Nonresidential Grid Integration

Measure Number: 2022-NR-GRID-INT-F | Nonresidential Grid Integration FINAL CASE REPORT

Prepared by Energy Solutions | August 2020

Please submit comments to info@title24stakeholders.com.

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Executive Summary

This document presents recommended code changes that the California Energy Commission will be considering for adoption in 2021. If you have comments or suggestions prior to the adoption, please email info@title24stakeholders.com. Comments will not be released for public review or will be anonymized if shared.

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

The Statewide CASE Team submits code change proposals to the Energy Commission, the state agency that has authority to adopt revisions to Title 24, Part 6. The Energy Commission will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The Energy Commission may revise or reject proposals. 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 nonresidential grid integration. The report contains pertinent information supporting the code change.

Measure Description

Background Information

The focus of the nonresidential grid integration measure is to update the existing the requirements to better align with the current demand management and demand response (DR) marketplaces. This includes new time depended valuation of energy prices, demand responsive lighting equipment and labor prices, available communication protocols, additional thermal energy storage (TES) systems aside from chilled water storage, and commercial heat pump water heaters (HPWHs). Bringing the requirements in line with current practices would help ensure that newly constructed nonresidential buildings are positively contributing to grid stability, which is critical as California aims to achieve its renewable portfolio goals and building zero net energy goals. In this CASE Report, the Statewide CASE Team refer to demand management as the ongoing or day-to-day holistic practice of using building controls to operate equipment to optimize electric demand, measured in kilowatts (kW). DR is thus a component of demand management, referring to the additional adjustments to equipment a customer takes when notified by the utility.

Demand management and grid integration play an important role in achieving California's clean energy goals. Lawrence Berkeley National Laboratory (LBNL) developed a framework and terminology to describe the multiple types of demand management that California needs. This includes **shape** and is facilitated by time-of-use rates that change the shape of a buildings energy usage profile over the entire year. **Shift** is changing the load profile of when energy is used over the course of a day. **Shed** is traditional, event-based DR and **shimmy** is Fast DR to support ancillary services needed by the grid (Alstone, et al. 2017). Nonresidential buildings can provide these services and it is important to continue to evolve the code requirements to harness the existing flexibility characteristics of buildings.

The current code change proposals in this Final CASE Report are needed due to the time of peak electricity usage moving to later in the day, technology evolution, and providing the groundwork for additional changes in the 2025 code change cycle. When the amount of renewable energy generation was low, California's electric system peak occurred mid-day between noon and 6 p.m. Additional solar supply resources are creating an oversupply of renewable energy during mid-day and causes peak electricity demand from the grid to move from mid-day to the late afternoon and evening hours. Adding compliance options to enable the shift of electricity use across hours of the day can decrease energy use on-peak or increase energy use off-peak. This would help alleviate the problem of oversupply of renewable electricity and ease the sharp demand in electricity usage when the sun goes down in the evening. Technology continues to change. Lighting controls are becoming more cost effective, commercial HPWHs are arriving on the market, ice- and eutectic salts-based TES in space cooling are making room for advances in phase change materials. The code change proposals in this Final CASE Report thus focuses on three nonresidential measures: amending DR control requirements for lighting systems, compliance credit for HPWHs, and compliance credit for TES systems. Through revising prescriptive requirements for lighting controls and adding compliance options for HPWH and TES, the Statewide CASE Team continues to evolve the code for technologies today and to lay the groundwork for additional grid integration measures in the future.

Demand Responsive Control Requirements for Lighting Systems and Shift to Solid State Lighting

DR controls for indoor lighting were first adopted in the 2008 Title 24, Part 6 Standards as a mandatory measure in Section 131(g). This language required the installation of automatic lighting controls to uniformly reduce lighting power consumption by at least 15 percent in retail buildings with sales floor areas greater than 50,000 square feet. The 2013 Title 24, Part 6 Standards in Section 130.1(e) kept the same uniformity and dimming requirements but expanded the mandatory measure to apply to all nonresidential buildings greater than 10,000 square feet, excluding spaces with a lighting power density (LPD) less than or equal to 0.5 watts per square foot. Aside from establishing building and space exemptions based on health and safety statues, ordinances, or regulations, no major updates to this requirement were adopted in either the 2016 (Section 130.1(e)) or 2019 (Section 110.12(c)) code cycles. However, since the last quantitative update in 2013, the lighting standards of Title 24, Part 6, relating to lighting power allowances and lighting controls, have continued to be updated to reflect a shift to solid state lighting.

Solid state lighting has a significantly higher efficacy (lumens per watt) than incandescent, halogen, and other historically common light bulbs and luminaires. The gradual shift in baseline has significantly decreased the LPD in many spaces resulting in lower energy savings potential from DR lighting. As the installed lighting power has decreased, the cost for effective implementation has decreased. Historically a piecemeal system controlled at the circuit level was common for DR lighting implementation, but now many networked lighting control (NLC) systems have native automated demand response (ADR) communication protocols (OpenADR) and piecemeal systems can control individual fixtures instead of the lighting circuit. Standalone OpenADR devices have also increased the number of communication protocols they can operate with, allowing them to better communicate directly with lighting controls. These advances dictate a new cost-effective analysis be conducted to ensure proper implantation. A new cost-effectiveness analysis, one based on a facilities total design wattage rather than square footage, would produce a new delineation compared to the existing 10,000 square feet threshold that directly targets the controlling end-use (lighting wattage) and more effectively establishes a cost-effective exemption delineation.[1] The new cost-effective threshold is 4,000 watts installed.

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[1] For the purposes of the analyses presented in this CASE Report, the Statewide CASE Team is using the term "design wattage" to mean lighting wattage that a space is designed for. This terms also assumes that the actual installed wattage in the space is equivalent to the "design wattage."

Compliance Option for HPWH Demand Management Systems

To achieve long-term greenhouse gas emissions goals, local jurisdictions and the state of California are exploring how to transition buildings to all electric construction. HPWH systems with demand management capabilities are an essential design strategy for all-electric nonresidential buildings. However, few buildings currently use commercial HPWHs. Technology must evolve and markets must transform if we are going to meet climate goals. This code change proposal would encourage investment in HPWH and award designers that choose to use HPWHs with demand management features with compliance credit.

Adding a compliance option to Title 24, Part 6 works in parallel with incentive programs to support the continued evolution of technologies and lays the groundwork for additional grid integration measures in the future.

Compliance Options for Thermal Energy Storage

The Title 24, Part 6 Standards first added definitions and requirements for demand management in 2008 for heating, ventilation, and air conditioning (HVAC) equipment. These requirements for HVAC expanded significantly between 2008 and 2013. The 2016 Title 24, Part 6 Standards provided compliance credit for thermal storage HVAC systems in nonresidential buildings for the first time, along with further clarifications to occupant controlled smart thermostats (OCSTs). However, only chilled water storage systems were included in the California Building Energy Code Compliance for Commercial Buildings Software (CBECC-Com) to receive compliance credit through the performance approach.

TES systems employ a wide variety of liquid, solid, and liquid-solid storage media solutions that improve efficiency and reliability of traditional mechanical cooling systems. Allowing additional TES systems, such as ice storage and phase change materials create more options for buildings to shift electricity use across hours of the day based on grid needs. The specific compliance options being considered include modifications to TES algorithms in CBECC-Com.

Demand Responsive Control Simplification and Cleanup

The requirements in Section 110.2(a) apply to all demand responsive controls used to comply with Title 24, Part 6 and covers how controls must communicate. This section would benefit from some minor revisions to remove complexity and redundancy.

Proposed Code Change

Demand Responsive Lighting Systems

The proposed measure would change the mandatory language in Section 110.12(c) demand responsive lighting controls by replacing the existing 10,000 square foot threshold with a threshold of 4,000 total design watts. The proposed code change would also revise the current 0.5 watts per square foot exemption so it references the 0.5 watt per square foot exemption of the multi-level lighting controls in Section 130.1(b).

In addition to revising when the demand responsive lighting controls would apply, the proposed code change simplifies and clarifies the acceptance test. Currently the acceptance test requires spaces to not reduce the illuminance of a space from electric and daylighting to less than 50 percent of the designed illuminance, however, this language is not in the standards. This requirement is being removed from the acceptance test which would align both languages. A proposed third acceptance test option would allow for a test of the full building lighting load if the circuits are disaggregated by end-use. This disaggregation is required for facilities with electric services rated at more than 50 kilovolt-amps (kVA) per Table 130.5-B. This additional test condition would help to expedite acceptance testing for demand responsive lighting, especially in larger facilities while the enclosed space sampling still represents a significant number of spaces.

These changes apply to all new construction, additions, and alterations to nonresidential facilities barring specific exemption for high efficacy installations — such as spaces with less than or equal to 0.5 watts per square foot, alterations where the altered lighting does not exceed 80 percent of the lighting power requirements, or one-for-one luminaire alterations in tenant spaces of 5,000 square feet or less where the total wattage is 50 percent lower compared to pre-altered wattage — and for facilities with specific safety ordinances that do not permit the reduction of lighting, such as hospitals.

Compliance Option for HPWH Demand Management Systems

The proposed code change would expand the HPWH demand flexibility compliance credit that is available for residential buildings that use the performance approach to comply with code so that a similar credit would also be available for nonresidential buildings. This change would help nonresidential buildings contribute positively to grid stability, which is critical as California aims to achieve its renewable portfolio and decarbonization goals. Specific revisions include updating Joint Appendix 13 – Qualification Requirements for Heat Pump Water Heating Demand Management Systems (JA13) so the language is more inclusive of HPWH systems installed in nonresidential buildings. The updated language in JA13 would align with the eligibility requirements for the Self-Generation Incentive Program (SGIP), which added HPWH as an eligible measure in January 2020.[2] For this compliance option to become available for use, the compliance software would need to be updated to add a feature that would simulate the energy impacts of operating HPWHs with demand management capabilities enabled, which could include optimizing for utility time-of-use or critical peak pricing rates. Additional data gathering, testing and software development as described in Appendix D2 to implement a credible modeling tool for both unitary and central HPWHs in nonresidential buildings.

The proposed compliance credit would apply to all nonresidential building types for new construction, additions, and alterations. The value of the credit would vary by building type with the value credit calculated by the compliance software and taking hot water draw schedules, control strategies, and climate impacts into account. The credit would apply to both integrated (with tank) HPWH units (unitary systems) and central HPWH systems commonly configured as split systems, with separate storage tank and pump.

Compliance Options for Thermal Energy Storage

To enable load shifting, the Statewide CASE Team proposes allowing compliance credit for thermal energy storage (TES) technologies beyond the existing chilled water systems by adding features to the compliance software for these additional systems. TES with phase change materials and ice storage enable a building to shift electricity use across hours of the day based on time-of-use or critical peak pricing rates and grid needs. The specific compliance options being considered include modifications to TES algorithms and compliance software to integrate the ThermalStorage:Ice:Detailed EnergyPlus object, which will allow designers to simulate the energy impacts and receive compliance credit for three additional types of TES systems that are already eligible to receive compliance credit but the software does not yet support: Ice-on-Coil Internal Melt, Ice-on-Coil External Melt, and Eutectic Salt.

Demand Responsive Control Simplification and Cleanup

This submeasure aims to simplify and streamline requirements for demand responsive controls. Section 110.12(a)2 would be amended to allow for any bi-directional communication methods to be used within the building site instead of limiting the allowable communication methods to only Wi-Fi, ZigBee, BACnet, Ethernet, or hard-wiring as 2019 Title 24, Part 6 requires. Sections 110.12(a)3 and 110.12(a)4 would be

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[2] SGIP is administered by CPUC and offers rebates to residential and nonresidential customers receiving electric service from PG&E, SCE, and SDG&E who install energy and thermal storage technology at their home or business. Eligibility criteria is available online at https://www.cpuc.ca.gov/sgipinfo.

removed in an effort to simplify code language, removing superfluous language that can be clarified in the compliance manual instead of the code language itself.

Section 110.12(a)3 states that products can have additional communications capabilities than those required to be minimally compliant with code. It is widely understood that codes describe minimum capabilities and additional features are allowed. This code language that explicitly states demand responsive controls can include features that go beyond minimal code compliance adds unnecessary complexity to the code language.

Section 110.12(a)4 states that when communication features of a demand responsive control are disabled or unavailable, the demand responsive control must continue to provide other functions provided by the control. The intent of this language is to confirm that the broader building control system continues to control building systems and meet minimum code compliance even if the demand responsive controls are not enabled or connected. Demand responsive controls are responsible for receiving demand response signals and initiating changes to the control strategies in response to demand response events. The code does not require demand responsive controls to do anything else, so there are no “other” control features that a demand response control must maintain if communication is disabled. Although there are other control requirements in the code, code does not state the “demand responsive control” is responsible for ensuring control requirements are met. If a building is going to comply with code, it has to meet all control requirements. If the communication functionality of the demand responsive control is disabled or reduced, the broader building control system (controlling technologies) are still required to be compliant with the rest of Title 24, Part 6. As such, this language is redundant and adds unnecessary complexity.

Scope of Code Change Proposal

Table 1 summarizes the scope of the proposed changes and which sections of Standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manual, and compliance documents that would be modified as a result of the proposed changes.

Table 1: Scope of Code Change Proposal

Measure Name	Type of Requirement	Modified Sections of Title 24, Part 6	Modified Title 24, Part 6 Appendices	Would Compliance Software Be Modified	Modified Compliance Documents
Demand Responsive Lighting	Mandatory	110.12(c) and 140.6	Nonresidential Appendix 7	No	NRCC-LTI-E NRCA-LTI-04-A NRCI-LTI-05-E
HPWHs	Compliance Option	N/A	Joint Appendix JA13[a]	Yes – NR ACM 5.9.1.1 System Loads and Configuration	NRCC-PRF-01-E
TES Systems	Compliance Option	N/A	N/A	Yes – NR ACM Manual Section 5.8.8 Thermal Energy Storage	NRCC-PRF-01-E
Communication Protocol Cleanup	Mandatory	110.12(a)2, 3, and 4	N/A	No	NRCA-LTI-04-A NRCA-MCH-11-A

a. At time of this publication, no field verification procedure is included in the current reference appendices. The Statewide CASE Team anticipates a need for field verification for these systems.

Market Analysis and Regulatory Assessment

Demand Responsive Lighting Systems

Products for implementing DR lighting are readily available in the market today. The DesignLights Consortium (DLC) creates a qualified product list (QPL) that includes reporting on a system DR capability. As of December 2019, this QPL includes 20 interior lighting control systems that are DR capable. These systems allow for effective and intelligent implementation of DR lighting, such as continuous dimming in all spaces, compared to historical DR lighting products that focused on controlling lighting on the circuit level to turn all lights associated with that circuit on or off. While effective in reducing lighting power, controlling fixtures in an on or off manner can result in more disruptive DR implementation.

Load Shifting Compliance Options for HPWH

Load management using standard storage water heaters currently targets the residential sector, given their significantly larger market share. Interest in HPWHs for load management has been gaining traction over the last few years and there have been two pilot programs with Energize Connecticut and Bonneville Power Administration (BPA). These pilots were focused on the residential sector.

HPWH requirements are in Title 24, Part 6 focus on low-rise residential buildings and hydronic heat pumps connected to a common heat pump water loop with central controls. There are currently no requirements for load shifting or load management functions for commercial HPWH controls. Outside of Title 24, Part 6 there are other state and federal codes for water heaters that focus on grid connection and the ability to receive DR signals from the utility. California’s Title 20 Appliance Efficiency Regulations includes energy and water efficiency requirements for both residential and commercial water heaters and HPWHs. The ENERGY STAR® program developed draft optional grid connected criteria for residential HPWHs and gas-storage and instantaneous residential-duty commercial water heaters for 2019. Neither standard includes requirements for load shifting or load management scheduling functions of commercial HPWH controls. Similarly, Northwest Energy Efficiency Alliance (NEEA), the Consortium for Energy Efficiency (CEE), and Electric Power Research Institute (EPRI) all have an efficiency specification’s for water heaters, including HPWHs, but do not include commercial systems and do not provide guidance for load shifting or load management scheduling control functions.

Thermal Energy Storage Systems

TES systems cool or heat a storage medium (liquid, solid or liquid-solid mixture) so that the stored energy (in Btus) can be used later to offset cooling and heating needs using mechanical means (consuming kWhs). From its inception, the primary purpose of TES is for load shifting. TES is a mature technology and market. TES is a flexible, scalable, and modular technology that is constrained only by its storage medium. These include underground (e.g., caverns, aquifers, packed beds) storage tanks, storage modules of various shapes and sizes, or even microspheres less than one millimeter in diameter embedded in building materials.

TES is discussed minimally in Title 24, Part 6, Section 140.4 as exceptions for chiller system efficiency requirements. To be exempt from chiller efficiency requirements, facilities using TES to supplement chiller operation must be designed to have charging temperature less than 40°F. The Reference Appendices in Section NA7.5.14 describes compliance testing for TES used in conjunction with chilled water air conditioning systems. TES designed to be used with chillers in a facility are partial storage TES systems rather than full storage TES systems. There is currently no language in Title 24, Part 6 pertaining to scheduling functions for load shifting or demand management with TES. There are no relevant local, state, or federal laws nor industry standards specifying schedules for TES for load shifting or demand management.

Communication Protocol Cleanup

Control systems within a facility are composed of multiple devices that must communicate information for the control system to work effectively. Typically, separate protocols are used for controls to communicate with a facility. Communication within a facility typically uses a wireless local area network with protocols such as ZigBee, Wi-Fi, or BACnet, all of which are well established in the market. Communication between devices in a facility can also be wired (i.e., Ethernet). Products that communicate with these protocols are common, as are system that use other existing (e.g., Z-Wave, X10, Insteon) or newer (e.g., 6LoWPAN, Thread, and Bluetooth Low Energy) protocols. Allowing systems that enable bi-directional communication, both widely accepted and newer protocols that allow for transmitting data in both directions, to the VEN and lighting system open up DR operations to a wider technology marketplace and put demand responsive lighting on the forefront of technology by allowing the marketplace to dictate available and preferred communication protocols.

Cost Effectiveness

The benefit-to-cost (B/C) ratio compares the benefits or cost savings to the costs over the 15-year period of analysis. Proposed code changes that have a B/C ratio of 1.0 or greater are cost effective. The larger the B/C ratio, the faster the measure pays for itself from energy cost savings. As the purpose of this measure was to establish a cost-effective threshold, the demand responsive lighting delineation was set at a B/C of 1.04. This resulted in a total design wattage threshold of 4,000 watts. See Section 2.4 for the methodology, assumptions, and results of the cost-effectiveness analysis.

The proposed changes that recommend new compliance options do not require a cost effectiveness analysis because they do not change the stringency of the code. Rather, they provide designers with additional design features to use to comply with the required energy budget. The recommended code cleanup and simplification changes do not require a cost effectiveness analysis either as they do not impact the stringency or require additional steps to verify compliance.

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

Table 2 presents the estimated energy and demand impacts of the proposed code change for lighting that would be realized statewide during the first 12 months that the 2022 Title 24, Part 6 requirements compared to the 10,000 square foot delineation of 2019 Title 24, Part 6. First-year statewide energy impacts are represented by the following metrics: electricity savings in gigawatt-hours per year (GWh/yr), peak electrical demand reduction in megawatts (MW), natural gas savings in million therms per year (million therms/yr), and time dependent valuation (TDV) energy savings in kilo British thermal units per year (TDV kBtu/yr). See Section 2.5 for more details on the first-year statewide impacts calculated by the Statewide CASE Team. Section 2.3 contains details on the per-unit energy savings calculated by the Statewide CASE Team.

Table 2: Demand Responsive Lighting First-Year Statewide Energy and Impacts Compared to 2019 Title 24, Part 6, 10,000 Square Foot Threshold[a]

Facility Type	Electricity Savings (GWh/yr)	Peak Electrical Demand Reduction (MW)	Natural Gas Savings (MMtherms/yr)	TDV Energy Savings (TDV kBtu/yr)
New Construction	0.02	0.05	0	7,469,561
Additions and Alterations	0.50	1.20	0	155,640,842
Total	0.53	1.25	0	163,110,403

a. HPWH & TES measures represent updates to the compliance software and are not subject to energy savings and subsequent statewide energy impact evaluation.

For HPWH and TES, the code change proposal would not modify the stringency of the existing Title 24, Part 6, so the savings associated with this proposed change are minimal. Although the energy savings are limited, the measure would encourage increased adoption of building technologies with load shifting and load management capabilities. As noted in the Introduction, demand management and grid integration play an important role in achieving California's clean energy goals.

Table 3 presents the estimated avoided GHG emissions associated with the proposed code change for the first year the standards are in effect compared to the 10,000 square foot delineation of 2019 Title 24, Part 6. Avoided GHG emissions are measured in metric tons of carbon dioxide equivalent (metric tons CO2e). Assumptions used in developing the GHG savings are provided in Section 2.5.2 and Appendix C of this report. The monetary value of avoided GHG emissions is included in TDV cost factors and is thus included in the cost-effectiveness analysis.

Table 3: First-Year Statewide GHG Emissions Impacts Compared to 2019 Title 24, Part 6, 10,000 Square Foot Threshold

Measure	Avoided GHG Emissions (Metric Tons CO2e/yr)	Monetary Value of Avoided GHG Emissions ($2023)
Demand Responsive Lighting	127	$3,806

Water and Water Quality Impacts

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

Compliance and Enforcement

Overview of Compliance Process

The Statewide CASE Team worked with stakeholders to develop a recommended compliance and enforcement process and to identify the impacts this process would have on various market actors. The compliance process is described in Sections 2.1.5, 3.1.5, 4.1.5, and 5.1.5. Impacts that the proposed measure would have on market actors is described in Appendix E. The key issues related to compliance and enforcement are summarized below.

Demand Responsive Lighting Systems

- Clarifying which lighting spaces are exempt due to the 0.5 watts per square foot exemption. Linking this exemption to the multi-level exemption of the same nature allows for more straightforward identification of spaces exempt from demand responsive lighting due to low watts per square footage.
- The existing acceptance test requires acceptance test technicians to verify that the facility sheds an area-weighted 15 percent lighting power but not more than 50 percent of the designed illuminance from daylight and electric light. This is documented in the acceptance test but was not clear in the standards. The proposed change removes this requirement and harmonizes the language in

the acceptance test with the Energy Efficiency Standards. Additionally, including a full building test when end-use loads are disaggregated at the circuit level would allow for expedited compliance for buildings with this disaggregation.

Compliance Option for HPWH Demand Management Systems

The designer would need to select a HPWH demand management system that is on the certified products list that the Energy Commission maintains. Confirmation that the control strategy implemented by the HPWH complies would be determined in the permit review phase via compliance software. The plumbing contractor installs the HPWH specified in the compliance documents. During the inspection phase, the enforcement agency would verify that the installed HPWH is the same model specified in design documents, which is on the JA13 certified products list.

Compliance Options for Thermal Energy Storage

Any storage types selected as a compliance option must be verified in accordance with system requirements specified in Reference Appendix NA7.5.14. The requirements in NA7.5.14 include system type and equipment metrics for both the chiller and storage tank utilized in the system.

Demand Responsive Control Simplification and Cleanup

Expanding the allowable communication protocols within a facility to communicate to the VEN allow for easier Title 24, Part 6 compliance by reducing restrictions on the communication protocols allowed so long as they allow for bi-directional communication.

Field Verification and Acceptance Testing

Demand Responsive Lighting Systems

The demand responsive lighting acceptance test is described in the 2019 Nonresidential Refence Appendices, Section NA7.6.3. The acceptance test is conducted to verify that a facility is capably of reducing their lighting load in response to a DR event signal by at least (an area-weighted) 15 percent, while not reducing the combined illuminance from electric light and daylight to less than 50 percent of the design illuminance of any individual space. For facilities with less than seven individual enclosed spaces, all spaces must be tested. For facilities with greater than seven individual enclosed spaces, sampling may be conducted by testing a single enclosed space in a group of seven similar enclosed spaces.

The test is conducted at a maximum lighting output to ensure the 15 and 50 percent thresholds are met, and a minimum lighting output to ensure that the 50 percent threshold is met. Both tests can be satisfied by using an illuminance meter or measuring the circuit current to verify appropriate lighting power level. Refer to Section 2.1.5 for additional information.

The proposed changes would no longer require the 50 percent illuminance threshold while introducing a third acceptance test, the full building method for buildings with disaggregated circuits by end-use. Reduce the requirements of the acceptance test while introducing the full building method should result in faster acceptance testing.

Compliance Option for HPWH Demand Management Systems

At this time, the Statewide CASE Team is not recommending adding an acceptance test to verify that HPWH demand management systems installed in nonresidential buildings are complaint with JA13, though an acceptance test would be valuable to ensure HPWH controls are functioning as intended. An acceptance test would increase probability that building occupants realize the full benefit of the load shifting capabilities of these advanced HPWH systems and that each system is providing maximum grid benefits. When the compliance software is updated so that it has the ability to simulate the impacts of HPWH demand management systems for nonresidential buildings, the Statewide CASE Team recommends that the Energy Commission also add an acceptance test that would be applicable to nonresidential HPWH systems.

Compliance Options for Thermal Energy Storage

All TES system types would be verified via the existing TES system acceptance test defined in the 2019 Nonresidential Reference Appendix NA7.5.14 Thermal Energy Storage (TES) Systems. This acceptance test allows the technician to verify proper installation of the system as well as ensure system controls and operation capability are consistent with compliance simulation. The controls and operation portion of the test includes confirmation that the system can charge, store, and discharge energy and that the system is controlled and monitored successfully by an energy management system.

Demand Responsive Control Simplification and Cleanup

The proposed change would not impact field verification or acceptance testing requirements.

1. Introduction

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1.1 Introduction to Statewide CASE Team

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

The Statewide CASE Team submits code change proposals to the Energy Commission, the state agency that has authority to adopt revisions to Title 24, Part 6. The Energy Commission will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The Energy Commission may revise or reject proposals. 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.

1.2 Document Structure

The overall goal of this CASE Report is to present a code change proposal for nonresidential grid integration. The report contains pertinent information supporting the four unique code change proposal. The submeasures names and the sections of the report in which they are presented are provided below:

- Section 2 – Demand Responsive Lighting Systems
- Section 3 – Compliance Option for HPWH Demand Management Systems
- Section 4 – Compliance Options for Thermal Energy Storage

- Section 5 – Demand Responsive Control Simplification and Cleanup

When developing the code change proposal and associated technical information presented in this report, the Statewide CASE Team worked with several industry stakeholders including building officials, manufacturers, manufacturer representative, utility incentive program managers, Title 24 energy analysts, research institutes, and others involved in the code compliance process. The proposal incorporates feedback received during public stakeholder workshops that the Statewide CASE Team held on September 10, 2019 and November 12, 2019 (Statewide CASE Team 2019b).

The following is a brief summary of the contents of subsections within Section 2 through 4 of the report:

- Measure Description: provides a description of the measure and its background. This section also presents a detailed description of how this code change is accomplished in the various sections and documents that make up the Title 24, Part 6 Standards.
- In addition to the Market Analysis section, this section includes a review of the current market structure. Subsections 2.2, 3.2, 4.2, and 5.2 describe the feasibility issues associated with the code change, including whether the proposed measure overlaps or conflicts with other portions of the building standards, such as fire, seismic, and other safety standards, and whether technical, compliance, or enforceability challenges exist.
- Energy Savings presents the per-unit energy, demand reduction, and energy cost savings associated with the proposed code change. This section also describes the methodology that the Statewide CASE Team used to estimate per-unit energy, demand reduction, and energy cost savings.
- Cost and Cost Effectiveness presents analysis of the materials and labor required to implement the measure and a quantification of the incremental cost. It also includes estimates of incremental maintenance costs, i.e., equipment lifetime and various periodic costs associated with replacement and maintenance during the period of analysis.
- First-Year Statewide Impacts presents the statewide energy savings and environmental impacts of the proposed code change for the first year after the 2022 code takes effect. This includes the amount of energy that would be saved by California building owners and tenants and impacts (increases or reductions) on material with emphasis placed on any materials that are considered toxic by the State of California. Statewide water consumption impacts are also reported in this section.
- Proposed Revisions to Code Language concludes the report with specific recommendations with ~~strikeout~~ (deletions) and <u>underlined</u> (additions) language for the Standards, Reference Appendices, ACM Reference Manual, Compliance Manual, and compliance documents.

- Section 6 – Bibliography presents the resources that the Statewide CASE Team used when developing this report.
- Appendix A: Statewide Savings Methodology presents the methodology and assumptions used to calculate statewide energy impacts.
- Appendix B: Embedded Electricity in Water Methodology presents the methodology and assumptions used to calculate the electricity embedded in water use (e.g., electricity used to draw, move, or treat water) and the energy savings resulting from reduced water use.
- Appendix C: Environmental Impacts Methodology presents the methodologies and assumptions used to calculate impacts on GHG emissions and water use and quality.
- Appendix D: California Building Energy Code Compliance (CBECC) Software Specification presents relevant proposed changes to the compliance software (if any).
- Appendix E: Impacts of Compliance Process on Market Actors presents how the recommended compliance process could impact identified market actors.
- Appendix F: Summary of Stakeholder Engagement documents the efforts made to engage and collaborate with market actors and experts.
- Appendix G: Other Measures Considered details additional measures and submeasures that were considered as part of the nonresidential grid integration CASE Report but were ultimately dropped. A high-level view of the work done to date, the barriers observed, and potential future steps are detailed in this section.

1.3 Context Applicable to All Measures

In this CASE Report, the Statewide CASE Team refers to demand management as the ongoing or day-to-day holistic practice of using building controls to operate equipment to optimize electric demand, measured in kilowatts (kW). This includes managing equipment operations to minimize demand to avoid demand charges on utility bills, shifting demand to align with time-dependent utility tariffs, and responding to utility calls for reducing or increase load via DR. DR is thus a component of demand management, referring to the additional adjustments to equipment a customer takes when notified by the utility. California utilities call DR events typically 12 to 15 times a year to meet grid reliability needs. However, the building automation and control systems and any other tools for energy management are geared towards energy (kWh) minimization rather than co-optimization of energy and demand (kW). Broad adoption of demand management promoted by programs and codes could actually reduce the number of needed DR events.

In 2017, Lawrence Berkeley National Laboratory (LBNL) published their phase two final report on demand management potential in California (Alstone et al. 2017) The report developed a framework and the terminology to describe multiple types of demand management that California needs by 2025. This includes **shape**, which is facilitated by time-of-use rates that change the load shape of a building's energy usage profile on a weekly, seasonal, and yearly basis. **Shift** involves changing the load profile of when energy is used over the course of a day. **Shed** is traditional, event-based DR lasting hours and **shimmy** is Fast DR over minutes timescale to support ancillary services needed by the grid. Nonresidential buildings can provide these services and it is important to continue to evolve the code requirements to harness the existing flexibility characteristics of buildings.

Demand management and grid integration play an important role in achieving California's clean energy goals. As the state moves towards 100 percent carbon free electricity consumption by 2040, building loads need to be increasingly more flexible. When the amount of renewable energy generation was low, California's electric system peak occurred mid-day between noon and 6 p.m. Additional solar supply resources are creating an oversupply of renewable energy during mid-day and causes peak electricity demand from the grid to move from mid-day to the late afternoon and evening hours as the sun sets.

The Energy Commission's (2015) Integrated Energy Policy Report stated that "Load shifting is likely to be a valuable strategy for achieving zero-net-energy code buildings, and the Energy Commission can develop compliance options that provide time dependent valuation (TDV) credit for such technologies." TDV was first introduced in California in 2005 to assess the energy and cost impacts of potential code changes and to quantify the energy impacts of building systems and equipment when using the performance approach (whole-building energy simulation) for compliance. TDV assigned a unique cost and energy valuation factor to energy savings that occur during each hour of the year. Savings that occur during peak periods were valued more than savings that occur off-peak. Introducing TDV enabled Energy Commission to quantify the value of measures that curtail loads during peak periods or shift loads away from peak times. TDV factors have been updated every code cycle to reflect changes in energy supply and expected peak periods. The 2022 TDV factors reflect peak electricity demand from the grid occurring in the late afternoon and evening.

1.4 Market Analysis Applicable to All Measures

1.4.1 Market Structure

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. It then considered how the proposed standard may impact the market in general as well as individual market actors. Information was gathered about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, Energy Commission staff, and a wide range of industry actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during public stakeholder meetings that the Statewide CASE Team held on September 17, 2019 (Statewide CASE Team 2019a), and March 3, 2020 (Statewide CASE Team 2020).

The California DR marketplace consists of three types of actors – market administrations, third party providers, and utility customers. The wholesale market administrator is the California Independent Service Operator (CAISO), while California IOUs, several municipal utilities, and community choice aggregators administer retail markets. Each administrator maintains a variety of DR programs that can vary by utility territory or customer size, type, or end-use.

California utilities also offer DR programs in which their customers can participate using third-party aggregators. The California Public Utility Commission Electric Rule 24 (for PG&E and SCE) and Electric Rule 32 (for SDG&E) extended this option to CAISO proxy and reliability resource DR programs, allowing customers to enroll with third party Demand Response Providers (DRPs) for bidding directly into the wholesale electricity market (CPUC n.d.). With Rule 24 and 32 specifying the rules for business-to-business operations between the DR aggregators and DRPs with utilities. The utility must have a bilateral agreement with the DR aggregator or DRP in order to purchase any DR resource adequacy credit. Third-party providers include companies such as Enerwise, OhmConnect, Stem, AutoGrid, Chai, Enel X, IPKeys, Olivine, and NRG. DR aggregators and DRPs are responsible for delivering an agreed-upon kW load shed to utilities when dispatched and in return have the flexibility to design their own DR programs for customers.

Customers of every type, size, and market sector can participate in DR programs in California, including residential, multifamily, commercial, industrial, and agricultural. Despite the availability of DR programs, understanding and communicating the benefits of DR participation to building operators can be a challenge. Traditional DR has the potential to compromise occupant comfort or standard business operations if poorly implemented. Mandatory building codes that required demand responsive controls can increase the uptake of DR technology adoption and lower costs, thereby encouraging more cost effective and greater levels of automated grid transactions in buildings. Additionally, mandatory standards can provide clear guidance to builders, engineers, contractors, and others as they design and build systems subject to DR requirements.

Beyond market participants, a wide variety of manufacturers (providing DR-capable controls), contractors (offering installation and commissioning to enable the controls), and organizations (offering to manage projects enrolled in DR incentive programs) play an integral role in the DR landscape. The variety of commercially available DR-capable products continues to grow and includes everything from integrated building management systems down to controller gateways with dry contact relays.

1.4.2 Technical Feasibility, Market Availability, and Current Practices

Participation in DR can be initiated at facility in one of several ways: manually, semi-automated (semi-ADR), and fully automated as illustrated in Figure 1. Manual DR requires the greatest amount of customer effort and involvement. A utility representative places a phone call, email, text, or paging message the customer contact at the facility. The customer must then manually turn off each energy consuming device that is part of the DR strategy. As related to lighting, this commonly involves turning off individual lighting switches in all rooms and floors participating in the DR event. This type of DR results in low participation rates and poorly operating DR load shed strategies. Relying on someone within the facility to see the response, stop what they are doing, and proceed to the lengthy process of manually enacting the load shed strategy across the building.

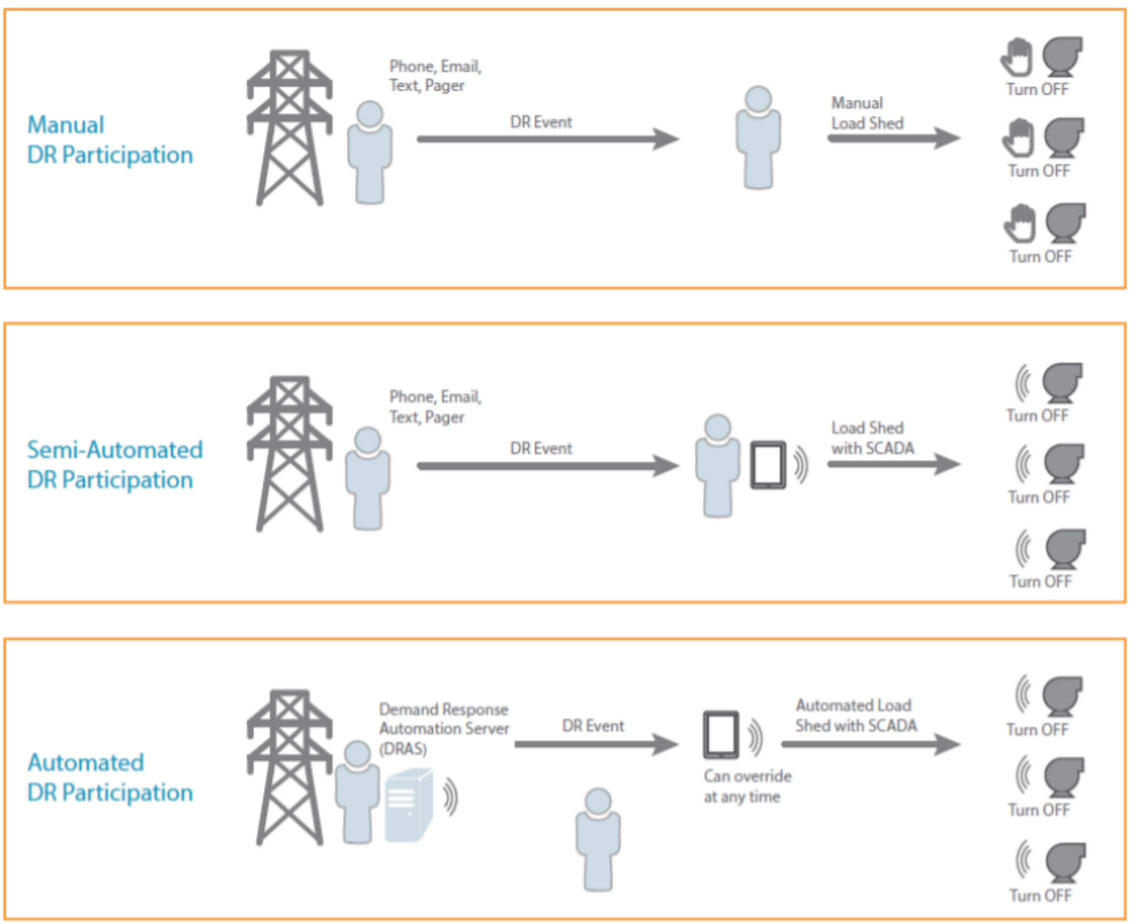

Figure 1: Illustration of manual, semi-auto (semi-ADR), and auto demand response (ADR).

Semi-ADR relies upon a connected system that has a preprogramed sequence of events, or load shed reduction strategy, in a controlling system. In practice, a semi-ADR event begins the same as a manual DR event, a building contact receives a DR event notification through a phone call, email, text, or paging system. However, to enact the load shed strategy, the building contact only needs to enact the preprogrammed strategy through the connected systems interface instead of manually going to each device in the load shed strategy and manually enacting the strategy. Semi-DR represents a significant reduction in effort and time for a facility operator because of pre-programmed can be initiated through a single command of a central controller. However, it still requires that the operator is available to receive the DR event notification from the utility and can initiate the load shed strategy.

Automated-DR (ADR) relies upon communications equipment in the form of gateways, also known as virtual end nodes (VENs), that are installed in facilities to receive notification of DR events. After identifying the details of a DR event, the VEN communicates to the facilities central control system or directly to the controlled equipment in order to enact the pre-programmed DR load shed strategies. Customer intervention is not required for ADR, but email, phone, or text communication is often sent in parallel to the event notification to the VEN. This allows the building operator to be aware of the pending event and override the event if other priorities exist that require the equipment tied to the DR measure to maintain normal operation. ADR events do not dictate what equipment should be controlled or what DR measure should be enacted, building operators retain full control over their facility and can decide how an event signal should be interpreted by their facility.

The current Title 24, Part 6 language requires lighting controls (in addition to HVAC controls) in new construction and alterations to be ADR-*capable*. That is, the standards require the energy controls be *capable* of receiving a communication signal for ADR and have the capability to automatically reduce lighting power in response to that signal. A building that is compliant with Title 24, Part 6 has the energy controls that are necessary to participate in DR events, but to carry out ADR, buildings must *enroll* in a DR program and *enable* the ADR capabilities through programming and end-to-end signal testing with the utility during commissioning. Customers who choose to enroll in a DR program can choose between different levels of DR reduction and requirements among different programs.

1.4.3 Market Impacts and Economic Assessments

Market impacts and economic assessment are discussed in this section for the following measures: demand responsive lighting, compliance option for HPWH demand management systems, and compliance options for thermal energy storage.

1.4.3.1 Impact on Builders

The proposed change to the demand responsive lighting mandatory requirement, allowing for a compliance credit for TES technologies beyond chilled water systems, and allowing for a compliance credit for HPWH systems that can store thermal energy would likely affect commercial builders but would not impact firms that focus on construction and retrofit of industrial buildings, utility systems, public infrastructure, or other heavy construction. Builders of commercial structures are directly impacted by many of proposed code changes for the 2022 code cycle. It is within the normal practices of these businesses to adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training to remain compliant with changes to design practices and building codes. California's commercial construction industry is comprised of about 17,000 business establishments and 340,000 employees (see Table 4).[3] In 2018, total payroll was $27.8 billion.

Table 4: California Construction Industry, Establishments, Employment, and Payroll

Construction Sectors	Establishments	Employment	Annual Payroll (billion $)
Commercial	**17,273**	**343,513**	**$27.8**
Commercial Building Construction	4,508	75,558	$6.9
Foundation, Structure, & Building Exterior	2,153	53,531	$3.7
Building Equipment Contractors	6,015	128,812	$10.9
Building Finishing Contractors	4,597	85,612	$6.2

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

The effects on the commercial building industry would not be felt by all firms and workers, but rather would be concentrated in specific industry subsectors. Table 5 shows the commercial building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report as a result of increased installations and commissioning of DR enabled lighting systems, connected HPWH, and TES systems. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 1.4.4 Economic Impacts.

