DOCKETED	
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Project Title:	Local Ordinance Applications Exceeding the 2022 Energy Code
TN #:	258418
Document Title:	City of Palo Alto June 3 City Council Special Meeting
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CITY OF PALO ALTO
CITY COUNCIL
Special Meeting
Monday, June 03, 2024
Council Chambers & Hybrid
4:00 PM

Agenda Item

17. PUBLIC HEARING: FIRST READING: Ordinance Amending Chapter 16.14 (California Green Building Standards, California Code of Regulations, Title 24, Part 11) of the Palo Alto Municipal Code to Adopt the 2022 Green Building Standards Code, Along With Local Modifications Related to Electrical Vehicle Charging Infrastructure Requirements and Building Electrification Requirements and an Ordinance Amending Chapter 16.17 (California Energy Code, California Code of Regulations, Title 24, Part 6) of the Palo Alto Municipal Code to Adopt the 2022 California Energy Code, Along with Local Modifications to Increase Energy Efficiency Standards for Buildings, Mandate Electric-Ready Requirements and Incentivize All-Electric New Construction. CEQA Status: Exempt under CEQA Guidelines Sections 15308 and 15061(b)(3) *Presentation*

City Council
Staff Report

From: City Manager
Report Type: ACTION ITEMS
Lead Department: Planning and Development Services

Meeting Date: June 3, 2024
Report #:2405-3073

TITLE

PUBLIC HEARING: FIRST READING: Ordinance Amending Chapter 16.14 (California Green Building Standards, California Code of Regulations, Title 24, Part 11) of the Palo Alto Municipal Code to Adopt the 2022 Green Building Standards Code, Along With Local Modifications Related to Electrical Vehicle Charging Infrastructure Requirements and Building Electrification Requirements and an Ordinance Amending Chapter 16.17 (California Energy Code, California Code of Regulations, Title 24, Part 6) of the Palo Alto Municipal Code to Adopt the 2022 California Energy Code, Along with Local Modifications to Increase Energy Efficiency Standards for Buildings, Mandate Electric-Ready Requirements and Incentivize All-Electric New Construction. CEQA Status: Exempt under CEQA Guidelines Sections 15308 and 15061(b)(3)

RECOMMENDATION

Staff recommends that the City Council take the following actions:

1. Introduce an ordinance amending Chapter 16.14 (California Green Building Standards, California Code of Regulations, Title 24, Part 11) of the Palo Alto Municipal Code to adopt the 2022 Green Building Standards Code, along with local modifications related to electrical vehicle charging infrastructure requirements and building electrification requirements and finding that such modifications or changes are reasonably necessary because of local climatic, geological or topographical conditions (Attachment A).

2. Introduce an ordinance amending Chapter 16.17 (California Energy Code, California Code of Regulations, Title 24, Part 6) of the Palo Alto Municipal Code to adopt the 2022 California Energy Code, along with local modifications to increase energy efficiency standards for buildings, mandate electric-ready requirements, and incentivize all-electric new construction and finding that such modifications or changes are reasonably necessary because of local climatic, geological or topographical conditions (Attachment B).

3. Provide direction regarding outdoor gas grills, stoves, and barbeques.

EXECUTIVE SUMMARY

Staff recommends local amendments the California Building Efficiency Standards (State Energy Code) and the California Green Building Standards (State Green Building Code). In general, the recommended local amendments to the State Energy Code are intended to implement an Energy Reach Code using the One Margin approach. The local amendments to the State Green Building Code are intended to 1) remove provisions related to the City's previous all-electric code that are inconsistent with the Ninth Circuit's decision, and 2) align the City's local Green Building Code amendments with updates to the State Green Building Code that are taking effect July 1, 2024, especially those related to electric vehicle infrastructure.

This report also highlights a policy consideration for the Council regarding outdoor gas grills/stoves and barbeques, which are not regulated by the Energy Policy and Conservation Act (EPCA). As proposed new plumbing infrastructure for these outdoor appliances would continue to be prohibited, unless Council directs otherwise.

Procedurally, following Council's endorsement of proposed ordinances, the local amendments will require approval from both the CEC and the California Building Standards Commission (CBSC).

Accordingly, staff anticipates the local amendments to the State Energy Code to become effective no sooner than September 1, 2024 and the local amendments to the State Green Building Code to become effective on the thirty-first day following second reading adoption.

BACKGROUND

Palo Alto has a history of leadership in sustainability and energy efficiency. In April 2016, the City Council adopted the Sustainability and Climate Action Plan Framework (S/CAP), which introduced the greenhouse gas (GHG) emissions reduction goal of 80% from the 1990 level by 2030, also known as 80-by-30. In October 2022, the City Council passed an ambitious carbon neutral goal by 2030 to build on the City's existing emissions reduction goals.

Over the past four code cycles for the State Energy Code and State Green Building Code, Palo Alto adopted local amendments establishing requirements that exceeded statewide requirements in support of sustainability and GHG reduction goals. In 2022, the City Council adopted local amendments to the State Green Building Code establishing whole building electrification requirements for new buildings and substantial remodels, as well as a heat pump water heater replacement and installation requirement for existing residential remodel and addition projects.

in light of the decisions in the U.S. Court of Appeals for the Ninth Circuit (Ninth Circuit)[1], City Council adopted a resolution to suspend enforcement of the City's all-electric building

[1] See California Restaurant Association v. City of Berkeley Case 21-16278, January 2, 2024; available at: https://www.publichealthlawcenter.org/sites/default/files/2024-01/CRA-v-Berkeley-Ninth-Circuit-Opinion-Jan2024.pdf. Retrieved March 7, 2024.

requirement and directed staff to return with amendments to the California Energy Code using a "One Margin" approach, which refers to a code that uses a metric defined by the California Energy Commission (CEC) called Hourly Source Energy[2]. The One Margin approach allows for the installation of both mixed fuel and all-electric construction while imposing requirements that consider the emissions of both types of construction. Mixed-fuel construction would generally require significant investments in energy efficiency, solar, and storage to offset the emissions of natural gas appliances in order to meet these requirements. These requirements would support Palo Alto's carbon neutrality goal, 80-by-30 while still applying identical requirements to all-electric and mixed-fuel construction consistent with the Ninth Circuit's ruling.

On February 26, 2024,[3] in response to the decision of the U.S. Court of Appeals for the Ninth Circuit (Ninth Circuit)[4] invalidating the City of Berkeley's natural gas prohibition ordinance, the City Council adopted a resolution suspending enforcement of the electrification requirements and directed staff to return with an alternative using a "One Margin" approach to enforce during the remainder of the 2022 code cycle (until December 31, 2025). The One Margin approach refers to a code that uses a metric defined by the California Energy Commission (CEC) called Hourly Source Energy[5]. The proposed local amendments to the State Energy Code leverages the Hourly Source Energy metric established by the CEC in the State Energy Code. This metric serves as a proxy for carbon emissions and is used to regulate energy performance in the same manner for both all-electric and mixed-fuel buildings. The One Margin approach allows for the installation of both mixed fuel and all-electric construction while imposing requirements that consider the emissions of both types of construction. Mixed-fuel construction would generally require significant investments in energy efficiency, solar, and storage to offset the emissions of natural gas appliances in order to meet these requirements. These requirements would support Palo Alto's carbon neutrality goal, 80-by-30 while still applying identical requirements to all-electric and mixed-fuel construction consistent with the Ninth Circuit's ruling.

Since the moratorium went into effect staff have tracked applications for gas appliances in all permits that would have been subject to the all-electric Reach Code before the moratorium

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[2] "One Margin" is a term used by some in the California building regulatory community to refer to an Energy Reach Code that uses the "Hourly Source Energy" metric defined by the California Energy Commission in the statewide Energy Code. A One Margin code sets a high standard for Hourly Source Energy that buildings must meet (the "Hourly Source Energy Margin") and applies a single Hourly Source Energy Margin to each building type regardless of whether that building is a mixed-fuel building or an all-electric building.

[3] February 24, 2024 Agenda with access to the City Council Staff Report and Minutes (Item 14): https://cityofpaloalto.primegov.com/Portal/Meeting?meetingTemplateId=13357.

[4] See California Restaurant Association v. City of Berkeley Case 21-16278, January 2, 2024; available at: https://www.publichealthlawcenter.org/sites/default/files/2024-01/CRA-v-Berkeley-Ninth-Circuit-Opinion-Jan2024.pdf. Retrieved March 7, 2024.

[5] "One Margin" is a term used by some in the California building regulatory community to refer to an Energy Reach Code that uses the "Hourly Source Energy" metric defined by the California Energy Commission in the statewide Energy Code. A One Margin code sets a high standard for Hourly Source Energy that buildings must meet (the "Hourly Source Energy Margin") and applies a single Hourly Source Energy Margin to each building type regardless of whether that building is a mixed-fuel building or an all-electric building.

went into effect. While staff is likely not tracking 100% of application requests, tracking efforts show 23% (41/180) of applications affected by the moratorium were submitted as a mixed fuel design. The most common gas appliances requested were tankless water heaters (25), cooking ranges (17), and tank water heaters (9).

ANALYSIS

There are two codes used by the State and local jurisdictions to achieve efficiency and lower carbon emissions in buildings:

- <u>2022 California Green Building Standards (State Green Building Code)</u>

The State Green Building Code was the first-in-the-nation green building standards code and developed to support AB 32 (Global Warming Solutions Act of 2006), which established a comprehensive, long-term approach to addressing climate change and required California to reduce its GHG emissions to 1990 levels by 2020. The State Green Building Code aims to improve public health, safety, and general welfare through enhanced design and construction techniques that emphasize positive environmental impact and sustainable construction practices.

The City's current all-electric requirements are codified as local amendments in the State Green Building Code but are not being enforced due to the aforementioned moratorium.

- <u>2022 California Building Efficiency Standards (State Energy Code)</u>

The State Energy Code sets energy efficiency standards for residential and nonresidential buildings throughout California such as a building's heating, ventilation, and air conditioning system, water heater, solar PV systems, thermal envelope, and nonresidential lighting. In 2022 the State Energy Code was updated to include metrics to demonstrate a building's compliance with these efficiency standards. One such metric included Hourly Source Energy, which represents the energy consumption of a building including losses incurred during production and delivery on an hourly basis to the meter located at the building. It is a metric for both electricity and natural gas. The CEC found that Hourly Source Energy values are proportional to the GHG emissions for each hour of the year and can be considered a good proxy for GHG emissions, encouraging fuel switching, decarbonization, and reducing natural gas use.

Given the proxy analysis available in the State Energy Code, staff proposes to rescind local electrification amendments to the State Green Building Code that may conflict with federal law and advance the City's carbon reduction goals using the Hourly Source Margin set forth in the State Energy Code.

<u>Proposed Local Amendments to the State Green Building Code (Attachment A)</u>

Attachment A repeals the local amendments to the State Green Building Code, including the all-electric requirement for new construction and replacement of gas water heaters with a heat pump water heater for residential remodels and additions. These standards appear to conflict with the Ninth Circuit ruling.

New State Green Building Code requirements related to EVs will become effective statewide in July 1, 2024 as a result of a state-initiated mid-code cycle update. The new state requirements will include changes related to specifications for chargers and cables, requirements for EV chargers at certain types of commercial buildings for medium- and heavy-duty vehicles, as well as minor administrative changes and updated definitions. In addition, the State updated two electric vehicle charging requirements for new construction as shown in Table 1. Staff recommends updating the relevant sections of PAMC 16.14 to align with the State Green Building Code requirements.

Table 1. Proposed EV Charger Requirements for New Construction

Building occupancy type	2022 PAMC 16.14 (local amendments to State Green Building Code) (Effective 1/1/23)	2022 State Green Building Code (Effective 7/1/24)	Staff Recommendation for updated local amendments to State Green Building Code, PAMC 16.14
New Multifamily guest parking spaces	EV Chargers: 5% of guest parking spaces	EV Chargers: 10% of guest parking spaces	EV Chargers: 10% of guest parking spaces
New Hotel/Motel	30% of spaces must be EV Ready[6] (with 10% EVSE installed)	40% of spaces must be EV Ready[5] (with 10% EVSE installed)	40% of spaces must be EV Ready[5] (with 10% EVSE installed)

<u>Proposed Local Amendments to the State Energy Code (Attachment B)</u>

Attachment B repeals the locally adopted State Energy Code and establishes new local amendments using a One Margin approach.

The proposed local amendments use the Hourly Source Energy metric established by the CEC. This metric acts as a proxy for carbon emissions. The proposed local amendments set an Hourly Source Energy Margin for each building occupancy type. The Hourly Source Energy Margin states how far below the “standard” energy budget set by the State Energy Code a proposed building’s energy budget must be, using the Hourly Source Energy metric. The developer must demonstrate this to comply with the code.

Because natural (methane) gas space and water heating has such high carbon emissions compared to electric gas and water heating, buildings using natural (methane) gas for these appliances will need to install significant energy efficiency measures and large amounts of PV and

[6] EV Ready means all electrical equipment is installed to support an EV charging port but the port itself has not yet been installed.

batteries to offset those emissions at significant cost. Newly constructed all-electric buildings will achieve up-front cost savings compared to code-compliant newly constructed mixed-fuel buildings by avoiding the need for additional efficiency, PV, and battery installations to meet the Hourly Source Energy Margin requirements. The proposed energy reach code ordinance adopts cost-effective compliance margins and would be triggered on permit applications for project types indicated in Table 2.

Additionally, the proposed ordinance extends the Hourly Source Energy Margins and electric readiness requirements to all substantial remodel projects. During the 2022 code cycle, several jurisdictions, including Palo Alto, extended new construction requirements to substantial remodels; this provision has been included in the attached ordinance.

The proposed local amendments to the State Energy Code primarily impact space heating and water heating, which represent as much as 90% of a home's emissions. The local amendments do not include any stricter requirements for cooking, clothes drying, or other appliances than the State Energy Code. So, while these local amendments are likely to drive deep reductions in emissions in new construction, they are unlikely to eliminate them entirely. Many homes may choose electric space heating and water heating, but include a gas stove, for example. However, under the previous electric-preferred ordinance in Palo Alto, as many as 50% of homeowners built all-electric despite not being required to. And a high percentage of homeowners (as high as 75%) are continuing to opt for all-electric new construction since the moratorium went into effect. Based on that, staff anticipates the majority of homeowners will opt for all-electric construction under these local amendments even if not required to.

A summary of the proposed standards is provided in the following table. Note that requirements for single-family homes use a metric based on source energy called Energy Design Rating 1 (EDR1), while requirements for other building occupancy types are expressed in terms of Hourly Source Energy Margin. This is consistent with way the State Energy Code expresses the compliance factors.

Table 2. Proposed Hourly Source Energy Margins		
Building occupancy type	**Source Energy Margin**	**Electric-Readiness Requirements**
Single-family Residential Buildings (including detached Accessory Dwelling Units)[7]	Exceed standard EDR1 by at least 8 points ADUs:[7] Exceed standard EDR1 by at least 2 points	2022 California Energy Code electric-ready requirements for space heating, water heating, cooking/ovens, and clothes dryers.
Low-Rise Multifamily Residential Buildings (3 habitable stories or less)	Exceed the standard Hourly Source Energy Margin requirement by 9%	2022 California Energy Code electric-ready requirements for space heating, cooking/ovens, and clothes dryers serving individual dwelling units and common areas when gas equipment is installed. Proposed electric-ready requirements for water heating.
High-Rise Multifamily Residential Buildings (4 habitable stories or more)	Exceed the standard Hourly Source Energy Margin requirement by 1%	2022 California Energy Code electric-ready requirements for space heating, cooking/ovens, and clothes dryers serving individual dwelling units and common areas when gas equipment is installed. Proposed electric-ready requirements for water heating.
Office/Mercantile	Exceed the standard Hourly Source Energy Margin requirement by 10%	Proposed electric-readiness requirements for systems using gas or propane to accommodate the future installation of an electric heating appliance.
Hotel/Motel Buildings	Exceed the standard So Hourly Source Energy Margin requirement by 7%	
Restaurants	Exceed the standard Hourly Source Energy Margin requirement by 12%	
Industrial/Manufacturing Buildings	Exceed the standard Hourly Source Energy Margin requirement by 0%	
All other Nonresidential Occupancies	Exceed the standard Hourly Source Energy Margin requirement by 9%	

The margins listed in Table 2 are based on the 2022 Cost-Effectiveness studies published by the California Energy Codes and Standards Statewide Utility Program (Attachments C, D, and E), which is comprised of the State's Investor-Owned Utilities (PG&E, SCE, and SDG&E, under the auspices of the California Public Utilities Commission). The studies include robust data sets to support the findings required for CEC approval. To demonstrate cost-effectiveness, all applicable source energy compliance margins must show a calculated benefit-to-cost ratio for a variety of measures, building occupancy types, and climate zones. A benefit-cost ratio value of "1" or more demonstrates that the efficiency measures analyzed result in higher savings than they cost and are considered "cost-effective".

As a part of the development of the local amendments to the State Energy Code staff engaged with an engineering and construction management consultant firm (TRC) to perform additional analyses based on real construction projects that were submitted to the City over the last year. The analysis confirmed the feasibility of reaching the proposed source energy margins that were found to be cost-effective in the published 2022 Cost-Effectiveness Studies using examples of Palo-Alto-specific construction.

Proposed Amendments – Exceptions

The proposed local amendments to the State Energy Code includes exceptions for specific building occupancy types and an infeasibility exemption procedure for projects with unique circumstances that cannot meet the local reach code requirements. One exception extends to small-to-medium retail, grocery, schools, and banks because the 2022 California Energy Code strongly encourages these buildings to install heat pump systems. A second exception is for new buildings that are exempt from the California Energy Code's solar PV installation requirement. This exception typically applies to smaller ADUs that may have challenges meeting a higher EDR1 requirement. In this circumstance, the new detached ADU would need to meet an EDR1 requirement of 2 points. Lastly, this ordinance also includes limited exceptions to the higher Hourly Energy Source Margin requirements, including an exemption for industrial/manufacturing buildings due to the high variation in building equipment and challenges in finding equipment to meet the enhanced compliance standards.

Direction on Gas Appliances Not Covered by EPCA

The Ninth Circuit issued a decision holding the City of Berkeley's all-electric requirements invalid because it is preempted by EPCA, which sets forth federally mandated appliance and equipment efficiency standards. In amending the Green Building Code, staff identified one area of regulation that is not covered by EPCA: such as outdoor cooking appliances such as grills/stoves and

[7] The code exception addressing ADUs actually references buildings that do not require PV under the Energy Reach Code. In practice this will almost exclusively apply to ADUs, but some very small homes might meet this exception, and some very large ADUs may not meet it and may be required to meet the higher EDR requirement.

barbeques. The City previously prohibited the installation of plumbing for outdoor combustion-based appliances and can continue to do so. The proposed local amendments to the State Green Building Code (Attachment A) in fact retain this prohibition as a reflection of previously expressed Council direction. However, as other outdoor equipment, such as swimming pool and spa heaters are regulated by EPCA, it is anticipated new gas lines may be installed for these other types of outdoor appliances. And, since outdoor grills/stoves and barbeques are not among the higher sources of GHG emissions, the Council may want to consider, in light of the Ninth Circuit decision, whether it still wants to regulate this equipment. If the Council does not want to regulate plumbing to outdoor grills/stoves and barbeques, specific direction to staff is needed before adopting the proposed ordinance.

Next Steps

If approved, staff will place the ordinances on the Council's June 17, 2024 meeting agenda for adoption. If adopted, staff will submit the ordinance amending Chapter 16.17 (California Energy Code) to the CEC for approval as required for enforcement of local amendments to the California Energy Code. Upon CEC acceptance, the ordinance will be posted for public review and undergo a 15-day public comment period. Towards the end of the public comment period, the CEC will consider the local ordinance at an upcoming regularly scheduled business meeting. If the local amendments are approved, it can then be filed with the CBSC. Based on these processes the estimated earliest possible effective date for this ordinance is September 1, 2024, but the actual timeline is dependent on the CEC and CBSC.

Staff will separately file both ordinances, along with associated findings regarding local climatic, geological or topographical conditions, with the California Building Standards Commission. Based on staff's experience adopting reach codes for previous cycles, the Building Standards Commission accepts the filing within three to four

FISCAL/RESOURCE IMPACT

Resource impacts from the adoption of the new local energy reach code ordinance are limited to staff training costs, updating and creating new handouts for new proposed amendments, and implementation of public outreach efforts. These can be absorbed from existing budgets.

Adoption of this ordinance required a new consulting contract in the amount of $132,200 (contract S24190818 with Integrated Design 360, approved by the City Council April 1, 2024),[8] absorbed from existing FY 2024 budgets, as well as approximately 0.5 FTE of staff time spread among several Departments from February through June, also absorbed from existing full-time and hourly (retiree) staff resources.

[8] April 1, 2024 Agenda with access to the City Council Staff Report and Minutes (Item 5): https://cityofpaloalto.primegov.com/meetings/ItemWithTemplateType?id=4492&meetingTemplateType=2&compiledMeetingDocumentId=9485

STAKEHOLDER ENGAGEMENT
Given Council's direction from February 26, 2024 to return before the summer break, there has been no stakeholder meetings. The subject noticed public hearing will be the first opportunity for the public comment on the staff recommendations. The agenda posting for this ordinance was published on May 23, 2024.

ENVIRONMENTAL REVIEW
The recommended policy is exempt from the California Environmental Quality Act (CEQA) in accordance with CEQA Guidelines section 15308 as an action by the City for the protection of the environment, and under section 15061(b)(3) on the grounds that the proposed standards are more stringent than the State energy standards, there are no reasonably foreseeable adverse environmental impacts and there is no possibility that the activity in question may have a significant adverse effect on the environment.

ATTACHMENTS
Attachment A: Ordinance Amending Ch. 16.14 California Green Building Standards Code
Attachment B: Ordinance Amending Ch. 16.17 California Energy Code
Attachment C: 2022 Single Family New Construction Cost-Effectiveness Study and SFNC Data
Attachment D: 2022 Multifamily New Construction Cost-Effectiveness Study and MFNC Study Data
Attachment E: 2022 Nonresidential New Construction Cost-Effectiveness Study and NRNC Study Data
Attachment F: Supplemental Modeling and Reality Testing Analysis

APPROVED BY:
Jonathan Lait, Planning and Development Services Director

ATTACHMENT A

Ordinance No. XXXX

Ordinance of the Council of the City of Palo Alto Amending Chapter 16.14 (California Green Building Standards, California Code of Regulations, Title 24, Part 11) of the Palo Alto Municipal Code to Adopt the 2022 Green Building Standards Code, Along With Local Amendments Thereto, Related to Electrical Vehicle Charging Infrastructure Requirements and Building Electrification Requirements

The Council of the City of Palo Alto does ORDAIN as follows:

SECTION 1. Findings and Declarations.

(a) The City of Palo Alto adopted a Sustainability and Climate Action Plan, or S/CAP, to meet the City's stated goal of "80 x 30": reducing greenhouse gas emissions 80% below 1990 levels by 2030.

(b) The S/CAP outlines goals and key actions in eight areas, one of which is energy and more specifically, energy efficiency and electrification. The goals for the energy area of the S/CAP are to reduce GHG emissions from the direct use of natural gas in Palo Alto's building sector by at least 60% below 1990 levels (116,400 MT CO2e reduction) and to modernize the electric grid to support increased electric demand to accommodate state-of-the-art technology.

(c) One key action the City is taking to accomplish those goals is use codes and ordinances - such as the energy reach code, green building ordinance, zoning code, or other mandates - to facilitate electrification in both existing buildings and new construction projects where feasible.

(d) The purpose of this ordinance is to formally adopt California Code of Regulations, Title 24, Part 11, 2022 California Green Building Standards Code, with local amendments in furtherance of the City of Palo Alto's S/CAP goals.

(e) California Health and Safety Code sections 17958.5 and 17958.7 requires that the City, in order to make changes or modifications in the requirements contained in the California Green Building Standards on the basis of local conditions, make express finding that such modifications or changes are reasonably necessary because of local climatic, geological or topographical conditions.

(f) The required findings are attached to this ordinance as Exhibit A.

SECTION 2. Chapter 16.14 (California Green Building Standards, California Code of Regulations, Title 24, Part 11) of the Palo Alto Municipal Code is hereby amended by repealing in its entirety existing 16.14 and adopting a new Chapter 16.14 to read as follows:

CHAPTER 16.14
CALIFORNIA GREEN BUILDING STANDARDS CODE, CALIFORNIA CODE OF REGULATIONS, TITLE 24, PART 11

Sections

16.14.140 Section A4.104 Site Preservation.

16.14.150 Section A4.105 Deconstruction and Reuse of Existing Materials.

16.14.160 Section A4.106.8 Electric Vehicle (EV) Charging for New Construction.

16.14.170 Section A4.106.9 Bicycle Parking.

16.14.180 Section A4.106.10 Light Pollution Reduction.

16.14.190 Section A4.203.1 Performance Approach for Newly Constructed Buildings.

16.14.200 Section A4.304.3 Irrigation Metering Device.

16.14.210 Section A4.305 Water Reuse Systems.

16.14.220 A4.305.4 Additions and Alterations.

16.14.230 Section A4.403.1 Frost Protection Foundation Systems.

16.14.240 Section A4.403.2 Reduction in Cement Use.

16.14.250 Section A4.408.1 Enhanced Construction Waste Reduction.

16.14.260 Section A4.504.1 Compliance with formaldehyde limits.

16.14.270 Section A4.504.3 Thermal Insulation.

Part 8 – Local Modifications to CHAPTER 5 – NONRESIDENTIAL MANDATORY MEASURES

16.14.280 Nonresidential Projects: Chapter 5 Preface Green Building Requirements for Project Type and Scope.

16.14.290 Section 5.106.1.1 Local Storm Water Pollution Prevention.

16.14.295 Section 5.106.8 Light Pollution Reduction.

16.14.300 Section 5.106 Full Electrification.

16.14.310 Reserved

16.14.320 Reserved

16.14.330 Section 5.304.2 Invasive Species Prohibited.

16.14.340 Section 5.306 Nonresidential Enhanced Water Budget.

16.14.350 Section 5.307 Cooling Tower Water Use.

16.14.360 Section 5.410.4.6 Energy STAR Portfolio Manager.

16.14.370 Section 5.410.4.7 Performance Reviews – Energy.

16.14.380 Section 5.410.4.8 Performance Reviews – Water.

16.14.390 Section 5.506 Indoor Air Quality.

Part 9 – Local Modifications to APPENDIX A5 – NONRESIDENTIAL VOLUNTARY

Part 1 – General

16.14.010 2022 California Green Building Standards Code, Title 24, Part 11 adopted and amended.

