3672	926,278	0.8%	7,410
9	4,286	88%	3780	1,250,479	0.8%	10,004
10	7,950	88%	7012	1,067,399	0.8%	8,539
11	5,840	90%	5256	335,468	0.8%	2,684
12	14,542	90%	13088	1,318,779	0.8%	10,550
13	7,257	90%	6531	634,709	0.8%	5,078
14	3,739	90%	3365	247,852	0.8%	1,983
15	3,160	88%	2787	177,670	0.8%	1,421
16	1,937	90%	1743	97,937	0.8%	783
TOTAL	**65,022**	**-**	**58,092**	**9,023,257**	**-**	**72,186**

Source: (California Energy Commission 2022)

Table 102: Estimated New Construction and Existing Building Stock for Single Family Buildings by Climate Zone – Crankcase Heating Mandatory

Building Climate Zone	Total Homes Completed in 2026 (New Construction) [A]	Percent of New Buildings Impacted by Proposal [B]	New Buildings Impacted by Proposal in 2026 C = A x B	Total Existing Homes in 2026 [D]	Percent of Existing Buildings Impacted by Proposal [E]	Buildings Impacted by Proposal in 2026 F = D x E
1	359	7%	25	44,875	1.51%	678
2	1,861	7%	130	265,807	1.51%	4014
3	3,035	7%	212	972,513	1.51%	14685
4	2,689	7%	188	497,321	1.51%	7510
5	616	7%	43	97,271	1.51%	1469
6	1,719	7%	120	594,544	1.51%	8978
7	1,869	7%	131	494,355	1.51%	7465
8	4,163	7%	291	926,278	1.51%	13987
9	4,286	7%	300	1,250,479	1.51%	18882
10	7,950	7%	557	1,067,399	1.51%	16118
11	5,840	7%	409	335,468	1.51%	5066
12	14,542	7%	1018	1,318,779	1.51%	19914
13	7,257	7%	508	634,709	1.51%	9584
14	3,739	7%	262	247,852	1.51%	3743
15	3,160	7%	221	177,670	1.51%	2683
16	1,937	7%	136	97,937	1.51%	1479
TOTAL	**65,022**	**-**	**4,552**	**9,023,257**	**-**	**136,251**

Source: (California Energy Commission 2022)

Table 103: Estimated New Construction and Existing Building Stock for Single Family Buildings by Climate Zone – Crankcase Heating Prescriptive

Building Climate Zone	Total Homes Completed in 2026 (New Construction) [A]	Percent of New Buildings Impacted by Proposal [B]	New Buildings Impacted by Proposal in 2026 C = A x B	Total Existing Homes in 2026 [D]	Percent of Existing Buildings Impacted by Proposal [E]	Buildings Impacted by Proposal in 2026 F = D x E
1	359	50%	180	44,875	3.35%	1503
2	1,861	50%	931	265,807	3.35%	8905
3	3,035	50%	1518	972,513	3.35%	32579
4	2,689	50%	1345	497,321	3.35%	16660
5	616	50%	308	97,271	3.35%	3259
6	1,719	50%	860	594,544	3.35%	19917
7	1,869	50%	935	494,355	3.35%	16561
8	4,163	50%	2082	926,278	3.35%	31030
9	4,286	50%	2143	1,250,479	3.35%	41891
10	7,950	50%	3975	1,067,399	3.35%	35758
11	5,840	50%	2920	335,468	3.35%	11238
12	14,542	50%	7271	1,318,779	3.35%	44179
13	7,257	50%	3629	634,709	3.35%	21263
14	3,739	50%	1870	247,852	3.35%	8303
15	3,160	50%	1580	177,670	3.35%	5952
16	1,937	50%	969	97,937	3.35%	3281
TOTAL	**65,022**	**-**	**32,511**	**9,023,257**	**-**	**302,279**

Source: (California Energy Commission 2022)

Table 104: Estimated New Construction and Existing Building Stock for Single Family Buildings by Climate Zone – Refrigerant Charge

Building Climate Zone	Total Homes Completed in 2026 (New Construction) [A]	Percent of New Buildings Impacted by Proposal [B]	New Buildings Impacted by Proposal in 2026 C = A x B	Total Existing Homes in 2026 [D]	Percent of Existing Buildings Impacted by Proposal [E]	Buildings Impacted by Proposal in 2026 F = D x E
1	359	88.2%	317	44,875	0.8%	359
2	1,861	0%	0	265,807	0%	0
3	3,035	88.2%	2,677	972,513	0.8%	7,780
4	2,689	88.2%	2,372	497,321	0.8%	3,979
5	616	88.2%	543	97,271	0.8%	778
6	1,719	0%	0	594,544	0.8%	4,756
7	1,869	0%	0	494,355	0.8%	3,955
8	4,163	0%	0	926,278	0%	0
9	4,286	0%	0	1,250,479	0%	0
10	7,950	0%	0	1,067,399	0%	0
11	5,840	0%	0	335,468	0%	0
12	14,542	0%	0	1,318,779	0%	0
13	7,257	0%	0	634,709	0%	0
14	3,739	0%	0	247,852	0%	0
15	3,160	0%	0	177,670	0%	0
16	1,937	88.2%	1,708	97,937	0%	783
TOTAL	**65,022**	**-**	**7,617**	**9,023,257**	**-**	**22,391**

Source: (California Energy Commission 2022)

Appendix B: Embedded Electricity in Water Methodology

There are no on-site water savings associated with the proposed code change.

Appendix C: California Building Energy Code Compliance (CBECC) Software Specification

Introduction

The purpose of this appendix is to present proposed revisions to CBECC for residential buildings (CBECC-Res) along with the supporting documentation that the CEC staff and the technical support contractors would need to approve and implement the software revisions. While this Appendix describes changes to CBECC-Res for single family buildings, similar updates would also apply to CBECC for multifamily buildings.

Technical Basis for Software Change

The proposed code changes would need to be incorporated into the software to accommodate updates to the Standard Design to match new mandatory and prescriptive requirements, incorporate software checks for mandatory requirements, and implement a new approach to reporting in the CF1R pertaining to design documentation for load calculations and system sizing, documentation of field verified supplementary heating lockout controls, defrost timer adjustment, and CCH control.