[3] Average total monthly employment in California in 2018 was 18.6 million; the construction industry represented 4.5 percent of 2018 employment.

Table 5: Specific Subsectors of the California Commercial Building Industry Impacted by Proposed Change to Code/Standard

Construction Subsector	Establishments	Employment	Annual Payroll (billion $)
Nonresidential Electrical Contractors	3,115	66,951	$5.6
Nonresidential plumbing and HVAC contractors	2,394	52,977	$4.5
Other Nonresidential equipment contractors	506	8,884	$0.9
All other Nonresidential trade contractors	988	17,960	$1.4

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

1.4.3.2 Impact on Building Designers and Energy Consultants

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

Businesses that focus on commercial building design are contained within the Architectural Services sector (North American Industry Classification System 541310). Table 6 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The code proposed code changes for the 2022 code cycle would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for demand responsive lighting, compliance credit for HPWHs that can store thermal energy, and TES systems in addition to chilled water systems to affect firms that focus on nonresidential construction.

There is not a North American Industry Classification System (NAICS)[4] code specific for energy consultants. Instead, businesses that focus on consulting related to building

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

energy efficiency are contained in the Building Inspection Services sector (NAICS 541350), which is comprised of firms primarily engaged in the physical inspection of residential and nonresidential buildings.[5] It is not possible to determine which business establishments within the Building Inspection Services sector are focused on energy efficiency consulting. The information shown in Table 6 provides an upper bound indication of the size of this sector in California.

Table 6: California Building Designer and Energy Consultant Sectors

Sector	Establishments	Employment	Annual Payroll (billions $)
Architectural Services [a]	3,704	29,611	$2.9
Building Inspection Services [b]	824	3,145	$0.2

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

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

1.4.3.3 Impact on Occupational Safety and Health

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

The proposed code changes would not apply to healthcare facilities.

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

1.4.3.4 Impact on Building Owners and Occupants

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

Building owners and occupants would benefit from lower energy bills. As discussed in Section 1.4.4.1, when building occupants save on energy bills, they tend to spend it elsewhere in the economy thereby creating jobs and economic growth for the California economy. The Statewide CASE Team does not expect the proposed code change for the 2022 code cycle to impact building owners or occupants adversely.

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

The proposed code change is not introducing any new mandatory requirements; the intent is to update, clarify, and reduce stakeholder burden with respect to demand responsive lighting and offering credits to stakeholders to provide quantitative value to HPWHs that can store thermal energy and non-chilled water TES systems. While the compliance credits are not mandatory, the compliance credit may encourage manufacturers and distributors to create products that would achieve these compliance credit.

1.4.3.6 Impact on Building Inspectors

Table 7 shows employment and payroll information for state and local government agencies in which many inspectors of commercial buildings are employed. Building inspectors participate in continuing training to stay current on all aspects of building regulations, including energy efficiency. This would include adapting to proposed changes to the demand responsive lighting acceptance test, which includes an additional test method as well as reduction in testing requirements, and the proposed demand responsive lighting threshold, which is proposed to be based on total design wattage instead of facility square footage.[6]

Additionally, the compliance credit and certification methods for the expanded TES systems and HPWHs with thermal storage capabilities is still being defined, but detailed processes for compliance would be included in Energy Code Ace in the form of trainings and informational sheets.

Table 7: Employment in California State and Government Agencies with Building Inspectors, 2018

Sector	Govt.	Establishments	Employment	Annual Payroll (millions $)
Administration of Housing Programs[a]	State	17	283	$29.0
	Local	36	2,882	$205.7
Urban and Rural Development Admin[b]	State	35	552	$48.2
	Local	52	2,446	$186.6

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

a. Administration of Housing Programs (NAICS 925110) comprises government establishments primarily engaged in the administration and planning of housing programs, including building codes and standards, housing authorities, and housing programs, planning, and development.
b. Urban and Rural Development Administration (NAICS 925120) comprises government establishments primarily engaged in the administration and planning of the development of urban and rural areas. Included in this industry are government zoning boards and commissions. Impact on Statewide Employment

1.4.3.7 Impact on Statewide Employment

As described in Sections 1.4.3.1 through1.4.3.6, the Statewide CASE Team does not anticipate significant employment or financial impacts to any particular sector of the California economy. This is not to say that the proposed change would not have modest impacts on employment in California. In Section 1.4.4, the Statewide CASE Team estimates the proposed change in demand responsive lighting, HPWH compliance credit, and TES compliance credits would affect statewide employment and economic output directly and indirectly through its impact on builders, designers and energy consultants, and building inspectors. In addition, the Statewide CASE Team estimated how energy savings associated with the proposed change in demand responsive

[6] For the purposes of the analyses presented in this CASE Report, the Statewide CASE Team is using the term “design wattage” to mean lighting wattage that a space is designed for. This terms also assumes that the actual installed wattage in the space is equivalent to the “design wattage.”

lighting, HPWH compliance credit, and TES compliance credits would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

1.4.4 Economic Impacts

For the 2022 code cycle, the Statewide CASE Team used the IMPLAN model software, along with economic information from published sources, and professional judgement to developed estimates of the economic impacts associated with each proposed code changes.[7] While this is the first code cycle in which the Statewide CASE Team develops estimates of economic impacts using IMPLAN, it is important to note that the economic impacts developed for this report are only estimates and are based on limited and to some extent speculative information. In addition, the IMPLAN model provides a relatively simple representation of the California economy and, though the Statewide Case Team are confident that direction and approximate magnitude of the estimated economic impacts are reasonable, it is important to understand that the IMPLAN model is a simplification of extremely complex actions and interactions of individual, businesses, and other organizations as they respond to changes in energy efficiency codes. In all aspect of this economic analysis, the CASE authors rely on conservative assumptions regarding the likely economic benefits associated with the proposed code change. By following this approach, the Statewide CASE Team believes the economic impacts presented below represent lower bound estimates of the actual impacts associated with this proposed code change.

The demand responsive lighting proposal is mandatory while the TES and HPWH proposals are voluntary through compliance credits, only the mandatory requirements are analyzed for their economic impact. Adoption of the mandatory demand responsive code change proposal would result in relatively modest economic impacts through the additional direct spending by those in the commercial building industry, architects, energy consultants, and building inspectors. The following tables detail the economic impact compared with no demand responsive lighting requirement and not compared to existing requirement in the 2019 Title 24, Part 6 Standards. The Statewide CASE Team does not anticipate that money saved by commercial building owners or other organizations affected by the proposed 2022 code cycle regulations would result in additional spending by those businesses.

[7] IMPLAN (Impact Analysis for Planning) software is an input-output model used to estimate the economic effects of proposed policies and projects. IMPLAN is the most commonly used economic impact model due to its ease of use and extensive detailed information on output, employment, and wage information.

Table 8: Estimated Impact that Adoption of the Proposed Measure would have on the California Commercial Construction Sector

Type of Economic Impact	Employment (jobs)	Labor Income (million $)	Total Value Added (million $)	Output (million $)
Direct Effects (Additional spending by Commercial Builders)	1,331	$88.0	$116.6	$192.9
Indirect Effect (Additional spending by firms supporting Commercial Builders)	289	$21.1	$33.7	$64.7
Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	579	$32.6	$58.3	$95.2
Total Economic Impacts	2,199	$141.7	$208.5	$352.9

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

Table 9: Estimated Impact that Adoption of the Proposed Measure would have on the California Building Designers and Energy Consultants Sectors

Type of Economic Impact	Employment (jobs)	Labor Income (million $)	Total Value Added (million $)	Output (million $)
Direct Effects (Additional spending by Building Designers & Energy Consultants)	165	$17.1	$16.9	$30.0
Indirect Effect (Additional spending by firms supporting Bldg. Designers & Energy Consult.)	105	$7.0	$9.5	$15.1
Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	129	$7.0	$12.9	$21.0
Total Economic Impacts	399	$31.3	$39.2	$66.1

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

Table 10: Estimated Impact that Adoption of the Proposed Measure would have on California Building Inspectors

Type of Economic Impact	Employment (jobs)	Labor Income (million $)	Total Value Added (million $)	Output (million $)
Direct Effects (Additional spending by Building Inspectors)	43	$4.3	$5.1	$6.1
Indirect Effect (Additional spending by firms supporting Building Inspectors)	5	$0.3	$0.6	$1.0
Induced Effect (Spending by employees of Building Inspection Bureaus and Departments)	25	$1.4	$2.5	$4.1
Total Economic Impacts	72	$6.0	$8.1	$11.1

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

1.4.4.1 Creation or Elimination of Jobs

The Statewide CASE Team does not anticipate that the measures the being proposed for the 2022 code cycle regulation would lead to the creation of new *types* of jobs or the elimination of *existing* types of jobs. In other words, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. Rather, the estimates of economic impacts discussed in Section 1.4.4 would lead to modest changes in employment of existing jobs.

1.4.4.2 Creation or Elimination of Businesses in California

As stated in Section 1.4.4.1, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. The proposed change represents a modest change to the demand responsive lighting mandatory standard, the only proposal to a mandatory measure, which would not excessively burden or competitively disadvantage California businesses – nor would it necessarily lead to a competitive advantage for California businesses. The compliance credits for non-chilled water TES and HPWH capable of thermal storage may encourage increased production of such products but its impact is expected to be limited as they are voluntary measures. Therefore, the Statewide CASE Team does not foresee any new businesses being created or believe any existing businesses would be eliminated due to the proposed code changes to Title 24, Part 6.

1.4.4.3 Competitive Advantages or Disadvantages for Businesses in California

The code changes the Statewide CASE Team is proposing for the 2022 code cycle would apply to all businesses located in California, regardless of whether the business is incorporated inside or outside of the state.[8] Therefore, the Statewide CASE Team does not anticipate that these measures proposed for the 2022 code cycle regulation would have an adverse effect on the competitiveness of California businesses. Likewise, the Statewide CASE Team does not anticipate businesses located outside of California would be advantaged or disadvantaged.

1.4.4.4 Increase or Decrease of Investments in the State of California

The Statewide CASE Team analyzed national data on corporate profits and capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI).[9] As Table 11 shows, between 2015 and 2019, NPDI as a percentage of corporate profits ranged from 26 to 35 percent, and the average was 31 percent. While only an approximation of the proportion of business income used for net capital investment, the Statewide CASE Team believes it provides a reasonable estimate of the proportion of proprietor income that would be reinvested by business owners into expanding their capital stock.

Table 11: Net Domestic Private Investment and Corporate Profits, U.S.

Year	Net Domestic Private Investment by Businesses, (billion $)	Corporate Profits After Taxes, (billion $)	Ratio of Net Private Investment to Corporate Profits
2015	$609.3	$1,740.4	35%
2016	$456.0	$1,739.8	26%
2017	$509.3	$1,813.6	28%
2018	$618.3	$1,843.7	34%
2019	$580.9	$1,827.0	32%
		5-Year Average	**31%**

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

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

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

The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed measure would lead to significant change (increase or decrease) in investment in any directly or indirectly affected sectors of California's economy. Nevertheless, the Statewide CASE Team is able to derive a reasonable estimate of the change in investment by California businesses by multiplying the sum of Business Income estimated in Table 8 through Table 10 above by 31 percent. The estimated increase in investment in California is approximately $8.3 million.

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

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

Cost of Enforcement

1.4.4.6 *Cost to the State*

State government already has budget for code development, education, and compliance enforcement. While state government will be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, these activities are already covered by existing state budgets. The costs to state government are small when compared to the overall costs savings and policy benefits associated with the code change proposals. While demand responsive lighting would be require for buildings above the proposed threshold, demand responsive lighting has been found to be cost effective above this threshold. The HPWH capable or thermal storage and non-chilled water TES compliance credit proposals are voluntary, and the benefits seen from these measures are expected to be small compared to the overall savings potential to the state.

1.4.4.7 *Cost to Local Governments*

All revisions to Title 24, Part 6 would result in changes to compliance determinations. Local governments would need to train building department staff on the revised Title 24, Part 6 Standards. While this re-training is an expense to local governments, it is not a new cost associated with the 2022 code change cycle. The building code is updated on a triennial basis, and local governments plan and budget for retraining every time the code is updated. There are numerous resources available to local governments to support compliance training that can help mitigate the cost of retraining, including tools, training, and resources provided by the IOU codes and standards program (such as Energy Code Ace). As noted in Sections 2.1.5, 3.1.5, 4.1.5 and Appendix E, the Statewide CASE Team considered how the proposed code change might impact various market actors involved in the compliance and enforcement process and aimed to minimize negative impacts on local governments.

1.4.4.8 Impacts on Specific Groups of Californians

The proposed changes to Title 24, Part 6 are not expected to have a differential impact on any groups relative to the state population as a whole, including migrant workers, commuters, or persons by age, race, or religion. Given that construction costs are not well correlated with building prices, the proposed code changes are no expected to have an impact on financing costs for business.

Renters would typically benefit from lower energy bills if they pay energy bills directly. Renters who do not pay directly for energy costs may see some net savings depending on if and how landlords accounts for energy costs when determining rent prices.

2. Demand Responsive Lighting Systems

2.1 Measure Description

2.1.1 Measure Overview

The proposed measure would change the mandatory language in Section 110.12(c) demand responsive lighting controls by replacing the existing 10,000 square foot threshold with a threshold of 4,000 total design watts. Total design wattage, as defined in the Section 140.6(a) of Title 24, Part 6, would replace square footage as the threshold metric because it more effectively captures the direct saving potential of demand responsive lighting. The proposed code change would also revise the current 0.5 watts per square foot exemption so it references the 0.5 watt per square foot exemption of the multi-level lighting controls in Section 130.1(b).

In addition to revising when the demand responsive lighting controls would apply, the proposed code change simplifies and clarifies the acceptance test. Currently, the acceptance test requires spaces to not reduce the illuminance of a space from electric and daylighting to less than 50 percent of the designed illuminance, but this language does not appear in the standards. This requirement is being removed from the acceptance test which would align both languages. A proposed third acceptance test option would allow for a test of the full building lighting load if the circuits are disaggregated by end-use. This disaggregation is required for facilities with electric services rated at more than 50 kilovolt-amps (kVA) per Table 130.5-B in Title 24, Part 6. This additional test condition would help to expedite acceptance testing for demand responsive lighting, especially in larger facilities while the enclosed space sampling still represents a significant number of spaces.

These changes apply to all new construction, additions, and alterations to nonresidential facilities barring specific exemption for high efficacy installations — such as spaces with less than or equal to 0.5 watts per square foot, alterations where the altered lighting does not exceed 80 percent of the lighting power requirements, or one-for-one luminaire alterations in tenant spaces of 5,000 square feet or less where the total wattage is 50 percent lower compared to pre-altered wattage — and for facilities with specific safety ordinances that do not permit the reduction of lighting, such as hospitals.

Finally, the term “non-habitable” is removed from the demand responsive lighting power allowance factor (PAF) requirements along with additional clarifications to the demand responsive lighting PAF section to allow the PAF to be applicable to facilities and spaces that were not required to implement demand responsive lighting. This term is not applicable to the nonresidential measure and its counterpart in the mandatory requirements was removed in the 2016 Title 24, Part 6 code cycle.

No changes to the compliance software would be made.

2.1.2 Measure History

Demand responsive (DR) controls for indoor lighting were first adopted in the 2008 Title 24, Part 6 Standards as a mandatory measure in Section 131(g). This language required the installation of automatic lighting controls to uniformly reduce lighting power consumption by at least 15 percent in retail buildings with sales floor areas greater than 50,000 square feet. The 2013 Title 24, Part 6 Standards in Section 130.1(e) kept the same uniformity and dimming requirements but expanded the mandatory measure to apply to all nonresidential buildings greater than 10,000 square feet, excluding spaces with a lighting power density (LPD) less than or equal to 0.5 watts per square foot. Aside from establishing building and space exemptions based on health and safety statues, ordinances, or regulations, no major updates to this requirement were adopted in either the 2016 (Section 130.1(e)) or 2019 (Section 110.12(c)) code cycles. However, since the last quantitative update in 2013, the lighting standards of Title 24, Part 6, relating to lighting power allowances and lighting controls, have continued to be updated to reflect a shift to solid state lighting.

Solid state lighting has a significantly higher efficacy (lumens per watt) than incandescent, halogen, and other historically common light bulbs and luminaires. The gradual shift in baseline has significantly decreased the LPD in many spaces resulting in lower energy savings potential from DR lighting.

As can be seen in Table 12, since the last substantial change to the demand responsive lighting requirements in 2013, the lighting power allowances for auditoriums and classrooms have decreased by 53 and 42 percent respectively. While exercise/fitness areas, laundry areas, and spaces not specifically called out in the area category method have effectively become exempt all together.

Table 12: Area Category LPD From Different Code Cycles

Area Category Space Types[a]	2013 LPD (W/ft^2)	2016 LPD (W/ft^2)	2019 LPD (W/ft^2)
Auditorium	1.5	1.4	0.7
Classroom & Training	1.2	1.2	0.7
Dining Area	1.1	1	0.4-5.5[b]
Exercise/Fitness	1	1	0.5
Lounges, Breakroom, & Waiting Area	1.1	0.9	0.65
Office Area: ≤250 ft^2	1	1	0.7
Laundry Area	0.9	0.7	0.45
Areas Not Specified	0.6	0.5	0.5

a. Listed spaces are a sample of those listed in the 2019, Title 24, Part 6 area category method.

b. Dining area encompasses three subsections: cafeteria/fast food, family and leisure, and bar/lounge and fine dining.

Source: Title 24, Part 6

As the installed lighting power has decreased, the cost for effective implementation has decreased. Historically, a piecemeal system controlled at the circuit level was common for DR lighting implementation, but now many networked lighting control (NLC) systems have native automated demand response (ADR) communication protocols (OpenADR) and piecemeal systems can control individual fixtures instead of the lighting circuit. Standalone OpenADR devices have also increased the number of communication protocols they can operate with, allowing them to better communicate directly with lighting controls. These advances dictate a new cost-effective analysis be conducted to ensure proper implantation. A new cost-effectiveness analysis, one based on a facilities total design wattage rather than square footage, would produce a new delineation compared to the existing 10,000 square feet threshold that directly targets the controlling end-use (lighting wattage) and more effectively establishes a cost-effective exemption delineation.

The 0.5 watts per square foot threshold is based on the Title 24, Part 6 multi-level lighting control requirements in Section 130.1(b) of Title 24, Part 6 – 2019, which requires multi-level lighting control above 0.5 watts per square foot. The logic for this link being spaces without the capability for multi-level control (e.g., dimming) are not well equipped to participate in DR. To prepare these spaces for effective DR participation, dimming capabilities would likely be added where not currently required by code. This would attribute the cost of such dimming controls to the DR savings, limiting the cost effectiveness of the measure.

The 10,000 square foot threshold was proposed in a CASE Report for the 2013 Title 24, Part 6 Standards. It was developed based on fluorescent sources and needs to be reevaluated in order to determine a new cost-effectiveness threshold. The shift to solid state lighting would decrease the controllable lighting load compared to the 2013 analysis, but other market forces, such as changing DR program hours and an increase in product availability for day-to-day demand management may offset those loses.

The term "non-habitable" was included for demand responsive lighting in the 2013 Title 24, Part 6 code cycle in both the mandatory and PAF sections. This term was removed from the mandatory language, Section 130.1(e), in the subsequent code cycle while "non-habitable" was left in place in the PAF language.

Acceptance testing for DR lighting controls were added in for the 2013 version of Title 24, Part 6. Since this time, the acceptance tests have remained largely unchanged despite confusion surrounding implementation. Specifically, since the 2013 version of Title 24, Part 6, the acceptance tests have required that spaces do not reduce the illuminance of a space from electric and daylighting to less than 50 percent of the designed illuminance. The source of confusion has been that this 50 percent requirement is part of the acceptance test but not a requirement specified in the standards.

2.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manuals, and compliance documents would be modified by the proposed change. See Section 2.6 of this report for detailed proposed revisions to code language.

2.1.3.1 Summary of Changes to the Standards

This proposal would modify the following sections of Title 24, Part 6 as shown below. See Section 2.6.2 of this report for marked-up code language.

Section 110.12 – Mandatory Requirements for Demand Management

- **(c) Demand responsive Lighting Controls**: The quantitative thresholds of 10,000 square feet of Section 110.12(c) would be changed to 4,000 total design wattage, as defined by 140.6(a) but not including spaces with LPDs (watts per square foot) less than or equal to the LPD trigger for multi-level lighting controls in Section 130.1(b), based on the result of the cost-effectiveness analysis. The direct listing of the 0.5 watts per square foot exemption on the same section would be removed in favor a reference to the multi-level lighting controls of the same exemption. This would allow a single exemption language to exist as the lack of dimming requirements for such spaces is the limiting factor for demand responsive lighting.

Section 140.6 – Prescriptive Requirements for Indoor Lighting

- **(a)2K:** This subsection relates to power allowance factors. This language would be updated to reflect the changes to the demand responsive lighting mandatory requirement of Section 110.12. The 10,000 square foot threshold would be replaced with the cost-effective 4,000 total design wattage, the 0.5 watts per square foot reference would be directed to the same exemption of the multi-level lighting controls, and the term "non-habitable" and corresponding text would be removed.
- **Table 140.6-A – Lighting Power Adjustment Factors (PAF)**: The 10,000 square foot and 0.5 watt per square foot thresholds called out in this table would be removed and the introductory language would be replaced with language defining eligible facilities and spaces as those that were not required to have demand responsive lighting controls.

2.1.3.2 Summary of Changes to the Reference Appendices

The proposed code change would modify the acceptance test, NA7.6.3.2, of the reference appendices two-fold. It would remove the 50 percent illuminance threshold of the full output test of the two existing verification methods and introduce a third verification method that would operate at the full building level when the building has their circuits disaggregated by end-use.

2.1.3.3 Summary of Changes to the Nonresidential ACM Reference Manual

The proposed code change would not modify the ACM Reference Manual. Section 5.4.4 of the Nonresidential ACM Reference Manual describes the approach for accounting for PAFs, but the language references the standards and therefore does not need to be updated.

2.1.3.4 Summary of Changes to the Nonresidential Compliance Manual

The proposed code change would modify the following sections of the Nonresidential Compliance Manual.

- **Section 5.4 Mandatory Lighting Controls, subsection 5.4.5 - Demand Responsive Lighting Controls:** The 10,000 square foot threshold would be replaced with the cost-effective 4,000 total design wattage and the 0.5 watts per square foot threshold would include a reference to the multi-level lighting controls exemption of the same level.
- **Section 5.6 Prescriptive Compliance Approach for Indoor Lighting – Part 1, Adjusted Indoor Lighting Power, subsection 5.6.2A Power Adjustment Factors (PAFs) or Reduction of Wattage Through Controls, 11:** The demand responsive language within would be replaced by the marked-up language detailed in the CASE Report for demand responsive PAFs. This includes

removing the 10,000 square foot and 0.5 watt per square foot reference bullets and including a more general statement noting that facilities and spaces that were not required to implement demand responsive lighting are eligible for the PAF.

- **Appendix D – Demand Responsive Controls**
    - **Table D-1 Summary of DR Control Requirements for Newly Constructed Nonresidential Buildings:** the 10,000 square foot threshold called out in this table would be replaced with the cost-effective 4,000 total design wattage.
    - **Section 4. DR Controls for Lighting Systems:** The 10,000 square foot threshold would be replaced with the cost-effective 4,000 total design wattage and the 0.5 watts per square foot threshold would include a reference to the multi-l**evel lighting controls exemption of the same level.**

2.1.3.5 Summary of Changes to Compliance Documents

The proposed code change would modify the compliance documents listed below.

- NRCC-LTI-E Indoor Lighting Certificate of Compliance: update to reflect the revised threshold requirements from 10,000 square feet to 4,000 watts design wattage.
- NRCA-LTI-04-A Demand Responsive Lighting Control Acceptance Document: refinements would be made to align with the modifications to the acceptance.
- NRCI-LTI-05-E Power Adjustment Factors Certificate of Installation: refinements would be made to align with the modifications to the demand responsive threshold including replace the 10,000 square foot threshold with the new cost-effective total design wattage, the reference to the watts per square foot exemption of the multi-level lighting control in place of the explicit 0.5 watts per square foot exemption, and removing the term “non-habitable.”

2.1.4 Regulatory Context

2.1.4.1 Existing Requirements in California Energy Code

The existing code language states lighting DR is not required for facilities that are larger than 10,000 square feet, where spaces with a watts per square foot less than or equal to 0.5 are exempt from the requirement and do not count towards the 10,000 square foot threshold. When complying with demand responsive lighting, a uniform level of dimming must be used based on the lighting technology installed as detailed in Table 130.1-A. Spaces where health or life safety statue, ordinance, or regulation does not permit lighting to be reduced are not required to install demand responsive controls are do not count towards the 10,000 square foot threshold.

The 2022 code cycle includes potential updates to the nonresidential indoor LPD. Decreasing the allowable LPD would result in lower energy savings from demand responsive lighting. Additionally, a proposal to move the prescriptive requirement for secondary side lit daylit zones to mandatory would reduce the energy savings for demand responsive lighting as it would reduce the available lighting load during daylight hours. These changes are presented in the nonresidential indoor lighting, and nonresidential daylighting controls CASE Reports for the 2022 code cycle.

2.1.4.2 Relationship to Requirements in Other Parts of the California Building Code

There are no relevant requirements in other parts of the California Building Code.

2.1.4.3 Relationship to Local, State, or Federal Laws

There are no relevant local, state, or federal laws.

2.1.4.4 Relationship to Industry Standards

There are several building codes and rating systems that recognize the importance of DR and include provisions to facilitate the participation in DR transactions. These model codes and rating systems include, but are not limited to, ASHRAE 90.1, ASHRAE 189.1, the International Energy Conservation Code (IECC), and Leadership in Energy and Environmental Design (LEED). Model building codes include requirements that support DR using the following strategies: (1) ensure buildings have curtailable load, (2) ensure load are equipped with DR controls, (3) require that DR systems have been commissioned and certified to confirm they are capable of responding to DR signals as designed, (4) require participation in DR transactions, and (5) require building energy use to be measured to enable better demand-side management in the future. These building codes and rating system requirements can be either voluntary or mandatory.

Title 24, Part 6 has more robust and detailed DR requirements that most other mandatory model codes. This is, in part, because California has both robust DR markets and building energy efficiency codes that are tailored to buildings, weather, and utility markets in California.

On the voluntary side, ASHRAE 189.1-2017 outlines that buildings shall be designed with ADR infrastructure capable of receiving DR requests from the utility, electrical system operator, or third-party DR program provided to automatically implement load adjustments to the HVAC and lighting systems. With respect to lighting, building projects with interior lighting control systems controlled at a central point shall be programmed to allow for ADR. The programming shall reduce the total connected lighting power demand during a DR event by no less than 15 percent, but no more than 50 percent of the baseline power level. Requiring uniform lighting level reduction for spaces not in daylighting zones. This measure excludes luminaires or signage on emergency circuits, luminaires within a daylight zone that are dimmable and connected to automated daylighting control systems, and lighting systems claiming a lighting power allowance for institutional tuning. This is significantly more descriptive than the specifications of ASHRAE 189-2014, which outlined outlines that buildings shall contain automatic systems, such as demand limiting or load shifting, that are capable or reducing electric peak demand of the building by not less than 10 percent of the project peak demand. The U.S. Green Building Council (USGBC) included a pilot credit for DR in LEED Version 4 and operating system with the requirement for ADR enabled systems with a minimum peak electricity demand reduction of 10 percent. LEED is currently on Version 4.1 which includes a DR credit with similar requirements of Version 4.0, but the 10 percent demand reduction has been clarified to occur during on-peak hours and not the general annual peak demand.

2.1.5 Compliance and Enforcement

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

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

- **Design Phase:** During the design phase, the lighting designer is responsible for ensuring demand responsive controls are incorporated into the design if the facility requires them. Additionally, the lighting designed must ensure that the lighting that is controlled by the demand responsive controls is capable of curtailing power usage (or lighting levels) by 15 percent of more. The designer is also responsible for specifying demand responsive controls that meet the code requirements. The design team documents intent to comply with demand responsive control requirements in the NRCC-LTI-E Indoor Lighting Certificate of Compliance document or NRCC-PRF-01-E Certificate of Compliance for the performance approach and other lighting design documents.
- **Permit Application Phase:** Plans examiner review design documents and confirm that the design complies with the demand responsive control requirements.
- **Construction Phase:** The lighting system, which can curtail load, and the demand responsive controls are installed and commissioned during the construction phase. The details and capabilities of these controls are documented in NRCI-LTI-02-E, the Certificate of Installation for Energy Management Control System or Lighting Control System. The controls must be programmed/configured so the system can automatically implement the control strategy that is tested during the acceptance test. A certified acceptance test technician (ATT) conducts functional performance testing on the control system

to complete required acceptance tests and the commissioning process. The ATT completes the NRCA-LTI-04-A: Demand Responsive Lighting Control Acceptance Document to document a passing score on the acceptance test.

- **Inspection Phase:** The building inspector confirms acceptance tests were completed and the appropriate controls were installed to complete those tests by reviewing the NRCA documents during inspection.

The compliance and enforcement process after the proposed code changes remain largely the same. The primary difference from this proposal is to reevaluate the thresholds at which this compliance process must take place. In 2019 Title 24, Part 6, nonresidential lighting in spaces larger than 10,000 square feet for spaces with lighting power densities greater than 0.5 watts per square foot (baring exemptions for safety ordinances) must have demand responsive controls capable of automatically reducing the lighting power of the facility. With the adoption of the proposal laid out in this CASE Report, the 10,000 square foot quantitative thresholds would change. The 10,000 square feet would be replaced by 4,000 total design wattage as listed in the 2019-NRCC-LTI-E certificate of compliance, with the same exemptions in place for 0.5 watt per square foot spaces and areas where health and safety statues, ordinance, or regulation does not permit lighting power to be reduced.

2.2 Market Analysis

2.2.1 Market Structure

DR enabled lighting systems involve two primary structures:

- A native network of lighting controls that enables demand responsive lighting through OpenADR, and
- A piecemeal system of lighting controls connected through a single communication protocol that extends to a standalone OpenADR certified device.

The market for wired and wireless controls is well established in the United States and available through established distribution chain, as highlighted in Table 13.

Table 13: Lighting Market Actors

Market Actor	Core Function
Manufacturer	Production
Wholesale Distributor	Distribution of Product, Logistics, and Financing
Manufacturer Representatives	Sales Generation
Electrical Contractors	Installation and Sales
Commercial End-Users	Decision Market

A 2015 study by Bonneville Power Administration characterized four distribution channels used by manufacturers to sell lighting products to end-users. The four channels include wholesale distribution, retail, online only, and direct distribution. Furthermore, both independent and in-house manufacturer representatives act as brokers for deals, thus playing an important role in the distribution chain (Bonneville Power Authority 2015).

Table 14: Lighting Distribution Chain

Distribution Channel	Description
Wholesale Distribution	• Dominant Channel • Not all inventory is physically store at distributor site, some manufacturers "drop-ship" directly from factor to project site
Retail	• Selling products through traditional brick and mortar storefronts
Online Only	• Selling only at sites, such as 1000bulbs.com; shipping directly from a central warehouse • Offering minimum customer service
Direct	• Smallest channel used by large customers "because they can" or by new manufacturers "because they have to"

Many fixture manufacturers offer standalone or integrated lighting controls, with the latter gaining more market share. This integration and advancement of integrated controls has only accelerated with the continued advancement of solid-state lighting technology. Some of the major manufacturers that offer lighting controls include that are OpenADR certified include, but are not limited to, Acuity Controls, Enlighted Inc., Daintree Enterprises, and Lutron Electronics.

The 2014 California Commercial Saturation (CSS) survey by Itron prepared for the California Public Utilities Commission collected "information on the distribution of interior lamps by control type and the business's participation in IOU EE lighting, EE lighting control, and DR registration" (Itron, Inc 2014). The study found that "participants have a statistically significant smaller share of their lamps manually controlled than non-participants and a higher share of their lamps controlled by EMS, occupancy sensors, motion sensors, and photocells and time clocks than non-participants" (Itron, Inc 2014). This insight demonstrates the early adoption of such controlling technologies. Since this study was completed, these controlling technologies have gained traction in the building codes such as Title 24, Part 6 to further increase adoption.

Additional non-lighting specific OpenADR devices are available from vendors such as Universal Devices Inc., IC Systems Inc, IPKeys Technologies, LLC, and THG Energy Solutions, LLC. These devices can be purchased directly from the device manufacturer through online marketplaces, online resellers, and distributors. Additionally, technology neutral device manufacturers, such as those previous listed, offer direct customer service lines to aid with installation and commissioning if the purchased device is being sent directly to the end-user.

2.2.2 Technical Feasibility, Market Availability, and Current Practices

There are three main DR strategies for indoor lighting in nonresidential facilities: 1) dimming; 2) non-essential lighting shutoff; and 3) partial shutoff. The selection of which strategy to employ depends on the installed lighting technology and facility layout. For example, lighting fixtures with dimmable ballasts or drivers can commonly be found in office spaces and can shed load through consistent dimming that would provide sufficient lighting in all occupied areas. Retail facilities may have non-essential accent or decorative lighting that can be turned off during an event. Warehouses and box stores tend to have high-bay lighting fixtures on different circuits allowing for a "checkerboard pattern" result when one circuit is shut off in response to a DR event signal, allowing for significant load shed while maintaining acceptable lighting levels in the facility. This tactic would be more disruptive in facilities where each fixture is (vertically) closer to the building occupants and the shutoff of any one fixture could prevent building occupants from effectively utilizing the space.

Several controls manufacturers have developed products designed to either integrate with existing lighting control systems or establish new lighting control capabilities. The OpenADR Alliance maintains a qualified product list (QPL) of OpenADR certified devices. Along with standalone OpenADR devices and whole building management systems, the QPL includes lighting specific controls such as those from Acuity Brands, Inc., Daintree Enterprise, Enlighted, Inc., Exergy Controls, and Lutron Electronics, Inc. The Design Lights Consortium (DLC) maintains a QPL that details lighting controls certified to a DLC specification, this specification includes load shedding (DR) capabilities (though OpenADR is not required).[10] At the time of writing, the DLC QPL consists of 37 interior lighting controls systems of which 20 have demand responsive capabilities. DLC defines DR capabilities as having "the capability to reduce the energy consumption of a lighting system, in a pre-defined way, on a temporary basis, in response to a demand response signal" (DLC 2019). A lighting control system does not have to be on the DLC QPL to have the same capabilities as those listed or to comply with the proposals within this CASE Report. The DLC QPL is solely used as a source of information showing available products with demand responsive capabilities.

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[10] The DLC networked lighting controls specifications and qualified product list (QPL) can be downloaded here: https://www.designlights.org/lighting-controls/download-the-qpl/. At the time of writing, the controls specification was on version 4.0 that was last updated on June 10, 2019 and the qualified product list was last updated on November 8, 2019. Specifications: https://www.designlights.org/lighting-controls/qualify-a-system/technical-requirements/.

2.3 Energy Savings

2.3.1 Key Assumptions for Energy Savings Analysis

The energy and cost analysis presented in this report used the TDV factors that are consistent with the TDV factors presented during the Energy Commission's March 27, 2020 workshop on compliance metrics (California Energy Commission 2020). The electricity TDV factors include the 15 percent retail adder and the natural gas TDV factors include the impact of methane leakage on the building site. The electricity TDV factors used in the energy savings analyses were obtained via email from Energy and Environmental Economics, Inc. (E3), the contractor that is developing the 2022 TDV factors for the Energy Commission, in a spreadsheet titled "Electric TDVs 2022 - 15 pct Retail Adj Scaled by Avoided Costs.xlsx". The natural gas TDV factors used in the energy savings analyses were obtained via email from E3 in a spreadsheet titled "2022_TDV_Policy_Compliant_CH4Leak_FlatRtlAdd_20191210.xlsx". The electricity demand factors used in the energy savings analysis were obtained via email from E3 in a spreadsheet titled "2022 TDV Demand Factors.xlsx". The final TDV factors that the Energy Commission released in June 2020 use 20-year global warming potential (GWP) values instead of the 100-year GWP values that were used to derive the current TDV factors. The 20-year GWP values increased the TDV factors slightly. As a result, the TDV energy savings presented in this report are lower than the values that are expected if the final TDV that use 20-year GWP values were used in the analysis. The proposed code changes will be more cost effective using the revised TDV. Energy savings presented in kWh and therms are not affected by TDV or demand factors.

The energy savings associated with this measure is focused on the potential savings associated with enacting demand responsive indoor lighting. The energy savings potential is evaluated across twelve building types with the intention of establishing new cost-effective demand responsive lighting thresholds based on the total design wattage.

Updates to the HPWH, TES, and communication protocols do not require an energy savings analysis as they are only changing the compliance software (HPWHs and TES) or do not have any energy savings associated with their language amendments (communication protocols).

The energy and cost analysis presented in this report used the TDV factors that are consistent with the TDV factors docketed on June 5, 2020 on the 2022 Energy Code Pre-Rulemaking Energy Commission Docket 19-BSTD-03 (California Energy Commission 2020).

2.3.1.1 Building Models

A total of twelve building models were reviewed for this submeasure: ten are based on the ASHRAE 90.1 prototypes while two, Large Retail and Retail Mixed Use, are based on the CBECC-Com building prototypes. The details of these models are discussed further in the energy savings methodology. While these building models contain many specific details of the facility, such as square footage, window to wall ratio, number of stories, and operational schedules, they do not contain a distribution of the square footage by space type. This space type distribution is needed in order to determine the lighting power allowance of the prototype buildings when using the area category method (which is discussed further in this section). The 2016 Database for Energy Efficient Resources (DEER) Commercial Indoor Lighting Summary provides such space type distributions for different building types (DEER 2015). This resource was used to provide this additional level of detail to the prototype buildings.

There are three lighting power allowance compliance methods: 1) the whole building method, 2) the area category method, and 3) the tailored method. The area category method is used to calculate the lighting power allowances for this submeasure as it offers a more detailed analysis than the whole building method and is applicable to all facility spaces unlike the tailored method. The CASE authors understand that not all buildings would use the area category method, but it is an appropriate generalization for the prototype building models.

While the area category method would provide the maximum allowable wattage for each prototype building, it does not represent the design (or installed) wattage, which would be lower than the maximum allowable wattage.[11] To identify the difference between maximum allowed and design wattage, a survey was distributed and conducted from late 2019 through early 2020 to lighting stakeholders, including lighting designers, engineers, contractors, property owners, and acceptance test technicians to ask, among other things, how often facilities are designed or at a prescribed fraction, such as 50 percent, of the allowable LPD. Thirty-five different respondents, predominately lighting designers, responded to this question. These respondents resulted in a distribution of installed lighting power further detailed in the energy savings methodology. The survey results are used to represent a market weighted average of facility installed wattage across all facility types and sizes.

Once applied to the building prototypes, the market weighted average installed LPDs were used to identify spaces where the LPD was less than or equal to 0.5 watts per

[11] The area category method provides maximum allowable wattage values, expressed in watts per square foot (LPDs). A space is allowed to be designed (and installed) with up to LPD value; meaning, a space with an LPD value of 0.6 watts per square foot can be designed to any wattage up to 0.6 watts per square foot.

square foot. These areas were subsequently excluded from analysis as they are not required to install demand responsive lighting controls.

The ASHRAE 90.1 and CBECC-Com building models include weekday lighting operational schedules for each prototype. These schedules were used to estimate facility unoccupied/closed schedules and the average amount of light available in those unoccupied/closed times.

2.3.1.2 Daylight Impacts

Nonresidential daylighting applies to general lighting in both the primary and secondary daylit zones as well as the skylit zone. Within those zones, if the illuminance from the daylight is greater the 150 percent of the designed space illuminance, the luminaires within those zones need to have their power reduced by at least 65 percent. To account for this lighting control requirement, some assumptions were made regarding when daylighting is applied, how much space is within the daylit and skylit zones, and what is the power reduction impact.

Lighting power reduction from daylighting applies when there is sufficient daylight in the daylit and skylit zones. While there are numerous factors that go into how much illuminance is provided to these zones, such as sun exposure through clouds, trees, other buildings, and window shades, a conservative assumption is that prior to sunset, greater than 150 percent of the designed space illuminance is being provided by daylight in the daylit zones. While this level of illuminance may not always be provided, for the site-by-site variations noted, the Statewide CASE Team used this assumption to create a conservative estimate of the available lighting level in the daylit and skylit zones. As discussed in more detail in Section 2.3.1.5, the daylighting impact is considered to start at 2 p.m., the historical starting time of demand responsive events and the starting time for evaluation of this measure, through sunset. Sunset times vary across California from both a longitude and latitude perspective. The Statewide CASE Team looked at the two extremes within California to understand the impact of geographic location on sunset times. Energy Commission Climate Zone (CZ) 1 represents the furthest north west zone in California while Climate Zone 15 represents the zone furthest southeast. In 2018, the average annual sunset time in Climate Zone 1 is 7:01 p.m. while Climate Zone 15 is 6:29 p.m.[12] These are not drastically different enough to merit separate analyses, but the average sunset time of 6:45 p.m. will be used to represent California as a whole.

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[12] Data for CZ1 is represented by the city of Arcata, CA and CZ15 by the city of Palm Springs, CA. Sunset times analyzed were taken from sunrise-sunset.org and were for the 2019 calendar year.

