DOCKETED

Docket Number:	21-BSTD-03
Project Title:	2022 Rulemaking for Part 11 (CalGreen) and Parts 2-5 of the Building Standards Code
TN #:	238641
Document Title:	Document relied upon - CASE report
Description:	Document relied upon for the California Building Energy Efficiency Standards, 2022 California Green Building Standards Code, Title 24, Part 11 and Parts 2, 2.5, 3, 4, and 5.
Filer:	Amber Beck
Organization:	California Energy Commission
Submitter Role:	Commission Staff
Submission Date:	7/2/2021 9:31:01 AM
Docketed Date:	7/2/2021

Codes and Standards Enhancement (CASE) Initiative

Voluntary Energy Efficiency Requirements for Title 24, Part 11 (CALGreen)

Title 24, Part 11 (CALGreen) Recommendations

June 2021

Prepared by Energy Solutions, Frontier Energy, and TRC

CALIFORNIA ENERGY CODES & STANDARDS

A STATEWIDE UTILITY PROGRAM

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

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Document Information

Category:	**Codes and Standards**
Keywords:	Statewide Codes and Standards Enhancement (CASE) Initiative; California Statewide Utility Codes and Standards Team; Codes and Standards Enhancements; 2022 California Energy Code; 2022 Title 24, Part 6; efficiency; multifamily, nonresidential, building envelope, fenestration, HVAC (Heating Ventilation and Air Conditioning), battery, domestic hot water, heat recovery, service hot water, lighting
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Executive Summary

The Codes and Standards Enhancement (CASE) Initiative submits code change proposals to the California Energy Commission (Energy Commission), the state agency that has authority to adopt revisions to the voluntary energy efficiency requirements in Title 24, Part 11 (CALGreen). This report presents the Statewide CASE Team's recommended revisions to the voluntary energy efficiency requirements for the 2022 version of the California Green Building Standards Code (Title 24, Part 11 or CALGreen). Voluntary energy efficiency requirements in CALGreen are intended to serve as a resource to jurisdictions that are considering adopting local energy code requirements (reach codes) that are more stringent than the California Energy Code (Title 24, Part 6). The proposal responds to the growing number of local jurisdictions adopting electrification new construction ordinances and considers a proposed new section of CALGreen for multifamily buildings.

Single Family

The single family code change proposal revises the Tier 1 and Tier 2 performance standards and changes the performance target from an absolute Energy Design Rating (EDR) score to an EDR Margin. Using an EDR Margin, which is similar to a compliance margin, treats buildings of different conditioned floor area more equitably. Tier 1 provides a path for both mixed-fuel and all-electric buildings but establishes a preference for all-electric buildings. All-electric construction is required for Tier 2. This proposal also adds five new prerequisite options and requires that two prerequisites be selected by project teams.

Multifamily

The multifamily code change recommendations include applying requirements from the 2019 low-rise residential and high-rise residential requirements across all multifamily buildings. It also adds three new prerequisite options and requires all-electric construction for both tiers. Proposed Tier 1 and Tier 2 performance requirements include climate zone-specific percentages of the Title 24, Part 6 Energy Budget.

Nonresidential

The proposed code changes for nonresidential buildings add two new prerequisite options while removing one that will likely be included in 2022 Title 24, Part 6. Seven prerequisite options for covered processes are included. The proposal recommends requiring electric readiness for mixed-fuel buildings.

1. Introduction

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support the California Energy Commission's (Energy Commission) efforts to update the voluntary energy efficiency provisions in the California Green Building Code Standards (Title 24, Part 11 or CALGreen) 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 support code change proposals that would result in cost-effective enhancements that improve energy efficiency and energy performance in California buildings. This report is part of an effort to develop technical and cost-effectiveness information for proposed requirements on building energy-efficient design practices and technologies.

The Energy Commission has authority to adopt revisions to the voluntary energy efficiency requirements in CALGreen. The Energy Commission may revise or reject proposals presented in this report. See the Energy Commission's 2022 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/2022-building-energy-efficiency.

The overall goal of this CASE Report is to present a code change proposal for the voluntary energy efficiency requirements in CALGreen. The report contains pertinent information supporting the code change, including:

- Section 1: Introduction provides relevant context, including historical and regulatory details.
- Section 2: Considerations for CALGreen Proposal details the objectives and factors guiding the prioritization, justification, and background analyses for the selected recommendations.
- Section 3: Structure of Voluntary Energy Efficiency Requirements in CALGreen provides an orientation to CALGreen and explains how the proposed recommendations fit within the preexisting format. Information that is relevant to all the building types are presented here to reduce redundancy.
- Section 4: Energy Savings and Cost-Effectiveness Methodology presents the methodology and assumptions that are consistent across analyses for single family, multifamily, and nonresidential buildings.

- Section 5: Single Family Code Change Recommendations contains descriptions, justifications, and energy and cost savings analysis for proposed changes to the single family CALGreen building standards code.
- Section 6: Multifamily Code Change Recommendations contains descriptions, justifications, and energy and cost savings analysis for proposed changes to the multifamily residential CALGreen building standards code.
- Section 7: Nonresidential Code Change Recommendations contains descriptions, justifications, and energy and cost savings analysis for proposed changes to the nonresidential CALGreen building standards code.
- Section 8: Proposed Revisions to Code Language concludes the report with recommended revisions to the code language with ~~strikeout~~ (deletions) and underlined (additions) language.
- Section 9: Bibliography presents the report development resources and references.
- Appendix A: Energy and Cost-Effectiveness Analysis – Single Family presents the details of analyses referenced in Section 5:Single Family Code Change Recommendations.
- Appendix B: Energy and Cost-Effectiveness Analysis – Nonresidential Buildings presents the details of analyses referenced in Section 7: Nonresidential Code Change Recommendations.

This draft report does not present greenhouse gas (GHG) reductions associated with the proposed code change. The final report will be released after the Energy Commission adopts the 2022 CALGreen requirements will include GHG emissions reduction data. The final report will reflect the costs and benefits of the adopted voluntary energy efficiency requirements in the 2022 CALGreen code.

2. Considerations for CALGreen Proposal

2.1 Provide a Useful Resource for Local Jurisdictions

For the 2022 code cycle, the Statewide CASE Team aimed to develop a CALGreen proposal consisting of voluntary energy efficiency measures that would be useful to jurisdictions seeking to enhance local codes. To accomplish this goal, the Statewide CASE Team considered the following when developing this proposal:

- Jurisdictions are interested in ordinances that go beyond Title 24, Part 6 because they help achieve local energy and GHG reduction goals and establish the jurisdiction as a local leader. The Statewide CASE Team has presented energy savings and GHG reductions of the proposed code changes. Local jurisdictions can build upon the analyses presented in this report to estimate the impact of adopting local ordinances based on CALGreen.

- Proposed local ordinances are developed by staff at each jurisdiction, discussed during public meetings, and approved by council members. Building codes can be complicated. It is more likely that an ordinance will be adopted if it is intuitive and includes clear narrative explaining how the ordinance will result in cost-effective energy and GHG savings. The Statewide CASE Team believes that providing an attractive, cost-effective option in CALGreen will reduce the burden on local jurisdictions, possibly leading to higher adoption rates. This report provides explanatory narrative that we hope will be helpful to audiences that may not have an extensive background in building codes.

- Local jurisdictions that wish to adopt an ordinance that exceeds the Title 24, Part 6 must demonstrate the ordinance is cost effective.[1] The Statewide CASE Team developed code change proposals for CALGreen that are expected to be cost effective and documented the methodology, assumptions, and results of cost-effectiveness analyses so that jurisdictions can adopt CALGreen requirements without additional analyses. Measures that are not cost effective in all climate zones may still be considered in others.

- Local jurisdictions typically prefer performance goals (e.g., percent better than Title 24, Part 6 energy budget) to prescriptive measures that target specific applications (e.g., prerequisite requirement for loading dock seals). Therefore, the CALGreen proposal proposes realistic Tier 1 and Tier 2 energy targets that can be achieved using a number of different design strategies.

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[1] More information here: https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2019-building-energy-efficiency-3

2.2 Encourage All Electric Construction

As of December 2020, nearly 40 cities and counties in California had approved codes that require or encourage all-electric buildings (Walker and Stampe 2020). At least 16 California jurisdictions have adopted all-electric whole-building requirements, including Oakland, San Jose, and San Francisco. The recent ordinances passed by these three cities apply to both residential and commercial buildings of all types and sizes. Electrifying buildings and transportation were identified by jurisdictions as some of the most important ways to help meet their greenhouse gas (GHG) emission reduction targets (Bloomberg Associates 2018). Favorable state policies and lower prices of renewable energy mean that substituting natural gas with electricity is one of the quickest, safest, and least expensive pathways to eliminating GHG emissions from buildings. All-electric building requirements has been shown to lower installation costs for new buildings because it eliminates the need for fossil fuel infrastructure to and in buildings.

2.3 Enable Harmonization Across Jurisdictions

In addition to creating CALGreen proposals that are useful and simple for local jurisdictions to draw from, the Statewide CASE Team aims to address market feedback that building developers and the design community face challenges in designing to building codes that differ across jurisdictions. While reach codes should be tailored to accommodate local needs, some degree of standardization across jurisdictions will help provide continuity for builders and developers that operate across multiple jurisdictions. Recently, jurisdictions have referenced several model ordinances available at LocalEnergyCodes.com or through the Building Decarbonization Coalition, then added regional adjustments.

2.4 Create a Separate Section of CALGreen for Multifamily Buildings

The Statewide CASE Team proposes a consolidation of multifamily voluntary CALGreen requirements into a new Section A4.204 for multifamily buildings. This section would include prerequisites, prerequisite options, and Tier 1 and Tier 2 performance requirements for all multifamily buildings.

Multifamily requirements are currently split across low-rise residential, high-rise residential, and nonresidential sections of code. Unification of multifamily requirements in CALGreen would create consistency with changes to Title 24, Part 6 for the 2022 cycle[2] and consolidate all requirements for multifamily buildings into one section of code. This consolidation of requirements would streamline CALGreen compliance,

[2] See the 2022 Title 24, Part 6 CASE Report on multifamily restructuring available here: https://title24stakeholders.com/measures/cycle-2022/multifamily-chapter-restructuring/.

particularly on sites with mixed-height multifamily buildings, which is expected to improve compliance.

2.5 Leverage Existing Data and Reports

When developing the CALGreen proposal, the Statewide CASE Team leveraged existing work as much as possible. Key sources of data include:

- Reach code reports available on LocalEnergyCodes.com:
    - 2019 Cost-effectiveness Study: Low-Rise Residential New Construction (August 2019)
    - 2019 Mid-Rise New Construction Reach Code Cost-Effectiveness Study (June 2020)
    - 2019 Nonresidential New Construction Reach Code Cost Effectiveness Study (July 2019)
- 2022 CASE Reports (multiple reports were leveraged) available on Title24Stakeholders.com
- California Energy Alliance 2022 Proposal for Demand Management in Nonresidential Buildings available on the California Energy Alliance website.
- Lawrence Berkeley National Laboratory (LBNL) report on Cool Walls: Solar-Reflective "Cool" Walls: Benefits, Technologies, and Implementation.

3. Structure of Voluntary Energy Efficiency Requirements in CALGreen

3.1 General Structure of Voluntary Energy Efficiency Requirements

The voluntary energy efficiency requirements appear in sections A4.2 and A5.2 of CALGreen for residential and nonresidential buildings, respectively. In the 2019 version of CALGreen, requirements for low-rise residential appear in section A4.2 and requirements for high-rise residential appear in section A5.2. Requirements in the voluntary energy efficiency sections of CALGreen serve as model code language that local jurisdictions can use as a starting point for local ordinances.

The CALGreen requirements follow a tiered structure where Tier 1 requirements are one step more stringent than Title 24, Part 6 and Tier 2 is more stringent than Tier 1. To meet the requirements, a building must comply with prerequisites, prerequisite options, and performance requirements. Each of these elements are described below.

3.2 Prerequisites

Prerequisites are requirements that all buildings that are seeking to comply with either Tier 1 or Tier 2 performance levels. Designers must implement these measures, and they cannot be traded off against anything in the list of prerequisite options or design features that can be modeled in the compliance software. There are two prerequisites for low-rise residential buildings in the 2019 version of CALGreen. There are no prerequisites for high-rise residential or nonresidential buildings in the 2019 version of CALGreen.

The Statewide CASE Team is recommending adding one prerequisite for nonresidential buildings.

Prerequisites require buildings to use specific design strategies or technologies, which provides the appropriate message that energy efficiency, load management, and high-quality installations are valued. Prerequisite also provide a pathway for builders to receive compliance credit for design strategies that cannot be simulated within the Title 24 compliance software.

3.3 Prerequisite Options

In addition to adhering to the prerequisites, the building must also include one or two of many options, depending on the tier. In the 2019 code, low-rise residential buildings must meet one of four options to comply with the Tier 1 or Tier 2 requirements. High-rise residential and nonresidential buildings must meet one of the prerequisite options to comply with Tier 1 and two to comply with Tier 2.

Five new prerequisite options are proposed for single family and three for multifamily. For nonresidential buildings, one prerequisite option will be removed because it will be required in Title 24, Part 6, one existing will be expanded, and eight new prerequisite options will be added. For single family and multifamily buildings, the number of prerequisite options that must be included in the building will be increased from one to two.

3.4 Energy Performance Targets

In addition to adhering to the prerequisites and prerequisite option requirements, buildings must achieve energy performance budgets that are more stringent than Title 24, Part 6.

Many local jurisdictions have adopted all-electric preferred or all-electric required ordinances for new buildings. The Statewide CASE Team seeks to support these ordinances by proposing a CALGreen structure that similarly encourages all-electric construction.

3.4.1 2019 CALGreen Performance Targets

For low-rise residential buildings, the 2019 CALGreen energy performance targets are established in Time Dependent Valuation Energy Design Ratings (TDV EDR). Buildings must achieve the specified EDR target, which vary by climate zone and fuel type (i.e., mixed-fuel or all-electric), to meet the Tier 1 or Tier 2 requirements. For most climate zones, the Tier 2 EDR target is zero. The Tier 1 EDR targets are between minimal compliance with the 2019 Title 24 Part 6 requirements and the Tier 2 targets. EDR is based on a 0-100 scale. A score of zero represents a building that has zero net energy consumption based on the TDV energy use. A score of 100 represents a building that is compliant with the 2006 International Energy Conservation Code (IECC).[3]

For high-rise residential and nonresidential buildings, the 2019 CALGreen energy performance targets are established based on a percentage of the Title 24, Part 6 TDV energy budget. The energy targets do not vary by climate zone or fuel type and are summarized in Table 1.

[3] energycodeace.com, “Fact Sheet: Residential EDR 2019”

Table 1: 2019 CALGreen Energy Performance Targets for Nonresidential and High-Rise Residential Buildings (percent of Title 24, Part 6 Energy Budget)

Building Type	Energy Performance Target	
	Tier 1	Tier 2
Nonresidential buildings with both mechanical and lighting systems	90%	85%
Nonresidential buildings with either a mechanical or lighting system	95%	90%
High-rise residential and hotel/motel	95%	90%

3.4.2 Proposed 2022 CALGreen Performance Targets

Single family buildings will have energy performance targets based on the TDV EDR margin rather than based on a set EDR value. This approach was successful and popular with jurisdictions adopting reach codes over the 2019 Energy Code. See Section 5.3.2 for additional discussion of using EDR margin instead of an absolute EDR value. The Statewide CASE Team proposes that Tier 1 encourage all-electric construction and that Tier 2 require buildings to be all-electric.

Multifamily buildings will be in a separate section of code, and the energy performance targets will be based on a percentage better than the Title 24 Part 6 TDV EDR Energy Budget with targets varying by climate zone. The Statewide CASE Team recommends that both Tier 1 and Tier 2 multifamily buildings be all-electric.

For nonresidential buildings, energy targets will be updated to vary by climate zone and fuel type. The Statewide CASE Team proposes that Tier 1 be structured to encourage all-electric construction and that Tier 2 require buildings to be all-electric.

4. Energy Savings and Cost-Effectiveness Methodology

Title 24, Part 6 Section 10-106 requires local jurisdictions that adopt local energy code ordinances to submit "findings and supporting analyses on the energy savings and cost effectiveness of the proposed energy standards" (California Energy Commission 2018) to the Energy Commission. While jurisdictions may quantify energy savings and cost effectiveness by any method determined appropriate, the analyses in this report use the procedures established by the Energy Commission to evaluate proposed revisions to Title 24, Part 6.

Energy and energy cost savings are based on electricity and natural gas time dependent valuation (TDV) energy savings.[4] TDV is a normalized metric for calculating energy cost savings, which accounts for the variable cost of electricity and natural gas each hour of the year, and how costs are expected to change over the period of analysis (30 years for residential measures and nonresidential envelope measures and 15 years for all other nonresidential measures).

The Statewide CASE Team estimated energy and demand impacts by simulating the proposed code changes using the 2022 Research Version of the California Building Energy Code Compliance (CBECC) software for commercial (CBECC-Com) and residential (CBECC-Res) buildings. CBECC-Com and CBECC-Res calculate whole-building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/yr) and therms per year (therm/yr), and annual peak electricity demand reductions in kilowatts (kW). The software then applies the 2022 TDV factors to calculate annual energy use in kilo British thermal units per year (TDV kBtu/yr). Energy cost savings are calculated by applying the TDV energy cost factors measured in 2023 present value dollars (2023 PV$) to the energy savings estimates (Energy + Environmental Economics 2020). The energy savings do not account for naturally occurring market adoption or compliance rates.

CBECC-Com and CBECC-Res generate two models based on user inputs: the Standard Design and the Proposed Design. The 2022 research versions of CBECC software use buildings that are minimally compliant with the 2019 Title 24, Part 6 requirements as the Standard Design. The Statewide CASE Team created a 2022 Standard Design to use for this analysis that incorporates code changes that Energy Commission will likely adopt for the 2022 version of Title 24, Part 6. This allowed the research team to evaluate the energy savings, GHG reductions, and cost-effectiveness

[4] See the Energy Commission's website for more information on the TDV metric: https://www.energy.ca.gov/event/workshop/2020-03/staff-workshop-2022-energy-code-compliance-metrics.

of proposed CALGreen requirements relative to the expected statewide California Energy Code for the 2022 code cycle.

The incremental first cost and incremental replacement and maintenance costs over the period of analysis are also included. 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 total cost benefits realized over the analysis period by the total incremental costs. The B/C ratio was calculated using 2023 PV$ costs and cost savings.

The cost-effectiveness analysis must show that there is a pathway to comply with the code that is cost effective, but it is not necessary to demonstrate that every possible compliance pathway is cost effective. This report presents the cost-effectiveness of all recommended prerequisites. Cost effectiveness analyses are presented for some of the prerequisite options. For the performance requirements, a cost effectiveness analysis is presented for the design strategies that were used to establish the energy targets. There are many other ways to achieve the same energy target. Notable, it is expected that many designers will choose to install more efficient equipment to meet energy targets. The analyses presented in this report assume equipment is minimally compliant with federal appliance efficiency standards. This was done to demonstrate that the energy targets can be achieved cost-effectively without violating federal preemption.

5. Single Family Code Change Recommendations

5.1 Overview of Single Family Proposals

The single family code change proposals cover two main aspects of the CALGreen voluntary Appendix A4. The proposal adds prerequisite options and changes the performance standards for both Tier 1 and Tier 2.

For all proposed changes, energy savings are calculated relative to the proposed mixed-fuel Standard Design for the 2022 Title 24, Part 6 code as presented by the Energy Commission at the January 26, 2021 staff workshop on decarbonization (California Energy Commission 2021).[5] Analysis was conducted for the two single family building prototypes that the Energy Commission uses to evaluate the cost effectiveness of proposed changes to Title 24 requirements: a 2,100 square foot single story home and a 2,700 square foot two-story home. Results in this report are presented for the blended average of these two prototypes, representing a 2,400 square foot home. See Appendix A for further details. The Energy Commission has since revised the details of the proposed mixed-fuel baseline and the final report will incorporate these changes in an updated analysis. Results are not expected to change significantly.

In addition to analysis demonstrating feasibility and cost effectiveness of the proposals, the Statewide CASE Team also conducted a cost-effectiveness analysis comparing an all-electric with a mixed-fuel 2022 Standard Design home. See Appendix A for further details.

5.2 Tier 1 and Tier 2 Prerequisite Options

CALGreen currently has four Tier 1 and Tier 2 prerequisite options in Section A4.203.1.2. They require that projects include one of the following:

1. Roof deck insulation (High Performance Attic) or verified low leakage ducts in conditioned space (VLLDCS)
2. High Performance Walls (HPW)
3. Home Energy Rating System (HERS)-Verified Compact Hot Water Distribution System (CHWDS-H)
4. HERS-Verified Drain Water Heat Recovery (DWHR-H)

The following measures are proposed in addition to the existing four Tier 1 and Tier 2 prerequisite options:

1. High Performance Fenestration

[5] More information available on the Energy Commission's website: https://www.energy.ca.gov/event/workshop/2021-01/staff-workshop-proposed-2022-energy-code-low-rise-residential-heat-pump/.

2. HERS-Verified Reduced Building Air Leakage
3. Heat Recovery Ventilator or Energy Recovery Ventilator (HRV/ERV)
4. Heat Pump Water Heater (HPWH) Demand Management System
5. Battery Storage System

The proposed change also requires that two prerequisite options be met rather than one. The proposed five new options are described individually below including rationale for adding the measure and a discussion of compliance and enforcement. Energy savings and cost effectiveness are not presented for each proposed measure individually. Instead, two measures were selected per the proposed requirement, CHWDS-H and VLLDCS, to demonstrate cost effectiveness.

5.2.1 Description of Prerequisite Options

5.2.1.1 High Performance Fenestration

Code Change Description

This measure would add a prerequisite option to use high efficiency fenestration products, including glazed doors, with an area weighted average U-factor no greater than 0.24 Btu/hr-ft^2 -°F.

Rationale

High performance fenestration reduces heating and cooling energy and improves interior comfort. In recent years, the window industry has continually advanced the performance of glazing products with technological advancements including lower cost thin-profile triple-pane windows and advanced coatings. Costs have decreased for at least some features of high efficiency windows, and durability has improved. Fenestration performance with a U-factor less than or equal to 0.24 can be met with triple pane products or a dual pane product with low-E coatings on multiple glazing surfaces. Encouraging the installation of high performance fenestration products in new buildings will help shift the market toward these products and reduce costs.

5.2.1.2 HERS-Verified Reduced Building Air Leakage

Code Change Description

This measure would add a prerequisite option to require building air leakage be tested by a HERS Rater to meet no greater than 1.5 air changes per hour at 50 pascals (ACH50). The procedures in Title 24, Part 6 Reference Appendix RA3.8 shall be followed.

Rationale

Requiring building air leakage testing and minimizing building infiltration to 1.5 ACH50 would result in energy benefits through improved air sealing practices that reduce heating and cooling loads and minimize unintentional air movement in and out of a building to allow for better control of air quality and moisture.

5.2.1.3 Heat Recovery Ventilator or Energy Recovery Ventilator

Code Change Description

This measure would add a prerequisite option for installation of a heat recovery ventilator (HRV) or an energy recovery ventilator (ERV) to satisfy the building mechanical ventilation requirements. The HRV or ERV shall have a minimum sensible recovery efficiency of 67 percent, rated at 32 °F (0 °C), and a minimum fan efficacy of 0.6 W per cfm.

Rationale

Balanced ventilation systems provide indoor air quality benefits as they control and filter outdoor air entering the building. Heat or energy recovery saves energy by tempering the incoming air using the exhaust air stream, reducing the heating or cooling loads as a result of ventilation.

5.2.1.4 HPWH Demand Management System

Code Change Description

This measure would add a prerequisite option for installation of a unitary HPWH with demand management capabilities to serve the domestic water heating needs of the building. The HPWH shall meet the requirements of Title 24, Part 6 Reference Appendix JA13 and qualify for either the Basic Plus or Advanced Load Up control option.

Rationale

Since HPWHs generally feature small compressors, operating cycles are considerably longer than conventional water heating technologies. When the compressor is unable to maintain tank temperature during high hot water draw events, supplemental electric resistance heating is energized. The 50 gallons of storage (or more) integrated into most HPWHs offer demand flexibility capabilities by allowing compressor operation to be shifted away from peak load events by charging the storage tank beyond the normal setpoint. A load-shifting operating mode shifts operation to the middle of the day to maximize the use of available renewable generation resources and reduce the use of non-renewable generation resources.

5.2.1.5 Battery Storage System

Code Change Description

This measure would add a prerequisite option for installation of a battery storage system. The battery storage system shall meet the requirements of Title 24, Part 6

Reference Appendix JA12 and qualify for either the Time-of-Use Control or Advanced Demand Flexibility Control option.

Rationale

Battery storage systems are beneficial to the occupant and the utility grid by serving the primary functions of daily cycling for load shifting, which maximizes solar self-utilization, and grid harmonization. Residential occupants purchase battery storage systems for a variety of use cases, including, but not limited to, solar PV self-consumption, backup power for grid emergencies, and avoiding electricity purchases during higher priced time-of-use periods.

5.2.2 Energy Savings

Energy savings and cost effectiveness are presented for two of the prerequisite options: CHWDS-H and VLLDCS. CBECC-Res 2022.0.4 RV (1174) was used for all simulations.

5.2.2.1 HERS-Verified Compact Hot Water Distribution System (CHWDS-H)

Energy savings and peak demand reductions per unit for CHWDS-H are presented in Table 2. Savings are relative to a single family home without CHWDS-H, regardless of whether it is specified in the Standard Design. CHWDS-H requirements are specified in the Title 24, Part 6 Reference Appendix RA3.6.5 and modeled in CBECC-Res as the expanded credit with a custom compactness factor of 0.6. Per-unit savings for the first year are expected to range from 2 to 243 annual kWh and 0 to 9 annual therms depending upon climate zone. Demand reductions are marginal for this water heating measure.

Table 2: CHWDS-H First-Year Energy Impacts Per Home – Single Family

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therm/yr)	TDV Energy Savings (TDV kBtu/yr)
1	243	0.09	0	6,309
2	174	0.04	0	4,319
3	2	0.00	9	3,135
4	2	0.00	8	2,906
5	2	0.00	9	3,111
6	2	0.00	8	2,765
7	2	0.00	8	2,724
8	2	0.00	7	2,631
9	2	0.00	7	2,679
10	2	0.00	7	2,644
11	140	0.01	0	3,696
12	140	0.03	0	3,819
13	2	0.00	7	2,631
14	2	0.00	8	2,764
15	2	0.00	5	1,997
16	144	0.02	0	3,012

5.2.2.2 Verified Low Leakage Ducts in Conditioned Space (VLLDCS)

Energy savings and peak demand reductions per unit for Verified Low Leakage Ducts in Conditioned Space are presented in Table 3. Savings are relative to a single family home that meets minimum code requirements with ducts in the attic and five percent duct leakage. Per-unit savings for the first year are expected to range from 35 to 466 annual kWh and 0 to 54 annual therms depending upon climate zone. Demand reductions are expected to range between 0 kW and 0.3 kW depending on climate zone.

Table 3: Verified Low Leakage Ducts in Conditioned Space First-Year Energy Impacts Per Single Family Home

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therm/yr)	TDV Energy Savings (TDV kBtu/yr)
1	36	0.00	54	20,703
2	35	0.01	29	18,260
3	258	0.00	0	8,272
4	197	0.04	0	10,554
5	343	0.00	0	10,614
6	95	0.04	0	6,218
7	80	0.04	0	4,195
8	90	0.11	0	6,442
9	121	0.12	0	7,545
10	180	0.16	0	10,049
11	145	0.17	20	17,417
12	53	0.05	17	12,953
13	329	0.20	0	15,329
14	466	0.18	0	18,401
15	375	0.30	0	17,078
16	53	0.03	40	16,623

5.2.3 Cost Effectiveness

Energy savings and cost effectiveness are presented for two of the prerequisite options: CHWDS-H and Verified Low Leakage Ducts in Conditioned Space. Cost-effectiveness for some of the other prerequisite options have been demonstrated in past code cycles and are prescriptively required in the current code. These include roof deck insulation (Statewide CASE Team 2017c), high performance walls (HPW) (Statewide CASE Team 2017d), drain water heat recovery (DWHR) (Statewide CASE Team 2017b), and CHWDS-H (Statewide CASE Team 2017a). Some of the measures have also been evaluated for the 2022 code cycle, including demand management for HPWHs (Statewide CASE Team 2020), battery storage systems (Statewide CASE Team 2020), and heat or energy recovery ventilators for multifamily buildings (Statewide CASE Team 2020a).

Table 4 summarizes the incremental cost assumptions for the two measures evaluated. Incremental costs represent the equipment, installation, replacement, and maintenance costs of the proposed measures relative to the base case. No replacement or maintenance costs were assumed for either CHWDS-H or Verified Low Leakage Ducts in Conditioned Space measures. Costs were estimated to reflect costs to the building owner. All costs are provided as present value in 2023 (2023 PV$). Costs due to variations in furnace, air conditioner, and heat pump capacity by climate zone were not accounted for in the analysis.

Table 4: Prerequisite Options Incremental Costs for a 2,400 Square Foot Single Family Building

Measure	Incremental First Cost (2023 PV$)	Source and Notes
CHWDS-H	$300	Cost based on re-locating the water heating on an interior garage wall ($150) and HERS Rater verification ($150) (Statewide Reach Codes Team 2019).
VLLDCS	$707	Costs based on a 2015 report on the Evaluation of Ducts in Conditioned Space for New California Homes (Davis Energy Group 2015). HERS incremental verification cost of $100 for the VLLDCS credit relative to standard duct testing for code compliance (Statewide Reach Codes Team 2019).

Results of the per-unit cost-effectiveness analyses for CHDWS-H and Verified Low Leakage Ducts in Conditioned Space are presented in Table 5 and Table 6, respectively. The proposed measures save money over the 30-year period of analysis and are cost effective in every climate zone.

Table 5: CHWDS-H 30-Year Cost-Effectiveness Summary Per Single Family Home

Climate Zone	Benefits - TDV Energy Cost Savings + Other PV Savings (2023 PV$)	Costs - Total Incremental PV Costs (2023 PV$)	B/C ratio
1	$1,091	$300	3.6
2	$747	$300	2.5
3	$542	$300	1.8
4	$503	$300	1.7
5	$538	$300	1.8
6	$478	$300	1.6
7	$471	$300	1.6
8	$455	$300	1.5
9	$463	$300	1.5
10	$457	$300	1.5
11	$639	$300	2.1
12	$661	$300	2.2
13	$455	$300	1.5
14	$478	$300	1.6
15	$345	$300	1.2
16	$521	$300	1.7

Table 6: Verified Low Leakage Ducts in Conditioned Space 30-Year Cost-Effectiveness Summary Per Single Family Home

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings (2023 PV$)	Costs Total Incremental PV Costs (2023 PV$)	B/C ratio
1	$3,582	$707	5.1
2	$3,159	$707	4.5
3	$1,431	$707	2.0
4	$1,826	$707	2.6
5	$1,836	$707	2.6
6	$1,076	$707	1.5
7	$726	$707	1.0
8	$1,115	$707	1.6
9	$1,305	$707	1.8
10	$1,738	$707	2.5
11	$3,013	$707	4.3
12	$2,241	$707	3.2
13	$2,652	$707	3.8
14	$3,183	$707	4.5
15	$2,954	$707	4.2
16	$2,876	$707	4.1

5.3 Tier 1 and Tier 2 Performance Standards and Prescriptive Requirements

5.3.1 Code Change Description

This measure would revise the Tier 1 and Tier 2 climate zone-specific performance targets and change the requirement from a TDV EDR (or EDR2) Target to an EDR2 Margin. Tier 1 is structured as an all-electric preferred option for jurisdictions with proposed EDR2 Margins for mixed-fuel buildings ranging from 17 to 32, depending on climate zone. All-electric buildings must meet proposed EDR2 Margins from 5 to 8, except in Climate Zone 16 where there is no above code requirement. Additionally, this proposal recommends a Tier 1 requirement where mixed-fuel buildings must install either a heat pump for space heating or water heating.

Tier 2 does not provide a path for mixed-fuel buildings and has proposed EDR2 Margins for all-electric buildings ranging from 8 to 25, depending on climate zone.