Description of Software Change

Background Information for Software Change

The proposed code change revises the mandatory and prescriptive CCH requirements, the mandatory supplementary heating requirements, the mandatory heat pump defrost requirements, and the prescriptive refrigerant charge requirements. The changes are summarized below.

- HVAC systems in all new construction, additions, and alterations projects will have a mandatory requirement to provide documentation and details of load calculations, system sizing, and duct/diffuser design. Minimum and maximum sizing limits will also be imposed to ensure adequate airflow.
- HVAC systems in all additions and alterations projects will have a mandatory requirement to use average infiltration assumptions (or blower door test) and allow simplifying assumptions in some authorized load calculations.
- For heat pumps in all climate zones except Climate Zone 15, a mandatory requirement will necessitate the installation and field verification of controls that lock out supplementary heating above a certain climate zone dependent outdoor temperature. Mandatory maximum strip heating capacity limits will also be

required. These mandatory requirements are not applicable to small homes 500 square feet and less.

- A mandatory requirement will necessitate that the defrost timer be set optimally for heat pumps in all climate zones. The requirement is not applicable to small homes 500 square feet and less in Climate Zones 5-10 and 15.
- Heat pumps and AC units in all climate zones will have a mandatory requirement that disallows the CCH to run during compressor operation.
- Heat pumps and AC units in all climate zones are prescriptively required to have CCH that does not operate when the outdoor dry bulb temperature is over 55°F.
- Prescriptive refrigerant charge verification is added for heat pumps in Climate Zones 1, 3-5, and 16 for new construction and Climates Zones 1, 3-7, and 16 for alterations. This requirement does not apply to small homes 500 square feet and less.

Existing CBECC-Res Building Energy Modeling Capabilities

- Design:
    - Currently CBECC-Res autosizes all air conditioners and furnaces using a sizing factor of 1.2 and 2.0, respectively. CBECC-Res autosizes heat pumps for the Standard Design using a sizing factor of 1.2 for cooling and 0.75 for heating. Heat pump capacity is determined based on the large of the calculated heating and cooling loads, after the factors are applied. In the Proposed Design users are required to input heat pump heating capacity at 47°F and 17°F.
- Supplementary Heating:
    - Currently CBECC-Res does not have a limit on strip supplementary heating size or temperature dependent operation. The software assumes that any heating load not met by the primary heat pump system is met using supplementary heat.
- Defrost:
    - Currently CBECC-Res incorporates defrost operation between outdoor air temperatures of 17°F and 45°F. It assumes a 10 percent reduction to heat pump capacity and 2.5 percent reduction to heat pump power at 35°F. During defrost period (17°F to 45°F) capacity & power are calculated based on the slope between the rated values at 17°F and the discounted values at 35°F. The software accounts for the degraded capacity by adding supplemental electric resistance heating.
- Crankcase Heating:

- Currently CBECC-Res models CCH by applying a parasitic load to the HVAC system of 33 Watts for systems under 3 tons and 11 Watts per ton for systems over 3 tons when the outdoor dry bulb temperature is below 50 °F and the compressor is not operating. This was updated in the software in early 2023.
- Refrigerant Charge Verification
  - Currently CBECC-Res implements the prescriptive requirements for refrigerant charge verification in Climate Zones 2 and 8-15. The software accounts for this by applying a performance factor to cooling efficiency that changes based on refrigerant charge verification. If a system's refrigerant charge has been verified, the performance factor is set to 96 percent, meaning the system will operate at 96 percent of its rated efficiency. Systems without refrigerant charge verification have a lower performance factor of 90 percent. The software does not account for changes to the heating performance based on refrigerant charge in the way that it does for cooling performance.

Summary of Proposed Revisions to CBECC-Res

The following changes would apply to CBECC-Res, California Simulation Engine, and both the Standard and Proposed Design:

- Design:
  - The software would be updated to apply a 1.1 sizing factor for heating and cooling for heat pumps and air conditioners. All systems would be autosized for both the Standard Design and Proposed Design. Furnaces would maintain the current 2.0 sizing factor.
- Supplementary Heating:
  - The software would be updated to reflect the mandatory requirement that supplemental heating does not occur above the maximum of either 25°F or the heating design temperature, depending on climate zone. This would not apply to homes in Climate Zone 15 and small homes 500 square feet and less in any climate zone.
- Defrost:
  - The CBECC-Res software team is currently updating the way that the software models heat pump defrost with the goal of incorporating the new defrost model into the software before 2025. The Statewide CASE Team will work with the software team to ensure that savings from optimal defrost timer adjustments are accounted for in the new model.
- Crankcase Heating:

- The Standard Design would be updated to turn off the CCH above 55°F instead of the current threshold of 50°F.
- The Proposed Design would be updated to allow the user to indicate if the prescriptive control capability is present that turns off the CCH when the outdoor dry bulb temperature is over 55°F.
- Both the Standard Design and the Proposed Design CCH sizing would be updated for air conditioners. For heat pumps the crankcase heater capacity would remain at 33 W for systems with a capacity under 3 tons and 11 W/ton for systems with a capacity 3 tons or larger. For air conditioners the CCH capacity would be reduced to 30 W for systems with a capacity under 3 tons and 10 W/ton for systems with a capacity 3 tons or larger.

- Refrigerant Charge Verification
  - The software would be updated to reflect the prescriptive requirement that charge verification will be added in Climate Zones 1, 3-5, and 16 for heat pumps in new construction except for single family homes 500 square feet and less. Refrigerant charge verification would become prescriptive for alterations in Climate Zones 1, 3-7 and 16. Refrigerant charge would continue to be prescriptive in Climate Zones 2 and 8-16 for all size homes and both air conditioners and heat pumps.
  - The software would be updated to reflect a heating performance factor of 92 percent for heat pumps without charge verification and a heating performance factor of 96 percent for heat pumps with charge verification. These factors would be applied to the heat pump coefficient of performance calculated based on the rated HSPF.

User Inputs to CBECC-Res

The software would add or revise the following inputs to integrate the mandatory and prescriptive requirements proposed in this report:

- Design
  - The user input for heat pump heating capacity at 47°F and 17°F would be removed and all systems would be autosized within the software.
- Crankcase Heating:
  - A checkbox would be added that allows the user to indicate whether the CCH of any heat pump or air conditioner includes a control to turn off operation when the outdoor dry bulb temperature is over 55°F.