The California Green Building Standards Code, 2022 Edition, Title 24, Part 11 of the California Code of Regulations, together with those omissions, amendments, exceptions and additions thereto, is adopted and hereby incorporated in this Chapter by reference and made a part hereof the same as if fully set forth herein.

Unless superseded and expressly repealed, references in City of Palo Alto forms, documents and regulations to the chapters and sections of the former California Code of Regulations, Title 24, shall be construed to apply to the corresponding provisions contained within the California Code of Regulations, Title 24, 2022. Ordinance No. 5570 of the City of Palo Alto and all other ordinances or parts of ordinances in conflict herewith are hereby suspended and expressly repealed.

Wherever the phrases “California Green Building Standards Code” or “CALGreen” are used in this code or any ordinance of the City, such phrases shall be deemed and construed to refer and apply to the California Green Building Standards Code, 2022 Edition, as adopted and amended by this chapter.

One copy of the California Green Building Standards Code, 2022 Edition, has been filed for use and examination of the public in the Office of the Chief Building Official of the City of Palo Alto.

16.14.020 Cross - References to California Green Building Standards Code.

The provisions of this Chapter contain cross-references to the provisions of the California Green Building Code, 2022 Edition, in order to facilitate reference and comparison to those provisions.

16.14.030 Local Amendments.

The provisions of this Chapter shall constitute local amendments to the cross-referenced provisions of the California Green Building Standards Code, 2022 Edition, and shall be deemed to replace the cross-referenced sections of said Code with the respective provisions set forth in this Chapter.

Part 2 – Local Modifications to CHAPTER 1 – ADMINISTRATION

16.14.040 Administration & Enforcement of 2022 California Green Building Standards Code.

Administration and enforcement of this code shall be governed by Chapter 1, Division II of the 2022 California Building Code as amended by Palo Alto Municipal Code Chapter 16.04.

16.14.050 Adoption of Chapter 1 Administration.

Chapter 1 Administration of the 2022 California Green Building Code is adopted by the City of Palo Alto to supplement, to the extent it does not conflict with, Chapter 1, Division II of the 2022 California Building Code, as amended.

16.14.060 Section 101.4 Appendices.

The following Appendix Chapters of the California Green Building Standards Code, 2022 Edition, are adopted and hereby incorporated in this Chapter by reference and made a part hereof the same as if fully set forth herein:

A. Appendix A4 - Residential Voluntary Measures (Tier 1 and Tier 2)

B. Appendix A5 - Nonresidential Voluntary Measures (Tier 1 and Tier 2)

Part 3 – Local Modifications to CHAPTER 2 – DEFINITIONS

16.14.070 Section 202 Definitions.

Section 202 of Chapter 2 of the California Green Building Standards Code is amended to include the following definitions:

ALL-ELECTRIC BUILDING / SITE. A building or parcel of land whose sole source of energy is electricity and contains no combustion equipment or plumbing for combustion equipment.

CPAU. City of Palo Alto Utilities Department.

CALGREEN MANDATORY. Mandatory measures are triggered for projects outlined in Section 301.1 Scope of this code, as amended.

Projects that only trigger Mandatory measures are not required to fulfill Tier 1 or Tier 2 measures in Appendix A4 and A5.

CALGREEN TIER 1. To achieve **Tier 1 status**, a project must comply with measures identified in Appendix A4, Section A4.601.4 for *residential projects* and Appendix A5, Section A5.601.2 for *nonresidential projects*.

Projects subject to **Tier 1** must fulfill all mandatory measures, all Tier 1 prerequisite measures and a defined number of Tier 1 elective measures.

CALGREEN TIER 2. To achieve **Tier 2 status**, a project must comply with requirements identified in Appendix A4, Section A4.601.5 for *residential projects* and Appendix A5, Section A5.601.3 for *nonresidential projects*.

Projects subject to **Tier 2** must fulfill all mandatory measures, all Tier 2 prerequisite measures and a defined number of Tier 2 elective measures.

CALGREEN TIER 1 AND TIER 2 PREREQUISITE MEASURES. Projects subject to **Tier 1** or **Tier 2** must fulfill all prerequisites as described within Appendix A4, Division A4.6 for *residential projects* and Appendix A5, Division A5.6 for *nonresidential projects.*

CALGREEN TIER 1 AND TIER 2 ELECTIVE MEASURES. Projects subject to **Tier 1** or **Tier 2** must fulfill a defined number of electives as described within Appendix A4, Division A4.6 for *residential projects* and Appendix A5, Division A5.6 for *nonresidential projects.*

CALGREEN INSPECTOR is a person certified as a CALGreen Inspector/Plans Examiner through the International Code Council (ICC), demonstrating knowledge and application of Green Building concepts during plan review and inspection. For projects that require a CALGreen Inspector/Plans Examiner verification, the Inspector must be contracted directly with the owner and may not be a contractor or employee of the design or construction firm.

CERTIFIED ENERGY ANALYST is a person registered as a Certified Energy Analyst with the California Association of Building Energy Consultants as of the date of submission of a Certificate of Compliance as required under section 10-103 of Building Energy Efficiency Standards for residential and nonresidential buildings.

MODEL WATER EFFICIENT LANDSCAPE ORDINANCE. The California Department of Water Resources Model Water Efficient Landscape Ordinance.

SALVAGE. Salvage means the controlled removal of items and material from a building, construction, or demolition site for the purpose of on- or off-site reuse, or storage for later reuse. Examples include air conditioning and heating systems, columns, balustrades, fountains, gazebos, molding, mantels, pavers, planters, quoins, stair treads, trim, wall caps, bath tubs, bricks, cabinetry, carpet, doors, ceiling fans, lighting fixtures, electrical panel boxes, fencing, fireplaces, flooring materials of wood, marble, stone or tile, furnaces, plate glass, wall mirrors, door knobs, door brackets, door hinges, marble, iron work, metal balconies, structural steel, plumbing fixtures, refrigerators, rock, roofing materials, siding materials, sinks, stairs, stone, stoves, toilets, windows, wood fencing, lumber and plywood.

SUBSTANTIAL REMODEL (or "50-50-50" RULE). Any project or projects that affects the removal or replacement of 50% or more of the linear length of the existing exterior walls of the building, and/or 50% or more of the linear length of the existing exterior wall plate height is raised, and/or 50% or more of the existing roof framing area is removed or replaced, over a 3-year period.

Any permit(s) applied for will trigger a review of a 3-year history of the project. This review will result in determining if a substantial remodel has occurred.

The Chief Building Official or designee shall make the final determination regarding the application if a conflict occurs.

SQUARE FOOTAGE. For application of green building requirements, “square footage” refers to all new or altered square footage, including basement areas (7 feet or greater in height), as calculated based on outer boundary of proposed construction area, including exterior walls.

Part 4 – Local Modifications to CHAPTER 3 – GREEN BUILDING

16.14.080 SECTION 301 - Voluntary Tiers Added.

SECTION 301 of Chapter 3 of the California Green Building Standards Code is amended to read:

SECTION 301 GENERAL

301.1 Scope. Buildings shall be designed to include the green building measures specified as mandatory in the application checklists contained in this code and any applicable local amendments. In addition, the City requires the use of Voluntary Tiers, as provided in Appendices A4 and A5, for certain residential and nonresidential new construction, additions, and alterations.

301.1.1 Residential additions and alterations. [HCD] The Mandatory provisions of Chapter 4 shall be applied to additions and/or alterations of existing residential buildings where the addition and/or alteration increases the building's conditioned area, volume, or size. The requirements shall apply only to and/or within the specific area of the addition or alteration.

Tier 1 adopted (Residential). All residential building additions and/or alterations exceeding 1000 square feet must meet CALGreen Mandatory plus the Tier 1 measures, as amended by this Chapter and as applicable to the scope of work.

For Tier 1 projects, the area of alterations will include any construction or renovation to an existing structure other than repair or addition. Alterations include raising the plate height, historic restoration, changes or rearrangements of the structural parts or elements, and changes or rearrangement of bearing walls and full height partitions.

Normal maintenance, reroofing, painting or wall papering, floor finishes, replacement-in-kind of mechanical, plumbing and electrical systems, or replacing or adding new kitchen counter and similar furniture, plumbing fixture to the building are excluded for the purposes of establishing scope of Tier 1 projects.

The area of alteration should be limited to the footprint of element(s) being altered.

This does not exclude mandatory CALGreen measures. The sum of the footprint of the elements being altered with respect to Tier 1, shall be calculated using the following methodology:

1. Raising the plate height: The calculation with respect to raising of the plate height will be based on the area of the footprint in which the plate height is being increased. Plate height means the vertical distance measured from the top of the finished floor to the top of the plates.

2. Historic restoration: The calculation with respect to historic restoration will be based on the area of work covered in the California Historical Building Code (Title 24, Part 8).
3. Structural parts or elements: The calculation with respect to changes or rearrangements of the structural parts or elements will be based on the sum of the individual footprints of each structural change or rearrangement. The footprint shall be calculated based on the proposed design and inclusive of any demolished structural parts or elements.
4. Bearing walls and full height partition: The calculation with respect to changes or rearrangement of walls and full height partitions will be based on the footprint of any demolished wall or full height partition and any new wall or new full height partition.

Exception: Attached and detached Accessory Dwelling Units, ADU conversions of existing structures shall meet the California Green Building Standards Code Mandatory measures only.

301.2 Low-rise and high-rise residential buildings. [HCD] The provisions of individual sections of CALGreen may apply to either low-rise residential buildings, high-rise residential buildings, or both. Individual sections will be designated by banners to indicate where the section applies specifically to low-rise only (LR) or high-rise only (HR). When the section applies to both low-rise and high-rise buildings, no banner will be used.

301.2.1 Low-Rise residential new construction – Tier 2 adopted. All new constructed or substantial remodel projects must meet CALGreen Mandatory plus Tier 2 measures, as amended by this ordinance and as applicable to the scope of work.

301.3 Nonresidential additions and alterations. [BSC-CG] The provisions of individual sections of Chapter 5 apply to building nonresidential additions of 1,000 square feet or greater, and/or building alterations with a permit valuation of $200,000 or above (for occupancies within the authority of California Building Standards Commission). Code sections relevant to additions and alterations shall only apply to the portions of the building being added or altered within the scope of the permitted work.

A code section will be designated by a banner to indicate where the code section only applies to newly constructed buildings [**N**] or to additions and alterations [**A**]. When the code section applies to both, no banner will be used.

Tier 1 adopted. Nonresidential alterations (including tenant improvements or renovations) of 5,000 square feet that include replacement of at least two of the following: HVAC system, building envelope, hot water system, or lighting system, must comply with CALGreen Mandatory plus Tier 1 measures, as amended by this Chapter and as applicable to the scope of work.

Tier 2 adopted. Nonresidential additions of 1000 square feet or greater must comply with CALGreen Mandatory plus Tier 2 measures, as amended by this Chapter and as applicable to the scope of work.

301.3.1 - 301.3.2 Unmodified

301.3.3 Nonresidential new construction – Tier 2 adopted. All new nonresidential construction must meet CALGreen Mandatory plus Tier 2 measures, as amended by this ordinance and as applicable to the scope of work.

301.6 Special inspector requirements. Residential and nonresidential project owners subject to CALGreen Mandatory, CALGreen Mandatory plus Tier 1, or CALGreen Mandatory plus Tier 2 measures shall contract a Special Inspector in accordance with section 702.2 of CALGreen, as amended.

301.7 Low-carbon concrete requirements for Tier 1 and Tier 2 projects. Plain and reinforced concrete installed as part of any project subject to the application of this code shall demonstrate compliance with the requirements of **PAMC 16.14.240**.

Part 5 – Local Modifications to CHAPTER 4 – RESIDENTIAL MANDATORY MEASURES

Division 4.1 – PLANNING AND DESIGN

16.14.090 Section 4.106.5 Full Electrification

Section 4.106 of Chapter 4 of the California Green Building Standards Code is amended to add new subsection, 4.106.5 as follows:

4.106.5 Full electrification. Full electrification is recommended for new buildings, substantial remodels, and new outdoor appliances/equipment such as fireplaces, firepits, heaters for swimming pool/spa, and similar equipment. Full electrification is required for outdoor grills, stoves, and barbecues. This subsection does not prohibit freestanding and/or portable grills, stoves, or barbecues whose sole source of energy is self-contained fuel canisters.

Division 4.3 – WATER EFFICIENCY AND CONSERVATION

16.14.100 Section 4.306 Swimming Pool and Spa Covers

Section 4.306 of Chapter 4 of the California Green Building Standards Code is added to read:

4.306 Swimming pool and spa covers. Swimming pools and spas shall be provided with a vapor retardant cover.

Part 6 – Local Modifications to CHAPTER 7 – INSTALLER AND SPECIAL INSPECTOR QUALIFICATIONS

16.14.120 Section 702.2 Special Inspection.

Section 702.2 of Chapter 7 of the California Green Building Standards Code is amended to read:

702.2 Green building special inspection. When required by the enforcing agency, the owner or responsible entity acting as the owner's agent shall employ one or more Green Building Special Inspectors to provide inspection or other duties necessary to substantiate compliance with this code. Green Building Special Inspectors shall demonstrate competence to the satisfaction of the enforcing agency for the particular type of inspection or task to be performed. In addition to other certifications or qualifications acceptable to the enforcing agency, the following certifications or education may be considered by the enforcing agency when evaluating the qualifications of a Special Inspector. The City shall maintain a list of pre-approved Special Inspectors in accordance with this section. The owner shall contract a Special Inspector from the pre-approved list meeting one of the following:

1. Certification by a national or regional green building program:
   ICC Certified CALGreen Inspector/Plans Examiner
2. Other programs acceptable to the enforcing agency.

Note: Special Inspectors shall be independent entities with no financial interest in the materials or the project they are inspecting for compliance with this code.

Part 7– Local Modifications to APPENDIX A4 – RESIDENTIAL VOLUNTARY MEASURES

Division A4.1 – PLANNING AND DESIGN

16.14.130 Residential Projects. Appendix A4 Preface: Green Building Measures for Project Type and Scope.

A preface is added to Chapter A4 of the California Green Building Standards Code to read:

Preface - Green Building Requirements for Project Type and Scope. For design and construction of residential projects, the City of Palo Alto requires compliance with the mandatory measures of Chapter 4, in addition to use of Tier 1 and Tier 2 as specified in Palo Alto Municipal Code Chapter 16.14. See Section 202 for definitions on CALGreen Mandatory, Tier 1 Prerequisites and Electives, and Tier 2 Prerequisites and Electives. All elective measures are adopted as written under Appendix A4 unless otherwise indicated in this Section.

16.14.140 Section A4.104 SITE PRESERVATION.

Section A4.104.1 of Appendix A4 of the California Green Building Standards Code is adopted as a Tier 1 and Tier 2 elective measure and is amended to read:

A4.104.1 Supervision and education by a special inspector. Individuals with oversight authority on the project, as defined in section 16.14.120 of this code, who have been trained in areas related to environmentally friendly development, shall teach green concepts to other members of the builder's staff and ensure training and written instruction has been provided to all parties associated with the development of the project. Prior to the beginning of the construction activities, the builder shall receive a written guideline and instruction specifying the green goals of the project.

Note: Lack of adequate supervision and dissemination of the project goals can result in negative effects on green building projects. If the theme of green building is not carried through the project, the overall benefit can be substantially reduced by the lack of knowledge and information provided to the various entities involved with the construction of the project.

16.14.150 Section A4.105 Deconstruction and Reuse of Existing Materials.

Section A4.105 of Appendix A4 of the California Green Building Standards Code is not adopted as an elective measure and is amended to read:

Section A4.105.1 Chapter 5.24 of Title 5 of the Municipal Code. See Chapter 5.24 of the Municipal Code for the local deconstruction requirements.

Section A4.105.2 is adopted as a Tier 1 and Tier 2 elective measure.

A4.105.2 Reuse of materials. Nonhazardous materials which can be easily reused include but are not limited to the following:

1. Light fixtures
2. Plumbing fixtures
3. Doors and trim
4. Masonry
5. Electrical devices
6. Appliances
7. Foundations or portions of foundations

Note: Reused material must be installed to comply the appropriate Title 24 provisions.

16.14.160 Section A4.106.8 Electric Vehicle (EV) Charging for New Construction.

Sections A4.106.8 – A4.106.8.2.1 of the California Green Building Standards Code are deleted in its entirety, adopted as mandatory measures and is amended to read:

A4.106.8 Electric vehicle (EV) charging for residential structures. Newly constructed single-family and multi-family residential structures, including residential structures constructed as part of a mixed-use development, shall comply with the following requirements for electric vehicle supply equipment (EVSE). All parking space calculations under this section shall be rounded up to the next full space. The requirements stated in this section are in addition to those contained in Section 4.106.4 of the California Green Building Standards Code. In the event of a conflict between this section and Section 4.106.4 of the California Green Building Standards Code, the more robust EV Charging requirements shall prevail.

A4.106.8.1 New single-family, duplex and townhouse dwellings. The following standards apply to newly constructed detached and attached single-family, duplex and townhouse residences.

(a) In general. The property owner shall provide One (1) Level 2 electrical vehicle supply equipment (EVSE) or one (1) EV ready space (Low Power Level 2 EV Charging Receptacle is acceptable provided that the infrastructure comply with section 4.106.4.1) for each residence (except for accessory dwelling unit (ADU)).

(b) Location. The proposed location of a charging station may be internal or external to the dwelling and shall be in close proximity to an on-site parking space consistent with city regulations.

A4.106.8.2 New multi-family dwellings. The following standards apply to newly constructed residences in a multi-family residential structure.

(a) **Resident parking.** The property owner shall provide at least one (1) Level 2 electrical vehicle supply equipment (EVSE) or one (1) Level 2 EV Ready space for each residential unit in the structure (Low Power Level 2 EV Charging Receptacle is acceptable for 60% of the total EV parking spaces) .

(b) **Guest parking**. The property owner shall provide EV Capable Space, EV-Ready Space, or EVSE Installed, for at least 25% of guest parking spaces, among which at least 10% (and no fewer than one) shall be EVSE Installed.

(c) **Accessible spaces.** Projects shall comply with the 2022 California Building Code requirements for accessible electric vehicle parking.

(d) **Minimum total circuit capacity.** The property owner shall ensure sufficient circuit capacity, as determined by the Chief Building Official or designee, to support the EV requirements specified in (a) and (b) above.

(e) **Location.** The EVSE, receptacles, and/or raceway required by this section shall be placed in locations allowing convenient installation of and access to EVSE. In addition, if parking is deed-restricted to individual residential units, the EVSE or receptacles required by subsection (a) shall be located such that each unit has access to its own EVSE or receptacle. Location of EVSE or receptacles shall be consistent with all city regulations.

A4.106.8.3 New hotels and motels. The following standards apply to newly constructed hotels.

(a) **In general.** The property owner shall provide at least 40% EV Ready Space and at least 10% Level 2 EVSE installed ~~for~~ of the total parking spaces.

(b) **Accessible spaces.** Projects shall comply with the 2022 California Building Code requirements for accessible electric vehicle parking.

(c) **Minimum total circuit capacity.** The property owner shall ensure sufficient circuit capacity, as determined by the Chief Building Official or designee, to support a Level 2 EVSE in every location where EV-Ready space or EVSE Installed is required.

(d) **Location.** The EVSE and/or receptacles, required by this section shall be placed in locations allowing convenient installation of and access to EVSE. Location of EVSE or receptacles shall be consistent with all City guidelines, rules, and regulations.

16.14.170 Section A4.106.9 Bicycle Parking.

Section A4.106.9 of Appendix A4 of the California Green Building Standards Code is not adopted as a Tier 1 and Tier 2 elective measure. Projects must comply with the bicycle parking requirements in the Palo Alto Municipal Code.

16.14.180 Section A4.106.10 Light Pollution Reduction.

Section A4.106.10 is added and adopted as a Tier 1 and Tier 2 elective measure for all covered projects and is amended to read:

A4.106.10 Light pollution reduction. Outdoor lighting systems shall be designed and installed to comply with the following:

1. The minimum requirements in the California Energy Code for Lighting Zones 1-4 as defined in Chapter 10 of the California Administrative Code; and
2. Backlight, Up light and Glare (BUG) ratings as defined in IES TM-15-11; and
3. Allowable BUG ratings not exceeding those shown in TABLE 5.106.8 [N]; or

   Comply with a local ordinance lawfully enacted pursuant to Section 101.7 of this code, whichever is more stringent.

Projects may use an approved equal reference standard for light fixtures where BUG ratings are unavailable.

Exceptions:

1. Luminaires that qualify as exceptions to the California Energy Code.
2. Emergency lighting.
3. One- and two-family dwellings.

Note: The International Dark-Sky Association (IDA) and the Illuminating Engineering Society of North America (IESNA) have developed a Model Lighting Ordinance (MLO). The MLO was designed to help municipalities develop outdoor lighting standards that reduce glare, light trespass, and skyglow. The model ordinance and user guides for the ordinance may be accessed at the International Dark-Sky Association web site.

Division A4.2 – ENERGY EFFICIENCY

16.14.190 Section A4.203.1 Performance Approach for Newly Constructed Buildings.

Section A4.203.1 of Appendix A4 of the California Green Building Standards Code is not adopted as a Tier 1 and Tier 2 elective measure. Projects shall comply with Chapter 16.17 of the Palo Alto Municipal Code (*California Energy Code*).

Division A4.3 – WATER EFFICIENCY AND CONSERVATION

16.14.200 Section A4.304.3 Irrigation Metering Device.

Section A4.304.3 of Appendix A4 of the California Green Building Standards Code is adopted as a Tier 1 and Tier 2 elective measure and is amended to read:

A4.304.3 Irrigation metering device. Dedicated irrigation meters from CPAU are to be installed in all new construction and rehabilitated landscapes when the landscape is greater than 1,000 square feet.

16.14.210 Section A4.305 Water Reuse Systems.

Sections A4.305.1, A4.305.2, and A4.305.3 of Appendix A4 of the California Green Building Standards Code are adopted as Tier 1 and Tier 2 elective measures and are amended to read:

A4.305.1 Graywater. Alternative plumbing piping is installed to permit the discharge from the clothes washer and other fixtures (except toilets and kitchen sinks) to be used for an irrigation system in compliance with the *California Plumbing Code*. In the event that the whole house graywater system is installed in compliance with the California Plumbing Code, then this measure shall count as 3 electives.

A4.305.2 Recycled water piping. Based on projected availability, dual water piping is installed for future use of recycled water at the following locations:

1. Interior piping for the use of recycled water is installed to serve all water closets, urinals, and floor drains.
2. Exterior piping is installed to transport recycled water from the point of connection to the structure. Recycled water systems shall be designed and installed in accordance with the *California Plumbing Code*.

A4.305.3 Recycled water for landscape irrigation. Recycled water piping is used for landscape irrigation.

16.14.220 A4.305.4 Additions and Alterations.

Section A4.305.4 is added as Tier 1 and Tier 2 prerequisite and amended to read:

A4.305.4 Additions and alterations. All multi-family residential additions and alterations must install recycled water infrastructure for irrigation when the landscape area exceeds 1,000 square feet.

Division A4.4 – MATERIAL CONSERVATION AND RESOUCE EFFICIENCY

16.14.230 Section A4.403.1 Frost Protection Foundation Systems.

Sections A4.403.1 is not adopted as a Tier 1 and Tier 2 elective measure.

16.14.240 Section A4.403.2 Reduction in cement use.

Section A4.403.2 of Appendix A4 of the California Green Building Standards Code is adopted as a Mandatory measure for all Tier 1 and Tier 2 projects and is amended to read:

A4.403.2 Low carbon concrete requirements.

A4.403.2.1 Purpose. The purpose of this chapter is to provide practical standards and requirements for the composition of concrete, as defined herein, that maintains adequate strength and durability for the intended application and at the same time reduces greenhouse gas emissions associated with concrete composition. This code includes pathways for compliance with either reduced cement levels or lower-emission supplementary cementitious materials.

A4.403.2.2 Definitions. For the application of this section the following definitions shall apply:

Concrete. Concrete is any approved combination of mineral aggregates bound together into a hardened conglomerate in accordance with the requirements of this code.

Environmental product declaration (EPD). EPDs present quantified environmental information on the life cycle of a product to enable comparisons between products fulfilling the same function. EPDs must conform to ISO 14025, and EN 15804 or ISO 21930, and have at least a "cradle to gate" scope (which covers product life cycle from resource extraction to the factory).

Upfront embodied carbon (embodied carbon). The greenhouse gasses emitted in material extraction, transportation and manufacturing of a material corresponding to life cycle stages A1 (extraction and upstream production), A2 (transportation), and A3 (manufacturing). Definition is as noted in ISO 21930 and as defined in V2.3 Product Category Rule for Concrete by NSF dated November 2023.

https://d2evkimvhatqav.cloudfront.net/documents/PCR-Product-Category-Rules/PCR-Concrete-2023-deviation.pdf

A4.403.2.3 Compliance. Compliance with the requirements of this chapter shall be demonstrated through any of the compliance options in Sections 4.403.2.3.2 through 4.403.2.3.5:

TABLE A4.403.2.3 Cement and Embodied Carbon Limit Pathways

	Cement limits for use with any compliance method A4.403.2.3.2 to A4.403.2.3.5	**Embodied Carbon limits** for use with any compliance method A4.403.2.3.2 to A4.403.2.3.5
Minimum specified compressive strength f'_c, psi (1)	Maximum ordinary Portland cement content, lbs/yd³ (2)	Maximum embodied carbon kg CO_2e/m^3, per EPD
up to 2500	362	260
3000	410	289
4000	456	313
5000	503	338
6000	531	356
7000	594	394
7001 and higher	657	433
up to 3000 light weight	512	578
4000 light weight	571	626
5000 light weight	629	675

Notes

(1) For concrete strengths between the stated values, use linear interpolation to determine cement and/or embodied carbon limits.