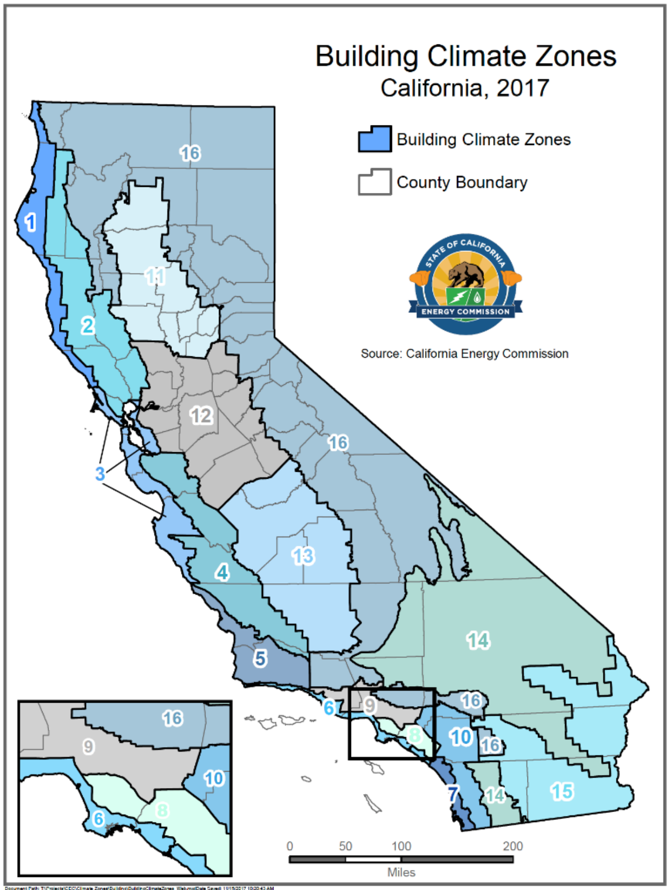


Figure 2: California Energy Commission climate zones.

Source: Energy.ca.gov

The square footage for each prototype that falls into the primary and secondary daylit zones as well as the skylit zone needs to be calculated in order to estimate how much wattage would be controlled by daylighting controls. The ASHRAE 90.1 and CBECC-Com prototype buildings, among other information, identify the glazing sill height, the window dimensions, building square footage, the number of floors, skylight dimensions, interior ceiling height, and present an image of the window and skylit distribution. With this information, the Statewide CASE Team calculated a conservative estimate of the square footage in each in the daylit zones and skylit zone (accounting for any overlapping square footage). The number of walls with windows was also considered in this analysis as only two walls at any one time will have direct sun exposure. Meaning for a prototype building with windows on all four walls, the sidelit zones subject to greater than 150 percent design illuminance can be expected to only impact the two sides of the building facing the sun at any one time. These considerations lead to a single conservative square footage number for each prototype building that is reasonably expected to be subject to luminaire dimming due to daylighting illuminance at any one time.

Table 15: Prototype Buildings Daylit and Skylit Square Footage

Prototype	Total Square Footage	Daylit (ft^2)	Walls with Windows	Skylit (ft^2)
Office Small	5,500	3,818	4	N/A
Office Medium	53,600	22,227	4	N/A
Office Large	498,600	33,870	1	N/A
Strip Mall	22,500	2,429	1	N/A
Stand-Alone Retail	24,695	2,463	1	8,192
Retail Large*	240,000	12,336	3	320,931*
Retail Mixed Use	9,375	1,875	1	N/A
Primary School	73,960	27,936	4	2,705
Secondary School	210,900	55,123	4	32,535
Warehouse (Non-Refrigerated)	49,495	864	2	18,662
Quick Service Restaurant	2,500	962	2	N/A
Small Hotel	43,200	5,038	2	N/A

*Primary and Secondary Daylit and Skylit zones were capped at the full square footage due primarily to the large number of skylights present in the Retail Large building model

The impacted square footage would reduce their lighting power by the minimum prescribed lighting power reduction of 65 percent per 2019 Title 24, Part 6, Section 130.1(d). The daylighting impacts are integrated with the open/closed operating conditions and occupancy sensory impacts (Section 2.3.2.1). The 65 percent reduction would be applied to the calculated lighting levels during both open and closed operating hours provided they occur before the average sunset time of 6:45 p.m. For example, if a facility closes at 5 p.m. and some lighting is on during these closed hours (as discussed in Section2.3.2.1), the reduction in power due to daylighting would impact the closed hour lighting demand as well as the open hour lighting demand. This approach assumes the available lighting load is distributed throughout the facility and applies to the same fraction of lighting during open and closed hours. Additionally, an enclosed space may be subject to both daylighting and occupancy sensor requirements. If the occupancy sensor requirements dictate the lighting be turned off when the space is unoccupied (as detailed in Title 24, Part 6, Section 130(c)), there would be zero lighting load in this enclosed space and thus, zero load shed potential.

2.3.1.3 Occupancy Sensor Impacts

Title 24, Part 6 130.1(c) identifies three different aspects of the occupancy sensing control requirements that apply to different space types:

- Section 130.1(c)5: lighting installed in offices 250 square feet or smaller, multipurpose rooms of less than 1,000 square feet, classrooms of any size, conference rooms of any size, and restrooms of any size must be controlled by an occupancy sensor that would shut off all lighting when the area is unoccupied. For these spaces, it is assumed that when unoccupied the lighting power reduces to zero.
- Section 130.1(c)6: lighting installed in aisle ways and open areas in warehouses, library book stack aisles of 10 or 20 feet in length depending on access, and corridors and stairwells must be controlled by an occupancy sensor that would at least reduce lighting power by 50 percent when the area is unoccupied. For these spaces, it is assumed that when unoccupied the lighting power reduces by 50 percent.
- Section 130.1(c)7: lighting installed in stairwells and common area corridors that provide access to guestrooms and dwelling units of hotel/motels must be controlled by an occupancy sensor that would reduce the lighting power by at least 50 percent when the area is unoccupied. For these spaces, it is assumed that when unoccupied the lighting power reduces to zero.

While the ASHRAE 90.1 and CBECC-Com models identify typical occupancy rates of the building as a whole, these do not identify the potential savings associated with occupancy sensors in specific spaces. To determine the occupancy rates of these spaces, the Statewide CASE Team looked to a 2016 application guide published by the U.S. Department of Energy (DOE) Energy Efficiency & Renewable Energy (EERE) division (U.S. DOE (Department of Energy) 2019). This report includes information identifying lighting energy savings by space type resulting in the savings data in Table 16. These values, or the average when a maximum and minimum value are presented, were used to estimate the amount of lighting energy saved in spaces Title 24, Part 6 requires occupancy sensor deployment.

Table 16: U.S. DOE EERE Application Guide for Federal Facility Managers Occupancy Sensor Energy Saving by Room Type

Room Type	Occupancy Sensor Lighting Energy Savings
Classroom	40-46%
Conference Room	45%
Corridor	30-80%
Office, Private	13-50%
Restroom	30-90%
Storage Area	45-80%
Warehouse	35-54%

Source: (U.S. DOE (Department of Energy) 2019)

The energy savings from the occupancy sensors were applied during the occupied/open period of each prototype building that were identified by the occupancy schedules of the building models.

2.3.1.4 Demand Responsive Lighting Reduction

The energy savings potential is the demand reduction of the installed lighting after considering the impact of the daylighting and occupancy sensors on operating wattage. A 15 percent lighting reduction is used since Title 24, Part 6 Section 110.12(c)1. calls for a 15 percent reduction in lighting power and this same reduction percent is echoed in Demand Responsive Controls Acceptance Tests in Section NA7.6.3 of the 2019 Title 24, Part 6 Reference Appendices.

2.3.1.5 Annual Participation Hours

DR programs are operated directly by utilities, such as PG&Es Peak Day Pricing (PDP) program and SCEs Critical Peak Pricing (CPP) program, or independently, such as with the Capacity Bidding Program (CBP) (PG&E n.d.) (SCE n.d.) (PG&E n.d.). PDP and CPP operate from four to five hours per event across nine to 15 events from May through October. While CBP operates across the same months, this program has historically initiated more frequent events - 29 and 45 different event days in 2017 and 2018 respectively – with shorter durations – on average between two and three hours per event. Accounting for all of these long running programs, an average DR program can be considered to have 25 events per year that each last for 3.5 hours, totaling 87.5 hours per year (CPUC 2017 & 2018). To align with this DR program operation, only the top 88 hours per year, equivalent to the top one percent of TDV hours, can be expected to result in DR action. While the DR window that these programs can call events range from 11 a.m. to 9 p.m., no event has been called earlier than 2 p.m. since 2012 (CPUC 2017 & 2018). For this reason, the top one percent of TDV hours would be restricted to within the 2 p.m. to 9 p.m. window. This closely aligns with utility time-of-use peak hours for the three largest investor owned utilities in California (PG&E, SCE, and SDG&E), which have historically had peak hours between noon and 6 p.m., but have either transitioned, or are in the midst of transitioning, to peak hours of 4 p.m. to 9 p.m.. Nonresidential facilities at all three utilities may move to a 4 p.m. to 9 p.m. peak window, with this window becoming the only option by the end of 2020. At which point the utilities would be transitioning nonresidential customers to the time-of-use electricity rates. While DR enrollment represents a small fraction of the overall utility nonresidential customers, as the investor owned utilities transition nonresidential customers to time-of-use rates, demand responsive lighting would become valuable to all nonresidential customers and not solely those in DR programs.

The three DR programs identified operate from May through October, commonly referred to as the "summer season", which has historically been the exclusive operating months of DR programs. However, in recent years three DR pilots have been operating with year-round windows: The Demand Response Auction Mechanism (DRAM), the Supply Side Pilot (SSP), and Excess Supply Side Pilot (XSP). Due to this push to expand operation of DR programs to year-round operation, the TDV hours being considered in the top one percent of this energy savings evaluation can occur during any month.

2.3.2 Energy Savings Methodology

2.3.2.1 Energy Savings Methodology per Prototypical Building

The Energy Commission directed the Statewide CASE Team to model the energy impacts using specific prototypical building models that represent typical building geometries for different types of buildings.[13] The prototype buildings that the Statewide CASE Team used in the analysis of this submeasure are presented in Table 17. The existing Title 24, Part 6 requirements apply to both new construction and alterations, so the Standard Design is minimally compliant with the 2019 Title 24, Part 6 requirements accounting for variances in installed LPDs based on market actor surveys. For the purpose of the energy savings analysis, there are not significant differences between

[13] ANSI/ASHRAE/IES Standard 90.1 and CBECC-Com building models and were used for this evaluation. Details concerning the models ANSI/ASHRAE/IES Standard 90.1 models can be found at the following link: https://www.energycodes.gov/development/commercial/prototype_models

new construction and alterations as both are subject to the same lighting power density, occupancy, and photosensor requirements that impact the energy savings analysis.

Table 17: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name[a]	Number of Stories	Floor Area (ft^2)	Description
Office Small	1	5,500	1 story, 5 zone office building with pitched roof and unconditioned attic. WWR- 0.24
Office Medium	3	53,600	3 story office building with 5 zones and a ceiling plenum on each floor. WWR-0.33
Office Large	13	498,600	12 story + 1 basement office building with 5 zones and a ceiling plenum on each floor. WWR-0.40
Strip Mall	1	22,500	Strip Mall building with WWR -11 percent
Stand-Alone Retail	1	24,695	Similar to a Target or Walgreens.7 percent WWR on the front façade, none on other sides. SRR of 2.1 percent.
Retail Large	1	240,000	Big-box type Retail building with WWR -12 percent and SRR-0.82 percent
Retail Mixed Use	1	9,375	Retail building with WWR -10 percent. Roof is adiabatic
Primary School	1	73,960	Elementary school with WWR of 35 percent
Secondary School	2	210,900	High school with WWR of 33 percent
Warehouse (Non-Refrigerated)	1	49,495	Single story high ceiling warehouse. Includes one office space. WWR- 0.7 percent, SRR-5 percent
Quick Service Restaurant	1	2,500	Fast food restaurant with a small kitchen and dining areas. 14 percent WWR. Pitched roof with an unconditioned attic.
Small Hotel	4	43,200	4 story hotel. WWR 11 percent on average

a. Large Retail and Retail Mixed Use are based on the CBECC-Com building model while all other building modes are based on the ASHRAE 90.1 prototypes.

Source: ASHRAE 90.1 Models at https://www.energycodes.gov/development/commercial/prototype_models

The Statewide CASE Team estimated energy and demand impacts by developing a custom excel calculator tool to estimate the indoor lighting load available for each of the prototype buildings. This tool takes into account the estimated installed LPDs (compared to the *allowed* LPD by the area category method), the areas exempted by the 0.5 watts per square foot exemption, the impact of occupancy sensors in spaces where occupancy sensors are required by Title 24, Part 6, the impact of photosensors where they are required by Title 24, Part 6, and sector specific items, such as closing times, unoccupied times, and lighting levels during unoccupied times. This analysis method allows the Statewide CASE Team to identify the indoor lighting load shed potential based on the requirements of Title 24, Part 6. The available load shed is then applied to the top one percent (or 88 hours) of TDV values to calculate the energy saving potential by building type.

Prototype Wattage Without Controls

The first step of the energy savings calculation is to determine the available lighting load without any controls. This calculated lighting load would then be reduced in subsequent steps as occupancy and photosensor controls are introduced to spaces that are required by Title 24, Part 6.

The area category lighting power allowances of 2019 Title 24, Part 6 Table 140.6-C are used in conjunction with the 2016 Database for Energy Efficient Resources (DEER) Commercial Indoor Lighting Summary to identify space type fractions of each building model identified in Table 17. The space type fractions of the Commercial Indoor Lighting Summary allow direct attribution of the area category lighting power allowance method to each building type. As an example, this attribution for the small office prototype is shown in Table 18. All the prototype buildings identified in Table 17 undergo this space type fraction and area category lighting power density pairing.

Table 18: DEER 2016 Small Office Area Faction Distribution

DEER 2016 Space Type	DEER 2016 Space Type Fraction	Prototype (ft²)	Title 24, Part 6 Area Category Space Type	2019 Title 24, Part 6 Lighting Power Density (W/ft²)	Allowable Lighting (W)
Break	4%	203	Lounge, Breakroom, or Waiting Area	0.65	132
CompRoomData	1%	71	Electrical, mechanical, Telephone Rooms	0.40	28
Conference	6%	313	Convention, Conference, Multipurpose and Meeting Area	0.85	266
CopyRoom	1%	55	Copy Room	0.50	28
Hall	6%	352	Corridor Area	0.60	211
LobbyWaiting	6%	324	Main Entry Lobby	0.85	275
MechElecRoom	2%	90	Electrical, mechanical, Telephone Rooms	0.40	36
OfficeOpen	36%	1,961	Office Area: Open plan office	0.60	1,177
OfficeSmall	25%	1,357	Office Area: <= 250 square feet	0.70	950
RestRoom	4%	235	Restrooms	0.65	153
StorageSmlCond	10%	539	Commercial / Industrial Storage: Warehouse	0.45	243
Total:	**100%**	**5,500**			**3,498**

Source: ASHRAE 90.1 and CBECC Building Models in Conjunction with (DEER 2015)

This data source pairing results in a prototype building model that provides the maximum allowable wattage of each prototype building by space type according to the area category prescriptive requirements. For the small office prototype, the maximum allowable wattage is 3,498 watts. However, not all alterations or new construction facilities install the maximum allowable lighting power. Designing a building to achieve the maximum allowable wattage would be difficult to do in practice. It is far more likely that lighting designers and building owners would have a design wattage somewhere below the LPD allowance. To account for this, a survey was distributed and conducted from 2019 through early 2020 to lighting stakeholders, including lighting designers, engineers, contractors, property owners, and acceptance test technicians to ask, among other things, how often facilities are designed or at a prescribed fraction, such as 50 percent, of the allowable LPD. Thirty-five different respondents, predominately lighting designers, responded to this question. This survey resulted in the distribution shown in Table 19.

Table 19: Actual Lighting Design Wattage Survey Results

LPD Designs	Weighted Design Results	Average LPD Realized of Maximum Allowable
At or around maximum allowable LPD	37%	95%
Between 10 and 24% below LPD	22%	83%
Between 25 and 49% below LPD	14%	63%
At or below 50% LPD	28%	50%
Weighted Average		85%

Source: 2019 & 2020 Stakeholder Survey

The weighted average shown in Table 19 is then applied to the maximum allowable LPD of each space type for each building prototype, resulting in the market weighted LPD for each space of each building prototype. At this stage those spaces with a market weighted LPD less than or equal to 0.5 watts per square foot can be excluded, per the existing demand responsive lighting exemption.

The market weighted LPD of each space type is then multiplied by the square footage of that specific space type (e.g., conference room, break room, or open office space) and separated into facility “open” and “closed” operation. The facility “open” are hours that the prototype facility is considered to be operating in occupied conditions while “closed” are hours at which the prototype facility is considered to be operating in unoccupied conditions. For example, while an office may remain occupied after 6 p.m., the occupancy rate, lighting activity, and HVAC operation, decrease significantly and settle into their unoccupied operation at this threshold, as can be seen in Figure 3.

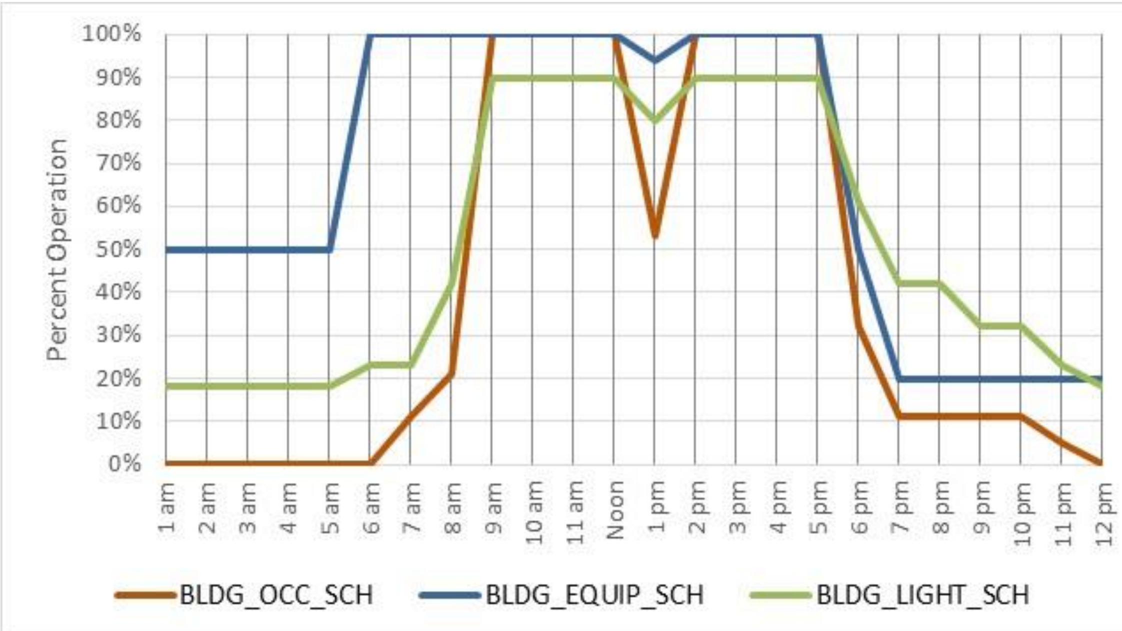


Figure 3: Small office occupancy, equipment, and lighting operation by time of day.

Source: ASHRAE 90.1 Building Model Operations

The open and closed hours have their own expected lighting operation that must be considered. To this point, the analysis considered the expected market weighted installed wattage but not the daily operational wattage. This difference is accounted for by reviewing the building model lighting operation schedule within the open and closed hours bound by the DR program hours of our evaluation, 2 to 9 p.m. For example, as can be seen in Figure 3, the lighting schedule indicates lighting levels at 90 percent from 2 to 5 p.m., with 5 to 6 p.m. having a lower lighting level of 61 percent, the average of these four hours is 83 percent which can be applied to the open hours installed wattage to achieve the operating wattage during the open hours. The same method is applied to the closed hours, which end at 9 p.m. to coincide with the end of the DR program operation hours. For the small office prototype, during the closed hours of 6 and 9 p.m., the lighting levels average 27 percent of the installed wattage.

The result of these steps is the market weighted operating wattages by space type for open and closed operation at each building prototype.

Prototype Wattage with Daylighting Controls

The second step in the energy savings calculations is to account for the daylighting requirements of Title 24, Part 6. Specifically, Section 130.1(d) that requires all general lighting in the skylit, primary, and secondary sidelit daylit zones have controls that automatically adjust the power of the installed lighting up and down to keep the total light level stable as the amount of incoming daylight changes. Section 130.1(d)3C states that all non-parking garage areas shall have their lighting dimmed by a minimum of 65 percent when the illuminance from daylight is greater than 150 percent of the design illuminance received from the general lighting system at full power.

To incorporate this requirement the Statewide CASE Team needed to understand when dimming due to daylighting would be in effect. This was done by determining the average sunset time across California during the typical DR season. Taking the average sunset time instead of the sunset time for individual climate zones was discussed in the energy savings key assumptions section. This assumption leads to an average sunset time of 6:45 p.m., as previously detailed. The Statewide CASE Team can conservatively generalize that before the sun has set at 6:45 p.m., there is sufficient illuminance from the natural light in the primary and secondary sidelit and skylit daylit zones to dim those fixtures down by 65 percent per Section 130.1(d)3C of 2019 Title 24, Part 6. This would produce a conservative estimate since presumably there are times when there is insufficient solar illuminance during daylight hours due to lack of direct sunlight exposure. As discussed in more detail in Section 2.3.1.5, the daylighting impact is considered to start at 2:00 p.m., the historical starting time of demand responsive events and the starting time for evaluation of this measure, through sunset

The fraction of each prototype building that is subject to the primary and secondary sidelit and skylit daylit zones is determined by the ASHRAE 90.1 and CBECC-Com building model schematics that identify the general building geometry, square footage, window fenestration details, skylight dimension, and the skylight locations. The daylighting impact on this fraction of the facility is subtracted from the uncontrolled wattage of the facility during open and closed hours to arrive at the prototype wattage with daylighting controls.

Prototype Wattage with Daylighting and Occupancy Controls

The third step in the energy savings calculations is to account for the occupancy control requirements of Title 24, Part 6 that reside in Section 130.1(c). As previously discussed, there are three different aspects of the occupancy sensing control requirements that apply to different space types:

- Section 130.1(c)5: lighting installed in offices 250 square feet or smaller, multipurpose rooms of less than 1,000 square feet, classrooms of any size, conference rooms of any size, and restrooms of any size must be controlled by an occupancy sensor that would shut off all lighting when the area is unoccupied.
- Section 130.1(c)6: lighting installed in aisle ways and open areas in warehouses, library book stack aisles of 10 or 20 feet in length depending on access, and corridors and stairwells must be controlled by an occupancy sensor that would at least reduce lighting power by 50 percent when the area is unoccupied.

- Section 130.1(c)7: lighting installed in stairwells and common area corridors that provide access to guestrooms and dwelling units of hotel/motels must be controlled by an occupancy sensor that would reduce the lighting power by at least 50 percent when the area is unoccupied.

Attributing the previously identified occupancy rates from Section 2.3.1.3 to the spaces that require occupancy sensors provide additional reduction in available lighting power during the open hours. Either reducing the lighting power to zero for spaces that apply to Section 130.1(c)5 or a 50 percent reduction for spaces that apply to Sections 130.1(c)6 and 7. Combining this calculated reduction in lighting power from the occupancy sensors with the initially calculated uncontrolled lighting power, and the daylighting reduction in lighting power provides the baseline lighting power available by space type and open/closed hours for each prototype building.

Demand Response Lighting Power Reduction of Prototype Buildings

The Proposed Design impact of this measures is identical to the Standard Design. The energy savings comes in the form of a 15 percent lighting reduction, as specified in 2019 Title 24, Part 6 110.12(c)1, during the top one percent of TDV hours for all facilities. 2019 Title 24, Part 6 identifies two exemptions for demand responsive lighting implementation that differ in this analysis: facilities greater than 10,000 square feet and spaces with less than or equal to 0.5 watts per square foot. For the purpose of energy savings evaluation, all nonresidential spaces that require demand response lighting controls are considered to be participating in the measure, except for spaces where health or life safety statue, ordinance, or regulation does not permit the lighting reduction. The new cost-effective exemptions are established by considering the energy savings results against the cost of implementation. See Section 2.5.1 for a discussion of statewide savings, including assumptions about how building occupants will use controls in light of new time-of-use rates.

The 15 percent reduction is applied to the final calculated prototype building wattage after accounting for the daylighting and occupancy control impacts.

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

Top One Percent of TDV Factors

The top one percent (equivalent to 88 hours) of TDV factors, where each TDV factor represents a single hour in a calendar year, between the hours of 2 and 9 p.m. are used to mirror expected DR program operation. The Statewide CASE Team sorted the top 88 hours by climate zone within these parameters and generated a distribution table of average TDV cost factors in 2023 present value (PV) dollars per kWh (2023 PV$/kWh) and the corresponding number of hours. Taking the weighted average across all 16 climate zones results in the distribution by hour ending, shown in Table 20.

A similar evaluation methodology was implemented for the peak demand impacts of this measure. Using the previously identified top 88 hours for each climate zone, a demand factor was attributed to each of the relevant hours. The demand factor is a TDV characteristic that is used to calculate a prototype's annual peak demand. An hourly demand factor value was developed when the 2022 TDV was created to accompany the annual TDV hourly distribution, with the sum of the annual demand factors equaling one. Multiplying the demand factor by the energy consumed for each particular hour yields the annual peak demand. To account for the demand reduction due to the prescribed 15 percent lighting load reduction, the demand factor was summed across each hour of each climate zone for their respective 88 hours, a weighted average was developed to account for all climate zones. The result of this weighted average is shown in Table 20.

Table 20: Top One Percent (88 Hours) Average TDV Value, Demand Factor, and Count of Hours

Hour Ending[a]	Average TDV Energy Cost Value (2023 PV$/kWh)	Demand Factor	Count of Hours Across all 16 CZs
3:00 p.m.	$40.26	0.0000	35
4:00 p.m.	$41.16	0.0000	54
5:00 p.m.	$51.75	0.0000	85
6:00 p.m.	$52.76	0.0088	178
7:00 p.m.	$22.71	0.0696	299
8:00 p.m.	$19.99	0.1223	436
9:00 p.m.	$16.19	0.0569	321

a. Each hour represents the entire hour preceding the listed hour. For example, 3:00 p.m. represents 2:00 to 3:00 p.m.

To account for the difference in open and close hours of different prototype buildings, the Statewide CASE Team took the information from Table 20 and distributed the results based on start and close times which could then be directly attributed to the energy savings of each prototype based on their specific operating hours. These distributions can be seen in Table 21, Table 22, and Table 23.

Table 21: Top One Percent (88 Hours) Climate Zone Average Count of Hours

	Hour Ending[a]	Window Start						
		3:00 p.m.	4:00 p.m.	5:00 p.m.	6:00 p.m.	7:00 p.m.	8:00 p.m.	9:00 p.m.
Window End	**3:00 p.m.**	2.2						
	4:00 p.m.	5.6	3.4					
	5:00 p.m.	10.9	8.7	5.3				
	6:00 p.m.	22.0	19.8	16.4	11.1			
	7:00 p.m.	40.7	38.5	35.1	29.8	18.7		
	8:00 p.m.	67.9	65.8	62.4	57.1	45.9	27.3	
	9:00 p.m.	88.0	85.8	82.4	77.1	66.0	47.3	20.1

a. Each hour represents the entire hour preceding the listed hour. For example, 3:00 p.m. represents 2:00 to 3:00 p.m.

Table 22: Top One Percent (88 Hours) Average TDV Energy Cost Values by Start and Close Times; TDV 2023 Present Value $ per kWh

	Hour Ending[a]	Window Start						
		3:00 p.m.	4:00 p.m.	5:00 p.m.	6:00 p.m.	7:00 p.m.	8:00 p.m.	9:00 p.m.
Window End	**3:00 p.m.**	$40.26						
	4:00 p.m.	$40.80	$41.16					
	5:00 p.m.	$46.15	$47.63	$51.75				
	6:00 p.m.	$49.49	$50.51	$52.43	$52.76			
	7:00 p.m.	$37.19	$37.02	$36.62	$33.92	$22.71		
	8:00 p.m.	$30.29	$29.96	$29.36	$27.27	$21.10	$19.99	
	9:00 p.m.	$27.08	$26.74	$26.15	$24.39	$19.61	$18.38	$16.19

a. Each hour represents the entire hour preceding the listed hour. For example, 3:00 p.m. represents 2:00 to 3:00 p.m.

Table 23: Top One Percent (88 Hours) Sum of Demand Factor Values by Start and Close Times

	Hour Ending[a]	Window Start						
		3:00 p.m.	4:00 p.m.	5:00 p.m.	6:00 p.m.	7:00 p.m.	8:00 p.m.	9:00 p.m.
Window End	**3:00 p.m.**	0.0000						
	4:00 p.m.	0.0000	0.0000					
	5:00 p.m.	0.0000	0.0000	0.0000				
	6:00 p.m.	0.0088	0.0088	0.0088	0.0088			
	7:00 p.m.	0.0784	0.0784	0.0784	0.0784	0.0696		
	8:00 p.m.	0.2006	0.2006	0.2006	0.2006	0.1919	0.1223	
	9:00 p.m.	0.2575	0.2575	0.2575	0.2575	0.2487	0.1791	0.0569

a. Each hour represents the entire hour preceding the listed hour. For example, 3:00 p.m. represents 2:00 to 3:00 p.m.

This information can be used to understand the TDV and demand factor implications based on a building prototype's open and closed hours within the proposed peak demand hours of 2 to 9 p.m. For example, the small office prototype open hours are 2 to 6 p.m. and closed hours are 6 to 9 p.m. The TDV for the open hours is $49.49/kWh over 22 hours per year with a demand factor of 0.0088, while the closed hours have a TDV factor of $19.61 over 66 hours per year with a demand factor of 0.2487. The breakdown for all the prototype buildings are shown in Table 24.

The DR reduction based on the 15 percent lighting reduction is used in conjunction with the TDV energy cost value, TDV hours, and demand factor to calculate the corresponding TDV savings and the peak demand reduction.

Table 24: TDV Energy Cost Value and Hours by Prototype and Open and Closed Hours

Prototype	Open Hours[a]	TDV Cost Value (2023 PV$/kWh)	TDV Hours	Demand Factor	Closed Hours[a]	TDV Cost Value (2023 PV$/kWh)	TDV Hours	Demand Factor
Office Small	2-6 PM	$49.49	22.0	0.0088	6-9 PM	$19.61	66.0	0.2487
Office Medium	2-6 PM	$49.49	22.0	0.0088	6-9 PM	$19.61	66.0	0.2487
Office Large	2-6 PM	$49.49	22.0	0.0088	6-9 PM	$19.61	66.0	0.2487
Stand-alone Retail	2-9 PM	$27.08	88.0	0.2575	N/A	N/A	N/A	N/A
Strip Mall	2-9 PM	$27.08	88.0	0.2575	N/A	N/A	N/A	N/A
Retail Large	2-9 PM	$27.08	88.0	0.2575	N/A	N/A	N/A	N/A
Retail Mixed Use	2-9 PM	$27.08	88.0	0.2575	N/A	N/A	N/A	N/A
Primary School	2-4 PM	$40.80	5.6	0.0000	4-9 PM	$26.15	82.4	0.2575
Secondary School	2-4 PM	$40.80	5.6	0.0000	4-9 PM	$26.15	82.4	0.2575
Warehouse (Non-Refrigerated)	2-6 PM	$49.49	22.0	0.0088	6-9 PM	$19.61	66.0	0.2487
Quick Service Restaurant	2-9 PM	$27.08	88.0	0.2575	N/A	N/A	N/A	N/A
Small Hotel	2-9 PM	$27.08	88.0	0.2575	N/A	N/A	N/A	N/A

a. If a facility closes or operates after 9 p.m., the close time was set to 9 p.m. since that is the end of the evaluation period.

2.3.2.2 Statewide Energy Savings Methodology

The per-unit energy impacts were extrapolated to statewide impacts using the Statewide Construction Forecasts that the Energy Commission provided (California Energy Commission 2020). The Statewide Construction Forecasts estimate new construction that will occur in 2023, the first year that the 2022 Title 24, Part 6 requirements are in effect. It also estimates the size of the total existing building stock in 2023 that the Statewide CASE Team used to approximate savings from building alterations. The construction forecast provides construction (new construction and existing building stock) by building type and climate zone. The building types used in the construction forecast, Building Type ID, are not identical to the prototypical ASHRAE 90.1 or CBECC-Com building types, so the Energy Commission provided guidance on which prototypical buildings to use for each Building Type ID when calculating statewide energy impacts. Table 25 presents the prototypical buildings and weighting factors that the Energy Commission requested the Statewide CASE Team use for each Building Type ID in the Statewide Construction Forecast.

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

Table 25: Nonresidential Building Types and Associated Prototype Weighting

Building Type ID from Statewide Construction Forecast	Building Prototype for Energy Modeling	Weighting Factors for Statewide Impacts Analysis
Small Office	Office Small	100%
Large Office	Office Medium	50%
Large Office	Office Large	50%
Restaurant	Quick Service Restaurant	100%
Retail	Stand-alone Retail	10%
Retail	Retail Large	75%
Retail	Strip Mall	5%
Retail	Retail Mixed Use	10%
Grocery Store	Grocery	100%
Non-Refrigerated Warehouse	Warehouse (Non-Refrigerated)	100%
Refrigerated Warehouse	RefrigWarehouse	N/A
Schools	Primary School	60%
Schools	Secondary School	40%
Colleges	Office Small	5%
Colleges	Office Medium	15%
Colleges	OfficeMediumLab	20%
Colleges	PublicAssembly	5%
Colleges	Secondary School	30%
Colleges	ApartmentHighRise	25%
Hospitals	Hospital	100%
Hotel/Motels	Small Hotel	100%

Building models for Grocery Stores, Refrigerated Warehouses, and Public Assemblies were not available for analysis and were excluded from a standalone analysis and the savings associated with these facilities was assumed to be on average with the rest of the building models.

The analysis conducted in this submeasure requires mapping space by space breakdown in order to apply the area category lighting power allowances compliance method and to incorporate occupancy and daylighting impacts to applicable space types. The Office Medium Lab prototype (designated as 20 percent of “Colleges” floorspace in Table 25) did not have space by space distribution available for mapping and was thus excluded from an individual analysis. The savings associated with this facility was assumed to be on average with the rest of the analyzed building models.

High-rise apartments and hotels/motel facilities are subject to nonresidential code compliance only in the nonresidential function areas, that is, not within the tenant or guest rooms. This results in limited application for this submeasure to these two building prototypes. As a result, the ApartmentHighRise building type was excluded from analysis while the hotel/motel building type ID represented by the Small Hotel building prototype identifies 37 percent of facility square footage can be considered common space and is therefore subject to nonresidential code compliance. This fraction of the overall square footage for small hotels was considered as it was specifically noted in the ASHRAE 90.1 building model description, even though the DEER space distribution differed from this value.

Spaces where health or life safety statue, ordinance, or regulation does not permit the lighting to be reduced are not required to install demand responsive controls, for this reason hospitals were not included in this analysis and are assumed to have zero energy savings from this submeasure.

2.3.3 Per-Square Foot Energy Impacts Results

2.3.3.1 Per-Square Foot Energy Impact Results: Demand Responsive Lighting

Energy savings and peak demand reductions per unit are presented in Table 26. The per-square foot energy savings figures do not account for naturally occurring market adoption or compliance rates. The savings per year are limited due to low hourly participation per year. As discussed in the key assumptions for energy savings section, only the top one percent, or 88 hours, of TDV are used for evaluating the per-unit energy saving impacts. For buildings that must comply with the demand responsive lighting requirements, the energy savings are the same for both new construction and alterations. No per-unit savings for natural gas are expected from this measure.

Table 26: First-Year Energy Impacts Per Square Foot

Prototype Building	Electricity Savings (Wh/yr/ft²)	Peak Electricity Demand Reductions (W/ft²)	Natural Gas Savings (therms/ yr/ft²)	TDV Energy Savings (TDV kBtu/yr/ft²)
Small Office	3.0	0.004	N/A	0.9334
Medium Office	2.6	0.003	N/A	0.9259
Large Office	3.0	0.003	N/A	1.1244
Strip Mall	9.9	0.029	N/A	3.0152
Stand-alone Retail	7.0	0.021	N/A	2.1426
Retail Large	4.5	0.013	N/A	1.3549
Mixed Use Retail	7.5	0.022	N/A	2.2730
Primary School	4.6	0.010	N/A	1.3943
Secondary School	4.9	0.011	N/A	1.4857
Warehouse (non-refrigerated)	1.7	0.001	N/A	0.7306
Quick Service Restaurant	5.7	0.017	N/A	1.7403
Small Hotel	3.0	0.009	N/A	0.9004

2.3.3.2 Per-Square Foot Energy Impact Results: Heat Pump Water Heater and Thermal Energy Storage and Communication Protocol Cleanup

The code change proposal would not modify the stringency of Title 24, Part 6, so there would be no savings on a per-unit basis. Section 2.3 of the Final CASE Report, which typically presents the methodology, assumptions, and results of the per-unit energy impacts, has been truncated for this measure. Although this measure does not result in electricity or gas savings, the measure would encourage increased adoption of building technologies with load shift and load management capabilities. As noted in the Introduction, Demand management and grid integration play an important role in achieving California's clean energy goals.

2.4 Cost and Cost Effectiveness

2.4.1 Energy Cost Savings Methodology

Energy cost savings were calculated by applying the TDV energy cost factors, as detailed in Section 2.3.2.1, to the energy savings estimates that were derived using the methodology described in Section 2.3.2. TDV is a normalized metric to calculate energy cost savings that accounts for the variable cost of electricity and natural gas for each hour of the year, along with how costs are expected to change over the period of analysis (30 years for residential measures and nonresidential envelope measures and

15 years for all other nonresidential measures). In this case, the period of analysis used is 15 years. The TDV cost impacts are presented in 2023 present value dollars and represent the energy cost savings realized over 15 years. Please see Appendix H for TDV cost impacts presented in nominal dollars.

This submeasure applies to additions, alterations, and new construction. As detailed in Section 2.4.3, the equipment and labor costs for additions, alterations, and new construction can be treated as equal.

2.4.2 Energy Cost Savings Results

Per-unit energy cost savings for newly constructed buildings and alterations that are realized over the 15-year period of analysis are presented in 2023 present value dollars in Table 27.

The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. This is particularity valuable for demand management related measures that are only implemented during the peak electricity demand hours. As discussed in Section 2.3.1.2, energy cost savings do not vary by climate zone, so all information listed for a prototype building accounts for all climate zones.

Table 27: 2023 PV TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot – New Construction & Alterations

Prototype Building	15-Year TDV Electricity Cost Savings (2023 PV$)	15-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 15-Year TDV Energy Cost Savings (2023 PV$)
Small Office	$0.083	N/A	$0.083
Medium Office	$0.083	N/A	$0.083
Large Office	$0.100	N/A	$0.100
Strip Mall	$0.269	N/A	$0.269
Stand-alone Retail	$0.191	N/A	$0.191
Retail Large	$0.121	N/A	$0.121
Mixed Use Retail	$0.203	N/A	$0.203
Primary School	$0.124	N/A	$0.124
Secondary School	$0.133	N/A	$0.133
Warehouse (non-refrigerated)	$0.065	N/A	$0.065
Quick Service Restaurant	$0.155	N/A	$0.155
Small Hotel	$0.080	N/A	$0.080

2.4.3 Incremental First Cost

Incremental first cost is the initial cost to adopt more efficient equipment or building practices when compared to the cost of an equivalent baseline project. Therefore, it was important that the Statewide CASE Team consider first costs in evaluating overall measure cost effectiveness. Incremental first costs are based on data available today and can change over time as markets evolve and professionals become familiar with new technology and building practices.

The Standard Design for this analysis is a minimally code compliant building without demand responsive lighting. The Proposed Design is the Standard Design plus the implementation of demand responsive lighting. With these design profiles, the incremental first cost is the equipment and labor necessary to allow a facility to automatically reduce lighting power in response to a DR signal in a manner that reduces the area-weighted lighting power by 15 percent. This does not include the direct connection to a utility, aggregator, or DR provided VTN which provides the DR event signals to the local VEN, or the time required to enroll in a DR program. Connection from a VEN to a VTN is a straightforward process that is primarily comprised of connecting the VEN to the VTN end point URL and verifying the authenticity of this connection through either a username and password combination or a VEN identifier number that is generated when first trying to establish the VEN to VTN connection. However, this connection is not required to comply with the demand responsive lighting requirements. To comply with the requirement two things are needed: 1) a manner to receive an OpenADR signal, and 2) in response to that signal, a scene must be enacted, or actions taken that results in the appropriate reduction in lighting power. This is only applicable for spaces that have an LPD greater than 0.5 watts per square foot and do not have a health or life safety statute, ordinance, or regulation in place that does not permit the reduction in lighting power. There are many pathways to achieve these two requirements and the Statewide CASE Team considered two straightforward approaches to establish the incremental first cost.

These pathways assume a baseline connected lighting control system that would only require the addition of the specified OpenADR and communication components outlined in the specific pathways to allow for demand responsive lighting. Some stakeholders noted that demand responsive lighting projects may have all components quoted at a higher cost or include a complexity surcharge in the project quote due to the perceived complicated nature of demand responsive projects. As demand responsive projects become more prevalent, potentially as a result of Title 24, Part 6 requirements, more contractors, manufacturers, lighting representatives, building owners, lighting designers, and other stakeholders involved in lighting DR would be more familiar with the requirements and process of such projects. This should reduce the market inefficiencies that were highlighted as a complexity surcharge for some real-world projects. This expected uptake would also continue to reduce labor hours to design and install demand responsive projects. Additionally, it may take a minimal amount of time for a lighting designer to prescribe the lighting output levels to comply with a demand responsive lighting project with a simple operating condition, reduce lighting output by a minimum of 15 percent, that may be quickly commissioned for systems that operate with an intuitive lighting scheduler. However, this may take more time for a more complicated DR implementation strategy on a less intuitive lighting controller. For this analysis, the incremental measure cost and designated pathways are implementing the straightforward DR measure of reducing lighting output by 15 percent. It is worth noting that more complex DR measures, such as deeper lighting output reductions over longer durations to allow building occupants eyes to adjust to the new lighting levels or reducing lighting output in different spaces by different amounts, may result in a higher savings rate and less disruption to those occupying the spaces affected by the demand responsive measure.