Simulation Engine Inputs

California Simulation Engine Inputs

California Simulation Engine's "RSYS" object would be changed in the following ways in order to accommodate the measures proposed in this CASE Report. This sections provides additional detail to augment the descriptions in the Summary of Proposed Revisions to CBECC-Res above.

- Crankcase Heating:
  - To accommodate the mandatory requirement that the CCH does not turn on during compressor operation, the default "rsParElec" input should be defined in the following ways:
    - For heat pumps with a capacity greater than 3 tons*:*

      *rsParElec = (1.-@RSYSRes[%c%s%c].prior.H.hrsOn) * @RSYS[%c%s%c].capNomC * 11./12000*
    - For air conditioners with a capacity greater than 3 tons*:*

      *rsParElec = (1.-@RSYSRes[%c%s%c].prior.H.hrsOn) * @RSYS[%c%s%c].capNomC * 10./12000*
    - For heat pumps with a capacity less than 3 tons*:*

      *rsParElec = (1.-@RSYSRes[%c%s%c].prior.H.hrsOn) * 33*
    - For air conditioners with a capacity less than 3 tons*:*

      *rsParElec = (1.-@RSYSRes[%c%s%c].prior.H.hrsOn) * 30*
  - To accommodate the prescriptive requirement that the CCH does not turn on when the outdoor dry bulb temperature is above 55°F, the "rsParElec" input should be defined in the following way:

    *rsParElec = ($tdboHrAv < 55.) * (1.-@RSYSRes[%c%s%c].prior.H.hrsOn) * [Watts of CCH]*

    Note that the part of the equation that incorporates the outdoor dry bulb temperature should only be used by CSE if the user indicates that a heat pump's CCH has temperature control capability.
- Refrigerant Charge Verification:
  - An input similar to the "rsFChg" object would be added to model the impact of refrigerant charge on heat pump heating efficiency. This factor would be multiplied by the coefficient of performance at 47°F and 17°F which is calculated within CSE from the user-entered rated HSPF value. The new refrigerant charge heating factor would be 0.92 if refrigerant charge verification is not performed and 0.96 if refrigerant charge verification is performed.

Simulation Engine Output Variables

The following output variables will be reviewed to confirm that the updates have been integrated properly into the software. CSE input files will also reviewed to confirm that inputs align with expectations.

- Compliance rates and annual energy use.
- Hourly primary heating, supplementary heating, and cooling energy use.
- Hourly "Defrost Heat" reported by the "RSys Hourly Out" CSE report.

Compliance Report

The following changes need to be made to the CF-1R-PRF-01E performance compliance report to reflect new requirements proposed by this report. Definitions for terms to be added to the Standards Data Dictionary are under development.

- Design:
    - Heating capacities in HVAC – HEAT PUMPS section should be removed.
    - HERS verification of heating capacity should be removed.
    - The following notes should be added to the report, perhaps in the Required Special Features section.
        - A load calculation report must be submitted with this CF-1R in compliance with Section 10-102(a)2A. The report may be generated from load calculation software or custom calculations may be provided along with documentation of the inputs, outputs, and algorithms used.
        - For projects with a duct system that serves heating or cooling in the Proposed Design:
            - A duct design report must be submitted with this CF-1R in compliance with Section 10-102(a)2B.
- Crankcase Heating
    - The "HVAC HEAT PUMPS" section should add a column indicating whether the prescriptive CCH temperature control is included.

Compliance Verification

See Appendix E for details on compliance verification for the proposed measures in this CASE Report.

Testing and Confirming CBECC-Res Building Energy Modeling

The testing plan for the measures proposed in this report is still under development and will be provided in the Final CASE Report.

Description of Changes to ACM Reference Manual

See Section 8.4 for proposed markup of the ACM Reference Manual.

Appendix D: Environmental Analysis

Potential Significant Environmental Effect of Proposal

The CEC is the lead agency under the California Environmental Quality Act (CEQA) for the 2025 Energy Code and must evaluate any potential significant environmental effects resulting from the proposed standards. A "significant effect on the environment" is "a substantial adverse change in the physical conditions which exist in the area affected by the proposed project." (Cal. Code Regs., tit. 14, § 15002(g).)

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

Direct Environmental Impacts

Direct Environmental Benefits

Direct environmental benefits from this proposal are energy savings, peak demand savings, and GHG emission reductions.

Direct Adverse Environmental Impacts

There are no direct adverse environmental impacts from the code change proposals.

Indirect Environmental Impacts

Indirect Environmental Benefits

There are no indirect environmental benefits from the code change proposals.

Direct Adverse Environmental Impacts

There are no direct adverse environmental impacts from the code change proposals.

Mitigation Measures

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

Reasonable Alternatives to Proposal

If an EIR is developed, CEQA requires a lead agency to evaluate reasonable alternatives to proposals that would have a significant adverse effect on the environment, including a “no project” alternative. (Cal. Code Regs. Tit. 14, §§ 15002(h)(4) and 15126.6.)

The Statewide CASE Team has considered alternatives to the proposal and believes that no alternative achieves the purpose of the proposal with less environmental effect.

Water Use and Water Quality Impacts Methodology

The proposed code change produces no impacts to water quality or water use.

Embodied Carbon in Materials

Accounting for embodied carbon emissions is important for understanding the full picture of a proposed code change’s environmental impacts. The embodied carbon in materials analysis accounts specifically for emissions produced during the “cradle-to-gate” phase: emissions produced from material extraction, manufacturing, and transportation. Understanding these emissions ensures the proposed measure considers these early stages of materials production and manufacturing instead of emissions reductions from energy efficiency alone.

The Statewide CASE Team determined there were no material impacts for the proposed measures and therefore did not calculate emissions impacts associated with embodied carbon from a change in materials.

Appendix E: Discussion of Impacts of Compliance Process on Market Actors

This appendix discusses how the recommended compliance process, which is described in Section 2.5 could impact various market actors. Table 105 identifies the market actors who will play a role in complying with the proposed change, the tasks for which they are responsible, how the proposed code change could impact their existing workflow, and ways negative impacts could be mitigated. The information contained in Table 105 is a summary of key feedback the Statewide CASE Team received when speaking to market actors about the compliance implications of the proposed code changes. Appendix F summarizes the stakeholder engagement that the Statewide CASE Team conducted when developing and refining the code change proposal, including gathering information on the compliance process.