Table 7 summarizes the EDR2 Margin targets by climate zone. For reference, Table 8 presents the equivalent source energy EDR1 Margins for the packages.

Table 7: Total EDR2 Margin Target by Climate Zone

Climate Zone	Tier 1 Mixed-Fuel	Tier 1 All-Electric	Tier 2 Mixed-Fuel	Tier 2 All-Electric
1	27	7	N/A	25
2	25	6	N/A	18
3	26	6	N/A	16
4	25	7	N/A	16
5	30	5	N/A	17
6	29	8	N/A	17
7	32	8	N/A	17
8	25	7	N/A	14
9	27	7	N/A	14
10	23	6	N/A	13
11	19	5	N/A	12
12	22	5	N/A	14
13	21	6	N/A	11
14	24	5	N/A	15
15	17	5	N/A	8
16	24	0	N/A	17

Table 8: Total EDR1 Margins by Climate Zone

Climate Zone	Tier 1 Mixed-Fuel	Tier 1 All-Electric	Tier 2 Mixed-Fuel	Tier 2 All-Electric
1	11	24	N/A	27
2	11	13	N/A	15
3	12	13	N/A	15
4	13	13	N/A	15
5	13	12	N/A	15
6	17	17	N/A	19
7	18	18	N/A	20
8	16	15	N/A	17
9	16	14	N/A	16
10	15	13	N/A	15
11	10	11	N/A	13
12	11	11	N/A	13
13	12	11	N/A	12
14	13	10	N/A	12
15	13	11	N/A	12
16	10	0	N/A	23

5.3.2 Rationale

The existing EDR2 Targets for Tier 1 are technically feasible but challenging to achieve cost effectively. The existing Tier 2 EDR2 Targets of 0 in most climates require a PV system sized substantially over the calculated annual electricity use of the building, which may violate current utility net energy metering (NEM) requirements and adversely impact the local and regional electricity grid. The proposed approach and EDR2 Margins represent a technically feasible and cost-effective approach that could more easily be adopted and justified by a local jurisdiction.

EDR2 Margins are proposed in place of absolute EDR2 Targets to treat buildings of different conditioned floor area more equitably. Smaller homes generally have slightly higher EDR2 values than larger homes, making it harder for smaller homes, such as accessory dwelling units, to meet the same EDR2 Target.

This proposal responds to two types of reach codes that have been consistently adopted by jurisdictions under the 2019 code cycle. The “electric-preferred” reach code, represented by the proposed Tier 1, provides a path for mixed-fuel buildings but establishes more stringent requirements for these buildings than for all-electric buildings. The other type of reach code currently adopted is “electric-required” where no path is provided for mixed-fuel buildings and all-electric construction is required. This approach is represented by the proposed Tier 2.

5.3.3 Energy Savings

EDR2 Margin targets were developed using reach code analysis conducted for low-rise residential buildings for the 2019 Title 24, Part 6 code as a starting point (Statewide Reach Codes Team 2019). The packages presented in the statewide report were refined to better align with CALGreen's two-tiered approach and reflect technology advancements and savings and cost-effectiveness impacts based on the 2022 TDV and revised proposed baselines. CBECC-Res 2022.0.4 RV (1174) was used for all simulations.

The following is a description of the measures applied in the packages. A summary of the differences between each package and the base case against which energy savings and cost impacts are evaluated is presented in Table 10 through Table 13. The highlighted cells in the tables represent any differences for each component.

Solar Photovoltaics (PV): Installation of on-site PV is prescriptively required in the 2019 residential code. The PV sizing methodology in each package was developed to offset annual building electricity use and avoid too much oversizing violating NEM rules.[6] The following sizing approach was applied. Table 9 provides details on the PV size by climate zone for each case.

- **Tier 1 Mixed-Fuel:** PV system sized to offset 120 percent of annual estimated electricity use (coupled with battery storage).
- **Tier 1 All-Electric:** Increase Standard Design PV system size by 0.4 to 1.1 kW_{DC} (except in Climate Zone 16). This increase was established to achieve a 3 Total EDR2 Margin relative to an all-electric home meeting the 2019 Title 24, Part 6 prescriptive requirements. Relative to the Energy Commission's proposed 2022 baseline (see Appendix A) a 2019 prescriptive all-electric code compliant home achieves a Total EDR2 Margin of 2 to 5, except in Climate Zone 16 where there is a compliance penalty of -4.
- **Tier 2 All-Electric:** PV system sized to offset 100 percent of annual estimated electricity use.

In all cases, PV is evaluated in CBECC-Res according to the California Flexible Installation (CFI1) assumptions.

[6] NEM rules apply to the IOU territories only.

Table 9: Proposed PV Size by Case and Climate Zone (kW_{DC})

Climate Zone	Base Case (per 2019 code)	Tier 1 Mixed-Fuel	Tier 1 All-Electric	Tier 2 Mixed-Fuel	Tier 2 All-Electric
1	3.4	5.8	4.5	n/a	8.4
2	2.8	4.6	3.6	n/a	5.9
3	2.7	4.2	3.4	n/a	4.9
4	2.7	4.2	3.5	n/a	4.8
5	2.5	3.9	3.0	n/a	4.5
6	2.5	3.4	3.0	n/a	3.9
7	2.7	3.5	3.2	n/a	4.1
8	2.9	3.8	3.4	n/a	4.2
9	2.8	3.8	3.3	n/a	4.1
10	3.0	4.2	3.5	n/a	4.5
11	3.7	5.4	4.6	n/a	6.3
12	2.9	4.6	3.7	n/a	5.4
13	3.8	5.7	4.8	n/a	5.9
14	2.9	4.9	3.6	n/a	5.2
15	5.0	6.4	5.6	n/a	6.1
16	2.7	4.4	2.7	n/a	6.7

Battery Storage: A ten kWh battery system was evaluated in CBECC-Res for the Tier 1 mixed-fuel case, with control type set to “Advanced DR Control” and with default efficiencies of 95 percent for both charging and discharging. This control option requires the battery storage system to meet the DR control requirements specified in Title 24, Part 6 Section 110.12(a) and have the ability to change the charging and discharging periods in response to signals from the local utility or a third-party aggregator.

In CBECC-Res a battery system with Advanced DR Control uses the current day’s TDV schedule to make dynamic time-of-use priorities. This strategy activates on days that have a peak TDV greater than ten TDV/kBtu. On all other days, the battery system charges when production exceeds demand and the battery is not fully charged, and discharges when demand exceeds production.

HPWH: To estimate energy savings and demonstrate cost effectiveness for the Tier 1 heat pump requirement for mixed-fuel buildings, the water heating end-use was evaluated. A HPWH was evaluated and compared to a gas tankless water heater, both of which are minimally compliant with federal standards. All other building characteristics were compliant with the proposed 2022 base case in both simulations, including the compact water heating and drain water heat recovery credits (see Table 74 in Appendix A).

Table 10: Summary of Difference Between Base Case and Proposed Case for Tier 1 Mixed-Fuel EDR2 Margin Analysis[1]

Climate Zone	Base Case					Proposed Case				
	Space Heating Type	Water Heating	Cooking/ Drying Fuel	PV (kW)	Battery	Space Heating	Water Heating	Cooking/ Drying Fuel	PV (kW)[2]	Battery
1	Gas Furnace	HPWH	Gas	3.4	None	Gas Furnace	HPWH	Gas	5.8	10kWh
2	Gas Furnace	HPWH	Gas	2.8	None	Gas Furnace	HPWH	Gas	4.6	10kWh
3	Heat Pump	Gas Tankless	Gas	2.7	None	Heat Pump	Gas Tankless	Gas	4.2	10kWh
4	Heat Pump	Gas Tankless	Gas	2.7	None	Heat Pump	Gas Tankless	Gas	4.2	10kWh
5	Heat Pump	Gas Tankless	Gas	2.5	None	Heat Pump	Gas Tankless	Gas	3.9	10kWh
6	Heat Pump	Gas Tankless	Gas	2.5	None	Heat Pump	Gas Tankless	Gas	3.4	10kWh
7	Heat Pump	Gas Tankless	Gas	2.7	None	Heat Pump	Gas Tankless	Gas	3.5	10kWh
8	Heat Pump	Gas Tankless	Gas	2.9	None	Heat Pump	Gas Tankless	Gas	3.8	10kWh
9	Heat Pump	Gas Tankless	Gas	2.8	None	Heat Pump	Gas Tankless	Gas	3.8	10kWh
10	Heat Pump	Gas Tankless	Gas	3.0	None	Heat Pump	Gas Tankless	Gas	4.2	10kWh
11	Gas Furnace	HPWH	Gas	3.7	None	Gas Furnace	HPWH	Gas	5.4	10kWh
12	Gas Furnace	HPWH	Gas	2.9	None	Gas Furnace	HPWH	Gas	4.6	10kWh
13	Heat Pump	Gas Tankless	Gas	3.8	None	Heat Pump	Gas Tankless	Gas	5.7	10kWh
14	Heat Pump	Gas Tankless	Gas	2.9	None	Heat Pump	Gas Tankless	Gas	4.9	10kWh
15	Heat Pump	Gas Tankless	Gas	5.0	None	Heat Pump	Gas Tankless	Gas	6.4	10kWh
16	Gas Furnace	HPWH	Gas	2.7	None	Gas Furnace	HPWH	Gas	4.4	10kWh

[1]Differences between the base case and proposed case are highlighted in blue.

[2]Proposed case PV system sized to 120 percent of annual estimated electricity use.

Table 11: Summary of Difference Between Base Case and Proposed Case for Tier 1 Mixed-Fuel Heat Pump Requirement[1]

Climate Zone	Base Case					Proposed Case				
	Space Heating Type	Water Heating	Cooking/ Drying Fuel	PV (kW)	Battery	Space Heating	Water Heating	Cooking/ Drying Fuel	PV (kW)	Battery
1	Gas Furnace	Gas Tankless	Gas	3.4	None	Gas Furnace	HPWH	Gas	3.4	None
2	Gas Furnace	Gas Tankless	Gas	2.8	None	Gas Furnace	HPWH	Gas	2.8	None
3	Heat Pump	Gas Tankless	Gas	2.7	None	Heat Pump	HPWH	Gas	2.7	None
4	Heat Pump	Gas Tankless	Gas	2.7	None	Heat Pump	HPWH	Gas	2.7	None
5	Heat Pump	Gas Tankless	Gas	2.5	None	Heat Pump	HPWH	Gas	2.5	None
6	Heat Pump	Gas Tankless	Gas	2.5	None	Heat Pump	HPWH	Gas	2.5	None
7	Heat Pump	Gas Tankless	Gas	2.7	None	Heat Pump	HPWH	Gas	2.7	None
8	Heat Pump	Gas Tankless	Gas	2.9	None	Heat Pump	HPWH	Gas	2.9	None
9	Heat Pump	Gas Tankless	Gas	2.8	None	Heat Pump	HPWH	Gas	2.8	None
10	Heat Pump	Gas Tankless	Gas	3.0	None	Heat Pump	HPWH	Gas	3.0	None
11	Gas Furnace	Gas Tankless	Gas	3.7	None	Gas Furnace	HPWH	Gas	3.7	None
12	Gas Furnace	Gas Tankless	Gas	2.9	None	Gas Furnace	HPWH	Gas	2.9	None
13	Heat Pump	Gas Tankless	Gas	3.8	None	Heat Pump	HPWH	Gas	3.8	None
14	Heat Pump	Gas Tankless	Gas	2.9	None	Heat Pump	HPWH	Gas	2.9	None
15	Heat Pump	Gas Tankless	Gas	5.0	None	Heat Pump	HPWH	Gas	5.0	None
16	Gas Furnace	Gas Tankless	Gas	2.7	None	Gas Furnace	HPWH	Gas	2.7	None

[1]Differences between the base case and proposed case are highlighted in blue.

Table 12: Summary of Difference Between Base Case and Proposed Case for Tier 1 All-Electric EDR2 Margin Analysis[1]

Climate Zone	Base Case					Proposed Case				
	Space Heating Type	Water Heating	Cooking/ Drying Fuel	PV (kW)	Battery	Space Heating	Water Heating	Cooking/ Drying Fuel	PV (kW)[2]	Battery
1	Gas Furnace	HPWH	Electric	3.4	None	Heat Pump	HPWH	Electric	4.5	None
2	Gas Furnace	HPWH	Electric	2.8	None	Heat Pump	HPWH	Electric	3.6	None
3	Heat Pump	Gas Tankless	Electric	2.7	None	Heat Pump	HPWH	Electric	3.4	None
4	Heat Pump	Gas Tankless	Electric	2.7	None	Heat Pump	HPWH	Electric	3.5	None
5	Heat Pump	Gas Tankless	Electric	2.5	None	Heat Pump	HPWH	Electric	3.0	None
6	Heat Pump	Gas Tankless	Electric	2.5	None	Heat Pump	HPWH	Electric	3.0	None
7	Heat Pump	Gas Tankless	Electric	2.7	None	Heat Pump	HPWH	Electric	3.2	None
8	Heat Pump	Gas Tankless	Electric	2.9	None	Heat Pump	HPWH	Electric	3.4	None
9	Heat Pump	Gas Tankless	Electric	2.8	None	Heat Pump	HPWH	Electric	3.3	None
10	Heat Pump	Gas Tankless	Electric	3.0	None	Heat Pump	HPWH	Electric	3.5	None
11	Gas Furnace	HPWH	Electric	3.7	None	Heat Pump	HPWH	Electric	4.6	None
12	Gas Furnace	HPWH	Electric	2.9	None	Heat Pump	HPWH	Electric	3.7	None
13	Heat Pump	Gas Tankless	Electric	3.8	None	Heat Pump	HPWH	Electric	4.8	None
14	Heat Pump	Gas Tankless	Electric	2.9	None	Heat Pump	HPWH	Electric	3.6	None
15	Heat Pump	Gas Tankless	Electric	5.0	None	Heat Pump	HPWH	Electric	5.6	None
16	Gas Furnace	HPWH	Electric	2.7	None	Heat Pump	HPWH	Electric	2.8	None

[1]Differences between the base case and proposed case are highlighted in blue.

[2]Proposed case PV system sized to be 0.4 to 1.1 kW_{DC} larger than the base case.

Table 13: Summary of Difference Between Base Case and Proposed Case for Tier 2 All-Electric EDR2 Margin Analysis[1]

Climate Zone	Base Case					Proposed Case				
	Space Heating Type	Water Heating	Cooking/ Drying Fuel	PV (kW)	Battery	Space Heating	Water Heating	Cooking/ Drying Fuel	PV (kW)[2]	Battery
1	Gas Furnace	HPWH	Electric	3.4	None	Heat Pump	HPWH	Electric	8.4	None
2	Gas Furnace	HPWH	Electric	2.8	None	Heat Pump	HPWH	Electric	5.9	None
3	Heat Pump	Gas Tankless	Electric	2.7	None	Heat Pump	HPWH	Electric	4.9	None
4	Heat Pump	Gas Tankless	Electric	2.7	None	Heat Pump	HPWH	Electric	4.8	None
5	Heat Pump	Gas Tankless	Electric	2.5	None	Heat Pump	HPWH	Electric	4.5	None
6	Heat Pump	Gas Tankless	Electric	2.5	None	Heat Pump	HPWH	Electric	3.9	None
7	Heat Pump	Gas Tankless	Electric	2.7	None	Heat Pump	HPWH	Electric	4.1	None
8	Heat Pump	Gas Tankless	Electric	2.9	None	Heat Pump	HPWH	Electric	4.2	None
9	Heat Pump	Gas Tankless	Electric	2.8	None	Heat Pump	HPWH	Electric	4.1	None
10	Heat Pump	Gas Tankless	Electric	3.0	None	Heat Pump	HPWH	Electric	4.5	None
11	Gas Furnace	HPWH	Electric	3.7	None	Heat Pump	HPWH	Electric	6.3	None
12	Gas Furnace	HPWH	Electric	2.9	None	Heat Pump	HPWH	Electric	5.4	None
13	Heat Pump	Gas Tankless	Electric	3.8	None	Heat Pump	HPWH	Electric	5.9	None
14	Heat Pump	Gas Tankless	Electric	2.9	None	Heat Pump	HPWH	Electric	5.2	None
15	Heat Pump	Gas Tankless	Electric	5.0	None	Heat Pump	HPWH	Electric	6.1	None
16	Gas Furnace	HPWH	Electric	2.7	None	Heat Pump	HPWH	Electric	6.7	None

[1]Differences between the base case and proposed case are highlighted in blue.

[2]Proposed case PV system sized to 100 percent of annual estimated electricity use.

5.3.3.1 Tier 1 EDR2 Margins

Energy savings and peak demand reductions per unit are presented in Table 14 for a mixed-fuel building and Table 15 for an all-electric building to meet the Tier 1 EDR2 Margins from Table 7. In both cases savings are presented relative to a mixed-fuel code compliant home meeting the proposed 2022 base case with a heat pump for either space heating or water heating, depending on climate zone. Cooking and clothes drying fuel are natural gas for the mixed-fuel home and electric for the all-electric home and are the same between the base case and proposed case.

For the mixed-fuel home, Tier 1 energy impacts are a result of electricity savings from a larger PV system as well as a ten kWh battery storage system. Per-unit electricity impacts for the first year are expected to range from 1,148 to 3,515 kWh and 0 therm depending upon climate zone. Demand reductions are expected to range between 1.18 kW and 2.11 kW depending on climate zone.

For the all-electric home, energy impacts are a result of electricity savings from a larger PV system as well as electrification of either the space heating or water heating load. Per-unit electricity impacts for the first year are expected to range from savings of 564 kWh to an increase of 2,352 kWh, depending upon climate zone. Natural gas savings range from 83 to 355 therm per year. Demand impacts are expected to range from savings of 0.03 kW to an increase of 0.13 kW, depending on climate zone. There is no proposed above-code requirement for Climate Zone 16; and therefore, no savings are presented.

Table 14: Tier 1 EDR Margin Performance Requirement First-Year Energy Impacts Per Home – Single Family Mixed-Fuel

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therm/yr)	TDV Energy Savings (TDV kBtu/yr)
1	2,873	1.28	0	121,241
2	2,559	1.31	0	124,379
3	2,197	1.18	0	108,383
4	2,140	1.20	0	112,577
5	2,207	1.50	0	118,820
6	1,358	1.30	0	101,867
7	1,148	2.11	0	103,845
8	1,312	1.20	0	104,732
9	1,539	1.56	0	116,562
10	1,946	1.47	0	106,754
11	2,564	1.73	0	121,632
12	2,429	1.30	0	122,106
13	2,923	1.96	0	133,445
14	3,515	1.74	0	141,809
15	2,250	1.69	0	113,078
16	2,480	1.36	0	122,006

Table 15: Tier 1 EDR Margin Performance Requirement First-Year Energy Impacts Per Home – Single Family All-Electric

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therm/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(2,352)	0.03	355	32,537
2	(992)	0.02	202	31,562
3	(240)	(0.11)	126	27,444
4	61	(0.11)	118	33,831
5	(432)	(0.10)	118	22,710
6	(139)	(0.10)	114	30,545
7	(216)	(0.13)	113	28,454
8	(110)	(0.06)	104	30,656
9	54	(0.05)	103	32,259
10	(11)	(0.03)	103	30,648
11	(463)	(0.05)	181	33,717
12	(477)	0.00	168	30,188
13	519	(0.02)	109	39,671
14	(69)	(0.02)	114	31,197
15	564	(0.00)	83	36,354
16	n/a	n/a	n/a	n/a

5.3.3.2 Tier 1 Heat Pump Requirement: HPWH

Water heating end-use was evaluated to estimate energy savings and demonstrate cost effectiveness for the Tier 1 heat pump requirement for mixed-fuel buildings. Energy and peak demand impacts per unit are presented in Table 16. Switching from a natural gas tankless water heater to a HPWH results in per-unit electricity increases for the first year between 566 and 1,687 kWh, depending on climate zone, and natural gas savings between 83 and 126 therm per year. Electricity demand increases are expected to range between 0.01 kW and 0.17 kW depending upon climate zone.

This measure on its own results in TDV energy savings in all case except in Climate Zones 1 and 16, where cold conditions impact HPWH performance. Energy savings can be realized with higher performance HPWHs, such as those rated by the Northwest Energy Efficiency Alliance[7] as Tier 3 or 4; however, this evaluation is limited by federal preemption and higher performance HPWHs cannot be used as the basis of a local ordinance. Other design strategies also improve performance, such as locating the

[7] https://neea.org/our-work/advanced-water-heating-specification

HPWH in conditioned space[8] and ducting the exhaust air streams, but CBECC-Res does not have the capability to evaluate ducted HPWHs currently. For Climate Zone 1 and 16 the combined impact of switching from gas to heat pump water heating and meeting the Tier 1 EDR2 Margin targets is evaluated and the results presented in Table 17. There are electricity and natural gas savings in both cases.

Table 16: Tier 1 Heat Pump Requirement First-Year Energy Impacts Per Home – Single Family Mixed-Fuel

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therm/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(1,687)	(0.17)	126	(482)
2	(1,425)	(0.14)	124	8,044
3	(1,409)	(0.13)	126	8,539
4	(1,195)	(0.13)	118	11,907
5	(1,233)	(0.11)	118	9,622
6	(1,028)	(0.12)	114	15,339
7	(1,002)	(0.14)	113	15,480
8	(852)	(0.07)	104	16,643
9	(867)	(0.07)	103	15,713
10	(884)	(0.04)	103	15,372
11	(1,166)	(0.05)	111	10,794
12	(1,235)	(0.11)	117	10,383
13	(1,048)	(0.05)	109	13,230
14	(1,237)	(0.04)	114	10,434
15	(566)	(0.01)	83	16,677
16	(1,311)	(0.08)	97	(9,591)

Table 17: Combined Tier 1 EDR2 Margin and Heat Pump Requirement First-Year Energy Impacts Per Home – Single Family Mixed-Fuel

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therm/yr)	TDV Energy Savings (TDV kBtu/yr)
1	1,186	1.11	126	120,759
16	1,170	1.28	97	112,415

[8] Or other locations that are warmer or more tempered than an unconditioned garage.

5.3.3.3 Tier 2 EDR2 Margins

The all-electric Tier 2 case was evaluated relative to a mixed-fuel code compliant home with a heat pump for either space heating or water heating depending on climate zone. Energy savings and peak demand reductions per unit are presented in Table 18 to meet the Tier 2 EDR2 Margins from Table 7. Energy impacts are a result of natural gas savings resulting from elimination of natural gas space or water heating appliance and electricity savings from a larger PV system. Cooking and clothes drying are electric in both the base case and proposed case. Per-unit savings for the first year are expected to range from 1,341 to 3,081 kWh and 83 to 359 therms depending upon climate zone. Demand impacts are expected to range from savings of 0.14 kW to an increase of 0.11 kW depending on climate zone.

Table 18: Tier 2 EDR2 Margin Performance Requirement First-Year Energy Impacts Per Home – Single Family All-Electric

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therm/yr)	TDV Energy Savings (TDV kBtu/yr)
1	2,795	0.14	355	114,134
2	2,534	0.08	202	90,626
3	2,242	(0.06)	126	67,691
4	2,153	(0.07)	118	70,457
5	2,244	(0.06)	118	66,458
6	1,499	(0.08)	114	58,800
7	1,341	(0.11)	113	54,525
8	1,365	(0.04)	104	58,649
9	1,549	(0.04)	103	59,225
10	1,834	(0.00)	103	63,027
11	2,267	(0.01)	181	79,124
12	2,341	0.05	168	76,686
13	2,470	0.01	109	72,494
14	3,081	0.02	114	86,951
15	1,450	0.01	83	51,768
16	2,416	0.10	359	89,268

5.3.4 Cost Effectiveness

5.3.4.1 Incremental Costs

Table 19: Tier 1 & 2 Performance Standards Incremental Costs for a 2,400 Square Foot Single Family Building presents incremental cost assumptions used to meet the

proposed Tier 1 and Tier 2 EDR2 Margin requirements. Table 20 summarizes HPWH incremental cost assumptions for the Tier 1 heat pump requirement. Costs are based on the 2019 low-rise residential new construction reach code report (Statewide Reach Codes Team 2019) and have been updated in some cases based on improved data. Incremental costs represent the equipment, installation, replacement, and maintenance costs of the proposed measures relative to the base case. Replacement costs are applied to water heating equipment, PV inverters, and battery systems over the 30-year evaluation period. Costs were estimated to reflect costs to the building owner. All costs are provided as present value in 2023 (2023 PV$).

Table 19: Tier 1 & 2 Performance Standards Incremental Costs for a 2,400 Square Foot Single Family Building

Measure	Incremental First Cost (2023 PV$)	Incremental Replacement Cost (2023 PV$)	Source and Notes
PV System	$3.43/$W_{DC}$	$0.44/$W_{DC}$	First costs are from LBNL's *Tracking the Sun* 2019 costs (Barbose 2019) and represent costs for the first half of 2019 of $3.70/$W_{DC}$ for residential systems. These costs were reduced by 7% for the solar investment tax credit, which is the average credit across years 2023-2025 (22% for 2023 and 0% for 2024-2025 unless the credit is extended). Inverter replacement cost of $0.14/$W_{DC}$ present value includes replacements at year 11 at $0.15/$W_{DC}$ (nominal) and at year 21 at $0.12/$W_{DC}$ (nominal) per the 2019 PV CASE Report (California Energy Commission 2017). System maintenance costs of $0.31/$W_{DC}$ present value assume $0.02/$W_{DC}$ (nominal) annually per the 2019 PV CASE Report (California Energy Commission 2017).
Battery Storage	$690/kWh	$584kWh	$1,000/kWh first cost in 2020 based on Self-Generation Investment Program residential participant cost data. To estimate the first cost in future years this was reduced by 7% annually based on SDG&E's Behind-the-Meter Battery Market Study (E Source Companies 2020). This cost is further reduced by the solar investment tax credit which is 22% for 2023 and 0% for 2024-2025 unless the credit is extended). Costs are presented as the average of 2023, 2024, and 2025. Replacement cost at year 10 and 20 are calculated based on the 2020 cost of 1,000/kWh reduced by 7% annually over the subsequent 11 years for a future value cost of $450 (present value of $335 in year 10 and $249 in year 20).

Table 20: HPWH Compared to a Gas Tankless Incremental Costs for a 2,400 Square Foot Single Family Building

Measure	Incremental Cost (2023 PV$) First Cost	Incremental Cost (2023 PV$) Replacement Cost	Incremental Cost (2023 PV$) Total
Equipment & Install[a]	$0	$478	$478
Electric Service Upgrade[b]	$0	$0	$0
In-House Gas Piping[c]	($200)	$0	($200)
Total	**($200)**	**$478**	**$278**

Sources and notes:

a. 2019 low-rise residential new construction reach code report (Statewide Reach Codes Team 2019). Replacement costs are based on 15 years for HPWH and 20 years for tankless natural gas water heater.

b. No cost since 2019 Title 24, Part 6 code requires 240V electrical infrastructure be provided to all water heater locations.

c. 2019 low-rise residential new construction reach code report (Statewide Reach Codes Team 2019).

Table 21: Heat Pump Space Heater Compared to a Gas Furnace and Air Conditioner Incremental Costs for a 2,400 Square Foot Single Family Building

Measure	Incremental Cost (2023 PV$) First Cost	Incremental Cost (2023 PV$) Replacement Cost	Incremental Cost (2023 PV$) Total
Equipment & Install[a]	($221)	$787	$567
Electric Service Upgrade[b]	$220	$0	$220
In-House Gas Piping[c]	($200)	$0	($200)
Total	**($201)**	**$787**	**$586**

Sources and notes:

a. 2019 low-rise residential new construction reach code report (Statewide Reach Codes Team 2019). Replacement costs are based on 15 years for the heat pump and 20 years for the gas furnace and air conditioner.

b. Costs based on 2020 RS Means. Material and labor to install 30A 240V circuit less cost to install 15A 120V duplex outlet.

c. 2019 low-rise residential new construction reach code report (Statewide Reach Codes Team 2019).

5.3.4.2 Tier 1 EDR2 Margins

Per-unit cost-effectiveness results of the Tier 1 EDR2 margins are presented in Table 22 and Table 23 for the mixed-fuel and all-electric cases, respectively. The proposed packages save money over the 30-year period of analysis relative to the existing conditions. The proposed code change is cost effective in every climate zone except in Climate Zone 1 with the mixed-fuel package. The Climate Zone 1 package will be evaluated further for the final report and is expected to be cost effective once additional efficiency measures are incorporated.

There is no proposed above-code requirement for the all-electric case in Climate Zone 16 and therefore no analysis results are presented.

Table 22: Tier 1 EDR2 Margin Performance Requirement 30-Year Cost-Effectiveness Summary Per Single Family Mixed-Fuel Home

Climate Zone	Benefits TDV Energy Cost Savings + Other Savings (2023 PV$)	Costs Total Incremental Costs (2023 PV$)	Benefit-to-Cost Ratio
1	$20,975	$21,966	0.95
2	$21,517	$19,741	1.1
3	$18,750	$18,617	1.0
4	$19,476	$18,349	1.1
5	$20,556	$18,279	1.1
6	$17,623	$16,296	1.1
7	$17,965	$16,063	1.1
8	$18,119	$16,340	1.1
9	$20,165	$16,681	1.2
10	$18,468	$17,580	1.1
11	$21,042	$19,664	1.1
12	$21,124	$19,129	1.1
13	$23,086	$20,228	1.1
14	$24,533	$20,435	1.2
15	$19,562	$18,282	1.1
16	$21,107	$18,996	1.1

Table 23: Tier 1 EDR2 Margin Performance Requirement 30-Year Cost-Effectiveness Summary Per Single Family All-Electric Home

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings (2023 PV$)	Costs Total Incremental PV Costs (2023 PV$)	Benefit-to-Cost Ratio
1	$5,629	$4,968	1.1
2	$5,460	$3,520	1.6
3	$4,748	$3,092	1.5
4	$5,853	$3,223	1.8
5	$3,929	$2,072	1.9
6	$5,284	$2,235	2.4
7	$4,922	$2,135	2.3
8	$5,303	$1,965	2.7
9	$5,581	$2,285	2.4
10	$5,302	$2,181	2.4
11	$5,833	$4,223	1.4
12	$5,222	$3,517	1.5
13	$6,863	$3,949	1.7
14	$5,397	$2,640	2.0
15	$6,289	$2,736	2.3
16	n/a	n/a	n/a

5.3.4.3 Tier 1 Heat Pump Requirement: HPWH

Results of the cost-effectiveness analyses for Tier 1 heat pump requirement are presented in Table 24. To estimate energy savings and demonstrate cost effectiveness for the Tier 1 heat pump requirement, the water heating end-use is evaluated. The proposed package saves money over the 30-year period of analysis relative to the existing conditions and is cost effective in every climate zone except Climate Zones 1 and 16. The combined impact of switching from gas to heat pump water heating and meeting the Tier 1 EDR2 Margin targets is evaluated for these two climate zones and the results presented in Table 25. The combined package saves money over the 30-year period of analysis in Climate Zone 16 but not in Climate Zone 1. The Climate Zone 1 package will be evaluated further for the final report and is expected to be cost effective once additional efficiency measures are incorporated.

Table 24: Tier 1 Heat Pump Requirement 30-Year Cost-Effectiveness Summary Per Single Family Mixed-Fuel Home

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings (2023 PV$)	Costs Total Incremental PV Costs (2023 PV$)	Benefit-to-Cost Ratio
1	($83)	$278	---
2	$1,392	$278	5.0
3	$1,477	$278	5.3
4	$2,060	$278	7.4
5	$1,665	$278	6.0
6	$2,654	$278	9.5
7	$2,678	$278	9.6
8	$2,879	$278	10.3
9	$2,718	$278	9.8
10	$2,659	$278	9.6
11	$1,867	$278	6.7
12	$1,796	$278	6.5
13	$2,289	$278	8.2
14	$1,805	$278	6.5
15	$2,885	$278	10.4
16	($1,659)	$278	---

Table 25: Combined Tier 1 EDR2 Margin and Heat Pump Requirement 30-Year Cost-Effectiveness Summary Per Home - Single Family Mixed-Fuel

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings (2023 PV$)	Costs Total Incremental PV Costs (2023 PV$)	Benefit-to-Cost Ratio
1	$20,891	$22,244	0.9
16	$19,448	$19,274	1.0

5.3.4.4 Tier 2 EDR2 Margins

Cost-effectiveness results for the all-electric Tier 2 EDR2 margins are presented in Table 26. The proposed package saves money over the 30-year period of analysis relative to the existing conditions and the proposed code change is cost effective in every climate zone except Climate Zones 1 and 16. These two packages will be evaluated further for the final report and are expected to be cost effective once additional efficiency measures are incorporated.