2.4.3.1 Pathway 1) Network Lighting Controls (NLC) with Native OpenADR VEN

Many NLC systems have native OpenADR VEN hardware or software and these VENs can be included with the NLC system at no or minimal cost. In 2019 the California Lighting Technology Center (CLTC) reached out to manufacturer representatives Cal Lighting (representative for Enlighted, Inc.) and Associated Lighting Representatives (ALR - representative for Lutron electronics, Inc.), and received a product purchase quote from an Acuity Brands. Inc. distributor, relating to the implementation of OpenADR for this respective NLC systems. Cal Lighting and ALR confirmed that their systems include the OpenADR communication protocol at no additional cost, while Acuity Brands, Inc. requires the purchase of a hardware add-on, the nADR, that connects with the NLC system. The nADR hardware add-on can be purchased for $350. A conservative assumption is that an installer would be purchasing this product and including a 15 percent markup to their purchase price.

The Acuity Brands, Inc. nADR module only requires power and ethernet connection to become operational. Once connected, programming an action or scene to reduce the lighting power by 15 percent is straightforward for those familiar with the NLC system. The labor associated with such an installation and DR scene commissioning is expected to be billed at the minimum hourly charge, for this evaluation, that is a single hour.

An acceptance test is required to verify the operation of demand responsive lighting requirement. The Statewide CASE Team conducted a survey of acceptance test technician's trough two lighting specific acceptance test technician organizations: The California Advanced Lighting Controls Training Program (CALCTP) and the National Lighting Contractors Association of America (NLCAA). This survey included a question asking about the expected duration of a demand responsive lighting acceptance test for a 10,000 square foot office and additional amount of time required to conduct the acceptance test of an office double the size. Of the recipients of the survey, 115 indicted that they had completed a demand responsive lighting acceptance test, of those 115, approximately 100 responded to the expected acceptance test duration for the DR lighting acceptance test. The weighted average of their responses resulted in an expected test duration for a 10,000 square foot office at 2.63 hours and a 57 percent increase in time when doubling the size of the office. The two acceptance test proposals within this CASE Report – removing the 50 percent illuminance requirement and introducing a third, full building test for facilities with their lighting load disaggregated – would reduce the duration of the acceptance test. The Statewide CASE Team estimates that removing the 50 percent illuminance threshold would reduce testing time by 10 percent and that buildings with disaggregated circuits by end-use (required for nonresidential, high-rise residential, and hotel/motel buildings with electrical services rated more than 50 kVA in 2019 Title 24, Part 6 – 2019) would take advantage of this new option to expedite testing, resulting in an additional reduction of 50 percent of time at each test and results in only a 15 percent increase in time per additional 10,000 square feet.

An example of the first costs associated with this pathway are detailed in Table 28. As the total design wattage and size of a facility changes the equipment, labor, and acceptance test time would scale as well.

Table 28: Incremental First Cost – Pathway 1) NLC Native VEN

Hardware	**Hardware Cost**	**Labor Hours**	**Labor Rate[b]**	**Total:**
Acuity Brands, Inc. nADR	$350	1	$116.02	**$466.02**
15% Markup	$52.50	N/A	N/A	**$52.5**
Sales Tax[a]	$30.19	N/A	N/A	**$30.19**
Acceptance Test[c]	N/A	2.36	$116.02	**$274.34**
Total:	**$432.69**	**3.36**		**$823.05**

a. California state, county, and local sales and use tax rate is 7.5 percent. Cities and counties with additional sales tax rates will have a higher tax rate.

b. The $116.02 labor rate is the weighted price per hour of an electrician in California. This was derived from the national RSMeans price and was scaled according to representative cities of the 16 climate zones and the amount of impacted new construction and retrofit buildings in California.

c. The labor hours listed here serve as an example of a 10,000 square foot facility that does not have disaggregated loads by end-use.

Each Acuity Brands, Inc. nADR VEN can connect with up to five nLight Eclypse controllers and each nLight Eclpyse controller can support up to 750 nLight, nLight AIR, or XPoint wireless devices. The Statewide CASE Team can assume that each controlled end node would correspond to a single fixture that represents the typical wattage of an LED troffer, 32 watts, allowing the Statewide CASE Team to extrapolate the cost of such a system to any size facility. This scaling represents a conservative pricing for an NLC system as other systems, such as Enlighed, Inc. and Lutron

Electronics, Inc., include the VEN at no additional price while the Acuity Brands, Inc. system requires the purchase of a native OpenADR add-on.

While a system with a native OpenADR add-on represents the most straightforward compliance pathway, this assumes that an NLC system is already installed in order to meet the other indoor lighting control requirements, as detailed in Section 130.1 of Title 24, Part 6. This may not always be the case.

2.4.3.2 Pathway 2) Piecemeal Control System with Non-Native OpenADR VEN

A lighting system can also meet the Title 24, Part 6 indoor lighting requirements of Section 130.1 with a piecemeal system. Installing dimmers and standalone occupancy and photosensors that are not part of a single networked system. With such a system, a non-native or standalone OpenADR VEN is required. Numerous standalone VENs exist and are documented on the OpenADR QPL. This QPL includes but is not limited to Universal Devices ISY994i ZW+, IC Systems Inc. GRIDlink, IPKeys EISSBox, and THG Energy Solutions ACT. In 2019, CLTC reached out to Universal Devices to receive pricing for an ISY994i ZW+ VEN, to an installer, the cost would be $179.00. The Universal Devices ISY994iZW+ comes with native Z-Wave+ communication and adding a PowerLinc Modem (PLM) would allow for communication with Insteon and X10 protocols. The PLM can be purchased separately for $79.98. Both devices can be found from online retailers such as smarthome.com. This hardware configuration would provide a building with an OpenADR VEN and allow for internal communication among lighting controllers within the building through Z-Wave+, Insteon, or X10 that would enable an appropriate lighting power reduction. The Universal Devices product was selected for analysis as it is a commonly used ADR product, it is readily available for purchase from multiple retailers, and has installation and commissioning support. This system would represent pathway 2 through it is not a strict endorsement of one manufacturer over another, as Title 24, Part 6 remains manufacturer agnostic.

According to the CLTC who, as an organization that has conducted trainings on the installation of such devices, connecting the ISY994 ZW+ and PLM to the local network, enabling connection and commissioning the dimming load shed in response to a DR signal would be billed for two hours from an electrician. An example of the first costs associated with this pathway are detailed in Table 29, as the total design wattage and size of a facility changes the equipment, labor, and acceptance test time would scale as well.

Table 29: Incremental First Cost – Pathway 2) Piecemeal Control System with Non-Native VEN

Hardware	Hardware Cost	Labor Hours	Labor Rate[b]	Total:
Universal Devices ISY994i ZW+	$179.00	2	$116.02	$411.04
PLM	$79.98	N/A	N/A	$79.89
15% Markup	$38.85	N/A	N/A	$38.85
Sales Tax[a]	$22.34	N/A	N/A	$22.34
Acceptance Test[c]	N/A	2.36	$116.02	$274.34
Total:	**$320.16**	**4.36**	**N/A**	**$826.46**

a. California state, county, and local sales and use tax rate is 7.5 percent. Cities and counties with additional sales tax rates will have a higher tax rate.

b. The $116.02 labor rate is the weighted price per hour of an electrician in California. This was derived from the national RSMeans price and was scaled according to representative cities of the 16 climate zones and the amount of impacted new construction and retrofit buildings in California.

c. The labor hours listed here serve as an example of a 10,000 square foot facility that does not have disaggregated loads by end-use.

Each ISY994i ZW+ VENs can control up to 254 end nodes. Conservatively assuming that each end node represents a single fixture (as some dimming controllers may control multiple fixtures) that represents the typical wattage of an LED troffer, 32 watts, the Statewide CASE Team can extrapolate the cost of such a system to facilities of any size.

As Pathway 2 represents the less restricted system, this pathway was selected to analyze the cost effectiveness of this measure. Although it is worth noting that both systems represent a similar incremental first cost as represented by the results of Table 28 and Table 29.

2.4.4 Incremental Maintenance and Replacement Costs

Incremental maintenance cost is the incremental cost of replacing the equipment or parts of the equipment, as well as periodic maintenance required to keep the equipment operating relative to current practices over the 15-year period of analysis. The present value of equipment maintenance costs (savings) was calculated using a three percent discount rate (d), which is consistent with the discount rate used when developing the 2022 TDV. The present value of maintenance costs that occurs in the n^{th} year is calculated as follows:

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

During the DR Program, Pilots, and Budgets for Program Years 2018-2022 review with the California Public Utility Commission (CPUC), two of the IOUs provided quantitative recommendations for the effective useful life (EUL) of automated demand management hardware. Pacific Gas and Electric (PG&E) proposed an EUL of 7.5 years based on the equipment amortization in PG&E's DR Cost-Effectiveness calculation for their ADR Program (PG&E 2018). Southern California Edison (SCE) proposed 10 years for non-smart thermostat technologies, based on their cost-effectiveness analysis (SCE 2018). To be conservative, an EUL of 7.5 was considered. This means that every 7.5 years the VEN and controlling equipment should be replaced. Over the 15-year period of analysis it can be expected that a new VEN would need to be purchased and connected to the relevant utility virtual top node (VTN) one time. It is not expected that any additional replacement costs would be incurred or that any maintenance cost would be required to maintain operation.

2.4.5 Cost Effectiveness

This measure proposes a mandatory requirement. As such, a cost analysis is required to demonstrate that the measure is cost effective over the 15-year period of analysis. This analysis provides the cost-effective exemption threshold for demand responsive lighting that would replace the existing 10,000 square foot threshold.

The Energy Commission establishes the procedures for calculating cost effectiveness. The Statewide CASE Team collaborated with Energy Commission staff to confirm that the methodology in this report is consistent with their guidelines, including which costs were included in the analysis. The incremental first, maintenance, and replacement costs over the 15-year period of analysis were included. The TDV energy cost savings from electricity savings were also included in the evaluation.

Design costs were not included nor were the incremental costs of code compliance verification.

According to the Energy Commission's definitions, a measure is cost effective if the benefit-to-cost (B/C) ratio is greater than 1.0. The B/C ratio is calculated by dividing the cost benefits realized over 15 years by the total incremental costs, which includes maintenance and replacement costs for 15 years. The B/C ratio was calculated using 2023 PV costs and cost savings.

Results of the per-unit cost-effectiveness analyses are presented in Table 30 for new construction and alterations.

Table 30: 15-Year Cost-Effectiveness Summary Per Square Foot – New Construction and Alterations

Measure	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
Small Office	$0.083	$0.269	0.31
Medium Office	$0.083	$0.054	1.52
Large Office	$0.100	$0.048	2.10
Strip Mall	$0.269	$0.157	1.72
Stand-alone Retail	$0.191	$0.119	1.61
Retail Large	$0.121	$0.083	1.46
Mixed Use Retail	$0.203	$0.195	1.04
Primary School	$0.124	$0.069	1.79
Secondary School	$0.133	$0.057	2.32
Warehouse (non-refrigerated)	$0.065	$0.294	0.22
Quick Service Restaurant	$0.155	$0.502	0.31
Small Hotel	$0.080	$0.193	0.42

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (California Energy Commission 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. PV maintenance cost savings are included 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.

The results of the B/C ratio show that larger facilities, such as the large office, primary and secondary schools have a high B/C ratio. Facilities that have less controlled wattage have a lower B/C ratio, such as the small office, non-refrigerated warehouse, quick service restaurant, and small hotels. These results show that demand responsive lighting is not cost effective for all building prototypes but there is a threshold that would result in cost-effective implementation. The Statewide CASE Team can discover this threshold by looking closer at the relationship between the B/C ratio and design wattage. When the B/C ratio equals one, that is the cost-effective delineation.

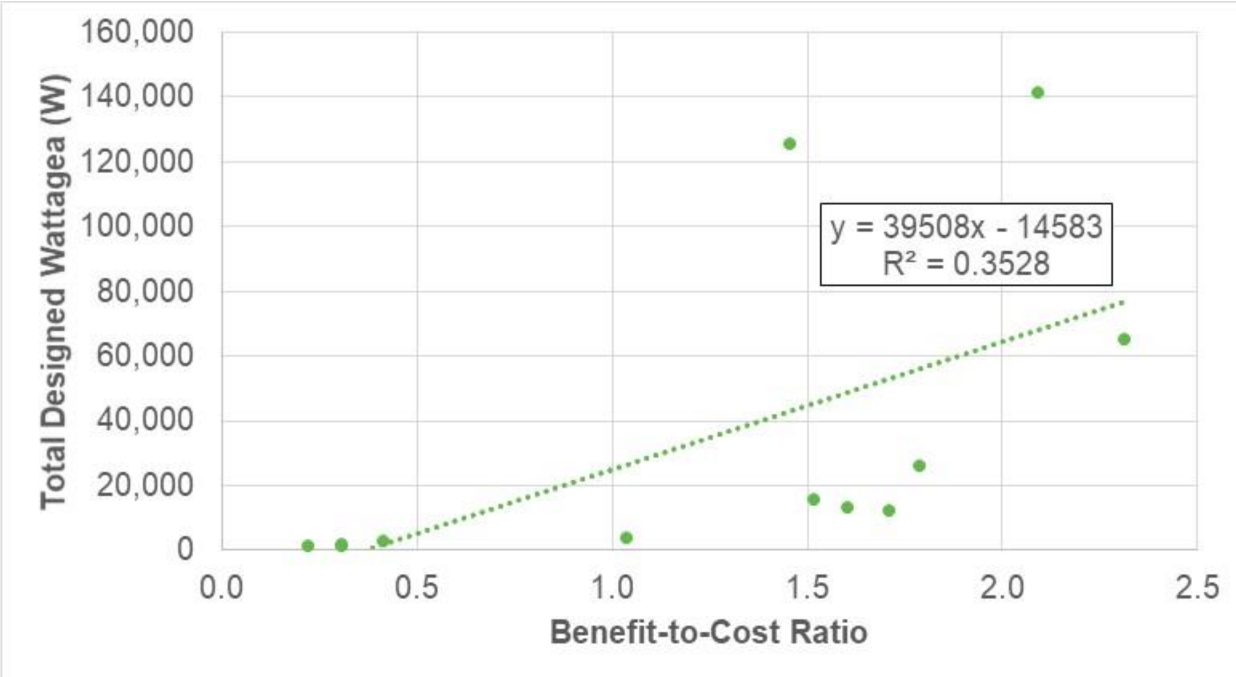
Table 31: Design Wattage and Weighted 15-Year Benefit-to-Cost Ratio

Prototype Building	Design Wattage[a]	Square Footage[a]	New Construction and Alteration Benefit-to-Cost Ratio[b]
Small Office	1,822	4,392	0.31
Medium Office	15,547	42,574	1.52
Large Office	141,408	393,872	2.09
Strip Mall	11,892	14,682	1.71
Stand-alone Retail	13,055	19,920	1.60
Retail Large	125,210	203,726	1.46
Mixed Use Retail	3,901	6,118	1.04
Primary School	26,168	62,312	1.79
Secondary School	64,901	150,889	2.31
Warehouse (non-refrigerated)	1,162	3,852	0.22
Quick Service Restaurant	1,230	2,256	0.31
Small Hotel	2,516	5,832	0.42

a. Design wattage excludes wattage that is not subject to demand responsive lighting requirements. This includes areas where safety ordinances do not permit the dimming of lighting, residential spaces, and spaces where the LPD is less than 0.5.

b. The benefit-to-cost ratios of new construction and alterations are weighted by the impacted square footage.

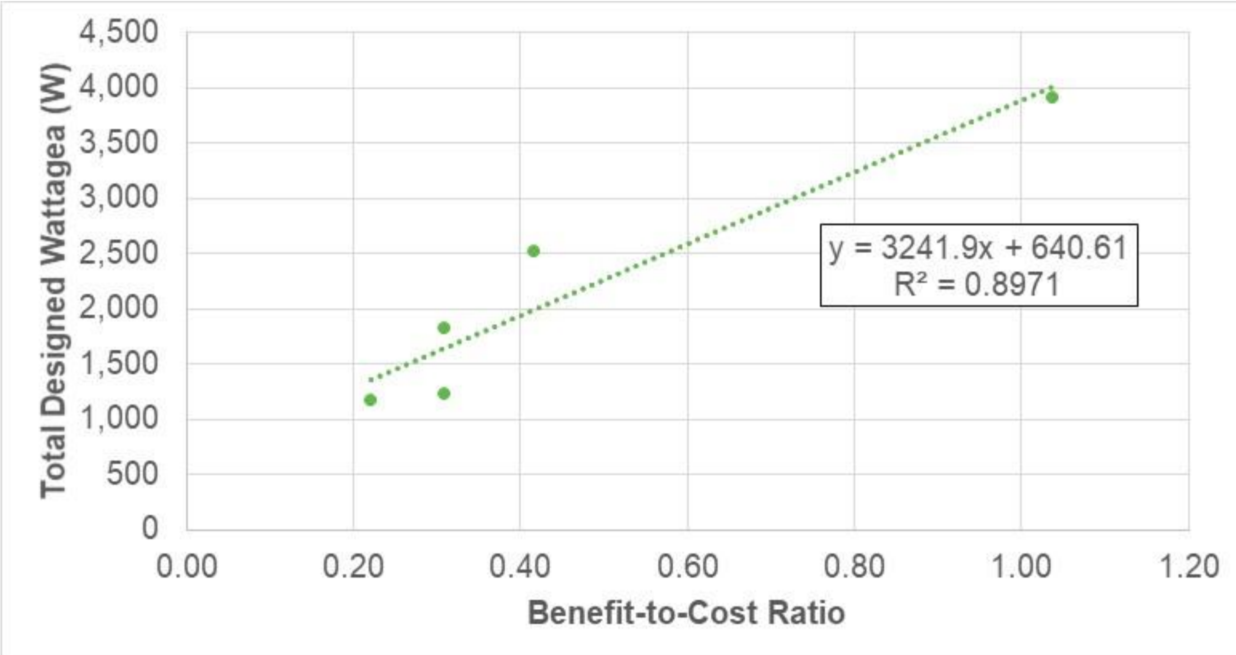
Graphing this relationship for all building models provides the relationship in Figure 4. While this figure shows a general relationship between higher design wattage and higher B/C ratio, the relationship is poor.



a. For spaces with installed LPD greater than 0.5 watts per square foot

Figure 4: Design wattage and weighted benefit-to-cost ratio. All building models.

Focusing on the five building models with a B/C ratio below or just above one – small office, mixed use retail, warehouse (non-refrigerated), quick service restaurant, and small hotel – allows a more focused analysis on the discovery of a threshold that would allow these building prototypes to see cost-effective implementation. When viewing only those building models a statistically significant relationship can be seen, as in Figure 5.

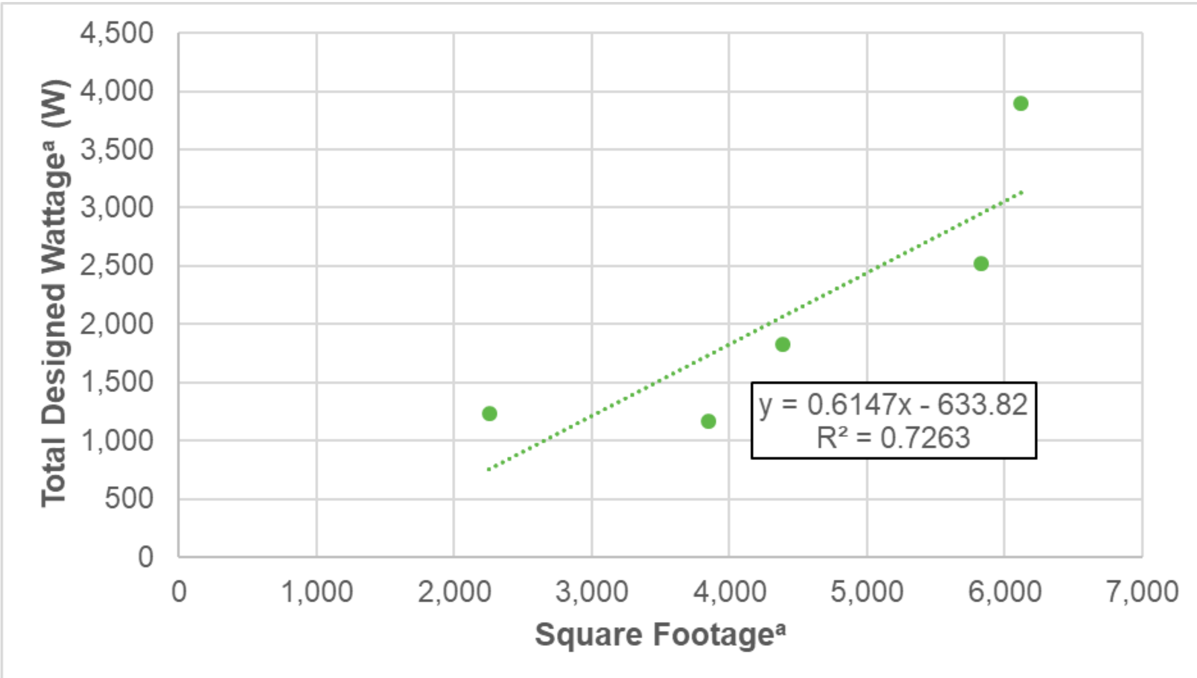


a. For spaces with installed LPD greater than 0.5 watts per square foot

Figure 5: Design wattage and weighted benefit-to-cost ratio. Building models with a benefit-to-cost below are just above one.

Following the linear relationship established from this analysis (the equation of which is shown in Figure 5) and setting the B/C ratio at one, the cost-effective threshold is calculated as 3,883 watts. This can be rounded up to 4,000 watts to be conservative and aid with Title 24, Part 6 compliance. The conservative threshold of 4,000 watts has a B/C ratio of 1.036.

We can compare this threshold to the existing threshold of 10,000 square feet by looking at the relationship of design wattage and square footage for the five facilities reviewed in Figure 5. Figure 6 shows this relationship. As with Figure 4 and Figure 5, the values in Figure 6 exclude spaces with installed LPD less than or equal to 0.5 watts per square foot.



a. For spaces with installed LPD greater than 0.5 watts per square foot

Figure 6: Design wattage and square footage. Building models with a benefit-to-cost ratio less than one.

Inputting 4,000 watts into the linear trendline relationship shown in Figure 6 calculates an equivalent square footage of 7,538.

2.5 First-Year Statewide Impacts

2.5.1 Statewide Energy and Energy Cost Savings

The Statewide CASE Team calculated the first-year statewide savings for new construction by multiplying the per-unit savings, which are presented in Section 2.3, by assumptions about the percentage of newly constructed buildings that would be impacted by the proposed code. The statewide new construction forecast for 2023 is presented in Appendix A as are the Statewide CASE Team's assumptions about the percentage of new construction that would be impacted by the proposal (by climate zone and building type).

While all new construction facilities would need to comply with the new demand responsive lighting requirement, additions and alterations have additional exceptions based on their installations. There are two situations that would result in exemptions for alterations from complying with the demand responsive requirement:

- Section 141.0(b)2Iii: Alterations that do not exceed 80 percent of their indoor lighting power allowance.

- Section 141.0(b)2Iiii: Alterations that are a one-for-one luminaire replacement within a building or tenant space of 5,000 square feet or less and the total wattage of the altered luminaires is at least 40 percent lower compared to their total pre-alteration wattage.

The survey conducted of lighting stakeholders described in Section 2.3.2.1 provides the Statewide CASE Team with information on the fraction of facilities that have installed wattage under their lighting power allowance and to what extent. If the Statewide CASE Team considers a linear distribution within each bucket of the survey, an extrapolation can be made from that information to see that 28 percent of installations were below 80 percent of their indoor lighting power allowance. That fraction of facilities would not be subject to the demand responsive lighting requirement. Additionally, alterations less than 5,000 square feet are not expected to be impacted by this measure, as determined by the cost-effectiveness threshold of Section 2.4.5 and the equivalent facility square footage.

The 28 percent of alterations that are expected to be excluded from this requirement based on these compliance pathways are not included in the statewide savings analysis while the remaining facilities that must comply with the demand responsive lighting language are calculated using the same methodology as new construction facilities.

The first-year energy impacts represent the first-year annual savings from all buildings that were completed in 2023. The 15-year energy cost savings represent the energy cost savings over the entire 15-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

Table 32 presents first-year statewide savings from new construction, additions, and alterations compared to the 10,000 square foot delineation of 2019 Title 24, Part 6. This table represent 100 percent participation rates from facilities that are subject to the demand responsive lighting requirement. In the 2013 demand responsive lighting CASE Report a lower participation rate was used which included a discount for facilities that opt-out of the time-of-use rate, technical difficulties with signal receipts, and a facilities decision to opt-out of an event (Statewide CASE Team 2013). This analysis excludes these discounts as nonresidential customers will be required to transition to time-of-use rates by 2021, the utility operated VTN has continued to improve, and issues with event signal receipt by a facility is not expected to be an ongoing issue, and for time-of-use rates, opting out of an event will result in surcharges during DR events, disincentivizing facilities from opting out of these events.

Table 32: Statewide Energy and Energy Cost Impacts – New Construction, Alterations, and Additions Over 2019 Title 24, Part 6, 10,000 Square Foot Threshold

Construction Type	Statewide Floor Space Impacted by Proposed Change in 2023 (million square feet)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (MMtherms)	15-Year Present Valued Energy Cost Savings (PV$ million in 2023)
New Construction	5.30	0.02	0.05	0.00	$0.93
Additions and Alterations	105.39	0.50	1.20	0.00	$19.47
TOTAL	**110.69**	**0.53**	**1.25**	**0.00**	**$20.40**

a. First-year savings from all buildings completed statewide in 2023.

2.5.2 Statewide Greenhouse Gas (GHG) Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions assuming the emissions factors specified in the United States Environmental Protection Agency (U.S. EPA) Emissions & Generation Resource Integrated Database (eGRID) for the Western Electricity Coordination Council California (WECC CAMX) subregion. Avoided GHG emissions from natural gas savings attributable to sources other than utility-scale electrical power generation are calculated using emissions factors specified in U.S. EPA's Compilation of Air Pollutant Emissions Factors (AP-42). See Appendix C for additional details on the methodology used to calculate GHG emissions. In short, this analysis assumes an average electricity emission factor of 240.4 metric tons CO2e per GWh based on the average emission factors for the CACX EGRID subregion.

Table 33 presents the estimated first year avoided GHG emissions of the proposed code change compared to the 10,000 square foot delineation of 2019 Title 24, Part 6. During the first year, GHG emissions of 126.86 metric tons of carbon dioxide equivalents (metric tons CO2e) would be avoided compared to no demand responsive lighting implementation.

Table 33: First-Year Statewide GHG Emissions Impacts Over 2019 Title 24, Part 6, 10,000 Square Foot Threshold

Measure	Electricity Savings[a] (GWh/yr)	Reduced GHG Emissions from Electricity Savings[a] (Metric Tons CO2e)	Natural Gas Savings[a] (MMtherms/yr)	Reduced GHG Emissions from Natural Gas Savings[a] (Metric Tons CO2e)	Total Reduced CO_2e Emissions[a,b] (Metric Tons CO2e)
Demand Responsive Lighting	0.528	126.86	0	0	126.86

a. First-year savings from all buildings completed statewide in 2023.

b. Assumes the following emission factors: 240.4 MTCO2e/GWh and 5454.4 MTCO2e/MMtherms.

2.5.3 Statewide Water Use Impacts

The proposed code change would not result in water savings.

2.5.4 Statewide Material Impacts

To implement demand responsive lighting controls, additional hardware may be required. Thus, slightly more plastic, copper, lead, steel, and other heavy metals in the hardware and associated printed circuit boards would be needed. The benefits of this measure are a reduction in the number of powerplants needed and a reduction in the size of the transmission and distribution systems. This reduces the amount of land and resources that must be dedicated to a larger electricity infrastructure.

The emissions impacts of this submeasure are calculated by multiplying the change in statewide electricity consumption by the hourly emission factors. In many scenarios, there would be no additional materials required to comply with the requirement for DR capabilities, since the technology enabling DR may already been installed as it was built into the standard lighting control offering. However, in other situations, the addition of a stand-alone DR module and PLM would be required. The Statewide CASE Team is using a worst-case scenario and assuming that every building would need to install a 1.2-pound ADR module (the approximate weight of the Universal Devices ISY994i ZW+) and a 0.4-pound PLM. The values for mercury and lead were calculated using the maximum allowed percentages, by weight, under the European RoHS requirements, which were incorporated into California state law effective January 1, 2010. The California Lighting Efficiency and Toxics Reduction Act applies RoHS to general purpose lights, i.e., “lamps, bulbs, tubes, or other electric devices that provide functional illumination for indoor residential, indoor commercial, and outdoor use.” RoHS allows a maximum of 0.1 percent by total product weight for both mercury and lead. In practice the actual percentage of mercury and lead in these components may be much less than these values, so the values in the table are conservative overestimates. The increased use of silicon and gold for circuitry in the module is estimated in the table below, at approximately 1.6oz of silicon, and 0.16 grams of gold for gold plated pins. The casing is comprised mostly of plastic with steel screws, thus estimates of 9.6oz of steel and eight ounces of plastic. Table 34 shows the expected incremental material use compared to the existing 10,000 square foot threshold.

Table 34: First-Year Statewide Impacts on Material Use Over 2019 Title 24, Part 6, 10,000 Square Foot Threshold

Material	Impact (I, D, or NC)[a]	Impact on Material Use (pounds/year)	
		Per-Square Foot Impacts	First-Year[b] Statewide Impacts
Mercury	I	0.00000003	91
Lead	I	0.00000003	91
Copper	I	0.00000829	22,801
Steel	I	0.00001244	34,201
Plastic	I	0.00001037	28,501
Silicon	I	0.00000207	5,700
Gold	I	0.00000001	18

a. Material Increase (I), Decrease (D), or No Change (NC) compared to base case (lbs/yr).

b. First-year savings from all buildings completed statewide in 2023.

2.5.5 Other Non-Energy Impacts

2.5.5.1 Other Non-Energy Impacts: Demand Responsive Lighting Systems

Non-energy impacts for DR enabling equipment represents a big opportunity for additional savings and improved building comfort. Lighting technologies that allow for effective demand responsive lighting participation, such as luminaire level lighting control, occupancy sensors throughout a facility, and continuous dimmers on individual fixtures, also provide opportunities for immense savings through non-energy impacts. A 2019 California Energy Commission study entitled The Value Proposition for Cost-Effective, Demand Responsive-Enabling, Nonresidential Lighting System retrofits in California Buildings details qualitative and quantitative non-energy benefits for such technologies (Schwartz 2019).

The report develops a Benefit Value Intensity (BVI) model which captures the non-energy benefits at the energy, building, people, and revenue levels. Where higher BVI categories (such as people and revenue) can have a magnitude of savings several times higher than the direct energy savings of effective demand responsive operation. A 2018 ACEEE Summery Study report on the same topic identified potential savings in offices through decreased operational and maintenance costs and in increased building value of $0.26 per square foot and $5.61 per square foot respectively (Kelly Sanders 2018). These values represent a significant value increase compared to the direct energy savings of demand responsive lighting. Space optimization is another metric evaluated under the BVI model to show the significant savings potential from non-energy benefits. Space optimization is defined as using NLCs to provide insights into optimal usage of office space. "the organization leveraged NLC occupancy data to identify the opportunity of adding 1,000 new employees to the existing space, reducing per employee space from 12.6 to 7.6 square meters per person, while still maintaining an effective work environment" (Kelly Sanders 2018). The savings associated with the savings was 167 times the value of the direct energy savings of the demand responsive lighting technology.

The potential non-energy impacts of lighting technologies that enable effective DR is significant and should be strongly considered for consideration.

2.5.5.2 Other Non-Energy Impacts: Load Shifting Compliance Options for HPWH and Thermal Energy Storage

The code change proposal would not modify the stringency of Title 24, Part 6, so the savings associated with this proposed change are minimal. Typically, the Statewide CASE Team presents a detailed analysis of statewide energy and cost savings associated with the proposed change in Section 6 of the Final CASE Report. As discussed in Section 2.3, although the energy savings are limited, the measure would encourage increased adoption of building technologies with load shifting and load management capabilities. As noted in the Introduction, demand management and grid integration play an important role in achieving California's clean energy goals.

2.6 Proposed Revisions to Code Language

2.6.1 Guide to Markup Language

The proposed changes to the standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2019 documents are marked with red <u>underlining</u> (new language) and ~~strikethroughs~~ (deletions).

2.6.2 Standards

SECTION 110.12 – MANDATORY REQUIREMENTS FOR DEMAND MANAGEMENT

Buildings, other than healthcare facilities, shall comply with the applicable demand responsive control requirements of Sections 110.12(a) through 110.12(d)

(c) **Demand Responsive Lighting Controls**. <u>Nonresidential lighting systems subject to the requirements of Section 130.1(b) with a total design lighting power of 4,000 watts or</u>

greater, shall have controls that are ~~Lighting controls in nonresidential buildings larger than 10,000 square feet shall be~~ capable of automatically reducing lighting power in response to a Demand Response Signal. General lighting shall be reduced in a manner consistent with the uniform level of illumination requirements in TABLE 130.1-A.

1. For compliance testing, the lighting controls shall demonstrate a lighting power reduction in controlled spaces of a minimum of 15 percent below the total installed lighting. The controls may provide additional demand responsive functions or abilities.

~~**EXCEPTION 1 to 110.12(c):** Spaces with a lighting power density of 0.5 watts per square foot or less are not required to install demand responsive controls and do not count toward the 10,000 square foot threshold.~~

EXCEPTION ~~2~~ to 110.12(c): Spaces where a health or life safety statute, ordinance, or regulation does not permit the lighting to be reduced are not required to install demand responsive controls and do not count toward the ~~10,000 square foot~~ 4,000-watt threshold

SECTION 130.1 – MANDATORY INDOOR LIGHTING CONTROLS

[No proposed changes to this section, provided for reference only.]

(b) **Multi-Level Lighting Controls.** The general lighting of any enclosed area 100 square feet or larger with a connected lighting load that exceeds 0.5 watts per square foot shall provide multi-level lighting controls that allow the level of lighting to be adjusted up and down. The multi-level controls shall provide the number of control steps and meet the uniformity requirements specified in TABLE 130.1-A.

EXCEPTION 1 to Section 130.1(b): An area enclosed by ceiling height partitions that has only one luminaire with no more than two lamps.

EXCEPTION 2 to Section 130.1(b): Restrooms.

EXCEPTION 3 to Section 130.1(b): Healthcare facilities.

SECTION 140.6 – PRESCRIPTIVE REQUIREMENTS FOR INDOOR LIGHTING

(a) **Calculation of Adjusted Indoor Lighting Power**. The adjusted indoor Lighting Power of all proposed building areas is the total watts of all planned permanent and portable lighting systems in all areas of the proposed building; subject to the applicable adjustments under Subdivisions 1 through 4 of this subsection.

2.K. To qualify for the PAF for a Demand Responsive Control in TABLE 140.6-A, the general lighting wattage receiving the PAF shall not be within the scope of Section 110.12(c) and a Demand Responsive Control shall meet all the following requirements:

~~I. The building shall be 10,000 square feet or smaller; and~~

I. ~~II~~ The controlled lighting shall be capable of being automatically reduced in response to a demand response signal; and

II. ~~III.~~ General lighting ~~Lighting~~, shall be reduced in a manner consistent with uniform level of illumination requirements in TABLE 130.1-A; and

~~IV. Spaces that are non-habitable shall not be used to comply with this requirement, and spaces with a lighting power density of less than 0.5 watts per square foot shall not be counted toward the building's total lighting power.~~

TABLE 140.6-A LIGHTING POWER ADJUSTMENT FACTORS (PAF)

TYPE OF CONTROL	TYPE OF AREA		FACTOR
a. To qualify for any of the Power Adjustment Factors in this table, the installation shall comply with the applicable requirements in Section 140.6(a)2 b. Only one PAF may be used for each qualifying luminaire unless combined below. c. Lighting controls that are required for compliance with Part 6 shall not be eligible for a PAF			
1. Daylight Dimming plus OFF Control	Luminaires in skylit daylit zone or primary sidelit daylit zone		0.10
2. Occupant Sensing Controls in Large Open Plan Offices	In open plan offices > 250 square feet: One sensor controlling an area that is:	No larger than 125 square feet	0.40
		From 126 to 250 square feet	0.30
		From 251 to 500 square feet	0.20
3.Institutional Tuning	Luminaires in non-daylit areas. Luminaires that qualify for other PAFs in this table may also qualify for this tuning PAF.		0.10
	Luminaires in daylit areas. Luminaires that qualify for other PAFs in this table may also qualify for this tuning PAF.		0.05
4. Demand Responsive Control	~~All building types~~ General lighting luminaires not in the scope of Section 110.12(c). ~~of 10,000 square feet or smaller~~. Luminaires that qualify for other PAFs in this table may also qualify for this demand responsive control PAF		0.05
5. Clerestory Fenestration	Luminaires in daylit areas adjacent to the clerestory. Luminaires that qualify for daylight dimming plus OFF control may also qualify for this PAF.		0.05
6. Horizontal Slats	Luminaires in daylit areas adjacent to vertical fenestration with interior or exterior horizontal slats. Luminaires that qualify for daylight dimming plus OFF control may also qualify for this PAF.		0.05
7.Light Shelves	Luminaires in daylit areas adjacent to clerestory fenestration with interior or exterior light shelves. This PAF may be combined with the PAF for clerestory fenestration. Luminaires that qualify for daylight dimming plus OFF control may also qualify for this PAF		0.10

2.6.3 Reference Appendices

NA7.6.3 Demand Responsive Controls Acceptance Tests

NA7.6.3.1 Construction Inspection

Prior to Functional testing, verify and document the following:

a) That the demand responsive control is capable of receiving a demand response signal directly or indirectly through another device and that it complies with the requirements in Section ~~130.1(e)~~ 110.12.

b) If the demand response signal is received from another device (such as an EMCS), that system must itself be capable of receiving a demand response signal from a utility meter or other external source.

NA7.6.3.2 Functional testing

There are three methods to verify the reduction in lighting power due to the demand responsive lighting controls. For methods 1 and 2, buildings with up to seven (7) enclosed spaces requiring demand responsive lighting controls, all spaces shall be tested. For buildings with more than seven (7) enclosed spaces requiring demand responsive lighting controls, sampling may be done on additional spaces with similar lighting systems; sampling shall include a minimum of 1 enclosed space for each group of up to 7 additional enclosed spaces. If the first enclosed space with a demand responsive lighting control in the sample group passes the acceptance test, the remaining building spaces in the sample group also pass. If the first enclosed space with a demand responsive lighting control in the sample group fails the acceptance test the rest of the enclosed spaces in that group must be tested. If any tested demand responsive lighting control system fails it shall be repaired, replaced or adjusted until it passes the test. Method 3 tests the entire facility at once, does not require sampling, but requires the facility lighting to be disaggregated from other end-use loads.

Test the reduction in lighting power due to the demand responsive lighting control using one of the following three ~~two~~ methods.

Method 1: Illuminance Measurement. Measure the reduction in illuminance in enclosed spaces required to meet Section ~~130.1(b)~~ 110.12(c), as follows:

(a) In each space, select one location for illuminance measurement. The chosen location must not be in a skylit or primary sidelit area. When placed at the location, the illuminance meter must not have a direct view of a window or skylight. If this is not possible, perform the test at a time and location at which daylight illuminance provides less than half of the design illuminance. Mark each location to ensure that the illuminance meter can be accurately located.

(b) Full output test

1. Using the manual switches/dimmers in each space, set the lighting system to full output. Note that the lighting in areas with photocontrols or occupancy/vacancy sensors may be at less than full output, or may be off.
2. Take one illuminance measurement at each location, using an illuminance meter.
3. Simulate a demand response condition using the demand responsive control.
4. Take one illuminance measurement at each location with the electric lighting system in the demand response condition.
5. Calculate the area-weighted average reduction in illuminance in the demand response condition, compared with the full output condition. The area-weighted reduction must be at least 15%~~ but must not reduce the combined illuminance from electric light and daylight to less than 50% of the design illuminance in any individual space~~.

(c) Minimum output test

1. Determine illuminance at minimum output condition
    - i. ~~1.~~Using the manual switches/dimmers in each space, set the lighting system to minimum output (but not off). Note that the lighting in areas with photocontrols or occupancy/vacancy sensors may be at more than minimum output, or may be off.
    - ii. ~~2.~~Take one illuminance measurement at each location, using an illuminance meter.
2. Determine illuminance at demand response condition:
    - i. ~~3.~~Simulate a demand response condition using the demand responsive control.
    - ii. ~~4.~~Take one illuminance measurement at each location with the electric lighting system in the demand response condition.
3. Determine compliance: ~~5.~~In each space, the illuminance in the demand response condition must not be less than the illuminance when set to minimum output condition (but not turned off) ~~or 50% of the design illuminance, whichever is less~~.

    EXCEPTION: In daylit spaces, the illuminance in the demand response condition may reduce below the illuminance when set to minimum output condition~~, but in the demand response condition the combined illuminance from daylight and electric light must be at least 50% of the design illuminance~~.

Method 2: Current measurement. Measure the reduction in electrical current in spaces required to meet Section ~~130.1(b)~~ 110.12, as follows:

(a) At the lighting circuit panel, select at least one lighting circuit that serves spaces required to meet Section ~~130.1(e)~~ 110.12.

(b) Full output test

1. Using the manual switches/dimmers in each space, set the lighting system to full output. Note that the lighting in areas with photocontrols or occupancy/vacancy sensors may be at less than full output, or may be off.
2. Take one electric current measurement for each selected circuit.
3. Simulate a demand response condition using the demand responsive control.
4. Take one illuminance measurement at each location with the electric lighting system in the demand response condition.
5. Add together all the circuit currents, and calculate the reduction in current in the demand response condition, compared with the full output condition. The combined reduction must be at least 15%~~ but must not reduce the output of any individual circuit by more than 50%~~.