Residential HVAC design (ACCA Manual J, S and D, or equivalent) is already required by the energy code, the green code and the mechanical code, but it has been poorly enforced, partly due to lack of consistent documentation requirements and a lack of understanding on the part of building departments in terms of what to ask for and how to plan check it. For new construction tract homes and larger commercial homes, where there is a budget to hire an independent consultant (e.g., mechanical engineer) to design the HVAC system it is more common for a building department to require submittal of mechanical plans, but plan checking usually only addresses specific mechanical code issues such as venting, combustion air, gas piping, clearances, accessibility, etc. Rarely do plan checkers know how to check load calculations, equipment selection and duct designs.

This measure is intended to clarify and formalize the compliance submittal requirements as well as the equipment sizing criteria. It will also add some new requirements for load calculations and sizing requirements for alterations (basic equipment changeouts) to take advantage of downsizing possibilities and to ensure comfort and efficiency, and thus homeowner satisfaction, of electrification efforts (replacing gas furnaces with heat pump systems).

On projects that don't have independent designers each contractor bidding on a project must do a basic design to determine the cost of a system. Because the odds of winning each bid is low, this is very expensive duplicative effort and incurs a cost on all contractors. This has led to shortcuts and rules of thumb, rather than proper designs. Formalizing the process and improving enforcement of the design requirements will add to this cost burden, however, using independent consultants, hired by the homeowner, can greatly reduce this cost burden and have other positive impacts as well. Facilitating and supporting a robust network of independent consultants doing at least part of the

HVAC design process (e.g., load calculations) will reduce the duplicated efforts by multiple contractors bidding on the same project, ensure consistency of sizing and bids, ensure that load calculations are actually done by a qualified individual. Note: load calculations require no more expertise than performing computer performance energy compliance simulations. Energy consultants are ideally suited for this work. They have more experience with this type of data input and computer software than most HVAC contractors. The vast majority of the information needed to run a computer performance model is exactly the same as what is needed for a load calculation.

Overall, the workflow process will be changed very little by this measure. The biggest change will come from the improved enforcement of the requirements adding additional workload on the market actors who are not currently meeting the requirements.

Table 105 identifies the market actors who will play a role in complying with the proposed change, the tasks for which they will be responsible, their objectives in completing the tasks, how the proposed code change could impact their existing workflow, and ways negative impacts could be mitigated.

Table 105: Roles of Market Actors in the Proposed Compliance Process

Market Actor	Task(s) in current compliance process relating to the CASE measure	How will the proposed measure impact the current task(s) or workflow?	How will the proposed code change impact compliance and enforcement?	Opportunities to minimize negative impacts of compliance requirement
HVAC Designer	*Much of this measure is already required by code but is poorly enforced. These requirements are mostly being clarified and formalized by this measure along with some new requirements.* • Note: For new construction production homes and some custom homes: the HVAC designer is often an independent consultant (e.g., mechanical engineer) • Note: For alterations to existing HVAC systems, smaller additions and some custom homes: The HVAC designer is usually the installing contractor (design/build). • Residential HVAC design involves four basic steps: 1. Collect information about the house (geometry) and energy features (insulation, levels, leakage rate, window types, etc.) 2. Perform room-by-room load calculations if duct system is also being designed otherwise only a simple block load is needed. 3. Select equipment such that the design capacity is appropriate to the home's heating and cooling loads. 4. Design the duct system if new or being replaced. For simple changeouts, this is rarely done. • The design is submitted to the building department as part of the permit application process. This is currently required for newly installed systems, but very poorly enforced due to lack of training and building departments not knowing what to ask for or how to plan check the designs.	• The overall workflow process will not change dramatically. It will be clarified, formalized and better enforced. • Increased enforcement of this measure will increase the workload on HVAC designers who are not currently meeting the requirements. • Clarification of the existing code requirements and documentation will make the process easier and more consistent between projects. • Requiring load calculations for simple changeouts, even with "simplifying assumptions" will increase the workload and add cost to the HVAC designers.	• Currently, there are no formalized documentation requirements for residential HVAC designs. The requirements, when enforced, vary from jurisdiction to jurisdiction, making compliance difficult. • This measure will clarify the documentation requirements for residential HVAC design submittals. • This measure will clarify and formalize the equipment selection process and sizing criteria for residential HVAC systems. • Some additional compliance documents will need to be learned and processed by HVAC designers.	• Training on the HVAC design process will help increase compliance with the current HVAC design requirements and the new requirements required by this measure. • There is already extensive training provided by utilities and other entities on residential HVAC design process. • Facilitating and supporting a robust network of independent consultants doing at least part of the HVAC design process will reduce the duplicated efforts by multiple contractors bidding on the same project

Market Actor	Task(s) in current compliance process relating to the CASE measure	How will the proposed measure impact the current task(s) or workflow?	How will the proposed code change impact compliance and enforcement?	Opportunities to minimize negative impacts of compliance requirement
Plans Examiner	• The plans examiner is responsible for reviewing the HVAC design during the permitting process. • They collect the required documentation and specifications, review them for accuracy and completeness.	Increased enforcement of this measure will increase the workload on plan checkers who are not currently enforcing the requirements.	Some additional compliance documents will need to be learned by plans examiners	• Training on the HVAC design requirements will help increase enforcement with the current HVAC design requirements and the new requirements required by this measure. • There is already extensive training provided by utilities and other entities on enforcement of the residential HVAC design requirements.
CEC	The CEC develops the energy codes that affect residential HVAC design and provides support and training.	Increased enforcement of this measure will increase the amount of questions that arise on this topic and the amount of training that is required.	Some additional compliance documents will need to be developed by the CEC and handled by the HERS registries.	• Training on the HVAC design requirements will help increase enforcement with the current HVAC design requirements and the new requirements required by this measure. • There is already extensive training provided by utilities and other entities on enforcement of the residential HVAC design requirements.
Plumbing Designer	Independent plumbing designers sometimes design the gas piping for gas heat systems, primarily for new construction, but rarely for alterations.	Increased enforcement of this measure will cause a small increase the workload on plumbing designers in that it might also increase the need for coordination with the HVAC designer	No impact	N/A
Electrical Designer	Independent electrical designers sometimes design the wiring circuits for HVAC systems, primarily for new construction, but rarely for alterations.	Increased enforcement of this measure will cause a small increase in the workload on electrical designers in that it might increase the need for coordination with the HVAC designer	No impact	N/A