Table 26: Tier 2 EDR Margin Performance Requirement 30-Year Cost-Effectiveness Summary Per Single Family All-Electric Home

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings (2023 PV$)	Costs Total Incremental PV Costs (2023 PV$)	Benefit-to-Cost Ratio
1	$19,745	$20,170	0.98
2	$15,678	$12,299	1.3
3	$11,710	$9,062	1.3
4	$12,189	$8,129	1.5
5	$11,497	$8,086	1.4
6	$10,172	$5,842	1.7
7	$9,433	$5,805	1.6
8	$10,146	$5,319	1.9
9	$10,246	$5,541	1.8
10	$10,904	$6,200	1.8
11	$13,688	$10,893	1.3
12	$13,267	$10,210	1.3
13	$12,541	$8,521	1.5
14	$15,042	$9,008	1.7
15	$8,956	$4,662	1.9
16	$15,443	$15,840	0.97

5.3.5 Additional Justification

Non-energy benefits of the proposed measures may include increased property valuation. For all-electric construction additional benefits are reduced greenhouse gas emissions and indoor air quality concerns.

5.4 Compliance and Enforcement

Single family projects will have to demonstrate compliance with two prerequisite options, instead of one as is currently required in the voluntary energy efficiency requirements (Section A4.2). Project teams will have to clearly note which options were chosen so that they can be confirmed by building inspectors. If project teams choose to verify the air infiltration rate of the building, they will have to coordinate with a third party HERS Rater for verification that the building does not exceed an infiltration rate of 1.5 air changes per hour at 50 Pascals. Since project teams also need to comply with a performance target that is more stringent than Title 24, Part 6, it will be important that the design and energy modeling stages of the project overlap so that there is an understanding of what adjustments need to be made to meet the performance targets. Building departments will need to confirm that the energy model complies with the relevant tier requirement and then confirm that those measures are implemented in the field.

6. Multifamily Code Change Recommendations

6.1 Tier 1 and Tier 2 Prerequisite Options

6.1.1 Description of Prerequisite Options

The Statewide CASE Team proposes a consolidation of multifamily voluntary CALGreen requirements into a new Section A4.204 for multifamily buildings. This section would include requirements from the 2019 low-rise residential and high-rise residential requirements which can be applied across all multifamily buildings and new prerequisite options. Prerequisite options from 2019 CALGreen requirements that would apply to multifamily buildings for the 2022 code include:

- Quality insulation installation
- High performance walls
- Drain water heat recovery
- Outdoor lighting

The following prerequisite options would be added:

- Building infiltration testing
- CPC Appendix M pipe sizing
- Induction cooktop

The proposed change also requires that buildings include two prerequisite options, rather than one, for Tier 1 and Tier 2. Changes to the existing prerequisite options and the proposed new options are described individually below including rationale for adding the measure and a discussion of compliance and enforcement. Energy savings and cost effectiveness are not presented for each proposed measure individually, but rather for the entire requirement that two prerequisite options be selected. CPC Appendix M pipe sizing, and outdoor lighting power are used to demonstrate cost effectiveness in this report.

6.1.1.1 High Performance Walls

Code Change Description

This measure would change the high performance walls prerequisite option from 0.048 to 0.051, consistent with the most stringent prescriptive U-factor listed in the proposed 2022 Title 24, Part 6 Table 170.2–A. It would additionally apply the prerequisite option to all multifamily buildings, including high-rise residential buildings.

Rationale

The 2019 CALGreen high performance walls prerequisite option is single-family-centric, aligning with the single family prescriptive U-factor. To apply this effectively in multifamily buildings, the U-factor must change to align with a wall assembly that is more feasible in multifamily buildings.

6.1.1.2 Drain Water Heat Recovery

Code Change Description

This measure would expand the existing prerequisite option for drain water heat recovery (DWHR) that applies to low-rise residential buildings so that would newly apply to high-rise residential buildings.

Rationale

DWHR is effective in taller multifamily buildings, where vertically stacked showers can share a DWHR system. Low-rise and high-rise residential buildings also have identical domestic hot water heating requirements in 2019 and proposed 2022 Title 24, Part 6. Including DWHR as a prerequisite option for high-rise buildings would align with Part 6 and create equity across multifamily buildings.

6.1.1.3 Outdoor Lighting Power

Code Change Description

This measure would extend the nonresidential (high-rise residential) prerequisite option to low-rise multifamily buildings. The measure would also add a color temperature requirement for Specific Applications (Table 170.2-Q in Title 24, Part 6) for outdoor lighting. Currently, Specific Applications are exempt from 3000K color temperature requirement and this measure would add a maximum 4000K color temperature requirement and remove the previous exemption.

Rationale

Multifamily buildings of all types have outdoor lighting and will have the same outdoor lighting requirements under 2022 Title 24, Part 6. Extending this high-rise prerequisite option would provide continuity for high-rise residential buildings and opportunity for savings in low-rise residential buildings.

This measure is possible due to two factors that influence the calculations employed by the Statewide CASE Team to determine outdoor lighting allowances for Title 24, Part 6. Outdoor lighting must meet the design criteria as established by the Illumination Engineering Society (IES) and LPA values must be calculated using lighting equipment available at the time of the calculations. The new requirements will go into effect several years later.

The gap between the calculation period and the code implementation date results in newer lighting products that employ the newest LED technology to become available. This makes the code proposed values easier to achieve by increasing the luminaire efficacy with the newest LED generations. If the LEDs are gaining five percent per year in efficacy, a two-year gap between the time of calculations to the time of adoption is expected to result in an improvement of light source efficacy of approximately ten percent, even if no other changes occur.

Second, the lighting calculations are normally dictated by a single criterion that will fail first within the set of criteria that the IES has established for the lighting situation. This is often the vertical illuminance minimum value or is sometimes a uniformity value. Taking this into account, comparing a reduced LPA allowance of 90 percent of the Title 24, Part 6 allowance shows that most of the lighting systems tested in the LPA calculations by the Statewide CASE Team meet or are below the Title 24, Part 6 LPA allowances by enough that they will still achieve the lower LPA values in CALGreen while also meeting the IES design criteria.

There is a growing body of evidence that suggests that exposure to blue light at night can be detrimental to people and many other animals. One specific strategy for reducing exposure to blue light at night is to use warmer (lower) correlated color temperature (CCT) light sources. Different CCT requirements for Specific Applications is important because some can be considered higher traffic areas which would benefit from higher visual acuity.

While limiting CCTs is a positive step towards addressing many issues related to health, light pollution, and consumer acceptance, the Statewide CASE Team recognizes it is not likely the best long-term solution. CCT is not a perfect indicator of melanopic content and does not address other inputs that may affect health, such as quantity of light and duration of exposure to light. The Statewide CASE Team made similar comments during the proposed updates to 2019 version of CALGreen and continues to agree that limiting CCT is likely still the best direction until a better metric is available. (Statewide CASE Team 2017f).

6.1.1.4 Building Infiltration Testing

Code Change Description

This measure would add a prerequisite option for all multifamily buildings to either test whole building infiltration or include both compartmentalization and balanced ventilation (where only one is required prescriptively in Title 24, Part 6).

Rationale

The whole building infiltration test would provide much needed data on baseline infiltration rates for California multifamily buildings as little currently exists. It would be valuable to collect typical infiltration values to establish a baseline infiltration rate that could support future code changes. At the project level, energy benefits would be realized as teams pay closer attention to air sealing, which would reduce heating and cooling needs and improve indoor air quality via compartmentalization and balanced ventilation.

6.1.1.5 CPC Appendix M Pipe Sizing

Code Change Description

This measure would add sizing of domestic hot water pipers using California Plumbing Code (CPC) Appendix M to the list of prerequisite options for all multifamily buildings.

Rationale

Appendix M was added to the Universal Plumbing Code in 2018 and includes a performance-based pipe sizing procedure. CPC 2019 Appendix M was adopted verbatim from the 2018 UPC. CPC Appendix M and the IAPMO water demand calculator account for modern low-flow fixtures required in California code and use a large new dataset of flow diversity in real buildings to create a more accurate prediction of peak flow for pipe sizing. Appendix M calculations typically result in smaller pipe sizes than standard practice sizing, which results in lower first costs and distribution system heat loss.

6.1.1.6 Induction Cooktop

Code Change Description

This measure would add a prerequisite option to use induction cooktops for all multifamily buildings.

Rationale

According to a recent study, induction stoves are over 85 percent efficient, compared to 70 percent for resistance (ceramic or coil) and methane gas burners (Frontier Energy 2019). Induction cooktops are safer and more efficient than other electric cooktop options. When a pot or pan is removed from an induction cooktop, the coil stops consuming energy. There is no flame or heat source to ignite a flammable object or cause burns (Frontier Energy 2019). The heat is used for the purpose of cooking and waste heat is significantly reduced. With proposed electrification of multifamily buildings under CALGreen, a prerequisite option for induction cooking will highlight that options exist within electric cooktops, send a signal to the market, and encourage smart selection, resulting in energy savings.

6.1.2 Energy Savings

6.1.2.1 CPC Appendix M Pipe Sizing

Energy savings per dwelling unit for CPC Appendix M Pipe Sizing are presented in Table 27 through Table 32 for each prototype building. Per-dwelling unit savings for the first year are expected to range from 1.0 to 3.1 therms per year depending upon climate zone and multifamily building type.

As shown in Table 27 and Table 29, prototypes with a greater number of pipes with large diameters have a higher percentage of surface area reduction. Table 27 and

Table 29 along with the energy savings results in Table 27 through Table 32 show that higher the surface area reduction leads to higher energy savings.

Table 27: Plumbing Design Summary and Pipe Lengths Using CPC Appendix A Sizing (Hunters Curve) (ft)

Pipe Diameter (inches)	Low-Rise Garden	Low-Rise Loaded Corridor	Mid-Rise Mixed Use	High-Rise Mixed Use
4	0	0	53	9
3	0	25	91	130
2.5	0	90	73	165
2	20	24	85	58
1.5	58	153	829	782
1	29	182	338	313
0.75	150	404	744	953

Table 28: Plumbing Design Summary, Pipe Lengths Using CPC Appendix M Sizing (IAPMO WDC) (ft), and Surface Area Reduction Compared to CPC Appendix A Sizing

Pipe Diameter (inches)	Low-Rise Garden	Low-Rise Loaded Corridor	Mid-Rise Mixed Use	High-Rise Mixed Use
4	0	0	0	0
3	0	0	0	5
2.5	0	0	121	129
2	0	80	66	80
1.5	52	107	244	148
1	55	287	1,058	1,095
0.75	150	404	724	953
Percent Surface Area Reduction for Each Prototype	**9%**	**14%**	**19%**	**20%**

Table 29: First-Year Energy Impacts Per Dwelling Unit – Low-Rise Garden

Climate Zone	Electricity Savings (kWh/Dwelling Unit)	Peak Electricity Demand Reductions (kW/Dwelling Unit)	Natural Gas Savings (therms/Dwelling Unit)	TDV Energy Savings (TDV kBtu/Dwelling Unit)
1	0	0	1.2	406
2	0	0	1.1	372
3	0	0	1.1	374
4	0	0	1.1	368
5	0	0	1.2	391
6	0	0	1.1	363
7	0	0	1.1	355
8	0	0	1.1	353
9	0	0	1.1	356
10	0	0	1.1	358
11	0	0	1.1	366
12	0	0	1.1	365
13	0	0	1.1	363
14	0	0	1.1	364
15	0	0	1.0	335
16	0	0	1.1	376

Table 30: First-Year Energy Impacts Per Dwelling Unit – Low-Rise Loaded Corridor

Climate Zone	Electricity Savings (kWh/Dwelling Unit)	Peak Electricity Demand Reductions (kW/Dwelling Unit)	Natural Gas Savings (therms/Dwelling Unit)	TDV Energy Savings (TDV kBtu/Dwelling Unit)
1	0	0	1.7	554
2	0	0	1.5	507
3	0	0	1.6	511
4	0	0	1.5	502
5	0	0	1.6	534
6	0	0	1.5	495
7	0	0	1.5	484
8	0	0	1.5	482
9	0	0	1.5	485
10	0	0	1.5	489
11	0	0	1.5	499
12	0	0	1.5	498
13	0	0	1.5	494
14	0	0	1.5	497
15	0	0	1.4	457
16	0	0	1.6	513

Table 31: First-Year Energy Impacts Per Dwelling Unit – Mid-Rise Mixed Use

Climate Zone	Electricity Savings (kWh/Dwelling Unit)	Peak Electricity Demand Reductions (kW/Dwelling Unit)	Natural Gas Savings (therms/Dwelling Unit)	TDV Energy Savings (TDV kBtu/Dwelling Unit)
1	0	0	2.8	681
2	0	0	2.6	624
3	0	0	2.6	628
4	0	0	2.6	617
5	0	0	2.7	656
6	0	0	2.5	609
7	0	0	2.5	596
8	0	0	2.5	593
9	0	0	2.5	598
10	0	0	2.5	601
11	0	0	2.5	613
12	0	0	2.5	613
13	0	0	2.5	608
14	0	0	2.5	611
15	0	0	2.3	562
16	0	0	2.6	631

Table 32: First-Year Energy Impacts Per Dwelling Unit – High-Rise Mixed Use

Climate Zone	Electricity Savings (kWh/Dwelling Unit)	Peak Electricity Demand Reductions (kW/Dwelling Unit)	Natural Gas Savings (therms/Dwelling Unit)	TDV Energy Savings (TDV kBtu/Dwelling Unit)
1	0	0	3.1	751
2	0	0	2.8	688
3	0	0	2.9	693
4	0	0	2.8	681
5	0	0	3.0	724
6	0	0	2.8	672
7	0	0	2.7	657
8	0	0	2.7	654
9	0	0	2.7	660
10	0	0	2.7	663
11	0	0	2.8	676
12	0	0	2.8	675
13	0	0	2.8	670
14	0	0	2.8	674
15	0	0	2.6	620
16	0	0	3.1	751

6.1.2.2 Outdoor Lighting Power Allowance

Table 33 provides the average characteristics observed through the analysis of approximately 24 different properties to help characterize the multifamily prototypes.

Table 33: Evaluated Site Characteristics by Prototype

Prototype	Floor Area (ft^2)	Unit Count	Building Footprint Area (ft^2)	Site Area (ft^2)	Hardscape Area (ft^2)	Site Perimeter (ft)	Hardscape Perimeter (ft)
High-Rise	143,729	145	43,959	88,801	36,876	1,330	3,255
Mid-Rise	179,832	161	77,048	185,011	74,109	1,742	6,718
Low Rise - Garden	46,150	45	38,584	153,578	66,136	1,608	5,546
Low Rise - Corridor	40,521	70	32,608	92,979	24,087	1,284	2,759

Table 34 provides the estimated first-year per-unit energy savings expected by implementing the CALGreen prerequisite of reducing the outdoor LPA to 90 percent of the standard allowance in Title 24, Part 6. Savings do not differ by climate zone.

Table 34: First-Year Energy Impacts Per Dwelling Unit – Outdoor Lighting LPA Reduction (90 Percent of Standard LPA)

Building Prototype	Electricity Savings (kWh/yr)	Peak Electricity Demand Reduction (kW)	Natural Gas Savings (therm/yr)	TDV Energy Savings (TDV kBtu/yr)
Low Rise Garden	26	0.0075	NA	247
Loaded Corridor	6.7	0.0019	NA	64
Mid-Rise Mixed Use	8.1	0.0023	NA	77
High Rise Mixed Use	4.5	0.0013	NA	43

6.1.3 Cost Effectiveness

6.1.3.1 CPC Appendix M Pipe Sizing

Because Appendix M (proposed case) sometimes leads to smaller pipe sizes than Hunter’s curve (baseline case), this is a cost saving measure, with the proposed case having a lower cost than the baseline case for all prototype buildings. Table 35 shows the incremental cost savings when comparing proposed Appendix M sizing to the base case using Hunter’s curve. This measure results in both energy and incremental cost savings, therefore it is cost-effective.

Table 35: Total Incremental Cost for Appendix M Pipe Sizing by Prototype Building

Prototype	Materials	Labor	Total
Low-Rise Garden	($1,172)	($2,052)	($3,224)
Low-Rise Loaded Corridor	($2,478)	($690)	($3,168)
Mid-Rise Mixed Use	($9,806)	($788)	($10,594)
High-Rise Mixed Use	($10,091)	($1,056)	($11,147)

6.1.3.2 Outdoor Lighting Power

There are no incremental costs associated with reducing outdoor lighting power. The same LED technology is used for both the base and proposed case. Additionally, the proposed case uses less equipment per square foot to achieve the recommended light levels as compared to the base case. Fewer luminaires, light poles, foundations, control equipment, wiring, and conduit are required to meet the lower lighting levels throughout the general hardscape areas. The Statewide CASE Team uses a conservative $0.00 incremental cost for this measure in the cost-effectiveness calculation.

Table 36 provides the savings, cost, and B/C ratio of the proposed measure.

Table 36: Cost Effectiveness of Multifamily Outdoor Lighting Power Reduction

Prototype	Units	**Benefits** TDV Energy Cost Savings + Other Savings[a] **(2023 PV$)**	**Costs** Total Incremental Costs **(2023 PV$)**	Benefit-to-Cost Ratio
2-Story Garden	Per Dwelling Unit	$22.98	$ 0	Infinite
3-Story Loaded Corridor	Per Dwelling Unit	$5.68	$ 0	Infinite
5-Story Mixed Use	Per Dwelling Unit	$6.82	$ 0	Infinite
10-Story Mixed Use	Per Dwelling Unit	$3.86	$ 0	Infinite

a. Nonresidential 15-year 2023 PV savings

6.2 Consultation with Utility Provider

6.2.1 Code Change Description

This measure would extend voluntary requirements for consultation with utility providers on solar photovoltaic (PV) system sizing to high-rise residential buildings.

6.2.2 Rationale

Proposed PV and battery storage requirements for 2022 Title 24, Part 6 necessitate extension of the low-rise CALGreen requirement for consultation with utility providers when sizing PV systems under CALGreen. Applying this measure universally across multifamily buildings will allow for unification for CALGreen requirements for multifamily buildings and streamline compliance and enforcement for multifamily buildings.

There are no energy savings associated with this measure.

6.3 Tier 1 and Tier 2 Performance Standards & Prescriptive Requirements

6.3.1 Code Change Description

This measure would revise the Tier 1 and Tier 2 performance targets for multifamily buildings, using the 2019 CALGreen high-rise structure of percentage of energy budget, rather than the EDR targets used for low-rise multifamily buildings under 2019 CALGreen. The Statewide CASE Team proposes climate zone-specific performance thresholds relative to the 2022 Title 24, Part 6 energy budget, as summarized in Table 37.

Table 37: Tier 1 and Tier 2 Multifamily Performance Targets by Climate Zone

Climate Zone	Tier 1 Mixed-Fuel	Tier 1 All-Electric	Tier 2 Mixed-Fuel	Tier 2 All-Electric
1	N/A	95%	N/A	93%
2	N/A	95%	N/A	93%
3	N/A	95%	N/A	93%
4	N/A	95%	N/A	93%
5	N/A	95%	N/A	93%
6	N/A	96%	N/A	94%
7	N/A	96%	N/A	94%
8	N/A	96%	N/A	94%
9	N/A	95%	N/A	93%
10	N/A	95%	N/A	93%
11	N/A	96%	N/A	94%
12	N/A	95%	N/A	93%
13	N/A	96%	N/A	94%
14	N/A	96%	N/A	94%
15	N/A	97%	N/A	96%
16	N/A	95%	N/A	93%

6.3.2 Rationale

The Statewide CASE Team suggests using percentage of energy budget as the performance metric for Tier 1 and Tier 2 because there are no EDR values for high-rise multifamily buildings currently. Using percent energy budget target for all multifamily buildings allows consistency with the consolidated structure of the 2022 Title 24 Part 6 standards and across low-rise and high-rise building. The existing performance targets for Tier 1 and Tier 2 for multifamily high-rise buildings are technically feasible but challenging to achieve cost effectively. The proposed performance targets represent a technically feasible and cost-effective approach that could more easily be adopted and justified by a local jurisdiction.

Note that the 2022 multifamily compliance software is not yet available, nor have ACM rules been assigned for multifamily buildings. The Statewide CASE Team used the 2022 research versions of CBECC-Res and CBECC-Com to estimate energy budgets and savings for low-rise and high-rise multifamily prototypes. Results may change with the transition to a 2022 multifamily software.

6.3.3 Energy Savings

The Statewide CASE Team developed energy budget performance targets based on packages of prerequisite options and other measures exceeding the proposed 2022 Title 24, Part 6 prescriptive requirements for multifamily buildings. The Statewide CASE Team analyzed several packages to establish appropriate Tier 1 and Tier 2 energy budget targets.

Package A: Domestic Hot Water (DHW)

- CPC Appendix M pipe sizing
- Drain water heat recovery

Package B: DHW + Lighting Power Density (LPD)

- Package A, plus
- 90 percent indoor common use area lighting power density for all common use areas and nonresidential spaces, except stairwells and hallways.

Package C: DHW + Envelope

- Package A, plus
- High performance walls with a 0.042 U-factor (0.048 for the 10-story prototype).
- Advanced Windows with a 0.22 U-factor

Note that package B was modeled only on CBECC-Com, and therefore only for the 5- and 10-story prototypes. Indoor lighting cannot be modeled in CBECC-Res. The Statewide CASE Team expects that the software used for multifamily buildings for 2022 Title 24 compliance will include ability to model indoor lighting for common use area and nonresidential spaces for all multifamily buildings.

Table 38: TDV Percent Savings from 2022 Title 24, Part 6 Multifamily Measures – 2-Story Garden Prototype

Climate Zone	Package A DHW	Package B DHW + LPD	Package C DHW + Envelope
1	7.2%	N/A	14.3%
2	8.0%	N/A	12.4%
3	10.6%	N/A	14.3%
4	8.5%	N/A	11.7%
5	11.0%	N/A	15.5%
6	10.1%	N/A	11.2%
7	11.0%	N/A	10.4%
8	7.9%	N/A	8.0%
9	7.7%	N/A	9.0%
10	6.9%	N/A	9.1%
11	5.5%	N/A	9.2%
12	6.9%	N/A	10.7%
13	5.6%	N/A	9.0%
14	5.7%	N/A	10.5%
15	3.8%	N/A	6.1%
16	6.0%	N/A	12.6%

Table 39: TDV Percent Savings from 2022 Title 24, Part 6 Multifamily Measures – 3-Story Loaded Corridor Prototype

Climate Zone	Package A DHW	Package B DHW + LPD	Package C DHW + Envelope
1	5.8%	N/A	10.3%
2	6.3%	N/A	9.0%
3	8.3%	N/A	10.4%
4	6.7%	N/A	8.1%
5	9.1%	N/A	11.3%
6	7.8%	N/A	7.3%
7	8.4%	N/A	7.1%
8	6.7%	N/A	6.4%
9	6.8%	N/A	7.3%
10	5.8%	N/A	7.1%
11	4.3%	N/A	6.6%
12	5.1%	N/A	7.1%
13	4.3%	N/A	6.4%
14	4.9%	N/A	7.9%
15	3.1%	N/A	4.3%
16	5.2%	N/A	9.7%

Table 40: TDV Percent Savings from 2022 Title 24, Part 6 Multifamily Measures – 5-Story Mixed Use Prototype

Climate Zone	Package A DHW	Package B DHW + LPD	Package C DHW + Envelope
1	5.0%	6.5%	9.1%
2	3.8%	5.5%	8.2%
3	4.7%	6.6%	7.8%
4	3.7%	5.5%	7.7%
5	5.1%	7.2%	7.9%
6	4.0%	6.1%	6.7%
7	4.3%	6.6%	6.4%
8	3.4%	5.4%	7.2%
9	3.4%	5.4%	7.2%
10	3.6%	5.4%	7.8%
11	3.2%	4.7%	8.7%
12	3.6%	5.2%	8.4%
13	3.0%	4.5%	8.3%
14	3.2%	4.9%	8.7%
15	2.3%	3.9%	7.9%
16	4.2%	5.4%	10.9%

Table 41: TDV Percent Savings from 2022 Title 24, Part 6 Multifamily Measures – 10-Story Mixed Use Prototype

Climate Zone	Package A DHW	Package B DHW + LPD	Package C DHW + Envelope
1	7.0%	8.0%	15.4%
2	5.0%	6.0%	12.7%
3	6.3%	7.5%	9.6%
4	4.8%	5.9%	9.9%
5	7.0%	8.2%	9.0%
6	5.2%	6.5%	5.4%
7	5.6%	7.0%	4.2%
8	4.3%	5.5%	6.6%
9	4.2%	5.3%	7.8%
10	4.5%	5.6%	9.7%
11	4.0%	4.9%	14.0%
12	4.7%	5.6%	13.0%
13	3.9%	4.7%	13.3%
14	4.0%	4.9%	13.6%
15	2.7%	3.6%	10.7%
16	5.2%	5.8%	19.5%

Table 42: Tier 1 Packages by Climate Zone and Prototype

Climate Zone	2-Story	3-Story	5-Story	10-Story
1	DHW	DHW	DHW	DHW
2	DHW	DHW	DHW + LPD	DHW + LPD
3	DHW	DHW	DHW + LPD	DHW
4	DHW	DHW	DHW + LPD	DHW + LPD
5	DHW	DHW	DHW	DHW
6	DHW	DHW	DHW + LPD	DHW
7	DHW	DHW	DHW	DHW
8	DHW	DHW	DHW + LPD	DHW
9	DHW	DHW	DHW + LPD	DHW + LPD
10	DHW	DHW	DHW + LPD	DHW + LPD
11	DHW	DHW	DHW + LPD	DHW
12	DHW	DHW	DHW + LPD	DHW + LPD
13	DHW	DHW	DHW + LPD	DHW + LPD
14	DHW	DHW	DHW + LPD	DHW + LPD
15	DHW	DHW	DHW + LPD	DHW + LPD
16	DHW	DHW	DHW + LPD	DHW

Table 43: Tier 2 Packages by Climate Zone and Prototype

Climate Zone	2-Story	3-Story	5-Story	10-Story
1	DHW	DHW + Envelope	DHW + Envelope	DHW
2	DHW	DHW + Envelope	DHW + Envelope	DHW + Envelope
3	DHW	DHW	DHW + Envelope	DHW + LPD
4	DHW	DHW + Envelope	DHW + Envelope	DHW + Envelope
5	DHW	DHW	DHW + LPD	DHW + LPD
6	DHW	DHW	DHW + LPD	DHW + LPD
7	DHW	DHW	DHW + LPD	DHW + LPD
8	DHW	DHW	DHW + Envelope	DHW + Envelope
9	DHW	DHW + Envelope	DHW + Envelope	DHW + Envelope
10	DHW + Envelope	DHW + Envelope	DHW + Envelope	DHW + Envelope
11	DHW + Envelope	DHW + Envelope	DHW + Envelope	DHW + Envelope
12	DHW + Envelope	DHW + Envelope	DHW + Envelope	DHW + Envelope
13	DHW + Envelope	DHW + Envelope	DHW + Envelope	DHW + Envelope
14	DHW + Envelope	DHW + Envelope	DHW + Envelope	DHW + Envelope
15	DHW + Envelope	DHW + Envelope	DHW + Envelope	DHW + Envelope
16	DHW + Envelope	DHW + Envelope	DHW + Envelope	DHW + Envelope

Energy cost savings by tier, climate zone, and prototype are summarized in Table 44 and Table 45.

Table 44: Tier 1 TDV Energy Cost Savings by Climate Zone and Prototype

Climate Zone	2-Story	3-Story	5-Story	10-Story
1	$830	$814	$913	$793
2	$773	$748	$1,187	$831
3	$782	$741	$1,190	$694
4	$761	$764	$1,161	$780
5	$795	$800	$857	$715
6	$706	$731	$1,149	$603
7	$710	$704	$749	$608
8	$675	$734	$1,132	$558
9	$669	$749	$1,146	$716
10	$720	$740	$1,196	$783
11	$779	$731	$1,225	$695
12	$792	$741	$1,243	$854
13	$753	$730	$1,211	$829
14	$742	$795	$1,227	$802
15	$613	$618	$1,129	$678
16	$952	$990	$1,363	$925

Table 45: Tier 2 TDV Energy Savings by Climate Zone and Prototype

Climate Zone	2-Story	3-Story	5-Story	10-Story
1	$830	$1,415	$1,654	$793
2	$773	$1,064	$1,787	$1,768
3	$782	$741	$1,405	$825
4	$761	$907	$1,631	$1,310
5	$795	$800	$1,198	$846
6	$706	$731	$1,149	$753
7	$710	$704	$1,142	$753
8	$675	$734	$1,509	$862
9	$669	$797	$1,532	$1,042
10	$941	$893	$1,719	$1,365
11	$1,305	$1,125	$2,291	$2,414
12	$1,219	$1,031	$2,025	$2,000
13	$1,217	$1,082	$2,237	$2,335
14	$1,348	$1,264	$2,189	$2,216
15	$965	$847	$2,290	$2,023
16	$1,992	$1,820	$2,759	$3,482

6.3.4 Cost Effectiveness

6.3.4.1 Incremental Costs

The Statewide CASE Team reviewed incremental measure costs from 2022 CASE Reports and combined costs for each measure package described in section 6.3.3 Energy . Incremental costs are summarized by measure below.

Table 46: Incremental Costs per Dwelling Unit by Measures and Prototype

Measure	2-Story Garden Style	3-Story Loaded Corridor	5-Story Mixed Use	10-Story Mixed Use	Source and Notes
CPC Appendix M pipe sizing	($403)	($88)	($120)	($95)	2022 Multifamily Domestic Hot Water Case Report
Drain water heat recovery	$618	$666	$997	$985	Draft 2022 Multifamily Domestic Hot Water Case Report, Drain Water Heat Recovery Appendix.
Window U-factor	$753	$740	$778	$1,190	2022 Multifamily Restructuring CASE Report
Wall-U-factor	$239	$134	$103	$32	2022 Multifamily Restructuring CASE Report
Lighting power density	$0	$0	$0	$0	

CPC Appendix M pipe sizing

Per Section 6.1.3.1, pipe sizing using Appendix M typically results in cost savings. Table 47 summarizes expected cost savings.

Table 47: Total Incremental Cost for Appendix M Pipe Sizing (Proposed)

Prototype	Materials	Labor	Total
Low-Rise Garden	($1,172)	($2,052)	($3,224)
Low-Rise Loaded Corridor	($2,478)	($690)	($3,168)
Mid-Rise Mixed Use	($9,806)	($788)	($10,594)
High-Rise Mixed Use	($10,091)	($1,056)	($11,147)

Drain water heat recovery

The Drain Water Heat Recovery Appendix in the Draft 2022 Multifamily Domestic Hot Water CASE Report includes cost information for various configurations of each of the multifamily prototypes. Table 48 includes incremental first costs per prototype building for drain water heat recovery configured to direct water back to the shower fixture.

Table 48: Incremental First Cost for DWHR by Prototype Building

Equipment/Material	2-Story Garden Style – DWHR shared by 2 DUs	3-Story Loaded Corridor – DWHR shared by 4 DUs	5-Story Mixed-Use – DWHR shared by 4 DUs	10-Story Mixed-Use – DWHR shared by 4.5 DUs
Heat Recovery Device	$1,555	$6,220	$18,660	$20,215
Floor Penetrations	$200	$1,600	$9,600	$11,700
Piping Cost	$72	$579	$7,455	$28,473
Meter Cost	$1,400	$9,100	$33,600	$40,950
Access Panel	$600	$1,950	$3,600	$3,900
Cold Water Pipe	$470	$1,410	$3,345	$6,690
Overhead/markup	15%	15%	15%	15%
Total	**$4,942**	**$23,987**	**$87,698**	**$115,262**

High performance walls

The cost of high performance walls is based on an increase in external continuous insulation at $0.37 per square foot in the 2-, 3-, and 5-story prototypes, and $0.14 per square foot in the 10-story prototype.