(2) Portland cement of any type per ASTM C150.

A4.403.2.3.1 Allowable increases.

(1) Cement and Embodied Carbon Limit Allowances. Cement or Embodied Carbon limits shown in Table A4.403.2.3 can be increased by 30% for concretes demonstrated to the Building Official as requiring high early strength. Such concretes could include, but are not limited to, precast, prestressed *concrete*; beams and slabs above grade; and shotcrete

(2) Approved Cements. The maximum cement content may be increased proportionately above the tabulated value when using an approved cement, or blended cement, demonstrated by approved EPD to have a plant-specific EPD lower than 1040 kg CO2e/metric ton. The increase in allowable cement content would be (1040 / plant=specific EPD) %.

A4.403.2.3.2 Cement limit method — mix. Cement content of a concrete mix using this method shall not exceed the value shown in the Table A4.403.2.3. Use of this method is limited to concrete with specified compressive strength not exceeding 5,000 psi.

A4.403.2.3.3 Cement limit method — project. Total cement content shall be based on total cement usage of all concrete mix designs within the same project. Total cement content for a project shall not exceed the value calculated according to Equation A4.403.2.3.3.

Equation A4.403.2.3.3:

$Cem_{proj} < Cem_{allowed}$

where

$Cem_{proj} = \Sigma Cem_n v_n$ and $Cem_{allowed} = \Sigma Cem_{lim} v_n$

and

n = the total number of *concrete* mixtures for the project

Cem_n = the cement content for mixture $_n$, kg/m ^{3} or lb/yd ^{3}

Cem_{lim} = the maximum cement content for mixture $_n$ per Table A4.403.2.3, kg/m ^{3} or lb/yd ^{3}

v_n = the volume of mixture $_n$ *concrete* to be placed, yd ^{3} or m ^{3}

Applicant can use yd ^{3} or m ^{3} for calculation, but must keep same units throughout

A4.403.2.3.4. Embodied carbon method — mix. Embodied carbon of a *concrete* mix, based on an approved environmental product declaration (EPD), shall not exceed the value given in Table A4.403.2.3.

A4.403.2.3.5. Embodied carbon method — project. Total embodied carbon (EC_{proj}) of all *concrete* mix designs within the same project shall not exceed the project limit ($EC_{allowed}$) determined using Table A4.403.2.3 and Equation A4.403.2.3.5.

Equation A4.403.2.3.5:

$EC_{proj} < EC_{allowed}$

where

$EC_{proj} = \Sigma EC_n v_n$ and $EC_{allowed} = \Sigma EC_{lim} v_n$

and

n = the total number of *concrete* mixtures for the project

EC_n = the embodied carbon potential for mixture n per mixture EPD, kg/m ^{3}

EC_{lim} = the embodied carbon potential limit for mixture n per Table A4.403.2.3, kg/m^3

v_n = the volume of mixture $_n$ *concrete* to be placed, yd ^{3} or m ^{3}

Applicant can use yd ^{3} or m ^{3} for calculation, but must keep same units throughout.

A4.403.2.3.6. Enforcement.

As a condition prior to the issuance of every building permit involving placement of concrete, the permit applicant shall be required to submit a completed low-carbon concrete compliance form that shall be provided by and reviewed for compliance by the building department prior to issuing the permit.

As a condition of such building permits, and prior to approving construction inspections following placement of concrete, the permit applicant shall be required to submit batch certificates and/or EPDs provided by the concrete provider that demonstrate compliance with the low-carbon concrete compliance form on file with the building permit. The batch certificates and/or EPDs shall be reviewed for compliance by the building department prior to approving any further inspections.

When deviations from compliance with this section occur, the chief building official or his designee is authorized to require evidence of equivalent carbon reductions from the portions of remaining construction of the project to demonstrate alternative compliance with the intent of this chapter.

For projects involving placement of concrete by, or on behalf of, a public works, parks, or similar department the director of such department, or his/her assignee, shall maintain accurate records of the total volume (in cubic yards) of all concrete placed, as well as the total compliant volume (in cubic yards) of all concrete placed, and shall report this data annually to the governing body in a form expressing an annual compliance percentage derived from the quotient of total compliant concrete volume placed divided by total concrete volume placed.

A4.403.2.3.7. Exemptions.

(a) Hardship or infeasibility exemption. If an applicant for a project subject to this chapter believes that circumstances exist that make it a hardship or infeasible to meet the requirements of this chapter, the applicant may request an exemption as set forth below. In applying for an exemption, the burden is on the applicant to show hardship or infeasibility. The applicant shall identify in writing the specific requirements of the standards for compliance that the project is unable to achieve and the circumstances that make it a hardship or infeasible for the project to comply with this chapter. Circumstances that constitute hardship or infeasibility may include, but are not limited to the following:

(1) There is a lack of commercially available material necessary to comply with this chapter;

(2) The cost of achieving compliance is disproportionate to the overall cost of the project;

(3) Compliance with certain requirements would impair the historic integrity of buildings listed on a local, state or federal list or register of historic structures as regulated by the California Historic Building Code (Title 24, Part 8).

(b) Granting of exemption. If the chief building official determines that it is a hardship or infeasible for the applicant to fully meet the requirements of this chapter and that granting the requested exemption will not cause the building to fail to comply with the California Building Standards Code, the chief building official shall determine the maximum feasible threshold of compliance reasonably achievable for the project. In making this determination, the chief building official shall consider whether alternate, practical means of achieving the objectives of this chapter can be satisfied. If an exemption is granted, the applicant shall be required to comply with this chapter in all other respects and shall be required to achieve the threshold of compliance determined to be achievable by the chief building official.

(c) Denial of exception. If the chief building official determines that it is reasonably possible for the applicant to fully meet the requirements of this chapter, the request shall be denied and the applicant shall be notified of the decision in writing. The project and compliance documentation shall be modified to comply with the standards for compliance.

16.14.250 Section A4.408.1 Enhanced Construction Waste Reduction.

Section A4.408.1 of Appendix A4 of the California Green Building Standards Code is adopted as a mandatory measure and is amended to read:

A4.408.1 Enhanced construction waste reduction. Nonhazardous construction and demolition debris generated at the site is diverted to recycle or salvage in compliance with the following:

Projects with a given valuation of $25,000 or more must have at least an 80-percent reduction. Any mixed recyclables that are sent to mixed-waste recycling facilities shall include a qualified third party verified facility average diversion rate. Verification of diversion rates shall meet minimum certification eligibility guidelines, acceptable to the local enforcing agency.

Exceptions:

1. Residential stand-alone mechanical, electrical or plumbing permits.
2. Commercial stand-alone mechanical, electrical or plumbing permits.

A4.408.1.1 Documentation. Documentation shall be provided to the enforcing agency which demonstrates compliance with all construction and demolition waste reduction requirements.

Division A4.5 – ENVIRONMENTAL QUALITY

16.14.260 Section A4.504.1 Compliance with Formaldehyde Limits.

Section A4.504.1 of Appendix A5 of the California Green Building Standards Code is adopted as a Tier 1 and Tier 2 elective measure.

16.14.270 Section A4.504.3 Thermal Insulation.

Section A4.504.3 of Appendix A5 of the California Green Building Standards Code is not adopted as a Tier 1 and Tier 2 prerequisite. Section A4.504.3 is adopted as a Tier 1 and Tier 2 elective measure.

Part 8 – Local Modifications to CHAPTER 5 – NONRESIDENTIAL MANDATORY MEASURES

Division 5.1 – PLANNING AND DESIGN

16.14.280 Nonresidential Projects: Chapter 5 Preface Green Building Requirements for Project Type and Scope.

A Preface is added to Chapter 5 of the California Green Building Standards Code to read:

Preface – Green Building Requirements for Project Type and Scope. For design and construction of nonresidential projects, the City requires compliance with the mandatory measures of Chapter 5, in addition to use of Tier 1 and Tier 2 as specified in Palo Alto Municipal Code Chapter 16.14. See Section 202 for definitions on CALGreen MANDATORY, Tier 1 prerequisites and electives, and Tier 2 prerequisites and electives. All elective measures are adopted as written under Appendix A5 unless otherwise indicated in this Section.

16.14.290 Section 5.106.1.1 Local Stormwater Pollution Prevention.

Section 5.106.1.1 of Chapter 5 of the California Green Building Standards Code is amended to read:

5.106.1.1 Local ordinance. Newly constructed projects and additions shall comply with additional City of Palo Alto stormwater runoff management and pollution prevention measures as applicable, and as may be amended from time to time.

16.14.295 Section 5.106.8 Light Pollution Reduction.

Section 5.106.8 of Chapter 5 of the California Green Building Standards Code is amended to read:

5.106.8 Light pollution reduction. Outdoor lighting systems shall be designed and installed to comply with the following:

1. The minimum requirements in the California Energy Code for Lighting Zones 0-4 as defined in Chapter 10, Section 10-114 of the California Administrative Code; and
2. Backlight (B) ratings as defined in IES TM-15-11 (shown in Table A-1 in Chapter 8);
3. Uplight and Glare ratings as defined in California Energy Code (shown in Tables 130.2-A and 130.2-B in Chapter 8); and
4. Allowable BUG ratings not exceeding those shown in Table 5.106.8 [N]; or

   Comply with a local ordinance lawfully enacted pursuant to Section 101.7, whichever is more stringent.

Projects may use an approved equal reference standard for light fixtures where BUG ratings are unavailable.

Exceptions:

1. Luminaires that qualify as exceptions in Section 103.2(b) and 140.7 of the California Energy Code.
2. Emergency lighting.
3. Building facade meeting the requirements in Table 140.7-B of the California Energy Code, Part 6.
4. Custom lighting features as allowed by the local enforcing agency, as permitted by Section 101.8 Alternate materials, designs and methods of construction.

5. Luminaires with less than 6,200 initial luminaire lumens.

16.14.300 Section 5.106.13 Full Electrification.

Section 5.106 of Chapter 4 of the California Green Building Standards Code is amended to add new subsection, 5.106.13 as follows:

> **5.106.13 Full electrification.** Full electrification is recommended for new buildings, substantial remodels, and new outdoor appliances/equipment such as fireplaces, firepits, heaters for swimming pool/spa, and similar equipment. Full electrification is required for outdoor grills, stoves, and barbecues. This subsection does not prohibit freestanding and/or portable grills, stoves, and barbecues whose source of energy is self-contained fuel canisters.

16.14.310 Reserved

16.14.320 Reserved

Division 5.3 – WATER EFFICIENCY AND CONSERVATION

16.14.330 Section 5.304.2 Invasive Species Prohibited.

Section 5.304.2 of Chapter 5 of the California Green Building Standards Code is added as mandatory measure to read:

> **5.304.2 Invasive species prohibited.** All nonresidential new construction, additions, and alterations shall not install invasive species in a landscape area of any size.

16.14.340 Section 5.306 Nonresidential Enhanced Water Budget.

Section 5.306 of Chapter 5 of the California Green Building Standards Code is added as mandatory measure to read:

> **5.306 Nonresidential enhanced water budget.** Nonresidential buildings anticipated to use more than 1,000 gallons of water a day shall complete an Enhanced Water Budget Calculator as established by the Chief Building Official or designee.

16.14.350 Section 5.307 Cooling Tower Water Use.

Section 5.307 Cooling Tower Water Use is added as mandatory to read:

> **5.307 COOLING TOWER WATER USE**
>
> **5.307.1. Cooling tower water use in high rise residential or nonresidential buildings.**
>
> Cooling tower water use must meet the conditions as follows and as outlined in Palo Alto

Municipal Code Section 16.08.100. Projects are required to perform a potable water analysis at the site to meet the maximum concentration of parameters noted in Table 5.307.1

TABLE 5.307.1

Ca (as CaCO3)	600 ppm
Total alkalinity	500 ppm
SiO2	150 ppm
Cr	300 ppm
Conductivity	3300 Us/cm

Calculate maximum number of cycles that can be achieved with these levels of concentration shall be included in the plumbing design plans.

Division 5.4 – MATERIAL CONSERVATION AND RESOUCE EFFICIENCY

16.14.360 Section 5.410.4.6 Energy STAR Portfolio Manager.

Section 5.410.4.6 of Chapter 5 of the California Green Building Standards is added as mandatory measure to read:

5.410.4.6 Energy STAR portfolio manager. All nonresidential projects exceeding $100,000 valuation must provide evidence of an Energy STAR Portfolio Manager project profile for both water and energy use prior to Permit Issuance, acquire an Energy STAR Portfolio Manager Rating, and submit the rating to the City of Palo Alto once the project has been occupied after 12 months.

16.14.370 Section 5.410.4.7 Performance Reviews – Energy.

Section 5.410.4.7 of Chapter 5 of the California Green Building Standards is added to read:

5.410.4.7 Performance reviews – energy. All projects over 10,000 square feet. The City reserves the right to conduct a performance review, no more frequently than once every five years unless a project fails review, to evaluate the building's energy use to ensure that resources used at the building and/or site do not exceed the maximum allowance set forth in the rehabilitation or new construction design. Following the findings and recommendations of the review, the City may require adjustments to the energy usage or energy-using equipment or systems if the building is no longer compliant with the original design. Renovation or rehabilitation resulting from such audit activity shall be considered a project and shall be subject to applicable documentation submittal requirements of the City. This section is effective only for those projects for which a building permit was issued after January 1, 2009.

16.14.380 Section 5.410.4.8 Performance Reviews – Water.

Section 5.410.4.8 of Chapter 5 of the California Green Building Standards is added to read:

5.410.4.8 Performance reviews – water. All sites greater than one acre: The City reserves the right to conduct performance reviews, no more frequently than once every five years unless a project fails review, to evaluate water use to ensure that resources used at the building and/or site do not exceed a maximum allowance set forth in the rehabilitation or new construction design. Water use reviews may be initiated by CPAU, or as a coordinated effort between the CPAU and the Santa Clara Valley Water District (SCVWD), or as part of SCVWD's established water conservation programs. Following the findings and recommendations of the review, the City may require adjustments to irrigation usage, irrigation hardware, and/or landscape materials to reduce consumption and improve efficiency. Renovation or rehabilitation resulting from such audit activity shall be considered a project and shall be subject to applicable documentation submittal requirements of the City.

16.14.390 Section 5.506 Indoor Air Quality.

Section 5.506.4 of Chapter 5 of the California Green Building Standards is added as mandatory measure to read:

Section 5.506.4 Indoor air quality management plan. All commercial and multi- family projects must submit an Indoor Air Quality Management Plan (IAQ) with building permit application in accordance with the Sheet Metal and Air Conditioning Contractors National Association (SMACNA IAQ) Guidelines for Occupied Buildings Under Construction, 2nd edition ANSI/SMACNA 008-2008.

Part 9 – Local Modifications to APPENDIX A5 – NONRESIDENTIAL VOLUNTARY MEASURES

Division A5.1 – PLANNING AND DESIGN

16.14.400 Section A5.106.5.3 Electric Vehicle (EV) Charging for New Construction.

Section A5.106.5.3 – A5.106.5.3.4 of the California Green Building Standards Code are deleted in its entirety, adopted as mandatory measures and is amended to read:

A5.106.5.3 Electric vehicle (EV) charging for nonresidential structures. New non-residential structures shall comply with the following requirements for electric vehicle supply equipment (EVSE). All parking space calculations under this section shall be rounded up to the next full space. The requirements stated in this section are in addition to those contained in Section 5.106.5.3 of the California Green Building Standards Code. In the event of a conflict between this section and Section 5.106.5.3, the more robust EV Charging requirements shall prevail.

A5.106.5.3.5 Nonresidential structures other than hotels. The following standards apply to newly constructed nonresidential structures other than hotels.

In general. For building with 10 to 20 parking spaces, the property owner shall provide at least 20% EV Capable or EVSE-Ready space, and at least 20% Level 2 EVSE installed of the total parking spaces.

For building with over 20 parking spaces, the property owner shall provide at least 15% EV Capable or EVSE-Ready space, and at least 15% EVSE installed for of the total parking spaces

Accessible spaces. Projects shall comply with the 2022 California Building Code requirements for accessible electric vehicle parking.

Minimum total circuit capacity. The property owner shall ensure sufficient circuit capacity, as determined by the Chief Building Official or designee , to support a Level 2 EVSE in every location where EVSE Capable space, EVSE-Ready space or EVSE Installed is required.

Location. The EVSE, receptacles, and/or raceway required by this section shall be placed in locations allowing convenient installation of and access to EVSE. Location of EVSE or receptacles shall be consistent with all city regulations.

Division A5.4 – ENERGY EFFICIENCY

16.14.410 Section A5.203.1 Performance Approach for Newly Constructed Buildings.

Section A5.203.1 of Appendix A5 of the California Green Building Standards Code is not adopted as a Tier 1 and Tier 2 elective measure. Projects shall comply with Chapter 16.17 of the Palo Alto Municipal Code (*California Energy Code*).

Division A5.4 – MATERIAL CONSERVATION AND RESOUCE EFFICIENCY

16.14.420 Section A5.405.5 Cement and Concrete.

Section A5.405.5 of Appendix A5 of the California Green Building Standards Code is adopted as a Mandatory measure for Tier 1 and Tier 2 projects and is amended to read:

A5.405.5 Cement and concrete. Use cement and concrete made with recycled products and complying with the following sections and requirements per **PAMC Chapter 16.14.240**.

16.14.430 Section A5.408 Construction Waste Reduction, Disposal and Recycling.

Section A5.408 of Appendix A5 of the California Green Building Standards Code is adopted as a Mandatory measure for Tier 2 projects and is amended to read:

A5.408.3.1 Waste enhanced construction waste reduction. (80% construction waste reduction) as a mandatory requirement for all nonresidential construction, including new construction, additions, and alterations, as long as the construction has a valuation of $25,000 or more. Nonresidential projects with a lower valuation shall remain subject to

California Green Building Standards Code Chapter 5 mandatory measures.

Exceptions:

1. Residential stand-alone mechanical, electrical or plumbing permits.
2. Commercial stand-alone mechanical, electrical or plumbing permits.

A5.408.3.1.1 - Deleted

A5.408.3.1.2 Documentation. Documentation shall be provided to the enforcing agency which demonstrates compliance with all construction and demolition waste reduction requirements.

SECTION 3. The Council adopts the findings for local amendments to the California Green Building Standards Code, 2022 Edition, attached hereto as Exhibit "A" and incorporated herein by reference.

SECTION 4. If any section, subsection, clause or phrase of this Ordinance is for any reason held to be invalid, such decision shall not affect the validity of the remaining portion or sections of the Ordinance. The Council hereby declares that it should have adopted the Ordinance and each section, subsection, sentence, clause or phrase thereof irrespective of the fact that any one or more sections, subsections, sentences, clauses or phrases be declared invalid.

SECTION 5. The Council finds that this project is exempt from the provisions of the California Environmental Quality Act ("CEQA"), pursuant to Section 15061 of the CEQA Guidelines, because it can be seen with certainty that there is no possibility that the amendments herein adopted will have a significant effect on the environment and Section 15308, because the amendments herein adopted is an action taken by the City to assure the maintenance, restoration, enhancement, or protection of the environment.

///

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SECTION 6. This Ordinance shall be effective on the thirty-first day after the date of its adoption.

INTRODUCED:

PASSED:

AYES:

NOES:

ABSENT:

ABSTENTIONS:

ATTEST:

______________________________	______________________________
City Clerk	Mayor
APPROVED AS TO FORM:	APPROVED:
______________________________	______________________________
Chief Assistant City Attorney	City Manager
	______________________________
	Director of Planning and Development Services
	______________________________
	Director of Administrative Services

Exhibit A
FINDINGS FOR LOCAL AMENDMENTS TO CALIFORNIA GREEN BUILDING STANDARD CODE TITLE 24, PART 11

Section 17958 of the California Health and Safety Code provides that the City may make changes to the provisions of the California Building Standards Code. Sections 17958.5 and 17958.7 of the Health and Safety Code require that for each proposed local change to those provisions of the California Building Standards Code which regulate buildings used for human habitation, the City Council must make findings supporting its determination that each such local change is reasonably necessary because of local climatic, geological, or topographical conditions.

Local building regulations having the effect of amending the uniform codes, which were adopted by the City prior to November 23, 1970, were unaffected by the regulations of Sections 17958, 17958.5 and 17958.7 of the Health and Safety Code. Therefore, amendments to the uniform codes which were adopted by the City Council prior to November 23, 1970 and have been carried through from year to year without significant change, need no required findings. Also, amendments to provisions not regulating buildings used for human habitation do not require findings.

Code: California Green Building Standard Code, Title 24, Part 11					
Chapter(s), Sections(s), Appendices	**Title**	**Add**	**Deleted**	**Amended**	**Justification (See below of keys)**
101.4	Appendices	✓			**A**
202	Definitions	✓			**A**
301	Voluntary Tiers Added			✓	**C, E**
301.1	Scope			✓	**C, E**
301.1.1	Residential additions and alterations			✓	**C, E**
301.2	Low-rise and high-rise residential buildings			✓	**C, E**
301.2.1	Low-Rise residential new construction – Tier 2 adopted			✓	**C, E**
301.3	Nonresidential additions and alterations			✓	**C, E**
301.3.3	No-residential new construction – Tier 2			✓	**C, E**
301.6	Special inspector requirements			✓	**C, E**
301.7	Low-carbon concrete requirements for Tier 1 and Tier 2 projects			✓	**C, E**
4.306	Swimming pool and spa covers	✓			**C, E**
4.509	Heat pump water heater		✓		
702.2	Green building special inspection			✓	**C, E**
A4.104.1	Supervision and education by a special inspector			✓	**C, E**
A4.105.1	Chapter 5.24 of Title 5 of the Municipal Code			✓	**C, E**

A4.105.2	Reuse of materials			✓	**C, E**
A4.106.8	Electric vehicle (EV) charging for residential structures				**C, E**
A4.106.8.1	New single-family, duplex and townhouse dwellings			✓	**C, E**
A4.106.8.2	New multi-family dwellings.			✓	**C, E**
A4.106.8.3	New hotels and motels			✓	**C, E**
A4.106.9	Bicycle Parking			✓	**C, E**
A4.106.10	Light pollution reduction			✓	**C, E**
A4.203.1	Performance Approach for Newly Constructed Buildings			✓	**C, E**
A4.304.3	Irrigation metering device			✓	**C, E**
A4.305.1	Graywater			✓	**C, E**
A4.305.2	Recycled water piping			✓	**C, E**
A4.305.3	Recycled water for landscape irrigation			✓	**C, E**
A4.305.4	Additions and alterations			✓	**C, E**
A4.403.1	Frost Protection Foundation Systems		✓		**C**
A4.403.2	Reduction in cement use			✓	**C, E**
A4.403.2.1	Purpose			✓	**C, E**
A4.403.2.2	Definitions			✓	**C, E**
A4.403.2.3	Compliance			✓	**C, E**
Table A4.403.2.3	Cement and Embodied Carbon Limit Pathways			✓	**C, E**
A4.403.2.3.1	Allowable increases			✓	**C, E**
A4.403.2.3.2	Cement limit method - mix			✓	**C, E**
A4.403.2.3.3	Cement limit method - project			✓	**C, E**
A4.403.2.3.4	Embodied carbon method - mix			✓	**C, E**
A4.403.2.3.5	Embodied carbon method - project			✓	**C, E**
A4.403.2.3.6	Enforcement			✓	**A**
A4.403.2.3.7	Exemptions			✓	**A**
A4.408.1	Enhanced construction waste reduction			✓	**C, E**
A4.408.1.1	Documentation			✓	**A**
A4.504.1	Compliance with Formaldehyde Limits			✓	**C, E**
A4.504.3	Thermal Insulation			✓	**C, E**
5.106.1.1	Local Storm Water Pollution Prevention			✓	**C, E**
5.106.1.1	Local ordinance			✓	**C, E**
5.106.8	Light pollution reduction			✓	**C, E**
5.304.2	Invasive species prohibited	✓			**C**
5.306	Nonresidential enhanced water budget	✓			**C, E**
5.307.1	Cooling tower water use in high-rise residential or nonresidential buildings	✓			**C, E**

5.410.4.6	Energy STAR portfolio manager	✓			**C, E**
5.410.4.7	Performance reviews – energy	✓			**C, E**
5.410.4.8	Performance reviews – water	✓			**C, E**
5.506.4	Indoor air quality management plan	✓			**E**
A5.106.5.3	Electric vehicle (EV) charging for nonresidential structures			✓	**C, E**
A5.106.5.3.5	Nonresidential structures other than hotels			✓	**C, E**
A5.203.1	Performance Approach for Newly Constructed Buildings			✓	**C, E**
A5.405.5	Cement and concrete			✓	**C, E**
A5.408.3.1	Waste enhanced construction waste reduction			✓	**C, E**
A5.408.3.1.1	Enhanced construction waste reduction – Tier 2		✓		**A**
A5.408.3.1.2	Documentation			✓	**A**

Key to Justification for Amendments to Title 24 of the California Code of Regulations

A This is an **administrative** amendment to clarify and establish civil and administrative procedures, regulations, or rules to enforce and administer the activities by the Palo Alto Building Inspection Department. These administrative amendments do not need to meet HSC 18941.5/17958/13869 per HSC 18909(c).