(c) Minimum output test

1. Using the manual switches/dimmers in each space, set the lighting system to minimum output (but not off). Note that the lighting in areas with photocontrols or occupancy/vacancy sensors may be at more than minimum output, or may be off.
2. Take one electric current measurement for each selected circuit.
3. Simulate a demand response condition using the demand responsive control.
4. Take one electric current measurement for each selected circuit with the electric lighting system in the demand response condition.
5. In each space, the electric current in the demand response condition must not be less than ~~50% or~~ the electric current in the minimum output condition~~, whichever is less~~.

   EXCEPTION: Circuits that supply power to the daylit portion of enclosed spaces as long as lighting in non-daylit portions of the enclosed space.

Method 3: Full facility current measurement. Measure the reduction in electrical current of the full facility on the lighting end-use disaggregated circuit for spaces that are required to meet Section 110.12, as follows:

(a) At the circuit panel, select the circuit that serves the lighting load of the entire facility.

(b) Full output test

1. Using the facility lighting controls, set the lighting system to full output. Note that the lighting in areas with photocontrols or occupancy/vacancy sensors may be at less than full output, or may be off.
2. Take one electric current measurement on the circuit. This is your pre-event (no DR response) current.

3. Simulate a demand response condition using the demand responsive control.
4. Take one electric current measurement on the circuit. This is your post-event current.
5. Calculate the difference between the pre-event current and the post-event current to determine your wattage reduction.
6. Divide the wattage reduction by the total design wattage for the lighting required to meet Section 110.12. The percent reduction in wattage must be at least 15%.

(c) Minimum output test

1. Using the facility controls, set the lighting system to minimum output (but not off). Note that the lighting in areas with photocontrols or occupancy/vacancy sensors may be at more than minimum output, or may be off.
2. Take one electric current measurement on the circuit. This is your pre-event current.
3. Simulate a demand response condition using the demand responsive control.
4. Take one electric current measurement on the circuit. This is your post-event current.
5. The post-event current must not be less than the pre-event current in the minimum output condition.

2.6.3 ACM Reference Manual

There are no proposed changes to the ACM Reference Manual.

2.6.4 Compliance Manual

Chapter 5.4.5. Demand Responsive Lighting Controls of the Nonresidential Compliance Manual would need to be revised. Quantitative changes to the exemption thresholds would need to be made to this section in replacing the 10,000 square foot threshold with the cost-effective 4,000 total design wattage of lighting.

These same quantitative thresholds need to be revised in **Section 5.6.2 Calculation of Adjusted Indoor Lighting Power** to account for when a power factor adjustment can be applied for demand responsive lighting.

Chapter 5.6.2. Calculation of Adjusted Indoor Lighting Power includes references to the 10,000 square foot exemption, the 0.5 watts per square foot exemption, and the term “non-habitable.” Both exemptions would be replaced with that proposed in this measure, 4,000 total design wattage for the 10,000 square feet and a reference to the watts per square foot exemption of the multi-level lighting requirements, while the term "non-habitable" would be removed.

Table D-1 Summary of DR Control Requirements for Newly Constructed Nonresidential Buildings in Appendix D – Demand Responsive Controls would be revised to replace the 10,000 square foot reference with 4,000 total design wattage of general lighting.

Lastly, **Section 4 DR Controls of Appendix D for Lighting Systems of Appendix D** would have the 10,000 square foot reference updated with the cost-effective 4,000 total design wattage of general lighting.

2.6.5 Compliance Documents

NRCC-LTI-E, the certificate of compliance for indoor lighting would require an update to reflect the revised threshold requirements and exceptions. Currently the form looks for building floorspace to determine if the demand responsive lighting controls are required. This would need to be updated so the design wattage determines the threshold.

NRCA-LTI-04-A, the certificate of acceptance for demand responsive lighting controls would require an update to include the proposed third method of acceptance testing, the full building method with circuit level disaggregated end-use loads. This includes outlining the functional testing aspects of the test, similar to the process outlined for the two existing methods and the construction inspection method that is currently outlined for the first two methods. Additionally, for the existing methods, the step which verifies that the reduction is not more than 50 percent shall be removed.

NRCI-LTI-05-E, the certificate of installation for power adjustment factors would require an update to replace the 10,000 square foot reference with the 4,000 total design wattage threshold, the 0.5 watts per square foot reference would be replaced with a reference to the multi-level lighting threshold of the same, and the term "non-habitable" and associated language shall be removed.

3. Compliance Option for HPWH Demand Management Systems

3.1 Measure Description

3.1.1 Measure Overview

The proposed code change would expand the HPWH demand flexibility compliance credit that is available for residential buildings that use the performance approach to comply with code so that a similar credit would also be available for nonresidential buildings. This change would help nonresidential buildings contribute positively to grid stability, which is critical as California aims to achieve its renewable portfolio and decarbonization goals. Specific revisions include updating Joint Appendix 13 – Qualification Requirements for Heat Pump Water Heating Demand Management Systems (JA13) so the language is more inclusive of HPWH systems installed in nonresidential buildings. The updated language in JA13 would align with the eligibility requirements for the Self-Generation Incentive Program (SGIP), which added HPWH as an eligible measure in January 2020.[14] For this compliance option to become available for use, the compliance software would need to be updated to add a feature that would simulate the energy impacts of operating HPWHs with demand management capabilities enabled, which could include optimizing for utility time-of-use or critical peak pricing rates.

The proposed compliance credit would apply to all nonresidential building types for new construction, additions, and alterations. The value of the credit would vary by building type with the value credit calculated by the compliance software and taking hot water draw schedules, control strategies, and climate impacts into account. The credit would apply to both integrated (with tank) HPWH units (unitary systems) and central HPWH systems commonly configured as split systems, with separate storage tank and pump.

The multifamily all electric package CASE Report for the 2022 code cycle provides recommendations for HPWH systems for multifamily buildings including adding qualification requirements for central heat pump water heating systems, which would be added to the code as Joint Appendix 14 (JA14). JA14 would apply to all central HPWH systems including central systems installed in nonresidential buildings.

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[14] SGIP is administered by CPUC and offers rebates to residential and nonresidential customers receiving electric service from PG&E, SCE, and SDG&E who install energy and thermal storage technology at their home or business. Eligibility criteria is available online at https://www.cpuc.ca.gov/sgipinfo/

The single family grid integration CASE Report recommends refinements to the existing HPWH demand flexibility compliance credit that would add a new control strategy (Basic Plus Load Up) and add a requirement that HPWH must have a communications interface that is compliant with the Consumer Technology Association standard titled "Modular Communications Interface for Energy Management" (ANSI/CTA-2045-A-2018, or CTA-2045-A) to be eligible for the compliance credit. The recommendation to require CTA-2045-A compliance would apply to the nonresidential compliance option.

The multifamily all electric package and single family grid integration CASE Reports are available on title24stakeholders.com.

3.1.2 Measure History

To achieve long-term greenhouse gas emissions goals, local jurisdictions and the state of California are exploring how to transition buildings to all electric construction. HPWH systems with demand management capabilities are an essential design strategy for all-electric nonresidential buildings. However, few buildings currently use commercial HPWHs. Technology must evolve and markets must transform if we are going to meet climate goals. This code change proposal would encourage investment in HPWH and award designers that choose to use HPWHs with demand management features with compliance credit.

There are no existing requirements in Title 24, Part 6 that require or encourage demand management for service water heating systems in nonresidential buildings. Existing mandatory requirements for demand responsive controls are limited to control requirements for heating ventilation and air conditioning systems (Section 110.12(b)), lighting systems (Section 110.12(c)) and electronic message centers (Section 1102.12(d). Although market adoption of water heating systems with demand management features is still low – too low to consider a mandatory requirement -- technology continues to advance and become more cost effective for wider market sectors. Load shifting options are becoming more mainstream and new models of HPWHs that are Wi-Fi enabled or grid connected out-of-the box for residential buildings. These innovations are readily applicable to commercial HPWHs.

In January 2020 the California Public Utilities Commission moved to add HPWH incentives to the state's Self-Generation Incentive Program (SGIP). The proposed incentive would pay a bonus for models with controls that enable HPWHs to be grid-responsive. California IOUs are currently discussing tying the bonus incentive to models complying with JA13 of 2019 Title 24, Part 6. Consistent with the Statewide CASE Team recommendations, efforts are underway to develop and add requirements in JA13 to allow commercial HPWHs to qualify for SGIP incentives by 2023.

Adding a compliance option to Title 24, Part 6 works in parallel with incentive programs to support the continued evolution of technologies and lays the groundwork for additional grid integration measures in the future.

Related efforts are underway to encourage all-electric construction for residential buildings, including a transition to HPWH systems. For the 2019 code cycle, the Energy Commission implemented the Energy Design Rating (EDR) approach to comply with residential standards. The demand flexibility EDR score established a mechanism for building features that adjust when electricity is being used to receive compliance credit through the performance approach.

HPWH were also added as a prescriptive alternative for low-rise residential buildings for the first time during the 2019 code cycle. One of the alternatives allows HPWH's that meet the requirements of the Northwest Energy Efficiency Alliance (NEEA) Advanced Water Heater Specification for Tier 3 or higher, which encourages DR features (Northwest Energy Efficiency Alliance (NEEA) 2019). The scope of NEEA's specification focuses on integrated (with tank) electric HPWHs only. "Split-system" units that separate the storage tank and the pump, common in central HPWH systems are not included in NEEA's spec. Tier 3 of the specification requires HPWHs to be "DR-enabled", which is "optional but preferred". For Tier 4 and Tier 5 specification (the highest tier), DR-enabled HPWHs are required.

On July 8, 2020, the Energy Commission approved JA13, which defines qualification requirements for HPWH demand management systems and clears the way to allow residential HPWH systems to receive compliance credit through the performance approach.[15] The Energy Commission is currently updating the residential compliance software to add new features that would allow designers to claim credit for installing JA13-compliant HPWH demand management systems.

3.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manuals, and compliance documents would be modified by the proposed change. See Section 3.6 of this report for detailed proposed revisions to code language.

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[15] The approved version of JA13 is available on the Energy Commission's website here: https://www.energy.ca.gov/filebrowser/download/2261.

3.1.3.1 Summary of Changes to the Standards

There would be no changes to language in the standards associated with proposed compliance options.

3.1.3.2 Summary of Changes to the Reference Appendices

This proposal would modify JA13, which currently targets residential HPWH control requirements, to be inclusive of nonresidential HPWH systems. See section 3.6 of this report for the detailed proposed revisions to the text of the reference appendices. The JA13 revisions in this report build on the JA13 proposed revisions described in the single family grid integration CASE Report for the 2022 code cycle, adding revisions to include nonresidential HPWH systems to JA13.

3.1.3.3 Summary of Changes to the Nonresidential ACM Reference Manual

This proposal would modify section 5.9.1 System Loads and Configurations of the Nonresidential ACM Reference Manual as shown below. See Section 3.6.4 of this report for the detailed proposed revisions to the text of the ACM Reference Manual.

- **5.9.1 System Loads and Configuration:** The proposed change would add parameter called "Control Strategy". This parameter would determine which algorithm the user has selected for their controls type. HPWHs demand management systems would affect when the water heater would create demand to heat water in its storage tank to a set point temperature. That load profile would change based on which controls strategy as outlined in JA13 the user selects to manage their load. The user would select the input for this parameter from a set list of options which would dictate which algorithm is utilized to control the water heaters kW demand schedule during simulation.

3.1.3.4 Summary of Changes to the Nonresidential Compliance Manual

The Statewide CASE Team recommends updating section 4.8 Performance Approach of chapter 4 – Mechanical to include a list of compliance options that are available and what is required to demonstrate compliance with each compliance option. This change would require revisions beyond the scope of this particular submeasure, but adding such a list would be a useful resources to designers who use the performance approach and are seeking clarification on eligibility criteria and compliance verification requirements for design strategies that are not included in the mandatory or prescriptive sections of code.

3.1.3.5 Summary of Changes to Compliance Documents

The proposed code change would modify the compliance document NRCC-PRF-01-E. The controls strategy intended to be used would need to be provided on this form so that it may be checked against the value used in the simulation for compliance. Recommended language for document revisions is presented in Section 3.6.

3.1.4 Regulatory Context

3.1.4.1 Existing Requirements in the California Energy Code

Water heating requirements are in Title 24, Part 6, Section 110.3. The section describes efficiency, installation, and temperature control requirements. There is no mention of scheduling operations to align with time-of-use rates. Water heating is also mentioned in Section 110.8 relating to tank insulation; in Section 120.3 relating to piping insulation; and in Section 150.0 relating to electrical connections and mechanical features. Sections 150.1 and 150.2 of the code lists performance and efficiency requirements for water heaters, including HPWH, in low-rise residential buildings respectively, but again does not mention scheduling functions for load shifting or load management purposes.

In the Joint Appendices of Title 24, Part 6, water heating requirements are mentioned in Sections RA3 and RA4 for residential facilities only. In Section RA4.4.11, multiple dwelling units with central hot water systems are required to have fixed or dynamic schedules for temperature recirculation but does not mention load management interactions with the grid nor applicable to commercial systems.

3.1.4.2 Relationship to Requirements in Other Parts of the California Building Code

Title 24, Part 4 is the mechanical code and includes requirements for HVAC, refrigeration, water heating, hydronic (water loop) heat pump systems, boilers, and related auxiliary equipment. Part 4 also defines conditions under which controls are required and acceptance testing of basic function controls. Discussion of controls in Part 4 include minimum operating functions such as on/off, fan speed, supply temperatures, as well as limit controls for safety. For example, in section 225.0, water heaters and boilers are defined as appliances designed to supply hot water for domestic purposes and equipped with automatic controls limiting water temperature to a maximum of 210^{o}F (99^{o}c). Requirements for automated controls are tied to safety requirements for temperature and pressure of operating fluids or vessels. Section 306.1 mentions that "heating appliances whose manual fuel controls are not readily accessible from the main portion of the building being heated shall be equipped with remote controls". There is no discussion of time-of-use operating schedules for either HVAC or water heater equipment.

Title 24, Part 5 is the plumbing code that defines requirements for water heaters, water supply and distribution, fixtures and fittings, sanitary and storm drainage, and fuel gas piping. Discussion of controls relate to flow, temperature (e.g., definitions 208 and 210), and other safety, thermal comfort, and operational controls. Section 505.2 requires storage-type water heaters and hot water heaters to be equipped with over-temperature safety protection temperature controls in addition to primary temperature controls. Section 501.4 requires recirculation pump controls to include “on-demand activation or time clocks combined with temperature sensing. Time clock controls shall not let the pump operate for more than 15 minutes every hour.” However, there is no language in this code mentioning time-specific operation or programming water heating operations based on time for the purposes of harmonizing operations with the electric grid.

3.1.4.3 Relationship to Local, State, or Federal Laws

For water heating, there are a couple of related state and federal codes which focus on grid connection and ability to receive signals from the utility for DR operation but no mention of capabilities for load shifting or day-to-day demand management. First, California’s Title 20 Appliance Efficiency Regulations includes additional energy and water efficiency requirements for both residential and commercial water heaters and HPWHs. The latest standard provides a definition of grid-enabled water heaters applicable to electric resistance water heaters but not for HPWH. Title 20 does not include requirements for water heaters related to scheduling control to modify usage hours or for load management purposes.

3.1.4.4 Relationship to Industry Standards

There are three related industry standards for HPWHs, but they focus on residential products due to its significantly larger market size compared to commercial HPWH. First, NEEA developed the Advanced Water Heating Specification (AWHS), with the current version 7.0 completed in June 2020. The specification prioritizes efficiency performance parameters and defines DR enabled units. On the other hand, the specification language focuses on inclusion of communication signaling capability using CTA-2045 communication port for HPWHs. The AWHA is intended to supplement the ENERGY STAR specifications, which targets residential and residential-duty commercial water heaters, rather than fully commercial-duty water heaters. There are no additional specifications around scheduling functions for everyday load management in the AWHS.

Second, the CEE has an efficiency specification for residential water heaters including HPWH. CEE’s specification includes optional connected criteria for HPWH that, similar to NEEA’s AWHS, focuses on a communications interface (CTA-2045) and using open communications protocols such as OpenADR or the Institute of Electrical and Electronics Engineers (IEEE) 2030.5 for DR event participation. The CEE specification does not have language describing scheduling functions for everyday load management for commercial HPWHs.

Third, the Electric Power Research Institute (EPRI) developed a specification for residential water heaters (EPRI 2014). The document spells out the desired load control setting or mode for the water heater associated with CTA-2045 DR commands. For example, the CTA-2045 message “Shed” shall correspond to the water heater avoiding operation and allowing the stored energy in the tank to reach a minimum, limited by occupant comfort. The EPRI specification does not provide guidance on scheduling capabilities for everyday load management for commercial HPWHs.

LEED Version 4.1 includes a load flexibility and management strategies credit which includes the use of onsite TES. One LEED point is awarded by showing a strategy that reduces on-peak load by at least 10 percent as compared to peak electrical demand using the TES system.

The ENERGY STAR program has developed draft optional grid-connected criteria for residential HPWHs and gas-storage and instantaneous residential-duty commercial water heaters for 2019. ENERGY STAR defines grid-connected HPWHs as ENERGY STAR certified water heaters with integrated or separate communications hardware, plus additional hardware to enable connected functionality. Connected functionality is defined as: Communication device(s), link(s) and/or processing that enables Open Standards-based communication between the [connected water heater product] and external application/device/system(s) (ENERGY STAR 2019).

In January 2020 the California Public Utilities Commission moved to add HPWH incentives to the state’s SGIP. The proposed incentive would pay a bonus for models with controls that enable HPWHs to be grid responsive. California IOUs are currently discussing tying the bonus incentive eligibility to models complying with JA13 of Title 24, Part 6. Consistent with the Statewide CASE Team recommendations, efforts are underway to develop and add requirements in JA13 to allow HPWHs used in nonresidential buildings to qualify for SGIP incentives by 2023.

3.1.5 Compliance and Enforcement

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

Because a compliance credit for grid enabled HPWHs in nonresidential buildings would be offered for the first time in 2022, no compliance and enforcement process currently exist. The following outlines the process that can be expected to take place if the proposed measure is adopted. This process would be part of the general installation and operation verification and enforcement. The activities that would need to occur during each phase of the project are described below:

- **Design Phase:** In the design phase, the energy consultant works with the designer and builder/owner to determine if compliance credit for HPWH load shifting would be pursued as part of the building design. The designer may select from available certified products list maintained by the Energy Commission and specify the unit to be installed. The designer uses CBECC-Com software or other Energy Commission approved computer software to model the HPWH demand management system.
- **Permit Application Phase:** The engineer, architect and energy consultant submit design documents and plans including load shifting modeling results for compliance credit. The permit review process for HPWH includes the verification by the plans examiner that that controls have been included in the design and sizing requirements are met.
- **Construction Phase:** The plumbing contractor procures and installs the HPWH specified in the compliance documents. For central HPWH systems, the plumbing contractor may need to coordinate with the mechanical and electrical controls contractors regarding connection to the building energy management system. The system is properly commissioned to ensure that the manufacturer’s load shifting control mode is activated and operates properly.
- **Inspection Phase:** Following installation and commissioning, the standard inspection process is conducted. The local inspector verifies that all applicable codes and standards have been met, including verification that the installed HPWH is the same unit as the certified product listed in design documents.

Because grid connectivity in HPWHs would be a performance option only, the compliance process would mirror the similar grid-interactive performance option of batteries. As part of JA13 the enforcement agency would verify that the HPWH installed meets certification standards of the Energy commission for credit as a HPWH and that the system is installed an operational with the control strategies listed in JA13. The Statewide CASE Team is recommending additional language in JA13 to reflect this, see Section 3.6 for further details.

The single family grid integration CASE Report for the 2022 code cycle recommends adding an acceptance test to verify compliance with JA13. To receive credit for a JA13-compliant HPWH installed in a single family building, the acceptance test would need to be completed. At this time, the Statewide CASE Team is not recommending adding an acceptance test to verify that HPWH demand management systems installed in nonresidential buildings are complaint with JA13, though an acceptance test would be valuable to ensure HPWH controls are functioning as intended. An acceptance test would increase probability that building occupants realize the full benefit of the load shifting capabilities of these advanced HPWH systems and that each system is providing maximum grid benefits. When the compliance software is updated so that it has the ability to simulate the impacts of HPWH demand management systems for nonresidential buildings, the Statewide CASE Team recommends that the Energy

Commission also add an acceptance test that would be applicable to nonresidential HPWH systems.

The multifamily all electric package CASE Report is recommending adding an acceptance test to verify compliance with JA14 – Qualification Requirements for Central Heat Pump Water Heater Systems. The proposed acceptance test would also be applicable to central HPWH systems in nonresidential buildings. JA14 does not include any demand management requirements. These proposed requirements are mentioned here because they impact HPWH systems.

3.2 Market Analysis

3.2.1 Market Structure

HPWHs follow a traditional product delivery model. Product delivery channels and market actors include manufacturers, manufacturer's representatives, wholesalers or distributors and retailers, and plumbing contractors. Equipment controls that would be used for water heating operation and for load management are developed by the water heater manufacturers and third-party controls manufacturers. Currently, Skycentrics is the only third party manufacturer that has an Open-ADR certified add-on controller for HPWHs.

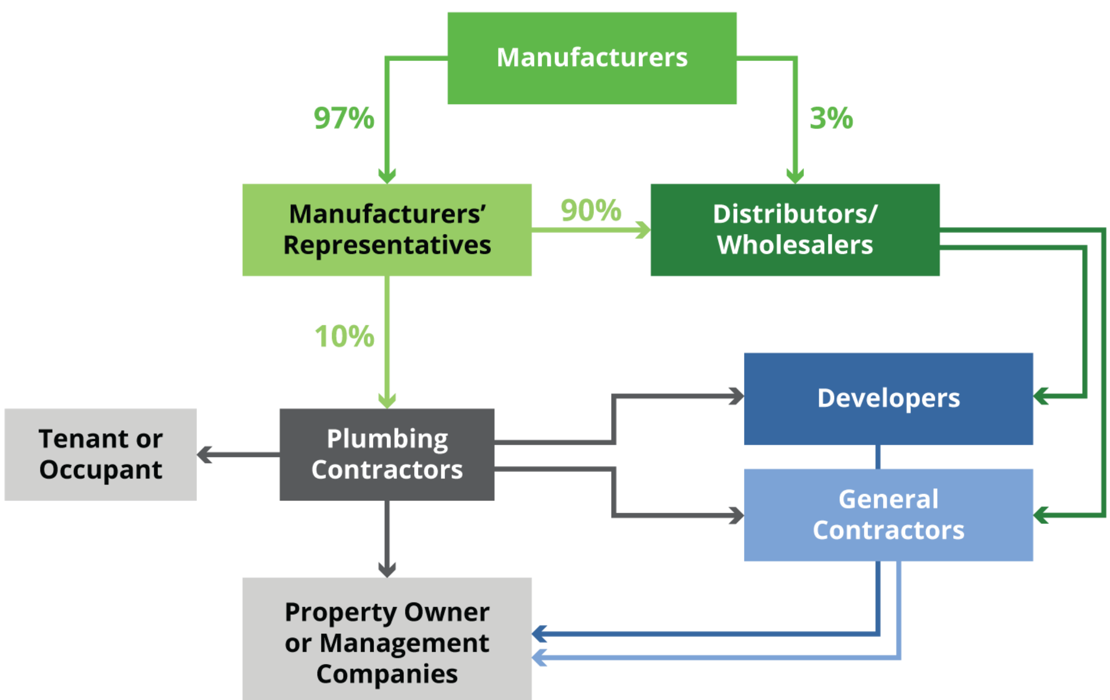

Figure 7. Water heater product delivery channels.

Major water heater manufacturers include A.O. Smith, Bradford White, and Rheem which make up 75 percent of the commercial water heater market. Once manufactured, water heaters are delivered to end users (e.g., building owners) through either distributors or retailers. Approximately half of the water heaters sold are through distributors, and the other half are sold through retailers. Major distributors include Ferguson, Johnstone Supply, and Winnelson. Major retailers include The Home Depot, Lowe's and Sears. A.O. Smith and Rheem sell to both distributors and retailers, while Bradford White sells only to wholesalers and distributors. Plumbing contractors purchase from wholesalers, distributors, and retailers for installation in homes and businesses. About a quarter of residential and commercial building owners install their own water heaters, purchased from retailers. General contractors work with individual commercial owners or management companies to install both unitary and central water heating systems controlled by building energy management systems.

3.2.2 Technical Feasibility, Market Availability, and Current Practices

Virtually every building requires hot water, both residential and commercial. Commercial water heaters are common in offices, restaurants, hotels, hospitals, multifamily dwellings, schools, commercial gyms, and other facilities. According to NIST, commercial water heaters have at least a 120-gallon storage volume (two-gallons or more for instantaneous), does not use single phase electric power, and designed to provide outlet hot water greater than 180 °F (Healy n.d.). EPA's ENERGY STAR defines commercial water heaters as using input power greater than or equal to 1.6 kW (maximum of 24 amperes and 240 volts) for electric heaters and input rate greater than 75,000 Btu per hour for gas units. Nevertheless, many small commercial facilities install residential-duty water heaters.

Commercial HPWHs are described in the federal register as "a water heater (including all ancillary equipment such as fans, blowers, pumps, storage tanks, piping, and controls, as applicable) that uses a refrigeration cycle, such as vapor compression, to transfer heat from a low-temperature source to a higher-temperature sink for the purpose of heating potable water, and has a rated electric power input greater than 12 kW. Such equipment includes, but is not limited to, air-source heat pump water heaters, water-source heat pump water heaters, and direct geo-exchange heat pump water heaters." (U.S. DOE (Department of Energy) 2000)Instead of consuming fuel to generate heat, HPWH uses electricity to move heat from the surrounding air to the water.

Market Size

Annual sales of commercial water heaters are between two percent and three percent of total annual storage tank water heater sales, according to Air Conditioning, Heating, & Refrigeration Institute (AHRI). Annual shipments of standard commercial storage water heaters total about 200,000 units, while residential water heaters shipments total about 8.3 million to 8.5 million annually (about four million for electric water heaters plus 4.3 to 4.5 million for natural gas) (AHRI n.d.). HPWHs currently make up about one percent of the total residential electric water heater market, and an even smaller percentage of the commercial water heater market. The commercial HPWH market is very new, with limited products and models. Using residential data from ENERGY STAR, approximately seven to eight percent of households replace their water heaters each year (U.S. EPA 2010).

Manufacturers and Models

Three major manufacturers make up 75 percent of the commercial water heating market: A.O. Smith, Bradford White, and Rheem (Coumas 2019). The rest of the market includes dozens of smaller manufacturers. All three major manufacturers currently have residential heat pump water heating models that are wifi enabled and grid enabled that could be installed in small commercial facilities. There are currently no commercial HPWH products on the market that are also grid enabled.

A.O. Smith's has a residential HPWH product line called Voltex, with a 50-gallon, 66-gallon, and 80-gallon model. They have worked closely with SkyCentrics in DR demonstration projects and requires the addition of a CTA-2045 controller that customers must purchase separately. Bradford White has a HPWH product called AeroTherm, including 50-gallon and an 80-gallon models targeting the residential sector. Similar to A.O. Smith, Bradford White's AeroTherm requires the addition of a CTA-2045 controller that customers must purchase separately to participate in load management. Rheem has two HPWH product lines, the Professional Prestige and Performance Platinum. Each line offers 50, 65, and 80-gallon tank sizes. The Professional Prestige and Performance Platinum product lines are Wi-Fi enabled with integrated EcoNet software platform, making these product lines DR-capable with no modifications required.

HPWH and Load Management

Load management using standard storage water heaters currently all target the residential sector, given their significantly larger market share. According to Smart Electric Power Alliance (2018), approximately 250 MW of residential electric heaters are actively enrolled in a DR program across 24 utilities around the country. For reference, active residential sector DR programs total 18.3 GW, and is dominated by air conditioning direct load control and thermostat programs.

Interest in HPWH for load management has been gaining traction over the last few years, and there have been two recent pilots with Energize Connecticut and Bonneville Power Administration (BPA). These pilots were also focused on the residential sector; there are no commercial HPWH load management programs. Energize Connecticut in

2018 studied Rheem HPWH since they come with integrated Wi-Fi connectivity and a 10-year warranty (Rodrigues 2019). Sixty-five homes were installed, 58 enrolled in a DR pilot. BPA's pilot was the largest HPWH load management demonstration pilot to date. Starting in 2016, BPA reached out to its utilities and suppliers to secure firm commitments for the pilot. Eight utilities and two suppliers signed on, and customers were recruited in 2017. A total of 600 DR events were dispatched over 220 days across 277 residential customers, with high participation rates.

3.3 Energy Savings

The proposed compliance option for HPWH would not result in energy savings because the required energy budget would not be modified. It is assumed that designers that choose to use HPWH demand management systems will design buildings to be minimally compliant with the energy code, meaning there will be no additional energy savings associated with using the proposed compliance option over any other design strategy available in the performance approach.

3.4 Cost Effectiveness

The code change proposal would not modify the stringency of Title 24, Part 6, so the Energy Commission does not need a complete cost-effectiveness analysis to approve the proposed change. For this proposed change, the Statewide CASE Team is presenting basic information on the cost implications in lieu of a full cost-effectiveness analysis.

Based on Statewide CASE Team's research, the cost difference between a standard HPWH and a standard electric resistance water heater is between $750 to $800. For HPWH owners, the cost difference between one that has Wi-Fi or grid communication capability is between $225 and $300. The difference involves the addition of a communication adaptor and communicating module. The module can support multiple communication options (AM, FM, Cellular, Wi-Fi). While there are several grid-enabled controllers available for water heaters, most are designed for electric resistance water heaters. The retrofit controllers cost between $150 and $200. Of the retrofit controller manufacturers (Aquanta, SkyCentrics, e-Radio, CASA SkyCentrics), SkyCentrics is currently the only controller capable of working with HPWH for demand management.

3.5 First-Year Statewide Impacts

The proposed compliance option for HPWH demand management systems does not have any associated energy savings, greenhouse gas emissions reductions, water use impacts, or material impacts.

3.6 Proposed Revisions to Code Language

3.6.1 Guide to Markup Language

The proposed changes to the standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2019 documents are marked with red underlining (new language) and ~~strikethroughs~~ (deletions).

3.6.2 Standards

There are no proposed changes to the standards.

3.6.3 Reference Appendices

Appendix JA1 – Definitions

The proposed changes to JA1 are described in the single family grid integration CASE Report for the 2022 code cycle. The mark-up language is provided here so all relevant proposed changes are included in one location.

ANSI/CTA–2045-A is the **C**onsumer Technology Association document titled "Modular Communications Interface for Energy Management" 2018 (ANSI/CTA-2045-A-2018).

HEAT PUMP WATER HEATER (ADVANCED LOAD UP) is a residential heat pump water heater controlled to store extra thermal energy in the storage tank by exceeding the user setpoint temperature. It will avoid use of electric resistance elements unless user needs cannot be met. This mode must only be enabled after agreement by the user and utility.

HEAT PUMP WATER HEATER (BASIC LOAD UP) is a residential heat pump water heater controlled to store extra thermal energy in the storage tank without exceeding the user setpoint temperature. It will avoid use of electric resistance elements unless user needs cannot be met.

HEAT PUMP WATER HEATER (BASIC PLUS LOAD UP) is a residential heat pump water heater controlled to store extra thermal energy in the storage tank by exceeding the user setpoint temperature. It will avoid use of electric resistance elements unless user needs cannot be met.

Appendix JA13 – Qualification Requirements for Heat Pump Water Heater Demand Management Systems

JA13.1 Purpose and Scope

Joint Appendix JA13 provides the qualification requirements for a heat pump water heater (HPWH) demand management system ("System") to meet the requirements for HPWH demand flexibility compliance credit to meet the performance standards specified in Title 24, Part 6, Sections 150.1(b) and 140.1. The primary function of the System is to serve the users' domestic hot water needs and provide daily load shifting, as applicable, for the purpose of user bill reductions, maximized solar self- utilization, and grid harmonization.

User interfaces referenced in these requirements shall be designed for use by a typical ~~residential~~ user.

JA13.2 Definitions

Heat Pump Water Heater Demand Management System

The HPWH Demand Management System is comprised of:

(a) Any hardware or software contained inside the water heater;

(b) Any hardware or software installed on premise (including a module); and

(c) Any software contained in applications or in the cloud;

which are necessary to fulfil the primary function of the System.

Heat Pump Water Heater System Types

The minimum thermal storage and load shifting requirements are dependent on the type of HPWH installed. The below table defines each system as referenced throughout the appendix.

Table JA13- 1: Types of Heat Pump Water Heaters

HPWH Type	**Definition**
Unitary Residential	Heat pump water heater with a total nominal compressor output power of 6 kW or less, including integrated heat pumps with storage as shipped from the point of manufacture and split-system heat pumps that consist of a separate heat pump and storage tank that are designed and marketed to operate together.
Unitary Nonresidential	Heat pump water heater with a total nominal compressor output power greater than 6 kW with integrated storage as shipped from the point of manufacture, including skid systems that are pre-plumbed and wired.
Central Residential	Heat pump water heater(s) without integrated storage as shipped from the manufacturer, and designed for residential, single and multifamily applications.
Central Nonresidential	Heat pump water heater(s), without integrated storage as shipped from the manufacturer, and designed for nonresidential applications.

Local and Remote Methods

A Local Method means a method that can be performed from within the building that does not require the System to have a live connection to an off-premise source. A temporary connection to a live off- premise source such as via a smart phone, may be used for local setup and updates.

A Remote Method means a method that is performed via a live connection to an off-premise source, such as the internet, advanced metering infrastructure (AMI), or cellular communication.

JA13.3 Qualification Requirements

To qualify for the HPWH Demand Management System performance compliance credit, the System shall be certified to the Energy Commission to meet the following requirements:

JA13.3.1 Safety Requirements

The System shall comply with applicable installation standards in the California electrical, mechanical, building and plumbing codes.

A thermostatic mixing valve conforming to ASSE 1017 shall be installed on the hot water supply line following all manufacturer installation instructions or a water heater that conforms to UL 60730-1, ASSE 1082, or ASSE 1084.

JA13.3.2 Minimum Performance Requirements

The installed System shall meet or exceed the following performance specification:

~~(a)~~ **Efficiency:** meet all requirements specified in Table JA13- 2. ~~of the version 7.0 of the Northwest Energy Efficiency Alliance (NEEA) Advanced Water Heater Specification Tier 3 or higher, excluding Appendix A~~

Table JA13- 2: Minimum efficiency requirements for each type of HPWH

Type of HPWH	**Efficiency Requirements**
Unitary Residential	Compliant with version 7.0 of the Northwest Energy Efficiency Alliance (NEEA) Advanced Water Heater Specification Tier 3 or higher excluding Appendix A.
Unitary Nonresidential	ENERGY STAR certified
Central Residential	N/A
Central Nonresidential	N/A

(b) **Thermal storage:** comply with the first hour rating requirements in Table JA13- 4 ~~the following table~~ (consistent with requirements in Chapter 5, Table 501.1(2) of the ~~in~~ 2019 California Plumbing Code):

Table JA13- 3: Thermal storage requirements for each type of HPWH

Type of HPWH	**Thermal Storage Requirements**
Unitary Residential	Comply with the first hour rating requirements in Table JA13- 3 (consistent with requirements in Chapter 5, Table 501.1(2) of the 2019 California Plumbing Code)
Unitary Commercial	Shall have a minimum hot water delivery of 300 gallons per day
Central Residential	Shall have a minimum 0.84 kWh thermal storage per person based on design occupancy of the project described in the NRCC-PRF-01-E . The sizing calculation is based on an ambient air temperature of 67.5 F and an inlet water temperature of 58 F
Central Commercial	Shall have sufficient thermal storage to support a minimum 4 hours of compressor operation. The sizing calculation is based on an ambient air temperature of 67.5 F and an inlet water temperature of 58 F

Table JA13- 4: First Hour Rating Requirements for Unitary Residential HPWHs (Replication of Table 501.1(2) in Chapter 5 of the 2019 California Plumbing Code

Number of bathrooms	1 to 1.5			2 to 2.5				3 to 3.5			
Number of bedrooms	1	2	3	2	3	4	5	3	4	5	6
First Hour Rating (gallons)	38	49	49	49	62	62	74	62	74	74	74

(c) **Grid Connectivity:** the installed system shall have a modular demand response communications port compliant with the March 2018 version of the ANSI/CTA–2045-A communication interface standard.

JA13.3.3 Control Requirements

The requirements below are applicable to all control strategies:

(a) **Time-of-use schedules:** The System shall have the capability of storing at a minimum five time-of-use schedule(s) locally, each supporting at a minimum five distinct time periods for both weekdays and weekends, at least three separate seasonal schedules, and daylight savings time changes. The System shall support both local and remote setup, selection, and update of time-of-use schedules. Local and remote setup, selection, and update shall be possible through a user interface (such as an app).

(b) Demand management functionality

Upon receiving a demand management price or dispatch signal, the System shall be capable of all the following automatic event responses:

1. **Basic Load Up:** The System will store extra thermal energy without exceeding the user set point temperature. It will avoid use of electric resistance elements unless user needs cannot be met;
2. **Basic Plus Load Up:** The System stores extra thermal energy, where some or all of the tank may exceed the set point temperature chosen by the user, within safe operating conditions. It will avoid use of electric resistance elements unless user needs cannot be met.
3. **Advanced Load Up:** The System stores extra thermal energy, where some or all of the tank may exceed the set point temperature chosen by the user, within safe operating conditions. Advanced Load Up must only be enabled after agreement by the user and utility as defined below. It will avoid use of electric resistance elements unless user needs cannot be met. Advanced Load Up will only be available in Advanced Demand Response Control mode as defined in JA13.3.3.2;
4. **Return to Standard Operation:** The System terminates any demand management function and returns to user-selected standard operation mode until the next demand management function is activated;
5. **Light Shed:** The System will defer complete recovery for the duration of the shed event unless user needs cannot be met; The water heater shall avoid use of electric resistance elements during and immediately after the event unless user needs cannot be met;
6. **Deep Shed:** same as Light Shed, but the System will completely avoid use of electric resistance elements during the event;
7. **Full Shed:** same as Light Shed, but the System will completely avoid use of both compressor and electric resistance element during the event.

The demand management signals may be sent from a local utility, a remote aggregator, a local demand manager (e.g. local time-of-use demand manager), or be internal to the System (e.g. internal schedule- or price-based demand management).

The "Advanced Load Up" function shall only be enabled by a deliberate action of the user through the system's physical or remote interface upon enrolling in a utility's demand response program. The "Advanced Load Up" function shall be capable of being disabled deliberately by the user, or remotely by the utility or third-party service provider without deliberate action by the user.

For a water heater sized in accordance with JA13.3.2(b) and with the default set point as shipped from the manufacturer, the System shall be able to shift in accordance with requirements in *Table JA13- 5*.~~:~~

- ~~A minimum of 0.5 kWh of user electrical energy per (Basic Load Up + Light Shed) event; and~~
- ~~A minimum of 1 kWh of user electrical energy per (Advanced Load Up + Light Shed) event, including at least 0.5 kWh on Advanced Load Up.~~

Table JA13- 5: Demand management functionality for each type of HPWH

Type of HPWH	**Basic Load Up + Light Shed**	**Basic Plus Load Up + Light Shed**	**Advanced Load Up + Light Shed**
Unitary Residential	A minimum of **0.5 kWh** of electrical energy per event	A minimum of **0.75 kWh** of electrical energy per event	A minimum of **1 kWh** of electrical energy per event, including at least **0.5 kWh** on Advanced Load Up
Unitary Commercial	A minimum of **1 kWh** of electrical energy **per 100 gallon** storage per event	N/A	A minimum of **2 kWh** of electrical energy **per 100 gallon** storage per event.
Central Residential	A minimum of **0.2 kWh** of electrical energy per person per event (design occupancy)	A minimum of **0.75 kWh** of electrical energy per event	A minimum of **0.4 kWh** of electrical energy per person per event, including at least **0.2 kWh** on Advanced Load Up (design occupancy)
Central Commercial	**4 hours** minimum of compressor run time at nominal rated power (same 4 hours as thermal storage requirement, not additive)		

(c) **Non-standard mode exception:** The demand management functionality shall be achieved in all user-selected modes except for vacation and off modes, which are deemed non- standard modes. The System shall return to the previous standard operation mode once the water heater exits from a non-standard mode.

(d) **Local time management:** In the event of a loss of power, the System settings, including operating mode, time-of-use schedules, and local clock, shall be retained, or reacquired, for at least three months. The local clock shall have a maximum drift of less than 5 minutes per year under standard operating conditions and without requiring remote connectivity.

(e) **Override and permanent disabling:** The System shall provide local and remote means for the user to override or permanently disable the demand management functions. The override shall be temporary and have a maximum duration of 72 hours. Permanent disabling shall not be available as an operating mode or as an option in the primary menu.

(f) **User interface:** The System shall provide both a remote and local user interface, such as a web-based portal or a mobile device application, that at a minimum provides the dwelling occupants access to the following information: control strategy that is currently active, remote or local demand management mode, selected time-of-use schedule if applicable, and confirmation of any settings change.

(g) **Measurement and validation:** When connected remotely, the System shall make the following data available to the local utility, remote aggregator, or local demand manager: Demand Management Override Status, Demand Management Disabled Status; power demand (watts); cumulative energy consumption (watt-hours); total energy storage capacity (watt-hours), available energy storage capacity (watt-hours).

The System shall be capable to use one of the following control strategies at the time of installation. The System also shall have the capability to switch to other control strategies if available. The “Advanced Load Up” function shall not be enabled at time of installation.