Advanced windows

Advanced window costs include the cost premium of a triple pane window, over double pane, at $7.35 per square foot of window area.

Lighting power density

There are no incremental costs associated with reducing lighting power. The same LED technology is used for both the base and proposed case. Additionally, the proposed case uses less equipment per square foot to achieve the recommended light levels as compared to the base case. Fewer luminaires, control equipment, wiring, and conduit are required to meet the lower lighting levels. The Statewide CASE Team uses a conservative $0.00 incremental cost for this measure in the cost-effectiveness calculation.

Cost-Effectiveness

Table 49 and Table 50 summarize cost-effectiveness of Tier 1 and Tier 2 packages over 30 years.

Table 49: Cost Effectiveness of Multifamily Tier 1 by Climate Zone and Prototype (Benefit-to-Cost Ratios)

Climate Zone	2-Story	3-Story	5-Story	10-Story
1	3.86	1.41	1.04	0.89
2	3.59	1.29	1.35	0.93
3	3.64	1.28	1.36	0.78
4	3.54	1.32	1.32	0.88
5	3.70	1.38	0.98	0.80
6	3.28	1.26	1.31	0.68
7	3.30	1.22	0.85	0.68
8	3.14	1.27	1.29	0.63
9	3.11	1.30	1.31	0.80
10	3.35	1.28	1.36	0.88
11	3.63	1.27	1.40	0.78
12	3.68	1.28	1.42	0.96
13	3.50	1.26	1.38	0.93
14	3.45	1.38	1.40	0.90
15	2.85	1.07	1.29	0.76
16	4.43	1.71	1.55	1.04

Table 50: Cost Effectiveness of Multifamily Tier 2 by Climate Zone and Prototype (Benefit-to-Cost Ratios)

Climate Zone	2-Story	3-Story	5-Story	10-Story
1	3.86	0.97	0.94	0.89
2	3.59	0.73	1.02	0.84
3	3.64	1.28	0.80	0.93
4	3.54	0.62	0.93	0.62
5	3.70	1.38	1.37	0.95
6	3.28	1.26	1.31	0.85
7	3.30	1.22	1.30	0.85
8	3.14	1.27	0.86	0.41
9	3.11	0.55	0.87	0.49
10	0.78	0.61	0.98	0.65
11	1.08	0.77	1.30	1.14
12	1.01	0.71	1.15	0.95
13	1.01	0.75	1.27	1.11
14	1.12	0.87	1.25	1.05
15	0.80	0.58	1.30	0.96
16	1.65	1.25	1.57	1.65

6.4 Compliance and Enforcement

Multifamily projects will have to demonstrate compliance with two prerequisite options, instead of one as is currently required. Project teams will have to clearly note which options were chosen so that they can be confirmed by building inspectors. If project teams choose to verify the air infiltration rate of the building they will have to coordinate with a third party HERS Rater or ATT for verification. Since project teams also need to comply with a performance target that is more stringent that Title 24, Part 6, it will be important that the design and energy modeling stages of the project overlap so that there is an understanding of what adjustments need to be made in order to meet the performance targets. Building departments will need to confirm that the energy model complies with the relevant tier requirement and then confirm that those measures are implemented in the field.

7. Nonresidential Code Change Recommendations

7.1 Prerequisite Requirement – Electric Readiness

7.1.1 Code Change Description

The nonresidential electric readiness prerequisite will add electrical and space requirements at the time of construction to accommodate the future retrofit or replacement of fossil-fuel burning devices with electricity-powered devices. It would be applicable for Tier 1 and Tier 2 compliance, in a new Section under A5.203.1.1. Specific requirements include:

1. Physical space to accommodate electric water heating equipment in the future.
2. Installation of condensate drain lines.
3. Electrical system sizing and design to accommodate shifts to electric devices in the future.

7.1.2 Rationale

This measure is intended to make future natural gas to electric retrofits feasible and cost-effective. Electric ready measures include new conduit or installing larger conductors at the time of construction so that wall penetrations and demolition work is avoided or minimized when the original gas systems are converted to electric systems. In some cases, electric appliances require more room in the building than natural gas appliances and a source of outside air. Requiring enough space for the electric appliances during construction will prevent large-scale and expensive renovation to accommodate retrofit from natural gas to electric in the future.

The measure requires documented space planning to show space available in the building to accommodate an electricity-powered device. In some circumstances it also requires installation of a condensate drain lines. It also requires that the electrical service to the location be either suitable to handle the future electricity-based equipment load, or that an accommodation for increased conduit size or an earmarked conduit be installed to provide easy access to the space for a future upgraded electrical service, depending on the circumstances.

The proposed requirements are based on calculations using specifications of equipment that is equivalent other than the primary fuel source being natural gas versus electricity. The proposed requirements are intended to guide the industry when the engineering resources are not available to perform electric-readiness analyses. Because these requirements govern conduit and panel sizes, which are relatively inexpensive to oversize in anticipation of future loads and will not become obsolete, the engineering calculations tend to oversize electrical capacity estimates to account for the wider range of equipment than has been analyzed.

Dozens of cities in California have adopted ordinances encouraging or requiring electrification.[9] The City of Seattle has adopted a code that requires large commercial to use heat pump space heating technology, including alterations.[10]

A few nuances to the approach are below:

- The Statewide CASE Team has not proposed electric ready measures for buildings that use packaged rooftop systems, which commonly use direct expansion air conditioning equipment. This is avoided because in the majority of nonresidential buildings the design cooling output of the packaged system will be equal to or larger than the design heating output, and the existing electrical infrastructure for the air conditioning equipment will accommodate the future heat pump conversion. The Statewide CASE Team confirmed that cooling loads are approximately equal to or higher than heating loads and for a variety of analyzed buildings, including offices, restaurants, retail, warehouses, and hotels.
- Conversely, where there is no cooling system installed, the Statewide CASE Team proposed that heating only systems be sized to be electric-ready. Cost effectiveness analysis has not yet been performed for this prototype, but the electric ready cost savings are anticipated to be similar to the cost savings in other prototypes. The Statewide CASE Team proposed to exempt heating-only ceiling hung heaters (e.g., infrared heaters) typically found in store fronts and warehouses as extensive demolition is not required to convert these to electric. Another proposed exemption is for heating-only systems with capacities larger than 300,000 Btu/h, because packaged air-to-air heat pumps are typically unavailable in these sizes.
- The Statewide CASE Team proposed an exemption for clothes drying appliances larger than 22,000 Btu/h, as heat pump technology is not currently available at these capacities. Research yielded that industrial-scale gas dryers may need to be replaced by multiple electric resistance clothes dryers, which may impact physical space needs or staff operational schedules.

7.1.3 Energy Savings

This measure does not result in energy savings, only retrofit cost savings.

7.1.4 Cost Effectiveness

Cost effectiveness for this measure is calculated by showing avoided cost of future retrofit. The Statewide CASE Team evaluated electric ready measures and incremental costs for space heating, service water heating (SHW), cooking, and clothes drying in

[9] https://www.buildingdecarb.org/active-code-efforts.html

[10] http://seattle.legistar.com/View.ashx?M=F&ID=9085266&GUID=545EA5F5-8C47-4A56-80FF-7846BA07EFCF

this analysis. Specifically, the Statewide CASE Team evaluated the following system types across different building types:

1. 53,000 ft^2 Medium Office
    a. HVAC: VAV reheat system - central hydronic gas boiler to heat pump boiler
    b. SHW: Gas water storage heater to heat pump water storage heater
2. 5,000 ft^2 Full-service restaurant and 2,500 ft^2 quick service restaurant SHW:
    a. Gas central water to heat pump water heater
    b. Gas cooking appliances to electric cooking appliances
3. 25,000 ft^2 Standalone Retail and 50,000 ft^2 Warehouse DHW: Gas instantaneous to electric instantaneous water heaters
4. 40,000 ft^2 Small Hotel:
    a. Gas clothes dryers to heat pump clothes dryers
    b. Service water heating serving clothes washers
    c. Central domestic water heating with recirculation loop serving guest rooms

Table 51 provides the present value cost savings estimates for scenarios employing the electric ready measure for the applicable building types and circumstances. Costs compare the current implementation to the present value of future work needed.

While the electric-ready measure includes physical space and condensate drain line requirements, determining the current design costs and future costs of retrofit for these measures is highly dependent on floorplan layout and structural design, and has not been performed. While these costs are excluded, the Statewide CASE Team found that engineers experienced with retrofitting existing buildings with central heat pump water heaters have the most challenges accommodating physical space and ductwork requirements for heat pump water heating equipment, storage, and heat exchange air. These considerations also tend to be the costliest.

Electrical system costs are included; the costs of other electrical changes that would be required now and would also be required at the time of the retrofit are not included as they are expected to be comparable. For example, if a larger building service were required to accommodate the new electric hardware and this same upgrade would likely happen in both the Electric Ready and non-Electric Ready situations, then it is not being priced in the exercise. Further detail is included in Appendix B.

Table 51: Present Value Savings of Electric-Ready Buildings Measure in Various Scenarios

Scenario	Electric Ready Conversion	Incremental Construction Cost for Electric Ready Measure	Present Value of Avoided Future Electrification Retrofit Costs	Present Value of Electric Ready Cost Savings
Medium Office – Central Hydronic Gas Space Heating	Office #1; Gas boiler (745,000 Btu/hr) for VAV reheat converted to heat pump boiler	$5,610	$7,558	$1,944
	Office #2; Gas boiler (500,000 Btu/hr) for VAV reheat converted to heat pump boiler	$3,819	$7,558	$3,739
Medium Office – Gas Storage Water Heating	Office #1; Gas water heater (76,000 Btu/hr) converted to heat pump	$2,381	$4,360	$1,980
	Office #2; Gas water heater (150,000 Btu/hr) converted to heat pump	$3,107	$5,450	$2,344
Full-Service Restaurant – Central Gas Water Heating	Gas central water heater (800,000 Btu/hr) with recirculation loop converted to heat pump	$5,610	$7,558	$1,944
Full-Service Restaurant - Cooking	2 gas ranges with oven, fryer, and broiler converted to electric	$9,498	$14,071	$4,574
Quick-Service Restaurant – Gas Water Heating	Gas central water heater (150,000 Btu/hr) with recirculation loop converted to heat pump	$3,819	$7,558	$3,739
Quick-Service Restaurant – Cooking	Gas range with oven and fryer converted to electric	$1,416	$3,687	$2,271
Standalone Retail – Gas Water Heating	Gas instantaneous water heater (1.3 gpm) converted to electric tankless water heater	$2,874	$11,077	$8,203
Warehouse – Gas Water Heating	Gas instantaneous water heater (1.3 gpm) converted to electric tankless water heater	$3,573	$12,828	$9,255
Small Hotel – On-Premise Laundry (Clothes Drying)	Gas dryer (425,000 btu/hr) converted to heat pump dryer	$4,144	$10,904	$6,760
Small Hotel – On-Premise Laundry (Clothes Washing)	Gas water heater (181,930 btu/hr) converted to heat pump water heater	$2,381	$4,360	$1,980
Small Hotel – Domestic Water Heating	Gas central water heater (181,930 btu/hr) with recirculation loop converted to heat pump water heater	$5,615	$8,758	$3,144

7.2 Exhaust Air Heat Recovery Prerequisite Option

7.2.1 Code Change Description

Requirements for exhaust air heat recovery will likely be included as a prescriptive requirement in 2022 Title 24, Part 6. If adopted into Title 24, Part 6, the corresponding prerequisite option should be removed from CALGreen. The prerequisite option that is available for 2019 CALGreen would no longer be available for the 2022 cycle.

7.2.2 Rationale

The existing exhaust air heat recovery prerequisite option in CALGreen requires heat to be recovered from exhaust air to precondition incoming outdoor air for situations that have been shown to be cost effective, based on building hours, fan size, and climate zone.

7.2.3 Energy Savings and Cost-Effectiveness

An energy savings and cost-effectiveness analysis is not required to remove a prerequisite option from CALGreen. The 2022 Title 24, Part 6 HVAC controls CASE Report presents energy savings and cost-effectiveness of a proposal to add to Title 24, Part 6.[11]

7.3 Outdoor Lighting Prerequisite Option

7.3.1 Code Change Description

The measure would add a color temperature requirement for Specific Applications (Table 140.7-B in Title 24, Part 6) for outdoor lighting. Currently, Specific Applications are exempt from 3000K color temperature requirement in CALgreen. This measure would add a maximum 4000K color temperature requirement and remove the previous exemption.

7.3.2 Rationale

There is a growing body of evidence that suggests exposure to blue light at night can be detrimental to both humans and animals. One step to minimizing unnecessary blue light at night is installing lighting controls to dim or turn off the lights when the area is not in use. Utilizing lighting controls saves energy and reduces the total amount of light at night which helps reduce over lighting in spaces not actively being used. Minimizing over lighting helps protect local flora, fauna, and humans. Another specific strategy for reducing exposure to blue light at night is to use lower (warmer) correlated color

[11] https://title24stakeholders.com/measures/cycle-2022/hvac-controls/.

temperature (CCT) light sources, and different CCT requirements for Specific Applications are important to allow a broader spectrum of light for improved visual acuity at building entrances and exits and where it may be desirable to align the exterior lighting with the interior lighting CCT.

Limiting CCTs is a positive step towards addressing many issues related to health, light pollution, and consumer acceptance, yet the Statewide CASE Team recognizes that it is not a perfect solution and is likely best utilized only as a short term solution. CCT is not always the best indicator of melanopic content and does not address other inputs that may affect health, such as quantity of light and duration of exposure to light. The Statewide CASE Team made similar comments during the proposed updates to 2019 version of CALGreen and continues to agree with them. Better metrics are under development but limiting CCTs is still the best short term solution at this time. (Statewide CASE Team 2017f) The Statewide CASE Team has chosen 4000K for Specific Applications instead of 3000K due to some evidence showing 4000K having an improved visual acuity over lower CCTs, which is important for the spaces covered by the Specific Applications LPAs. (Northwest Energy Efficiency Alliance 2014) The 4000K limit ultimately allows the higher visual acuity while still reducing exposure to blue light at night.

7.3.3 Energy Savings and Cost-Effectiveness

The Statewide CASE Team anticipates minimal to no energy savings or cost impacts from this measure. As noted in the 2022 Nonresidential Outdoor Sources Final CASE Report, the Specific Applications LPAs were updated in the 2019 Title 24, Part 6 code cycle but not in the current 2022 Title 24, Part 6 code cycle. Additionally, the 2019 Specific Applications LPAs were developed specifically with 3000K LEDs which are less efficacious than higher CCT LEDs. Therefore, there are no expected issues with meeting the proposed 4000K maximum. Additional information can be found in section 2.2.2 of the 2022 Nonresidential Outdoor Sources Final CASE Report (Statewide CASE Team 2020b).

7.4 Automatic Daylighting Controls Wattage Thresholds Prerequisite Option

7.4.1 Code Change Description

The measure would adjust the wattage thresholds that apply to both the primary and secondary sidelit daylit zones. The change would modify Exception 3 to Section 130.1(d) and Exception 1 to Section 140.6(d), substituting 75W where 120W appears, and 150W where 240W is now indicated. This revision reflects the appropriate threshold wattage now based on greater savings from daylighting controls.

7.4.2 Rationale

Title 24, Part 6 includes a mandatory requirement that the general lighting in skylit daylit zones, primary sidelit daylit zones, and secondary sidelit zones must have automatic daylighting controls unless there is less than 120 watts of general lighting installed in these daylit zones [Section 130.1(d) and Section 140.6(d)].[12] This 120-watt threshold has remained unchanged for multiple code cycles while lighting efficacy (lumens per watt) has significantly increased since the threshold was established. As the lighting power densities (LPDs) for indoor spaces continued to be reduced but the 120-watt threshold remained unchanged, fewer spaces were subject to the automatic daylighting controls requirement. These thresholds were developed with the assumption that under full daylight conditions, the lighting power is reduced to 35 percent of full power. The lighting to ten percent of full power, the minimum required control step for LED lighting in accordance with existing mandatory multi-level lighting control requirements in Table 130.1-A. Thus, daylighting controls would save more energy (larger full load hours per year savings) under the 2022 code than they do when the current threshold was proposed in 2013.

7.4.3 Energy Savings

Energy cost savings for an average office with 150 watts of lighting in the combined primary and secondary sidelit zone that are realized over the 15-year period of analysis are presented in 2023 present value dollars in Table 52.

Any instances of negative values are denoted in red with ( ) in the tables below.

Table 52: First-Year Energy Impacts and 2023 PV TDV Energy Cost Savings Over 15-Year Period of Analysis – Per 150 Watt Zone – New Construction/Additions/Alterations – Office Large

Climate Zone	Electricity Savings (kWh/150-watt Zone)	Natural Gas Savings (therm/150- watt Zone)	TDV Energy Savings (TDV kBtu/150-watt Zone)	15-Year TDV Energy Cost Savings (2023 PV$/150-watt Zone)
1	175	-1.3	3,081	$274
2	194	-0.5	4,494	$400
3	191	0.0	4,122	$367
4	199	0.0	4,747	$422
5	196	-0.2	3,849	$343
6	196	-0.5	4,352	$387
7	191	0.4	4,043	$360
8	206	0.3	5,276	$470
9	205	0.3	5,363	$477
10	233	0.3	6,081	$541
11	197	-0.3	4,501	$401
12	197	-0.3	4,554	$405
13	203	-0.2	4,787	$426
14	205	-0.2	5,261	$468
15	213	0.4	5,208	$464
16	190	-0.9	3,571	$318

7.4.4 Cost-Effectiveness

7.4.4.1 Incremental Cost

The incremental cost of adding daylighting controls to a 150-watt zone is presented in Table 53 as are assumptions used in the cost estimates. As discussed, the incremental cost is adding a photosensor to an existing wireless daylighting control system with local controls (not networked). The incremental maintenance cost is limited to replacing the battery of the added photosensor during years 6 and 12 during the 15-year period of analysis. It was assumed that the photosensor would not need to be replaced during the 15-year period of analysis.[7]

Table 53: Total Incremental PV Costs Per Square Foot – New Construction/ Additions and Alterations – OfficeLarge

ID	Factor	Value	Notes
A	Total Incremental First Cost (2023 PV$ per additional photosensor)	$290.51	B + C
B	Equipment (Photosensor cost ($/unit))	$142.50	Cost collected from outreach described in Section 4.3.1; only includes data points from photosensors that can be used to collect information for both a primary and secondary zone.
C	Labor (2023 PV$)	$148.01	C x D Installation and Commissioning Cost
D	Installation and commissioning time per zone (hours)	1.25	Assumed – includes time to install photosensor, connect to control system, and commission each photosensor for one primary zone and one secondary zone.
E	Labor rate ($/hr)	$118.41	See Table 20 in the Indoor Lighting CASE Report (California Utilities Statewide Codes and Standards Team 2020)
F	Total Incremental Maintenance Cost (2023 PV$ per photosensor)	$8.20	Calculated using 3% discount rate and battery replacements happening in year 6 and 12
G	Battery replacement ($ Nominal per photosensor per replacement)	$5.33	H + J
H	Battery (nominal $ per photosensor)	0.54	Two AA batteries; bulk pricing assumes $0.27/battery
I	Labor hours per photosensor (hours)	0.08	five minutes per photosensor
J	Labor cost ($)	$9.87	I x E
K	Photosensor battery lifetime (years)	6	Per photosensor specifications.
L	**Total Incremental Cost Over 15-year Period of Analysis (2023 PV$ per photosensor)**	**$299**	**A + F**

7.4.4.2 Cost Benefit by Climate Zone

The B/C ratio is calculated by dividing the cost benefits realized over 15 years by the total incremental costs, which includes maintenance costs over 15 years. The B/C ratio was calculated using 2023 PV costs and cost savings. Results are presented in Table 54. The revision would result in cost savings over the 15-year analysis period relative to the existing conditions in 15 of 16 climate zones. As mentioned previously, the energy simulations assumed lighting power would be reduced to 20 percent. If the Energy Commission accepts the Statewide CASE Team's proposal for the 2022 cycle that lighting power be reduced to ten percent, we expect the B/C ratio to be over 1 for all 16 climate zones.

Table 54: 15-Year Cost-Effectiveness Summary Per 150-Watt Zone – New Construction/Additions and Alterations - OfficeLarge

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings per ft² (2023 PV$/150-watt Zone) [a]	Costs Total Incremental PV Costs per ft² (2023 PV$ / 150-watt Zone) [b]	Benefit-to-Cost Ratio
1	$274	$299	0.9
2	$400	$299	1.3
3	$367	$299	1.2
4	$422	$299	1.4
5	$343	$299	1.1
6	$387	$299	1.3
7	$360	$299	1.2
8	$470	$299	1.6
9	$477	$299	1.6
10	$541	$299	1.8
11	$401	$299	1.3
12	$405	$299	1.4
13	$426	$299	1.4
14	$468	$299	1.6
15	$464	$299	1.6
16	$318	$299	1.1

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis. 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. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

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

7.5 Air Barrier Verification Prerequisite Option

7.5.1 Code Change Description

This measure would add a prerequisite option to require building air leakage be tested to confirm the air barrier is effective at limiting leakage to 0.25 cubic cfm/ft^2 when pressurized to 75 Pascals (Pa).

7.5.2 Rationale

2022 Title 24, Part 6 was updated to required buildings perform a field verification to confirm that the air leakage is below 0.40 cfm/ft^2 when pressurized to 75 Pascals (Pa). Consistent with Section C406 Additional Efficiency Package Options of the 2018 IECC (International Code Council 2017), the Statewide CASE Team is proposing a prescriptive option to verify that the measured air-leakage rate of the building does not exceed 0.25 cubic cfm/ft^2 when pressurized to 75 Pascals (Pa). Stakeholders have provided feedback that in the State of Washington where project teams are required to verify the building air-leakage rate already it is attractive to be able to receive credit for a lower rate. Achieving a lower rate does not require changes in construction practices, rather an attention to detail and strong coordination between building trades.

7.5.3 Energy Savings

Energy savings from this measure were also included as part of the performance tier modeling in Section 7.10.

7.5.4 Cost-Effectiveness

This measure does not have an incremental cost and so cost-effectiveness calculations are not needed.

7.6 Computer Room Efficiency Power Usage Effectiveness Monitoring Prerequisite Option

7.6.1 Code Change Description

This measure proposes adding mandatory power usage effectiveness (PUE) monitoring requirements for large computer rooms. This would apply to computer rooms where the information technology equipment (ITE) design load is over 2,000 kW and makes up 80 percent of the building’s overall cooling use.

7.6.2 Rationale

PUE is a common metric to evaluate energy efficiency for data centers. Measuring PUE provides data center operators feedback on how efficiently their computer room is performing and indicates its energy savings potential. Measuring PUE over time can also indicate reduced data center efficiency that occurs over time. The goal of making PUE monitoring mandatory is to give data center operators information they can act on to maintain high energy performance in the data center after construction. See the computer room efficiency CASE Report from the 2022 code cycle for additional background information.[13]

7.6.3 Energy Savings

The per-unit energy savings do not account for naturally occurring market adoption or compliance rates. Table 55 shows the first year per-unit energy savings and demand reduction ranges, which vary by climate zone and system type. There is a positive net energy savings in all climate zones.

Because this submeasure reduces mechanical system energy, which varies by climate zone, the energy savings vary with climate zone. The hotter the climate zone, the more energy savings this measure provides by resulting in a more efficient mechanical cooling and fan system.This submeasure would not have a significant impact on DR/flexibility, peak power demand, or load shifting.

Table 55: First-Year Energy Impacts Per IT Equipment Load kW – Chilled Water CRAH Case, PUE Monitoring Submeasure

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reduction (kW)	Natural Gas Savings (therm/yr)	TDV Energy Savings (TDV kBtu/yr)
1	8	0.0	0	215
2	9	0.0	0	254
3	9	0.0	0	251
4	9	0.0	0	251
5	9	0.0	0	239
6	11	0.0	0	301
7	10	0.0	0	297
8	11	0.0	0	305
9	10	0.0	0	294
10	11	0.0	0	300
11	10	0.0	0	294
12	10	0.0	0	277
13	11	0.0	0	303
14	10	0.0	0	294
15	12	0.0	0	345
16	9	0.0	0	255
TOTAL	**158**	**0.1**	**0**	**4,475**

[13] https://title24stakeholders.com/measures/cycle-2022/data-center-efficiency/.

7.6.4 Cost-Effectiveness

The Statewide CASE Team used the work completed in the 2022 Nonresidential Reduced Infiltration CASE Report to determine the cost effectiveness of PUE monitoring. This measure is cost effective in all climate zones.

Table 56: Incremental First Cost Assumptions: PUE Monitoring Measure

Cost Item	Incremental First Cost ($ per ITE design load kW)	Cost Source
Electric submeter for whole building load	$6.52	Average cost of 9 power meter products.
Installation Labor	$4.30	Estimate based on data from electrical and controls contractors
Controls	$0	N/A
Commissioning	$0.56	Estimate based on input from commissioning agents
In-house maintenance	$7.50	Estimate of $100,000/yr salary, does not include taxes and benefits
Total	**$18.88**	

Table 57: 15-Year Cost-Effectiveness Summary Per IT Equipment Load kW – New Construction and Additions/Alterations, PUE Monitoring Measure, Case 1: CHW CRAH

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$19	$19	1.0
2	$23	$19	1.2
3	$22	$19	1.2
4	$22	$19	1.2
5	$21	$19	1.1
6	$27	$19	1.4
7	$26	$19	1.4
8	$27	$19	1.4
9	$26	$19	1.4
10	$27	$19	1.4
11	$26	$19	1.4
12	$25	$19	1.3
13	$27	$19	1.4
14	$26	$19	1.4
15	$31	$19	1.6
16	$23	$19	1.2

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2020). 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. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

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

7.6.5 Compliance and Enforcement

- **Design Phase:** Electrical design engineers determine if the computer room ITE design load triggers the requirement for PUE monitoring. The ITE design load is typically calculated by the mechanical engineer, but the electrical engineer needs to know this information for sizing the electrical system. The electrical design engineer includes a PUE utilization monitoring system that meets code requirements in the electrical permit drawings and specifications. The project's building automation system can be used to monitor and trend PUE, and therefore this system may be included in the mechanical or controls specifications. The electrical design engineer completes NRCC forms with the permit package.

- **Permit Application Phase**: The plans examiner reviews electrical permit drawings and specifications to confirm if PUE monitoring is required and, if so, that it is shown on the permit documents.
- **Construction Phase**: The electrical contractor reviews electrical design documents to confirm PUE monitoring requirements, and then selects and installs a PUE monitoring system that meets the design specification. The controls contractor assists with integration of the electric submeters and dashboard.
- **Inspection Phase:** The electrical contractor completes NRCI and NRCA forms

7.7 Computer Room Heat Recovery Prerequisite Option

7.7.1 Code Change Description

This measure would add a prescriptive option for computer rooms in new buildings to include heat recovery systems. Computer room heat recovery is being defined as a mechanical system that transfers heat from computer rooms to other zones in the building that require heating. This would apply to buildings with large cooling ITE and heating design loads, depending on climate zone, and at least 1,400 hours of annual heating load.

7.7.2 Rationale

Computer rooms produce constant heat 24 hours a day, seven days a week. When a computer room is located in a facility that also requires heating, heat recovered from the computer room can provide heating while reducing the cooling load on the computer room cooling system. While not yet industry standard practice, computer room heat recovery provides significant heating savings opportunities for buildings where computer rooms are collocated with spaces with significant heating loads. See the computer room efficiency CASE Report from the 2022 code cycle for additional background information.[14]

[14] https://title24stakeholders.com/measures/cycle-2022/data-center-efficiency/.

7.7.3 Energy Savings

Table 58 shows the first year per-unit energy savings and demand reduction ranges, which vary by climate zone and system type. There is a positive net energy savings in all climate zones.

Computer room heat recovery provides the most energy savings in colder climates that have more heating load such as offices and schools. Milder climates zones (6 through 10, and 15) show less energy savings than colder climate zones (1 through 5, 11 through 14, and 16). Electricity savings are negative because the analysis uses an electric heat recovery chiller in the proposed case compared to all heating being done with natural gas boilers in the baseline case.

This submeasure would not have a significant impact on load flexibility, peak power demand, or load shifting in buildings that use natural gas heating sources, which is the Standard Design system used in this analysis. For buildings that use electric heating sources, which are expected to increase in number, this submeasure will have electric energy and peak demand savings.

Table 58: First-Year Energy Impacts Per IT Equipment Load kW – Heat Recovery Submeasure

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reduction (kW)	Natural Gas Savings (therm/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(224)	0.0	51	5,031
2	(139)	0.0	32	4,175
3	(139)	0.0	32	4,175
4	(124)	0.0	28	3,464
5	(124)	0.0	28	3,464
6	(165)	0.0	39	5,034
7	(165)	0.0	39	5,034
8	(165)	0.0	39	5,034
9	(165)	0.0	39	5,034
10	(165)	0.0	39	5,034
11	(133)	0.0	30	3,823
12	(133)	0.0	30	3,823
13	(133)	0.0	30	3,823
14	(124)	0.0	28	3,464
15	(165)	0.0	39	5,034
16	(224)	0.0	51	5,031
TOTAL	**(2,490)**	**0.0**	**571**	**70,475**

7.7.4 Cost-Effectiveness

The Statewide CASE Team used the work completed in the 2022 Nonresidential Computer Room Efficiency CASE Report to determine the cost effectiveness of computer room heat recovery. Results of the per-unit cost-effectiveness analyses are presented in Table 59 for new construction. This submeasure does not apply to alterations. The proposed Measure saves money over the 15-year period of analysis relative to existing requirements. The proposed change is cost effective in every climate zone. The results apply only to new construction.

Table 59: 15-Year Cost-Effectiveness Summary Per IT Equipment Load kW – New Construction, Computer Room Heat Recovery Measure

Climate Zone	Benefits - TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs - Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$448	$296	1.5
2	$372	$296	1.3
3	$372	$296	1.3
4	$308	$296	1.0
5	$308	$296	1.0
6	$448	$424	1.1
7	$448	$424	1.1
8	$448	$424	1.1
9	$448	$424	1.1
10	$448	$424	1.1
11	$340	$296	1.1
12	$340	$296	1.1
13	$340	$296	1.1
14	$308	$296	1.0
15	$448	$296	1.1
16	$448	$296	1.5

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2020). 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. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

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

7.7.5 Compliance and Enforcement

- **Design Phase:** Mechanical design engineers determine if the computer room ITE design load along with the building design heating load trigger the heat recovery requirement. The mechanical design engineer performs these load calculations as current standard practice. If the heat recovery requirement is triggered, mechanical design engineers must include the heat recovery system on the mechanical permit plans and show the system efficiency (coefficient of performance) on the mechanical schedules. To provide sufficient information for the permit plans examiner to verify the coefficient of performance, the permit plans must show the computer room heat recovery system's total input power and amount of heat transferred at design conditions. Mechanical design engineers complete NRCC forms with the permit package.
- **Permit Application Phase:** The mechanical design engineer documents the computer room design cooling loads, building total and zone heating loads, and heat recovery system power at design conditions, which are used to calculate heat recovery system COP. This information is developed as part of the design process and is not a new requirement. The plans examiner reviews mechanical permit drawings and specifications to confirm if heat recovery is required and, if so, that it is shown on the permit documents. The plans examiner reviews the computer room heat recovery system COP and, if an exception is utilized, the heating system COP.
- **Construction Phase:** The mechanical contractor reviews mechanical design documents to confirm heat recovery requirements, and then selects and installs a heat recovery system that meets the design specification. The controls contractor installs controls to allow the heat recovery system to operate per the design specification.
- **Inspection Phase:** The mechanical contractor completes NRCI forms.

7.8 Controlled Environment Horticulture Prerequisite Options

This measure would create two prerequisite options for buildings used for controlled environment horticulture (CEH).

7.8.1 Efficient Dehumidification and Reuse of Transpired Water

7.8.1.1 Code Change Description

This measure would reduce energy use in indoor growing facilities by requiring more efficient dehumidification systems that use heat recovered on site to reheat dehumidified air. Facilities would only be required to meet 60 percent of their peak dehumidification needs with on-site heat recover systems. Systems must have the capability to reused transpired water for irrigation.