C This amendment is justified on the basis of a local climatic condition. The seasonal climatic conditions during the late summer and fall create severe fire hazards to the public health and welfare in the City. The hot, dry weather frequently results in wild land fires on the brush covered slopes west of Interstate 280. The aforementioned conditions combined with the geological characteristics of the hills within the City create hazardous conditions for which departure from California Building Standards Code is required. Natural gas combustion and gas appliances emit a wide range of air pollutants, such as carbon monoxide (CO), nitrogen oxides (NOx, including nitrogen dioxide (NO2)), particulate matter (PM), and formaldehyde, which according to a UCLA Study, have been linked to various acute and chronic health effects, and additionally exceed levels set by national and California-based ambient air quality standards. The burning of fossil fuels used in the generation of electric power and heating of buildings contributes to climate change, which could result in rises in sea level, including in San Francisco Bay, that could put at risk Palo Alto homes and businesses, public facilities, and Highway 101 (Bayshore Freeway), particularly the mapped Flood Hazard areas of the City. Energy efficiency is a key component in reducing GHG emissions, and construction of more energy efficient buildings can help Palo Alto reduce its share of the GHG emissions that contribute to climate change. All-electric new buildings benefit the health, safety, and welfare, of Palo Alto and its residents. Requiring all-electric construction, without gas infrastructure will reduce the amount of greenhouse gas produced in Palo Alto and will contribute to reducing the impact of climate change and the associated risks. Due to decrease in annual rain fall, Palo Alto experiences the effect of drought and water saving more than some other communities in California. Embodied carbon of concrete is a significant contributor to greenhouse gas emissions and climate change, and this amendment includes a requirement to use low-carbon concrete. Providing additional capacity for electric vehicle use reduces use of gasoline which is a major contributor to climate change.

E Green building enhances the public health and welfare by promoting the environmental and economic health of the City through the design, construction, maintenance, operation and deconstruction of buildings and sites by incorporating green practices into all development. The green provisions in this Chapter are designed to achieve the following goals:

(a) Increase energy efficiency in buildings;

(b) Reduce the use of natural gas in buildings which improves indoor environmental quality and health;

(c) Reduce the use of natural gas which will reduce the natural gas infrastructure and fire risk over time;

(d) Reduce the embodied carbon of concrete which reduces greenhouse gas emissions;

(e) Increase water and resource conservation;

(f) Reduce waste generated by construction and demolition projects;

(g) Provide durable buildings that are efficient and economical to own and operate;

(h) Promote the health and productivity of residents, workers, and visitors to the city;

(i) Recognize and conserve the energy embodied in existing buildings;

(j) Increase capacity for use of electric vehicles which reduces greenhouse gas emissions and improves air quality;

(k) Encourage alternative transportation; and

(l) Reduce disturbance of natural ecosystems.

G This amendment is justified on the basis of a local geological condition. The City of Palo Alto is subject to earthquake hazard caused by its proximity to San Andreas fault. This fault runs from Hollister, through the Santa Cruz Mountains, epicenter of the 1989 Loma Prieta earthquake, then on up the San Francisco Peninsula, then offshore at Daly City near Mussel Rock. This is the approximate location of the epicenter of the 1906 San Francisco earthquake. The other fault is Hayward Fault. This fault is about 74 mi long, situated mainly along the western base of the hills on the east side of San Francisco Bay. Both of these faults are considered major Northern California earthquake faults which may experience rupture at any time. Thus, because the City is within a seismic area which includes these earthquake faults, the modifications and changes cited herein are designed to better limit property damage as a result of seismic activity and to establish criteria for repair of damaged properties following a local emergency. Reduction or eliminating of natural gas infrastructure over time will reduce maintenance costs and fire risk in difficult geological conditions.

T The City of Palo Alto topography includes hillsides with narrow and winding access, which makes timely response by fire suppression vehicles difficult. Palo Alto is contiguous with the San Francisco Bay, resulting in a natural receptor for storm and waste water run-off. Also, the City of Palo Alto is located in an area that is potentially susceptible to liquefaction during a major earthquake. The surface condition consists mostly of stiff to dense sandy clay, which is highly plastic and expansive in nature. The aforementioned conditions within the City create hazardous conditions for which departure from California Building Standards Code is warranted. In addition, the reduction or elimination of natural gas infrastructure reduces the likelihood of fire or environmental damage should they become disrupted due to challenging topographic conditions during construction or repair.

Ordinance No. XXXX

Ordinance of the Council of the City of Palo Alto Amending Chapter 16.17 (California Energy Code, California Code of Regulations, Title 24, Part 6) of the Palo Alto Municipal Code to Adopt the 2022 California Energy Code, Along With Local Amendments Thereto, to Increase Energy Efficiency Standards for Buildings, Mandate Electric-Ready Requirements, and Incentivize All-Electric New Construction.

The Council of the City of Palo Alto does ORDAIN as follows:

SECTION 1. Findings and Declarations.

(a) The City of Palo Alto adopted a Sustainability and Climate Action Plan, or S/CAP, to meet the City's stated goal of "80 x 30": reducing greenhouse gas emissions 80% below 1990 levels by 2030.

(b) The S/CAP outlines goals and key actions in eight areas, one of which is energy and more specifically, energy efficiency and electrification. The goals for the energy area of the S/CAP are to reduce GHG emissions from the direct use of natural gas in Palo Alto's building sector by at least 60% below 1990 levels (116,400 MT CO2e reduction) and to modernize the electric grid to support increased electric demand to accommodate state-of-the-art technology.

(c) One key action the City is taking to accomplish those goals is to use codes and ordinances - such as the energy reach code, green building ordinance, zoning code, or other mandates - to facilitate electrification in both existing buildings and new construction projects where feasible.

(d) The purpose of this ordinance is to formally adopt California Code of Regulations, Title 24, Part 11, 2022 California Green Building Standards Code, with local amendments in furtherance of the City of Palo Alto's S/CAP goals.

(e) California Health and Safety Code sections 17958.5 and 17958.7 requires that the City, in order to make changes or modifications in the requirements contained in the California Green Building Standards on the basis of local conditions, make express finding that such modifications or changes are reasonably necessary because of local climatic, geological or topographical conditions.

(f) The required findings are attached to this ordinance as Exhibit A.

SECTION 2. Chapter 16.17 (California Energy Code, California Code of Regulations, Title 24, Part 6) of the Palo Alto Municipal Code is hereby amended by repealing in its entirety existing Chapter 16.17 and adopting a new Chapter 16.17 to read as follows:

CHAPTER 16.17
CALIFORNIA ENERGY CODE,
CALIFORNIA CODE OF REGULATIONS, TITLE 24, PART 6

Sections

16.17.010 2022 California Energy Code, Title 24, Part 6 adopted.

The California Energy Code, 2022 Edition, Title 24, Part 6 of the California Code of Regulations together with those omissions, amendments, exceptions and additions thereto, is adopted and hereby incorporated in this Chapter by reference and made a part hereof the same as if fully set forth herein. Except as amended herein, all requirements of the California Energy Code, 2022 Edition, Title 24, Part 6 of the California Code of Regulations shall apply.

Unless superseded and expressly repealed, references in City of Palo Alto forms, documents and regulations to the chapters and sections of the former editions of the California Code of Regulations, Title 24, shall be construed to apply to the corresponding provisions contained within the California Code of Regulations, Title 24, 2022. Ordinance No. 5571 of the City of Palo Alto and all other ordinances or parts of ordinances in conflict herewith are hereby suspended and expressly repealed.

One copy of the California Energy Code, 2022 Edition, has been filed for use and examination of the public in the Office of the Chief Building Official of the City of Palo Alto.

16.17.020 Cross - References to California Energy Code

The provisions of this Chapter contain cross-references to the provisions of the California Energy Code, 2022 Edition, in order to facilitate reference and comparison to those provisions.

16.17.030 Local Amendments

The provisions of this Chapter shall constitute local amendments to the cross-referenced provisions of the California Energy Code, 2022 Edition, and shall be deemed to replace the cross-referenced sections of said Code with the respective provisions set forth in this Chapter.

16.17.040 Administration & Enforcement of 2022 California Energy Code

Administration and enforcement of this code shall be governed by Chapter 1, Division II of the 2022 California Building Code as amended by Palo Alto Municipal Code Chapter 16.04.

16.17.050 Violations - Penalties

It is unlawful for any person to violate any provision or to fail to comply with any of the requirements of this Chapter or any permits, conditions, or variances granted under this Chapter. Violators shall be subject to any penalty or penalties authorized by law, including but not limited to: administrative enforcement pursuant to Chapters 1.12 and 1.16 of the Palo Alto Municipal Code; and criminal enforcement pursuant to Chapter 1.08 of the Palo Alto Municipal Code. Each separate day or any portion thereof during which any violation of this Chapter occurs or continues shall be deemed to constitute a separate offense.

When the chief building official determines that a violation of this Chapter has occurred, the chief building official may record a notice of pendency of code violation with the Office of the County Recorder stating the address and owner of the property involved. When the violation has been corrected, the chief building official shall issue and record a release of the notice of pendency of code violation.

16.17.060 Section 100.1 Definitions and Rules of Construction

Section 100.1(b) of Subchapter 1 of the California Energy Code is amended by adding the following definitions:

CERTIFIED ENERGY ANALYST is a person registered as a Certified Energy Analyst with the California Association of Building Energy Consultants as of the date of submission of a Certificate of Compliance as required under section 10-103 of Building Energy Efficiency

Standards for residential and nonresidential buildings.

ELECTRIC EQUIPMENT OR APPLIANCE means one or more devices that use electric energy to serve the needs for heating and cooling, water heating, cooking, and electric vehicle charging. In addition, ancillary equipment such as an electric panel, photovoltaic equipment, and energy storage systems that are deployed to support such devices shall be considered Electric Equipment or Appliance.

ELECTRIC HEATING APPLIANCE is a device that produces heat energy to create a warm environment by the application of electric power to resistance elements, refrigerant compressors, or dissimilar material junctions, as defined in the California Mechanical Code.

NET FREE AREA (NFA) is the total unobstructed area of the air gaps between louver and grille slats in a vent through which air can pass. The narrowest distance between two slats, perpendicular to the surface of both slats is the air gap height. The narrowest width of the gap is the air gap width. The NFA is the air gap height multiplied by the air gap width multiplied by the total number of air gaps between slats in the vent.

SUBSTANTIAL REMODEL (or "50-50-50" RULE) is any project or projects that affects the removal or replacement of 50% or more of the linear length of the existing exterior walls of the building, and/or 50% or more of the linear length of the existing exterior wall plate height is raised, and/or 50% or more of the existing roof framing area is removed or replaced, over a 3-year period.

Any permit(s) applied for will trigger a review of a 3-year history of the project. This review will result in determining if a substantial remodel has occurred.

The Chief Building Official or designee shall make the final determination regarding the application if a conflict occurs.

16.17.070 Section 110.10 MANDATORY REQUIREMENTS FOR SOLAR READY BUILDINGS

Section 110.10 of Subchapter 2 of the California Energy Code is amended by adding Section 110.10 (f) to read:

> **(f) Existing tree canopies.** In the event of a conflict between the provisions of this Code, the Solar Shade Act of 2009, and the Palo Alto Tree Ordinance (Chapter 8.10), the most protective of existing tree canopies shall prevail.

16.17.080 SUBCHAPTER 4 NONRESIDENTIAL AND HOTEL/MOTEL OCCUPANCIES – MANDATORY REQUIREMENTS FOR LIGHTING SYSTEMS AND EQUIPMENT, AND ELECTRICAL POWER DISTRIBUTION SYSTEMS

SECTION 130.0 LIGHTING SYSTEMS AND EQUIPMENT, AND ELECTRICAL POWER DISTRIBUTION SYSTEMS – GENERAL.

Section 130.0 (a) of Subchapter 4 of the California Energy Code is amended to read:

(a) The design and installation of all lighting systems and equipment in nonresidential and hotel/motel buildings, outdoor lighting, and electrical power distribution systems within the scope of Section 100.0(a), shall comply with the applicable provisions of Sections 130.0 through 130.6.

NOTE: The requirements of Sections 130.0 through 130.6 apply to newly constructed buildings and substantial remodels. Section 141.0 specifies which requirements of Sections 130.0 through 130.6 also apply to additions and alterations to existing buildings.

16.17.090 SECTION 130.6 ELECTRIC READINESS REQUIREMENTS FOR SYSTEMS USING GAS OR PROPANE

Subchapter 4 of the California Energy Code is amended to add Section 130.6 to be numbered, entitled, and to read:

130.6 ELECTRIC READINESS REQUIREMENTS FOR SYSTEMS USING GAS OR PROPANE

Where nonresidential systems using gas or propane are installed, the construction drawings shall indicate electrical infrastructure and physical space accommodating the future installation of an electric appliance in the following ways, as certified by a registered design professional or licensed electrical contractor.

a) Branch circuit wiring, electrically isolated and designed to serve all electric heating appliances in accordance with manufacturer requirements and the *California Electrical Code*, including the appropriate voltage, phase, minimum amperage, and an electrical receptacle or junction box within five feet of the appliance that is accessible with no obstructions. Appropriately sized conduit may be installed in lieu of conductors; and

b) Labeling of both ends of the unused conductors or conduit shall be with “For Future Electrical Appliance”; and

c) Reserved circuit breakers in the electrical panel for each branch circuit, appropriately labeled (e.g. “Reserved for Future Electric Range”), and positioned on the opposite end of the panel supply conductor connection; and

d) Connected subpanels, panelboards, switchboards, busbars, and transformers shall be sized to serve the future electric heating appliances. The electrical capacity requirements shall be adjusted for demand factors in accordance with the *California Electrical Code*; and

e) Physical space for future electric appliances, including equipment footprint, and if needed a pathway reserved for routing of ductwork to heat pump evaporator(s), shall be depicted on the construction drawings. The footprint necessary for future electric appliances may overlap with non-structural partitions and with the location of currently designed combustion equipment.

16.17.100 SUBCHAPTER 5 NONRESIDENTIAL AND HOTEL/MOTEL OCCUPANCIES — PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES FOR ACHIEVING EFFICIENCY

SECTION 140.0 PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES

Section 140.0 of Subchapter 5 of the California Energy Code is amended to read:

Nonresidential and hotel/motel buildings shall comply with all of the following:

a) The requirements of Sections 100.0 through 110.12 applicable to the building project (mandatory measures for all buildings).

b) The requirements of Sections 120.0 through 130.~~5~~6 (mandatory measures for nonresidential and high-rise residential and hotel/motel buildings).

c) Either the performance compliance approach (energy budgets) specified in Section 140.1 or the prescriptive compliance approach specified in Section 140.2 for the Climate Zone in which the building will be located. Climate zones are shown in FIGURE 100.1-A.

NOTE to Section 140.0(c): The Commission periodically updates, publishes, and makes available to interested persons and local enforcement agencies precise descriptions of the Climate Zones, which is available by zip code boundaries depicted in the Reference Joint Appendices along with a list of the communities in each zone.

16.17.110 SECTION 140.1 PERFORMANCE APPROACH: ENERGY BUDGETS

Section 140.1 of Subchapter 5 of the California Energy Code is amended to read:

Sections 140.1 (a) – (c) are adopted without modification.

A newly constructed building or substantial remodel complies with the performance approach ~~if~~ provided that:

1. The time-dependent valuation (TDV) energy budget calculated for the Proposed Design Building under Subsection (b) is no greater than the TDV energy budget calculated for the Standard Design Building under Subsection (a), and
2. The source energy budget calculated for the proposed design building under Subsection (b) has a source energy compliance margin, relative to the energy budget calculated for the standard design building under Subsection (a), of at least the value specified for the corresponding occupancy type in Table 140.1-A below.

TABLE 140.1-A NONRESIDENTIAL BUILDING SOURCE ENERGY COMPLIANCE MARGINS

Occupancy Type	**Source Energy Compliance Margins**
Office/Mercantile	10%
Hotel/Motel	7%
Restaurants	12%
Industrial/ Manufacturing	0%
All other Nonresidential Occupancies	9%

Exception 1 to Section 140.1 Item 2: A source energy compliance margin of 0 percent or greater is required when nonresidential occupancies are designed with single zone space-conditioning systems complying with Section 140.4(a)2.

3. **Certificate of Compliance.** The Certificate of Compliance shall be prepared and signed by a Certified Energy Analyst and the energy budget for the Proposed Design shall be no greater than the Standard Design Building.

16.17.120 SUBCHAPTER 7 SINGLE-FAMILY RESIDENTIAL BUILDING – MANDATORY FEATURES AND DEVICES

Section 150.0 MANDATORY FEATURES AND DEVICES

Section 150.0 of Subchapter 7 of the California Energy Code is amended to read:

Single-family residential buildings shall comply with the applicable requirements of Sections 150(a) through 150.0(v).

NOTE: The requirements of Sections 150.0 (a) through (v) apply to newly constructed buildings and substantial remodels. Sections 150.2(a) and 150.2(b) specify which requirements of Sections 150.0(a) through 150.0(r) also apply to additions or alterations. The electric readiness requirements of Sections 150.0 (n), (t), (u) and (v) apply to residential remodels or additions when the applicable system is included in the remodel.

Subsections 150.0 (a) – (s) are adopted without modification.

(t) Heat pump space heater ready. Systems using gas or propane furnace to serve individual dwelling units shall include the following:

1. A dedicated 240 volt branch circuit wiring shall be installed within 3 feet from the furnace and accessible to the furnace with no obstructions. The branch circuit conductors shall be rated at 30 amps minimum. The blank cover shall

be identified as "240V ready." All electrical components shall be installed in accordance with the *California Electrical Code*.

2. The main electrical service panel shall have a reserved space to allow for the installation of a double pole circuit breaker for a future heat pump space heater installation. The reserved space shall be permanently marked as "For Future 240V use."
3. A designated exterior location for a future heat pump compressor unit.

Subsections 150.0 (u) – (v) are adopted without modification.

16.17.130 SUBCHAPTER 8 SINGLE-FAMILY RESIDENTIAL BUILDINGS – PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES

SECTION 150.1 PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES FOR SINGLE-FAMILY RESIDENTIAL BUILDINGS

Section 150.1 of Subchapter 8 of the California Energy Code is amended to read:

Section (a) is adopted without modification.

(b) **Performance Standards.** A building complies with the performance standards if the energy consumption calculated for the proposed design building is no greater than the energy budget calculated for the standard design building using Commission-certified compliance software as specified by the Alternative Calculation Methods Approval Manual, as specified in sub-sections 1, 2 and 3 below.

1. **Newly Constructed Buildings and substantial remodels.** The Energy Budget for newly constructed buildings is expressed in terms of the Energy Design Ratings, which are based on source energy and time-dependent valuation (TDV) energy. The Energy Design Rating 1 (EDR1) is based on source energy. The Energy Design Rating 2 (EDR2) is based on TDV energy and has two components, the Energy Efficiency Design Rating, and the Solar Electric Generation and Demand Flexibility Design Rating. The total Energy Design Rating shall account for both the Energy Efficiency Design Rating and the Solar Electric Generation and Demand Flexibility Design Rating. The proposed building shall separately comply with the Source Energy Design Rating, Energy Efficiency Design Rating and the Total Energy Design Rating.

   A building complies with the performance approach if the TDV energy budget calculated for the proposed design building is no greater than the TDV energy budget calculated for the Standard Design Building AND Source Energy compliance margin of at least 8 points, relative to the Source Energy Design Rating 1 calculated for the Standard Design building.

   Exception 1 to Section 150.1(b)1. A community shared solar electric generation system, or other renewable electric generation system, and/or community shared battery storage system, which provides dedicated power, utility energy reduction credits, or payments for energy bill reductions, to the permitted building and is approved by the Energy Commission as specified in Title 24, Part 1, Section 10-115, may offset part or all of the solar electric generation system Energy Design Rating required to comply with the Standards, as calculated according to methods established by the Commission in the Residential ACM Reference Manual.

Exception 2 to Section 150.1(b)1. A newly constructed building that does not require a PV system in accordance with Section 150.1(c)14 needs a Source Energy compliance margin of at least 2 points, relative to the Source Energy Design Rating 1 calculated for the Standard Design building.

2. **Additions and Alterations to Existing Buildings.** The Energy Budget for additions and alterations is expressed in terms of TDV energy.
3. **Compliance demonstration requirements for performance standards.**

Section 150.1 (b) 3A of Subchapter 8 of the California Energy Code amended to add subsection i:

i. **Certificate of Compliance.** The Certificate of Compliance is prepared and signed by a Certified Energy Analyst and the Total Energy Design Rating of the Proposed Design shall be no greater than the Standard Design Building.

Section (c) is adopted without modification.

16.17.140 SUBCHAPTER 10 MULTIFAMILY BUILDINGS — MANDATORY REQUIREMENTS

SECTION 160.4 MANDATORY REQUIREMENTS FOR WATER HEATING SYSTEMS

Section 160.4 (a) of Subchapter 10 of the California Energy Code is deleted:

Sections (b) – (f) are adopted without amendments.

16.17.150 SECTION 160.9 MANDATORY REQUIREMENTS FOR ELECTRIC READY BUILDINGS

Section 160.9 of Subchapter 10 of the California Energy Code is amended to read:

Mandatory requirements for electric-ready buildings apply to newly constructed buildings and substantial remodels.

Section 160.9 Sections (a) – (c) are adopted without amendments.

Sections (d) - (f) are added to read:

(d) **Systems using gas or propane water heaters to serve individual dwelling units shall**

include the following components:

1. A dedicated 125 volt, 20 amp electrical receptacle that is connected to the electric panel with a 120/240 volt 3 conductor, copper branch circuit rated to 30 amps, within 3 feet from the water heater and accessible to the water heater with no obstructions. In addition, all of the following:

   A. Both ends of the unused conductor shall be labeled with the word “spare” and be electrically isolated; and

   B. A reserved single pole circuit breaker space in the electrical panel adjacent to the circuit breaker for the branch circuit in A above and labeled with the words “Future 240V Use”;

   All electrical components shall be installed in accordance with the *California Electrical Code*.

2. A condensate drain that is no more than 2 inches higher than the base of the installed water heater, and allows natural draining without pump assistance,

   All plumbing components shall be installed in accordance with the *California Plumbing Code*.

3. The construction drawings shall indicate the location of the future heat pump water heater. The reserved location shall have minimum interior dimensions of 39”x39”x96”,

4. A ventilation method meeting one of the following:

   A. The location reserved for the future heat pump water heater shall have a minimum volume of 700 cu. ft.,

   B. The location reserved for the future heat pump water heater shall vent to a communicating space in the same pressure boundary via permanent openings with a minimum total net free area of 250 sq. in., so that the total combined volume connected via permanent openings is 700 cu. ft. or larger. The permanent openings shall be:

      i. Fully louvered doors with fixed louvers consisting of a single layer of fixed flat slats; or

      ii. Two permanent fixed openings, consisting of a single layer of fixed flat slat louvers or grilles, one commencing within 12 inches from the top of the enclosure and one commencing within 12 inches from the bottom of the enclosure.

   C. The location reserved for the future heat pump water heater shall include two 8” capped ducts, venting to the building exterior.

      i. All ducts connections and building penetrations shall be sealed.

      ii. Exhaust air ducts and all ducts which cross pressure boundaries shall be insulated to a minimum insulation level of R-6.

iii. Airflow from termination points shall be diverted away from each other.

All mechanical components shall be installed in accordance with the *California Mechanical Code*.

(e) **Central Heat Pump Water Heater Electric Ready.** Water heating systems using gas or propane to serve multiple dwelling units shall meet the requirements of 160.9(f) and include the following for the future heat pump:

1. The system input capacity of the gas or propane water heating system shall be determined as the sum of the input gas or propane capacity of all water heating devices associated with each gas or propane water heating system.

2. Space reserved shall include:

   A. **Heat Pump.** The minimum space reserved shall include space for service clearances, air flow clearances, and keep outs and shall meet one of the following:

      i. If the system input capacity of the gas water heating system is less than 200,000 BTU/HR, the minimum space reserved for the heat pump shall be 2.0 square feet per input 10,000 Btu/ HR of the gas or propane water heating system, and the minimum linear dimension of the space reserved shall be 48 linear inches.

      ii. If the system input capacity of the gas water heating system is greater than or equal to 200,000 BTU/HR, the minimum space reserved for the heat pump shall be 3.6 square feet per input 10,000 Btu/ HR of the gas or propane water heating system, and the minimum linear dimension of the space reserved shall be 84 linear inches.

      iii. The space reserved shall be the space required for a heat pump water heater system that meets the total building hot water demand as calculated and documented by the responsible person associated with the project.

   B. **Tanks.** The minimum space reserved shall include space for service clearances and keep outs and shall meet one of the following:

      i. If the system input capacity of the gas water heating system is less than 200,000 BTU/HR, the minimum space reserved for the storage and temperature maintenance tanks shall be 4.4 square feet per input 10,000 BTU/HR. of the gas or propane water heating system.

      ii. If the system input capacity of the gas water heating system is greater than or equal to 200,000 BTU/HR, the minimum physical space reserved for the storage and temperature maintenance tanks shall be 3.1 square feet per input 10,000 BTU/HR. of the gas or propane water heating system.

iii. The space reserved shall be the space required for a heat pump water heater system that meets the total building hot water demand as calculated and documented by the responsible person associated with the project.

3. Ventilation shall be provided by meeting one of the following:

   A. Physical space reserved for the heat pump shall be located outside, or

   B. A pathway shall be reserved for future routing of supply and exhaust air via ductwork from the reserved heat pump location to an appropriate outdoor location. Penetrations through the building envelope for louvers and ducts shall be planned and identified for future use. The reserved pathway and penetrations through the building envelope shall be sized to meet one of the following:

      i. If the system input capacity of the gas water heating system is less than 200,000 BTU/HR, the minimum air flow rate shall be 70 CFM per input 10,000 BTU/HR of the gas or propane water heating system and the total external static pressure drop of ductwork and louvers shall not exceed 0.17” when the future heat pump water heater is installed.

      ii. If the system input capacity of the gas water heating system is greater than or equal to 200,000 BTU/HR, the minimum air flow rate shall be 420 CFM per input 10,000 BTU/HR of the gas or propane water heating system and the total external static pressure drop of ductwork and louvers shall not exceed 0.17” when the future heat pump water heater is installed.

      iii. The reserved pathway and penetrations shall be sized to serve a heat pump water heater system that meets the total building hot water demand as calculated and documented by the responsible person associated with the project.

   All mechanical components shall be installed in accordance with the *California Mechanical Code*.

4. **Condensate drainage piping**. An approved receptacle that is sized in accordance with the California Plumbing Code to receive the condensate drainage shall be installed within 3 feet of the reserved heat pump location, or piping shall be installed from within 3 feet of the reserved heat pump location to an approved discharge location that is sized in accordance with the California Plumbing Code, and meets one of the following:

   A. If the system input capacity of the gas water heating system is less than 200,000 BTU/HR, condensate drainage shall be sized for 0.2 tons of refrigeration capacity per input 10,000 BTU/HR.