JA13.3.3.1 Time-of-Use (TOU) Control

To qualify for the TOU Control, the System shall be installed in the default operation mode to serve domestic hot water user needs while optimizing System operation to reduce user bills under the selected time-of-use schedule. The System shall load up (charge) during the lowest priced TOU hours of the day and shed (minimize charging while serving user needs) during the highest priced TOU hours.

JA13.3.3.2 Advanced Demand Response Control

To qualify for the Advanced Demand Response Control, the System shall meet the demand responsive control requirements specified in Section 110.12(a) of the 2019 Building Energy Efficiency Standards. Additionally, the System shall be capable of changing the load-up and shed periods in response to real-time or day-ahead dispatch or price signals from the local utility, a remote aggregator, or a local demand manager. If remote communication is lost for more than 12 hours while the water heater is under Advanced Demand Response Control, the water heater shall revert to TOU Control until remote communication is reestablished, and then revert back to Advanced Demand Response Control.

JA13.3.3.3 Alternative Control Approved by the Executive Director

The Executive Director may, after stakeholder comments, approve alternative control strategies that demonstrate equal or greater benefits to one of the JA13 control strategies. To qualify for Alternative Control, the System shall be operated in a manner that increases self-utilization of the PV array output, responds to utility rates, responds to demand response signals, and/or other strategies that achieve equal or greater benefits. This alternative control option shall be accompanied with well-documented algorithms for incorporation into the compliance software for compliance credit calculations.

JA13.4 Enforcement Agency

To receive the HPWH Demand Management System compliance credit, the completed Certificate of Installation shall be a model that has been certified to the Energy Commission as qualified for the credit. As part of their normal enforcement activities, this certification shall be subject to local building department checking.

Appendix JA14 – Qualification Requirements for Central Heat Pump Water Heater Systems

See the multifamily all electric CASE Report for proposed language for JA14. The requirements in JA14 would apply all central HPWH systems, including systems in nonresidential buildings. JA14 does not include demand management requirements, but a note is provided here to direct readers to other proposed changes that are applicable to HPWHs in nonresidential buildings. The Statewide CASE Team is recommending an acceptance test be added to verify compliance with JA14.

3.6.4 ACM Reference Manual

5.9 Miscellaneous Energy Uses

Miscellaneous energy uses are defined as those that may be treated separately since they have little or no interaction with the conditioned thermal zones or the HVAC systems that serve them.

5.9.2 Water Heaters

This section describes the building descriptors for water heaters. Typically, a building will have multiple water heating systems and each system can have multiple water heaters, so these building descriptors may need to be specified more than once.

Control Strategy	
Applicability	Heat Pump Water Heaters Demand Management Systems
Definition	Heat Pump Water heaters installed to the specifications of JA13 may select which controls strategy they will utilize to schedule their energy use
Units	Unitless (or Data structure - schedule, fractional)
Input Restrictions	None, Basic, Time-of-Use, Advanced DR Control
Standard Design	Not applicable
Standard Design: Existing Buildings	

3.6.5 Compliance Manual

The Statewide CASE Team recommends updating Section 4.8 Performance Approach of Chapter 4 – Mechanical to include a list of compliance options that are available and what is required to demonstrate compliance with each compliance option. Mark-up language has not been provided because such a change would require updates to the structure of this section content for existing compliance options that are not discussed in this CASE Report. The Statewide CASE Team can work with the Energy Commission to develop compliance manual language if the Energy Commission would like to pursue this recommended revision.

3.6.6 Compliance Documents

The control method selected by the user would be indicated in the **NRCC-PRF-01-E** document in a “Control Strategy (Heat Pump Water Heaters Only)” field as column 12 in Section K5. DHW Equipment Summary as shown in below. If an acceptance test is deemed necessary, a new NRCA acceptance document would be created to verify completion of testing.

K5. DHW EQUIPMENT SUMMARY											
1	2	3	4	5	6	7	8	9	10	11	12
DHW Name	**Heater Element Type**	**Tank Type**	**Qty**	**Tank Vol (gal)**	**Rated Input (kBtu/h)**	**Efficiency**	**Tank Insulation R-value (Int/Ext)**	**Standby Loss Fraction**	**Heat Pump Type**	**Tank Location or Ambient Condition**	**Controls**
WaterHeaterElec	Electricity	NA	1	127.11	12.2 (kW)	EF:3.00	NA	NA	Heat-Pump Packaged	Zone	Basic

4. Compliance Options for Thermal Energy Storage

4.1 Measure Description

4.1.1 Measure Overview

To enable load shifting, the Statewide CASE Team proposes allowing compliance credit for thermal energy storage (TES) technologies beyond the existing chilled water systems by adding features to the compliance software for these additional systems. TES with phase change materials and ice storage enable a building to shift electricity use across hours of the day based on time-of-use or critical peak pricing rates and grid needs. The specific compliance options being considered include modifications to TES algorithms and compliance software to integrate the ThermalStorage:Ice:Detailed EnergyPlus object, which will allow designers to simulate the energy impacts and receive compliance credit for three additional types of TES systems that are already eligible to receive compliance credit but the software does not yet support: Ice-on-Coil Internal Melt, Ice-on-Coil External Melt, and Eutectic Salt.

4.1.2 Measure History

TES for space cooling is a mature technology and market, with ice- and eutectic salts-based TES options widely available for all building types. Allowing ice- and eutectic salts-based TES to receive compliance credit will allow more buildings in California to practice demand management compared to chilled water alone. Ice has greater thermal storage capacity than water and requires a smaller footprint than chilled water storage, an option for buildings with space limitations. Eutectic salts and advanced phase change materials enable TES applications across a greater range of operating temperatures. Businesses with low temperature refrigeration needs can leverage TES to shift their demand without significantly impacting business operations. TES systems are often installed in large commercial and industrial space heating systems. Expansions to TES compliance options have the potential to provide significant savings and flexibility. Innovations in over the last decade involve embedding phase change materials into building materials such as wall board is another promising trend to watch.

Title 24, Part 6 Standards first added definitions and requirements for demand management in 2008 for heating, ventilation, and air conditioning (HVAC) equipment. The Energy Commission passed three DR-related requirements for lighting, HVAC, and large display signs. The impacted HVAC and lighting systems must be equipped with demand responsive controls that are capable of automatically initiating the load shed in response to a DR signal. These requirements for HVAC expanded significantly between 2008 and 2013 for Title 24, Part 6 Standards. In 2008, DR enabled controls devices for HVAC systems were only required for nonresidential buildings with direct digital control[16] down to the zone level. This was largely applicable only to buildings with centralized Energy Management Control Systems (EMCS). In 2013, the Energy Commission added DR requirements for an additional measure, OCST measure.[17] OCSTs are required to be installed in nonresidential buildings where more robust DR HVAC controls are not used (i.e., direct digital controls down to the zone level).

The 2016 Title 24, Part 6 Standards provided compliance credit for thermal storage HVAC systems in nonresidential buildings for the first time, along with further clarifications to OCSTs. However, only chilled water storage systems were included in CBECC-Com to receive compliance credit through the performance approach. Limited updates for OCSTs in 2016 focused on clarifying communication requirements in Joint Appendix 5 (JA5) – Reference Design for Upgradeable Setback Thermostats" for event-based DR operation. This included, for example, that OCSTs shall be capable of connecting to either a Wi-Fi network or a Zigbee network.

4.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manuals, and compliance documents would be modified by the proposed change. See Section 4.6 of this report for detailed proposed revisions to code language.

4.1.3.1 Summary of Changes to the Standards

There would be no changes to language in the standards associated with proposed compliance options.

4.1.3.2 Summary of Changes to the Reference Appendices

This proposal would modify the sections NA7.5.14. Thermal Energy Storage (TES) Systems. The proposed compliance options would add "freezing temperature of storage medium" as required specification of TES systems so plans can be compared to

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[16] Direct Digital Control (DDC) systems consist of networked microprocessor-based controllers connected to analog and digital devices, which sense information and control components of a building's energy-using equipment.

[17] The OCST measure is a mandatory measure for the nonresidential sector and largely applicable to buildings exempted from the ADSC measure. For the residential sector, the OCST measure is treated as an alternative compliance pathway to solar ready requirements for rooftops. This means that a homeowner must fulfill *either* the solar ready requirements or the OCST requirements, but they are not obligated to meet the requirements of both.

simulation inputs. See Section 4.6.3 of this report for the detailed proposed revisions to the text.

4.1.3.3 Summary of Changes to the Nonresidential ACM Reference Manual

This proposal would modify section 5.8.8 of the Nonresidential ACM Reference Manual as shown below. The ACM language must be updated to be inclusive of more storage types than just chilled water systems. See Section 4.6.4 of this report for the detailed proposed revisions to the text of the ACM Reference Manual.

- **5.8.8 Thermal Energy Storage:** The proposed change would add a parameter called "Storage Medium Freezing Temperature" to be used in the simulation to model storage system types that are mixtures or mediums other than water. This new parameter "Storage Medium Freezing Temperature" is used to define which storage medium the system is utilized. How the medium is modelled is dictated by the freezing point. Giving the user the ability to input this value allows for any eutectic mix, slurry, or brine storage types to be modelled for compliance in CBECC-Com. This change is necessary so the software can simulate the impacts of thermal energy storage systems other than chilled water systems.

4.1.3.4 Summary of Changes to the Nonresidential Compliance Manual

The Statewide CASE Team recommends updating section 4.8 Performance Approach of chapter 4 – Mechanical to include a list of compliance options that are available and what is required to demonstrate compliance with each compliance option. This change would require revisions beyond the scope of this particular submeasure, but adding such a list would be a useful resources to designers who use the performance approach and are seeking clarification on eligibility criteria and compliance verification requirements for design strategies that are not included in the mandatory or prescriptive sections of code.

4.1.3.5 Summary of Changes to Compliance Documents

The proposed code change would modify the compliance document NRCC-PRF-01-E. The "Storage Medium Freezing Temperature" specification would need to be provided on this form so that it may be checked against the value used in the simulation for compliance. Recommended language for document revisions is presented in Section 4.6.6.

4.1.4 Regulatory Context

4.1.4.1 Existing Requirements in the California Energy Code

TES is discussed minimally in Title 24, Part 6, Section 140.4 as exceptions for chiller system efficiency requirements. To be exempt from chiller efficiency requirements, facilities using TES to supplement chiller operation must be designed to have charging temperature less than 40ºF. The Reference Appendices in Section NA7.5.14 describes compliance testing for TES used in conjunction with chilled water air conditioning systems. TES designed to be used with chillers in a facility are partial storage TES systems rather than full storage TES systems. There is currently no language in the code pertaining to scheduling functions for load shifting or load management with TES.

4.1.4.2 Relationship to Requirements in Other Parts of the California Building Code

There are no relevant requirements in other parts of the California Building Code.

4.1.4.3 Relationship to Local, State, or Federal Laws

There are no relevant local, state, or federal laws.

4.1.4.4 Relationship to Industry Standards

For TES, the American Society of Mechanical Engineers (ASME) has a draft safety standard for molten salt systems. The safety standard applies to the design, construction, installation, commissioning, operation, maintenance and decommissioning of molten salt TES systems, defined as two-tank sensible heat systems using molten salts. The draft standard only applies to one type of TES and does not provide operational guidelines such as scheduling for load management or load shifting. The current 2018 draft standard is available for trial use through ASME's website (ASME 2018).

LEED Version 4.1 includes a load flexibility and management strategies credit which includes the use of onsite TES. One LEED point is awarded by showing a strategy that reduces on-peak load by at least 10 percent as compared to peak electrical demand using the TES system.

4.1.5 Compliance and Enforcement

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

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

- **Design Phase:** In the design phase, the energy consultant works with the designer and builder/owner to determine if compliance credit for TES would be pursued as part of the building design. The manufacturer works with the customer's engineer to design the custom system based on facility functional specifications and operating parameters. The designer models TES in Energy

Commission approved computer software. The compliance documents would be generated listing the model and specification of the compliance credit.

- **Permit Application Phase:** The standard permitting process applies for TES projects.
- **Construction Phase:** The standard construction process applies for TES projects using industry best installation practices. The installation contractor would procure, install, and commission the system in accordance with plans. The acceptance test technician would verify the installation according to the test procedures in NA7.5.14.
- **Inspection Phase:** The standard inspection process applies for TES projects to obtain the Certificate of Acceptance (NRCA) documents. The installing contractor relies upon the plans and upon the NRCC-PRF-01-E certificate of compliance document printed on the plans. Field verification is required for TES systems and would be demonstrated in the NRCA-MCH-15-A certificate of acceptance form.

For TES, the proposed measure would result in little change to the existing compliance process. Ice and eutectic salts are common TES media types in addition to chilled water. If the system designer utilizes the new system types, the storage medium freezing temperature would be confirmed on the NRCC-PRF-01-E certificate and verified during acceptance testing.

All TES system types would be verified via the existing TES system acceptance test defined in the 2019 Nonresidential Reference Appendix NA7.5.14 Thermal Energy Storage (TES) Systems. This acceptance test allows the technician to verify proper installation of the system as well as ensure system controls and operation capability are consistent with compliance simulation. The controls and operation portion of the test includes confirmation that the system can charge, store, and discharge energy and that the system is controlled and monitored successfully by an energy management system The acceptance testing processes that is already in place can be employed.

4.2 Market Analysis

4.2.1 Market Structure

The TES market consists of manufacturers, developers and turnkey solution providers. Manufacturers may supply either the TES medium (e.g., ice, eutectic salt solution, or phase change material) or the containment or housing unit (e.g., concrete tanks, packed bed or modular packs) or both. Developers assist customers in designing and constructing the TES system, which includes stand-alone or full storage TES systems that serve the entire facility or partial TES systems that supply cooling in coordination with a traditional mechanical chiller system. Other manufacturers and contractors provide major auxiliary equipment such as pipes, pumps and valves needed for a distribution system and cooling towers as applicable for water-cooled systems. Controls manufacturers and contractors are also integral to many TES systems. Controls are an important component of TES systems that add significant benefits. Controls help optimize energy consumption from mechanical refrigeration and facilitate everyday demand management and event-based DR. Because of the variety of TES solutions and the complexity of the project depending on the selected solution, the market also has turnkey solution providers that help customers with the end-to-end process of design, procurement, construction, and commissioning of TES system.

Notable manufacturers include Axiom Energy, Baltimore Air Coil Company, Cryogel, Ice Energy, Trane Company, and Viking Cold Solutions.

4.2.2 Technical Feasibility, Market Availability, and Current Practices

TES stocks thermal energy by heating or cooling a storage medium so that the stored energy (in Btus) can be used later to offset heating and cooling energy, as well as power generation (in kWhs) such as stored solar energy. Thus, the primary purpose of investing in TES is for load shifting, thermal and/or electrical. TES is a mature technology and market. The earliest recorded use of TES date back over 350 years in China, using water injection into natural aquifers for industrial cooling. Modern day technologies use a range of liquid and solid media to store sensible heat, as well as latent heat solutions also known as phase-change materials.[18] TES is a flexible, scalable, and modular technology that is constrained only by its storage medium. These include underground (e.g., caverns, aquifers, packed beds) in storage tanks, storage modules of various shapes and sizes, or even embedded in building materials as microspheres less than 1mm in diameter. The storage performance of TES solutions varies based on characteristics or variables such as the capacity, power, efficiency, storage period, and charge or discharge time. These characteristics are defined in Table 35. This CASE Report focuses on the application of TES solutions to offset or shift mechanical cooling or heating by HVAC equipment in nonresidential buildings, from on-peak periods when utility demand and rates are highest to off-peak periods when demand and rates are lower. TES solutions can also be passive (building materials) or active, and this CASE Report focuses on active systems.

[18] Sensible heat exchange involves the increase in temperature of a substance while leaving other properties unchanged, such as pressure or volume. Latent heat refers to energy released or absorbed from a substance during a phase change from solid to liquid or liquid to gas. The most common example of latent heat is melting ice into water and converting water to steam. Latent heat changes the substance's volume, density, or pressure, while temperature remains constant.

Table 35: Performance Characteristics of TES

Performance Characteristic	Definition
Capacity	The energy stored in the system. Depends on the storage process, the medium, and the size of the system
Power	How fast the energy stored in the system can be charged or discharged
Efficiency	The ratio of the energy provided to the user to the energy needed to charge the storage system. It accounts for the energy loss during the storage period and the charging/discharging cycle;
Storage Period	How long the energy is stored. Can be hours, days, weeks, and months for seasonal storage solutions
Charge and Discharge Time	Time needed to charge (store heat or cold into the storage medium) and discharge (release heat or cold into the facility) the system

Source: (Sarb and Sebarchievici 2018)

The Department of Energy (DOE) Global Energy Storage Database (GESD) provides data on 213 TES systems in 18 countries worldwide, totaling 2,788 MW. About three-fourths of these systems or 160 are in the United States, totaling roughly 700 MW (Sandia National Laboratories n.d.). The worldwide installations in this database consist of large-scale utility-owned systems. About a quarter of the U.S. systems are privately-owned by school districts, universities, other institutions, and commercial facilities. California makes up 56 percent of the installed systems in the U.S. in the BESD. However, California's TES installations total 57 MW or only 8 percent of the total capacity in the U.S., suggesting that these installations are primarily building scale rather than utility scale systems.

Manufacturers

According to Thomas Register online (ThomasNet n.d.), Federal Energy Management Program (FEMP) (U.S. DOE (Department of Energy) 2000), Energy User News, and International District Energy Association, there are more than 30 manufacturers throughout the U.S. providing various types of TES solutions (e.g., water, ice, phase change materials), plus about a dozen companies providing TES-related services. Listed companies include TES manufacturers, storage tanks and parts suppliers, turnkey solutions and integration service providers. Several companies specifically target collaboration with utilities around load shifting programs, including: Axiom Energy based in Richmond, California; Viking Cold Solutions based in Houston, Texas, and Ice Energy based in Windsor, Colorado.

TES and Load Management

LBNL studied the feasibility of using TES for load shifting in California (Rongxin, et al. 2015). The study concluded that TES systems can provide cooling demand shifting for buildings on most days. Buildings with partial storage TES systems can provide reliable and fast load shed by allowing customers to turn off chiller plants during DR event periods. Partial TES installations provide lowest utility costs at six hours, and optimal bill savings at nine hours for old and new office buildings. The study also noted that TES is more economically attractive for new buildings from a payback period perspective. Partial storage systems require the mechanical cooling system to provide part of the cooling load. Full storage systems involve larger and more expensive implementation but allows for greater shifting of energy usage from peak to off-peak hours. With the peak hours in California shifting from mid-day (2 p.m. to 6 p.m.) to early evening (4 p.m. to 9 p.m.), TES would benefit businesses with evening operating hours. These include, for example, facilities in the entertainment and hospitality sector, warehousing including refrigerated and cold storage, academic and research campuses, hospitals, and data centers.

4.3 Energy Savings

The proposed compliance options for TES would not result in energy savings because the required energy budget would not be modified. It is assumed that designers that choose to use TES will design buildings to be minimally compliant with the energy code, meaning there will be no additional energy savings associated with using TES over any other design strategy available in the performance approach.

4.4 Cost Effectiveness

The code change proposal would not modify the stringency of Title 24, Part 6, so the Energy Commission does not need a complete cost-effectiveness analysis to approve the proposed change. For this proposed change, the Statewide CASE Team is presenting basic information on the cost implications in lieu of a full cost-effectiveness analysis. Costs vary significantly for TES systems because of the large variety of technology options, project size, plus variations in site-specific conditions. TES costs depend on the design temperature differential and size of the refrigeration capacity required (measured in Btus). For example, the same equipment would have twice the storage capacity if operated through a 20°F differential compared to a 10°F differential. Alternatively, the same capacity could be achieved with a tank that is 50 percent smaller. TES effectiveness is further defined by the surface area available for heat transfer to and from the medium being used. Ice-on-coil and encapsulated ice storage system costs are dominated by the heat transfer surface, which is the piping or coils for the former and the flexible encapsulating material for the latter. Storage capacity (and cost) is directly proportional to the heat transfer area and the amount of ice that can be generated and stored at full charge per unit of heat transfer area. Similarly, eutectic salt system costs are dominated by components (the salt and its enclosure) that vary directly in size and cost with the required system capacity. The tank or storage vessel represents a relatively small portion of the total TES system cost, so its economies-of-scale are driven by the cost of the salt and its enclosure (U.S. DOE (Department of Energy) 2000).

Available cost data are based on past studies conducted in early 2000 and 2011. The Statewide CASE Team expects that costs reported here are at the high end of the scale. The DOE's FEMP study reported installed cost for ice-on-coil and encapsulated ice storage systems were about $70/ton-hour. The installed cost of eutectic salt storage is about $125/ton-hour. These costs estimates do not include the auxiliary pipes, valves, pumps, instrumentation, controls, and possibly heat exchangers (U.S. DOE (Department of Energy) 2000).

For ice in tank style TES applications in small to medium-sized commercial buildings such as retail stores, LBNL's reported costs averaging $2,170/kW. These types of systems are often deployed at facilities with rooftop air conditioning units in recent years. This is consistent with the Statewide CASE Team's analysis estimates using cost data from manufacturer case studies targeting medium and large-sized retail and cold storage warehouses, that showed a first installed cost of $1,700/kW - $2,200/kW. Costs are anticipated to decline further as TES leverage advanced materials such as phase change materials and sophisticated controls to optimize HVAC system operations.

In their 2015 study, LBNL also analyzed the cost savings and simple payback periods for TES systems across climate zones throughout California. The study modeled existing and new construction office and retail commercial buildings for both full storage and partial storage TES systems. LBNL's analysis showed that annual utility cost savings range from nine percent to 18 percent for TES deployment in large office buildings and seven percent to 18 percent in retail stores, respectively (Rongxin, et al. 2015). Payback periods were either about the same or significantly shorter for new construction compared to existing buildings. For offices, payback periods for new construction ranged from 4.5 to 15 years depending on the utility tariff and whether the TES was deployed for a full day (8 a.m. to 6 p.m.) or during the peak hours (12 p.m. – 6 p.m.). This was similar to the payback periods of existing office buildings, which also ranged from 4.5 to 15 years. Retail facilities produced payback periods of 2.5 to 28 years compared to seven to 35 years for existing buildings depending on the tariff and climate zone modeled.

4.5 First-Year Statewide Impacts

The proposed compliance options for TES do not have any associated energy savings, greenhouse gas emissions reductions, water use impacts, or material impacts.

4.6 Proposed Revisions to Code Language

4.6.1 Guide to Markup Language

The proposed changes to the standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2019 documents are marked with red underlining (new language) and ~~strikethroughs~~ (deletions).

4.6.2 Standards

There are no proposed changes to the standards.

4.6.3 Reference Appendices

NA7.5.14 Thermal Energy Storage (TES) Systems

NA7.5.14.1 Eligibility Criteria

The following types of TES systems are eligible for compliance credit:

(a) Chilled Water Storage

(b) Ice-on-Coil Internal Melt

(c) Ice-on-Coil External Melt

(d) Ice Harvester

(e) Brine

(f) Ice-Slurry

(g) Eutectic Salt

(h) Clathrate Hydrate Slurry (CHS)

(i) Cryogenic

(j) Encapsulated (e.g., Ice Balls)

The following Certificate of Compliance information for both the chiller and the storage tank shall be provided on the plans to document the key TES System parameters and allow plan check comparison to the inputs used in the compliance software.

Chiller:

(k) Brand and Model

(l) Type (Centrifugal, Reciprocating, Other)

(m) Heat Rejection Type (Air, Water, Other)

(n) Charge Mode Capacity (Tons)

(o) Discharge Mode Capacity (Tons)

(p) Discharge Mode Efficiency (kW/Ton or EER)

(q) Charge Mode Efficiency (kW/Ton or EER)

(r) Fluid Type and Percentage

Storage Tank:

(s) Brand and Model

(t) Number of Tanks

(u) Storage Capacity per Tank (ton-hours)

(v) Storage Rate (tons)

(w) Minimum Charging Temperature

(x) Discharge Rate (tons)

(y) Storage Medium Freezing Temperature (°F)

4.6.4 ACM Reference Manual

5.8 HVAC Primary Systems

5.8.8 Thermal Energy Storage

The compliance model inputs below document the requirements to model a chilled water ice, or eutectic salt thermal energy storage system with compliance software. Some systems (e.g., cryogenic, encapsulated ~~ice storage, eutectic salts~~) cannot be modeled with compliance software.

Thermal Energy Storage Systems Type	
Applicability	All thermal energy storage systems
Definition	The type of thermal energy storage system being used. ~~Chilled water storage system is the only currently supported option.~~
Units	List chilled water, Ice-on-Coil Internal Melt, Ice-on-Coil External Melt, Eutectic Salt
Input Restrictions	As designed
Standard Design	Not applicable

Operation Mode Schedule	
Applicability	All thermal energy storage systems
Definition	A schedule which controls operating mode of the thermal energy storage system. A thermal energy storage system can be discharging (supplying ~~chilled water~~ stored thermal energy to meet cooling loads), charging (receiving ~~chilled water~~ extra thermal energy input to be stored for later use), or off. The operation mode schedule specifies one of these modes for each of the 8,760 hours in a year.
Units	Data structure - thermal energy storage mode schedule, specifies charging, discharging, or off on an hourly basis
Input Restrictions	As designed
Standard Design	Not applicable

Rated Capacity	
Applicability	All thermal energy storage systems
Definition	The design cooling capacity of the thermal energy storage system. The rated cooling capacity of the thermal energy storage system is determined by design flow rate of the thermal energy storage system and the temperature difference between the fluid system supply and return water temperature during discharging.
Units	Btu/h
Input Restrictions	As designed
Standard Design	Not applicable

Tank Volume	
Applicability	All thermal energy storage systems
Definition	The volume of water, ice, or mixture held in the thermal energy storage system tank. The tank volume and the rated capacity will determine how long the storage system can meet the load.
Units	Gallons, pounds (lbs.)
Input Restrictions	As designed
Standard Design	Not applicable

Tank Height	
Applicability	All thermal energy storage systems
Definition	For vertical cylinder or rectangular tank, the height will be the maximum internal height of water, ice, or mixture held in the upright storage tank. For horizontal cylinder tank, the height of the storage tank will be the inner diameter of the storage tank.
Units	Feet
Input Restrictions	As designed
Standard Design	Not applicable

Storage Medium Freezing Temperature	
Applicability	All thermal energy storage systems
Definition	This parameter defines the freezing/melting temperature of systems with a storage medium other than chilled water. For ice media, this is simply 32.0 °F. However, some media may use other materials or salts which would change the freezing temperature. This can be changed using this parameter.
Units	°F
Input Restrictions	As designed
Standard Design	Not applicable

4.6.5 Compliance Manual

The Statewide CASE Team recommends updating Section 4.8 Performance Approach of Chapter 4 – Mechanical to include a list of compliance options that are available and what is required to demonstrate compliance with each compliance option. Mark-up language has not been provided because such a change would require updates to the structure of this section content for existing compliance options that are not discussed in this CASE Report. The Statewide CASE Team can work with the Energy Commission to develop compliance manual language if the Energy Commission would like to pursue this recommended revision.

4.6.6 Compliance Documents

Compliance document **NRCC-PRF-01-E** would need to be revised. This change would add an output for "Storage Medium Freezing Temperature" in Section K4. Wet Systems Equipment (boilers, chillers, cooling towers, etc.) as shown below. The "Storage Medium Freezing Temperature" would need to be provided in the plans so that it may be checked against the value used in the simulation for compliance.

K4. Wet System Equipment (boilers, chillers, cooling towers, etc.)												
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Name or Item Tag	**Equipment Type**	**Qty**	**Vol (gal)**	**Rated Capacity (kBtu/h)**	**Efficiency**	**Standby Loss**	**Pumps**				**Storage Medium Freezing Temperature**	**Status**
							GPM	**HP**	**VSD**	**(Y/N)**		
Large Path A Chiller	Centrifugal	NA	NA	6600	kW/ton: 0.56	NA	1	659.7	20	No	NA	N
Medium Path A Chiller	Centrifugal	NA	NA	4200	kW/ton: 0.56	NA	1	419.8	15	No	NA	N
Small Path A Chiller	Centrifugal	NA	NA	2400	kW/ton: 0.635	NA	1	239.9	5	No	NA	N
Thermal Storage	ChilledWater Discharge Priority - Chiller	NA	197771	6600	NA	NA	1	659.7	15	No	32 °F	N
HotWater Loop HW Primary Return	Heating Hot Water, Primary Only	NA	NA	NA	NA	NA	1	749.7	15	Yes	NA	N
Electric HW Boiler	HotWater	NA	NA	5000	Thrml. Eff: 0.98	NA	NA	NA	NA	No	NA	N

Compliance document **CEC-NRCA-MCH-15-A** would also need to be revised. This change would add a check for “Storage Medium Freezing Temperature” under the “TES system Storage” section of the document. The “Storage Medium Freezing Temperature” would need to be provided in the plans so that it may be checked against the value used in the simulation for compliance. This additional check in the acceptance form would ensure that that accurate information is provided.

5. Demand Responsive Control Simplification and Cleanup

5.1 Measure Description

5.1.1 Measure Overview

This submeasure aims to simplify and streamline requirements for demand responsive controls. Section 110.12(a)2 would be amended to allow for any bi-directional communication methods to be used within the building site instead of limiting the allowable communication methods to only Wi-Fi, ZigBee, BACnet, Ethernet, or hard-wiring as 2019 Title 24, Part 6 requires. Sections 110.12(a)3 and 110.12(a)4 would be removed in an effort to simplify code language, removing superfluous language that can be clarified in the compliance manual instead of the code language itself.

Section 110.12(a)3 states that products can have additional communications capabilities than those required to be minimally compliant with code. It is widely understood that codes describe minimum capabilities and additional features are allowed. This code language that explicitly states demand responsive controls can include features that go beyond minimal code compliance adds unnecessary complexity to the code language.

Section 110.12(a)4 states that when communication features of a demand responsive control are disabled or unavailable, the demand responsive control must continue to provide other functions provided by the control. The intent of this language is to confirm that the broader building control system continues to control building systems and meet minimum code compliance even if the demand responsive controls are not enabled or connected. Demand responsive controls are responsible for receiving demand response signals and initiating changes to the control strategies in response to demand response events. The code does not require demand responsive controls to do anything else, so there are no “other” control features that a demand response control must maintain if communication is disabled. Although there are other control requirements in the code, code does not state the “demand responsive control” is responsible for ensuring control requirements are met. If a building is going to comply with code, it has to meet all control requirements. If the communication functionality of the demand responsive control is disabled or reduced, the broader building control system (controlling technologies) are still required to be compliant with the rest of Title 24, Part 6. As such, this language is redundant and adds unnecessary complexity.

5.1.2 Measure History

The requirements in Section 110.2(a) apply to all demand responsive controls used to comply with Title 24, Part 6 and covers how controls must communicate. This section would benefit from some minor revisions to remove complexity and redundancy.

Section 110.12(a)2 was developed to limit stranded assets and the desire prescribe the means to communicate with the component of the DR system that initiates the control strategy to receive the DR signal using non-proprietary communication. Allowing for a greater diversity of communication methods, providing they allow for bi-directional communication, creates a more competitive marketplace. Allowing for a more diverse selection of communication methods that may be better tuned to a facility's specific needs.

5.1.3 Summary of Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manuals, and compliance documents would be modified by the proposed change. See Section 5.6 of this report for detailed proposed revisions to code language.

5.1.3.1 Summary of Changes to the Standards

Section 110.12 – Mandatory Requirements for Demand Management

- **Section 110.12(a)2:** This section would be modified to not limit the communication methods to the five (Wi-Fi, ZigBee, BACnet, Ethernet, or hard-wiring) methods currently listed. Instead the proposed language would expand the communication methods to any system that allow for bi-directional communication. This would maintain existing functionality while opening the market to enabling technology that utilize other communication methods, such as Z-wave, X10, or Bluetooth low energy.
- **Section 110.12(a)3:** This subsection of code would be removed. This language was developed to provide manufacturers with reassurance that they could include additional proprietary protocols. It is widely understood that codes describe minimum capabilities and additional features are allows. This code language that explicitly states demand responsive controls can include features that go beyond minimal code compliance adds unnecessary complexity to the code language.
- **Section 110.12(a)4**: This subsection of code would be removed. This language was developed to address concerns about the functionality of all building controls if the communications features within the demand responsive control were disabled or unavailable. The "demand responsive control" is not responsible for implementing all control requirements specified in the code. If the communication

functionality of the demand responsive control is disabled or reduced, the broader building control system (controlling technologies) are still required to be compliant with the rest of Title 24, Part 6, thus this requirement can be considered redundant.

5.1.3.2 Summary of Changes to the Reference Appendices

The proposed code change would not modify the reference appendices.

5.1.3.3 Summary of Changes to the Nonresidential ACM Reference Manual

The proposed code change would not modify the ACM reference manual.

5.1.3.4 Summary of Changes to the Nonresidential Compliance Manual

The proposed code change would require modifications to **Appendix D Section 1. Communication Requirements for DR Controls** to align with the more expansive view of acceptable communication methods and the remove of specifically allowing additional communications (**Appendix D Section 1.3**) as this section becomes redundant with the proposed language changes.

5.1.3.5 Summary of Changes to Compliance Documents

- **NRCA-LTI-04-A Demand Responsive Lighting Control Acceptance Document:** refinements would be made to align with the modifications to the communication protocol requirements.
- **NRCA-MCH-11-A Automatic Demand Shed Control Acceptance Document:** refinements would be made to align with the modifications to the communication protocol requirements.

5.1.4 Regulatory Context

5.1.4.1 Existing Requirements in the California Energy Code

The existing general communication requirements, in addition to any specific requirements described for different end-uses, for demand responsive controls are in Section 110.12(a). This language states that all demand responsive controls must be a certified OpenADR 2.0a or 2.0b VEN or be certified by the manufacturer as being capable of responding from a certified OpenADR 2.0b VEN. Within the facility, the demand responsive controls shall be capable of communicating using at least one of Wi-Fi, ZigBee, BACnet, Ethernet, of hard-wiring. Other communication protocols may be used as well, but at least one of those five previously listed must be available. If communications to the DR server over OpenADR are disabled or unavailable, the demand responsive controls shall continue to perform all other control functionality provided by the control.

5.1.4.2 Relationship to Requirements in Other Parts of the California Building Code

There are no relevant requirements in other parts of the California Building Code.

5.1.4.3 Relationship to Local, State, or Federal Laws

There are no relevant local, state, or federal laws.

5.1.4.4 Relationship to Industry Standards

The OpenADR 2.0a and 2.0b are communication standards managed by the OpenADR Alliance. The OpenADR Alliance manages the standard and works with other organizations, such as LBNL and the National Institute of Standards and Technology (NIST) to continue improving the functionality and security of the standard. Additionally, they maintain a qualified product list (QPL) of OpenADR certified devices.

Common communication protocols or standards are managed and exist within the IEEE, such as IEEE 802.11 (Wi-Fi), 802.15.4 (ZigBee), and IEEE 802.15.1 (Bluetooth). There are numerous additional existing protocols and standards that are managed both by other organizations or industry members for open and proprietary communication methods.

5.1.5 Compliance and Enforcement

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

The general communication requirements that are being proposed apply to all end-uses of Section 110.12 – Mandatory Requirements for Demand Management. The general activities that need to occur during each phase of the project as they relate to the general communication requirements of Section 110.12(a) are described below:

- **Design Phase:** During the design phase, the lighting of HVAC designer is responsible for ensuring demand responsive controls are incorporated into the design if the facility requires them. This includes ensuring that the VEN being used is OpenADR certified and that a proper communication protocol and/or standard is being used to communication within the controlling technology and with the VEN. The design team documents intent to comply with demand responsive control requirements in the relevant certificate of compliance (NRCC) forms. This includes, but is not limited to, NRCC-LTI-E for indoor lighting, NRCC-MCH-E for HVAC systems, or NRCC-PRF-01-E for the performance approach.

- **Permit Application Phase:** Plans examiner would review design documents and confirm that the design complies with the demand responsive control requirements.
- **Construction Phase:** The demand responsive controls are purchased, installed and commissioned during the construction phase. The details and capabilities of these controls are documented in the relevant certificate of installation (NRCI). The controls must be programmed/configured so the system can automatically implement the control strategy that is tested during the acceptance test using the communication methods denoted in Section 110.12(a). A certified acceptance test technician (ATT) would conduct functional performance testing on the control system to complete required acceptance tests and the commissioning process. The ATT completes the relevant certificate of acceptance (NRCA), such as NRCA-LTI-04-A for indoor lighting and NRCA-MCH-11-A for HVAC systems, to document a passing score on the acceptance test.
- **Inspection Phase:** The building inspector confirms acceptance tests were completed and the appropriate controls were installed to complete those tests by reviewing the NRCA documents during inspection.

The compliance and enforcement process after the proposed code changes remain largely the same. The primary difference from this proposal is that the communication requirements are less restrictive.

5.2 Market Analysis

5.2.1 Market Structure

Communication protocols and standards are often developed and managed through individual non-profit organizations such as the IEEE which manages the IEEE 802.15.4 technical standard which defines the operation of low-rate wireless personal area networks. This technical standard is the basis for communication protocols such as Zigbee and 6LoWPAN. Communication standards and protocols may also be developed through sources of public funding, such as the original OpenADR 1.0 standard which was developed through the Energy Commission Public Interest Energy Research Program. Lastly, many new and innovative communication protocols are developed through individual businesses that seek to implement a protocol that specifically address the needs of their products and the marketplace they their products are trying to influence. Often times these businesses developed protocols that are proprietary and only work with the products from that specific business. All three methods offer value and one method over the other shouldn’t be discouraged where.

5.2.2 Technical Feasibility, Market Availability, and Current Practices

For DR controls to function properly, information must be exchanged between the entity that initiates the DR signal and the building or end-use control system. To facilitate successful communication the signaler and the building control use the same information exchange models (also called communication protocols) to send and receive information. The information exchange model can be thought of as a language; the signaler and the building control system need to speak the same language for the control strategy to be implemented effectively. The communication protocols specify packets of information to be sent, such as event status, event start date/time, event end date/time, override, suppression, and event cancel. Different protocols vary in the richness of functions they can support. Advanced functions include two-way communications between sender and recipient, and remote device telemetry data (e.g., lighting or HVAC setpoints). In California, ADR communications between a facility and the IOUs and SMUD use OpenADR, an internet-based communication standard utilizing extensible markup language (XML). Proprietary communication protocols and standards also exist on the market. These protocols and standards are developed by controls manufacturers such as Automatic Logic Corporation, Johnson Controls, and Honeywell. Proprietary controls can offer even richer sets of functions to serve additional and specific needs of buildings.

OpenADR was initially developed by LBNL in 2002 as version 1.0, with funding from the Energy Commission Public Interest Energy Research Program. LBNL describes OpenADR as a "communications data model designed to facilitate sending and receiving DR signals from a utility or independent system operator to electric customers. The OpenADR specification is a high flexible infrastructure design to facilitate information exchange between a utility or Independent System Operator (ISO) and their end-use participants. The concept of an open specification is intended to allow anyone to implement the signaling system," (OpenADR Alliance 2011). Improvements were made continuously to the protocol over time, and in 2010 the OpenADR Alliance was formed by industry stakeholders "to support the development, testing, and deployment of commercial OpenADR and facilitates its acceleration and widespread adoption," (OpenADR Alliance 2020). OpenADR 2.0 evolved from LBNL work through the NIST Smart Grid Interoperability Panel.

OpenADR is adopted by the California IOUs and SMUD for ADR. The IOU customers must adopt technology solutions that use OpenADR to be eligible for enabling technology incentives. Additionally, DR aggregators who provide DR services to the IOUs receive their dispatch instructions through OpenADR even if their DR communication to customers use a proprietary protocol. Many municipal utilities in California do not yet have ADR programs. With their smaller territories, most municipal utilities have used DR for reliability purposes focusing on their largest customers, calling them and requesting that they voluntarily reduce load.

Oftentimes, control systems within a facility are composed of multiple devices that must communicate information for the control system to work effectively. Typically, separate protocols are used for controls to communicate with a facility. Communications within a facility typically uses a wireless local area network with communication or messaging protocols such as ZigBee, Wi-Fi, or BACnet. Communication between devices in a facility can also be wired (i.e., hard-wiring or through Ethernet).

5.3 Energy Savings

There are no energy savings associated with this code cleanup recommendation.

5.4 Cost Effectiveness

There are no costs associated with this code cleanup recommendation.

5.5 First-Year Statewide Impacts

Updates to communication protocols do not have any associated energy savings, greenhouse gas emissions reductions, water use impacts, or material impacts.

5.6 Proposed Revisions to Code Language

5.6.1 Guide to Markup Language

The proposed changes to the standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2019 documents are marked with red underlining (new language) and ~~strikethroughs~~ (deletions).

5.6.2 Standards

SECTION 110.12 – MANDATORY REQUIREMENTS FOR DEMAND MANAGEMENT

Buildings, other than healthcare facilities, shall comply with the applicable demand responsive control requirements of Sections 110.12(a) through 110.12(d).

(a) Demand responsive controls.

1. All demand responsive controls shall be either:
    A. A certified OpenADR 2.0a or OpenADR 2.0b Virtual End Node (VEN), as specified under Clause 11, Conformance, in the applicable OpenADR 2.0 Specification; or
    B. Certified by the manufacturer as being capable of responding to a demand response signal from a certified OpenADR 2.0b Virtual End Node by automatically implementing the control functions requested by the Virtual End Node for the equipment it controls.
2. All demand responsive controls shall be capable of communicating to the VEN using ~~one or more of the following:~~ Wi-Fi, ZigBee, BACnet, Ethernet, or ~~hard-wiring~~ any other bi-directional communication pathway.

3. ~~Demand responsive controls may incorporate and use additional protocols beyond those specified in Sections 110.12(a)1 and 2.~~
4. ~~When communications are disabled or unavailable, all demand responsive controls shall continue to perform all other control functions provided by the control.~~
5. Demand responsive control thermostats shall comply with Reference Joint Appendix 5 (JA5), Technical Specifications For Occupant Controlled Smart Thermostats.