Market Actor	Task(s) in current compliance process relating to the CASE measure	How will the proposed measure impact the current task(s) or workflow?	How will the proposed code change impact compliance and enforcement?	Opportunities to minimize negative impacts of compliance requirement
Commissioning Agent	Commissioning agents are rarely involved in residential HVAC design.	No impact	No impact	N/A
Architect	• Architects are loosely involved in the HVAC design for new homes, but rarely for alterations. • They coordinate with the HVAC designer for location of equipment, ducts, access, registers, etc.	Increased enforcement of this measure will cause a small increase the workload on architects in that it might increase the need for coordination with the HVAC designer	Some additional compliance documents will need to be learned and processed by architects.	• Training on the HVAC design process will help increase compliance with the current HVAC design requirements and the new requirements required by this measure. • There is already extensive training provided by utilities and other entities on residential HVAC design process.
Inspector	• The building inspector is responsible for the field verification of the system to meet the applicable codes and to be consistent with the design. • The compare the design to the as-built condition, including equipment specifications, location, duct sizes, register locations, etc.	Increased enforcement of this measure will increase the workload on building inspectors who are not currently enforcing the requirements.	Some additional compliance documents will need to be learned by field inspectors.	• Training on the HVAC design requirements will help increase enforcement of the current HVAC design requirements and the new requirements required by this measure. • There is already extensive training provided by utilities and other entities on enforcement of the residential HVAC design requirements.
HERS	• ATTs are not involved in the single family residential HVAC design process or verification of the design. HERS Raters verify some features that are accounted for in the design process (e.g., duct leakage, airflow, infiltration, etc.) • When performance credit is taken for special duct design criteria, the HERS Rater will verify the overall HVAC design.	Increased enforcement of this measure will cause a small increase the workload on HERS Raters working in jurisdictions that are not currently enforcing the HVAC design requirements in that it might also increase the awareness and enforcement of the HERS verification process.	Some additional compliance documents will need to be developed by the CEC and handled by the HERS registries.	• Training on the HVAC design requirements will help increase enforcement with the current HVAC design requirements and the new requirements required by this measure. • There is already extensive training provided by utilities and other entities on enforcement of the residential HVAC design requirements.

Appendix F: Summary of Stakeholder Engagement

Collaborating with stakeholders that might be impacted by proposed changes is a critical aspect of the Statewide CASE Team's efforts. The Statewide CASE Team aims to work with interested parties to identify and address issues associated with the proposed code changes so that the proposals presented to the CEC in this Draft CASE Report are generally supported. Public stakeholders provide valuable feedback on draft analyses and help identify and address challenges to adoption including: cost effectiveness, market barriers, technical barriers, compliance and enforcement challenges, or potential impacts on human health or the environment. Some stakeholders also provide data that the Statewide CASE Team uses to support analyses.

This appendix summarizes the stakeholder engagement that the Statewide CASE Team conducted when developing and refining the recommendations presented in this report.

Utility-Sponsored Stakeholder Meetings

Utility-sponsored stakeholder meetings provide an opportunity to learn about the Statewide CASE Team's role in the advocacy effort and to hear about specific code change proposals that the Statewide CASE Team is pursuing for the 2025 code cycle. The goal of stakeholder meetings is to solicit input on proposals from stakeholders early enough to ensure the proposals and the supporting analyses are vetted and have as few outstanding issues as possible. To provide transparency in what the Statewide CASE Team is considering for code change proposals, during these meetings the Statewide CASE Team asks for feedback on:

- Proposed code changes
- Draft code language
- Draft assumptions and results for analyses
- Data to support assumptions
- Compliance and enforcement, and
- Technical and market feasibility

The Statewide CASE Team hosted a stakeholder meeting Residential HVAC performance via webinar described in Table 106. Please see below for the dates and link to event pages on Title24Stakeholders.com. Materials from the meeting, such as slide presentations, proposal summaries with code language, and meeting notes, are included in the bibliography section of this report.

Table 106: Utility-Sponsored Stakeholder Meetings

Meeting Name	Meeting Date	Event Page from Title24stakeholders.com
First Round of Residential HVAC Performance Utility-Sponsored Stakeholder Meeting	Tuesday, January 24, 2023	https://title24stakeholders.com/event/residential-hvac-utility-sponsored-stakeholder-meeting/

The utility-sponsored stakeholder was important for providing transparency and a forum for stakeholders to offer feedback on measures being pursued by the Statewide CASE Team. The objectives of the meeting were to solicit input on the scope of the 2025 code cycle proposals; request data and feedback on the specific approaches, assumptions, and methodologies for the energy impacts and cost-effectiveness analyses; and understand potential technical and market barriers. The Statewide CASE Team also presented initial draft code language for stakeholders to review.

The utility-sponsored stakeholder meeting was open to the public. For the stakeholder meeting, two promotional emails were distributed from info@title24stakeholders.com One email was sent to the entire Title 24 Stakeholders listserv, totaling over 3,000 individuals, and a second email was sent to a targeted list of individuals on the listserv depending on their subscription preferences. The Title 24 Stakeholders' website listserv is an opt-in service and includes individuals from a wide variety of industries and trades, including manufacturers, advocacy groups, local government, and building and energy professionals. The meeting was posted on the Title 24 Stakeholders' LinkedIn page (and cross-promoted on the CEC LinkedIn page) two weeks before the meeting to reach out to individuals and larger organizations and channels outside of the listserv. The Statewide CASE Team conducted extensive personal outreach to stakeholders identified in initial work plans who had not yet opted in to the listserv. Exported webinar meeting data captured attendance numbers and individual comments, and recorded outcomes of live attendee polls to evaluate stakeholder participation and support.

Statewide CASE Team Communications

The Statewide CASE Team held personal communications over email and phone with numerous stakeholders when developing this report, listed in Table 107.