   B. If the system input capacity of the gas water heating system is greater than or equal to 200,000 BTU/HR, condensate drainage shall be sized for

0.7 tons of refrigeration capacity per input 10,000 BTU/HR.

C. Condensate drainage shall be sized to serve a heat pump water heater system that meets the total building hot water demand as calculated and documented by the responsible person associated with the project.

All plumbing components shall be installed in accordance with the *California Plumbing Code*.

5. **Electrical**

A. Physical space shall be reserved on the bus system of the main switchboard or on the bus system of a distribution board to serve the future heat pump water heater system including the heat pump and temperature maintenance tanks. In addition, the physical space reserved shall be capable of providing adequate power to the future heat pump water heater as follows:

i. **Heat Pump.** For the Heat Pump, the physical space reserved shall comply with one of the following:

A. If the system input capacity of the gas water heating system is less than 200,000 BTU/HR, provide 0.1 kVA per input 10,000 BTU/HR.

B. If the system input capacity of the gas water heating system is greater than or equal to 200,000 BTU/HR, provide 1.1 kVA per input 10,000 Btu/HR.

C. The physical space reserved supplies sufficient electrical power required to power a heat pump water heater system that meets the total building hot water demand as calculated and documented by the responsible person associated with the project.

All electric components shall be installed in accordance with the *California Electrical Code*.

ii. **Temperature Maintenance Tank.** For the Temperature Maintenance Tank, the physical space reserved shall comply with one of the following:

A. If the system input capacity of the gas water heating system is less than 200,000 BTU/HR, provide 1.0 kVA per input 10,000 BTU/HR.

B. If the system input capacity of the gas water heating system is greater than or equal to 200,000 BTU/HR, provide 0.6 kVA per input 10,000 BTU/HR.

C. The physical space reserved supplies sufficient electrical power required to power a heat pump water heater system that meets the total building hot water demand as calculated and documented by the responsible person associated with the project.

(f) The building electrical system shall be sized to meet the future electric requirements of the electric ready equipment specified in sections 160.9 (a) - (e). To meet this requirement the building main service conduit, the electrical system to the point specified in each subsection, and any on-site distribution transformers shall have sufficient capacity to supply full rated amperage at each electric ready appliance in accordance with the *California Electric Code*.

16.17.160 SUBCHAPTER 11 MULTIFAMILY BUILDINGS — PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES

SECTION 170.1 PERFORMANCE APPROACH

Section 170.1 of Subchapter 11 of the California Energy Code is amended to read:

Subsections 170.1 (a) – (c) are adopted without modification.

A newly constructed building or substantial remodel complies with the performance approach if the TDV energy budget calculated for the proposed design building under Subsection (b) is no greater than the TDV energy budget calculated for the Standard Design Building under Subsection (a). Additionally,

1. **Low-Rise Multifamily:** The energy budget, expressed in terms of source energy, of a newly constructed low-rise multifamily building (less than four habitable stories) shall be at least 9% lower than that of the Standard Design Building.
2. **High-Rise Multifamily:** Newly Constructed high-rise multifamily buildings (greater than four habitable stories) shall be at least 1% lower than that of the Standard Design Building.
3. **Compliance demonstration requirements for performance standards.** Section 170.1(d)1 is modified to add subsection is as follows:
   i. **Certificate of Compliance.** The Certificate of Compliance is prepared and signed by a Certified Energy Analyst and the Total Energy Design Rating of the Proposed Design shall be no greater than the Standard Design Building.

16.17.170 Infeasibility Exemption.

(a) **Exemption.** If an applicant for a Covered Project believes that circumstances exist that makes it infeasible to meet the requirements of this Chapter, the applicant may request an exemption as set forth below. In applying for an exemption, the burden is on the Applicant to show infeasibility.

(b) **Application.** If an applicant for a Covered Project believes such circumstances exist, the applicant may apply for an exemption at the time of application submittal in accordance with the Planning and Development Services administrative guidelines. The applicant shall indicate the maximum threshold of compliance the energy compliance design professional believes is feasible for the covered project and the circumstances that make it infeasible to fully comply with this Chapter. Circumstances that constitute infeasibility include, but are not limited to the following:

(1) There is conflict with the compatibility of the currently adopted California Building Standards Code;

(2) There is a lack of commercially available materials and technologies to comply with the requirements of this Chapter;

Applying the requirements of this Chapter would effectuate an unconstitutional taking of property or otherwise have an unconstitutional application to the property.

(c) **Granting of Exemption.** If the Director of Planning and Development Services, or designee, determines that it is infeasible for the applicant to fully meet the requirements of this Chapter based on the information provided, the Director, or designee, shall determine the maximum feasible threshold of compliance reasonably achievable for the project. The decision of the Director, or designee, shall be provided to the applicant in writing. If an exemption is granted, the applicant shall be required to comply with this Chapter in all other respects and shall be required to achieve, in accordance with this Chapter, the threshold of compliance determined to be achievable by the Director or designee.

(d) **Denial of Exemption.** If the Director of Planning and Development Services or designee determines that it is reasonably possible for the applicant to fully meet the requirements of this Chapter, the request shall be denied, and the Director or designee shall so notify the applicant in writing. The project and compliance documentation shall be modified to comply with this Chapter prior to further review of any pending planning or building application.

(e) **Council Review of Exemption.** For any covered project that requires review and action by the City Council, the Council shall act to grant or deny the exemption, based on the criteria outlined above, after recommendation by the Director of Planning and Development Services.

16.17.180 Appeal.

(a) Any aggrieved Applicant may appeal the determination of the Director of Planning and Development Services or designee regarding the granting or denial of an exemption pursuant to 16.17.170.

(b) Any appeal must be filed in writing with the Planning and Development Services

Department not later than fourteen (14) days after the date of the determination by the Director. The appeal shall state the alleged error or reason for the appeal.

(c) The appeal shall be processed and considered by the City Council in accordance with the provisions of Section 18.77.070 (f) of the City of Palo Alto Municipal Code.

SECTION 3. The Council adopts the findings for local amendments to the California Green Building Standards Code, 2022 Edition, attached hereto as Exhibit "A" and incorporated herein by reference.

SECTION 4. If any section, subsection, clause or phrase of this Ordinance is for any reason held to be invalid, such decision shall not affect the validity of the remaining portion or sections of the Ordinance. The Council hereby declares that it should have adopted the Ordinance and each section, subsection, sentence, clause or phrase thereof irrespective of the fact that any one or more sections, subsections, sentences, clauses or phrases be declared invalid.

SECTION 5. The Council finds that this ordinance is exempt from the provisions of the California Environmental Quality Act ("CEQA"), pursuant to Section 15061 of the CEQA Guidelines, because it can be seen with certainty that there is no possibility that the amendments herein adopted will have a significant effect on the environment and Section 15308, because the amendments herein adopted is an action taken by the City to assure the maintenance, restoration, enhancement, or protection of the environment .

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<u>SECTION 6</u>. This Ordinance shall be effective on the thirty-first day after the date of its adoption.

INTRODUCED:

PASSED:

AYES:

NOES:

ABSENT:

ABSTENTIONS:

ATTEST:

____________________________	____________________________
City Clerk	Mayor
APPROVED AS TO FORM:	APPROVED:
____________________________	____________________________
Chief Assistant City Attorney	City Manager
	____________________________
	Director of Planning and Development Services
	____________________________
	Director of Administrative Services

Exhibit A
FINDINGS FOR LOCAL AMENDMENTS TO CALIFORNIA ENERGY CODE, 2022 EDITION
TITLE 24, PART 6

Section 17958 of the California Health and Safety Code provides that the City may make changes to the provisions of the California Building Standards Code. Sections 17958.5 and 17958.7 of the Health and Safety Code require that for each proposed local change to those provisions of the California Building Standards Code which regulate buildings used for human habitation, the City Council must make findings supporting its determination that each such local change is reasonably necessary because of local climatic, geological, or topographical conditions.

Regarding the Energy Code, local jurisdictions have the authority to adopt local energy efficiency ordinances—or reach codes—that exceed the minimum standards defined by Title 24 (as established by Public Resources Code Section 25402.1(h)2 and Section 10-106 of the Building Energy Efficiency Standards, provided the City Council finds that the requirements of the proposed ordinance are cost-effective and do not result in buildings consuming more energy than is permitted by Title 24.

Local building regulations having the effect of amending the uniform codes, which were adopted by the City prior to November 23, 1970, were unaffected by the regulations of Sections 17958, 17958.5 and 17958.7 of the Health and Safety Code. Therefore, amendments to the uniform codes which were adopted by the City Council prior to November 23, 1970 and have been carried through from year to year without significant change, need no required findings. Also, amendments to provisions not regulating buildings used for human habitation do not require findings.

Code: California Energy Code, Title 24, Part 6					
Chapter(s), Sections(s), Appendices	**Title**	**Add**	**Deleted**	**Amended**	**Justification (See below of keys)**
100.1	Definitions and Rules of Construction	✓			**C & E**
110.10 (f)	Existing tree canopies				
130.0	Lighting Systems and Equipment, and Electrical Power Distribution Systems - General			✓	**C & E**
130.6	Electric Readiness Requirements for Systems Using Gas or Propane	✓		✓	**C & E**
140.0	Performance and Prescriptive Compliance Approaches			✓	**C & E**
140.1	Performance Approach: Energy Budgets			✓	**C & E**
150.0	Mandatory Features and Devices			✓	**C & E**
150.1	Performance and Prescriptive Compliance Approaches for Single-Family Residential Buildings			✓	**C & E**

150.1 (b) 3A i	Certificate of Compliance	✓			
160.4 (a)	Mandatory Requirements for Water Heating Systems		✓		**C & E**
160.9	Mandatory Requirements for Electric Ready Buildings			✓	**C & E**
170.1	Performance Approach			✓	**C & E**
	Infeasibility Exemption	✓			**A**
	Appeal	✓			**A**

Key to Justification for Amendments to Title 24 of the California Code of Regulations

A This is an **administrative** amendment to clarify and establish civil and administrative procedures, regulations, or rules to enforce and administer the activities by the Palo Alto Building Inspection Department. These administrative amendments do not need to meet HSC 18941.5/17958/13869 per HSC 18909(c).

C This amendment is justified on the basis of a local **climatic** condition. The seasonal climatic conditions during the late summer and fall create severe fire hazards to the public health and welfare in the City. The hot, dry weather frequently results in wild land fires on the brush covered slopes west of Interstate 280. The aforementioned conditions combined with the geological characteristics of the hills within the City create hazardous conditions for which departure from California Energy Code is required. Failure to address and significantly reduce greenhouse gas (GHG) emissions could result in rises in sea level, including in San Francisco Bay, that could put at risk Palo Alto homes and businesses, public facilities, and Highway 101 (Bayshore Freeway), particularly the mapped Flood Hazard areas of the City. Energy efficiency is a key component in reducing GHG emissions, and the construction of more energy efficient buildings can help Palo Alto reduce its share of the GHG emissions that contribute to climate change. The burning of fossil fuels used in the generation of electric power and heating of buildings contributes to climate change, which could result in rises in sea level, including in San Francisco Bay, that could put at risk Palo Alto homes and businesses 1 public facilities, and Highway 101. Due to a decrease in annual rainfall, Palo Alto experiences the effect of drought and water saving more than some other communities in California.

E Energy efficiency enhances the public health and welfare by promoting the **environmental** and economic health of the City through the design, construction, maintenance, operation, and deconstruction of buildings and sites by incorporating green practices into all development. The provisions in this Chapter are designed to achieve the following goals:
(a) Increase energy efficiency in buildings;
(b) Increase resource conservation;
(c) Provide durable buildings that are efficient and economical to own and operate;
(d) Promote the health and productivity of residents, workers, and visitors to the city;
(e) Recognize and conserve the energy embodied in existing buildings; and
(f) Reduce disturbance of natural ecosystems.

G This amendment is justified on the basis of a local **geological** condition. The City of Palo Alto is subject to earthquake hazards caused by its proximity to San Andreas fault. This fault runs from Hollister, through the Santa Cruz Mountains, epicenter of the 1989 Loma Prieta earthquake, then on up the San Francisco Peninsula, then offshore at Daly City near Mussel Rock. This is the approximate location of the epicenter of the 1906 San Francisco earthquake. The other fault is the Hayward Fault. This fault is about 74 mi long, situated mainly along the western base of the hills on the east side of San Francisco Bay. Both of these faults are considered major Northern California earthquake faults which may experience rupture at any time. Thus, because the City is within a seismic area that includes these earthquake faults, the modifications and changes cited herein are designed to better limit property damage as a result of seismic activity and to establish criteria for repair of damaged properties following a local emergency.

T The City of Palo Alto **topography** includes hillsides with narrow and winding access, which makes timely response by fire suppression vehicles difficult. Palo Alto is contiguous with the San Francisco Bay, resulting in a natural receptor for storm and waste water run-off. Also the City of Palo Alto is located in an area that is potentially susceptible to liquefaction during a major earthquake. The surface condition consists mostly of stiff to dense sandy clay, which is highly plastic and expansive in nature. The aforementioned conditions within the City create hazardous conditions for which departure from California Building Standards Codes is warranted.

CALIFORNIA ENERGY CODES & STANDARDS
A STATEWIDE UTILITY PROGRAM

Last modified: 2024/03/25
Revision: 1.1

2022 Cost-Effectiveness Study: Single Family New Construction

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Pacific Gas and Electric Company | Southern California Edison — Energy for What's Ahead | SDGE

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Acronym List

2023 PV$ – Present value costs in 2023

ACH50 – Air Changes per Hour at 50 pascals pressure differential

ACM – Alternative Calculation Method

ADU – Accessory Dwelling Unit

AFUE – Annual Fuel Utilization Efficiency

B/C – Lifecycle Benefit-to-Cost Ratio

BEopt – Building Energy Optimization Tool

BSC – Building Standards Commission

CA IOUs – California Investor-Owned Utilities

CASE – Codes and Standards Enhancement

CBECC-Res – Computer program developed by the California Energy Commission for use in demonstrating compliance with the California Residential Building Energy Efficiency Standards

CFI – California Flexible Installation

CFM – Cubic Feet per Minute

CO_2 – Carbon Dioxide

CPAU – City of Palo Alto Utilities

CPUC – California Public Utilities Commission

CZ – California Climate Zone

DHW – Domestic Hot Water

DOE – Department of Energy

DWHR – Drain Water Heat Recovery

EDR – Energy Design Rating

EER – Energy Efficiency Ratio

EF – Energy Factor

GHG – Greenhouse Gas

HERS Rater – Home Energy Rating System Rater

HPA – High Performance Attic

HPWH – Heat Pump Water Heater

HSPF – Heating Seasonal Performance Factor

IECC – International Energy Conservation Code

IOU – Investor Owned Utility

kBtu – kilo-British thermal unit

kWh – Kilowatt Hour

LBNL – *Lawrence Berkeley National Laboratory*

LCC – Lifecycle Cost

LLAHU – Low Leakage Air Handler Unit

LSC – Long-term System Cost (2025 Title 24, Part 6 compliance metric)

MF – Multifamily

NEEA – Northwest Energy Efficiency Alliance

NEM – Net Energy Metering

NPV – Net Present Value

NREL – *National Renewable Energy Laboratory*

PG&E – Pacific Gas and Electric Company

POU – Publicly-Owned-Utilities

PV – Photovoltaic

SCE – Southern California Edison

SDG&E – San Diego Gas and Electric

SEER – Seasonal Energy Efficiency Ratio

SF – Single Family

SMUD – Sacramento Municipal Utility District

SoCalGas – Southern California Gas Company

TDV – Time Dependent Valuation (2022 Title 24, Part 6 compliance metric)

Therm – Unit for quantity of heat that equals 100,000 British thermal units

Title 24 – Title 24, Part 6

TOU – Time-Of-Use

UEF – Uniform Energy Factor

VLLDCS – Verified Low Leakage Ducts in Conditioned Space

ZNE – Zero-net Energy

Summary of Revisions

Date	Description	Reference (page or section)
9/12/2022	Original Release (1.0)	N/A
3/25/2024	Updated analysis (1.1)	• New simulation results with latest CBECC-Res version (Section 2.1.1) • Updated utility cost estimates using recent utility tariff and net billing tariff (Section 2.1.3) • New measure costs for heat pumps, batteries, and PV (Section 3.3) • Revised packages (Section 3.4) • Revised Results, Summary, References, and Appendices (Sections 4-7)

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Executive Summary

The California Codes and Standards (C&S) Reach Codes program provides technical support to local governments considering adopting a local ordinance (reach code) intended to support meeting local and/or statewide energy efficiency and greenhouse gas (GHG) reduction goals. The program facilitates adoption and implementation of the code when requested by local jurisdictions by providing resources such as cost-effectiveness studies, model language, sample findings, and other supporting documentation.

This report documents cost-effectiveness analysis results for traditional new detached single family and detached accessory dwelling unit (ADUs) building types. It evaluates mixed fuel and all-electric package options in all sixteen California climate zones (CZs). Packages include combinations of efficiency measures, on-site renewable energy, and battery energy storage.

This analysis used two different metrics to assess the cost-effectiveness of the proposed upgrades. Both methodologies require estimating and quantifying the incremental costs and energy savings associated with each energy efficiency measure over a 30-year analysis period. On-Bill cost-effectiveness is a customer-based lifecycle cost (LCC) approach that values energy based upon estimated site energy usage and customer utility bill savings using today's electricity and natural gas utility tariffs. Time Dependent Valuation (TDV) is the California Energy Commission's LCC methodology, which is intended to capture the long-term projected cost of energy, including costs for providing energy during peak periods of demand, carbon emissions, grid transmission and distribution impacts. This is the methodology used by the Energy Commission in evaluating cost-effectiveness for efficiency measures in Title 24, Part 6.

The following are key takeaways and recommendations from the analysis.

Conclusions and Discussion:

- All-electric buildings have lower GHG emissions than mixed fuel buildings, due to the clean power sources currently available from California's power providers as well as accounting for increased penetration of renewables in the future. Almost all the all-electric packages evaluated resulted in greater GHG emission savings than the mixed fuel packages, with the exception of the mixed fuel package with battery storage in climate zones with low heating loads.
- The Reach Codes Team found code-compliant all-electric new construction to be feasible and cost-effective based on TDV for single family homes in all cases except Climate Zone 16.
- All-electric single family new construction was On-Bill cost-effective in all cases except Climate Zones 1, 3, 14, and 16.
- The all-electric ADU home was cost-effective based on TDV in all cases except in Climate Zones 3, 4, 13, and 14 where the higher cost of installing a ducted heat pump water heater (HPWH) instead of the prescriptively required gas tankless water heater exceed the resulting energy cost savings. In the other climate zones there were first cost savings for installing a heat pump space heater instead of a gas furnace, contributing to an overall TDV cost-effective result.
- Few cases were cost-effective On-Bill for the ADU.
- All-electric code minimum construction results in an increase in first year utility costs relative to a mixed fuel home, except for CPAU and SMUD where electricity rates are much lower than for the investor-owned utilities (IOUs). The addition of efficiency measures, market dominant HPWHs that meet the Northwest Energy Efficiency Alliance's (NEEA's) Advanced Water Heating Specification[1], high efficiency heat pumps, increased solar photovoltaics (PV), and batteries all reduce utility costs, and a combination of these options was found to reduce annual utility costs relative to a mixed fuel home in all cases.

[1] Refer to Section 0 for an explanation of HPWHs certified through NEEA's Advanced Water Heating Specification, their market status, and how they compare to federal minimum efficiency standards.

- Under the Net Biling Tariff (NBT)[2], utility cost savings for increasing PV system size beyond code minimum are substantially less than what they were under prior net energy metering rules (NEM 2.0); however, savings are sufficient to be On-Bill cost-effective in all climate zones for the all-electric single family home. Coupling PV with battery systems increases utility cost savings as a result of improved on-site utilization of PV generation and fewer exports to the grid.
- Applying California Alternate Rates for Energy (CARE) rates in the IOU territories improves On-Bill cost-effectiveness for all-electric buildings, as compared to the same case under standard rates, due to higher utility cost savings compared to a code compliant mixed fuel building also on a CARE rate. This is due to the CARE discount on electricity being higher than that on gas.
- If gas tariffs are assumed to increase substantially over time, in line with the escalation assumption from the 2025 LSC development, all-electric new construction was found to be On-Bill cost-effective in almost all scenarios over the 30-year analysis period. There is much uncertainty surrounding future tariff structures as well as escalation values. While it's clear that gas rates are anticipated to increase, how much and how quickly is not known. Electricity tariff structures are expected to evolve over time, and the California Public Utilities Commission (CPUC) has an active proceeding to adopt an income-graduated fixed charge that benefits low-income customers and supports electrification measures[3]. The CPUC will make a decision in mid-2024 and the new rates are expected to be in place later that year or in 2025. While the anticipated impact of this rate change is lower volumetric electricity rates, the rate design is not finalized. While lower volumetric electricity rates provide many benefits like incentivizing electrification, it also will make building efficiency measures harder to justify as cost-effective due to lower utility bill cost savings.

Recommendations:

- A reach code with a single performance target based on source energy (EDR1) can be structured to strongly encourage electrification. This approach requires equivalent performance for all buildings and allows mixed fuel buildings which minimizes the risk of violating federal preemption. Below are examples of how a reach code for single family homes could be set up based on the results summarized in Table 27.
    - A jurisdiction in Climate Zone 12 could set a performance target at an EDR1 margin of 11.5 (the EDR1 margin for the all-electric Code Minimum package). Any all-electric home meeting or exceeding the prescriptive requirements would comply, and a mixed fuel home would likely need to incorporate a combination of efficiency measures and a battery system to comply.
    - Similarly, a jurisdiction in Climate Zone 7 may consider setting a performance target of 2.8 EDR1 margin (also the EDR1 margin for the all-electric Code Minimum package). Any all-electric home meeting or exceeding the prescriptive requirements would comply, but a mixed fuel home would likely be able to comply with only a suite of above-code efficiency measures (no battery). Alternatively, a higher EDR1 margin target of 5 would incentivize more energy efficiency or additional PV for all-electric construction, and mixed fuel construction would likely need to incorporate a battery system to comply.
    - A jurisdiction in Climate Zone 16 may want to set a performance target at an EDR1 margin of 20.5 (the EDR1 margin for the mixed fuel efficiency + PV + battery package). This would establish a target that a mixed fuel home could cost-effectively meet, likely only after incorporating a combination of efficiency measures and a battery system, and that an all-electric home could easily meet.
- The 2022 Title 24 code's new source energy metric combined with the heat pump baseline encourage all-electric construction, providing an incentive that allows for some amount of prescriptively required building efficiency to be traded off, still meeting minimum code compliance. This compliance benefit for all-electric homes highlights a unique opportunity for jurisdictions to incorporate efficiency into all-electric reach codes. Efficiency and electrification have symbiotic benefits and are both critical for decarbonization of buildings. As demand on the electric grid is increased through electrification, efficiency can reduce the negative impacts of

[2] Refer to Section 2.1.3 for discussion on NBT and NEM
[3] https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-costs/demand-response-dr/demand-flexibility-rulemaking

additional electricity demand on the grid, reducing the need for increased generation and storage capacity, as well as the need to upgrade upstream transmission and distribution equipment. The Reach Codes Team recommends that jurisdictions adopting a reach code for single family buildings also include an efficiency requirement with EDR1 margins at minimum consistent with the all-electric code minimum package results in Table 27.

- The code compliance margins for the ADU all-electric code minimum package are lower than for the single family prototype; code compliance and cost-effectiveness can be more challenging for smaller dwelling units. As a result, the Reach Codes Team does not recommend EDR1 targets above those reported for the all-electric Code Minimum package in Table 28.

This report presents measures or measure packages that local jurisdictions may consider adopting to achieve energy savings and emissions reductions beyond what will be accomplished by enforcing minimum state requirements, the 2022 Building Energy Efficiency Standards (Title 24, Part 6), effective January 1, 2023.

Local jurisdictions may also adopt ordinances that amend different Parts of the California Building Standards Code or may elect to amend other state or municipal codes. The decision regarding which code to amend will determine the specific requirements that must be followed for an ordinance to be legally enforceable. For example, jurisdictions may amend Part 11 instead of Part 6 of the CA Building Code requiring review and approval by the Building Standards Commission (BSC) but not the California Energy Commission (Energy Commission). Reach codes that amend Part 6 of the CA Building Code and require energy performance beyond state code minimums must demonstrate the proposed changes are cost-effective and obtain approval from the Energy Commission. Although a cost-effectiveness study is only required to amend Part 6 of the CA Building Code, this study provides valuable context for jurisdictions pursuing other ordinance paths to understand the economic impacts of any policy decision. This study documents the estimated costs, benefits, energy impacts and greenhouse gas emission reductions that may result from implementing an ordinance based on the results to help residents, local leadership, and other stakeholders make informed policy decisions.

Model ordinance language and other resources are posted on the C&S Reach Codes Program website at LocalEnergyCodes.com. Local jurisdictions that are considering adopting an ordinance may contact the program for further technical support at info@localenergycodes.com. In addition, jurisdictions in a CCA territory with rates or rate structures that are significantly different than IOU rates may email the program at info@localenergycodes.com to request a custom analysis.

1 Introduction

This report documents cost-effective combinations of measures that exceed the minimum state requirements, the 2022 Building Energy Efficiency Standards, effective January 1, 2023, for newly constructed single family buildings. This report was developed in coordination with the California Statewide Investor-Owned Utilities (CA IOUs) Codes and Standards Program, key consultants, and engaged cities—collectively known as the Reach Codes Team.

The analysis considers traditional detached single family and detached accessory dwelling unit (ADUs) building types and evaluates mixed fuel and all-electric package options in all sixteen California climate zones (CZs).[4] Packages include combinations of efficiency measures, on-site renewable energy, and battery energy storage.