5.6.3 Reference Appendices

The proposed code change would not modify the reference appendices.

5.6.4 ACM Reference Manual

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

5.6.5 Compliance Manual

Appendix D Section 1 and 1.2 would need to be revised to reflect the proposed changes to Section 110.12(a)2. This includes not limiting the communication methods to only Wi-Fi, ZigBee, BACnet, Ethernet, or hard-wiring but expanding eligible communication to those that communication bi-directionally.

Appendix D Section 1.3 would be removed in its entirety as it becomes unnecessary due to more expansive view of eligible communication methods and the removal of Section 110.12(a)3.

5.6.6 Compliance Documents

NRCA-LTI-04-A the Demand Responsive Lighting Control Acceptance Document Certificate of Compliance would need to have Table A updated to remove the prescriptive list of five communication methods (Wi-Fi, ZigBee, BACnet, Ethernet, and hard-wiring) in favor of bi-directional communication within the proposed language and remove the references to 110.12(a)4 and the language therein.

NRCA-MCH-11-A Automatic Demand Shed Control Acceptance Certificate of Compliance shall implement similar changes to Table A.

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Appendix A: Statewide Savings Methodology

This section presents the methodology, assumptions, and results of the per-unit energy impacts for lighting systems. The code change proposals for HPWHs, TES systems, and communication protocols would not modify the stringency of the Title 24, Part 6. As such, there would be no savings estimated on a per-unit basis for these measures.

To calculate first-year statewide savings, the Statewide CASE Team multiplied the per-unit savings by statewide construction estimates for the first year the standards would be in effect (2023). The projected nonresidential new construction forecast that would be impacted by the proposed code change in 2023 is presented in Table 36. The projected nonresidential existing statewide building stock that would be impacted by the proposed code change as a result of additions and alterations in 2023 is presented in Table 37. This section describes how the Statewide CASE Team developed these estimates.

The Energy Commission Building Standards Office provided the nonresidential construction forecast, which is available for public review on the Energy Commission's website: https://www.energy.ca.gov/title24/participation.html.

The construction forecast presents total floorspace of newly constructed buildings in 2023 by building type and climate zone. The building types included in the Energy Commissions' forecast are summarized in Table 36. This table also identifies the prototypical buildings that were used to model the energy use of the proposed code changes. This mapping was required because the building types the Energy Commission defined in the construction forecast are not identical to the prototypical building types that the Energy Commission requested that the Statewide CASE Team use to model energy use. This mapping is consistent with the mapping that the Energy Commission used in the Final Impacts Analysis for the 2019 code cycle (California Energy Commission 2018).

The Energy Commission's forecast allocated 19 percent of the total square footage of new construction in 2023 to the miscellaneous building type, which is a category for all space types that do not fit well into another building category. It is likely that the Title 24, Part 6 requirements apply to the miscellaneous building types, and savings would be realized from this floorspace. The new construction forecast does not provide sufficient information to distribute the miscellaneous square footage into the most likely building type, so the Statewide CASE Team redistributed the miscellaneous square footage into the remaining building types so that the percentage of building floorspace in each climate zone, net of the miscellaneous square footage, would remain constant. See Table 38 for a sample calculation for redistributing the miscellaneous square footage among the other building types.

After the miscellaneous floorspace was redistributed, the Statewide CASE Team made assumptions about the percentage of newly constructed floorspace that would be impacted by the proposed code change.

Table 39 presents the assumed percentage of floorspace that would be impacted by the proposed code change by building type. If a proposed code change does not apply to a specific building type, it is assumed that zero percent of the floorspace would be impacted by the proposal. If the assumed percentage is non-zero, but less than 100 percent, it is an indication that no buildings would be impacted by the proposal. Table 40 presents percentage of floorspace assumed to be impacted by the proposed change by climate zone.

All sixteen climate zones would be impacted by this measure with the floor space for new construction and alterations, the percent of impacted square footage, as shown in Table 40, is limited by the spaces that must comply with these proposed measures. There are three exemptions, the first two apply to new construction and alteration square footage while the third only applies to alteration spaces: 1) square footage that is expected to have an LPD less than or equal to 0.5 watts per square foot is excluded, 2) square footage that fell below the proposed total design wattage threshold, and 3) alterations square footage that is less or equal to 80 percent of their allowed LPD, per the exemption of Title 24, Part 6 Section 141 (b)2Iii. The assumptions that led to the defined fraction of impacted square footage includes the field survey of expected LPD for installations and square footage building allocation and size across California as detailed in Table 19 and the Commercial Buildings Energy Consumption Survey (EIA (Energy Information Administration) 2016). Food, refrigerated warehouse, medium office/lab, and public assembly prototypes were not available for analysis. In order to include the affect square footage in this analysis the energy cost savings associated with the other building models were attributed to these four building models. The expected energy savings per square foot, TDV energy savings per square foot, and peak demand reduction for the 12 building models analyzed was averaged and attributed to each of the four building models that were not analyzed. The square footage where the demand responsive measure is applicable for a prototype was more targeted where applicable as the prototype facility designs were expected to be more similar than the average of all analyzed prototypes. Food used the average of all four retail and the quick service restaurant prototypes; refrigerated warehouse used non-refrigerated warehouse; public assembly and medium office/lab used the average of all 12 building models that were analyzed.

Table 36: Estimated New Nonresidential Construction Impacted by Proposed Code Change in 2023, by Climate Zone and Building Type (Million Square Feet)

Climate Zone	New Construction in 2023 (Million Square Feet)											
	Small Office	Restaurant	Retail	Food	Non-Refrigerated Warehouse	Refrigerated Warehouse	School	College	Hospital	Hotel/ Motel	Large Office	TOTAL
1	0.02	0.01	0.12	0.03	0.08	0.01	0.05	0.041	0	0.01	0.13	0.50
2	0.09	0.04	0.71	0.17	0.50	0.04	0.32	0.242	0	0.08	0.52	2.71
3	0.34	0.18	3.21	0.70	2.59	0.19	1.32	1.159	0	0.36	4.10	14.14
4	0.17	0.09	1.65	0.35	1.33	0.09	0.67	0.599	0	0.19	1.73	6.86
5	0.04	0.02	0.34	0.07	0.25	0.02	0.14	0.114	0	0.04	0.40	1.43
6	0.24	0.18	2.27	0.50	1.97	0.06	0.71	0.709	0	0.21	2.27	9.12
7	0.32	0.12	1.60	0.42	1.16	0.01	0.75	0.532	0	0.23	1.29	6.43
8	0.31	0.26	3.26	0.71	2.84	0.09	0.98	1.030	0	0.30	3.97	13.75
9	0.51	0.43	5.07	1.09	4.51	0.13	1.37	1.819	0	0.46	7.71	23.10
10	0.42	0.32	3.16	0.77	3.74	0.08	1.35	0.744	0	0.26	1.54	12.39
11	0.11	0.04	0.64	0.19	0.68	0.07	0.35	0.187	0	0.05	0.36	2.69
12	0.58	0.20	3.46	0.79	3.37	0.23	1.49	1.075	0	0.30	3.49	14.98
13	0.24	0.09	1.36	0.40	1.18	0.18	0.78	0.368	0	0.10	0.57	5.27
14	0.08	0.07	0.74	0.17	0.80	0.03	0.28	0.185	0	0.06	0.50	2.91
15	0.08	0.03	0.42	0.13	0.58	0.02	0.19	0.086	0	0.04	0.18	1.74
16	0.03	0.02	0.24	0.06	0.24	0.02	0.11	0.061	0	0.02	0.15	0.95
TOTAL	3.58	2.10	28.25	6.55	25.81	1.28	10.85	8.95	0	2.70	28.91	118.99

Table 37: Estimated Existing Nonresidential Floorspace Impacted by Proposed Code Change in 2023 (Alterations), by Climate Zone and Building Type (Million Square Feet)

Climate Zone	Altered Floorspace in 2023 (Million Square Feet)											
	Small Office	Restaurant	Retail	Food	Non-Refrigerated Warehouse	Refrigerated Warehouse	School	College	Hospital	Hotel/ Motel	Large Office	TOTAL
1	0.39	0.16	2.69	0.64	1.89	0.14	1.52	1.101	0	0.28	3.36	12.16
2	2.29	0.93	15.98	3.79	11.24	0.82	9.03	6.537	0	1.69	19.94	72.24
3	8.45	3.78	71.44	15.50	57.03	4.10	37.45	30.735	0	7.69	108.39	344.56
4	4.24	1.92	36.46	7.82	29.10	2.07	19.05	15.851	0	3.96	56.61	177.09
5	0.93	0.40	7.55	1.68	5.57	0.43	3.93	3.087	0	0.79	10.38	34.75
6	6.14	4.23	57.79	12.89	50.99	1.75	25.28	20.511	0	4.98	73.25	257.82
7	7.77	2.68	41.40	10.85	28.83	0.33	19.92	15.086	0	5.36	47.76	179.99
8	8.11	6.11	82.45	18.09	72.57	2.52	35.27	29.434	0	6.85	108.37	369.79
9	12.98	10.08	126.60	27.36	113.46	3.68	53.55	50.505	0	10.63	191.10	599.94
10	11.13	8.37	90.66	21.58	105.27	2.30	40.51	22.488	0	6.12	50.14	358.56
11	2.73	0.90	15.71	4.58	17.18	1.66	9.80	5.132	0	1.10	9.67	68.48
12	13.17	4.32	81.50	18.75	75.18	5.54	41.42	28.304	0	6.38	87.15	361.71
13	5.97	2.03	33.32	9.84	28.58	4.31	22.33	10.235	0	2.10	14.41	133.13
14	2.20	1.79	20.60	4.74	22.14	0.78	9.17	5.542	0	1.32	15.07	83.35
15	2.02	0.87	12.18	3.57	15.99	0.44	5.38	2.496	0	0.93	4.80	48.67
16	0.85	0.49	6.32	1.61	6.53	0.46	3.33	1.783	0	0.40	3.89	25.67
TOTAL	89.36	49.04	702.67	163.28	641.55	31.33	336.94	248.83	0	60.60	804.29	3,127.90

Table 38: Example of Redistribution of Miscellaneous Category - 2023 New Construction in Climate Zone 1

Building Type	2023 Forecast (Million Square Feet) [A]	Distribution Excluding Miscellaneous Category [B]	Redistribution of Miscellaneous Category (Million Square Feet) [C] = B × [D = 0.145]	Revised 2023 Forecast (Million Square Feet) [E] = A + C
Small Office	0.036	7%	0.010	0.046
Large Office	0.114	21%	0.031	0.144
Restaurant	0.015	3%	0.004	0.020
Retail	0.107	20%	0.029	0.136
Grocery Store	0.029	5%	0.008	0.036
Non-Refrigerated Warehouse	0.079	15%	0.021	0.101
Refrigerated Warehouse	0.006	1%	0.002	0.008
Schools	0.049	9%	0.013	0.062
Colleges	0.027	5%	0.007	0.034
Hospitals	0.036	7%	0.010	0.046
Hotel/Motels	0.043	8%	0.012	0.055
Miscellaneous **[D]**	0.145	---	0.000	---
TOTAL	0.686	100%	0.147	0.686

Table 39: Percent of Floorspace Impacted by Proposed Measure, by Building Type

Building Type *Building Sub-Type*	**Composition of Building Type by Subtypes**[a]	**Percent of Square Footage Impacted**[b]	
		New Construction	**Existing Building Stock (Alterations)**[c]
Small Office		33%	18%
Restaurant		39%	21%
Retail		89%	47%
Stand-Alone Retail	10%	55%	29%
Large Retail	75%	100%	53%
Strip Mall	5%	55%	29%
Mixed-Use Retail	10%	55%	29%
Food		78%	41%
Non-Refrigerated Warehouse		86%	46%
Refrigerated Warehouse		78%	41%
Schools		95%	51%
Small School	60%	95%	51%
Large School	40%	95%	51%
College		71%	38%
Small Office	5%	33%	18%
Medium Office	15%	100%	53%
Medium Office/Lab	20%	95%	51%
Public Assembly	5%	95%	51%
Large School	30%	95%	51%
High-Rise Apartment	25%	0%	0%
Hospital		0%	0%
Hotel/Motel		25%	13%
Offices		100%	53%
Medium Office	50%	100%	53%
Large Office	50%	100%	53%

a. Presents the assumed composition of the main building type category by the building subtypes. All 2022 CASE Reports assumed the same percentages of building subtypes.

b. When the building type is composed of multiple subtypes, the overall percentage for the main building category was calculated by weighing the contribution of each subtype.

c. Percent of existing floorspace that would be altered during the first year the 2022 standards are in effect.

Table 40: Percent of Floorspace Impacted by Proposed Measure, by Climate Zone

Climate Zone	Percent of Square Footage Impacted	
	New Construction	Existing Building Stock (Alterations)[a]
1	100%	100%
2	100%	100%
3	100%	100%
4	100%	100%
5	100%	100%
6	100%	100%
7	100%	100%
8	100%	100%
9	100%	100%
10	100%	100%
11	100%	100%
12	100%	100%
13	100%	100%
14	100%	100%
15	100%	100%
16	100%	100%

a. Percent of existing floorspace that would be altered during the first year the 2022 standards are in effect.

Appendix B: Embedded Electricity in Water Methodology

There are no on-site water savings associated with the proposed code change.

Appendix C: Environmental Impacts Methodology

Greenhouse Gas (GHG) Emissions Factors

As directed by Energy Commission staff, GHG emissions were calculated making use of the average emissions factors specified in the United States Environmental Protection Agency (U.S. EPA) Emissions & Generation Resource Integrated Database (eGRID) for the Western Electricity Coordination Council California (WECC CAMX) subregion (United States Environmental Protection Agency 2018). This ensures consistency between state and federal estimations of potential environmental impacts. The electricity emissions factor calculated from the eGRID data is 240.4 Metric Tons CO2e per GWh. The summary table from eGRID 2016 reports an average emission rate of 529.9 pounds CO2e/MWh for the WECC CAMX subregion. This value was converted to metric tons/GWh.

Avoided GHG emissions from natural gas savings attributable to sources other than utility-scale electrical power generation are calculated using emissions factors specified in Chapter 1.4 of the U.S. EPA's Compilation of Air Pollutant Emissions Factors (AP-42) (United States Environmental Protection Agency 1995). The U.S. EPA's estimates of GHG pollutants that are emitted during combustion of one million standard cubic feet of natural gas are: 120,000 pounds of CO_2 (Carbon Dioxide), 0.64 pounds of N_2O (Nitrous Oxide) and 2.3 pounds of CH_4 (Methane). The emission value for N_2O assumed that low NOx burners are used in accordance with California air pollution control requirements. The carbon equivalent values of N_2O and CH_4 were calculated by multiplying by the global warming potentials (GWP) that the California Air Resources Board used for the 2000-2016 GHG emission inventory, which are consistent with the 100-year GWPs that the Intergovernmental Panel on Climate Change used in the fourth assessment report (AR4). The GWP for N_2O and CH_4 are 298 and 25, respectively. Using a nominal value of 1,000 Btu per standard cubic foot of natural gas, the carbon equivalent emission factor for natural gas consumption is 5,454.4 metric tons per million therms.

GHG Emissions Monetization Methodology

The 2022 TDV energy cost factors used in the lifecycle cost-effectiveness analysis include the monetary value of avoided GHG emissions based on a proxy for permit costs (not social costs). To demonstrate the cost savings of avoided GHG emissions, the Statewide CASE Team disaggregated the value of avoided GHG emissions from the other economic impacts. The authors used the same monetary values that are used in the TDV factors – $106.20 per metric ton CO_2e.

Water Use and Water Quality Impacts Methodology

There are no on-site water savings associated with the proposed code change.

Appendix D: California Building Energy Code Compliance (CBECC) Software Specification

Introduction

The purpose of this appendix is to present proposed revisions to the compliance software, specifically the California Building Energy Code Compliance software for Commercial buildings (CBECC-Com), along with the supporting documentation that the Energy Commission staff and the technical support contractors would need to approve and implement the software revisions.

Appendix D1: Demand Responsive Lighting Systems

There are no recommended revisions to the compliance software as a result of this code change proposal for lighting systems.

Appendix D2: Load Shifting Compliance Options for HPWH

The Statewide CASE Team recommends providing compliance credit for HPWHs with load shifting. Implementation of demand management capabilities for HPWH systems within compliance software is an ongoing effort for both residential and nonresidential buildings. The implementation of demand management control strategies for residential buildings is expected to be added CBECC-Res 2019 by the end of 2020. The Statewide CASE Team recommends collaborating with software development team that is implementing changes to CBECC-Res for residential applications as revisions for CBECC-Com are developed.

D.2.1 Technical Basis for Software Change

HPWHs can flex or shift when they make hot water with minimal impacts to facility occupants. Water heating manufacturers have grid-connected HPWHs on the market for residential applications and are developing grid-connected commercial models in response to increasing market demand. CBECC-Com allows designers to select and take credit for using a HPWH. However, the current software does not include capabilities to simulate the impacts of load shifting with grid-connected HPWHs. In this section, the Statewide CASE Team discusses modeling enhancements needed to offer compliance credit for grid-connected HPWHs.

D.2.2 Description of Software Change

D.2.2.1 Background Information for Software Change

Modeling capabilities to support HPWHs with load shifting is more developed for residential compliance software compared to nonresidential compliance software. Further data gathering, testing and software development are needed to implement a credible modeling tool of both unitary and central HPWHs in nonresidential buildings. To achieve the goal of offering credit in the 2022 cycle the Statewide CASE team has provided alternative approaches until the necessary software is available, as well as recommended next steps for ensuring a viable model for these systems is created.

Additionally, the Statewide CASE Team is recommending an updated user interface in the compliance software to complement the model enhancements discussed above. The interface would support user choice of load management for HPWHs. How that interface would affect compliance documents has been included in the following sections and throughout this report.

The proposed new user input in CBECC-Com would specify the type of “Control” for connected nonresidential HPWH. The control options would align with those provided in Joint Appendix 13 (i.e., Basic, Load up, Time-of-use, Advanced DR etc.). The user interface for HPWH would be like that of the batteries measure in CBECC-Com with a drop down for the user to select their control strategies. A mockup of the updated HPWH user interface is drafted below in Figure 8.

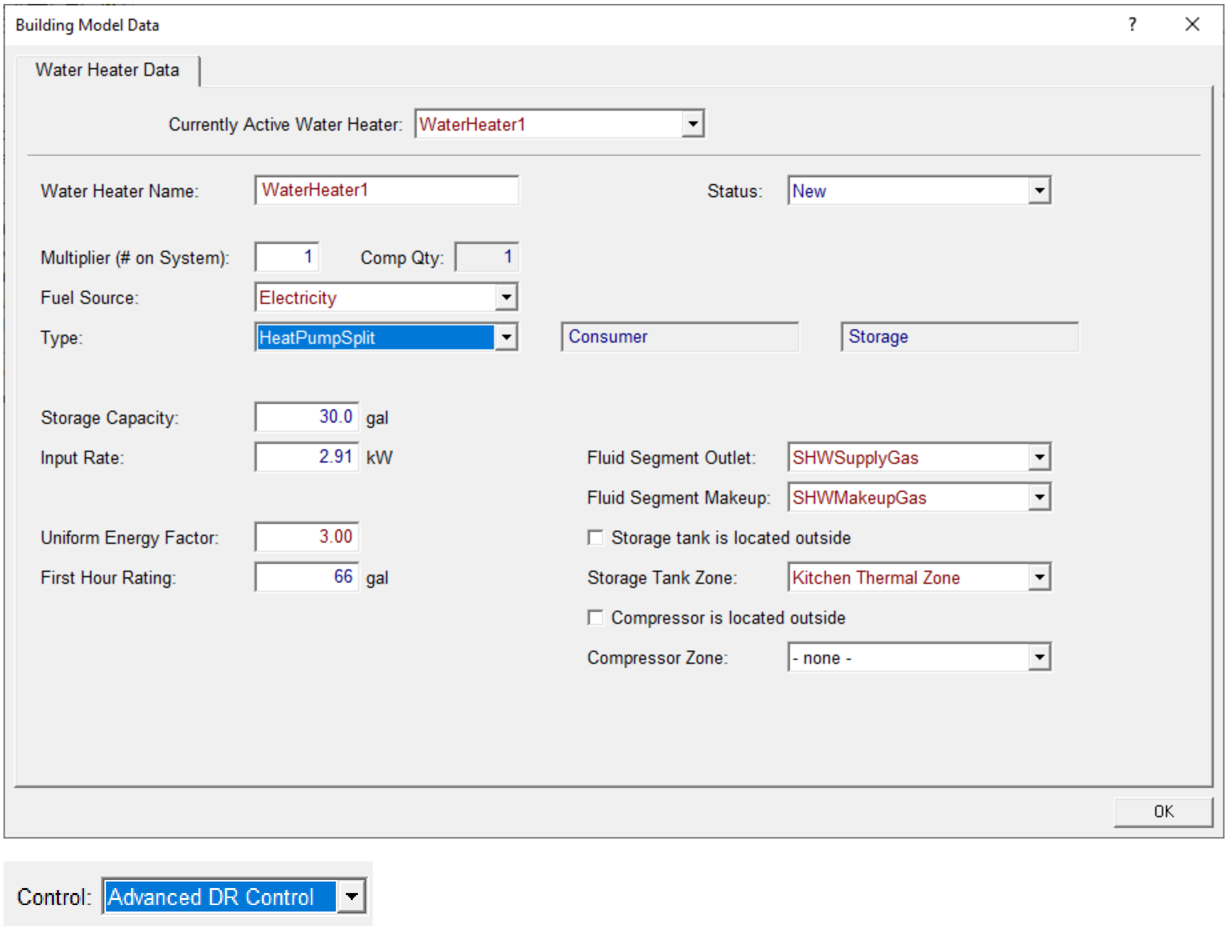

Figure 8. Proposed addition to compliance software for HPWH measure.

HPWH systems can be designed for all nonresidential building types in all California climate zones. The proposed CBECC-Com feature would be available for use in all nonresidential building types and climate zones.

D.2.2.2 Existing CBECC-Com Modeling Capabilities

HPWHs for service hot water (SHW) systems in nonresidential spaces are supported in CBECC-Com 2019.1.1, which uses the EnergyPlus simulation engine. Domestic hot water (DWH) systems serving residential space types (e.g., Hotel/Motel Guest Room and High-Rise Residential Living Spaces) are simulated in CBECC-Com using the California Simulation Engine (CSE). A physics-based, preliminary HPWH model was developed for CSE to support the CBECC-Res 2022 Research Version software. This dual-engine environment complicates modeling efforts, as EnergyPlus and CSE produce different outputs for a given set of inputs due to differences in modeling algorithms. One major difference is the water draw profiles. The SHW draw profiles used in CBECC-Com for nonresidential spaces resemble a more traditional, yet less accurate approach to estimate water heating energy where water consumption is averaged on an hourly basis throughout the day. In reality, hot water draws are discrete and intermittent events (on and off) that can cause water heaters to operate in recovery mode where they are less efficient. The lack of fidelity in the CBECC-Com draw profiles reduces the accuracy of the simulation, especially for HPWH systems which are more sensitive to high flow, short duration events. This limits the ability to estimate SHW energy savings resulting from shifting hot water usage to different times of the day based on TDV. The DHW draw profiles used in CSE were updated in 2016 and reflect more realistic intermittent consumption patterns. However, these draw profiles are currently only developed for the residential space types simulated in CSE.

CBECC-Com is currently unable to model varying domestic hot water setpoint schedules. The model assumes a constant setpoint temperature of 135 °F. This limitation also prevents performance credits for grid-connected HPWHs. When the model was first created for CBECC-Com 2016, the limitation was accepted by developers on the assumption that domestic hot water consumption in commercial buildings are insignificant compared to residential hot water consumption. According to Energy Information Administration's end use consumption surveys, however, commercial hot water consumption is 507 trillion Btus or 30 percent of residential consumption of 1,745 trillion Btus. As the prevalence of grid-connected WHs and HPWHs grows, there will be an increasing need for accurate modeling capabilities, including varying domestic hot water setpoint and consumption schedules.

D.2.2.3 Recommended Project Plan for Nonresidential HPWH Load Shifting Inclusion

The Statewide CASE team recommends that before load shifting can be accurately modeled in CBECC-Com and the underlying engine (EnergyPlus), several enhancements to CBECC-Com are needed to simulate the benefits of grid controlled HPWHs:

- **Update Nonresidential hot water draw schedules.** As noted in D.2.2.2 above, Currently, the Statewide CASE Team does not have access to updated water draw studies or actual water draw site data. It is crucial that these draw profiles are updated to more accurately evaluate energy savings associated with load shifting. The default water draw profiles need to be updated for each nonresidential space type based on actual domestic hot water usage data. Ideally, the draw profiles would be based on actual data collected across a statistically significant sample across commercial building types and climate zones.
- **Lab testing to support simulation of nonresidential unitary and central HPWHs.** This testing would measure the performance of a range of equipment with varying temperature setpoint adjustments for load management operations and develop modeling parameters for nonresidential unitary and central HPWHs. The following and other questions would be tested to better quantify savings and

impacts. For example: What is the demand and how much energy is used to achieve setpoint temperatures specified during load up? How long does it take a unit sized for nonresidential unit to "load up" to the specified load up temperature? How long to deplete the water heated during load up? The goals of this testing are to establish performance maps so the HPWH systems can be integrated into the software simulation engine.

- **Test and optimize load shifting savings.** Algorithms behave differently when optimized against either the TDV used in CBECC-Com simulation or to the TOU prices set by utilities. One may optimize cost to the customer while another may optimize grid impacts. Both methods need to be tested to understand which is more impactful.
- **Collect data on HPWH operation with load management in nonresidential applications.** The goal of the assessment would be to study actual and preferred load management strategies used in nonresidential buildings, and user acceptance. Separate studies would need to be conducted for unitary and central HPWH systems. The assessment would also study effect of load shifting on building operations and customer satisfaction.
- **Collaborate directly with EnergyPlus software support team to implement findings from above studies.** Since EnergyPlus is the underlying engine used in compliance modelling in (CBECC-Com). A revision and enhancement to the existing heat pump water heater model is recommended. A research version of CBECC-Com including the proposed enhancements would need to be developed before implementation in the final certified version of the software.
- **Investigate field research findings on central HPWH performance optimization strategies.** Significant research has been completed in recent years to assess how best to configure central HPWH systems in larger non-residential buildings. Sizing and location of storage tanks, specification of tank setpoints, piping insulation and various strategies to address recirculation losses are all key elements in optimizing system efficiency. Understanding the operational impacts of these various system designs are useful to further inform modeling enhancements for nonresidential HPWH load shifting control.

D.2.2.4 Alternate Approaches to Compliance Credit

Since the recommended steps for modeling would take significant time to complete, it is beneficial to explore alternate options for compliance credit to encourage accelerated adoption of this emerging technology. Some strategies that may be used to provide credit outside of modeling directly in CBECC-Com could include:

- A simplified credit that provides a percentage reduction in water heater energy use when installing HPWH with load shifting capabilities according to JA13. Analysis would need to be conducted to determine the appropriate percentage.
- Use either the CSE engine or Ecotope's HPWH Sim software to model HPWH load shifting in nonresidential buildings. This strategy would require thorough assessment of each software and testing to understand if this is possible.

D.2.2.5 Summary of Proposed Revisions to CBECC-Com

Several enhancements to CBECC-Com are needed to simulate the benefits of grid controlled HPWHs. A research version of CBECC-Com including the proposed enhancements would need to be developed before implementation in the final certified version of the software. First, water draw profiles must be reviewed and updated in order to estimate energy consumption accurately, as noted above. The ongoing End Use Load Profiles[19] project led by National Renewable Energy Laboratory (NREL) may help inform the development of improved hot water draw profiles that could be used to update the draw profiles in CBECC-Com. The Statewide CASE Team will continue to monitor the progression of this work however updating draw profiles is currently outside of the scope of this CASE Report. While the Statewide CASE Team recognizes a need for improvements, existing service hot water use schedules may be used to implement preliminary load shifting simulation.

Second, a schedule function needs to be added to allow users to modify water setpoint temperatures by time of day for each control option. The temperature setpoint may be used to simulate the load up and shedding events associated with controls strategies described in JA13.

Demonstration projects and lab testing could be leveraged to determine the appropriate parameters to utilize for simulating load up and shed options, and then apply a schedule set by the appropriate algorithm for each climate zone to estimate the energy savings. Once some of the research steps listed in the section above have been completed, recommended specifications for load shifting algorithms can be developed.

Third, distinguishing time of day operation based on the selected control strategy is a challenge since CBECC-Com does not directly have access to specific TOU schedules as set by utilities. To overcome this the CASE Team proposes a load shifting schedule and TOU simulation approach like that of the nonresidential batteries compliance option to be utilized directly in CBECC-Com. It is the Statewide CASE Teams expectation that creating algorithms optimized to TOU schedules would provide the most benefit to building owners. However, it may be shown that optimizing using TDV values proves more valuable from the perspective of greenhouse gas emissions reductions and grid reliability. As algorithms are developed both approaches should be tested to find the best solution. These algorithms would be designed to incorporate the water heater use to decide when shifting is appropriate much as batteries consider battery and solar photovoltaic use.

D.2.3 User Inputs to CBECC-Com

The expected changes to the software would require just one additional input form the user. This input would dictate which control strategy the user intends to implement.

Table 41: Proposed CBECC-Com User Input

CBECC-Com Input Name	Function	Input Options	Data Type	Units
Control	This input would dictate which algorithm to use when calculating domestic hot water energy use	None, Basic, Time-of-Use, Advanced DR Control	Enumerated List	N/A

This table details the user input proposed in Figure 8.

D.2.4 EnergyPlus Inputs

There is not an equivalent EnergyPlus or CSE input for the control user input. EnergyPlus or CSE would need to be updated to add inputs or the control algorithms would be implemented directly to CBECC-Com.

D.2.5 Simulation Engine Output Variables

There are no anticipated new output variables at this time. The effects of the control strategy selected would be reflected in the total TDV of the domestic hot water end use of the simulation.

D.2.6 Compliance Report

The control method selected by the user would be indicated in the NRCC-PRF-01-E document in a “Control Strategy (Heat Pump Water Heaters Only)” field as column 12 in Section K5. DHW Equipment Summary. Marked up language for this change can be found in Section 2.6.5

D.2.7 Description of Changes to ACM Reference Manual

Please refer to Section 3.6.4 for recommended updated code language for the Nonresidential ACM Reference Manual.

Appendix D3: Thermal Energy Storage

D.3.1 Technical Basis for Software Change

TES systems are an increasingly popular tool to manage Nonresidential HVAC demands. Currently the only system type included in the performance software is chilled water systems. The Reference Appendices recognizes numerous system types as eligible for a compliance credit, yet they cannot be modelled in CBECC-Com. The system updates recommended in this Final CASE Report would improve the software to be more in line with the reference appendices and include other common system types as identified by stakeholders and market enactors including ice-on coil internal and external melt and Eutectic salt type systems.

D.3.2 Description of Software Change

D.3.2.1 Background Information for Software Change

Currently appendix NA7.5.14 lists the following types of TES Systems as eligible for compliance credit:

(a) Chilled Water Storage
(b) Ice-on-Coil Internal Melt
(c) Ice-on-Coil External Melt
(d) Ice Harvester
(e) Brine
(f) Ice-Slurry
(g) Eutectic Salt
(h) Clathrate Hydrate Slurry (CHS)
(i) Cryogenic
(j) Encapsulated (e.g., Ice Balls)

However only chilled Water Storage systems are currently included in CBECC-Com and thus are the only available system type for those seeking compliance through the performance approach.

TES Systems can be designed for all nonresidential building types in all California climate zones. The CBECC-Com feature proposed in this appendix would be available for use in all nonresidential building types and climate zones.

D.3.2.2 Existing CBECC-Com Modeling Capabilities

- CBECC-Com utilizes the ThermalStorage:ChilledWater:Stratified Energy Plus object to model chilled water TES systems.
- The TES schedule is set by the user as separate object. The user can specify charging, discharging and off states for the system.

The current software is only able to model one type of storage system while stakeholder engagement and market research has indicated that other storage types are popular in the market. The compliance software needs to be updated to include more storage types to reflect a diverse market.

Figure 9 and Figure 10 show the current user interface and inputs for the chilled water storage system and TES schedule.

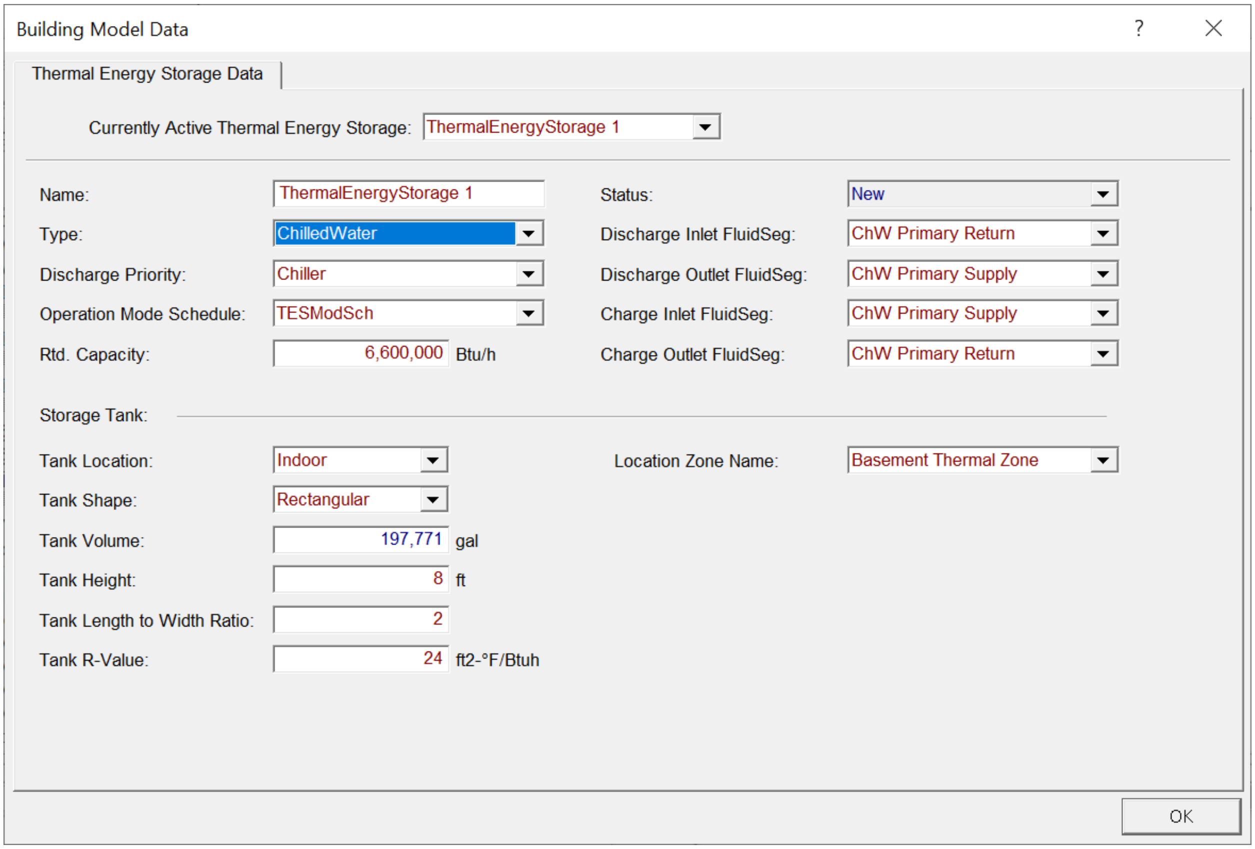

Figure 9. Current thermal energy storage object user inputs and data in CBECC-Com.

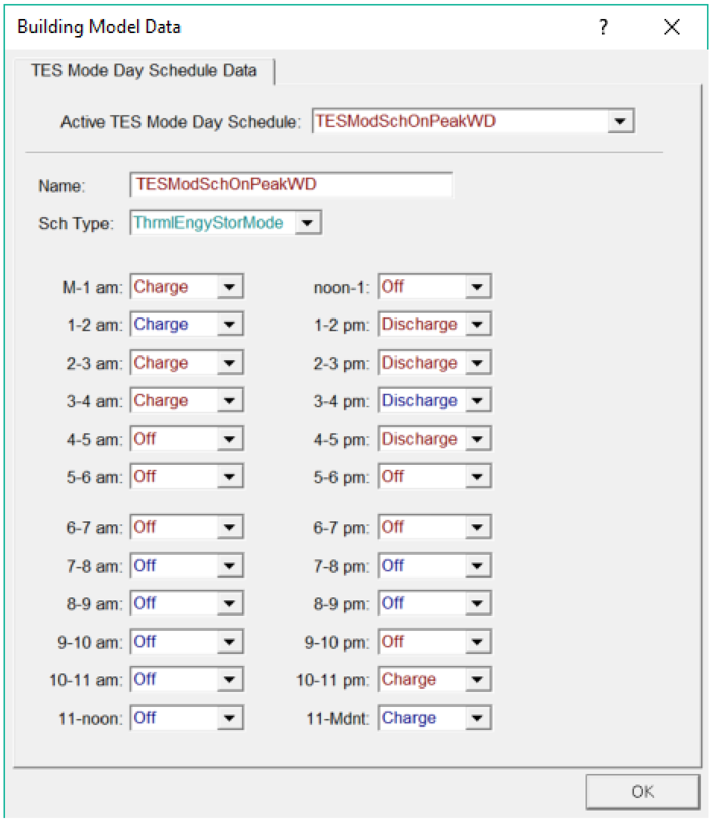

Figure 10. User input for TES schedule.

The Statewide CASE Team is recommending the addition of the following system types to the drop-down menu for system type. A final list is pending further research on the applicability of the EnergyPlus ThermalStorage:Ice:Detailed model for mediums other than ice and eutectic mixes (phase change materials, Clathrate Hydrate Slurry (CHS), Encapsulated, etc.). This EnergyPlus object could be used to simulate the following TES systems that are already eligible for compliance credit, per Section NA7.5.14 of the Nonresidential Appendix:

- Ice-on-Coil Internal Melt
- Ice-on-Coil External Melt
- Eutectic Salt

These system types would be modelled in CBECC-Com via the addition of the ThermalStorage:Ice:Detailed object type from EnergyPlus. This feature would be integrated into CBECC-Com in the same way that the existing ThermalStorage:ChilledWater:Stratified object is implemented. A comparable feature specification can be provided if further detail is needed past what is detailed in this appendix D. More detailed information on how ThermalStorage:Ice:Detailed interacts with the simulation engine can be found in the Input Output Reference Guide for EnergyPlus (Software n.d.).

The EnergyPlus object used by the simulation would be determined based on the user input for the “Type” field with Chilled water storage corresponding to the ThermalStorage:ChilledWater:Stratified and all other options corresponding to the ThermalStorage:Ice:Detailed model. Required user inputs would also differ based on which system type the user selects. Inputs for the ThermalStorage:Ice:Detailed object are detailed in the following section of this report.

The updated user experience is laid out in Figure 11 below.

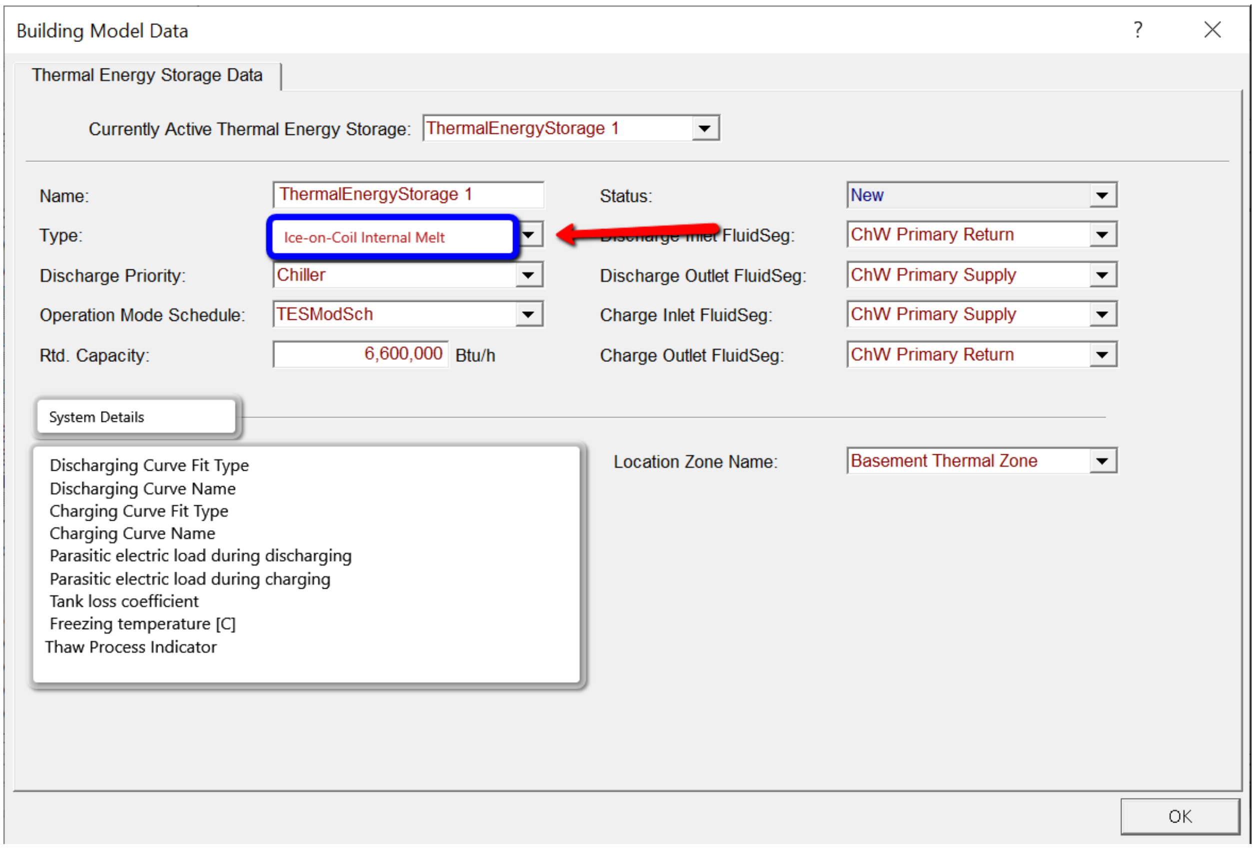

Figure 11. Example of Thermal Energy Storage Object user inputs and data in an updated CBECC-Com.