Table 107: Engaged Stakeholders

Organization/Individual Name	Market Role	Mentioned in CASE Report Sections
Greg Mahoney, County of Sacramento Building Department	Code Official	No
Brower Mechanical, Duayne Knickerbocker	Contractor	No
CPHAC, Bob Wiseman	Contractor	No
Greiner HAC, Nathan Breeder	Contractor	No
Villara, Brian Longhurst	Contractor	No
ACCA, Wes Davis	Contractor Association	No
SMACNA, Eli Howard	Contractor Association	No
Siglers, LesKarcher, Jason Phillis	Distributor	No
CalCERTS, David Choo	HERS Provider	No
Daikin, Rhohei Hinokuma, Hiroshi Yoh	Manufacturer	No
Lennox, Dave Winningham	Manufacturer	No
Mitsubishi, Chris Bradt, Kimberly Llwewllyn, Ken Johnson, Sam Beeson	Manufacturer	No
NIST, Vance Payne	Researcher	No
University Nebraska, David Yuill	Researcher	No
Ecobee, Andrew Gaichuk	Thermostat Manufacturer	No
Nest, Michael Blasnik	Thermostat Manufacturer	No
measureQuick, Jim Bergman	Tool Provider	No

Engagement with DIPs

None.

Contractor Survey

A survey was developed by Evergreen Economics, to assess current practices for HVAC contractors and estimate time and costs for some of the proposed measures. It was distributed to members of the Title24 Stakeholder mailing list, and industry allies were asked to further distribute the survey.

Stakeholder Focus Group

A two-part Stakeholder Focus Group was held online on May 16 and 26. Individuals representing key stakeholder categories were invited to attend. Attendees were:

- Contractors: Brian Longhurst (Villara), Bob Wiseman (Canoga Park Heating and Air, IHACI)
- HERS and Code Officials: David Choo (CalCERTS), Greg Mahoney (County of Sacramento Building Department)
- Manufacturers/Distributors: Les Karcher and Jason Phillis (Siglers), Dave Winningham (Lennox), Hiroshi Yoh and Ryohei Hinokuma (Daikin), Ken Johnson, Kimberly Llewellyn, Chris Bradt, and Sam Beeson (Mitsubishi)
- Thermostat Manufacturers: Andrew Gaichuk (ecobee), Michael Blasnik (NEST)
- Others:
    - Res HVAC CASE Team: Kristin Heinemeier, Claudia Pingatore, Alea German, Keith Saechao, David Springer, and Stephen Becker (Frontier Energy), Marshall Hunt (Marshall B Hunt, P.E.), Russ King (Coded Energy), Parker Wall and Ritesh Nayyar (TRC), Abram Conant (Proctor Engineering Group), John McHugh (McHugh Energy),
    - Statewide CASE Team: Bach Tsan and Javier Perez (CEC), Mark Alatorre and Kelly Cunningham (PG&E), Cosimina Panetti (Energy Solutions), Brian Selby (Brian Selby, Inc.).

At these meetings, the current proposals were presented for design, supplementary heating (and other configuration issues), and refrigerant charge verification. Stakeholders were asked to discuss their comments on each proposal, and also to submit their thoughts in writing following the meetings.

Appendix G: Energy Cost Savings in Nominal Dollars

The CEC requested energy cost savings over the 30-year period of analysis in both 2026 present value dollars (2026 PV$) and nominal dollars. The cost effectiveness analysis uses energy cost values in 2026 PV$. Costs and cost effectiveness using and 2026 PV$ are presented in Section 5 of this report. This appendix presents energy cost savings in nominal dollars.

Table 108: Nominal LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction – Design – 2100/2700 Weighted Prototype

Climate Zone	30-Year LSC Electricity Savings (Nominal $)	30-Year LSC Natural Gas Savings (Nominal $)	Total 30-Year LSC Savings (Nominal $)
1	$608	$0	$608
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	$63	$0	$63

Table 109: Nominal LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction – Design – 500 ft^2 Prototype

Climate Zone	30-Year LSC Electricity Savings (Nominal $)	30-Year LSC Natural Gas Savings (Nominal $)	Total 30-Year LSC Savings (Nominal $)
1	$102	$0	$102
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	$272	$0	$272

Table 110: Nominal LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations – Design – 1665 ft^2 Existing Home Prototype

Climate Zone	30-Year LSC Electricity Savings (Nominal $)	30-Year LSC Natural Gas Savings (Nominal $)	Total 30-Year LSC Savings (Nominal $)
1	$942	$0	$942
2	$69	$0	$69
3	$16	$0	$16
4	$250	$0	$250
5	$11	$0	$11
6	$77	$0	$77
7	$113	$0	$113
8	$212	$0	$212
9	$212	$0	$212
10	$275	$0	$275
11	$448	$0	$448
12	$231	$0	$231
13	$566	$0	$566
14	$325	$0	$325
15	$1,013	$0	$1,013
16	$980	$0	$980

Table 111: Nominal LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction – Supplementary Heating – 2100/2700 Weighted Prototype

Climate Zone	30-Year LSC Electricity Savings (Nominal $)	30-Year LSC Natural Gas Savings (Nominal $)	Total 30-Year LSC Savings (Nominal $)
1	$6,925	$0	$6,925
2	$4,192	$0	$4,192
3	$2,480	$0	$2,480
4	$2,927	$0	$2,927
5	$2,486	$0	$2,486
6	$655	$0	$655
7	$485	$0	$485
8	$678	$0	$678
9	$984	$0	$984
10	$987	$0	$987
11	$2,780	$0	$2,780
12	$3,338	$0	$3,338
13	$1,991	$0	$1,991
14	$3,850	$0	$3,850
15	$158	$0	$158
16	$4,949	$0	$4,949

Table 112: Nominal LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction – Supplementary Heating – 500 ft^2 Prototype

Climate Zone	30-Year LSC Electricity Savings (Nominal $)	30-Year LSC Natural Gas Savings (Nominal $)	Total 30-Year LSC Savings (Nominal $)
1	$659	$0	$659
2	$227	$0	$227
3	$130	$0	$130
4	$164	$0	$164
5	$34	$0	$34
6	$0	$0	$0
7	$0	$0	$0
8	$0	$0	$0
9	$3	$0	$3
10	$1	$0	$1
11	$128	$0	$128
12	$177	$0	$177
13	$135	$0	$135
14	$366	$0	$366
15	$0	$0	$0
16	$529	$0	$529

Table 113: Nominal LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations – Supplementary Heating – 1665 ft^2 Existing Home Prototype