This report documents the key results and conclusions from the Reach Codes Team analysis. A full dataset of all results can be downloaded from the Local Energy Codes Resources[5] webpage. Results alongside policy options and the potential citywide impacts for specific jurisdictions can also be explored using the Cost-effectiveness Explorer at https://explorer.localenergycodes.com/.

The California Building Energy Efficiency Standards Title 24, Part 6 (Title 24) (California Energy Commission, 2021a) is maintained and updated every three years by two state agencies: the California Energy Commission (Energy Commission) and the Building Standards Commission (BSC). In addition to enforcing the code, local jurisdictions have the authority to adopt local energy efficiency ordinances—or reach codes—that exceed the minimum standards defined by Title 24 (as established by Public Resources Code Section 25402.1(h)2 and Section 10-106 of the Building Energy Efficiency Standards). Local jurisdictions must demonstrate that the requirements of the proposed ordinance are cost-effective and do not result in buildings consuming more energy than is permitted by Title 24. In addition, the jurisdiction must obtain approval from the Energy Commission and file the ordinance with the BSC for the ordinance to be legally enforceable.

The Department of Energy (DOE) sets minimum efficiency standards for equipment and appliances that are federally regulated under the National Appliance Energy Conservation Act, including heating, cooling, and water heating equipment (E-CFR, 2020). Since state and local governments are prohibited from adopting higher minimum efficiencies than the federal standards require — herein referred to as federal preemption — the focus of this study is to identify and evaluate cost-effective packages that do not include high efficiency heating, cooling, and water heating equipment. High efficiency appliances are often the easiest and most affordable measures to increase energy performance. While federal preemption limits reach code mandatory requirements for covered appliances, in practice, builders may install any package of compliant measures to achieve the performance requirements.

[4] See Appendix 7.1 Map of California Climate Zones for a graphical depiction of climate zone locations.
[5] https://localenergycodes.com/content/resources/?q=newly%20constructed%20buildings:%20efficiency%20and%20electrification

2 Methodology and Assumptions

2.1 Analysis for Reach Codes

This section describes the approach to calculating cost-effectiveness including benefits, costs, metrics, and utility rate selection.

2.1.1 Modeling

The Reach Codes Team performed energy simulations using software approved for 2022 Title 24 Code compliance analysis, CBECC-Res 2022.3.0.

The general approach applied in this analysis is to evaluate performance and determine cost-effectiveness of various energy efficiency upgrade measures, individually and as packages, in single family buildings. Using the 2022 baseline as the starting point, prospective measures and packages were identified and modeled in each of the prototypes to determine the projected energy use (therm and kWh) and compliance impacts. A large set of parametric runs were conducted to evaluate various options and develop packages of measures that met or exceeded minimum code performance. The analysis utilized a Python based parametric tool to automate and manage the generation of CBECC-Res input files. This allowed for quick evaluation of various efficiency measures across multiple climate zones and prototypes and improved quality control. The batch process functionality of CBECC-Res was utilized to simulate large groups of input files at once.

2.1.2 Cost-effectiveness

2.1.2.1 Benefits

This analysis used two different metrics to assess cost-effectiveness of the proposed upgrades. Both methodologies require estimating and quantifying the incremental costs and energy savings associated with each energy efficiency measure. The main difference between the methodologies is the manner in which they value energy and thus the cost savings of reduced or avoided energy use:

Utility Bill Impacts (On-Bill): Customer-based lifecycle cost (LCC) approach that values energy based upon estimated site energy usage and customer utility bill savings using today's electricity and natural gas utility tariffs. Total savings are estimated over a 30-year duration and include discounting of future costs and energy cost inflation.

Time Dependent Valuation (TDV): Energy Commission LCC methodology, which is intended to capture the total value or cost of energy use over 30 years. This method accounts for long-term projected costs, such as the cost of providing energy during peak periods of demand, and other societal costs, such as projected costs for carbon emissions as well as grid transmission and distribution impacts. This metric values energy use differently depending on the fuel source (natural gas, electricity, and propane), time of day, and season. For example, electricity used (or saved) during peak periods has a much higher value than electricity used (or saved) during off-peak periods due to the less inefficient energy generation sources providing peak electricity (Horii, Cutter, Kapur, Arent, & Conotyannis, 2014). This is the methodology used by the Energy Commission in evaluating cost-effectiveness for efficiency measures in Title 24, Part 6.

2.1.2.2 Costs

The Reach Codes Team assessed the incremental costs of the measures and packages over a 30-year lifecycle. Incremental costs represent the equipment, installation, replacement, and maintenance costs of the proposed measure relative to the 2022 Title 24 Standards minimum requirements or standard industry practices. Present value of replacement cost is included only for measures with lifetimes less than the 30-year evaluation period.

In calculating On-Bill cost-effectiveness, incremental first costs were assumed to be financed into a mortgage or loan with a 30-year loan term and four percent interest rate. Financing was not applied to future replacement or maintenance costs. In calculating TDV cost-effectiveness, incremental first costs were not assumed to be financed into a mortgage or loan.

2.1.2.3 Metrics

Cost-effectiveness is presented using net present value (NPV) and benefit-to-cost (B/C) ratio metrics.

NPV Savings: The lifetime NPV savings is reported as a cost-effectiveness metric; Equation 1 demonstrates how this is calculated. If the net savings of a measure or package is positive, it is considered cost-effective. Negative savings represent net costs.

B/C Ratio: Ratio of the present value of all benefits to the present value of all costs over 30 years (present value of benefits divided by present value of costs). The criteria benchmark for cost-effectiveness is a B/C ratio greater than one. A value of one indicates the present value of the savings over the analysis period is equivalent to the present value of the lifetime incremental cost of that measure. A value greater than one represents a positive return on investment. The B/C ratio is calculated according to Equation 2.

Equation 1

$$NPV\ Savings = Present\ value\ of\ lifetime\ benefit - Present\ value\ of\ lifetime\ cost$$

Equation 2

$$Benefit - to - Cost\ Ratio = \frac{Present\ value\ of\ lifetime\ benefit}{Present\ value\ of\ lifetime\ cost}$$

Improving the efficiency of a project often requires an initial incremental investment. In most cases the benefit is represented by annual On-Bill utility or TDV savings, and the cost is represented by incremental first cost and replacement costs. However, some packages result in initial construction cost savings (negative incremental cost), and either energy cost savings (positive benefits), or increased energy costs (negative benefits). In cases where both construction costs and energy-related savings are negative, the construction cost savings are treated as the 'benefit' while the increased energy costs are the 'cost.' In cases where a measure or package is cost-effective immediately (i.e., upfront construction cost savings and lifetime energy cost savings), B/C ratio cost-effectiveness is represented by ">1".

The lifetime costs or benefits are calculated according to Equation 3.

Equation 3

$$PV\ of\ lifetime\ cost\ or\ benefit = \sum_{t=0}^{n} \frac{(Annual\ cost\ or\ benefit)_t}{(1+r)^t}$$

Where: *n* = analysis term in years

- *r* = discount rate

The following summarizes the assumptions applied in this analysis to both methodologies.

- Analysis term of 30 years
- Real discount rate of three percent

TDV is a normalized monetary format and there is a unique procedure for calculating the present value benefit of TDV energy savings. The present value of the energy cost savings in dollars is calculated by multiplying the TDV savings (reported by the CBECC-Res simulation software) by a NPV factor developed by the Energy Commission (see (Energy + Environmental Economics, 2020)). The 30-year residential NPV factor is $0.173/kTDV kBtu for the 2022 code cycle.

Equation 4

- $TDV\ PV\ of\ lifetime\ benefit = TDV\ energy\ savings * NPV\ factor$

2.1.3 Utility Rates

In coordination with the CA IOU rate team (comprised of representatives from Pacific Gas and Electric (PG&E), Southern California Edison (SCE) and San Diego Gas and Electric (SDG&E)) and two Publicly-Owned-Utilities (POUs) (Sacramento Municipal Utility District (SMUD) and City of Palo Alto Utilities (CPAU)), the Reach Codes Team determined appropriate utility rates for each climate zone in order to calculate utility costs and determine On-Bill cost-effectiveness for the proposed measures and packages. The utility tariffs, summarized in Table 1, were determined based on the most prevalent active rate in each territory. Utility rates were applied to each climate zone based on the predominant IOU serving the population of each zone, with a few climate zones evaluated multiple times under different utility scenarios. Climate Zones 10 and 14 were evaluated with both SCE/SoCalGas and SDG&E tariffs since each utility has customers within these climate zones. Climate Zone 5 is evaluated under both PG&E and SoCalGas natural gas rates. Two POU or municipal utility rates were also evaluated: SMUD in Climate Zone 12 and CPAU in Climate Zone 4.

Some community choice aggregations (CCAs) have utility rates that are very similar to IOU rates, often within $0.02 per kWh. For these CCA customers, total utility costs will be very similar to those calculated in this study and the results from this study will generally apply. The study results cannot be easily applied to CCAs with rates that do not closely track the IOU rates or municipal utilities outside of SMUD and CPAU.

First-year utility costs were calculated using hourly electricity and natural gas output from CBECC-Res and applying the utility tariffs summarized in Table 1. Annual costs were also estimated for IOU customers eligible for the CARE tariff discounts on both electricity and natural gas bills. Appendix 7.2 Utility Rate Schedules includes details of each utility tariff. For cases with onsite generation (i.e. solar photovoltaics (PV)), the approved Net Billing Tariff (NBT) was applied along with monthly service fees and hourly export compensation rates for 2024[6]. In December 2022, the California Public Utilities Commission (CPUC) issued a decision adopting NBT as a successor to prior net energy metering rules (NEM 2.0) that went into effect April of 2023.[7] The ADU was assumed to have separate electric and gas meters from the main house.

Table 1: Utility Tariffs Used Based on Climate Zone

Climate Zones	Electric / Gas Utility	Electricity Tariff	Natural Gas Tariff
IOUs			
1-5,11-13,16	PG&E / PG&E	E-ELEC	G1
5	PG&E / SoCalGas	E-ELEC	GR
6, 8-10, 14, 15	SCE / SoCalGas	TOU-D-PRIME	GR
7, 10, 14	SDG&E / SDG&E	EV-TOU-5 (TOU-ELEC for ADU cases without PV systems[8])	GR
POUs			
4	CPAU / CPAU	E-1	G1
12	SMUD / PG&E	R-TOD	G1

Utility rates are assumed to escalate over time according to the CPUC 2021 En Banc hearings on utility costs through 2030 (California Public Utilities Commission, 2021a). Escalation rates through the remainder of the 30-year evaluation period are based on the escalation rate assumptions within the 2022 TDV factors. A second set of escalation rates were also evaluated to demonstrate the impact that utility cost changes over time have on cost-effectiveness. This utility rate escalation sensitivity analysis, presented in Section 4.6.3, was based on those used within the 2025 Long-

[6] https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/net-energy-metering-nem/nemrevisit/nbt-model--12142022.xlsb
[7] https://www.cpuc.ca.gov/nemrevisit
[8] See Section 3.2 Prototype Characteristics for a description of ADU cases that don't require solar PV prescriptively.

term System Cost (LSC) factors (LSC replaces TDV in the 2025 code cycle) which assumed steep increases in gas rates in the latter half of the analysis period. See Appendix 7.2.7 Fuel Escalation Assumptions for details.

2.2 Greenhouse Gas Emissions

The analysis reports the greenhouse gas (GHG) emission estimates based on assumptions within CBECC-Res. There are 8,760 hourly multipliers accounting for time-dependent energy use and carbon based on source emissions, including renewable portfolio standard projections. There are two strings of multipliers—one for Northern California climate zones, and another for Southern California climate zones.[9] GHG emissions are reported as average annual metric tons of CO_2 equivalent over the 30-year measure analysis period.

2.3 Energy Design Rating

The 2019 Title 24 Code introduced California's Energy Design Rating (EDR) as the primary metric to demonstrate compliance with the energy code for single family buildings. This EDR was based on the hourly TDV energy use from a building that is compliant with the 2006 International Energy Conservation Code (IECC) as the Reference Building. The Reference Building has an EDR score of 100 while a zero-net energy (ZNE) home has an EDR score of zero. While the Reference Building is used to set the scale for the rating, the Proposed Design is still compared to the Standard Design based on the Title 24 prescriptive baseline assumptions to determine compliance. In the 2022 Title 24 Code a second new EDR metric was introduced based on hourly source energy. The two EDR metrics are described below:

- EDR1 is calculated based on source energy.
- EDR2 is calculated based on TDV energy.

EDR1 has only one component, "Total EDR1" which represents source energy use for the entire building. EDR2 is composed of two components for compliance purposes: the "Efficiency EDR2", which represents the energy efficiency features of a home, and the PV/Flexibility EDR2, which includes the effects of PV and battery storage systems. "Total EDR2" combines all energy use of the building including both the Efficiency and PV/Flexibility impacts. While the Efficiency EDR2 does not include the full impact of a battery system, it can include a self-utilization credit for batteries if certain conditions are met.

For a new, single family building to comply with the 2022 Title 24 Code, three criteria must be met:

1. The Proposed Total EDR1 must be equal to or less than the Total EDR1 of the Standard Design, and
2. The Proposed Efficiency EDR2 must be equal to or less than the Efficiency EDR2 of the Standard Design, and
3. The Proposed Total EDR2 must be equal to or less than the Total EDR2 of the Standard Design.

This concept, consistent with California's "loading order" which prioritizes energy efficiency ahead of renewable generation, requires projects to meet a minimum Efficiency EDR2 before PV is credited but allows for PV to be traded off with additional efficiency when meeting the Total EDR2. A project may improve building efficiency beyond the minimum required and subsequently reduce the PV generation capacity necessary to achieve the required Total EDR2. However, it may not increase the size of the PV system and trade this off with a reduction of efficiency measures.

Results from this analysis are presented as EDR Margin, a reduction in the EDR score relative to the Standard Design. EDR Margin is a better metric to use than absolute EDR in the context of a reach code because absolute values vary based on the home design and characteristics such as size and orientation. This approach aligns with how compliance is reported for the 2019 and 2022 Title 24 Code. The EDR Margin is calculated according to Equation 5.

Equation 5

$$EDR\ Margin = Standard\ Design\ EDR - Proposed\ Design\ EDR$$

[9] CBECC-Res multipliers are the same for CZs 1-5 and 11-13 (Northern California), while there is another set of multipliers for CZs 6-10 and 14-16 (Southern California).

3 Prototypes, Measure Packages, and Costs

This section describes the prototypes and the scope of analysis drawing from previous research where necessary, including the 2019 low-rise residential single family reach code study (Statewide Reach Codes Team, 2019).

3.1 Prior Reach Code Research

In 2019, the Reach Codes Team analyzed the cost-effectiveness of residential single family new construction projects for mixed fuel and all-electric packages (Statewide Reach Codes Team, 2019). Using this analysis, several cities and counties in California adopted local energy code amendments encouraging or requiring that low-rise residential new construction be all-electric. As there were few changes to the single family requirements, this analysis for the 2022 code cycle leveraged the work completed for the 2019 reports. Initial efficiency packages were based on the final packages from the 2019 research and were revised to reflect measure specifications and costs based on new data.

3.2 Prototype Characteristics

The Energy Commission defines building prototypes which it uses to evaluate the cost-effectiveness of proposed changes to Title 24 requirements. For the 2022 code cycle the Energy Commission used two single family prototypes, both of which were used in this analysis. Additional details on the prototypes can be found in the Alternative Calculation Method (ACM) Approval Manual (California Energy Commission, 2018).

Additionally, a detached new construction ADU prototype was developed to reflect recent trends in California construction related to the high cost of housing (TRC, 2021). ADUs are additional dwelling units typically built on the property of an existing single-family parcel. ADUs are defined as new construction in the energy code when they are ground-up developments, do not convert an existing space to livable space, and are not attached to the primary dwelling. The evaluated prototype is not representative of an attached ADU constructed as an addition to an existing home.

The Reach Codes Team leveraged prior research to define the detached ADU baseline and measure packages. The house size and number of bedrooms were based on data from a survey conducted by UC Berkeley's Center for Community Innovation (UC Berkeley Center for Community Innovation, 2021). The survey found that the average square footage for new ADUs statewide is 615 square feet and that the majority (61 percent) of new ADUs have one bedroom.

Table 2 describes the basic characteristics of each prototype. The prototypes have equal geometry on all walls, windows and roof to be orientation neutral.

Table 2: Prototype Characteristics

Characteristic	Single Family One-Story	Single Family Two-Story	ADU
Conditioned Floor Area	2,100 ft^2	2,700 ft^2	625 ft^2
Num. of Stories	1	2	1
Num. of Bedrooms	3	4	1
Window-to-Floor Area Ratio	20%	20%	19.2%

The Energy Commission's protocol for the two single family prototypes is to weigh the simulated energy impacts by a factor that represents the distribution of single-story and two-story homes being built statewide. Consistent with this protocol, this study assumed 50 percent single-story and 50 percent two-story. Simulation results in this study are characterized and presented according to this ratio, which is approximately equivalent to a 2,400-square foot (ft^2) house.[10] ADU results are presented separately.

The methodology used in the analyses for each of the prototypical building types begins with a design that precisely meets the minimum 2022 prescriptive requirements (zero compliance margin). Table 150.1-A in the 2022 Standards (California Energy Commission, 2021a) lists the prescriptive measures that determine the baseline design in each climate zone. Other features are consistent with the Standard Design in the ACM Reference Manual (California Energy Commission, 2022), and are designed to meet, but not exceed, the minimum requirements. See Appendix 7.4 for a list of prescriptive values relevant to the measures explored in this analysis.

Table 3 describes additional characteristics as they were applied to the base case, or baseline, energy model in this analysis. In a shift from the 2019 Standards, the 2022 Standards apply a prescriptive fuel source for space heating and water, where one is gas-fueled and one is a heat pump depending on climate zone. This establishes a prescriptive heat pump baseline. In most climate zones the prescriptive base case includes a heat pump water heater and a natural gas furnace for space heating. In Climate Zones 3, 4, 13, and 14 this is reversed, where the base case has a heat pump space heater and natural gas tankless water heater.

Table 4 summarizes the PV capacities for the base case packages.

[10] 2,400 ft^2 = (50% x 2,100 ft^2) + (50% x 2,700 ft^2)

Table 3: Base case Characteristics of the Prototypes

Characteristic	Single Family	ADU
Space Heating/Cooling[1,2]	CZs 1-2,5-12,15-16: Natural gas furnace, split AC 80 AFUE, 14.3 SEER2, 11.7 EER2 CZs 3-4,13-14: Split heat pump – 7.5 HSPF2, 14.3 SEER2, 11.7 EER2	Same as single family
Air Distribution	Ductwork located in vented attic	Same as single family
Water Heater[1,2]	CZs 1-2,5-12,15-16: Heat pump water heater (HPWH) UEF = 2.0 located in the garage CZs 3-4,13-14: Natural gas tankless – UEF = 0.81	Same equipment type as SF except HPWH is located inside the conditioned space with the supply air ducted from outside and exhaust air ducted to outside.[3]
Hot Water Distribution	Code minimum CZs 1,16: Basic compact distribution credit	Same as single family
Cooking	Natural Gas	Same as single family
Clothes Drying	Natural Gas	Same as single family
PV System	Sized to offset 100% of electricity use for space cooling, ventilation, lighting, appliance, & other miscellaneous electric loads. Size differs by climate zone ranging from 2.64 kW to 5.21 kW, see Table 4.	PV is not required when the PV system size required based on the prescriptive calculations is less than 1.8 kW, as is the case in Climate Zones 1-9, 12, 14, and 16. In the other climate zones the PV size ranges from 1.73 kW to 2.51 kW, see Table 4.[4]
Foundation	Slab-on-grade	Same as single family

[1] Equipment efficiencies are equal to minimum federal appliance efficiency standards.
[2] AFUE = annual fuel utilization efficiency. SEER = seasonal energy efficiency ratio. EER = energy efficiency ratio. HSPF = heating seasonal performance factor. UEF = uniform energy factor.
[3] This version of CBECC-Res used in this analysis did not have the capability to directly model ducted HPWHs even though this configuration is called out as the Standard Design in the 2022 ACM (California Energy Commission, 2022). This was modeled by indicating that the tank is located within the conditioned space with the compressor unit located outside.
[4] Exception 2 to Section 150.1(I)14 states that “no PV system is required when the minimum PV system size specified by section 150.1(c)14 is less than 1.8 kWdc.” In this analysis this exception is applied based on the sizes calculated per Equation150.1-C of Section 150.1(c)14. The performance software sizes the PV system based on the estimated energy use, which differs slightly from the prescriptive sizing. As a result, the baseline PV capacity from the performance software for Climate Zone 10 is less than 1.8 kWdc.

Table 4: Base Package PV Capacities (kW-DC)

Climate Zone	Base Package	
	Single Family	ADU
CZ01	3.57	0
CZ02	3.03	0
CZ03	2.83	0
CZ04	2.91	0
CZ05	2.64	0
CZ06	2.65	0
CZ07	2.83	0
CZ08	3.11	0
CZ09	2.96	0
CZ10	3.17	1.73
CZ11	3.90	2.06
CZ12	3.14	0
CZ13	4.05	2.09
CZ14	3.15	0
CZ15	5.21	2.51
CZ16	2.93	0

3.3 Measure Definitions and Costs

Measures evaluated in this study fall into two categories: those associated with general efficiency — onsite generation (solar PV), and demand flexibility (batteries) — and those associated with building electrification. Furthermore, general efficiency measures are broken into those that are federally preempted and those that are not; see Section 1 for background information on preemption and Section 3.4 for details of measure packages evaluated in this study. The Reach Codes Team selected measures based on cost-effectiveness as well as decades of experience with residential architects, builders, and engineers along with general knowledge of the relative consumer acceptance of many measures.

The following sections describe the details and incremental cost assumptions for each of the measures. Incremental costs represent the equipment, installation, replacement, and maintenance costs of the proposed measures relative to the base case.[11] Replacement costs are applied for roofs, mechanical equipment, PV inverters and battery systems over the 30-year evaluation period. Maintenance costs are estimated for PV systems, but not any other measures. Costs were estimated to reflect costs to the building owner. All costs are provided as present value in 2023 (2023 PV$).

The Reach Codes Team obtained measure costs from distributors, contractors, literature review, and online sources such as Home Depot and RS Means. Contractor markups are incorporated. These are the Reach Codes Team's best estimates of average costs statewide. However, it's recognized that local costs may differ, and that inflation and supply chain issues may also impact costs.

3.3.1 Efficiency, Solar PV, and Batteries

The following are descriptions of each of the efficiency, PV, and battery measures evaluated under this analysis and applied in at least one of the packages presented in this report, including how they compare to the current prescriptive requirements. Throughout this report, "Efficiency" measures refer specifically to the following non-preempted

[11] All first costs are assumed to be financed in a mortgage and interest costs due to financing are included in the incremental costs. See Section 2.1.2 for details.

measures. These measures are in addition to or in place of the relevant 2022 base case prototype characteristics outlined in Table 3, and their applicability to measure packages are summarized in Table 39 through Table 41. Table 5 summarizes the incremental cost assumptions for each of these measures.

Reduced Infiltration (ACH50): Reduce infiltration in single family homes from the default infiltration assumption of five (5) air changes per hour at 50 Pascals (ACH50)[12] by 40 percent to 3 ACH50. HERS rater field verification and diagnostic testing of building air leakage according to the procedures outlined in the 2022 Reference Appendices RA3.8 (California Energy Commission, 2021b).

Lower U-Factor Fenestration: Reduce window U-factor to 0.24. The prescriptive U-factor is 0.30 in all climate zones.

Higher SHGC Fenestration: Increase solar heat gain coefficient (SHGC) to 0.50 in climate zones where heating loads dominate (1, 3, 5 and 16). The baseline SHGC applied in the Standard Design is 0.35 in these climate zones.

Cool Roof: Install a roofing product that's rated by the Cool Roof Rating Council to have an aged solar reflectance (ASR) equal to or greater than 0.25. Steep-sloped roofs were assumed in all cases. The prescriptive ASR is 0.20 for Climate Zones 10 through 15.

Increased Ceiling Insulation: Increase ceiling level insulation in a vented attic to R-38, R-49, or R-60 insulation.

Slab Insulation: Install R-10 perimeter slab insulation at a depth of 16-inches. This measure doesn't apply to Climate Zone 16 where slab insulation is required prescriptively.

Low Pressure Drop Ducts: Upgrade the duct distribution system to reduce external static pressure and meet a maximum fan efficacy of 0.35 Watts per cfm (compared to the prescriptively required 0.45 W/cfm). This may involve upsizing ductwork, reducing the total effective length of ducts, and/or selecting low pressure drop components such as filters. Fan watt draw must be verified by a HERS rater according to the procedures outlined in the 2022 Reference Appendices RA3.3 (California Energy Commission, 2021b). This applies to the single family prototype only.

Buried Radial Duct Design: Bury all ductwork in ceiling insulation by laying the ducts across the ceiling joists or in-between ceiling joists directly on the ceiling drywall. Duct design is based on a radial design where individual ducts are run to each supply register. This allows for smaller diameter ducts, reducing duct losses and more easily meeting fully or deeply buried conditions.[13] Duct burial and duct system design must be verified by a HERS rater according to the procedures outlined in the 2022 Reference Appendices RA3.1.4.1.5 and RA3.1.4.1.6 (California Energy Commission, 2021b). This applies to the single family prototype only.

Ductless Mini-Split Heat Pump: In the ADU prototype install a ductless mini-split heat pump with three indoor heads. The system is evaluated as meeting the criteria for the variable capacity heat pump (VCHP) credit, introduced in the 2019 code cycle, which must be verified by a HERS rater according to the procedures outlined in the 2022 Reference Appendices RA3.4.4.3 (California Energy Commission, 2021b). This credit requires verification of refrigerant charge, that all equipment is entirely within conditioned space, that airflow is directly supplied to all habitable space, and that wall mounted thermostats serve any zones greater than 150 square feet. This measure is non-preempted because it does not require the installation of equipment with efficiencies above federal minimum requirements.