D.3.3 User Inputs to CBECC-Com

Table 42: EnergyPlus User Inputs Relevant to Ice and Eutectic Salt Thermal Storage

CBECC-Com Input Name	Function	Input Options	Data Type	Units
Parasitic electric load during discharging	This field defines the amount of parasitic electric consumption (for controls or other miscellaneous electric consumption associate with the ice storage unit itself) during the discharge phase. This parameter is dimensionless and gets multiplied by the current load on the tank.		Decimal	dimensionless and gets multiplied by the current load on the tank.
Parasitic electric load during charging	This field defines the amount of parasitic electric consumption (for controls or other miscellaneous electric consumption associate with the ice storage unit itself) during the charge phase. This parameter is dimensionless and gets multiplied by the current load on the tank.		Decimal	dimensionless and gets multiplied by the current load on the tank.
Tank loss coefficient	This field defines the loss of ice stored during a particular hour. This field is dimensionless (per hour). It is not multiplied by any temperature difference between the tank and the environment in which it might be located.		Decimal	dimensionless
Freezing temperature [C]	This parameter defines the freezing/melting temperature of the ice storage medium in ° Fahrenheit. For most tanks, this is simply 0.0 °C (the default value). However, some tanks may use other materials or salts which would change the freezing temperature. This can be changed using this parameter.	Ice-on-Coil Internal Melt: 0 Ice-on-Coil External Melt: 0 Eutectic Salt: User specified	Decimal	°C

CBECC-Com Input Name	Function	Input Options	Data Type	Units
Thaw Process Indicator	This input field assists in more accurate modeling of the charging process by defining how the thawing of ice takes place. There are two options for this input: InsideMelt and OutsideMelt. Some ice storage systems, by their nature, start the charging process with a bare coil or no ice left on the charging surface even though there is still ice stored in the tank. An example of such a system is sometimes referred to as an ice-on-coil inside melt system, and these systems would define this parameter using the “InsideMelt” option for this field. Other systems melt the ice from the outside, leaving ice still on the charging surface when charging begins. These systems are modeled using the “OutsideMelt” option. For systems that have a charging process that does not vary significantly with fraction charged can ignore this input by accepting the default value. The default value for this field is “OutsideMelt”.	Ice-on-Coil Internal Melt: InsideMelt, Ice-on-Coil External Melt: OutsideMelt Eutectic Salt: N/A	String	

D.3.4 Simulation Engine Inputs

D.3.4.1 EnergyPlus/California Simulation Engine Inputs

Table 43 provides recommended translation information for generating EnergyPlus inputs from CBECC-Com generated data. EnergyPlus input and outputs were found in the Input Output reference document put together by Big Ladder Software (Software n.d.)

Table 43: EnergyPlus Input Variables Relevant to Ice and Eutectic Salt Thermal Storage

EnergyPlus Object= ThermalStorage:Ice:Detailed **Applicable if** System Type = Ice-on-Coil Internal Melt, Ice-on-Coil External Melt, Eutectic Salt			
EnergyPlus Field	**CBECC-Com user** input/specified value (if applicable)	**Units**	**Notes**
Ice Storage Name	Thermal Energy Storage Systems Name specified by user		
Ice Storage availability schedule	ON		This does not dictate charging/ discharging - just availability. ON means always available
Ice Storage Capacity	Rated Capacity	GJ	
Plant Loop Inlet Node	Created by OS		
Plant Loop Outlet Node	Created by OS		
Discharging Curve Fit Type	QuadraticLinear		EnergyPlus Default
Discharging Curve Name	DischargeCurve		User shouldn't see this so it shouldn't matter
Charging Curve Fit Type	QuadraticLinear		EnergyPlus Default
Charging Curve Name	ChargeCurve		User shouldn't see this so it shouldn't matter
Timestep of Curve Fit Data	1	Hours	
Parasitic electric load during discharging	Created by OS		
Parasitic electric load during charging	Created by OS		
Tank loss coefficient	Created by OS		
Freezing temperature [F]	0, Created by OS	F	This dictates the medium (water vs salts etc.) 32 for water - specified for Eutectic
Thaw Process Indicator	InsideMelt, OutsideMelt		The default value for this field is "OutsideMelt".

```
ThermalStorage:Ice:Detailed,
    Ice Tank,                !- Ice Storage Name
    ON,                      !- Ice Storage availability schedule
    0.5,                     !- Ice Storage Capacity {GJ}
    Ice Tank Inlet Node,     !- Plant Loop Inlet Node
    Ice Tank Outlet Node,    !- Plant Loop Outlet Node
    QuadraticLinear,         !- Discharging Curve Fit Type
    DischargeCurve,          !- Discharging Curve Name
    QuadraticLinear,         !- Charging Curve Fit Type
    ChargeCurve,             !- Charging Curve Name
    1.0,                     !- Timestep of Curve Fit Data
    0.0001,                  !- Parasitic electric load during discharging
    0.0002,                  !- Parasitic electric load during charging
    0.0003,                  !- Tank loss coefficient
    0.0;                     !- Freezing temperature [C]
```

Figure 12. Example EnergyPlus input for a ThermalStorage:Ice:Detailed.

D.3.4.2 Alternate Configurations

The ice storage model may not be applicable to all other storage mediums specified in NA7.5.14 and system types such as CHS, Encapsulated, and Cryogenic are not expected to be supported after this update.

D.3.5 Simulation Engine Output Variables

The new object should produce similar outputs of interest to the existing chilled water object.

Table 44: EnergyPlus Outputs: ThermalStorage:Ice:Detailed Object

Output	Description
Ice Thermal Storage Requested Load [W]	The load requested by the plant control scheme. A positive value indicates a cooling load or a request to discharge (melt) the tank. A negative value indicates a request to charge (freeze) the tank.
Ice Thermal Storage End Fraction []	The fraction of full ice storage which is present at the end of the current HVAC timestep. When reported at a frequency less than detailed, this value is averaged over the reporting period.
Ice Thermal Storage Mass Flow Rate [kg/s]	The total water mass flow rate through the ice storage component. Because the component includes an implied 3-way valve, this flow may be all through the tank, all bypassed through the valve, or a mixture of both.
Ice Thermal Storage Inlet Temperature [C]	The water temperature entering the ice storage component.
Ice Thermal Storage Outlet Temperature [C]	The water temperature leaving the ice storage component.
Ice Thermal Storage Cooling Discharge Rate [W]	The rate of cooling delivered by the ice storage component. A positive value indicates the ice tank is discharging (melting). A zero value indicates the tank is charging or dormant.
Ice Thermal Storage Cooling Discharge Energy [J]	The cooling energy delivered by the ice storage component. A positive value indicates the ice tank is discharging (melting). A zero value indicates the tank is charging or dormant.
Ice Thermal Storage Cooling Charge Rate [W]	The rate of charging delivered to the ice storage component. A positive value indicates the ice tank is charging (freezing). A zero value indicates the tank is discharging or dormant.
Ice Thermal Storage Cooling Charge Energy [J]	The charging energy delivered to the ice storage component. A positive value indicates the ice tank is charging (freezing). A zero value indicates the tank is discharging or dormant.

D.3.6 Calculated Values, Fixed Values, and Limitations

Energy Plus inputs for the ThermalStorage:Ice:Detailed Freezing temperature input is in ° Celsius while CBECC-Com utilizes the standard temperature measurement of Fahrenheit. Because of this the CBECC-Com user input would prompt users for the storage medium freezing temperature in Fahrenheit and this value would need to be converted to Celsius before use in the Energy Plus model.

$$T_{(°C)} = (T_{(°F)} - 32) / 1.8$$

The original user entered temperature in ° Fahrenheit would be what is used on compliance reports and documents.

D.3.7 Compliance Report

The compliance report NRCC-PRF-01-E would need to be updated to reflect this CBECC-Com change. An additional output for "Storage Medium Freezing Temperature" would be added in Section K4. Wet Systems Equipment (boilers, chillers, cooling towers, etc.). The "Storage Medium Freezing Temperature" would need to be provided in the plans so that it may be checked against the value that the user entered as "Freezing temperature [F]" for compliance. Marked up language for this change can be found in Section 4.6.5.

D.3.8 Compliance Verification

All installed TES systems must be verified by completion of an acceptance test detailed in reference appendix NA7.5.14.2. Section 4.1.5 of this report has further details on the compliance verification process. Compliance document CEC-NRCA-MCH-15-A must be completed for all TES systems.

D.3.9 Testing and Confirming CBECC-Com Modeling

Testing should be completed to ensure newer system types in EnergyPlus produce expected results. Further the Statewide CASE Team intends to support the software team in further testing as the newer EnergyPlus model is integrated into compliance software.

D.3.10 Description of Changes to ACM Reference Manual

Please refer to Section 4.6.4for recommended updated code language for the Nonresidential ACM Reference Manual.

Appendix E: Impacts of Compliance Process on Market Actors

This appendix discusses how the recommended compliance process, which is described in Sections 2.1.5, 3.1.5, 4.1.5, and 5.1.5. could impact various market actors. Table 45, Table 46,

Table 47, and Table 48 identify the market actors who would play a role in complying with the proposed change, the tasks for which they would be responsible, their objectives in completing the tasks, how the proposed code change could impact their existing work flow, and ways negative impacts could be mitigated. The information contained in these tables are a summary of key feedback the Statewide CASE Team received when speaking to market actors about the compliance implications of the proposed code changes. Appendix F summarizes the stakeholder engagement that the Statewide CASE Team conducted when developing and refining the code change proposal, including gathering information on the compliance process.

Table 45: Roles of Market Actors in the Proposed Compliance Process: Demand Responsive Lighting Systems

Market Actor	Tasks In Compliance Process	Objectives in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Facility Owner/Occupant	• Initiates project. • Coordinates with designer and contractors to approve design and construction. • Ongoing maintenance of controls system once project is completed. • Enables DR controls and signs up to participate in DR programs.	• Occupy constructed facility within schedule timeframe and budget parameters. • Experience energy benefits as modeled • Experience a comfortable, functionally optimized facility.	Reevaluating the cost-effectiveness threshold and changing the exemption to focus on installed lighting would allow for most cost-effective implementation resulting in lower costs and higher savings for owners and occupants.	• Educate owner/occupants so they understand the building's DR capabilities and are aware of how to enable controls and enroll in DR programs so they can realize the energy and energy cost benefits of lighting DR. • Create a resource that would educate owner/occupants of Title 24 compliant DR controls, the benefits of participating in DR programs, how to enroll, and the non-energy benefits of DR lighting enabling technologies.

Market Actor	Tasks In Compliance Process	Objectives in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Lighting Designer & Electricians (Design / Build)	• Design systems to meeting Title 24, Part 6 requirements. • Specify DR controls in construction documents • Complete compliance document, NRCC-LTI-E.	• Ensure that the lighting system meets the facility owner's needs. • Complete within budget and on schedule. • Implement the DR measure requirements in a cost-effective manner. • Ensure system is Title 24, Part 6 compliant • Provide controls so that owners/occupants may be able to enroll in DR programs and realized energy and cost benefits. • Understand triggers for DR requirement for new construction separate from alterations due to existing alterations exemptions.	• Replacing the 10,000 square foot exemption with a more direct "total design wattage" of the lighting system would allow for most cost-effective implementation. • Would require careful consideration of chosen fixtures and whether a configuration triggers this requirement, compared to the 2019 code language which would be trigger by the space size regardless of the number and power of installed fixtures. • Linking the 0.5 watts per square foot exemption to the multi-level lighting exemption would show where the limitation in DR implementation lies. Linking these two may ease compliance for lighting designers as it is simpler to understand which fixtures are exempt from multi-level and DR lighting.	• Train designers to know where to find compliant control systems, such as the DLC networked lighting controls QPL or the OpenADR QPL. • Train designers on best practices for implementing effective and non-disruptive demand responsive lighting. • Conduct outreach to confirm lighting designers understand DR control requirements and how building with DR controls can benefit the owners/occupants, utilities, and grid managers. • Add resources related to DR requirements to Energy Code Ace. • Further delineate compliance documents or provide training to highlight the potential importance of delineating between installed wattage that is less than or equal to the watts per square foot threshold.

Market Actor	Tasks In Compliance Process	Objectives in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Builder / Contractor	• Build systems exactly as designed to meet code. • Purchase system from retailers/distributors. • Provide lighting control capabilities to owner/occupant. • Coordinate with other market actors, including acceptance testers and commissioning authority.	• Complete tasks within budget and on schedule. • Installed system is Title 24, Part 6 compliant as designed.	• Increase likelihood of plans and specifications correctly reflecting DR requirements for contractors to follow by more clearly stating DR lighting operational requirements.	• Define roles and responsibilities of who would educate owner/occupant on DR lighting capabilities of their facility. • Add resources related to DR lighting requirements and acceptance testing to Energy Code Ace.
Acceptance Testers (ATT) and Commissioning Authority (ATTCP)	• Ensuring that a simulated signal is available that meets the open ADR criteria. • Ensuring that the DR measure complies with the acceptance test to dim the lighting power at least an area-weighted 15 percent. While also maintaining minimum output if a DR signal is sent while the lighting level is set at the minimum lighting output pre-event. • ATTCPs provide training to ATTs to complete NRCAs and meet NA7 testing procedures.	• Ensure that all ATTs understand the acceptance test and the expectations of the facility therein. • Compliance demonstrated on first visit and with minimal disruption.	• Clarification of the acceptance test requirements between the reference appendices and the standards language should ease compliance as it would allow designers to fully understand the expectations of the DR lighting requirement. • By including an additional whole building test method, the proposed verification method can expedite acceptance testing for applicable buildings.	• Add resources related to DR lighting requirements and acceptance testing to Energy Code Ace. • Update training materials for ATTCPs so they received the necessary training to complete the DR acceptance test correctly.

Market Actor	Tasks In Compliance Process	Objectives in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Building Inspector	Confirmed proper installation and Title 24, Part 6 documentation.	Only one site visit required per inspection item.	No changes to workflow.	Add resources related to DR lighting requirements and acceptance testing to Energy Code Ace.
Lighting Controls Manufacturers and Service Providers	Provide compliant equipment to marketplace to allows for effective lighting DR and OpenADR certified communication.	• Provide equipment that is compatible with DR incentive programs. • Sell equipment that owners/occupants can enable with straightforward controls and use to enroll in DR programs.	No changes to workflow.	Create simplified method to set lighting DR scene or measures based on dimming requirements of the acceptance test.
California Energy Commission	Code development.	Gain better understanding of how Title 24 compliant buildings are participating in DR programs, or what barriers exist that limit participation, to inform future code changes.	Linking DR lighting exemption thresholds with the lighting wattage under control may remove a previously existing cost-effective barrier for facilities that exceeded the 2019 Title 24, Part 6 square footage threshold but had a low wattage under control. Removing this barrier would allow future code improvements to address newly identified barriers or focus on identified quantifiable non-energy benefits.	Provide frequently asked questions document for DR lighting implementation.

Table 46: Roles of Market Actors in the Proposed Compliance Process: Compliance Option for HPWH Demand Management Systems

Market Actor	Tasks In Compliance Process	Objectives in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Designer / Engineer	• Identify relevant requirements and/or compliance path. • Perform required calculations by space to confirm compliance. • Coordinate design with other team members (lighting and modeler). • Complete compliance document for permit application. • Review submittals during construction. • Coordinate with commissioning agent/ATT as necessary.	• Quickly and easily determine requirements based on scope. • Demonstrate compliance with calculations required for other design tasks. • Clearly communicate system requirements to constructors. • Quickly complete compliance documents. • Easily identify noncompliant substitutions. • Minimize coordination needed during construction.	• Need to evaluate this as an EE measure. • Designers may be hesitant to design because they aren't as familiar with load shifting operation.	Spread the word this is a new compliance credit option.

Market Actor	Tasks In Compliance Process	Objectives in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Architect	• Keeping the project within budget. • Determine best pathway for showing compliance considering all building features by working with designer and energy consultant.	N/A	• May require additional infrastructure & footprint for HPWH systems. • Need to be aware of time-of-use (TOU) or dynamic rate schedules.	Architects would need to be trained on identifying additional space necessary for these systems.
Energy Consultant/ Modeler	Support design team to provide guidance on energy code requirements on methods to show compliance.	Utilize compliance method determined by team to be the best method for the project and complete compliance documentation (certificate of compliance NRCC).	• Need to evaluate this as an EE measure. Used to be able to take more credit for this but wasn't implemented in CBECC software. It's been on the list, but as a relatively low priority. • Under 2019 Title 24, Part 6, many of the common trade-offs went away. So, adding more compliance options would be a plus to industry. Many times, people are trading off for a lower performing envelope. However, it's relatively expensive system type to trade off for envelope features. Right now, industry is using these systems for high-performance buildings to meet other goals such as stretch codes or LEED, etc.	• Outreach for modelers to understand this is an option for credit. • Modeling software would need to be updated to include proposed values. Software training updates.

Market Actor	Tasks In Compliance Process	Objectives in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Plans Examiner	Confirm that plan set and compliance documents are supporting each other, and that compliance is achieved.	Verify that controls have been included in the design and sizing requirements are met.	• Need to be aware of sizing and layout requirements of HPWH • Need to be aware of time-of-use (TOU) or dynamic rate schedules.	More education for plans examiners to understand what to look for and check it meets prescriptive requirements.
The California Energy Commission	Provide compliance documents and compliance software supporting code requirements and options.	• Provide mechanical system forms to support HPWH implementation • Support for incorporation of measures into compliance software • Support field data collection as needed to update compliance software modeling algorithms	• Updating TDV values to give more credit for load shifting or demand responsive operation of equipment. HPWH isn't implemented well in software currently because less about when they're charging & discharging. HPWH with grid connectivity too has additional advanced charging & discharging operating modes. • Need to think about NRCA form & how the different methods would be reflected. NRCA forms would need to be completed through ATTCP.	• Ensure compliance documents clearly identify how these building features are being documented • Compliance software includes updated algorithms to make measure successful

Market Actor	Tasks In Compliance Process	Objectives in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Contractors	• Bid and install building features per the design documents (plan set/specifications/compliance documents). • Keep project in budget and on time. • Build and warranty work. • Provide certificate of installation compliance documents (NRCI) to support installed features meet the promise of the plan set/specifications/compliance documents (NRCC).	Provide submittals to design team to confirm installed features meet plan set/specifications/compliance documents.	• Need to understand load shifting configuration for HPWH models that they install. • May need to configure or program temperature setpoint schedule to align with utility TOU or dynamic rates at system startup for unitary models. • For central HPWH systems, coordinate how equipment needs to be installed correctly between trades. • Coordination of technology with building management system if applicable. • Implement commissioning procedure for central systems.	• Provide contractor trainings to gain familiarity with load shifting control strategy and qualified equipment for load shifting HPWH. • Communicate load shifting or TOU setup and configuration options with builder and homeowner.
ATT / ATTCP	Verify installed controls are working per the testing criteria as supported by the certificate of acceptance (NRCA) and communicate with installing contractor if there are any “failed” controls.	Provide submittals to design team to confirm installed features meet plan set/specifications/compliance documents.	• Currently there are no acceptance testing procedures for boilers. Develop ATT for load shifting HPWH systems. • No acceptance testing technicians (ATT) for boilers currently.	Training and certification for additional ATT to initiate the load shifting HPWH requirements.

Market Actor	Tasks In Compliance Process	Objectives in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Building Inspector	• Confirm building is meeting plan set/specifications/compliance documents. • Confirm NRCI and NRCA compliance documents have been completed and make available to building owner.	N/A	Verify that the acceptance testing happened to fully realize the load shifting measure.	NRCA form for domestic hot water needs to be developed.

Table 47: Roles of Market Actors in the Proposed Compliance Process: Compliance Options for Thermal Energy Storage

Market Actor	Tasks In Compliance Process	Objectives in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Designer/Engineer	Same as HPWH	Same as HPWH	Same as HPWH	N/A
Architect	Same as HPWH	Same as HPWH	Same as HPWH	N/A
Energy Consultant/ Modeler	Same as HPWH	Same as HPWH	• Select appropriate TES object when modeling using CBECC-Com • Simulate TES operating schedule using utility TOU or dynamic rates	Provide training on compliance model new features and education on utility dynamic rates
Plans Examiner	Same as HPWH	Same as HPWH	No impact to existing work flow	N/A
California Energy Commission	Same as HPWH	Same as HPWH	No impact to existing work flow	N/A
Contractors	Same as HPWH	Same as HPWH	No impact to existing work flow	N/A
ATT/ ATTCP	Same as HPWH	Same as HPWH	No impact to existing work flow	N/A
Building Inspector	Same as HPWH	Same as HPWH	No impact to existing work flow	N/A

Table 48: Roles of Market Actors in the Proposed Compliance Process: Demand Responsive Control Simplification and Cleanup

Market Actor	Tasks In Compliance Process	Objectives in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Facility Owner / Occupant	• Initiates project. • Coordinates with designer and contractors to approve design and construction. • Ongoing maintenance of controls system once project is completed. • Enables DR controls and signs up to participate in DR programs.	• Occupy constructed facility within schedule timeframe and budget parameters. • Experience energy benefits as modeled • Experience a comfortable, functionally optimized facility.	More enabling technologies may be available for selection during the design phase.	• Educate owner/occupants so they understand the building's DR capabilities and are aware of how to enable controls and enroll in DR programs so they can realize the energy and energy cost benefits of DR. • Create a resource that would educate owner/occupants of Title 24 compliant DR controls, the benefits of participating in DR programs, how to enroll, and the non-energy benefits of DR.

Market Actor	Tasks In Compliance Process	Objectives in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
HVAC, Electrical, and Lighting Designer & Electricians (Design / Build)	• Design systems to meeting Title 24, Part 6 requirements. • Specify DR controls in construction documents • Complete relevant compliance document.	• Ensure that the system meets the facility owner's needs. • Complete within budget and on schedule. • Implement the DR measure requirements in a cost-effective manner. • Ensure system is Title 24, Part 6 compliant • Provide controls so that owners/occupants may be able to enroll in DR programs and realized energy and cost benefits. • Understand triggers for DR requirement for new construction separate from alterations due to existing alterations exemptions.	More enabling technologies may be available for selection during the design phase.	• Train designers to know where to find compliant control systems, such as the or the OpenADR QPL. • Conduct outreach to confirm designers understand DR control requirements and how building with DR controls can benefit the owners/occupants, utilities, and grid managers. • Add resources related to DR requirements to Energy Code Ace.
Builder/Contractor	• Build systems exactly as designed to meet code. • Purchase system from retailers/distributors. • Provide lighting control capabilities to owner/occupant. • Coordinate with other market actors, including acceptance testers and commissioning authority.	• Complete tasks within budget and on schedule. • Installed system is Title 24, Part 6 compliant as designed.	No changes to workflow	• Define roles and responsibilities of who would educate owner/occupant on DR lighting capabilities of their facility. • Add resources related to DR lighting requirements and acceptance testing to Energy Code Ace.

Market Actor	Tasks In Compliance Process	Objectives in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Acceptance Testers (ATT) and Commissioning Authority (ATTCP)	• Ensuring that there is a signal that meets the open ADR criteria. • Ensuring that the DR measure complies with the relevant acceptance test. • ATTCPs provide training to ATTs to complete NRCAs and meet NA testing procedures.	• Ensure that all ATTs understand the acceptance test and the expectations of the facility therein. • Compliance demonstrated on first visit and with minimal disruption.	Allows for a broader range of technology to comply with the Title 24, Part 6.	• Add resources related to DR communication requirements and acceptance testing to Energy Code Ace. • Update training materials for ATTCPs so they received the necessary training to complete the DR acceptance test correctly.
Building Inspector	Confirmed proper installation and Title 24, Part 6 documentation.	• Only one site visit required per inspection item.	No changes to workflow.	Add resources related to DR lighting requirements and acceptance testing to Energy Code Ace.
HVAC and Lighting Controls Manufacturers and Service Providers	Provide compliant equipment to marketplace to allows for effective DR and OpenADR certified communication.	• Provide equipment that is compatible with DR incentive programs. • Sell equipment that owners/occupants can enable with straightforward controls and use to enroll in DR programs.	No changes to workflow.	Create simplified method to set lighting DR scene or measures based on dimming requirements of the acceptance test.
California Energy Commission	Code development.	• Gain better understanding of how Title 24 compliant buildings are participating in DR programs, or what barriers exist that limit participation, to inform future code changes.	No changes to workflow.	Provide frequently asked questions document for DR implementation and the communication requirements.

Appendix F: Summary of Stakeholder Engagement

Collaborating with stakeholders that might be impacted by proposed changes is a critical aspect of the Statewide CASE Team's efforts. The Statewide CASE Team aims to work with interested parties to identify and address issues associated with the proposed code changes so that the proposals presented to the Energy Commission in this Final CASE Report are generally supported. Public stakeholders provide valuable feedback on draft analyses and help identify and address challenges to adoption including cost effectiveness; market barriers; technical barriers; compliance and enforcement challenges; or potential impacts on human health or the environment. Some stakeholders also provide data that the Statewide CASE Team uses to support analyses.

This appendix summarizes the stakeholder engagement that the Statewide CASE Team conducted when developing and refining the recommendations presented in this report.

Utility-Sponsored Stakeholder Meetings

Utility-sponsored stakeholder meetings provide an opportunity to learn about the Statewide CASE Team's role in the advocacy effort and to hear about specific code change proposals that the Statewide CASE Team is pursuing for the 2022 code cycle. The goal of stakeholder meetings is to solicit input on proposals from stakeholders early enough to ensure the proposals and the supporting analyses are vetted and have as few outstanding issues as possible. To provide transparency in what the Statewide CASE Team is considering for code change proposals, during these meetings the Statewide CASE Team asks for feedback on:

- Proposed code changes
- Draft code language
- Draft assumptions and results for analyses
- Data to support assumptions
- Compliance and enforcement, and
- Technical and market feasibility

The Statewide CASE Team hosted two stakeholder meetings for demand responsive lighting via webinar. Please see below for dates and links to event pages on Title24Stakeholders.com. Materials from each meeting. Such as slide presentations, proposal summaries with code language, and meeting notes, are included in the bibliography section of this report.

Meeting Name	Meeting Date	Event Page from Title24stakeholders.com
First Round of Nonresidential Grid Integration Utility-Sponsored Stakeholder Meeting	Tuesday, September 10, 2019	https://title24stakeholders.com/event/grid-integration-utility-sponsored-stakeholder-meeting/
Second Round of Lighting Utility-Sponsored Stakeholder Meeting	Tuesday, March 3, 2020	https://title24stakeholders.com/event/lighting-utility-sponsored-stakeholder-meeting-2/

The first round of utility-sponsored stakeholder meetings occurred from September to November 2019 and were important for providing transparency and an early forum for stakeholders to offer feedback on measures being pursued by the Statewide CASE Team. The objectives of the first round of stakeholder meetings were to solicit input on the scope of the 2022 code cycle proposals; request data and feedback on the specific approaches, assumptions, and methodologies for the energy impacts and cost-effectiveness analyses; and understand potential technical and market barriers. The Statewide CASE Team also presented initial draft code language for stakeholders to review.

The second round of utility-sponsored stakeholder meetings occurred from March to May 2020 and provided updated details on proposed code changes. The second round of meetings introduced early results of energy, cost-effectiveness, and incremental cost analyses, and solicited feedback on refined draft code language.

Utility-sponsored stakeholder meetings were open to the public. For each stakeholder meeting, two promotional emails were distributed from info@title24stakeholders.com One email was sent to the entire Title 24 Stakeholders listserv, totaling over 1,900 individuals, and a second email was sent to a targeted list of individuals on the listserv depending on their subscription preferences. The Title 24 Stakeholders' website listserv is an opt-in service and includes individuals from a wide variety of industries and trades, including manufacturers, advocacy groups, local government, and building and energy professionals. Each meeting was posted on the Title 24 Stakeholders' LinkedIn page[20] (and cross-promoted on the Energy Commission LinkedIn page) two weeks before each meeting to reach out to individuals and larger organizations and channels outside of the listserv. The Statewide CASE Team conducted extensive personal outreach to stakeholders identified in initial work plans who had not yet opted into the listserv.

[20] The Title 24 Stakeholders' LinkedIn page can be found here: https://www.linkedin.com/showcase/title-24-stakeholders/.

Exported webinar meeting data captured attendance numbers and individual comments, and recorded outcomes of live attendee polls to evaluate stakeholder participation and support.

Statewide CASE Team Communications

The Statewide CASE Team held personal communications over email and phone with numerous stakeholders when developing this report. This included other energy efficiency advocates, such as the California Energy Alliance and the California Lighting Technology Center (CLTC) who represent and have direct contact with numerous stakeholders. Early proposals were discussed with a large group of lighting stakeholders who attended an energy seminar at sixteen5hundred, a lighting manufacturer rep, as well as discussions from individuals who expressed interest or concern in the topic through the stakeholder meeting process.

Additionally, two surveys were conducted to better capture lighting stakeholder input. The Statewide CASE Team coordinated with Evergreen Economics to distribute a lighting survey concerned numerous lighting topics in late 2019 through early 2020. There were 62 respondents to the survey, 35 of which responded to questions relating to their designed lighting wattage relative to their allowable lighting power density. The respondents were primarily lighting designers. The result of this survey is noted throughout the CASE Report as the results were valuable to the energy savings analysis. Additionally, the Statewide CASE Team, through CLTC, conducted a survey of lighting acceptance technicians through two acceptance test organizations: The National Lighting Contractors Association of America (NLCAA) and California Advanced Lighting Controls Training Program (CALCTP). This survey was conducted from February through March 2020 and asked questions relating to DR lighting, occupancy sensor lighting, and daylighting. Specifically, for DR lighting, the survey asked about the length of time it takes to complete the DR lighting acceptance test, if the 50 percent illuminance threshold was appropriate or useful, and if the uniformity requirement (Table 130-A) was useful for appropriate. The DR lighting aspect of the survey had 115 respondents that responded that they have completed a demand responsive lighting controls acceptance test.

The Statewide CASE Team is proposing to remove the 50 percent illuminance but has received stakeholder opinions to remove as well as keep this requirement. During the second stakeholder meeting on March 3rd, 2020, a survey was conducted where the majority of the respondents, 60 percent, wished to remove this threshold. This position has been espoused by the CEA. The acceptance test technician survey resulted in the contrary position, with 71 percent of respondents indicating this threshold was useful or appropriate. After considering of both positions, the Statewide CASE Team is continuing to propose to remove the 50 percent illuminance threshold.

Additionally, the majority of acceptance test technicians, 73 percent of respondents, found the reference to the table of uniformity, 130.1-A, useful or appropriate.

Appendix G: Other Measures Considered

The nonresidential grid integration team considered many approaches and technologies to grid integration for the 2022 codes cycle. Compiled here is a summary of considerations and findings that prevented consideration for implementation in the 2022 code cycle

Compressor Capacity Control for Load Management (HVAC)

The proposal involves adding variable-speed compressors control testing as an additional option to automated demand shed controls acceptance test procedure under section NA7.5.10. This would only be applicable to variable speed HVAC systems. Based on past projects, including the VRF Market Characterization Study conducted for SCE in 2018, the Statewide CASE Team assumed initially that compressor speed control was continuously variable due to use of variable frequency drives and therefore would be better able to maintain occupant comfort while flexibly meeting needs of the grid. It was also assumed that compressor speed control would not adversely impact multi-split and VRFs because it was a part of their normal operating condition.

One other advantage of the compressor control is it directly impacts kW demand and energy requirements of the HVAC. It has the potential to precisely change HVAC load. Thermostats setpoint control, by contrast, indirectly effects kW demand for load management since the occupant is changing the temperature which then signals the HVAC system to react to meet the new setpoint. This may or may not result in kW change to the HVAC system, particularly as systems get more complex (fans and dampers, chilled water pumps, etc.)

Email and phone conversations with a few VRF manufacturers raised the question of compressor speed control versus compressor capacity limiting. It became apparent that existing VRF equipment could limit the compressor capacity to specific levels (e.g., 75 percent or 50 percent of rated capacity). However existing equipment did not have controls to set compressor speeds. Rather, the compressor adjusts its speed in response to a setpoint command from the thermostat, based on black-box control algorithms proprietary for each manufacturer. Following this feedback, the proposed measure was adjusted from compressor speed control to compressor capacity limit control ahead of the 1st stakeholder meeting.

Discussion

One barrier to compressor capacity limiting is that it would impact all the zones served by the outdoor unit. A critical zone calling for more cooling/heating may not be able to meet the comfort needs if the compressor capacity is capped. A few manufacturers the

Statewide CASE Team interviewed commented that capacity limiting is not continuously variable like compressor speed, and the control sophistication varies among manufacturers. A few manufacturers have bi-level 0-50-100 control only while other manufacturers have more sophisticated granular control.

VRF systems and multi-splits could experience similar challenges as rooftop units of lacking load to shed or increase because they are already operating at reduced (or maximum) capacity when a utility sends an event notification. If the outdoor unit is already running at 45 percent of full capacity, that's below the 50 percent capacity control limit setting. The HVAC system and the building would experience no incremental load reduction if a DR event was called. A relative capacity limit control would be preferred, where a VRF system would reduce by 50 percent (or some other value) relative to the operating capacity at the time the DR event is called.

Trane and AHRI supported a whole-system approach where the HVAC system executes a load reduction strategy (Braddy 2019). This suggestion is indistinct from relying on zone controllers to call for a setpoint change and allowing the HVAC system to react. There were also concerns that only controlling compressors would affect warranties, health and safety such as flammability of refrigerants. The latter claim should be followed up with testing to verify (Petrillo-Groh 2019).

Finally, Beth Braddy of Ingersoll-Rand highlighted that the capacity limiting control for load management would need to be developed (Braddy 2019). This comment is consistent with other VRF manufacturer interviews. While multi-splits and VRF systems can limit compressor capacity, these capabilities were developed for reasons other than load management (i.e., efficiency, noise control). The application of capacity limiting to the load management use case requires further technology development by manufacturers.

Recommendations and Next Steps

The intent of this change is to make it easier for code-compliant buildings to participate in day-to-day load management and DR events. The goal of the Statewide CASE Team for the grid integration topic is to move new construction in the direction of being more grid responsive and to be capable of day-to-day load management. Consider options to achieve the overall intent of the code change proposal. One is adding a compliance option that provides extra credit to systems that are installed and programmed to offer day-to-day load management. VRF modeling assumptions and performance curves should be reviewed to check that compliance software accounts for load management strategies appropriately. Feedback from VRF manufacturers indicated a desire for more specific guidance from utilities and regulations on the load response desired associated with a specific load management signal sent from the utility. This could involve developing a joint appendix, similar to JA13 and how it treats HPWHs with load management features. Additionally, the Statewide CASE Team could work with a national standards organization such as AHRI to develop a technical specification that can be incorporated by Title 24, Part 6. AHRI Standard 1380 is an existing technical specification for DR for residential variable capacity HVAC systems. A similar standard should be considered for development by a consortium of utilities, consumers, manufacturers, and technical experts nationwide. Utilities could conduct lab of VRFs and other variable speed systems to support the standards development and acceptance testing procedures. In addition to load management performance capabilities of VRF equipment and mini-splits, testing can verify whether outdoor units have limitations on managing critical zones versus non-critical zones in a capacity limited state. Testing can also be conducted to collect data on impact of compressor capacity limiting control on other VRF system components

Demand Response for Outdoor Lighting

In the 2019 Title 24, Part 6 only indoor lighting requires DR controls under certain conditions (as specified in Section 110.12). Since the adoption of DR lighting requirements across building types in 2013, the highest value time dependent valuation hours have shifted to later in the evening compared to mid-day. This shift highlighted the potential for outdoor lighting, that do not typically operate during daylight hours, to serve as a valuable flexible resource.

While evaluating the potential for this measure, a significant barrier was observed. The 2019 Standards require occupancy sensors for hardscape exterior lighting in the majority of conditions while the multi-level lighting requirement for the same spaces only require a single dimming step between 50 and 90 percent dimmed between the maximum output and off. Meaning that if a DR event were to be initialized and the space was occupied, the DR measure would move from the maximum output lighting level to the single step dimming lighting level. Depending on the maximum output and the level of dim within the 50 to 90 percent range, this could create an unsafe lighting environment according to the IES RP-20-14 recommend lux levels. Similarly, if the space was unoccupied and operating at the single step dimmed level, the only reduction a DR measure could enact would be to shut the lighting level off entirely. Potentially creating an unsafe environment if the Statewide CASE Team anticipates the space to become occupied as people are less likely to venture towards the area of complete darkness. For these safety concerns, the measure was ultimately dropped.

This measure should be reevaluated if more than a single level of dimming is required for hardscape areas in future code cycles as this may help alleviate the safety concerns regarding lux levels.

DC-DC Circuitry Credit when PV and Battery Storage are installed on site

After review of existing research, standards, and case studies the Statewide CASE Team does not recommend implementation of a compliance credit for DC to DC circuitry in Nonresidential buildings for the 2022 codes cycle. This technology holds promise for future consideration; however, the current market is not mature enough for the Statewide CASE Team to confidently qualify the energy savings on a large scale. Factors contributing to this include gaps in existing standards, the absence of an applicable testing standard for appliances, and the wide range of energy savings claimed by existing modeled and physical projects. These findings were presented at the November 12, 2019 Stakeholder meeting and did not receive any objection from stakeholders. Standards and other key barriers such as lack of industry familiarity and limited direct-current compatible products are expected to continue to improve in coming years, the Statewide CASE Team recommends reviewing in the next code cycle for implementation.

Nonresidential Pre-Cooling Compliance Credit

After review of existing research, standards, and case studies it is not recommended to implement a compliance credit for pre-cooling in nonresidential buildings for the 2022 Title 24, Part 6 Building Code. Pre-cooling is a method to harness the thermal mass of a building to shift electricity, use due to HVAC operation, across different hours of the day based on grid needs such as reduced electricity consumption during the peak time window. Another use case is to pre-cool a building before increasing HVAC set-points to allow a building to participate in longer DR events or with deeper load reductions with decreased occupant discomfort. The Statewide CASE Team was considering efforts to add features to the compliance software that provide compliance credit for technologies and design solutions that enable load shifting through pre-cooling.

A substantial amount of research and case studies have been conducted regarding the grid benefits of pre-cooling in the morning hours for commercial office buildings to avoid the previous peak electricity usage time window of 12 to 6 p.m. (Davis Energy Group, Inc 2015) (Xu Peng 2008) (Braun 2003) (Peng Xu and Laboratory 2004).

Unfortunately, there was no significant research regarding the effectiveness of pre-cooling commercial buildings during the hottest part of the day from noon to 4 p.m. to help mitigate the new peak electricity time window of 4 to 9 p.m. There is concern that pre-cooling in the middle of the day would result in such significant energy loss that the grid benefits realized later in the day would be negatively outweighed. Also, with the changing peak, pre-cooling would not be very applicable to office buildings, the main building type that research has been conducted on. More applicable building types would be retail, grocery, restaurant and hospitality.

For residential buildings, HVAC pre-cooling was added to the ACM for the 2019 code cycle though the compliance credit and is derated because it requires proper programming and setup to operate effectively. A transferable lesson learned is that a thermal load increase measure should also include a specific building thermal capacity to be eligible. Therefore, if this measure is pursued in the future it would need guidelines in building design such as performance metrics to characterize building internal mass. It may only be a recommended strategy if certain building design criteria on the amount of thermal capacity can be achieved.

These findings were presented at the September 11, 2019 and November 12, 2019 Utility Sponsored Stakeholder meetings and did not receive any objection from stakeholders. Potential actions that would support moving this measure forward for the next code cycle include:

- Model energy and TDV net cost impacts of nonresidential precooling during the new peak time window of 4 to 9 p.m.
    - Across all climate zones
    - Across all building types operating during the new peak time window
- Research/model to determine the appropriate length of time to pre-cool as well as the depth or temperature change to initiate during pre-cooling.
- Develop guidelines on amount of thermal capacity needed to effectively pre-cool.
- Determine if there is an impact to AC sizing such as a benefit to having a larger capacity unit to enable load shifting through pre-cooling.
- Operate an incentive program that has clear requirements around the temperature adjustment for precooling, how long the precooling takes place, and require/document specific building characteristics such as thermal capacity.

Appendix H: Nominal Savings Tables

In Section 2.4, the energy cost savings of the proposed code changes over the 15-year period of analysis are presented in 2023 present value dollars.

This appendix presents energy cost savings in nominal dollars. Energy costs are escalating as in the TDV analysis but the time value of money is not included so the results are not discounted.

Table 49: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot – New Construction & Alterations

Prototype Building	15-Year TDV Electricity Cost Savings (Nominal $)	15-Year TDV Natural Gas Cost Savings (Nominal $)	Total 15-Year TDV Energy Cost Savings (Nominal $)
Small Office	$0.117	N/A	$0.117
Medium Office	$0.116	N/A	$0.116
Large Office	$0.141	N/A	$0.141
Strip Mall	$0.378	N/A	$0.378
Stand-alone Retail	$0.269	N/A	$0.269
Retail Large	$0.170	N/A	$0.170
Mixed Use Retail	$0.285	N/A	$0.285
Primary School	$0.175	N/A	$0.175
Secondary School	$0.186	N/A	$0.186
Warehouse (non-refrigerated)	$0.092	N/A	$0.092
Quick Service Restaurant	$0.218	N/A	$0.218
Small Hotel	$0.113	N/A	$0.113