Climate Zone	30-Year LSC Electricity Savings (Nominal $)	30-Year LSC Natural Gas Savings (Nominal $)	Total 30-Year LSC Savings (Nominal $)
1	$5,990	$0	$5,990
2	$2,313	$0	$2,313
3	$2,212	$0	$2,212
4	$1,497	$0	$1,497
5	$2,347	$0	$2,347
6	$572	$0	$572
7	$432	$0	$432
8	$997	$0	$997
9	$1,111	$0	$1,111
10	$999	$0	$999
11	$1,757	$0	$1,757
12	$2,069	$0	$2,069
13	$1,490	$0	$1,490
14	$2,618	$0	$2,618
15	$277	$0	$277
16	$3,949	$0	$3,949

Table 114: Nominal LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction – Defrost – 2100/2700 Weighted Prototype

Climate Zone	30-Year LSC Electricity Savings (Nominal $)	30-Year LSC Natural Gas Savings (Nominal $)	Total 30-Year LSC Savings (Nominal $)
1	$2,747	$0	$2,747
2	$1,855	$0	$1,855
3	$734	$0	$734
4	$1,508	$0	$1,508
5	$813	$0	$813
6	$55	$0	$55
7	$55	$0	$55
8	$111	$0	$111
9	$332	$0	$332
10	$387	$0	$387
11	$1,461	$0	$1,461
12	$1,539	$0	$1,539
13	$1,161	$0	$1,161
14	$1,739	$0	$1,739
15	$142	$0	$142
16	$2,576	$0	$2,576

Table 115: Nominal LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction – Defrost – 500 ft^2 Prototype

Climate Zone	30-Year LSC Electricity Savings (Nominal $)	30-Year LSC Natural Gas Savings (Nominal $)	Total 30-Year LSC Savings (Nominal $)
1	$385	$0	$385
2	$147	$0	$147
3	$57	$0	$57
4	$136	$0	$136
5	$45	$0	$45
6	$0	$0	$0
7	$0	$0	$0
8	$0	$0	$0
9	$0	$0	$0
10	$0	$0	$0
11	$124	$0	$124
12	$136	$0	$136
13	$113	$0	$113
14	$170	$0	$170
15	$0	$0	$0
16	$260	$0	$260

Table 116: Nominal LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations – Defrost – 1665 ft^2 Existing Home Prototype

Climate Zone	30-Year LSC Electricity Savings (Nominal $)	30-Year LSC Natural Gas Savings (Nominal $)	Total 30-Year LSC Savings (Nominal $)
1	$4,633	$0	$4,633
2	$2,862	$0	$2,862
3	$1,394	$0	$1,394
4	$2,599	$0	$2,599
5	$1,620	$0	$1,620
6	$75	$0	$75
7	$75	$0	$75
8	$490	$0	$490
9	$829	$0	$829
10	$942	$0	$942
11	$2,975	$0	$2,975
12	$3,051	$0	$3,051
13	$2,298	$0	$2,298
14	$3,770	$0	$3,770
15	$415	$0	$415
16	$5,202	$0	$5,202

Table 117: Nominal LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction – VCHPcase – 2100/2700 Weighted Prototype

Climate Zone	30-Year LSC Electricity Savings (Nominal $)	30-Year LSC Natural Gas Savings (Nominal $)	Total 30-Year LSC Savings (Nominal $)
1	$916	$0	$916
2	$403	$0	$403
3	$237	$0	$237
4	$458	$0	$458
5	$158	$0	$158
6	$87	$0	$87
7	$79	$0	$79
8	$166	$0	$166
9	$221	$0	$221
10	$245	$0	$245
11	$600	$0	$600
12	$411	$0	$411
13	$600	$0	$600
14	$601	$0	$601
15	$798	$0	$798
16	$814	$0	$814

Table 118: Nominal LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction – Crankcase – 500 ft^2 Prototype

Climate Zone	30-Year LSC Electricity Savings (Nominal $)	30-Year LSC Natural Gas Savings (Nominal $)	Total 30-Year LSC Savings (Nominal $)
1	$396	$0	$396
2	$124	$0	$124
3	$68	$0	$68
4	$328	$0	$328
5	$34	$0	$34
6	$91	$0	$91
7	$181	$0	$181
8	$317	$0	$317
9	$294	$0	$294
10	$340	$0	$340
11	$464	$0	$464
12	$317	$0	$317
13	$520	$0	$520
14	$464	$0	$464
15	$679	$0	$679
16	$396	$0	$396

Table 119: Nominal LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations – Crankcase – 1665 ft^2 Existing Home Prototype

Climate Zone	30-Year LSC Electricity Savings (Nominal $)	30-Year LSC Natural Gas Savings (Nominal $)	Total 30-Year LSC Savings (Nominal $)
1	$904	$0	$904
2	$640	$0	$640
3	$377	$0	$377
4	$866	$0	$866
5	$339	$0	$339
6	$188	$0	$188
7	$301	$0	$301
8	$452	$0	$452
9	$490	$0	$490
10	$603	$0	$603
11	$1,168	$0	$1,168
12	$866	$0	$866
13	$1,168	$0	$1,168
14	$1,131	$0	$1,131
15	$1,357	$0	$1,357
16	$1,282	$0	$1,282

Table 120: Nominal LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction – Charge Verification – 2100/2700 Weighted Prototype

Climate Zone	30-Year LSC Electricity Savings (Nominal $)	30-Year LSC Natural Gas Savings (Nominal $)	Total 30-Year LSC Savings (Nominal $)
1	$2,305	$0	$2,305
2	N/A	N/A	N/A
3	$955	$0	$955
4	$1,563	$0	$1,563
5	$726	$0	$726
6	$363	$0	$363
7	$395	$0	$395
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	$2,639	$0	$2,639

Table 121: Nominal LSC Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction – Charge Verification – 500 ft^2 Prototype

Climate Zone	30-Year LSC Electricity Savings (Nominal $)	30-Year LSC Natural Gas Savings (Nominal $)	Total 30-Year LSC Savings (Nominal $)
1	$181	$0	$181
2	N/A	N/A	N/A
3	$90	$0	$90
4	$283	$0	$283
5	$34	$0	$34
6	$136	$0	$136
7	$271	$0	$271
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	$181	$0	$181