Compact Hot Water Distribution: Design the hot water distribution system to meet minimum requirements for the basic compact hot water distribution credit according to the procedures outlined in the 2022 Reference Appendices RA4.4.6 (California Energy Commission, 2021b). In many single family homes this may require moving the water heater from an exterior to an interior garage wall. CBECC-Res software assumes a 30% reduction in distribution losses for the basic credit. This is prescriptively required in Climate Zones 1 and 16 only.

Solar PV: Installation of on-site PV is required in the 2022 residential code unless an exception is met. The PV sizing methodology in each package was developed to offset annual building electricity use and avoid oversizing. In all cases,

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[12] Whole house leakage tested at a pressure difference of 50 Pascals between indoors and outdoors.
[13] The duct systems in the Central Valley Research Homes Project Final Project Report are illustrative of this approach (Proctor, Wilcox, & Chitwood, 2018).

PV is evaluated in CBECC-Res according to the California Flexible Installation (CFI) 1 assumptions. To meet CFI eligibility, the requirements of 2022 Reference Appendices JA11.2.2 (California Energy Commission, 2021b) must be met.

The Reach Codes Team used two options within the CBECC-Res software for sizing the PV system. The first option, “Standard Design PV”, was applied in the base case simulations and packages where the PV system size was not changed from the minimum system size required[14]. For the PV packages, the second option, “Specify PV System Scaling”, was used. In these cases, a scaling of 100 was applied, indicating that the PV system be sized to offset 100% of the estimated electricity use of the Proposed Design case.

One exception to the PV requirement is when the minimum PV system size required is less than 1.8 kW. This exception applies to the ADU models in Climate Zones 1-9, 12, 14, and 16. For these cases no PV system is required by code and no PV system was modeled in the base case simulations.

Battery Energy Storage: A 10 kWh battery system was evaluated in CBECC-Res with control type set to “Basic” and with default efficiencies of 95% for both charging and discharging. 10kWh battery capacity is representative of systems installed in single family homes based on the Self-Generation Incentive Program (SGIP) participant data. The “Basic” control option charges the battery system anytime PV generation is greater than the house load and discharges the battery whenever the house load exceeds PV generation. The battery does not discharge to the grid, maximizing on-site utilization of the PV system and in turn utility bill benefits under NBT. To qualify for the battery storage compliance credit the battery system must meet the requirements outlined in the 2022 Reference Appendices JA12 (California Energy Commission, 2021b). Batteries are not prescriptively required in any climate zone.

Table 5: Incremental Cost Assumptions: Efficiency, PV, and Battery Measures

Measure	Performance Level	Incremental Cost (2023 PV$)[1]		Source & Notes
		Single Family	ADU	
Reduced Infiltration	3.0 vs 5.0 ACH50	\$591	\$362	\$0.115/ft² based on NREL’s BEopt cost database plus \$250 HERS rater verification.
Window U-factor	0.24 vs 0.30	\$2,280	\$285	\$4.23/ft² window area based on analysis conducted for the 2019 and 2022 Title 24 cycles (Statewide CASE Team, 2018).
Window SHGC	0.50 vs 0.35	\$0	\$0	Based on feedback from Statewide CASE Team that higher SHGC does not necessarily have any incremental cost (Statewide CASE Team, 2017).
Cool Roof	0.25 vs 0.20 aged solar reflectance	\$219	\$53	\$0.07per ft² of roof area first incremental cost for asphalt shingle product based on the 2022 Nonresidential High Performance Envelope CASE Report (Statewide CASE Team, 2020a). Total costs assume present value of replacement at year 20 and residual cost for remaining product life at end of 30-year analysis period. Higher reflectance values for lower cost are achievable for tile roof products
Attic Insulation	R-49 vs R-30	\$872	n/a	Based on costs from the 2022 Residential Additions & Alterations CASE Report (Statewide CASE Team, 2020b).
	R-60 vs R-30	\$1,420	n/a	
	R-60 vs R-38	\$1,096	n/a	
Slab Edge Insulation	R-10 vs R-0	\$651	\$449	\$4 per linear foot of slab perimeter based on internet research. Assumes 16in depth.

[14] The Standard Design PV system is sized to offset the electricity use of the building loads which are typically electric in a mixed fuel home, which includes all loads except space heating, water heating, clothes drying, and cooking.

Measure	Performance Level	Incremental Cost (2023 PV$)[1]		Source & Notes
		Single Family	ADU	
Low Pressure Drop Ducts	0.35 vs 0.45 W/cfm	$99	n/a	Costs assume one-hour labor for single family and half-hour for the ADU. Labor rate of $88 per hour is from 2022 RS Means for sheet metal workers and includes a weighted average City Cost Index for labor for California.
Buried Ducts	Buried, radial design	$281	n/a	No cost for laying ducts on attic floor versus suspending, in some cases there will be cost savings. Neutral cost for radiant design versus trunk and branch design. A $250 HERS Rater verification fee is included.
Duct Insulation	R-8 vs R-6	$201	n/a	Based on costs from the 2022 Residential Additions & Alterations CASE Report (Statewide CASE Team, 2020b).
Ductless Mini-Split Heat Pump	Ductless system meeting the VCHP credit vs. ducted split heat pump	n/a	$1,571	Costs were developed based on data from E3's 2019 report Residential Building Electrification in California (Energy & Environmental Economics, 2019) and the 2022 All-Electric Multifamily CASE Report (Statewide CASE Team, 2020c). Equipment costs are from the CASE Report for the 10-story multifamily prototype assuming similar sized equipment between the multifamily dwelling unit and the ADU. Thermostat, wiring, electrical, and ducting costs are from the E3 study. A $250 HERS Rater verification fee is also included. Where this measure is applied to the mixed fuel home with a gas furnace, this cost is in addition to the cost difference for a heat pump versus a gas furnace/split AC reported in Section 3.3.2.
Compact Hot Water Distribution	Basic credit – homes with gas tankless	$196	$0	For single family homes with a gas tankless water heater (mixed fuel homes in Climate Zones 3, 4, 13, 14) assumes adding 20-feet venting at $14.69 per linear foot to locate water heater on interior garage wall, less 20-feet savings for PEX and pipe insulation at $5.98 per linear foot. Costs obtained from online retailers. For single family homes with a HPWH there is an incremental cost savings from less pipe being required. For the ADU it is assumed the credit can be met without any changes to design and there is no cost impact.
	Basic credit – homes with HPWH	-$134	$0	
PV System	First Cost	$3.11/W	$3.11/W	First costs are from LBNL's Tracking the Sun 2022 (Barbose, Galen; Darghouth, Naim; O'Shaughnessy, Eric; Forrester, Sydney, 2022) and represent median costs in California in 2022 of $3.78/WDC for residential systems. The first cost was reduced by the solar energy Investment Tax Credit of 30%.[2] Inverter replacement cost of $0.14/WDC present value includes replacements at year 11 at $0.15/WDC (nominal) and at year 21 at $0.12/WDC (nominal) per the 2019 PV CASE Report (California Energy Commission, 2017). System maintenance costs of $0.31/WDC present value assume $0.02/WDC (nominal) annually per the 2019 PV CASE Report (California Energy Commission, 2017).
	Inverter replacement	$0.14/W	$0.14/W	
	Maintenance	$0.31/W	$0.31/W	
	Replacement cost	$648/kWh	$648/kWh	

Measure	Performance Level	Incremental Cost (2023 PV$)[1]		Source & Notes
		Single Family	ADU	
Battery (10 kWh)	First cost	$782/ kWh	$782/ kWh	First costs of $1,101/kWh are from SGIP residential participant cost data for single family projects between 2020 and 2023. The first cost is reduced by 30% due to the Investment Tax Credit[2] and also by $0.15/Wh due to the base SGIP incentive[3]. The SGIP incentive is only accounted for in IOU territories and not for SMUD and CPAU analyses. Replacement cost at years 10 and 20 was calculated based on the first cost reduced by 7% annually over the next 10 years for a future value cost of $533/kWh. The 7% reduction is based on SDG&E's Behind-the-Meter Battery Market Study (E-Source companies, 2020). For projects constructed in 2024 or 2025, the first replacement at year 10 would occur in 2034 or 2035. This replacement cost includes an average Investment Tax Credit of 22% in 2034 and 0% in 2035[2].

[1]All first costs are assumed to be financed in a mortgage and interest costs due to financing are included in the incremental costs. See Section 2.1.2 for details. Interest costs were not included for calculating TDV cost-effectiveness.

[2]As part of the Inflation Reduction Act in August 2022 the Section 25D Investment Tax Credit was extended and raised to 30% through 2032 with a step-down beginning in 2033. https://www.seia.org/sites/default/files/2022-08/Inflation%20Reduction%20Act%20Summary%20PDF%20FINAL.pdf

[3]SGIP incentives vary by 'steps' which reflect utility-specific funding across program implementation years. See: https://www.selfgenca.com/home/program_metrics/

3.3.2 Electrification

This analysis compared a code compliant mixed fuel prototype, which uses natural gas for three appliances (cooking, clothes drying and either space heating or water heating), with a code compliant all-electric prototype. The associated costs included the relative costs between natural gas and electric appliances, differences between in-house electricity and natural gas infrastructure, and the associated infrastructure costs for providing natural gas to the building. To estimate costs the Reach Codes Team leveraged costs from the 2019 reach code cost-effectiveness studies for residential new construction (Statewide Reach Codes Team, 2019) and detached accessory dwelling units (Statewide Reach Codes Team, 2021b), 2022 RS Means, PG&E data, published utility schedules and rules, and online research.

3.3.2.1 Utility Infrastructure

This section addresses utility infrastructure costs during construction; appliance-specific infrastructure costs are addressed in Section 0. Table 6 presents total costs for natural gas infrastructure for a single family building within CA gas IOU territory, including distribution and service line extensions, meter installation, and plan review. These costs are applied as cost savings for an all-electric home when compared to a mixed fuel home. This is the component with the highest degree of variability for all-electric homes, as they are project-dependent and may be significantly impacted by such factors as utility territory, site characteristics, distance to the nearest natural gas main and main location, joint trenching, whether work is conducted by the utility or a private contractor, and number of dwelling units per development. All gas utilities participating in this study were solicited for cost information. The CA IOU costs for single family homes presented are based on cost data provided by PG&E.

Extension of service lines from a main distribution line to the home were provided separately for a new subdivision in an undeveloped area ($1,300) as well as an infill development ($6,750). The service extension is typically more costly in an infill scenario due to the disruption of existing roads, sidewalks, and other structures. For this analysis an average of the new subdivision and infill development costs was used, representing 80 percent of the new subdivision and 20 percent infill. In the case of distribution line extensions, the estimated cost is for new greenfield development.

For the single family analysis, based on the Reach Codes Team's conversations with the industry it is assumed that no upgrades to the electrical panel are required and that a 200 Amp panel is typically installed for both mixed fuel and all-electric homes.

Table 6: Single Family IOU Total Natural Gas Infrastructure Costs

Item	Cost
Distribution Line Extension	$1,020
Service Line Extension	$2,390
Meter	$300
Plan Review Costs	$850
Total	**$4,560**

CPAU provides gas service to its customers and therefore separate costs were evaluated based on CPAU gas service connection fees.[15] Table 7 presents the breakdown of gas infrastructure costs used in this analysis for CPAU. There is no main distribution line component since Palo Alto has little greenfield space remaining and most of the development is infill.

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[15] CPAU Schedule G-5 effective 09-01-2019: https://www.cityofpaloalto.org/files/assets/public/utilities/utilities-engineering/general-specifications/gas-service-connection-fees.pdf

Table 7: Single Family CPAU Total Natural Gas Infrastructure Costs

Item	Cost
Service Extension	$5,892
Meter	$1,012
Plan Review Costs	$924
Total	**$7,828**

Electricity infrastructure costs for single family homes were not estimated as part of this work as they are expected to be the same for both all-electric and mixed fuel construction. This will change in July 2024 based on the CPUC's recent decision to eliminate electric line extension subsidies for new construction projects that use natural gas and/or propane.[16] This will increase the utility infrastructure costs for mixed fuel homes, relative to all-electric homes, improving the cost-effectiveness of all-electric construction. The Reach Codes Team intends to quantify this impact in future studies.

Table 8 presents utility infrastructure costs for the detached ADU, both mixed fuel and all-electric designs. These costs are directly from the 2019 detached ADU reach code report (Statewide Reach Codes Team, 2021b) and were obtained from stakeholder interviews and RS Means. For the ADU scenario it's assumed that natural gas infrastructure already exists on the lot and is being extended to the location of the ADU typically at the back of the lot. There are incremental cost savings for an all-electric ADU from not extending the natural gas service; however, there is also a small incremental cost for upgrading the electric service to accommodate the additional electrical load. The Reach Codes Team found that a new detached ADU would require that the building owner upgrade the service connection to the lot in both the mixed fuel ADU design and the all-electric design. The most common size for this upgrade is to upsize the existing panel to 225A, which would not represent an incremental cost from the mixed fuel project to the all-electric project. Feeder wiring to the ADU and the ADU subpanel, on the other hand, will need to be slightly upgraded for the all-electric design.

Table 8: ADU Utility Infrastructure Total and Incremental Costs

Mixed Fuel Measure	Mixed Fuel Total Cost	All-Electric Measure	All-Electric Total Cost	All-Electric Incremental Cost
Site natural gas service extension	$1,998	No site natural gas service	$0	($1,998)
Site electrical service connection upgrade 225A	$3,500	Site electrical service connection upgrade 225A	$3,500	$0
100A feeder to ADU with breaker	$933	125A feeder to ADU with breaker	$1,206	$273
100A ADU subpanel	$733	125A ADU subpanel	$946	$213
Totals	**$7,164**		**$5,652**	**($1,512)**

3.3.2.2 Equipment

This section provides descriptions and costs of the equipment applied to electrify mixed fuel homes in the all-electric packages. The equipment meets but does not exceed federal efficiency requirements to avoid federal preemption concerns.

[16] https://www.cpuc.ca.gov/news-and-updates/all-news/cpuc-eliminates-last-remaining-utility-subsidies-for-new-construction-of-buildings-using-gas-2023

For the water heating and space conditioning equipment analyzed, cost analyses incorporated the equipment's effective useful lifetime (EUL), which are summarized in Table 9. The EUL for the heat pump, furnace, and air conditioner are based on the Database for Energy Efficient Resources (DEER) (California Public Utilities Commission, 2021b). Water heating equipment lifetimes are based on DOE's recent water heater rulemaking (Department of Energy, 2022). Replacement costs are applied when equipment reaches its EUL within the 30-year evaluation period, and in such cases are included in the total lifetime costs. Residual value of the gas furnace and gas tankless at the end of the 30-year analysis period was accounted for to represent the remaining life of the equipment.

In this analysis, replacement costs assume a like-for-like replacement of equipment type and fuel (as listed in Table 9). However, this may be precluded in the future due to efforts to prohibit the sale of gas equipment currently being considered or undertaken by air districts (ex. BAAQMD, SCAQMD) and the California Air Resources Board (ex. zero NOx appliance rules).

Table 9: Effective Useful Lifetime (EUL) of Water Heating & Space Conditioning Equipment

Measure	EUL (Years)
Gas Furnace	20
Air Conditioner	15
Heat Pump	15
Gas Tankless Water Heater	20
Heat Pump Water Heater	15

Space Conditioning: This measure covers replacing a prescriptive air conditioner and gas furnace with a minimum efficiency heat pump in applicable climate zones (1, 2, 5 to 12, 15 and 16; see Table 3). Typical incremental costs for this equipment were based on contractor feedback and price variation by system capacity from the AC Wholesalers website and the RS Means cost database (RSMeans, 2022). Costs were applied based on the system capacity from heating and cooling load calculations in CBECC-Res as presented in Table 10. Air conditioner nominal capacity was calculated as the CBECC-Res cooling load, rounded up to the nearest half ton. Heat pump nominal capacity was calculated as the maximum of either the CBECC-Res heating or cooling load, rounded up to the nearest half ton. In both cases a minimum capacity of 1.5-ton was applied as this represents the typical smallest available split system heat pump equipment. Load calculations demonstrated that Climate Zones 2, 5 to 12, and 15 were cooling-dominated while Climate Zones 1 and 16 were heating-dominated. In the heating dominated climate zones the heat pump for the single family home needs to be upsized relative to an air conditioner that only provides cooling.

Replacement costs were estimated based on a contractor survey conducted by the Statewide Reach Codes Team in 2023 (Statewide Reach Codes Team, tbd), less any gas and electric infrastructure costs, and the equipment lifetimes listed in Table 9. Resultant incremental costs are presented in Table 11.

This measure, and thus the incremental cost, does not apply to climate zones where heat pump space conditioning is already prescriptively required (Climate Zones 3, 4, 13, and 14).

Table 10: Space Conditioning System Nominal Capacities

Climate Zone	Single Family		ADU	
	Air Conditioner Capacity (tons)	Heat Pump Capacity (tons)	Air Conditioner Capacity (tons)	Heat Pump Capacity (tons)
1	1.5	2.5	1.5	1.5
2	3	3	1.5	1.5
3	-	-	-	-
4	-	-	-	-
5	3	3	1.5	1.5
6	3	3	1.5	1.5
7	3	3	1.5	1.5
8	2.5	2.5	1.5	1.5
9	2.5	2.5	1.5	1.5
10	2.5	2.5	1.5	1.5
11	3	3	1.5	1.5
12	2.5	2.5	1.5	1.5
13	-	-	-	-
14	-	-	-	-
15	4	4	1.5	1.5
16	2	3.5	1.5	1.5

Table 11: Space Conditioning System Incremental Costs (2023 PV$)

Climate Zone	Single Family		ADU	
	First Cost	Total Lifetime Cost (Financed)	First Cost	Total Lifetime Cost (Financed)
1	$803	$2,705	($2,120)	($1,717)
2	($1,044)	($44)	($2,120)	($1,717)
3	-	-	-	-
4	-	-	-	-
5	($1,044)	($44)	($2,120)	($1,717)
6	($1,044)	($44)	($2,120)	($1,717)
7	($1,044)	($44)	($2,120)	($1,717)
8	($1,445)	($673)	($2,120)	($1,717)
9	($1,445)	($673)	($2,120)	($1,717)
10	($1,445)	($673)	($2,120)	($1,717)
11	($1,044)	($44)	($2,120)	($1,717)
12	($1,445)	($673)	($2,120)	($1,717)
13	-	-	-	-
14	-	-	-	-
15	($1,032)	$368	($2,120)	($1,717)
16	$2,331	$5,123	($2,120)	($1,717)

Water Heater: This measure covers replacing a prescriptive gas tankless water heater with a minimum efficiency HPWH in applicable climate zones (3, 4, 13, and 14; see Table 3). Typical incremental costs were based on costs from prior reach code work and recent contractor feedback. Incremental first costs assume a 65-gal HPWH and incremental replacement costs account for equipment lifetimes listed in Table 9. Replacement costs assume no change in cost from the first cost estimates before accounting for inflation, less any gas and electric infrastructure costs. For the ADU analysis the water heater is evaluated within the conditioned space with the supply air ducted from the outside and exhaust air ducted to the outside. A mechanical contractor provided a cost estimate of $943 for ducting through the attic in an ADU where the water heater is in an interior room. This cost is included in the equipment and installation total for the ADU. Resultant incremental costs are presented in Table 12.

Table 12: Heat Pump Water Heating System Incremental Costs (2023 PV$)

Item	ADU		Single Family	
	First Cost	Total Lifetime Cost (Financed)	First Cost	Total Lifetime Cost (Financed)
Equipment & Installation	$2,243	$3,930	$1,300	$2,267
Electric Service Upgrade	$43	$48	$45	$51
In-House Gas Piping	($580)	($651)	($580)	($651)
Total	**$1,706**	**$3,327**	**$765**	**$1,666**

For this electrification analysis, a HPWH that just meets the federal minimum efficiency standards[17] of close to 2.0 Uniform Energy Factor (UEF) was evaluated in order to satisfy preemption requirements. However, the Reach Codes Team is not aware of any 2.0 UEF products that are available on the market. The Northwest Energy Efficiency Alliance (NEEA) established its own rating system for high efficiency HPWHs[18] and maintains a database of qualified products. The lowest UEF currently reported in the database is 2.73. In fact, of the four rating tiers offered by NEEA, those meeting Tier 3 or Tier 4 are the dominant products on the market today. According to NEEA all major HPWH manufacturers are represented in NEEA's qualified product list[19] and there are fewer than 10 integrated products certified as Tier 1 or Tier 2, all of which have UEFs greater than 3.0.[20]

NEEA Tier 3 water heaters were included in the high-efficiency measure packages (see Section 3.4).

Clothes Dryer and Range: After review of various sources, the Reach Codes Team concluded that the cost difference between gas and electric resistance equipment for clothes dryers and stoves is negligible and that the lifetimes of the two technologies are similar. Resultant incremental costs are presented in Table 13. Note that while induction stoves may be a more likely installation option in many homes, CBECC-Res does not currently differentiate between electric technologies for stoves and therefore they were not considered in this analysis. Relative to electric resistance, induction stoves use less energy and improve performance and user satisfaction, at an additional cost.

Electric Service Upgrade (appliance-specific): The 2022 Title 24 Code requires electric readiness for gas appliances; as a result, the incremental costs to provide electrical service for electric appliances are minimal. The incremental costs accounted for in this study — shown in Table 13 — are calculated as the cost to install 220V service for the electric appliances less the cost for the electric ready requirements and for installing 110V service for the

[17] The Department of Energy establishes minimum energy conservation standards for consumer products, as directed in the Energy Policy and Conservation Act. See https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32.

[18] Based on operational challenges experienced in the past, NEEA established rating test criteria to ensure newly installed HPWHs perform adequately, especially in colder climates. The NEEA rating requires products comply with ENERGY STAR and includes requirements regarding noise and prioritizing heat pump use over supplemental electric resistance heating.

[19] https://neea.org/success-stories/heat-pump-water-heaters

[20] As of 3/8/2024: https://neea.org/img/documents/residential-unitary-HPWH-qualified-products-list.pdf

comparable gas appliance. Incremental costs are applied for the space conditioner, water heater, and cooking range. Based on builder surveys, it's assumed that in a typical mixed fuel home both electric and gas service are provided to the dryer location and therefore no incremental costs for the dryer were applied. Costs assume 50A service for the range and 30A service for the space conditioner and water heater. Costs are assumed to be the same for the single family and ADU analyses.

In-House Natural Gas Infrastructure (from meter to appliances): Installation cost to run a natural gas line from the meter to the appliance location was estimated at $580 per appliance, as shown in Table 13. These costs were based on material costs from Home Depot and labor costs from 2022 RS Means. The material costs were about 1/3 higher in RS Means than Home Depot, so the Reach Codes Team used the lower costs from Home Depot. The Reach Codes Team conducted a pipe sizing analysis for the two single family and one ADU prototype homes to estimate the length and diameter of gas piping required assuming the home included a gas furnace, gas tankless water heater, gas range, and gas dryer. Total estimated costs were very similar for each of the three prototypes and an average cost per appliance of $580 was determined. Costs are assumed to be the same for the single family and ADU analyses.

Table 13: Single Family All-Electric Appliance Incremental Costs

Item	ADU & Single Family	
	First Cost	Total Lifetime Cost (Financed)
Electric Resistance vs Gas Cooking		
Equipment & Installation	$0	$0
Electric Service Upgrade	$100	$113
In-House Gas Piping	($580)	($651)
Total	**($480)**	**($539)**
Electric Resistance vs Gas Clothes Drying		
Equipment & Installation	$0	$0
Electric Service Upgrade	$0	$0
In-House Gas Piping	($580)	($651)
Total	**($580)**	**($651)**

3.4 Measure Packages

The Reach Codes Team evaluated two packages for mixed fuel homes and five packages for all-electric homes for each prototype and climate zone, as described below.

1. All-Electric Code Minimum: This package applied the prescriptive requirements of the 2022 Title 24 Code and replaced gas equipment with minimum efficiency electric equipment.
2. Efficiency Only, all-electric: This package used only efficiency measures that don't trigger federal preemption issues including envelope, water heating distribution, and duct distribution efficiency measures. For ADUs, this also included ductless variable capacity heat pumps (VCHPs). This package was evaluated for the all-electric homes only.
3. Efficiency + High Efficiency (Preempted) Equipment, all-electric and mixed fuel: This package builds off the Efficiency Only package, adding water heating and space conditioning equipment that is more efficient than federal standards. The Reach Codes Team considers this more reflective of how builders meet above code requirements in practice. This package was evaluated to compare compliance results against the other non-preempted packages (see Table 27 and Table 28), however cost-effectiveness was not evaluated for this package since it cannot serve as the basis for adoption of a local ordinance. Specifically, it applied:
    a. Water heating, all-electric: Heat pump water heaters with a NEEA Tier 3 rating (3.45 UEF).
    b. Water heating, mixed fuel: High efficiency (0.95 UEF) gas tankless.

   c. Space conditioning, single family: High efficiency (16 SEER2/8 HSPF2) heat pumps. In mixed fuel packages, for climate zones with prescriptive gas heating, high efficiency (16 SEER2/95 AFUE) units were applied.

4. Efficiency + PV, all-electric: This package also builds on the Efficiency Only package, excluding preempted equipment. Instead, PV capacity was added to offset all of the estimated annual electricity use. This package was evaluated for the all-electric homes only.
5. Efficiency + PV + Battery, all-electric and mixed fuel: Using the Efficiency + PV package as a starting point for the all-electric analysis, a battery system was added. For mixed fuel homes the package of efficiency measures differed from the all-electric homes in some climate zones to arrive at a cost-effective solution.

To reiterate previous statements, the non-preempted measures used in all of the above packages (except for the All-Electric Code Minimum package) are referred to as “Efficiency measures”. As noted above, these measures may differ by prototype (single family vs. ADU) and by package. See Table 40 and Table 41 for the details of these measures.

4 Results

Section 4.1 presents compliance results for all-electric versus mixed fuel code minimum packages to provide a broad overview of how these different approaches impact code compliance. Sections 4.2 to 4.5 present EDR results along with other savings data for packages of particular interest, as well as cost-effectiveness results for all packages. Section 4.5 presents results for sensitivity analyses. All results reflect savings over a 30-year analysis period and are compared against the 2022 prescriptive baseline.