7.8.1.2 Rationale

The use of site-recovered energy for reheat saves a significant amount of natural gas, as natural gas makes up approximately 90 percent of the air reheat fuel type. The reuse of transpired water for irrigation would lower water consumption of indoor growing facilities, resulting in water savings and the embedded energy savings associated with extracting, treating, transporting, and collecting water. The measure has been adapted from standards recently developed and adopted by the City and County of Denver.

Compliant dehumidification systems are:

- Integrated HVAC systems with on-site heat recovery for reheating dehumidified air; or
- Chilled water systems with on-site heat recovery for reheating dehumidified air; or
- Solid or liquid desiccant dehumidification systems.

7.8.1.3 Energy Savings

The energy impacts of the proposed code change vary by climate zone. The Statewide CASE Team simulated the energy impacts in every climate zone and applied the climate-zone specific TDV factors when calculating energy and energy cost impacts. Energy savings and peak demand reductions per unit are presented in Table 60 and apply to both new construction and alterations. Electricity increases associated with this measure are due to an electric penalty for the proposed heat recovery systems. The natural gas savings results in a net positive energy savings in all climate zones.

Table 60: First-Year Energy Impacts Per Square Foot of Canopy – Dehumidification

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therm/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(2.2)	(0.00026)	3.3	785
2	(1.4)	(0.00017)	3.4	809
3	(1.3)	(0.00016)	3.4	811
4	(1.4)	(0.00018)	3.4	807
5	(1.3)	(0.00015)	3.4	812
6	(1.3)	(0.00015)	3.4	820
7	(1.3)	(0.00015)	3.4	823
8	(1.5)	(0.00017)	3.4	815
9	(1.6)	(0.00019)	3.4	811
10	(1.6)	(0.00019)	3.4	808
11	(1.9)	(0.00022)	3.4	788
12	(1.5)	(0.00018)	3.4	800
13	(1.8)	(0.00021)	3.4	796
14	(1.9)	(0.00021)	3.4	798
15	(2.4)	(0.00026)	3.4	789
16	(1.4)	(0.00019)	3.4	811

Water savings were estimated by calculating the amount of water transpired throughout a year of crop production for each crop. It is assumed that all water provided to the plants is transpired and removed by the dehumidification system. Survey data and discussions with designers provided insight that approximately 60 percent of existing growers reuse water from their dehumidification equipment. This existing reuse rate was applied across the statewide facility stock to estimate statewide impacts. The water savings calculation assumes 100 percent of the transpired water is recovered for reuse.

7.8.1.4 Cost Effectiveness

The proposed submeasure saves money over the 15-year period of analysis relative to the existing conditions. The proposed code change is cost effective in every climate zone. Cost effectiveness is identical between new construction and alterations.

Table 61: 15-Year Cost-Effectiveness Summary Per Square Foot of Canopy – Indoor Dehumidification

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$69.87	$21.37	3.27
2	$71.99	$21.37	3.37
3	$72.22	$21.37	3.38
4	$71.84	$21.37	3.36
5	$72.29	$21.37	3.38
6	$72.99	$21.37	3.42
7	$73.26	$21.37	3.43
8	$72.54	$21.37	3.39
9	$72.19	$21.37	3.38
10	$71.88	$21.37	3.36
11	$70.16	$21.37	3.28
12	$71.22	$21.37	3.33
13	$70.86	$21.37	3.32
14	$71.01	$21.37	3.32
15	$70.18	$21.37	3.28
16	$72.19	$21.37	3.38

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 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. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

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

7.8.1.5 Compliance and Enforcement

This controlled environment horticulture dehumidification prerequisite option would involve changes to the compliance and enforcement processes of multiple parties. Namely, the mechanical HVAC designer will need to create a system that meets the dehumidification system requirements and assist in completing the certificate of compliance for the permit application. Furthermore, HVAC designers would need to analyze the cut sheet and indicated on the certificate that installed systems have the ability to reuse transpired water.

Field inspectors would need to verify that the installed dehumidification system(s) meet the three available compliance options and the plans inspector would ensure the certification forms indicate the proper ratio of total cooling capacity to total reheat and that the system has the ability to reuse transpired water. The plans reviewer would need to check the ratio of total cooling capacity to total reheat provided by the dehumidification equipment from dehumidification equipment specifications.

7.8.2 Horticultural Lighting Minimum Efficacy

7.8.2.1 Code Change Description

This measure would set a minimum 2.1-µMol/J PPE for electric lighting systems used for plant growth and maintenance in larger CEH facilities (buildings with 40 kW or more of connected horticultural lighting load). It would also require installation of lighting controls that enable schedule and multiple light level programing.

7.8.2.2 Rationale

CEH lighting load represents a significant and growing energy load in California. An efficient lighting prerequisite represents an opportunity to significantly reduce energy use and cost. One case study shows that an LED lighting retrofit in Oregon, which cost roughly $160,000, led to nearly $34,000 in annual savings.

The American Society of Agricultural and Biological Engineers (ASABE) and the DesignLights Consortium (DLC) laid the foundation for this Measure by establishing definitions and a testing procedure for horticultural lighting. A similar proposal on horticultural lighting minimum efficacy was considered and approved as part of International Energy Conservation Code (IECC) 2021 standards setting cycle (IECC 2019).

7.8.2.3 Energy Savings

The Statewide CASE team found significant energy savings as a result of this proposal.

The CBECC software does not support space functions and conditioning equipment associated with CEH facilities and would not be an appropriate tool to model energy consumption in CEH facilities. The Statewide CASE Team estimated energy and demand impacts by simulating the proposed code change using a spreadsheet-based calculation tool specific to CEH facilities.

Energy savings and peak demand reductions per unit are presented in Table 62 and

Table 63 and include both new construction and alterations savings. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. Per-unit savings for the first year are expected to range from 13.5 to

199.0 kWh/yr depending upon climate zone and facility type. Demand reductions are expected to range between 0.002 to 0.012 kW depending on climate zone.

Savings per square foot of canopy of indoor facilities are much higher than that of greenhouses. This is due to the higher PPE standard for lighting in indoor growing facilities, sunlight contributing to the PPFD requirements of the plants in greenhouses, and the additional HVAC requirements that apply to indoor growing facilities.

Table 62: First-Year Energy Impacts Per Square Foot of Canopy – Indoor

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therm/yr)	TDV Energy Savings (TDV kBtu/yr)
1	189.5	0.012	0.0	4,318.4
2	192.4	0.012	0.0	4,886.1
3	191.2	0.012	0.0	4,636.7
4	193.1	0.012	0.0	5,011.9
5	191.8	0.012	0.0	4,501.0
6	193.2	0.012	0.0	4,842.6
7	192.8	0.012	0.0	4,611.1
8	194.4	0.012	0.0	5,213.4
9	194.3	0.012	0.0	5,210.2
10	195.0	0.012	0.0	5,020.3
11	194.8	0.012	0.0	4,956.6
12	193.7	0.012	0.0	4,881.8
13	195.1	0.012	0.0	4,948.7
14	195.1	0.012	0.0	5,146.7
15	199.0	0.012	0.0	5,100.7
16	191.2	0.012	0.0	4,394.2

Table 63: First-Year Energy Impacts Per Square Foot of Canopy – Greenhouse

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therm/yr)	TDV Energy Savings (TDV kBtu/yr)
1	23.2	0.003	0.0	597.3
2	18.5	0.002	0.0	473.2
3	18.7	0.002	0.0	478.7
4	17.6	0.002	0.0	447.7
5	16.0	0.002	0.0	417.8
6	16.4	0.002	0.0	429.0
7	15.5	0.002	0.0	390.3
8	16.3	0.002	0.0	443.0
9	15.9	0.002	0.0	414.9
10	15.6	0.002	0.0	398.2
11	18.7	0.002	0.0	468.8
12	18.6	0.002	0.0	464.9
13	18.2	0.002	0.0	457.5
14	13.5	0.002	0.0	331.4
15	14.1	0.002	0.0	343.8
16	17.5	0.002	0.0	452.2

7.8.2.4 Cost-Effectiveness

Results of the per-unit cost-effectiveness analyses are presented in Table 64 and

Table 65 for indoor grow and greenhouse facilities. Cost effectiveness is identical for new construction and alterations. Indoor facility cost effectiveness is higher due to increased light intensity requirements for indoor facilities and decreased maintenance costs going from high intensity discharge luminaires to LED luminaires.

The proposed submeasure saves money over the 15-year period of analysis relative to the existing conditions. The proposed code change is cost effective in every climate zone.

Table 64: 15-Year Cost-Effectiveness Summary Per Square Foot of Canopy – Indoor Lighting

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$384.34	$63.99	6.0
2	$434.87	$63.99	6.8
3	$412.66	$63.99	6.4
4	$446.06	$63.99	7.0
5	$400.59	$63.99	6.3
6	$430.99	$63.99	6.7
7	$410.39	$63.99	6.4
8	$463.99	$63.99	7.3
9	$463.71	$63.99	7.2
10	$446.80	$63.99	7.0
11	$441.14	$63.99	6.9
12	$434.48	$63.99	6.8
13	$440.43	$63.99	6.9
14	$458.05	$63.99	7.2
15	$453.96	$63.99	7.1
16	$391.09	$63.99	6.1

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 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. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

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

Table 65: 15-Year Cost-Effectiveness Summary Per Square Foot of Canopy – Greenhouse Lighting

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$53.16	$14.76	3.6
2	$42.12	$14.76	2.9
3	$42.60	$14.76	2.9
4	$39.85	$14.76	2.7
5	$37.18	$14.76	2.5
6	$38.18	$14.76	2.6
7	$34.74	$14.76	2.4
8	$39.43	$14.76	2.7
9	$36.93	$14.76	2.5
10	$35.44	$14.76	2.4
11	$41.72	$14.76	2.8
12	$41.37	$14.76	2.8
13	$40.72	$14.76	2.8
14	$29.49	$14.76	2.0
15	$30.60	$14.76	2.1
16	$40.25	$14.76	2.7

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 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. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

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

7.8.2.5 Compliance and Enforcement

For non-cannabis crop types, permit applicants would need to list the electric usage of their horticultural lighting. In cases when Measure applies to the project, the permit applicants would need to gather PPE ratings of the proposed luminaires to demonstrate compliance.

For cannabis crops, compliance with the existing California Department of Food & Agriculture (CDFA) CalCannabis regulations would support the compliance process with the proposed Measure. Specifically, as part of CDFA CalCannabis licensing requirements, license applicants must submit canopy size calculations and a lighting diagram for indoor and mixed-light license types. The lighting diagram must include locations of all lights in the canopy areas and maximum wattage for each light (California Code of Regulations (CCR) n.d.). Thus, applicants can determine if they trigger the 40 kW threshold based upon the maximum wattages noted in their lighting diagram. If the project is subject to the proposed horticultural lighting code, the permit applicants would have to still gather PPE rating(s) of the proposed luminaires since CDFA CalCannabis licensing requirements only call for luminaire count and wattage not PPE ratings.

For all crop types in facilities with at least 40 kW of horticulture connected lighting load, the permit applicants would also need to install multi-level and time-switch lighting controls as well as coordinate an acceptance test for the time-switch controls to comply with the proposed measure.

7.9 Refrigerated Warehouses Prerequisite Option

This measure would create two prerequisite options for large, refrigerated warehouses (greater than or equal to 3,000 square feet) and refrigerated spaces (with a sum total of 3,000 square feet or more served by the same refrigeration system). See the refrigeration system opportunities CASE Report from the 2022 Title 24, Part 6 CASE Report for additional information on the two prerequisite options.[15]

7.9.1 Minimum Air-Cooled Condenser Sizing and Specific Efficiency for Packaged Refrigeration Systems

7.9.1.1 Code Change Description

This measure would decrease the minimum size requirement for air cooled condensers in packaged refrigeration systems utilized to enable cost-effective installations. Condenser size is defined by the temperature difference (TD) between the design dry bulb temperature and saturated condensing temperature. The larger the temperature difference, the smaller the condenser. The measure would increase the temperature difference (TD) for freezer systems from 10°F TD to 15°F TD, and for cooler systems from 15°F TD to 20°F TD. Specific efficiency, which is related to condenser sizing, would also be modified from 65 Btuh/W to 60 Btuh/W.

The proposal would eliminate confusion around condenser requirement exemptions for packaged units and condensing units. The code change is applicable to new construction only.

[15] https://title24stakeholders.com/measures/cycle-2022/refrigeration-system-opportunities/.

7.9.1.2 Rationale

Packaged refrigeration systems are a growing alternative to traditional centralized refrigeration systems used to cool refrigerated warehouses because of their ability to lower system charge, reduce system footprint, reduce pressure drop in the suction piping due to shorter piping runs, and reduce installation costs (in some cases). Because they can offer systems with reduced charge, they can help eliminate potential market barriers for low global warming potential (GWP) refrigerants, such as ammonia.

The proposed code changes would reduce the minimum size requirement for air cooled condensers for these systems to make them more cost effective.

7.9.1.3 Energy Savings and Cost-Effectiveness

The code change proposal would not increase the stringency, so there would be no savings on a per-square foot basis. Although this measure does not result in electricity or gas savings, the measure would promote additional options for low charge, low GWP refrigerant systems for refrigerated warehouse end users in the state of California. This aligns with other statewide goals related to reducing statewide GHG emissions via reducing refrigerant emissions.

7.9.1.4 Compliance and Enforcement

The activities that need to occur during each phase of the project are described below:

- **Design Phase:** Design engineers, contractors, and owners collaborate to develop refrigeration system design loads and select the best system configuration and pieces of equipment to supply adequate cooling. All parties involved should be aware of the proposed code changes as it relates to sizing air cooled condensers if a packaged system is selected to meet the loads.
- **Permit Application Phase:** Typically, a contractor would develop a set of stamped engineering plan drawings on the owner’s behalf, that would include refrigeration system design and equipment schedules. The drawings can also be developed by an independent engineering firm and are used as the basis for contractors to supply bids for the project. This set of plan drawings should incorporate information on the packaged refrigeration units and the related condenser design specifications. If the selected equipment does not comply with Title 24, Part 6, the authority having jurisdiction should provide plan check comments to correct this before providing any building permits.
- **Construction Phase:** Contractors install the refrigeration system as described in the approved plan drawings, with oversight from the owner and authority having jurisdiction. The installed equipment should match what was approved and specified in the equipment schedule. This is documented by the Covered Process Certificate of Installation and signed by the responsible party – typically

the licensed mechanical contractor.

- **Inspection Phase:** After construction, the owner or contractor have the responsibility to have the building and its various mechanical systems inspected by the authority having jurisdiction. This inspection phase should include an examination of the refrigeration system to verify the compliant equipment described in the plan drawings matches what was physically installed.

The compliance process described above is very similar to the process that currently exists for measures related to refrigerated warehouses and commercial refrigeration. No additional acceptance testing is expected to be required as this an equipment specification and not a control specification.

7.9.2 Evaporator Specific Efficiency

7.9.2.1 Code Change Description

This measure would require minimum evaporator specific efficiency in non-process cooling/freezing applications in refrigerated warehouses. Evaporator specific efficiency is defined as cooling capacity of the evaporator (Btu/hr) divided by the power input (watts) required for the fan motors at rated temperature conditions at 100 percent fan speed. The rated capacity is defined at 10°F of temperature difference between the incoming air temperature and the saturated evaporating temperature of the refrigerant, assuming a dry coil. This metric is similar to what is used currently in Title 24, Part 6 for comparing the efficiency of refrigeration condensers.

7.9.2.2 Rationale

Evaporators are heat exchangers used in vapor compression refrigeration systems that allow heat transfer from the air inside a refrigerated space to the refrigerant, thus providing cooling to the air. Fans are integrated as part of the evaporator in order to draw air across the heat exchanger surface area, as well as provide adequate mixing to avoid temperature stratification. As discussed in the section above, specific efficiency is a metric defined as the capacity of the evaporator divided by the input power requirement. The higher the specific efficiency of the evaporator, the less fan power is required to achieve the necessary cooling, thus resulting in both direct energy savings from the fan motor as well as indirect compressor energy savings. This is because the heat produced by the fans will eventually be removed from the refrigerated spaces and is thus added load on the refrigeration system.

2019 Title 24, Part 6 does not currently have a minimum efficiency requirement for evaporators. Almost all manufacturers have product selection software, and the capacity ratings are becoming more standardized. Some manufacturers are now providing certified ratings in their product catalogues to provide more confidence in the capacity of the equipment being sold. Additionally, some manufacturers provide the applied fan power at the operating conditions.

Evaporators use significant amount of energy in refrigerated warehouses. Therefore, the efficiency of evaporators is a key factor in annual energy usage of refrigerated warehouses, even with the 2019 Title 24, Part 6 mandatory requirement of variable speed control of evaporator fans.

The market research conducted by the Statewide CASE Team showed a large variation in efficiency of evaporator models available in the market. The proposed code change is expected to save significant energy by prohibiting the installation of low efficiency units.

7.9.2.3 Energy Savings

Annual savings for the first year are expected to range from 0.37 to 2.83 kWh/ft2 depending upon climate zone and depending on the evaporator refrigerant/liquid feed type. Demand reductions are expected to range between 0.00012 kW/ft2 and 0.00107 kW/ft2 depending on climate zone and depending on the evaporator refrigerant/liquid feed type. The proposed measure also reduces peak demand for refrigerated warehouses by approximately 5 percent. See the 2022 Title 24, Part 6 CASE Report for more detailed energy savings results.

7.9.2.4 Cost-Effectiveness

Analysis conducted for the 2022 Refrigeration System Opportunities CASE Report determined proposed efficiency thresholds by evaluating what is reasonably available in the marketplace, without excessive restriction of market options. The proposed thresholds were found to be cost effective for every evaporator type in every climate zone, with ratios ranging from approximately 2.2 to 4.5.

7.9.2.5 Compliance and Enforcement

The activities that need to occur during each phase of the project are described below:

- **Design Phase:** Design engineers, contractors, and owners collaborate to develop refrigeration system design loads and select the best system configuration and pieces of equipment to supply adequate cooling. All parties involved should be aware of the proposed code changes as it relates to selecting evaporators for each refrigerated space and ensure that the calculated specific efficiency at rated conditions meets the minimum requirements.
- **Permit Application Phase:** Typically, a contractor would develop a set of stamped engineering plan drawings on the owner's behalf, that would include refrigeration system design and equipment schedules. The drawings can also be developed by an independent engineering firm and are used as the basis for

contractors to supply bids for the project. This set of plan drawings should incorporate information on the selected evaporators for the refrigerated spaces. If the selected equipment does not comply with Title 24, Part 6, the authority having jurisdiction should provide plan check comments to correct this before providing any building permits.

- **Construction Phase:** Contractors install the refrigeration system as described in the approved plan drawings, with oversight from the owner and authority having jurisdiction. The installed equipment should match what was approved and specified in the equipment schedule.
- **Inspection Phase:** After construction, the owner or contractor have the responsibility to have the building and its various mechanical systems inspected by the authority having jurisdiction. This inspection phase should include an examination of the refrigeration system to verify the compliant equipment described in the plan drawings matches what was physically installed.

7.10 Tier 1 and Tier 2 Performance Standards

7.10.1 Code Change Description

This measure would revise the Tier 1 and Tier 2 performance targets. Tier 1 is structured as an all-electric preferred option for jurisdictions, with proposed Energy Budget targets for mixed-fuel buildings that are consistent with the 2019 CALGreen Tier 1 budgets, while all-electric building would comply with Tier 1 by being compliant with Title 24, Part 6.

Tier 2 does not provide a path for mixed-fuel buildings and requires all-electric buildings to meet the same Energy Budget that mixed-fuel buildings had to meet in Tier 1. This change therefore eliminates the more stringent Tier 2 Energy Budgets that are in the 2019 version of CALGreen.

Given the number of energy efficiency measures included for nonresidential buildings in 2022 Title 24, Part 6, as well as new requirements for solar and storage, the Statewide CASE Team did not have sufficient measures developed to achieve a further 10 percent or 15 percent savings over 2022 Title 24, Part 6 – which are the performance targets for 2019 CALGreen. Applying the 2019 performance targets for Tier 1 and Tier 2 for nonresidential buildings in 2022 is technically feasible but challenging to achieve cost effectively. Using the measures available, the Statewide CASE Team determined climate zone-specific performance targets relative to the 2022 Title 24, Part 6 energy budget. These improvements are weighted based on statewide construction forecasts.

The Statewide CASE Team understands that the savings determined in Table 67 may not be deemed significant by the Energy Commission or by local jurisdictions. The Statewide CASE Team recommends the Energy Commission adopt performance tiers that are more stringent than what can be shown to be cost effective with the current measures but less stringent than the percent reductions in 2019 CALGreen. These targets are of a similar magnitude as those proposed for multifamily buildings. See Table 66 for our proposed tiers.

Table 66: Proposed Nonresidential Performance Tiers

Climate Zone	Tier 1 Mixed-Fuel	Tier 1 All-Electric	Tier 2 Mixed-Fuel	Tier 2 All-Electric
1	95%	100%	N/A	95%
2	95%	100%	N/A	95%
3	95%	100%	N/A	95%
4	95%	100%	N/A	95%
5	95%	100%	N/A	95%
6	95%	100%	N/A	95%
7	95%	100%	N/A	95%
8	95%	100%	N/A	95%
9	95%	100%	N/A	95%
10	95%	100%	N/A	95%
11	95%	100%	N/A	95%
12	95%	100%	N/A	95%
13	95%	100%	N/A	95%
14	95%	100%	N/A	95%
15	95%	100%	N/A	95%
16	95%	100%	N/A	95%

Table 67: Tier 1 and Tier 2 Nonresidential Performance Targets by Climate Zone

Climate Zone	Tier 1 Mixed-Fuel	Tier 1 All-Electric	Tier 2 Mixed-Fuel	Tier 2 All-Electric
1	98%	100%	N/A	98%
2	97%	100%	N/A	97%
3	98%	100%	N/A	98%
4	98%	100%	N/A	98%
5	98%	100%	N/A	98%
6	97%	100%	N/A	97%
7	98%	100%	N/A	98%
8	97%	100%	N/A	97%
9	97%	100%	N/A	97%
10	98%	100%	N/A	98%
11	97%	100%	N/A	97%
12	98%	100%	N/A	98%
13	98%	100%	N/A	98%
14	97%	100%	N/A	97%
15	98%	100%	N/A	98%
16	98%	100%	N/A	98%

7.10.2 Rationale

Given the significant increase in stringency of the nonresidential portion of Title 24, Part 6, it will now be more difficult to cost-effectively achieve the same percent reductions in the Energy Budget that are presented in the 2019 version of CALGreen, particularly Tier 2. At the same time, this proposal is responsive to the two styles of reach codes that have been consistently adopted by jurisdictions under the 2019 code cycle. The “electric-preferred” reach code, represented by the proposed Tier 1, provides a path for mixed-fuel buildings but establishes more stringent requirements for these buildings than for all-electric buildings. The other style of reach code is “electric-required” where no path is provided for mixed-fuel buildings and all-electric construction is required. This approach is represented by Tier 2.

7.10.3 Energy Savings

7.10.3.1 Description of 2022 CALGreen Baseline (Minimally Compliant with Title 24, Part 6)

The Statewide CASE incorporated nonresidential measures from the 2022 Title 24, Part 6 code cycle that are likely to be adopted into EnergyPlus and CBECC-Com to create a 2022 Title 24, Part 6 baseline. This was done for measures that were modeled in EnergyPlus and does not include measures for which the energy savings were determined through calculations rather than modeling. It also only includes measures when they are applicable for the building prototype being used. Table 68 indicates for which building prototypes the measures apply. The measures that were included are the following:[16]

1. **<u>Expand Economizer:</u>** Lowers the economizer threshold from 54,000 Btu/hr to 33,000 Btu/hr.
2. **<u>Exhaust Air Heat Recovery:</u>** Energy recovery is available only during periods when the outside air economizer is not in operation (outside air temperatures above 75°F and below 55°F). Heating and cooling energy in the exhaust/relief air is transferred to the fresh air supply via fixed plate heat exchanger equipped with bypass dampers. Energy recovery performance is assumed at 60 percent sensible energy recovery ratio.
3. **<u>VAV Deadband Airflow:</u>** Standard Design for CBECC-Com utilizes a 20 percent minimum air flow for every zone. The Statewide CASE Team modified the Standard Design to match the current code requirements using a lookup table that references requirements listed in Section 120.1(c)3.
4. **<u>Lighting Power Densities:</u>** Lowers the allowable lighting power densities in Section 140.6 Tables 140.6-B, 140.6-C, 140.6-D, and 140.6-G.
5. **<u>Automatic Daylighting Dimming to 10 percent:</u>** Current code requires general lighting power in the daylit zone to be reduced to 35 percent or less when daylight illuminance is greater than 150 percent of design illuminance. This measure reduces general lighting power to ten percent or less when daylight illuminance is greater than 150 percent of design illuminance.
6. **<u>Fan Power Budget:</u>** Overhauls the fan power limit calculation. Savings are determined by reducing the total static pressure in the system from 5.362 to 4.267 inch water column.
7. **<u>Duct Leakage:</u>** Modifies EnergyPlus to add in duct leakage. Assumes a duct leakage of 7.4 percent for supply air leakage and 25 percent for exhaust leakage in the Standard Design (2019) and 3.0 and 2.0 percent, respectively, in the Proposed Design (2022).
8. **<u>Gas Boiler System:</u>** Increases required gas boiler efficiency from 80 percent to 90 percent.
9. **<u>Fenestration:</u>** This updates the prescriptive requirements for solar heat gain

[16] Note: this does not include all of the measures for the 2022 code cycle as not all measures were modeled in EnergyPlus.

coefficient (SHGC), U-factor, depending on climate zone and fenestration type, for Climate Zones 9, 11-15.

10. **Wall Insulation:** Increase wall insulation by R-2 across all California climate zones above the 2019 Title 24, Part 6 prescriptive requirement.
11. **Air Barrier Verification:** Adds air barrier requirements to Climate Zones 1-9, adds air barrier verification requirements for all climate zones except CZ7. Revises the baseline infiltration rate to 0.4 cfm/ft^2 through the building and 1.2 cfm/ft^2 through the walls only for all climate zones except CZ7, which is revised to 0.7 cfm/ft^2 and 2.1 cfm/ft^2, respectively.

Table 68: Applicability of Each Measure for Each Prototype

Measure	OfficeMedium	RetailStandAlone	SchoolPrimary	Warehouse
Expand Economizer	NA	NA	Applicable	NA
Exhaust Air Heat Recovery	Applicable	NA	NA	NA
VAV Deadband Airflow	Applicable	NA	NA	NA
Lighting Power Densities	Applicable	Applicable	Applicable	Applicable
Automatic Daylight Dimming to 10%	Applicable	Applicable	Applicable	Applicable
Fan Power Budget	Applicable	Applicable	Applicable	Applicable
Duct Leakage	Applicable	NA	NA	NA
Gas Boiler System	Applicable	NA	NA	NA
Wall Insultation	Applicable	Applicable	Applicable	Applicable
Air Barrier Verification	Applicable	Applicable	Applicable	Applicable

The Statewide CASE Team determined the percent savings associated with the above measures in comparison with the 2019 Title 24, Part 6 baseline, shown in Table 69.

Table 69: TDV Energy Percent Savings from 2019 to 2022 Title 24, Part 6

Climate Zone	OfficeMedium	RetailStandAlone	SchoolPrimary	Warehouse
1	7%	5%	7%	10%
2	7%	8%	8%	9%
3	9%	10%	10%	12%
4	9%	8%	10%	10%
5	7%	8%	9%	11%
6	8%	9%	10%	11%
7	7%	11%	10%	7%
8	8%	10%	10%	8%
9	9%	9%	11%	9%
10	9%	9%	11%	7%
11	13%	8%	9%	8%
12	8%	8%	9%	7%
13	9%	8%	9%	7%
14	10%	9%	9%	8%
15	9%	8%	10%	9%
16	15%	7%	8%	6%

7.10.3.2 CALGreen Energy Targets

CALGreen Energy Targets were developed based on reach code analysis conducted for nonresidential buildings for the 2019 Title 24, Part 6 code, measures developed for the 2022 Title 24, Part 6 code cycle that were not included in the code update, and work completed by Lawrence Berkeley National Laboratory. The package presented in the statewide report were refined to reflect the updates that are planned for 2022 Title 24, Part 6 for energy efficiency and generation requirements. Following is a description of the measures applied in the package.

1. **Daylighting Dimming to Off:** Turn off general lighting power in the daylight zone when daylight illuminance is greater than 150 percent of design illuminance. 2022 Title 24, Part 6 is expected to be updated to require general lighting power to be reduced to ten percent in the above case.
2. **Air Infiltration Verification:** Reduce infiltration from the default infiltration assumption of 0.4 cfm/ft^2 to 0.25 cfm/ft^2.
3. **Roof Insulation:** Increase roof insulation by R-4 across all California climate zones above the 2022 Title 24, Part 6 prescriptive requirement.
4. **Wall Insulation:** Increase wall insulation by R-2 across all California climate zones above the 2022 Title 24, Part 6 prescriptive requirement.

5. **Fenestration:** This updates the prescriptive requirements for solar heat gain coefficient (SHGC), U-factor, depending on climate zone and fenestration type, for Climate Zones 2, 5-9.
6. **Cool Roofs:** In Climate Zone 4 and 6-15 the minimum aged solar reflectance and Solar Reflective Index (SRI) are increased to 0.70 and 85, respectively. The other climate zones would remain unchanged.
7. **Cool Walls:** Increase wall reflectance from 0.30 to 0.60 in all climate zones.
8. **DR Controlled Receptacles:** In all building areas required to install controlled receptacles and demand responsive lighting controls, make the controlled receptacles DR capable.

Table 70: TDV Energy Savings of Nonresidential Energy Performance Package (TDV kBtu/ft^2)

Climate Zone	OfficeMedium	RetailStandAlone	SchoolPrimary	Warehouse
1	3.22	1.22	3.97	2.77
2	7.39	2.94	6.04	1.67
3	5.14	(2.03)	3.47	2.11
4	6.02	1.74	3.14	0.98
5	3.47	2.70	2.79	1.68
6	7.36	1.44	5.72	1.28
7	5.01	(1.57)	5.22	0.35
8	9.91	5.45	6.84	1.23
9	9.00	2.53	3.34	1.10
10	7.03	(1.74)	3.28	1.45
11	7.36	6.25	5.13	2.58
12	6.17	2.58	4.43	1.41
13	7.15	6.15	4.54	1.33
14	8.76	5.36	4.17	2.20
15	8.42	8.41	4.87	1.11
16	4.96	3.84	5.55	3.05

() *indicates negative energy savings*

Table 71: TDV Percent Savings from Nonresidential Energy Performance Package

Climate Zone	OfficeMedium	RetailStandAlone	SchoolPrimary	Warehouse	Construction Weighted Average
1	1.8%	0.5%	1.9%	2.6%	2.1%
2	3.5%	1.1%	2.7%	2.0%	2.6%
3	2.7%	(0.9%)	1.8%	2.7%	2.4%
4	2.9%	0.7%	1.5%	1.3%	1.9%
5	1.9%	1.2%	1.5%	2.4%	2.0%
6	3.6%	0.6%	2.9%	2.1%	2.7%
7	2.7%	(0.7%)	2.9%	0.6%	1.6%
8	4.5%	2.0%	3.3%	1.8%	3.0%
9	4.0%	0.9%	1.5%	1.6%	2.6%
10	3.1%	(0.6%)	1.4%	2.1%	2.0%
11	3.3%	2.1%	2.0%	2.9%	2.8%
12	2.9%	0.9%	1.9%	1.7%	2.0%
13	3.0%	2.0%	1.8%	1.6%	1.9%
14	3.6%	1.8%	1.6%	2.4%	2.5%
15	3.2%	2.6%	1.7%	1.7%	1.9%
16	2.6%	1.4%	2.3%	2.6%	2.5%

() *indicates negative energy savings*

7.10.4 Cost Effectiveness

The cost for each measure was taken from the relevant report and compiled in order to determine the benefit to cost ratio (BCR) of the energy efficiency performance package. A BCR above 1.0 means that the energy cost savings are greater than the incremental cost.