Table 122: Nominal LSC Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations – Charge Verification – 1665 ft^2 Existing Home Prototype

Climate Zone	30-Year LSC Electricity Savings (Nominal $)	30-Year LSC Natural Gas Savings (Nominal $)	Total 30-Year LSC Savings (Nominal $)
1	$3,766	$0	$3,766
2	N/A	N/A	N/A
3	$1,921	$0	$1,921
4	$4,407	$0	$4,407
5	$1,582	$0	$1,582
6	$1,055	$0	$1,055
7	$1,280	$0	$1,280
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	$5,503	$0	$5,503

Appendix H: Description of Existing Building Prototype

The single family alteration prototype was developed from the alteration prototypes described in the ACM Approval Manual. The manual presents two prototypes, a 1,440 square foot existing alteration prototype and a second which is the same 1,440 square foot existing home with a 225 square foot addition. The average size of existing homes in the United States built in the 1970s was between 1,650 and 1,750 square feet, with size steadily increasing over time. To better represent the existing building stock, the alteration with addition prototype was revised to reflect a 1,665 square feet existing home. See Table 123 for a description of the prototype.

The total window area is 218 square feet, or 13.1 percent of the conditioned floor area, based on the alteration prototype floor plan with addition in Figure A-16 of the ACM Approval Manual. The total opaque door area of 40 square feet (two standard size doors) is also based on Figure A-16. The model was converted to be orientation neutral with wall, window, and door area equally divided across the four cardinal directions. The number of bedrooms was defined to reflect the predominant number of bedrooms in California homes per the 2013-2017 American Community Survey 5-Year Estimates (U.S. Census Bureau 2017b).

Table 123: Single Family Alteration Prototype Description

Building Component	Assumption
Conditioned Floor Area	1,665 square feet (~41 feet x 41 feet)
Ceiling Height	8 feet
Wall Area	1,312 square feet
Window Area	218 square feet
Opaque Door Area	40 square feet
Number of Bedrooms	3
Attached Garage	2-car garage

There is no defined protocol for assigning building characteristics for existing home prototypes. Characteristics were applied to represent a home that was constructed in the 1990s with mechanical equipment replaced between 2010 and 2015, and are based on prior Title 24, Part 6 code requirements, literature review and industry standards. The primary prototypes are mixed-fuel with natural gas used for space heating, water heating, cooking, and clothes drying to represent the majority of existing residential buildings. 85 percent of residential buildings use natural gas for space heating and 86 percent use natural gas for water heating (California Energy Commission 2009).

Table 124 summarizes the baseline building characteristics for the alteration prototypes used in the analysis along with the basis for the assumptions where applicable. A more detailed discussion of the rationale is included for detailed discussion of the rationale is included for select building characteristics.

Table 124: Alteration Prototype Baseline Assumptions

Building Component	Efficiency Feature	Baseline Assumption	Reference
Envelope	Exterior Walls & Demising Walls	2x4 16"oc Wood Frame, R-13 cavity insulation	2013 T24 Residential Vintage Table R3-50, default for 1992 to 1998 vintage. (California Energy Commission 2014)
	Foundation Type & Insulation	Uninsulated slab	2013 T24 Residential Vintage Table R3-50, default for 1992 to 1998 vintage. (California Energy Commission 2014)
	Roof/Ceiling Insulation & Attic Type	R-19 (@ ceiling for attic & rafter for low-sloped)	2013 T24 Residential Vintage Table R3-50, default for 1992 to 1998 vintage. (California Energy Commission 2014)
	Roofing Material & Color	Asphalt shingles, default values (0.10 reflectance, 0.85 emittance)	CBECC-Res default
	Radiant Barrier	No	2013 T24 Residential Vintage Table R3-50, default for 1992 to 1998 vintage. (California Energy Commission 2014)
	Window Properties: U-Factor/Solar Heat Gain Coefficient (SHGC)	Metal, Dual Pane 0.79 U-factor 0.70 SHGC CZ 1-7,16 0.40 SHGC CZ 8-15	2013 T24 Residential Vintage Table110.6-A and 110.6-B. U-factor default for metal double-pane operable windows; SHGC default for metal double-pane operable windows in CZ 1-7,16 and low-e elsewhere. (California Energy Commission 2014) Basis for selecting window types discussed in detail below.
	Opaque Doors	0.50	CBECC-Res default
	Quality Insulation Inspection Credit (HERS)	No	CBECC-Res default
	House Infiltration	10 ACH50 (single family) 7 ACH50 (multifamily)	10 ACH50 Based on a literature review of blower door test data for existing homes. See detailed discussion below. 7 ACH50 is the CBECC-Res default for multifamily

Building Component	Efficiency Feature	Baseline Assumption	Reference
HVAC Equipment	System Type & Description	Ducted FAU split system with gas furnace & A/C	Typical system for California homes
	Heating Efficiency	0.78 AFUE	Federal minimum efficiency level in effect around 2015.
	Cooling Efficiency	13 SEER 11 EER	Federal minimum efficiency level in effect around 2015 for SEER. EER estimated based on CBECC-Res equations.
	Duct Location & Insulation	Attic, R-4.2, 15% leakage	2013 T24 Residential Vintage Table R3-50, default for 1992 to 1998 vintage for duct insulation. (California Energy Commission 2014) Assume ducts were sealed and tested when HVAC system last replaced.
	Mechanical Ventilation	None	CBECC-Res default
	Verified Refrigerant Charge (HERS)	No	CBECC-Res default
	Verified Cooling Airflow ≥350 cfm/ton (HERS)	No, 350 cfm/ton	CBECC-Res default
	Verified Fan Watt Draw ≤0.58 W/cfm (HERS)	Single Speed PSC 0.58	CBECC-Res default
Water Heating Equipment	System Type & Description	Gas Storage	Typical system for California homes
	Water Heater Efficiency	0.575 EF	Federal minimum efficiency level in effect around 2015.
	Water Heater Size (gal.)	40	Typical for residential storage gas water heaters.
Appliance & Lighting	Lighting Type	per CBECC-Res	CBECC-Res default
	Appliances	per CBECC-Res	CBECC-Res default
	Cooking	Gas	Typical for mixed fuel home
	Clothes Dryer	Gas	Typical for mixed fuel home