Measure	OfficeMedium ($/CFA)	RetailStandAlone ($/CFA)	SchoolPrimary ($/CFA)	Warehouse ($/CFA)
Daylighting Dimming to Off	-	-	-	-
Air Infiltration Verification	-	-	-	-
Roof Insulation	$0.10	$0.17	$0.28	$0.26
Wall Insulation	$0.01	$0.02	$0.02	$0.03
Cool Roof	$0.02	$0.06	$0.06	$0.06
Fenestration	$0.23	$0.06	$0.36	$0.01
Cool Wall	-	-	-	-
DR Controlled Receptacles	$0.08	$0.15	$0.07	$0.15

“ – ” Indicates no incremental cost

Table 72: Cost Effectiveness of Nonresidential Energy Efficiency Performance Package – Benefit-to-Cost Ratios

Climate Zone	OfficeMedium	RetailStandAlone	SchoolPrimary	Warehouse	Construction Weighted Average
1	2.62	0.55	1.62	0.98	1.62
2	2.71	1.13	1.26	0.58	1.46
3	4.18	(0.92)	1.42	0.75	2.03
4	4.39	0.66	1.10	0.31	1.98
5	1.27	0.89	0.58	0.58	0.85
6	2.57	0.48	1.10	0.39	1.26
7	1.75	(0.52)	1.00	0.11	0.76
8	3.46	1.80	1.32	0.37	1.70
9	6.57	0.96	1.16	0.34	3.04
10	5.13	(0.66)	1.14	0.45	1.22
11	5.37	2.37	1.79	0.80	1.84
12	4.50	0.98	1.55	0.44	1.77
13	5.22	2.34	1.59	0.41	1.52
14	6.40	2.04	1.45	0.69	2.13
15	6.15	3.19	1.70	0.35	1.33
16	4.03	1.74	2.27	1.08	1.87

() *indicates negative BCR due to negative energy savings*

The energy targets are cost effective in a majority of climate zones and adding measures to increase the generation of the PV System and enhanced battery system controls is likely to increase cost effectiveness across all building types and climate zones. Furthermore, the warehouse prototype is heating only, and so the energy savings are underestimated.

7.11 Renewable Energy

The Energy Commission has proposed prescriptive requirements for onsite photovoltaic and battery storage systems in Title 24, Part 6. The Statewide CASE Team is therefore proposing that buildings complying with Tier 1 or Tier 2 also be required to comply with these prescriptive requirements.

The 2019 CALGreen states that "If offered by local utility provider, participate in a renewable energy portfolio program that provides a minimum of 50-percent electrical power from renewable sources." The Statewide CASE Team is proposing that this be revised so that buildings complying with Tier 1 procure 50-percent of electrical sources and those complying with Tier 2 procure 100-percent of electrical sources from renewable sources. Since the 2019 requirements were written, load-serving entity programs that offer 100-percent renewable electricity have become widely available and are growing rapidly (Trumbull, Gattaciecca and DeChazo 2020).

7.12 Compliance and Enforcement

Prerequisite options that are being proposed for covered processes each speak to the relevant compliance and enforcement considerations. For other nonresidential buildings, projects will have to demonstrate compliance with one or two prerequisite options for Tier 1 and Tier 2, respectively. Project teams will have to clearly note which options were chosen so that they can be confirmed by building inspectors. Since project teams also need to comply with a performance target that is more stringent that Title 24, Part 6, it will be important that the design and energy modeling stages of the project overlap so that there is an understanding of what adjustments need to be made in order to comply. Building departments will need to confirm that the energy model complies with the relevant tier requirement and then confirm that those measures are implemented in the field.

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 2019 documents are marked with red underlining (new language) and ~~strikethroughs~~ (deletions).

California Green Building Standards Code

Chapter 2- Definitions

Section 201

General

201.1 Scope. Unless otherwise stated, the following words and terms shall, for the purposes of this code, have the meanings shown in this chapter.

201.2 Interchangeability. Words used in the present tense include the future; words stated in the masculine gender include the feminine and neuter; the singular number includes the plural, and the plural, the singular.

201.3 Terms defined in other documents. Where terms are not defined in this code and are defined in the *California Building Standards Code* or other referenced documents, such terms shall have the meaning ascribed to them as in those publications.

201.4 Terms not defined. Where terms are not defined as specified in this section, such terms shall have ordinarily accepted meanings such as the context implies.

Section 202

Definitions

BATTERY STORAGE SYSTEM is a rechargeable energy storage system consisting of storage device and associated electrical equipment, including controls and inverters, designed to store and supply electrical power at a future time.

ALL-ELECTRIC BUILDING is a building that uses electricity as the only source of energy and has no gas plumbing in the building.

ENERGY DESIGN RATING (EDR) is a way to express the energy consumption of a building as a rating score index where a score of 100 represents the energy consumption of the building built to the specifications of the Residential Energy Services (RESNET) reference home characterization of the 2006 International Energy Conservation Code (IECC) with Title 24, Part 6 modeling assumptions, and a score of

0 (zero) represents a building that has zero net energy consumption. The EDR is calculated using Commission-approved compliance software as specified by the Alternative Calculation Method Approval Manual. ~~The sum of the annual TDV energy consumption for energy use components included in the performance compliance approach for the Standard Design Building (Energy Budget) and the annual time dependent valuation (TDV) energy consumption for lighting and components not regulated by Title 24, Part 6 (such as domestic appliances and consumer electronics) and accounting for the annual TDV energy offset by an on-site renewable energy system. The Design Rating is calculated by Compliance Software certified by the Energy Commission.~~

ENERGY DESIGN RATING, ENERGY EFFICIENCY is an Energy Design Rating based on the TDV energy consumption of a building that results from the building's energy efficiency characteristics, calculated using Commission-approved compliance software as specified by the Alternative Calculation Methods Approval Manual.

ENERGY DESIGN RATING, SOLAR ELECTRIC GENERATION AND DEMAND FLEXIBILITY is the reduction in TDV energy consumption of a building expressed in terms of an Energy Design Rating reduction that results from the combination of the building's solar electric generation system and demand flexibility measures.

ENERGY DESIGN RATING, TOTAL is the total Energy Design Rating for the building that is determined by subtracting the Solar Electric Generation System and Demand Flexibility Energy Design Rating from the Energy Efficiency Energy Design Rating.

ENERGY DESIGN RATING, MARGIN is the difference between the Energy Design Rating of the Standard Design and the Energy Design Rating of the Proposed Design.

MIXED-FUEL BUILDING is a building that is plumbed for the use of natural gas or propane as fuel for space heating, water heating, cooking, clothes drying, or other building loads.

COMPUTER ROOM EFFICIENCY definitions:

ANSI/NEMA WD 6 is the National Electrical Manufacturers Association Document titled, "Wiring Devices—Dimensional Specifications," 2016 (ANSI/NEMA WD 6-2016).

COEFFICIENT OF PERFORMANCE (COP), COMPUTER ROOM HEAT RECOVERY is the ratio of heat transferred from the computer room to the rate of energy input of the computer room heat recovery system, calculated under design conditions and expressed in consistent units.

COMPUTER ROOM is a room within a building whose primary function is to house electronic equipment and that has a design information technology equipment (ITE) power density exceeding 20 watts/ft2 (215 watts/m2) of conditioned floor area.

COMPUTER ROOM HEAT RECOVERY is a mechanical system that transfers heat from computer room ITE to provide heating to other zones in the building with heating loads.

CUMULATIVE POWER USAGE EFFECTIVENESS (PUE) is equal to total building cumulative electricity use (measured in kilowatt hours) in the time period divided by total cumulative ITE electricity use (measured in kilowatt hours) in that time period. Total building cumulative electricity use includes electricity produced on site (e.g., by photovoltaics) that is consumed on site.

INFORMATION TECHNOLOGY EQUIPMENT (ITE) includes computers, data storage, servers, and network/communication equipment located in a computer room.

ITE DESIGN LOAD is the combined power of all the ITE loads for which the ITE cooling system is designed.

CONTROLLED ENVIRONMENT HORTICULTURE (CEH) definitions:

CANOPY IN BUILDINGS WITH CEH SPACES may be noncontiguous, but each unique area included in the total canopy calculation shall be separated by an identifiable boundary that includes, but is not limited to, interior walls, shelves, and fencing. If plants are being cultivated using a shelving system, the surface area of each level is included in the total canopy calculation. Canopy is calculated by summing the surface area of spaces that will be used for growing and maintaining plants.

CONTROLLED ENVIRONMENT HORTICULTURE (CEH) SPACE is a building space dedicated to plant production by manipulating indoor environmental conditions, such as through electric lighting, irrigation, and HVAC. CEH space does not include building space where plants are grown solely to decorate that same space. Greenhouse and indoor growing are types of CEH spaces (see "greenhouse" and "indoor growing").

DESICCANT DEHUMIDIFICATION SYSTEMS are mechanical dehumidification technologies that use a solid or liquid material to remove moisture from the air.

HORTICULTURAL LIGHTING consists of luminaires used for plant growth and maintenance. Horticultural luminaires may have either plug-in or hard-wired connections for electric power.

INDOOR GROWING is a type of CEH space in a building with a Skylight Roof Ratio less than 50%. Growing plants in a warehouse with or without skylights is an example of an indoor growing.

PHOTOSYNTHETIC PHOTON EFFICACY (PPE) is photosynthetic photon flux divided by input electric power in units of micromoles per second per watt, or micromoles per joule as defined by ANSI/ASABE S640.

PACKAGED REFRIGERATION SYSTEMS are mechanical refrigeration systems consisting of compressors, condensers, evaporators and vessels used to provide direct or indirect cooling for refrigerated spaces that have been integrated into a single packaged unit designed to be installed on the roof of a refrigerated warehouse or on grade. Applies to systems with evaporators integrated into the package or with evaporators pre-engineered as a split system.

STEAM TRAP OPERATING PRESSURE is the steam pressure entering the steam trap during normal design operating conditions.

APPENDIX A4 RESIDENTIAL VOLUNTARY MEASURES

Division A4.2 – ENERGY EFFICIENCY

SECTION A4.201 GENERAL

A4.201.1 Scope.

For the purposes of mandatory energy efficiency standards in this code, the California Energy Commission will continue to adopt mandatory standards. It is the intent of these voluntary provisions to encourage local jurisdictions through codification to achieve exemplary performance in the area of building energy efficiency. Local jurisdictions adopting these voluntary provisions as mandatory local energy efficiency standards shall submit the required application and receive the required approval of the California Energy Commission in compliance with prior to enforcement. Once approval is granted by the Energy Commission, local jurisdictions shall file an ordinance expressly marking the local modification along with findings and receive the required acceptance from the California Building Standards Commission in compliance with Section 101.7 of this code, prior to enforcement. (Title 24, Part 1, Section 10-106 is available at http://www.energy.ca.gov/title24/2019standards/)

SECTION A4.202 DEFINITIONS

A4.202.1 Definitions. The following terms are defined in Chapter 2.

ALL-ELECTRIC BUILDING.

BATTERY STORAGE SYSTEM.

ENERGY BUDGET.

ENERGY DESIGN RATING (EDR).

ENERGY DESIGN RATING, ENERGY EFFICIENCY.

ENERGY DESIGN RATING, SOLAR ELECTRIC GENERATION AND DEMAND FLEXIBILITY.

ENERGY DESIGN RATING, TOTAL.

ENERGY DESIGN RATING, MARGIN.

MIXED-FUEL BUILDING.

TIME DEPENDENT VALUATION (TDV) ENERGY.

SECTION A4.203 PERFORMANCE APPROACH FOR NEWLY CONSTRUCTED SINGLE FAMILY BUILDINGS

A4.203.1 Energy efficiency. Newly constructed single family ~~low-rise residential~~ buildings shall comply with Sections A4.203.1.1 through A4.203.1.4.

A4.203.1.1 Tier 1, and Tier 2 prerequisites. ~~A4.203.1.1.1 Energy design ratings, and A4.203.1.1.2 Quality Insulation Installation~~ The following are required for all applicable components of the building project.

A4.203.1.1.1 Energy design ratings: Total Energy Design Rating (Total EDR) and Energy Efficiency Design Rating (Efficiency EDR). Total EDR and Efficiency EDR ratings for the Proposed Design Building shall be computed by Compliance Software certified by the Energy Commission described in Title 24, Part 6, Section 100.1 and 150.1(b), and these ratings shall be included in the Certificate of Compliance documentation.

A4.203.1.1.2 Quality Insulation Installation (QII). The QII procedures specified in the Building Energy Efficiency Standards Reference Appendices RA3.5 shall be completed.

A4.203.1.2 Tier 1 and Tier 2 prerequisite options. In addition, TWO~~ONE~~ of the following efficiency measures are ~~will be~~ required~~: A4.203.1.2.1 Roof deck insulation, or ducts in conditioned space OR A4.203.1.2.2 High Performance Walls OR A4.203.1.2.3 HERS-Verified Compact Hot Water Distribution System OR A4.203.1.2.4 HERS-Verified Drain Water Heat Recovery~~.

A4.203.1.2.1 Roof deck insulation, or ducts in conditioned space. Meet one of the three options for the location of ducts and air handler as well as insulation R values and installation of a radiant barrier as specified in Title 24, Part 6, Section 150.1(c)9A or B:

1. Below roof deck insulation with a minimum R-value of 19; or
2. Continuous above deck insulation with a minimum R-8 and with an air space present between the roofing and the roof deck; or
3. All ducts and air handlers in conditioned space as specified in the Title 24, Part 6 Reference Appendices RA3.1.

A4.203.1.2.2 High Performance Walls (HPW). HPW meet the climate zone dependent U-factor and insulation values for either 2x6 or 2x4 framing as specified in Title 24, Part 6, Section 150.1(c)1B: maximum U-factor of 0.048.

A4.203.1.2.3 HERS-Verified Compact Hot Water Distribution System (CHWDS-H). CHWDS-H shall be installed as specified in the Title 24, Part 6 Reference Appendix RA3.6.5.

A4.203.1.2.4 HERS-Verified Drain Water Heat Recovery (DWHR-H). DWHR-H shall be installed as specified in Title 24, Part 6 Reference Appendix RA4.4.21.

A4.203.1.2.5 High Performance Fenestration. Installed fenestration products, including glazed doors, shall have an area weighted average U-factor no greater than 0.24.

A4.203.1.2.6 HERS-Verified Reduced Building Air Leakage. Building air leakage shall be no greater than 1.5 air changes per hour at 50 pascals (ACH50) as determined utilizing the procedures in Title 24, Part 6 Reference Appendix RA3.8.

A4.203.1.2.7 Heat Recovery Ventilator or Energy Recovery Ventilator (HRV/ERV). The mechanical ventilation system shall be either an HRV or ERV with a minimum sensible recovery efficiency of 67 percent, rated at 32 degrees F (0 degrees C), and a minimum fan efficacy of 0.6 W per cfm.

A4.203.1.2.8 Heat Pump Water Heater (HPWH) Demand Management System. A unitary residential HPWH and demand management system shall be installed that meets the requirements of Title 24, Part 6 Reference Appendix JA13 and qualifies for the Basic Plus Option control.

A4.203.1.2.9 Battery Storage System. A battery storage system shall be installed that meets the requirements of Title 24, Part 6 Reference Appendix JA12 and qualifies for either the Time-of-Use Control or Advanced Demand Response Control option.

A4.203.1.3 Performance standard. Comply with one of the advanced efficiency levels, either A4.201.1.3.1 OR A4.201.1.3.2, indicated below.

Table A4.203.1.1.1

Recommended Total EDR2 Margins~~Targets~~ by Climate Zones				
CZ	Tier 1		Tier 2	
	Mixed Fuel	All-Electric	Mixed Fuel	All-Electric
1	~~23~~27	~~36~~7	~~13~~n/a	~~0~~25
2	~~12~~25	~~16~~6	~~5~~n/a	~~0~~18
3	~~10~~26	~~14~~6	~~0~~n/a	~~0~~16
4	~~8~~25	~~12~~7	~~0~~n/a	~~0~~16
5	~~10~~30	~~16~~5	~~0~~n/a	~~0~~17
6	~~10~~29	~~12~~8	~~0~~n/a	~~0~~17
7	~~5~~32	~~7~~8	~~0~~n/a	~~0~~17
8	~~10~~25	~~10~~7	~~0~~n/a	~~0~~14
9	~~13~~27	~~13~~7	~~0~~n/a	~~0~~14
10	~~10~~23	~~11~~6	~~0~~n/a	~~0~~13
11	~~11~~19	~~12~~5	~~0~~n/a	~~0~~12
12	~~12~~22	~~13~~5	~~0~~n/a	~~0~~14
13	~~11~~21	~~13~~6	~~0~~n/a	~~0~~11
14	~~15~~24	~~16~~5	~~5~~n/a	~~0~~15
15	~~11~~17	~~8~~5	~~0~~n/a	~~7~~8
16	~~22~~24	~~39~~0	~~14~~n/a	~~10~~17

Note: Community shared options complying with Title 24, Part 1, Section 10-115 may be used to achieve Total EDR targets.

~~Note: For Energy Budget calculations, high-rise residential and hotel/motel buildings are considered nonresidential buildings.~~

A4.203.1.3.1 Tier 1. Buildings complying with the first level of advanced energy efficiency shall meet the following:

A4.203.1.3.1.1. Mixed-fuel buildings shall comply with the following:

A4.203.1.3.1.1.1 Heat Pump. Install either a heat pump for space heating or a heat pump water heater for water heating, and

A4.203.1.3.1.2. H~~h~~ave additional integrated efficiency and onsite renewable energy generation sufficient to achieve a Total EDR2 Margin equal to or greater than ~~of~~ the Tier 1 value indicated by Table A4.203.1.1.1 ~~or lower~~ as calculated by Title 24, Part 6 Compliance Software approved by the Energy Commission. This requirement is in addition to meeting the Efficiency EDR required for compliance with Title 24, Part 6. Measures used ~~considered~~ to meet the Total EDR targets calculated by the compliance software include, but are not limited to, the prerequisite options above specified in Section A4.203.1.2~~, use of Demand Response, additional energy efficiency measures (e.g., triple pane windows), as well as onsite electric battery and/or thermal storage~~.

A4.203.1.3.2 Tier 2. Buildings complying with this second elective designation shall meet the following:

A4.203.1.3.2.1. Be an all-electric building, and

A4.203.1.3.2.2. H~~h~~ave additional integrated efficiency and on~~-~~site renewable energy generation sufficient to achieve a Total EDR2 Margin equal to or greater than ~~of~~ the Tier 2 value indicated by Table A4.203.1.1.1 ~~or lower~~ as calculated by Title 24, Part 6 Compliance Software approved by the Energy Commission. ~~This may be reached by various paths including improved space and water heating efficiencies, advanced electric battery controls, as well as modest oversizing of the photovoltaic system.~~ This requirement is in addition to meeting the efficiency EDR required for compliance with Title 24, Part 6. Measures used ~~considered~~ to meet the Total EDR targets calculated by the compliance software include, but are not limited to, the prerequisite options specified in Section A4.203.1.2~~, use of Demand Response,. additional energy efficiency measures (e.g. triple pane windows), as well as onsite electric battery and/or thermal storage~~.

A4.203.1.4 Consultation with local electric service provider. Local jurisdictions considering adoption of Tier I as specified by A4.203.1.3.1 or Tier II as specified by A4.203.1.3.2, including local jurisdictions considering community shared solar or storage options consistent with Part 1 Section 10-115, shall consult with the local electric service provider to ensure that that solar system sizing required to comply will be acceptable to the local electric service provider. The local jurisdiction shall not require onsite renewable energy generation systems that are larger than the local electric service provider will allow to be interconnected.

~~**Note:** For Energy Budget calculations, high-rise residential and hotel/motel buildings are considered nonresidential buildings.~~

SECTION A4.20~~3~~4 PERFORMANCE APPROACH FOR NEWLY CONSTRUCTED MULTIFAMILY BUILDINGS

A4.20~~3~~4.1 Energy efficiency. Newly constructed multifamily ~~low-rise residential~~ buildings shall comply with Sections A4.20~~3~~4.1.1 through A4. 20~~3~~4.1.4.

A4. 20~~3~~4.1.1 Tier 1 and Tier 2 prerequisites. ~~A4.203.1.1.1 Energy design ratings, and A4.203.1.1.2 Quality Insulation Installation~~ The following are required for all applicable components of the building project.

~~**A4.203.1.1.1 Energy design ratings: Total Energy Design Rating (Total EDR) and Energy Efficiency Design Rating (Efficiency EDR).** Total EDR and Efficiency EDR ratings for the Proposed Design Building shall be computed by Compliance Software certified by the Energy Commission described in Title 24, Part 6, Section 100.1 and 150.1(b), and these ratings shall be included in the Certificate of Compliance documentation.~~

A4.204.1.1.1 All-electric building. All space heating, water heating, cooking, and laundry appliances shall use electric fuel.

A4. 20~~3~~4.1.1.2 Quality Insulation Installation (QII). The QII procedures specified in the Building Energy Efficiency Standards Reference Appendices RA3.5 shall be completed, as required by Section 170.2(a)6.

A4.20~~3~~4.1.2 Tier 1 and Tier 2 prerequisite options. In addition, TWO ~~ONE~~ of the following efficiency measures are ~~will be~~ required~~: A4.203.1.2.1 Roof deck insulation, or ducts in conditioned space OR A4.203.1.2.2 High Performance Walls OR A4.203.1.2.3 HERS-Verified Compact Hot Water Distribution System OR A4.203.1.2.4 HERS-Verified Drain Water Heat Recovery~~.

A4. 20~~3~~4.1.2.~~2~~1 High Performance Walls (HPW). HPW meet the climate zone dependent U-factor and insulation values for either 2x6 or 2x4 framing as specified in Title 24, Part 6, Section ~~150.1(c)1B~~170.2(a)2: maximum U-factor of 0.0~~48~~51.

A4.204.1.2.2 Building Infiltration. Building air leakage shall be tested utilizing the procedures in Title 24, Part 6 Reference Appendix NA2.4; or dwelling units shall have balanced ventilation and less than or equal to 0.3 cubic feet per minute at 50 Pa (0.2 inch water) per ft^2 of dwelling unit envelope surface area as confirmed by field verification and diagnostic testing in accordance with the procedures specified in

Reference Residential Appendix RA3.8.

A4.204.1.2.3 CPC Appendix M pipe sizing. CPC Appendix M shall be used to size DHW recirculation systems supply pipes.

A4. 20~~3~~4.1.2.4 HERS-Verified Drain Water Heat Recovery (DWHR-H). DWHR-H shall be installed as specified in Title 24, Part 6 Reference Appendix RA4.4.21.

A~~5~~4. 20~~3~~4.1.~~1.1~~2.5 Outdoor lighting. Newly installed outdoor lighting power shall be no greater than 90 percent of the Allowed Outdoor Lighting Power, and general hardscape lighting within the scope of Title 24, Part 6, Section ~~140.7(db)1~~170.2(e)2Di shall have a color temperature no higher than 3000K. Lighting for Specific Applications within the scope of Title 24, Part 6, Section 170.2(e)2Dii shall have a color temperature no higher than 4000K. The Allowed Outdoor Lighting Power calculation is specified in Title 24, Part 6, Section ~~140.7~~ 170.2(e)2~~Requirements For~~ Outdoor Lighting.

Exception: The color temperature requirement is not applicable to the applications identified in the Exceptions to Section ~~140.7(a)~~ 170.2(e)2A ~~nor to the applications identified as "specific applications" in Section 140.7(b)2 and Table 140.7~~.

A2.204.1.2.6 Induction cooktops. Induction cooktops shall be installed in all dwelling unit and common use area kitchens.

A~~5~~4.203.1.~~2~~3 Performance standard. Comply with one of the advanced efficiency levels, in terms of percentage of Energy Budget, indicated below.

Table A4.203.1.3

CZ	Tier 1	Tier 2
1	95%	93%
2	95%	93%
3	95%	93%
4	95%	93%
5	95%	93%
6	96%	94%
7	96%	94%
8	96%	94%
9	95%	93%
10	95%	93%

11	96%	94%
12	95%	93%
13	96%	94%
14	96%	94%
15	97%	96%
16	95%	93%

A4. 20~~3~~4.1.4 Consultation with local electric service provider. Local jurisdictions considering adoption of Tier I as specified by A4.203.1.3.1 or Tier II as specified by A4.203.1.3.2, including local jurisdictions considering community shared solar or storage options consistent with Part 1 Section 10-115, shall consult with the local electric service provider to ensure that that solar system sizing required to comply will be acceptable to the local electric service provider. The local jurisdiction shall not require onsite renewable energy generation systems that are larger than the local electric service provider will allow to be interconnected.

Note: Authority: Sections 25213, 25218, 25218.5, 25402 and 25402.1, Public Resources Code. Reference: Sections 25402, 25402.1, 25402.4, and 25402.8, Public Resources Code

APPENDIX A5 NONRESIDENTIAL VOLUNTARY MEASURES

Division A5.2 – ENERGY EFFICIENCY

SECTION A5.201 GENERAL

A5.201.1 Scope. For the purposes of mandatory energy efficiency standards in this code, the California Energy Commission will continue to adopt mandatory standards. It is the intent of these voluntary provisions to encourage local jurisdictions through codification to achieve exemplary performance in the area of building energy efficiency. Local jurisdictions adopting these voluntary provisions as mandatory local energy efficiency standards shall submit the required application and receive the required approval of the California Energy Commission in compliance with Title 24, Part 1, Section 10-106, prior to enforcement. Once approval is granted by the Energy Commission, local jurisdictions shall file an ordinance expressly marking the local modifications along with findings and receive the required acceptance from the California Building Standards Commission in compliance with Section 101.7 of this code, prior to enforcement. (Title 24, Part 1, Section 10-106 is available at http://www.energy.ca.gov/title24/2019standards/)

SECTION A5.202 DEFINITIONS

A5.202.1 Definitions. The following terms are defined in Chapter 2.

ALL-ELECTRIC BUILDING.

ANSI/NEMA WD 6.

CANOPY IN BUILDINGS WITH CEH SPACES

COEFFICIENT OF PERFORMANCE (COP), COMPUTER ROOM HEAT RECOVERY.

COMPUTER ROOM.

COMPUTER ROOM HEAT RECOVERY.

CONTROLLED ENVIRONMENT HORTICULTURE (CEH)

CUMULATIVE POWER USAGE EFFECTIVENESS (PUE).

DESICCANT DEHUMIDIFICATION SYSTEMS

HORTICULTURAL LIGHTING

INDOOR GROWING

INFORMATION TECHNOLOGY EQUIPMENT (ITE).

ITE DESIGN LOAD.

MIXED-FUEL BUILDING.

PACKAGED REFRIGERATION SYSTEMS.

PHOTOSYNTHETIC PHOTON EFFICACY (PPE)

STEAM TRAP OPERATING PRESSURE.

SECTION A5.203 PERFORMANCE APPROACH

A5.203.1 Energy efficiency. Nonresidential~~, high-rise residential~~ and hotel/motel buildings that include lighting and/or mechanical systems shall comply with Sections A5.203.1.1 and A5.203.1.2. Newly constructed buildings and additions are included in the scope of these sections.

Buildings permitted without lighting or mechanical systems shall comply with Section A5.203.1.1 but are not required to comply with Section A5.203.1.2.

A5.203.1.1 Tier 1 and Tier 2 prerequisites. To comply with Tier 1, ONE of the following efficiency measures is required for all applicable components of the building project. To comply with Tier 2, TWO of the following efficiency measures are required.

A5.203.1.1.1 Outdoor lighting. Newly installed outdoor lighting power shall be no greater than 90 percent of the Allowed Outdoor Lighting Power, and general hardscape lighting within the scope of Title 24, Part 6, Section 140.7(d~~b~~)1 shall have a color temperature no higher than 3000K. Lighting for Specific Applications within the scope of Title 24, Part 6, Section 140.7(d)2 shall have a color temperature no higher than 4000K. The Allowed Outdoor Lighting Power calculation is specified in Title 24, Part 6, Section 140.7 Requirements For Outdoor Lighting.

Exception: The color temperature requirement is not applicable to the applications identified in the Exceptions to Section 140.7(a)~~ nor to the applications identified as "specific applications" in Section 140.7(b)2 and Table 140.7~~.

A5.203.1.1.2 Service water heating in restaurants. Newly constructed restaurants 8,000 square feet or greater and with service water heaters rated 75,000 Btu/h or greater shall install a solar water-heating system with a minimum solar savings fraction of 0.15.

Exceptions:

1. Buildings with a natural gas service water heater with a minimum of 95-percent thermal efficiency.

2. Buildings where greater than 75 percent of the total roof area has annual solar access that is less than 70 percent. Solar access is the ratio of solar insolation, including shade, to the

solar insolation without shade. Shading from obstructions located on the roof or any other part of the building shall not be included in the determination of annual solar access.

A5.203.1.1.3 Warehouse Dock Seal Doors. Exterior loading dock doors that are adjacent to conditioned or indirectly conditioned spaces shall have dock seals or dock shelters installed at the time of permitting. This requirement shall apply to newly constructed buildings and to loading dock doors added to existing buildings.

A5.203.1.1.4 Daylight Design Power Adjustments Factors (PAFs). Daylighting devices shall be installed as specified in Title 24, Part 6, Section 140.3(d).

~~**A5.203.1.1.5 Exhaust Air Heat Recovery.** Heat recovery requirements based on ASHRAE 90.1 Section 6.5.6.1 are adapted and modified for California climate zones as described below.~~

1. ~~Systems with minimum design outdoor air fraction of 80% or greater and supply air flow of 200 cfm or greater in climate zones 2, 9, 10, 11, 12, 13, 14, 15 shall have a heat recovery system.~~
2. ~~Heat recovery systems required by this section shall result in a net sensible energy recovery ratio of at least 60 percent for both heating and cooling as tested using AHRI 1060-2014 or 1061-2014 and certified by AHRI. A 60 percent sensible energy recovery ratio shall mean a change in the dry-bulb of the outdoor air supply equal to 60 percent of the difference between the outdoor air and exhaust air dry-bulb at design conditions. Provisions shall be made to bypass or control the energy recovery system to permit air economizer operation as required by Title 24, Part 6, Section 140.4(e): Economizers.~~

~~**Exceptions:**~~

1. ~~Systems serving spaces that are not cooled and that are heated to less than 60°F.~~
2. ~~Where more than 60 percent of the outdoor air heating energy is provided from site- recovered energy.~~
3. ~~Where the sum of the airflow rates exhausted and relieved within 20 feet of each other is less than 75 percent of the design outdoor airflow rate, excluding exhaust air that is either:~~
    1. ~~used for another energy recovery system,~~
    2. ~~not allowed by ASHRAE Standard 170 for use in energy~~

~~recovery systems with leakage potential, or~~

~~3. of Class 4 as defined in ASHRAE Standard 62.1.~~

~~4. Systems expected to operate less than 20 hours per week.~~

A5.203.1.1.5 Automatic Daylighting Controls Wattage Thresholds. Automatic daylighting controls shall be installed as specified in Title 24, Part 6, Section 130.1(d) and Section 140.6(d) with the following updates:

1. **EXCEPTION 3 to Section 130.1(d):** Rooms in which the combined total installed general lighting power in the Skylit Daylit Zone, and Primary Sidelit Daylit Zone, is less than 75 Watts, or parking garage areas where the total combined general lighting power in the sidelit daylight zones is less than 60 watts

2. **EXCEPTION 1 to Section 140.6(d):** Luminaires in Secondary Sidelit Daylit Zone(s) in an enclosed space in which the combined total general lighting power in Secondary Daylit Zone(s) is less than 75 watts, or where the combined total general lighting power in Primary and Secondary Daylit Zone(s) is less than 150 watts.

A5.203.1.1.6 Air Barrier Verification. The entire building shall have an air leakage rate not exceeding 0.25 cfm/ft^2 of building shell area at a pressure differential of 0.3 in of water (1.57 psf) (2.0 L/ m2 at 75 pa), when the entire building is tested, after completion of construction, in accordance with NA2.4 of Title 24, Part 6.

A5.203.1.1.7 Steam Trap Fault Detection. Buildings with steam systems may elect to use the following to meet prerequisite requirements:

A5.203.1.1.7.1 Tier 1: Steam Trap Requirements for Steam Traps Serving Newly Installed Process Equipment. Steam traps serving newly installed industrial process equipment with an operating pressure greater than 15 psig and connected to a steam system with a total combined connected boiler input rating greater than 5 Million Btu/hr, shall comply with the requirements of Title 24, Part 6 Section 120.6(j) items 1 through 4.

A5.203.1.1.7.2 Tier 2: Industrial Steam Traps Replacements. Steam traps serving industrial processes with an operating pressure greater than 15 psig and connected to a steam system with a total combined connected boiler input rating greater than 5

Million Btu/hr, shall comply with the requirements of Title 24, Part 6 Section 120.6(j) items 1 through 4.

A5.203.1.1.8 Computer Room Efficiency. Buildings with computer rooms may elect to use the following to meet prerequisite requirements:

A5.203.1.1.8.1 Computer Room: Power Usage Effectiveness Monitoring. Buildings with at least 2,000 kW of computer room ITE design load and where at least 80 percent of the total building cooling capacity serves computer rooms or associated electrical rooms and where IT equipment loads are served by an AC-output UPS shall include a power usage effectiveness monitoring system with the following minimum requirements:

1. True root mean square (RMS) power measurements of total computer room ITE power demand and total building power demand. ITE power shall be measured immediately downstream of any UPS, such that UPS losses are not included in ITE energy.
2. Data transfer on a server capable of trending and storing data for a minimum of 18 months, with data collected at 15-minute intervals or less.
3. Time series plots of hourly, daily, and monthly cumulative PUE are displayed on a visual dashboard visible to the building operator. If electricity produced and consumed on site is not included in the whole building electricity meter then it shall be metered and included in the total building electricity use.

A5.203.1.1.8.2 Computer Room Heat Recovery. New buildings with a total building cooling ITE design load and total building heating design load exceeding the values in Table A5.203.1.1.8.2 and an annual heating load for at least 1,400 hours, computer room heat recovery is required. The heat recovery system must have a computer room heat recovery COP of at least 3.0 at design conditions The computer room heat recovery system shall be capable of transferring at least 50 percent of the total building ITE design load or at least 50 percent of the total building design heating load from the computer room(s) to conditioned space(s) requiring heating.

TABLE A5.203.1.1.8.2: COMPUTER ROOM HEAT RECOVERY

Climate Zone	Total Building Cooling ITE Design Load	Total Building Heating Design Load [a]
1-5, 11-14, 16	> 200 kW (57 tons)	> 4 million Btu/hr
1-5, 11-14, 16	> 500 kW (141 tons)	> 2.5 million Btu/hr
6-10, 15	> 300 kW (85 tons)	> 5 million Btu/hr

a. Includes heating load for comfort and process loads.

EXCEPTION to Section A5.203.1.1.8.2 Buildings that use electric heating equipment with a building-wide average heating COP of 4.0 or greater.

A5.203.1.1.9 Controlled Environment Horticulture. Buildings utilized for controlled environment horticulture may elect to use the following to meet prerequisite requirements:

A5.203.1.1.9.1 Indoor Growing, Dehumidification. Dehumidification systems used in indoor growing shall conform to the following requirements:

1. **Dehumidification Equipment.** Dehumidification equipment shall be one of the following:
   a. Integrated HVAC system with on-site heat recovery to achieve dehumidification reheat, or
   b. Chilled water system with on-site heat recovery to achieve dehumidification reheat, or
   c. Solid or liquid desiccant dehumidification system.

EXCEPTION to A5.203.1.1.9.1: In buildings with less than 2,000 square feet of canopy in combined CEH spaces, stand-alone dehumidification units with a minimum energy factor of 1.9 L/kWh are permitted.

2. **Reheat.** The on-site heat recovery system in Section 120.6(h)3A shall be designed to fulfill at least 60% of the facility's dehumidification air reheat needs during peak dehumidification periods.
3. **Transpired Water Reuse.** Dehumidification equipment shall have the capability to reuse transpired water for irrigation.

A5.203.1.1.9.2: Indoor Growing, Horticultural Lighting. In a building with more than 40 kW of aggregate horticultural lighting load, the electric lighting systems used for plant growth and plant maintenance shall meet the following requirements:

1. Luminaires shall have a photosynthetic photon efficacy of not less than 2.1 micromoles per joule rated in accordance with ANSI / ASABE S640 for wavelengths from 400 to 700 nanometers.
2. Time-switch lighting controls shall be installed and comply with Section 110.9(b)1, Section 130.4(a)4, and applicable sections of NA7.6.2.
3. Multilevel lighting controls shall be installed and comply with Section 130.1(b).

A5.203.1.1.10 Requirements for Refrigerated Warehouses

Refrigerated Warehouses that are greater than or equal to 3,000 square feet and refrigerated spaces with a sum total of 3,000 square feet or more that are served by the same refrigeration system may elect to use the following to meet prerequisite requirements:

A5.203.1.1.10.1 Minimum Air-Cooled Condenser Sizing for Packaged Refrigeration Systems. Design saturated condensing temperatures for air-cooled condensers shall be less than or equal to the following:

1. Condensing units and packaged refrigeration systems
   1. The design dry bulb temperature plus 15°F for systems serving freezers;
   2. The design dry bulb temperature plus 20°F for systems serving coolers.
2. All other refrigeration systems
   1. The design dry bulb temperature plus 10°F for systems serving freezers;
   2. The design dry bulb temperature plus 15°F for systems serving coolers.

EXCEPTION to Section A5.203.1.1.10.1: Compressors and condensers on a refrigeration system for which more than 20 percent of the total design refrigeration cooling load is for quick chilling or freezing (space with design cooling capacities of greater than 240 Btu/hr-ft^2 (2 tons per 100 ft^2), or process refrigeration cooling for other than a refrigerated space.

A5.203.1.1.10.2 Fan-powered evaporators shall meet the evaporator specific efficiency requirements listed in Table *A5.203.1.1.10.1- B and Table A5.203.1.1.10.1- C at* the conditions listed in Table

A5.203.1.1.10.1-A. Evaporator specific efficiency is defined as the total refrigeration capacity (Btu/h) divided by the electrical input power at 100 percent fan speed. Capacity is rated at 10°F of temperature difference between the incoming air temperature and the saturated evaporating temperature. For glide refrigerants, the saturated evaporating temperature is defined as the dewpoint temperature. Input power is rated at 100% fan speed at rated temperature conditions.

EXCEPTION to Section A5.203.1.1.10.2: Evaporators designed solely for the purpose of quick chilling/freezing of products, including but not limited to spaces with design cooling capacities of greater than 240 Btu/hr-ft^2 (2 tons per 100 ft^2).

TABLE A5.203.1.1.10.1-A EVAPORATOR SPECIFIC EFFICIENCY RATING CONDITIONS

	FREEZER APPLICATION	**COOLER/DOCK APPLICATION**
Saturated evaporating temperature (°F)	-20	25
Entering air temperature (°F)	-10	35
External Static pressure (in. WC)	0	0
Rating type	Dry Coil	Dry Coil

TABLE A5.203.1.1.10.1-B EVAPORATOR SPECIFIC EFFICIENCY FOR FREEZER APPLICATIONS

LIQUID FEED TYPE	**REFRIGERANT TYPE**	**MINIMUM EFFICIENCY (Btuh/Watt)**
Direct Expansion	Halocarbon	35
	Ammonia	25
Flooded/Recirculated Liquid	Ammonia	45

TABLE A5.203.1.1.10.1-C EVAPORATOR SPECIFIC EFFICIENCY FOR COOLER APPLICATIONS

EVAPORATOR TYPE	**REFRIGERANT TYPE**	**MINIMUM EFFICIENCY (Btuh/Watt)**
Direct Expansion	Halocarbon	40
	Ammonia	35

Flooded/Recirculated Liquid	Ammonia	50

A5.203.1.1.10.4 Static Pressure Drop. The applied static pressure drop for evaporators installed in refrigerated warehouses shall not exceed 0.5" water column.

EXCEPTION to Section A5.203.1.1.10.4: Evaporators designed solely for the purpose of quick chilling/freezing of products, including but not limited to spaces with design cooling capacities of greater than 240 Btu/hr-ft^2 (2 tons per 100 ft^2).

A5.203.1.1.10.5 Acceptance Test Verified Commercial Refrigeration System. Condensers and condenser fan motor variable speed control shall be installed and verified as specified in Title 24, Part 6 Reference Appendix NA7.10.3

A5.203.1.2 Performance standard. Comply with one of the advanced efficiency levels indicated below.

Table A5.203.1.2

Building Type	Tier 1		Tier 2	
	All-Electric	Mixed-Fuel	All-Electric	Mixed-Fuel
Nonresidential and hotel/motel building projects	100 Percent	95 Percent	95 Percent	N/A

A5.203.1.2.1 Tier 1. Buildings complying with the first level of advanced energy efficiency have an Energy Budget that is no greater than indicated ~~below~~ in Table A5.203.1.2, depending on fuel type ~~building type and the type of energy systems included in the building project~~. If the newly constructed building or addition does not include indoor lighting or mechanical systems, then no additional performance requirements above Title 24, Part 6 are required.

A5.203.1.2.1.1. Electric Ready Design. Newly installed systems using gas or propane in new construction buildings and additions shall be electric ready by complying with the following requirements.

Exception. Systems that use electricity as the only fuel source.

A5.203.1.2.1.2 Space Heating-Only Furnaces. Space heating-only furnaces shall be supplied with conductors or raceway installed with termination points at the main electrical panel, via subpanels panels if applicable, to a location no more than 10 feet from each gas or propane outlet or a designated location of future electric replacement equipment. Both ends of the conductors or raceway shall be labelled appropriately to indicate "For Future Electric Space Heating." The conductors or raceway and any intervening subpanels, panelboards, switchboards, and busbars shall be physically sized to meet the future electric power requirements, as specified below, at the service voltage to the point at which the conductors serving the building connect to the utility distribution system. The capacity requirements may be adjusted for demand factors in accordance with the California Electric Code. Fuel flow rates shall be determined in accordance with the California Plumbing Code. Capacity shall be either:

1. 2,000 Volt-Amps for each 10,000 Btus per hour of rated fuel input or pipe capacity.
2. The electrical power required to provide equivalent functionality of the propane- or gas-powered equipment as calculated and documented by a licensed design professional.

Exceptions.

1. Furnaces larger than 300,000 Btu/h in capacity.
2. Unit heaters, spot heaters, and combination air-conditioners and warm air furnaces.

A5.203.1.2.1.2 Space Heating - Central Hydronic. Space conditioning systems that provide heating hot water shall comply with the following:

1. **Physical Space.** Construction documents shall indicate the physical space necessary for future equipment footprint, indoors or outdoors, and designate it as reserved for future heat pump water heating equipment, and if needed, a future pathway reserved for routing of ductwork from the outside to the heat pump evaporator. The footprint necessary for future heat pump water heating equipment may overlap with non-structural partitions and with the location of currently designed natural gas or propane water heating equipment.
2. **Input Capacity.** The central water heating system input fuel capacity shall be the sum of the input capacity of all water heating devices associated with the central water heating system. Where propane or natural gas service is provided for central water heating, but the equipment has not been specified, the fuel flowrates and input energy

capacity shall be determined in accordance with the California Plumbing Code.

3. **Sizing.** The electric power capacity of raceway or conductors and the size of areas allocated for hot water storage, heat pump equipment, and tertiary supporting equipment required to provide equivalent functionality of the propane- or gas-powered equipment shall be indicated on construction documents and sized as follows:

   i. Construction documents shall indicate occupiable space allocated for the location of future heat pump water heating equipment of at least 1.5 square feet per 10,000 Btu/hr of the input fuel capacity for water heating.
   ii. Raceway and/or conductors for the heat pump system shall be installed from the main electrical panel to the intended location of the heat pumps shall be sized for a continuous duty load of 1,600 Volt-Amps per 10,000 Btu/hr of fuel input fuel capacity for water heating.
   iii. If the location of the future heat pump evaporator is indoors, the construction documents shall indicate a pathway reserved for future routing of supply and exhaust air via ductwork to the heat pump evaporator, in compliance with the California Mechanical Code. Duct pathways shall be sized to accommodate a duct with 90 square inches of cross-sectional area per 10,000 Btu/hr of input fuel capacity
   iv. Drain lines for condensate shall be provided at the location of the future heat pumps, compliant with the California Plumbing code and no less than ¾ inch in diameter.

Exception. Power capacity and allocated areas as calculated and documented by a licensed design professional.

4. **Panelboards.** Raceway with or without electrical conductors shall be installed from the main electrical panel, via subpanels if applicable, to no more than 10 feet from the location of the future electric central hydronic heat pump location as indicated on the construction documents. Both ends of the conductors or raceway shall be labelled to indicate future use "For Future Electric Space Heating." The conductors or raceway and any intervening subpanels, panelboards, switchboards, and busbars shall be physically sized to accommodate the future electric power requirements, as specified in item 3, including reserved breakers or spaces as needed. The electrical capacity requirements may be adjusted for demand factors in accordance with the California Electric Code.

A5.203.1.2.1.3 Domestic/Service Water Heating – Central with Recirculation Loop. Central water heating systems with recirculation loops shall comply with the following:

1. **Physical Space.** Construction documents shall indicate the physical space necessary for future equipment footprint, indoors or outdoors, and designate it as reserved for future heat pump water heating equipment, and if needed, a future pathway reserved for routing of ductwork from the outside to the heat pump evaporator. The footprint necessary for future heat pump water heating equipment may overlap with non-structural partitions and with the location of currently designed natural gas or propane water heating equipment.
2. **Input Capacity.** The central water heating system input fuel capacity shall be the sum of the input capacity of all water heating devices associated with the central water heating system. Where propane or natural gas service is provided for central water heating, but the equipment has not been specified, the fuel flowrates and input energy capacity shall be determined in accordance with the California Plumbing Code.
3. **Sizing.** The electric power capacity of raceway or conductors and the size of areas allocated for hot water storage and heat pump equipment required to provide equivalent functionality of the propane- or gas-powered equipment shall be indicated on construction documents and sized as follows.
    i. Construction documents shall indicate occupiable space allocated for the location of future heat pump water heating equipment of at least 1.5 square feet per 10,000 Btu/hr of the input fuel capacity for water heating.
    ii. Raceway and/or conductors for the heat pump system shall be installed from the main electrical panel to where the heat pumps are intended to be located and shall be sized for a continuous duty load of 1,000 Volt-Amps per 10,000 Btu/hr of input fuel capacity.
    iii. Construction documents shall indicate occupiable space allocated for future heat pump hot water storage where the current fuel water heating system tanks are located, or where propane or natural gas service is provided for central water heating. The space allocated for hot water storage shall be at least 2 square feet per 10,000 Btu/hr of the input capacity of the water heating equipment.
    iv. Raceway and/or conductors for back-up electric resistance heating shall be installed from the main electrical panel to the

intended location of the hot water storage tank area and shall be sized for a continuous duty load of 1,000 Volt-Amps per 10,000 Btu/hr of the input fuel capacity.

v. If the location of the future heat pump evaporator is indoors, the construction documents shall indicate a pathway reserved for future routing of supply and exhaust air via ductwork to the heat pump evaporator, in compliance with the California Mechanical Code. Duct pathways shall be sized to accommodate a duct with 90 square inches of cross-sectional area per 10,000 Btu/hr of input fuel capacity

vi. Drain lines for condensate shall be provided at the location of the future heat pumps, compliant with the California Plumbing code and no less than ¾ inch in diameter.

Exception. Power capacity and allocated areas as calculated and documented by a licensed design professional.

4. **Panelboards.** Raceway with or without electrical conductors shall be installed from the main electrical panel, via subpanels if applicable, to no more than 10 feet from the intended location of future heat pump water heater system as indicated on the construction documents. Both ends of the conductors or raceway shall be labelled to indicate future use "For Future Electric Water Heating." The conductors or raceway and any intervening subpanels, panelboards, switchboards, and busbars shall be physically sized to meet the future electric power requirements, as specified in item 3, including reserved breakers or spaces as needed. The electrical capacity requirements may be adjusted for demand factors in accordance with the California Electric Code.

A5.203.1.2.1.4 Domestic/Service Water Heating – Storage without Recirculation. Water heating systems that do not use a recirculation loop shall comply with the following:

1. **Physical Space.** Construction documents shall indicate the physical space necessary for future equipment footprint and designate it as reserved for future heat pump water heating equipment, and if needed, a future pathway reserved for routing of ductwork from the outside to the heat pump evaporator. The footprint necessary for future heat pump water heating equipment may overlap with non-structural partitions and with the location of currently designed natural gas or propane water heating equipment.

2. **Input Capacity.** The central water heating system input fuel capacity shall be the sum of the input capacity of all water heating devices associated with the central water heating system. Where propane or natural gas service is provided for central water heating but the

equipment has not been specified, the fuel flowrates and input energy capacity shall be determined in accordance with the California Plumbing Code.

3. **Sizing.** The electric power capacity of raceway or conductors and the size of areas allocated for hot water storage and heat pump equipment required to provide equivalent functionality of the propane- or gas-powered equipment shall be indicated on construction documents and sized as follows.

    i. Construction documents shall indicate occupiable space allocated for future heat pump equipment and hot water storage where the current gas or propane water heating system tanks are located, or where propane or natural gas service is provided for central water heating. The space allocated for hot water storage shall be at least 2 square feet per 10,000 Btu/hr of the input fuel capacity for water heating.
    ii. Raceway and/or conductors for the heat pump system shall be installed from the main electrical panel to where the heat pumps are designed to be located and shall be sized for a continuous duty load of 2,000 Volt-Amps per 10,000 Btu/hr of input fuel capacity for water heating.
    iii. The construction documents shall indicate the pathway for supply and exhaust air via ductwork to the heat pump evaporator, in compliance with the California Mechanical Code. Duct pathways shall be sized to accommodate a duct with 90 square inches of cross-sectional area per 10,000 Btu/hr of input fuel capacity.
    iv. Drain lines for condensate shall be provided at the location of the future heat pumps, compliant with the California Plumbing code and no less than ¾ inch in diameter.

    Exception. Power capacity and allocated areas as calculated and documented by a licensed design professional.

4. **Panelboards.** Raceway with or without electrical conductors shall be installed from the main electrical panel, via subpanels if applicable, to no more than 5 feet from the location of future electric systems as indicated on the construction documents. Both ends of the conductors or raceway shall be labelled appropriately to indicate future use "For Future Electric Water Heating." The conductors or raceway and any intervening subpanels, panelboards, switchboards, and busbars shall be physically sized to meet the future electric power requirements, as specified in item 3, including reserved breakers as needed. The electrical capacity requirements may be adjusted for demand factors in accordance with the

California Electric Code.

A5.203.1.2.1.5 Service Water Heating - Instantaneous. Instantaneous water heating systems shall be supplied with conductors or raceway installed with termination points at the main electrical panel, via subpanels panels if applicable, to a location no more than 3 feet from each gas or propane outlet or a designated location of future electric replacement equipment. Both ends of the conductors or raceway shall be labelled appropriately to indicate "For Future Electric Water Heating." The conductors or raceway and any intervening subpanels, panelboards, switchboards, and busbars shall be physically sized to meet the future electric power requirements, as specified below, at the service voltage to the point at which the conductors serving the building connect to the utility distribution system. The capacity requirements may be adjusted for demand factors in accordance with the California Electric Code. Fuel flow rates shall be determined in accordance with the California Plumbing Code. Capacity shall be either:

1. 2,000 Volt-Amps for each 10,000 Btus per hour of rated fuel input or pipe capacity.
2. The electrical power required to provide equivalent functionality of the propane- or gas-powered equipment as calculated and documented by a licensed design professional.

A5.203.1.2.1.6 Cooking Equipment. Cooking equipment shall be supplied with conductors or raceway installed with termination points at the main electrical panel, via subpanels panels if applicable, to a location no more than 10 feet from each gas or propane outlet or a designated location of future electric replacement equipment. Both ends of the conductors or raceway shall be labelled appropriately to indicate "Future Electric Cooking." The conductors or raceway and any intervening subpanels, panelboards, switchboards, and busbars shall be sized to meet the future electric power requirements, as specified below, at the service voltage to the point at which the conductors serving the building connect to the utility distribution system. The capacity requirements may be adjusted for demand factors in accordance with the California Electric Code. Fuel flow rates shall be determined in accordance with the California Plumbing Code. Capacity shall be either:

1. 1,500 Volt-Amps for each 10,000 Btus per hour of rated fuel input or pipe capacity.

2. The electrical power required to provide equivalent functionality of the propane- or gas-powered equipment as calculated and documented by a licensed design professional.

A5.203.1.2.1.7 Clothes Drying Equipment. Clothes drying equipment shall be supplied with conductors or raceway installed with termination points at the main electrical panel, via subpanels panels if applicable, to a location no more than 10 feet from each gas or propane outlet or a designated location of future electric replacement equipment. Both ends of the conductors or raceway shall be labelled appropriately to indicate "Future Electric Clothes Drying." The conductors or raceway and any intervening subpanels, panelboards, switchboards, and busbars shall be sized to meet the future electric power requirements, as specified below, at the service voltage to the point at which the conductors serving the building connect to the utility distribution system. The capacity requirements may be adjusted for demand factors in accordance with the California Electric Code. Fuel flow rates shall be determined in accordance with the California Plumbing Code. Capacity shall be either:

1. 2,600 Volt-Amps for each 10,000 Btus per hour of rated fuel input or pipe capacity.
2. The electrical power required to provide equivalent functionality of the propane- or gas-powered equipment as calculated and documented by a licensed design professional.

Exception. Gas or propane clothes dryers larger than 22,000 Btu/h input capacity per appliance.

1. ~~For nonresidential building projects that include indoor lighting or mechanical systems, but not both: No greater than 95 percent of the Title 24, Part 6, Energy Budget for the Standard Design Building as calculated by compliance software certified by the Energy Commission.~~
2. ~~For nonresidential building projects that include indoor lighting and mechanical systems: No greater than 90 percent of the Title 24, Part 6 Energy Budget for the Standard Design Building as calculated by compliance software certified by the Energy Commission.~~
3. ~~For high-rise residential and hotel/motel building projects: No greater than 95 percent of the Title 24, Part 6, Energy Budget for the Standard Design Building as calculated by compliance software certified by the Energy Commission.~~

A5.203.1.2.2 Tier 2. Buildings complying with the second level of advanced energy efficiency shall:

A5.203.1.2.2.1 Be an all-electric building, and

A5.203.1.2.2.2 H~~h~~ave an Energy Budget that is no greater than indicated ~~below~~ in Table A5.203.1.2~~, depending on building type and the type of energy systems included in the building project~~. If the newly constructed building or addition does not include indoor lighting or mechanical systems, then no additional performance requirements above Title 24, Part 6 are required.

1. ~~For nonresidential building projects that include indoor lighting or mechanical systems, but not both: No greater than 90 percent of the Title 24, Part 6, Energy Budget for the Standard Design Building as calculated by compliance software certified by the Energy Commission.~~

2. ~~For nonresidential building projects that include indoor lighting and mechanical systems:~~

   a. ~~No greater than 85 percent of the Title 24, Part 6, Energy Budget for the Standard Design Building as calculated by compliance software certified by the Energy Commission.~~

   b. ~~For high-rise residential and hotel/motel building projects: No greater than 90 percent of the Title 24, Part 6, Energy Budget for the Standard Design Building as calculated by compliance software certified by the Energy Commission.~~

Note: For Energy Budget calculations~~, high-rise residential~~ and hotel/motel buildings are considered nonresidential buildings.

SECTION A5.211 RENEWABLE ENERGY

A5.211.1 Onsite renewable energy. ~~Use onsite renewable energy sources such as solar, wind, geothermal, low-impact hydro, biomass and bio-gas for at least 1 percent of the electric power calculated as the product of the building service voltage and the amperage specified by the electrical service overcurrent protection device rating or 1kW, (whichever is greater), in addition to the electrical demand required to meet 1 percent of the natural gas and propane use. The building project's electrical service overcurrent protection device rating shall be calculated in accordance with the California Electrical Code. Natural gas or propane use is calculated in accordance with the California Plumbing Code.~~ Comply with the prescriptive requirements for photovoltaic and battery storage systems in Section 140.10 of Title 24, Part 6.

A5.211.1.1 Documentation. Using a calculation method approved by the California Energy Commission, calculate the renewable onsite energy system to meet the requirements of Section A5.211.1, expressed in kW. Factor in net metering, if offered by local utility, on an annual basis.

A5.211.3 Green power. If offered by local load-serving entity ~~utility provider~~, buildings complying with the first level of advanced energy efficiency shall participate in a renewable energy portfolio program that provides a minimum of 50-percent electrical power from renewable sources. If offered by local load-serving entity, buildings complying with the second level of advanced energy efficiency shall participate in a renewable energy portfolio program that provides a minimum of 100-percent electrical power from renewable sources. Maintain documentation through utility billings.

SECTION A5.212 ELEVATORS, ESCALATORS AND OTHER EQUIPMENT

A5.212.1 Elevators and escalators. In buildings with more than one elevator or two escalators, provide systems and controls to reduce the energy demand of elevators and escalators as follows. Document systems operation and controls in the project specifications and commissioning plan.

A5.212.1.1 Elevators. Traction elevators shall have a regenerative drive system that feeds electrical power back into the building grid when the elevator is in motion.

A5.212.1.1.1 Car lights and fan. A parked elevator shall turn off its car lights and fan automatically until the elevator is called for use.

A5.212.1.2 Escalators. An escalator shall have a VVVF motor drive system that is fully regenerative when the escalator is in motion.

A5.212.1.34 Controls. Controls that reduce energy demand shall meet requirements of CCR, Title 8, Chapter 4, Subchapter 6 and shall not interrupt emergency operations for elevators required in CCR, Title 24, Part 2, *California Building Code*.

SECTION A5.213 ENERGY EFFICIENT STEEL FRAMING

A5.213.1 Steel framing. Design steel framing for maximum energy efficiency. Techniques for avoiding thermal bridging in the envelope include:

1. Exterior rigid insulation;
2. Punching large holes in the stud web without affecting the structural integrity of the stud;
3. Spacing the studs as far as possible while maintaining the structural integrity of the structure; and
4. Detailed design of intersections of wall openings and building intersections of floors, walls and roofs.

Note: Authority: Sections 25213, 25218, 25218.5, 25402 and 25402.1, Public Resources Code. Reference: Sections 25402, 25402.1, 25402.4, and 25402.8, Public Resources Code

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Appendix A: Energy and Cost-Effectiveness Analysis – Single Family Buildings

Base Case Prototype Description

The Energy Commission defines building prototypes which it uses to evaluate the cost-effectiveness of proposed changes to Title 24 requirements. At the time that this report was written, there are two single family prototypes. Both of these are used in this analysis in development of the above-code packages. Table 73 describes the basic characteristics of each prototype. Additional details on the prototypes can be found in the Alternative Calculation Method (ACM) Approval Manual (California Energy Commission 2018). The prototypes have equal geometry on all walls, windows, and roof to be orientation neutral.

Table 73: Prototype Characteristics

Characteristic	Single Family One-Story	Single Family Two-Story
Conditioned Floor Area	2,100 ft^2	2,700 ft^2
Num. of Stories	1	2
Num. of Bedrooms	3	4
Window-to-Floor Area Ratio	20%	20%

Source: ACM Approval Manual (California Energy Commission 2018).

The Energy Commission's protocol for single family prototypes is to weight the simulated energy impacts by a factor that represents the distribution of single-story and two-story homes being built statewide. In past code cycles it was assumed that 45 percent of homes being built were one-story and 55 percent were two-story. As part of the Title 24, Part 6 CASE effort for the 2022 code cycle, the Statewide CASE Team requested HERS Registry data from CalCERTS for permitted projects in the 2016 code cycle. Included in this data is a breakdown by climate zone of new construction single family homes according to conditioned floor area and number of stories. Based on almost 137,500 single family homes, 49 percent of homes were one-story, and 51 percent of homes were two-story or greater. Based on this data the Statewide CASE Team recommended that the statewide weighting factors be revised to 50 percent one-story and 50 percent two-story. Therefore, the results in this report are presented for a 2,400 square foot home.[17]

The methodology used in the analyses for each of the prototypical building types begins with a design that precisely meets the minimum 2022 prescriptive requirements (zero

[17] 2,400 square feet = (50 percent * 2,100 square feet) + (50 percent * 2,700 square feet)

compliance margin) as best as is known before adoption of the 2022 code. This is based on Table 150.1-A in the 2019 Standards (California Energy Commission 2018) lists the prescriptive measures that determine the baseline design in each climate zone. Other features are consistent with the Standard Design in the ACM Reference Manual (California Energy Commission 2019) and the proposed mixed-fuel Standard Design as presented by the Energy Commission at the January 26, 2021 staff workshop on decarbonization (California Energy Commission 2021). The prototype building is based on the following characteristics:

- Slab-on-grade foundation.
- Vented attic.
- Ductwork located in the attic.

Both mixed-fuel and all-electric prototypes are evaluated in this study. While in past code cycles an all-electric home was compared to a home with gas for certain end-uses, the 2019 code included separate prescriptive and performance paths for mixed-fuel and all-electric homes. The fuel specific characteristics of the mixed-fuel and all-electric prototypes are defined according to the 2019 ACM Reference Manual.

For the 2022 code the Energy Commission proposes a shift back to a single prototype. Table 74 summarizes the base case characteristics used in this analysis, which reflects the Energy Commission's draft proposal with the exception that high performance windows were included in Climate Zone 15 and have been omitted for this analysis. The Energy Commission has since revised the proposed baseline and the final report will incorporate these changes in an updated analysis. Results are not expected to change significantly.

Table 74: 2022 Proposed Standard Design by Climate Zone

Climate Zone	Space Heating Type	Water Heating Type	Compact Distribution	Drain Water Heat Recovery
1	Gas Furnace	HPWH	Expanded credit	None
2	Gas Furnace	HPWH	None	None
3	Heat Pump	Gas Tankless	None	None
4	Heat Pump	Gas Tankless	None	None
5	Heat Pump	Gas Tankless	Expanded credit	None
6	Heat Pump	Gas Tankless	None	None
7	Heat Pump	Gas Tankless	None	None
8	Heat Pump	Gas Tankless	Basic credit	None
9	Heat Pump	Gas Tankless	Expanded credit	None
10	Heat Pump	Gas Tankless	Expanded credit	None
11	Gas Furnace	HPWH	None	None
12	Gas Furnace	HPWH	None	None
13	Heat Pump	Gas Tankless	None	None
14	Heat Pump	Gas Tankless	None	None
15	Heat Pump	Gas Tankless	Basic credit	None
16	Gas Furnace	HPWH	Expanded credit	Equal flow to shower & water heater, 65% efficiency

All-Electric Versus Mixed-Fuel Comparison

Analysis is presented here for an all-electric prescriptive minimum home as compared to the mixed-fuel 2022 code baseline. The all-electric home has electric water heating, space heating, cooking, and clothes drying with all other characteristics equivalent to the mixed-fuel baseline[18]. Although the Statewide CASE Team recommends efficiency requirements for any reach code, this analysis can be used by jurisdictions to justify a reach code that prohibits mixed-fuel homes and only requires that all-electric homes meet code minimum requirements.

Following is a description of the measures applied to the all-electric home. All other building characteristics were compliant with the proposed 2022 base case in both simulations (see Table 74).

[18] The mixed-fuel baseline has either electric space heating or water heating, depending on climate zone and gas cooking and clothes drying.

Heat Pump Water Heater (HPWH): Where the mixed-fuel 2022 code baseline includes gas water heating a HPWH was evaluated that is minimally compliant with federal standards.

Heat Pump Space Heater: Where the mixed-fuel 2022 code baseline includes gas space heating a heat pump space heater was evaluated that is minimally compliant with federal standards.

Cooking and Clothes Drying: Electric resistance appliances were included in place of gas appliances for cooking and clothes drying.

Improved Fenestration: Once all appliances are electrified in Climate Zone 16 with minimum efficiency equipment, the result is not code compliant due to higher TDV energy use for space heating. In this case high performance windows were added to the building to meet compliance. Window U-factor was reduced to 0.24 and the solar heat gain coefficient (SHGC) increased to 0.50 from the default assumption of 0.35.

Energy savings and peak demand impacts per unit are presented in Table 75 for an all-electric home relative to a mixed-fuel home. In all climates the energy impacts are based on switching cooking, clothes drying, and either water heating or space heating (depending on climate zone) to electric from natural gas. Additionally, in climate zone 16 high performance windows are included in the package. Per-unit impacts for the first year are expected to range from an increase of 1,659 to 4,946 annual kWh and savings of 129 to 403 annual therm depending upon climate zone. Demand increases are expected to range between 0.22 kW and 0.51 kW depending on climate zone.

Table 75: All-Electric versus Mixed-Fuel Single Family Home First-Year Energy Impacts Per Home

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therm/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(4,946)	(0.22)	398	(4,383)
2	(3,279)	(0.22)	246	(3,065)
3	(2,527)	(0.35)	172	(2,871)
4	(2,310)	(0.35)	164	(954)
5	(2,353)	(0.34)	163	(3,081)
6	(2,140)	(0.33)	159	4,160
7	(2,114)	(0.36)	158	3,785
8	(1,958)	(0.28)	149	5,677
9	(1,974)	(0.28)	148	4,488
10	(1,991)	(0.25)	148	3,894
11	(3,053)	(0.29)	226	(2,751)
12	(2,816)	(0.24)	212	(3,020)
13	(2,152)	(0.26)	154	1,179
14	(2,351)	(0.25)	159	(1,293)
15	(1,659)	(0.23)	129	2,640
16	(4,501)	(0.51)	403	(4,412)

Table 76 presents incremental cost assumptions. Costs are based on the 2019 low-rise residential new construction reach code report (Statewide Reach Codes Team 2019) and have been updated in some cases based on improved data. Incremental costs represent the equipment, installation, replacement, and maintenance costs of the proposed measures relative to the base case. Replacement costs are applied to water heating and space heating equipment over the 30-year evaluation period. All costs are provided as present value in 2023 (2023 PV$).

Table 76: All-Electric Versus Mixed-Fuel Incremental Costs for 2,400 Square Foot Single Family Building

Measure	Incremental Cost (2023 PV$) First Cost	Incremental Cost (2023 PV$) Replacement Cost	Incremental Cost (2023 PV$) Total	Source and Notes
Heat Pump vs Gas Furnace/Split AC	**($201)**	**$787**	**$586**	
Equipment & Install	($221)	$787	$567	(Statewide Reach Codes Team 2019). Replacement costs are based on 15 years for heat pump and 20 years for furnace / air conditioner.
Electric Service Upgrade	$220	$0	$220	2020 RS Means. Material and labor to install 30A 240V circuit less cost to install 15A 120V duplex outlet.
In-House Gas Piping	($200)	$0	($200)	(Statewide Reach Codes Team 2019)
HPWH vs Gas Tankless	**($200)**	**$478**	**$278**	
Equipment & Install	$0	$478	$478	(Statewide Reach Codes Team 2019). Replacement costs are based on 15 years for HPWH and 20 years for tankless natural gas water heater.
Electric Service Upgrade	$0	$0	$0	No cost since 2019 Title 24, Part 6 code requires 240V electrical infrastructure be provided to all water heater locations.
In-House Gas Piping	($200)	$0	($200)	(Statewide Reach Codes Team 2019)
Electric Resistance vs Gas Cooking	**($105)**	**$0**	**($105)**	
Equipment & Install	($270)	$0	($270)	(Energy & Environmental Economics 2019)
Electric Service Upgrade	$365	$0	$365	2020 RS Means. Material and labor to install 50A 240V circuit less cost to install 15A 120V duplex outlet.
In-House Gas Piping	($200)	$0	($200)	(Statewide Reach Codes Team 2019)
Electric Resistance vs Gas Clothes Drying	**($465)**	**$0**	**($465)**	
Equipment & Install	($265)	$0	($265)	(Energy & Environmental Economics 2019)
Electric Service Upgrade	$0	$0	$0	No cost, assumed most builders provide both gas and electric infrastructure to dryer location.
In-House Gas Piping	($200)	$0	($200)	(Statewide Reach Codes Team 2019)
Site Gas Infrastructure	($5,000)	$0	($5,000)	See below

Site gas infrastructure costs of $5,000 are based on a memo from PG&E to Energy Commission staff. Cost includes $1,020 for main extension, $2,830 for service extension, $300 plan review costs, and $850 for the natural gas meter. These costs have not been reduced due to application of Utility Gas Main Extensions rules, which allow for costs to the developer to be reduced by 50 percent to account for the portion of the costs included in the utility's rate base and recovered via rates to all customers. This reduction was not applied under the TDV cost-effectiveness methodology used in this analysis based on input received from the Energy Commission and agreement from the Reach Code technical advisory team that the approach is appropriate. TDV cost savings impacts extend beyond the customer and account for societal impacts of energy use. Accounting for the full cost of the infrastructure upgrades was determined to be justified when evaluating under the TDV methodology.

Table 77 presents incremental costs for the window measure applied in Climate Zone 16.

Table 77: High Performance Window Incremental Costs for a 2,400 Square Foot Single Family Building

Measure	Incremental First Cost (2023 PV$)	Source and Notes
Window U-factor 0.24 vs 0.30	$2,030	$4.23/ft^2 window area based on analysis conducted for the 2019 and 2022 Title 24 cycles (Statewide CASE Team 2018).
Window SHGC 0.50 vs 0.35	$0	Data from CASE Report along with direct feedback from Statewide CASE Team that higher SHGC does not necessarily have any incremental cost (Statewide CASE Team 2017e).

Results of the per-unit cost-effectiveness analyses for an all-electric code compliant home presented in Table 78. The proposed package saves money over the 30-year period of analysis relative to the mixed-fuel base case and is cost effective in every climate zone.

Table 78: All-Electric 2019 Code Compliant Home 30-Year Cost-Effectiveness Summary Per Home

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings (2023 PV$)	Costs Total Incremental PV Costs (2023 PV$)	Benefit-to-Cost Ratio[a]
1	($758)	($4,983)	6.6
2	($530)	($4,983)	9.4
3	($497)	($5,292)	10.7
4	($165)	($5,292)	32.1
5	($533)	($5,292)	9.9
6	$720	($5,292)	>1
7	$655	($5,292)	>1
8	$982	($5,292)	>1
9	$776	($5,292)	>1
10	$674	($5,292)	>1
11	($476)	($4,983)	10.5
12	($522)	($4,983)	9.5
13	$204	($5,292)	>1
14	($224)	($5,292)	23.7
15	$457	($5,292)	>1
16	($763)	($2,953)	3.9

a. “>1” indicates cases where there are both incremental measure cost savings and energy cost savings.

Appendix B: Energy and Cost-Effectiveness Analysis – Nonresidential Buildings

Electric Ready Buildings Analysis Documentation

The Statewide CASE Team evaluated electric ready measures and incremental costs for space heating, service water (SHW) heating, commercial cooking, and clothes drying in this analysis. Specifically, the Statewide CASE Team evaluated the following system types across different building types:

1. 53,000 ft^2 Medium Office
    a. HVAC: VAV reheat system - central hydronic gas boiler to heat pump boiler
    b. SHW: Gas water storage heater to heat pump water storage heater
2. 5,000 ft^2 Full-service restaurant and 2,500 ft^2 quick service restaurant SHW:
    a. Gas central water with recirculation to heat pump water heater
    b. Gas cooking appliances to electric cooking appliances
3. 25,000 ft^2 Standalone Retail and 50,000 ft^2 Warehouse DHW: Gas instantaneous to electric instantaneous water heaters
4. 40,000 ft^2 Small Hotel:
    a. Gas clothes dryers to heat pump clothes dryers
    b. Service water heating serving clothes washers
    c. Central domestic water heating with recirculation loop serving guest rooms

To determine electric ready measures for each building type, the Statewide CASE Team modeled baseline dual-fuel buildings based on the Energy Commission prototypes buildings. The buildings were sized for hot water and space heating using natural gas. For the restaurant cooking electric ready measures, the Statewide CASE Team leveraged a workbook of eleven (11) prototypical restaurant designs containing commercial kitchen designs for gas appliances and equivalent electric cooking appliances. For clothes dryer specifications, the Statewide CASE Team interviewed on-premises laundry vendors for typical gas and electric system configurations.

The Statewide CASE Team sized the electric ready measures based on energy modeling in CBECC-Com to meet comparable output as the gas-fueled baseline buildings, depending on the application and meeting the suitability of retrofit into the assumed baseline building systems. The details of the individual electric ready options are provided in the following sections.

Assumptions

In all buildings, the following assumptions were developed to determine the baseline conditions and the electric ready design solutions:

- The buildings are built upon the prototypes as established in the 2016 Title 24 Nonresidential Prototype models as developed by NORESCO[19].
- The energy source used for the baseline building for space heating, service water heating, cooking, and clothes drying is natural gas.
- Actual performance specifications for products available in the marketplace were used to establish the output energy requirements for each building system subject to the electric ready measure.
- The electric ready solution included the most energy efficient product type available to replace the natural gas system, but within that, a reasonable level of performance was selected to ensure that the accommodations for this measure are representative of the broader market of available options.
- Wherever the original baseline building system utilized comparable voltage, the electric ready solution uses the same panel and increases the load on that panel.
- In situations where the voltage must be increased to accommodate high electrical load, the electric ready solution uses a new electrical panel for the electrical loads that do not exist in the baseline design. In this circumstance, the Statewide CASE Team assumes a new panel will be installed when the electrification retrofit occurs in the future. The cost of the new electrical panel was not included in the electric ready measures and costs.
- In all cases, there will be substantial electrical system retrofits and improvements to replace a natural gas system with an electricity-based building system. This measure includes the minimum necessary to avoid certain high-cost or high-impact changes that would be required at the time of the electrification retrofit would be more cost-effectively installed as part of a new construction project.
- In addition to the necessary electrical accommodations, there is a need to plan for future electric equipment, such as heat pump compressors and evaporators, storage, and a source of outside air for heat exchange. The proposal includes guidance to ensure that the space available for the retrofit is planned and will be available in the appropriate locations to be useful for this electrification retrofit in the future. While the electric-ready measure includes physical space and condensate drain requirements, determining the current design costs and future costs of retrofit for these measures is highly dependent on floorplan layout and

[19] Information available at: http://bees.archenergy.com/resources.html

structural design, and has not been performed. While these costs are excluded, the CASE Team found that implementers of the Low Income Weatherization Program that install central heat pump water heaters in existing buildings have the most challenges accommodating physical space requirements for heat pump water heating equipment, storage, and heat exchange air. These considerations are often the most challenging and costly.

Medium Office

- Two office sizes are shown below for HVAC and DHW. Both sizes are the same prototype with Office #1 and Office #2 using different climate zones for the HVAC calculations. Office #1 assumes twice the occupants as Office #2 for SHW calculations.
- **Office #1 HVAC** – The baseline system is a gas boiler with 745,000 Btu/hr input. It uses a single 120V, 20-amp circuit for controls wiring. The baseline electrical requirements are a single ¾-inch conduit with (3)-#12 conductors. The retrofit solution is a HP boiler with input requirement of 57.2 KW and is supplemented by a 31.3 kW electric resistance coil backup. The retrofit electrical requirements are 480V, three-phase to meet a total of 184 amps of power. This is met using (4)-3/0 conductors in a 2-1/2-inch conduit. The measure assumes that the conduit is installed from the main electrical room to the approximate location of the future HP boiler system, but no connections are made at either end at this time. Approximately 150 feet of conduit is installed, and this installation avoids approximately 200 feet of conduit and 3 concrete penetrations and 3 firestop sealing locations in the retrofit condition.
- **Office #2 HVAC** – The baseline system is a gas boiler with 500,000 Btu/hr input. It uses a single 120V, 20-amp circuit for controls wiring. The baseline electrical requirements are a single ¾-inch conduit with (3)-#12 conductors. The retrofit solution is a HP boiler with input requirement of 43.4 KW and is supplemented by a 31.3 kW electric resistance coil backup. The retrofit electrical requirements are 480V, three-phase to meet a total of 153 amps of power. This is met using (4)-2/0 conductors in a 2-inch conduit. The measure assumes that the conduit is installed from the main electrical room to the approximate location of the future HP boiler system, but no connections are made at either end at this time. Approximately 150 feet of conduit is installed, and this installation avoids approximately 200 feet of conduit and 3 concrete penetrations and 3 firestop sealing locations in the retrofit condition.
- **Office #1 Service Water Heating** – The baseline system is a 150,000 Btu/hr natural gas water heater with an internal storage tank of 100 gallons. The baseline system uses a single 20-amp circuit for control wiring and uses (3)-#12 conductors in a ¾-inch conduit. The retrofit solution is two (2) HPWH with a combined power requirement of 27.87 kW. This will run on a 208V single phase power supply with (5) #4 conductors in a 1-1/2-inch conduit. The measure assumes that the conduit is installed from the main electrical room to the approximate location of the future HPWH, but no connections are made at either

end at this time. Approximately 150 feet of conduit is installed, and this installation avoids approximately 200 feet of conduit and 3 concrete penetrations and 3 firestop sealing locations in the retrofit condition.

- **Office #2 Service Water Heating** – The baseline system is a 76,000 Btu/hr natural gas water heater with an internal storage tank of 100 gallons. The baseline system uses a single 20-amp circuit for control wiring and uses (3)-#12 conductors in a ¾-inch conduit. The retrofit solution is a heat pump water heater (HPWH) with a power requirement of 13.94 kW. This will run on a 208V single phase power supply with (3) #6 conductors in a 1-inch conduit. The measure assumes that the conduit is installed from the main electrical room to the approximate location of the future HPWH, but no connections are made at either end at this time. Approximately 150 feet of conduit is installed, and this installation avoids approximately 200 feet of conduit and 3 concrete penetrations and 3 firestop sealing locations in the retrofit condition.

Full-Service Restaurant

- **Service Water Heating** – The baseline system is two (2) natural gas storage water heaters with 400,000 Btu/hr input each. The baseline system will require a 120V, 20-amp circuit each, but can be fed in a single ¾-inch conduit with (4)- or (5)-#12 conductors. The approximate length of conduit to feed the baseline system from the panel is 150 feet. The retrofit solution is four (4) HPWH with 11.8 kW input with an additional 5 kW electric resistance coil backup heater. This will be fed by a 208V three-phase power supply to balance the loads across the power supply. The conductors will be (4) 250 kcmil in a 2-1/2 inch conduit. The measure assumes that the conduit is installed from the main electrical room to the approximate location of the future HPWH, but no connections are made at either end at this time. Approximately 150 feet of conduit is installed, and this installation avoids approximately 200 feet of conduit and 3 concrete penetrations and 3 firestop sealing locations in the retrofit condition.

- **Cooking** – The baseline system is two (2) gas ranges with ovens, a fryer, and a broiler for a total input of 592,000 Btu/hr. The total estimated electric load of the four appliances is 25 amps and additional load on the panel will total to 170 amps including safety multiplier. The baseline system will require a 208V, three phase, 200-amp panel, and can be fed in a single 2-inch conduit with (4)-3/0 conductors. The approximate length of conduit to feed the baseline system from the main service is 150 feet. The retrofit solution is two (2) induction cooktops, two (2) convection ovens, an electric fryer, and an electric broiler for a total power requirement of 75.5 kW, resulting in a load of 223 amps and a total panel load of 400 amps including safety multiplier. This electric ready design will be fed by a 208V, three phase, 400-amp panel. The conductors will be (4)-600 kcmil in a 3-1/2-inch conduit. The measure assumes that the conduit is installed from the main electrical room to the approximate location of the future electric cooking equipment, but no connections to future electric appliances are made at this time. Approximately 150 feet of conduit is installed, and this installation avoids approximately 200 feet of conduit and 3 concrete penetrations and 3 firestop sealing locations in the retrofit condition.

Quick-service Restaurant

- **Service Water Heating** – The baseline system is a natural gas storage water heater with 150,000 Btu/hr output and 100-gallon storage capacity. The baseline system will require a 120V, 20-amp circuit, fed in a ¾-inch conduit with (3)-#12 conductors. The approximate length of conduit to feed the baseline system from the panel is 150 feet. The retrofit solution is four (4) HPWH with 11.8 kW input with an additional 5 kW electric resistance coil backup heater. This will be fed by a 208V three-phase power supply to balance the loads across the power supply. The conductors will be (4)1/0 in a 1-1/2 inch conduit. The measure assumes that the conduit is installed from the main electrical room to the approximate location of the future HPWH, but no connections are made at either end at this time. Approximately 150 feet of conduit is installed, and this installation avoids approximately 200 feet of conduit and 3 concrete penetrations and 3 firestop sealing locations in the retrofit condition.
- **Cooking** – The baseline system is a gas range with oven and a fryer for a total input of 342,000 Btu/hr. The total electric load for the two appliances will be approximately 10 amps and an additional load on the panel will total 125 amps including the safety multiplier. The baseline system will require a 208V, three phase, 125-amp panel, and can be fed in a single one and one quarter inch conduit with (4)-#1 conductors. The approximate length of conduit to feed the baseline system from the main service is 50 feet. The retrofit solution is an induction cooktop, a convection oven, and an electric fryer for a total power requirement of 42.5 kW resulting in a load of 118 amps and a total panel load of 250 amps including the safety multiplier. This electric ready design will be fed by a 208V, three-phase, 250-amp panel. The conductors will be (4)-250 kcmil in a 2-1/2 inch conduit. The measure assumes that the conduit is installed from the main electrical room to the approximate location of the future electric cooking equipment, but no connections to future electric appliances are made at either end at this time. Approximately 50 feet of conduit is installed, and this installation avoids approximately 75 feet of conduit and 3 concrete penetrations and 3 firestop sealing locations in the retrofit condition.

Retail

- **Service Water Heating** – The baseline system is a natural gas tankless on-demand water heater that can supply 1.3 gpm of hot water with a 50-degree temperature rise. The baseline system will require a 120V, 20-amp circuit, fed in a ¾-inch conduit with (3)-#12 conductors. The retrofit solution is to install an electric resistance heater tankless on-demand water heater. The retrofit solution will require 208V, single-phase connections, so there will be (3) #8 in a ¾-inch conduit. This measure assumes that the existing electrical panel is sized with spaces available to replace the 120V single phase breakers with 208V two-pole breakers but that the panel service is not sized to accommodate the additional load of the electric water heater. The electric ready solution requires a larger panel disconnect and larger feed wiring and conduit to meet the future need. Doing this work as part of electric ready avoids the resizing of the panel disconnect, the removal of the old service wiring and conduit, and the installation of new electrical service to the panel. It also avoids some potential wall penetrations and firestopping needs.

Warehouse

- **Service Water Heating** – The baseline system is a natural gas tankless on-demand water heater that can supply 1.3 gpm of hot water with a 50-degree temperature rise. The baseline system will require a 120V, 20-amp circuit, fed in a ¾-inch conduit with (3)-#12 conductors. The retrofit solution is to install an electric resistance heater tankless on-demand water heater. The retrofit solution will require 208V, single-phase connections, so there will be (3) #8 in a ¾-inch conduit. This measure assumes that the existing electrical panel is sized with spaces available to replace the 120V single phase breakers with 208V two-pole breakers but that the panel service is not sized to accommodate the additional load of the electric water heater. The electric ready solution requires a larger panel disconnect and larger feed wiring and conduit to meet the future need. Doing this work as part of electric ready avoids the resizing of the panel disconnect, the removal of the old service wiring and conduit, and the installation of new electrical service to the panel. It also avoids some potential wall penetrations and firestopping needs.

Small Hotel

- **On-Site Laundry (Clothes Washing Water Heating)** – The baseline system is a gas water heater with an input of 181,930 Btu/hr. The baseline system will require a 208V, 20-amp circuit, but can be fed in a single three-quarter inch conduit with (3)-#12 conductors. The approximate length of conduit to feed the baseline system from the main service is 150 feet. The retrofit solution is two (2) Colmac CxV-5 heat pump water heaters with a total power requirement of 12.6 kW. This will be fed by a 208V, three-phase panel for a total load of 31 amps for each HPWH. Each HPWH requires a single phase feed, so the conductors will be (5)-#8 in a 1 inch conduit. The measure assumes that the conduit is installed from the main electrical room to the approximate location of the future HPWHs, but no connections are made at either end at this time. Approximately 150 feet of conduit is installed, and this installation avoids approximately 200 feet of conduit and 3 concrete penetrations and 3 firestop sealing locations in the retrofit condition.

- **On-Site Laundry (Clothes Drying)** – The baseline system is 15 gas clothes dryers with a total combined input of 425,000 Btu/hr.
- The baseline system will require a 120V, 15-amp circuit for each appliance in a 208v, three phase, 125-amp panel, and can be fed in a one and one half inch conduit with (5)-#1 conductors. The clothes washers will be on a separate panel. The branch circuit feeds from the panel to the dryer locations are not considered. The approximate length of conduit to feed the baseline system from the main service to the laundry room panel is 150 feet. The retrofit solution is 15 heat pump dryers with a total power requirement of 68 kW. Each HP dryer has an electrical requirement of 22 amps of single phase, 208v power. The conductors to feed the laundry dryer panel will be (5)-400kcmil in a three inch conduit. The measure assumes that the conduit is installed from the main electrical room to the approximate location of the future heat pump dryer, but no connections are made at either end at this time. Approximately 150 feet of conduit is installed, and this installation avoids approximately 200 feet of conduit and 3 concrete penetrations and 3 firestop sealing locations in the retrofit condition.
- **Domestic Water Heating** – The baseline system is a gas water heater with a total input of 181,930 Btu/hr. The baseline system will require a 120V, 20-amp circuit, but can be fed in a single three-quarter inch conduit with (3)- #12 conductors. The approximate length of conduit to feed the baseline system from the main service is 150 feet. The retrofit solution is a main HPWH and a recirculation HPWH with two electric resistance coil backup heaters for a total power requirement of 42 kW. This will be fed by a 208v, three-phase, 250-amp panel. The conductors will be (5)-250kcmil in a two and one half inch conduit. The measure assumes that the conduit is installed from the main electrical room to the approximate location of the future heat pump water heater, but no connections are made at either end at this time. Approximately 150 feet of conduit is installed, and this installation avoids approximately 200 feet of conduit and 3 concrete penetrations and 3 firestop sealing locations in the retrofit condition.

Electric Ready Results

Using equipment cutsheets, the Statewide CASE Team developed kVA to Btu/hr to guide designers on selecting the appropriate electric technology for their existing gas equipment for sizing electrical infrastructure. The factors are defined as kVA to 10,000 Btu/hr and are shown below for the evaluated system types.

Table 79: Electric Ready KVA per Building Type

Building Type	Retrofit Scenario	Calculated kVA to 10,000 Btu/hr Conversion Factor	Recommended kVA to 10,000 Btu/hr Conversion Factor
Medium Office #1 – HVAC	Replace central hydronic gas boiler with heat pump boiler in VAV reheat system	1.19	1.6
Medium Office #2 – HVAC		1.49	
Medium Office #1 – Service Hot Water	Replace gas storage water heater with heat pump storage water heater (no recirculation)	1.91	2.0
Medium Office #2 – Service Hot Water	Replace gas water heater with heat pump water heater	1.83	
Full-Service Restaurant – Service Hot Water	Replace gas water heater with heat pump water heater (with recirculation loop)	0.65*	2.0
Quick-Service Restaurant – Service Hot Water	Replace gas water heater with heat pump water heater	1.91	
Full-Service Restaurant – Cooking	Replace gas cooking with electric cooking	1.30	1.5
Quick-Service Restaurant – Cooking	Replace gas cooking with electric cooking	1.24	
Retail – Service Hot Water	Replace gas instantaneous water heater with electric instantaneous water heater	1.66	2.0
Warehouse – Service Hot Water		1.66	
Small Hotel – Domestic Water Heating	Replace gas water heater with heat pump water heater (with recirculation loop)	1.80	2.0
Small Hotel – Clothes Washing	Replace gas storage water heater with heat pump water heater	0.7	
Small Hotel – Clothes Drying	Replace electric clothes dryer with heat pump dryer	2.60	2.60

a) *kVA conversion factors are typically between 1-2. Gas water heaters in restaurants are often oversized and this likely resulted in a lower-than-average conversion factor.

Electric Ready Costs

The Statewide CASE Team evaluated the cost-effectiveness of the proposed electric ready measures by evaluating the incremental cost at construction compared to avoided retrofit costs. The Statewide CASE Team used RSMeans time, material, overhead, and profit rates for materials and labor for Sacramento to represent an average cost for the state of California. Electric ready cost savings for all evaluated system types are shown in Table 80 through

Table 85. The Statewide CASE Team used the same assumptions for electric ready distance and service requirements for Full-Service SHW and Medium Office #1 HVAC

and thus these two scenarios present the same costs (Table 80).Similarly, electric ready costs for Quick-Service SHW are the same as Medium Office #2 HVAC electric ready costs (Table 81). Electric readiness results in approximately $2,000 - $10,000 in avoided retrofit costs per new construction building, depending on the scenario.

Table 80: Electric Ready Cost Summary - Medium Office – Office #1 VAV reheat: Gas boiler to HP boiler and Full-service restaurant SHW: Gas water heater to HP

Scenario	Cost at Time of Construction ($ NPV)	Future Retrofit Cost ($ NPV)	Source/Notes	Total Cost ($ NPV)
Electric Ready	$5,610	$0	RSMeans. Materials and installation cost of 2 – ½-inch, 150 LF conduit	$5,610
Not Electric Ready	$0	$7,558	RSMeans. Materials and installation cost for 2 – 1/2-inch, 200 LF conduit, 3 wall penetrations and fireproofing	$7,558
Incremental Cost of Electric Ready	$5,610	($7,558)		($1,944)

Table 81: Electric Ready Cost Summary - Medium Office – Office #2 VAV Reheat: Gas boiler to HP boiler and Quick-service restaurant SHW: Gas water heater to HP

Scenario	Cost at Time of Construction ($ NPV)	Future Retrofit Cost ($ NPV)	Source/Notes	Total Cost ($ NPV)
Electric Ready	$3,819	$0	RSMeans. Materials and installation cost of 2-inch, 150 LF conduit	$3,819
Not Electric Ready	$0	$7,004	RSMeans. Materials and installation cost for 2-inch, 200 LF conduit, 3 wall penetrations and fireproofing	$7,004
Incremental Cost of Electric Ready	$3,819	($7,004)		($3,815)

Table 82: Electric Ready Cost Summary - Medium Office #1 SHW: Gas water heater to HP

Scenario	Cost at Time of Construction ($ NPV)	Future Retrofit Cost ($ NPV)	Source/Notes	Total Cost ($ NPV)
Electric Ready	$3,107	$0	RSMeans. Materials and installation cost of 1 – 1/2-inch, 150 LF conduit	$3,107
Not Electric Ready	$0	$5,450	RSMeans. Materials and installation cost for 1 – 1/2-inch, 200 LF conduit, 3 wall penetrations and fireproofing	$5,450
Incremental Cost of Electric Ready	$3,107	($5,450)		($2,344)

Table 83: Electric Ready Cost Summary - Medium Office #2 SHW: Gas water heater to HP

Scenario	Cost at Time of Construction ($ NPV)	Future Retrofit Cost ($ NPV)	Source/Notes	Total Cost ($ NPV)
Electric Ready	$2,381	$0	RSMeans. Materials and installation cost of 1-inch, 150 LF conduit	$2,381
Not Electric Ready	$0	$4,360	RSMeans. Materials and installation cost for 1-inch, 200 LF conduit, 3 wall penetrations and fireproofing	$4,360
Incremental Cost of Electric Ready	$2,381	($4,360)		($1,980)

Table 84: Electric Ready Cost Summary - Retail: Gas tankless water heater to electric tankless water

Scenario	Cost at Time of Construction ($ NPV)	Future Retrofit Cost ($ NPV)	Source/Notes	Total Cost ($ NPV)
Electric Ready	$11,885	$0	RSMeans. Materials and installation cost of 2 – 1/2-inch, and 250-amp service 200 LF conduit	$11,885
Not Electric Ready	$9,011	$11,077	RSMeans. Materials and installation cost for 2-inch conduit for new construction and 2 – 1/2-inch for renovation, 250-amp service 200 LF conduit for new construction and renovation, and 3 wall penetrations and fireproofing for demolition	$20,088
Incremental Cost of Electric Ready	$2,874	($11,077)		($8,203)

Table 85: Electric Ready Cost Summary - Warehouse: Gas tankless water heater to electric tankless water

Scenario	Cost at Time of Construction ($ NPV)	Future Retrofit Cost ($ NPV)	Source/Notes	Total Cost ($ NPV)
Electric Ready	$14,164	$0	RSMeans. Materials and installation cost of 2 – 1/2-inch, and 250-amp service 250 LF conduit	$14,164
Not Electric Ready	$10,591	$12,828	RSMeans. Materials and installation cost for 2-inch conduit for new construction and 2 – 1/2-inch for renovation, 250-amp service 250 LF conduit for new construction and renovation, and 3 wall penetrations and fireproofing for demolition	$23,419
Subtotal Incremental Cost of Electric Ready	$3,573	($12,828)		($9,255)

Table 86: Electric Ready Cost Summary - Full-Service Restaurant: Gas Cooking to Electric Cooking

Scenario	Cost at Time of Construction ($ NPV)	Future Retrofit Cost ($ NPV)	Source/Notes	Total Cost ($ NPV)
Electric Ready	$17,449	$0	RSMeans. Materials and installation cost of 3 – 1/2-inch, and 400-amp service 150 LF conduit	$17,449
Not Electric Ready	$7,951	$14,071	RSMeans. Materials and installation cost for 2-inch conduit for new construction and 3-1/2-inch conduit for renovation, 200-amp service 150 LF conduit for new construction and 200 LF renovation, and 3 wall penetrations and fireproofing for demolition	$22,023
Subtotal Incremental Cost of Electric Ready	$9,498	($14,071)		($4,574)

Table 87: Electric Ready Cost Summary - Quick-Service Restaurant: Gas Cooking to Electric Cooking

Scenario	Cost at Time of Construction ($ NPV)	Future Retrofit Cost ($ NPV)	Source/Notes	Total Cost ($ NPV)
Electric Ready	$5,490	$0	RSMeans. Materials and installation cost of 2 – 1/2-inch, and 250-amp service 50 LF conduit	$5,490
Not Electric Ready	$4,074	$3,687	RSMeans. Materials and installation cost for 1-1/4-inch conduit for new construction and 2 – 1/2"-inch conduit for renovation, 100-amp service 50 LF conduit for new construction and 75 LF for renovation, and 3 wall penetrations and fireproofing for demolition	$7,762
Subtotal Incremental Cost of Electric Ready	$1,416	($3,687)		($2,271)

Table 88: Electric Ready Cost Summary - Small Hotel: Domestic Water Heating

Scenario	Cost at Time of Construction ($ NPV)	Future Retrofit Cost ($ NPV)	Source/Notes	Total Cost ($ NPV)
Electric Ready	$5,615	$0	RSMeans. Materials and installation cost of 2 –1/2 -inch conduit, 150LF	$5,615
Not Electric Ready	$0	$8,758	RSMeans. Materials and installation cost for 2-inch, 200 LF conduit for and 3 wall penetrations and fireproofing for demolition	$8,758
Subtotal Incremental Cost of Electric Ready	$5,615	(8,758)		($3,144)

Table 89: Electric Ready Cost Summary - Small Hotel: Laundry (Clothes Washing)

Scenario	Cost at Time of Construction ($ NPV)	Future Retrofit Cost ($ NPV)	Source/Notes	Total Cost ($ NPV)
Electric Ready	$2,381	$0	RSMeans. Materials and installation cost of 1-inch conduit, 150LF	$2,381
Not Electric Ready	$0	$4,360	RSMeans. Materials and installation cost for 1-inch, 200 LF conduit for and 3 wall penetrations and fireproofing for demolition	$4,360
Subtotal Incremental Cost of Electric Ready	$2,381	($4,360)		($1,980)

Table 90: Electric Ready Cost Summary - Small Hotel: Laundry (Clothes Drying)

Scenario	Cost at Time of Construction ($ NPV)	Future Retrofit Cost ($ NPV)	Source/Notes	Total Cost ($ NPV)
Electric Ready	$8,286	$0	RSMeans. Materials and installation cost of 3-inch conduit, 150 LF	$8,286
Not Electric Ready	$4,142	$10,904	RSMeans. Materials and installation cost for 1-1/2-inch conduit for new construction, and 3-inch conduit for retrofit, 200 LF conduit for and 3 wall penetrations and fireproofing for demolition	$15,046
Subtotal Incremental Cost of Electric Ready	$12,428	($10,904)		($6,760)