4.1 Compliance Results: All-Electric vs. Mixed Fuel Code Minimum

The Reach Codes Team evaluated the compliance impacts of a prescriptive all-electric home as well as a traditional mixed fuel home with four gas appliances (space heating, water heating, cooking, clothes drying). Compliance is relative to the 2022 prescriptive base case home with three gas appliances which, by definition, has a compliance margin of zero in all climate zones. The impacts for the all-electric single family home and the ADU are presented in Figure 1 and Figure 2, respectively. The all-electric single family and ADU home prototypes are code compliant with both EDR1 (source energy) and efficiency EDR2 (TDV energy) in all climate zones, though the compliance margin is highly variable across climate zones. The four gas appliance single family home is presented in Figure 3. This case is not code compliant in any climate zone.

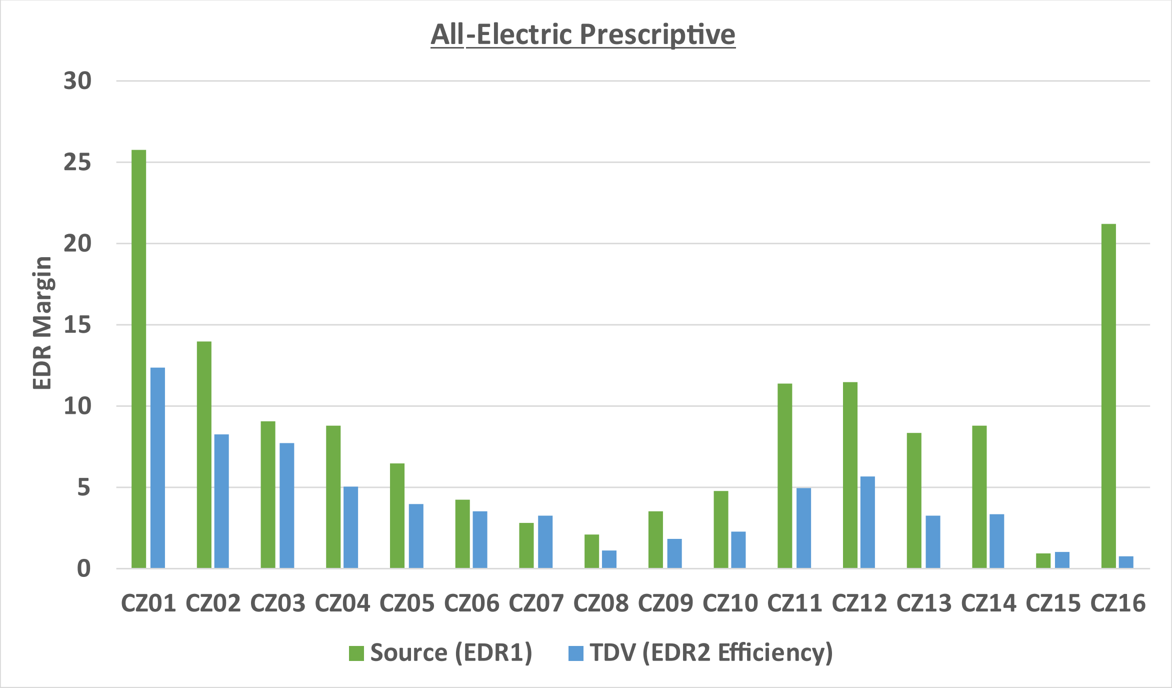

Figure 1: Single family all-electric home compliance impacts.

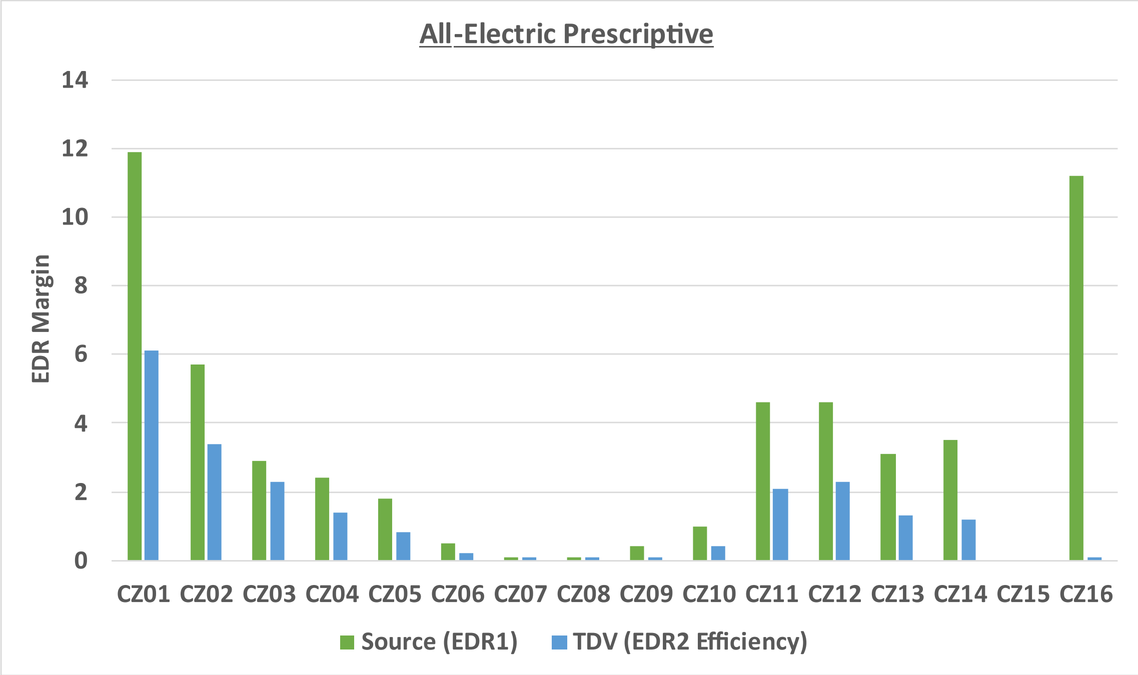

Figure 2: ADU all-electric home compliance impacts.

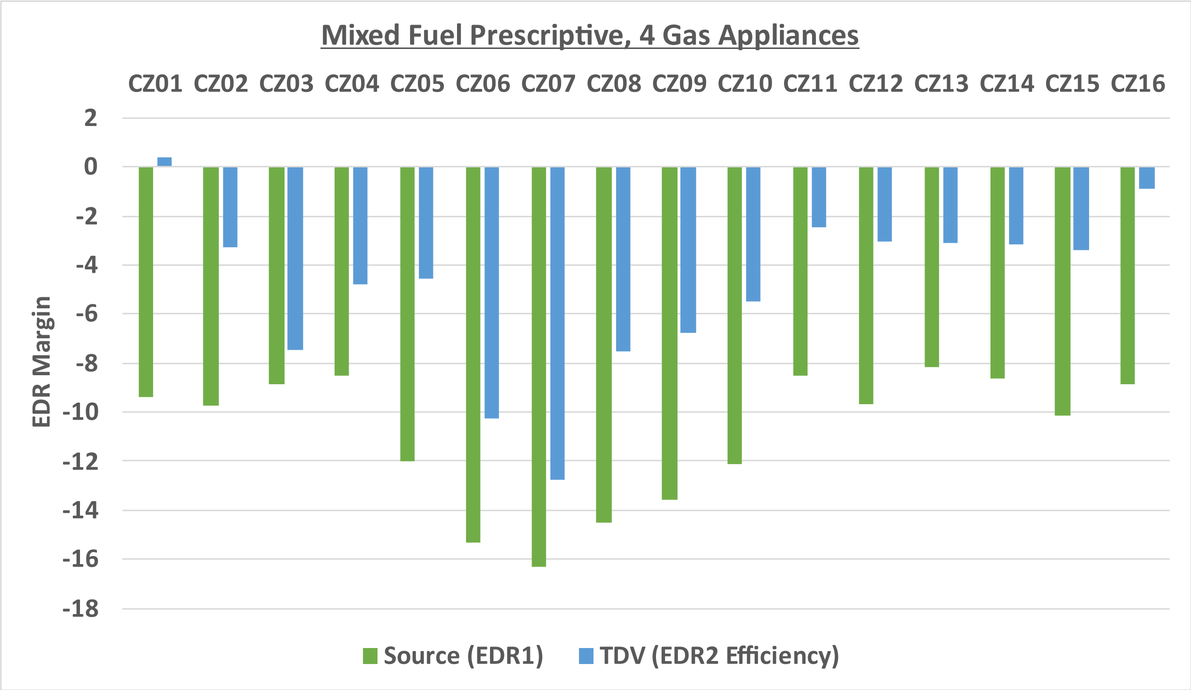

Figure 3: Single family four gas appliance home compliance impacts.

This analysis illustrates a couple of interesting points:

1. The 2022 compliance metrics are important drivers encouraging electrification. The compliance penalties associated with the four gas appliance home scenarios are significant and will require deep efficiency measures to overcome.
2. The 2022 Title 24 Code's new source energy metric combined with the heat pump baseline encourage all-electric construction, providing a compliance benefit that allows for some amount of prescriptively required building efficiency to be traded off and still comply when using the performance method.

4.2 All-Electric Code Minimum Results

Table 14 shows results for the single family all-electric Code Minimum measure package. Utility cost savings are negative, indicating an increase in utility costs for the all-electric building, everywhere except in CPAU and SMUD territories. In all cases the incremental cost is negative, which reflects cost savings for the all-electric building due to elimination of gas infrastructure costs. The package is cost-effective based on TDV in all cases but one (Climate Zone 16); it's not cost-effective On-Bill in Climate Zones 1, 3, 14, and 16.

Table 15 shows the all-electric Code Minimum package results for the ADU. Utility savings and incremental costs reflect the same general trend as single family homes. Cost-effectiveness is less favorable than the single family application, with TDV cost-effectiveness not met in Climate Zones 3, 4, 13, and 14, and On-Bill cost-effectiveness met only in Climate Zones 4 in CPAU territory, 10 in SCE/SCG territory, 12 in SMUD/PG&E territory, 11 and 15. Cost-effectiveness in Climate Zones 3, 4, 13, and 14 is worse than in the other climate zones due to the higher cost of converting from a gas tankless to a ducted HPWH (see Table 3) which isn't offset enough by the energy savings. Cost savings due to elimination of gas infrastructure costs are also lower for the ADU relative to the single family home.

Table 14: Single Family Cost-Effectiveness: All-Electric Code Minimum

Climate Zone	Electric /Gas Utility	Total EDR1 Margin	Efficiency EDR2 Margin	Annual Elec Savings (kWh)	Annual Gas Savings (therms)	Utility Cost Savings		Incremental Cost[1]		On-Bill		TDV	
						First Year	Lifecycle (2022$)	First Year	Lifecycle (2022$)	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	25.8	12.4	-4,308	398	($431)	($3,873)	($4,816)	($3,605)	0.9	($268)	>1	$5,702
CZ02	PGE	14.0	8.3	-2,888	246	($327)	($4,000)	($6,664)	($6,355)	1.6	$2,355	>1	$7,711
CZ03	PGE	9.1	7.7	-2,433	171	($303)	($4,734)	($4,854)	($4,644)	0.98	($90)	25.3	$3,887
CZ04	PGE	8.8	5.0	-2,232	163	($251)	($3,665)	($4,854)	($4,644)	1.3	$979	>1	$4,494
CZ04	CPAU	8.8	5.0	-2,232	163	($36)	$2,123	($8,122)	($8,314)	>1	$10,437	>1	$7,762
CZ05	PGE	6.5	4.0	-1,960	133	($292)	($4,981)	($6,664)	($6,355)	1.3	$1,373	6.1	$4,633
CZ05	PGE/SCG	6.5	4.0	-1,960	133	($277)	($4,532)	($6,664)	($6,355)	1.4	$1,823	6.1	$4,633
CZ06	SCE/SCG	4.2	3.5	-1,432	84	($231)	($4,015)	($6,664)	($6,355)	1.6	$2,339	4.7	$4,353
CZ07	SDGE	2.8	3.2	-1,293	69	($266)	($5,731)	($6,664)	($6,355)	1.1	$624	4.2	$4,211
CZ08	SCE/SCG	2.1	1.1	-1,293	67	($228)	($4,192)	($7,065)	($6,983)	1.7	$2,792	4.2	$4,674
CZ09	SCE	3.6	1.9	-1,453	84	($237)	($4,153)	($7,065)	($6,983)	1.7	$2,831	5.5	$5,013
CZ10	SCE/SCG	4.8	2.3	-1,683	107	($258)	($4,342)	($7,065)	($6,983)	1.6	$2,642	7.4	$5,287
CZ10	SDGE	4.8	2.3	-1,683	107	($265)	($5,158)	($7,065)	($6,983)	1.4	$1,825	7.4	$5,287
CZ11	PGE	11.4	4.9	-2,712	226	($306)	($3,803)	($6,664)	($6,355)	1.7	$2,552	>1	$7,153
CZ12	PGE	11.5	5.6	-2,554	212	($294)	($3,773)	($7,065)	($6,983)	1.9	$3,210	>1	$7,504
CZ12	SMUD/PGE	11.5	5.6	-2,554	212	$79	$4,731	($7,065)	($6,983)	>1	$11,714	>1	$7,504
CZ13	PGE	8.3	3.2	-2,095	154	($224)	($3,164)	($4,854)	($4,644)	1.5	$1,480	>1	$4,490
CZ14	SCE/SCG	8.8	3.3	-2,291	159	($322)	($5,166)	($4,854)	($4,644)	0.9	($522)	>1	$4,105
CZ14	SDGE	8.8	3.3	-2,291	159	($344)	($6,361)	($4,854)	($4,644)	0.7	($1,717)	>1	$4,105
CZ15	SCE/SCG	0.9	1.0	-1,167	53	($217)	($4,152)	($6,652)	($5,942)	1.4	$1,791	3.0	$3,439
CZ16	PG&E	21.3	0.7	-4,729	403	($548)	($6,581)	($3,289)	($1,187)	0.2	($5,394)	0.4	($1,339)

[1] Though uncommon, incremental costs can be negative, reflecting initial construction cost savings. When paired with increased energy costs (negative benefits), the construction cost savings are treated as the 'benefit' while the increased energy costs are the 'cost,' which may yield positive cost effectiveness. See Section 2.1.2.3 for more information.

Table 15: ADU Cost-Effectiveness: All-Electric Code Minimum

Climate Zone	Electric /Gas Utility	Total EDR1 Margin	Efficiency EDR2 Margin	Annual Elec Savings (kWh)	Annual Gas Savings (therms)	Utility Cost Savings		Incremental Cost[1]		On-Bill		TDV	
						First Year	Lifecycle (2022$)	First Year	Lifecycle (2022$)	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	11.9	6.1	-1,641	114	($353)	($6,682)	($4,692)	($4,605)	0.7	($2,077)	3.9	$2,986
CZ02	PGE	5.7	3.4	-1,245	75	($312)	($6,347)	($4,692)	($4,605)	0.7	($1,742)	2.7	$2,515
CZ03	PGE	2.9	2.3	-1,672	123	($377)	($7,138)	($863)	$442	0.0	($7,581)	0.0	($1,489)
CZ04	PGE	2.4	1.4	-1,612	118	($366)	($6,964)	($863)	$442	0.0	($7,406)	0.0	($801)
CZ04	CPAU	2.4	1.4	-1,612	118	$25	$3,035	($863)	$442	6.9	$2,592	0.0	($801)
CZ05	PGE	1.8	0.8	-1,026	49	($302)	($6,517)	($4,692)	($4,605)	0.7	($1,912)	2.0	$2,021
CZ05	PGE/SCG	1.8	0.8	-1,026	49	($257)	($5,178)	($4,692)	($4,605)	0.9	($574)	2.0	$2,021
CZ06	SCE/SCG	0.5	0.2	-904	38	($243)	($4,923)	($4,692)	($4,605)	0.9	($318)	2.1	$2,135
CZ07	SDGE	0.1	0.1	-884	37	($337)	($7,903)	($4,692)	($4,605)	0.6	($3,298)	2.2	$2,205
CZ08	SCE/SCG	0.1	0.1	-878	36	($241)	($4,894)	($4,692)	($4,605)	0.9	($289)	2.3	$2,274
CZ09	SCE	0.4	0.1	-903	38	($243)	($4,914)	($4,692)	($4,605)	0.9	($310)	2.4	$2,321
CZ10	SCE/SCG	1.0	0.4	-952	43	($189)	($3,629)	($4,692)	($4,605)	1.3	$976	2.8	$2,577
CZ10	SDGE	1.0	0.4	-952	43	($249)	($5,689)	($4,692)	($4,605)	0.8	($1,084)	2.8	$2,577
CZ11	PGE	4.6	2.1	-1,209	71	($224)	($4,405)	($4,692)	($4,605)	1.0	$200	3.5	$2,870
CZ12	PGE	4.6	2.3	-1,183	69	($306)	($6,315)	($4,692)	($4,605)	0.7	($1,710)	3.0	$2,684
CZ12	SMUD/PGE	4.6	2.3	-1,183	69	($65)	($808)	($4,692)	($4,605)	5.7	$3,797	3.0	$2,684
CZ13	PGE	3.1	1.3	-1,611	112	($218)	($3,689)	($863)	$442	0.0	($4,131)	0.0	($858)
CZ14	SCE/SCG	3.5	1.2	-1,714	115	($375)	($6,933)	($863)	$442	0.0	($7,375)	0.0	($1,089)
CZ14	SDGE	3.5	1.2	-1,714	115	($483)	($10,348)	($863)	$442	0.0	($10,790)	0.0	($1,089)
CZ15	SCE/SCG	0.0	0.0	-864	36	($172)	($3,359)	($4,692)	($4,605)	1.4	$1,246	2.6	$2,477
CZ16	PG&E	11.2	0.1	-1,781	122	($379)	($7,167)	($4,692)	($4,605)	0.6	($2,562)	2.1	$2,133

[1] Though uncommon, incremental costs can be negative, reflecting initial construction cost savings. When paired with increased energy costs (negative benefits), the construction cost savings are treated as the 'benefit' while the increased energy costs are the 'cost,' which may yield positive cost effectiveness. See Section 2.1.2.3 for more information.

4.3 All-Electric Efficiency, PV, and Battery Results

Table 16 and Table 17 compare cost-effectiveness results for the all-electric packages for the single family and ADU prototypes, respectively, with the exception of the all-electric Efficiency + High Efficiency (Preempted) Equipment package (cost-effectiveness was not evaluated for this package but see Table 27 and Table 28 for a comparison of compliance impacts). In almost all cases the packages are cost-effective based on TDV. On-Bill cost-effectiveness generally improves with the addition of efficiency measures, further improves with an upsized PV system, and improves even more once batteries are added. A summary of measures included in each package is provided in Appendix 7.3 Summary of Measures by Package. The efficiency measures added to the all-electric package to meet minimum code requirements are described in Table 39 and Table 41.

Table 16: Single Family Cost-Effectiveness: Comparison of All-Electric Efficiency Only, PV, and Battery Packages

Climate Zone	Electric /Gas Utility	All-Electric Code Minimum				All-Electric Efficiency Only				All-Electric-Efficiency + PV				All-Electric Efficiency + PV + Battery			
		On-Bill		TDV		On-Bill		TDV		On-Bill		TDV		On-Bill		TDV	
		B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	0.9	($268)	>1	$5,702	>1	$2,945	>1	$8,168	0.9	($1,313)	1.8	$9,817	1.0	$1,012	1.2	$4,391
CZ02	PGE	1.6	$2,355	>1	$7,711	8.9	$3,870	>1	$9,325	1.5	$2,242	4.2	$12,452	1.3	$4,962	1.5	$8,190
CZ03	PGE	1.0	($90)	25.3	$3,887	1.1	$168	>1	$3,939	0.8	($903)	2.8	$6,465	1.1	$2,114	1.1	$1,347
CZ04	PGE	1.3	$979	>1	$4,494	1.7	$1,054	>1	$4,849	1.1	$204	3.5	$7,893	1.2	$3,709	1.3	$4,506
CZ04	CPAU	>1	$10,437	>1	$7,762	>1	$10,021	>1	$8,117	>1	$14,776	>1	$11,161	0.9	($1,076)	1.5	$6,724
CZ05	PGE	1.3	$1,373	6.1	$4,633	1.6	$1,975	>1	$4,985	2.2	$1,457	8.5	$7,927	1.4	$6,203	1.3	$3,876
CZ05	PGE/SCG	1.4	$1,823	6.1	$4,633	1.9	$2,424	>1	$4,985	2.6	$1,907	8.5	$7,927	1.4	$6,652	1.3	$3,876
CZ06	SCE/SCG	1.6	$2,339	4.7	$4,353	1.6	$1,813	>1	$4,119	109.5	$2,638	152.4	$6,727	1.5	$7,153	1.2	$2,276
CZ07	SDGE	1.1	$624	4.2	$4,211	1.2	$839	8.3	$4,070	5.7	$469	>1	$6,079	2.0	$13,798	1.1	$1,186
CZ08	SCE/SCG	1.7	$2,792	4.2	$4,674	1.8	$2,574	17.7	$4,642	>1	$3,329	>1	$7,492	1.7	$8,899	1.2	$2,085
CZ09	SCE	1.7	$2,831	5.5	$5,013	1.9	$2,699	>1	$5,087	>1	$3,634	>1	$8,007	1.7	$9,151	1.3	$3,630
CZ10	SCE/SCG	1.6	$2,642	7.4	$5,287	2.0	$2,668	>1	$5,376	>1	$3,765	>1	$8,347	1.7	$10,088	1.3	$3,901
CZ10	SDGE	1.4	$1,825	7.4	$5,287	1.8	$2,438	>1	$5,376	>1	$2,539	>1	$8,347	2.4	$19,463	1.3	$3,901
CZ11	PGE	1.7	$2,552	>1	$7,153	>1	$4,159	>1	$8,524	1.8	$2,984	4.6	$11,310	1.4	$7,781	1.5	$8,757
CZ12	PGE	1.9	$3,210	>1	$7,504	4.6	$3,742	>1	$8,084	1.9	$2,561	5.5	$11,063	1.3	$6,021	1.5	$8,216
CZ12	SMUD/PGE	>1	$11,714	>1	$7,504	>1	$10,665	>1	$8,084	5.8	$13,407	5.5	$11,063	0.9	($1,237)	1.4	$7,166
CZ13	PGE	1.5	$1,480	>1	$4,490	>1	$2,876	>1	$5,773	1.7	$2,334	3.7	$8,341	1.4	$7,848	1.4	$7,005
CZ14	SCE/SCG	0.9	($522)	>1	$4,105	1.8	$811	>1	$5,461	1.6	$2,558	3.6	$9,965	1.6	$10,569	1.4	$6,204
CZ14	SDGE	0.7	($1,717)	>1	$4,105	1.5	$643	>1	$5,461	1.2	$922	3.6	$9,965	2.1	$20,099	1.4	$6,204
CZ15	SCE/SCG	1.4	$1,791	3.0	$3,439	8.0	$3,267	>1	$4,669	>1	$3,940	>1	$6,120	2.0	$13,576	0.99	($80)
CZ16	PG&E	0.2	($5,394)	0.4	($1,339)	0.2	($1,946)	1.7	$1,894	0.8	($3,199)	1.6	$6,711	1.0	$206	1.1	$1,690

Table 17: ADU Cost-Effectiveness: All-Electric Energy Efficiency + Additional PV + Battery

Climate Zone	Electric /Gas Utility	All-Electric Code Minimum				All-Electric Efficiency Only				All-Electric Efficiency + PV				All-Electric Efficiency + PV + Battery			
		On-Bill		TDV		On-Bill		TDV		On-Bill		TDV		On-Bill		TDV	
		B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	0.7	($2,077)	3.9	$2,986	0.7	($1,341)	>1	$3,243	1.2	$2,389	1.5	$5,353	1.0	($216)	1.0	($366)
CZ02	PGE	0.7	($1,742)	2.7	$2,515	0.5	($2,155)	>1	$2,289	1.5	$3,918	1.9	$6,704	1.1	$2,456	1.3	$5,648
CZ03	PGE	0.0	($7,581)	0.0	($1,489)	0.0	($8,481)	0.0	($2,235)	0.83	($1,988)	1.2	$1,882	0.86	($3,653)	1.0	($492)
CZ04	PGE	0.0	($7,406)	0.0	($801)	0.0	($8,319)	0.4	($1,419)	0.9	($1,094)	1.4	$3,933	0.9	($2,801)	1.1	$1,875
CZ04	CPAU	6.9	$2,592	0.0	($801)	1.5	$1,330	0.4	($1,419)	1.7	$8,884	1.4	$3,933	0.7	($8,335)	1.0	$825
CZ05	PGE	0.7	($1,912)	2.0	$2,021	0.5	($2,810)	1.7	$1,095	1.7	$4,515	2.1	$5,881	1.2	$3,324	1.1	$2,563
CZ05	PGE/SCG	0.9	($574)	2.0	$2,021	0.7	($1,472)	1.7	$1,095	2.0	$5,853	2.1	$5,881	1.2	$4,662	1.1	$2,563
CZ06	SCE/SCG	0.9	($318)	2.1	$2,135	0.7	($1,078)	2.5	$1,548	2.1	$6,366	2.4	$6,996	1.2	$3,195	1.3	$4,863
CZ07	SDGE	0.6	($3,298)	2.2	$2,205	0.4	($4,038)	2.2	$1,386	2.0	$6,167	2.1	$5,939	1.5	$11,261	1.1	$2,674
CZ08	SCE/SCG	0.9	($289)	2.3	$2,274	0.7	($1,046)	2.5	$1,523	2.1	$6,750	2.5	$8,280	1.2	$4,320	1.4	$6,678
CZ09	SCE	0.9	($310)	2.4	$2,321	0.7	($1,108)	2.7	$1,624	2.2	$6,954	2.5	$8,052	1.2	$4,600	1.4	$8,273
CZ10	SCE/SCG	1.3	$976	2.8	$2,577	1.1	$280	4.3	$1,936	5.7	$1,120	15.1	$3,840	1.0	($593)	1.1	$940
CZ10	SDGE	0.8	($1,084)	2.8	$2,577	0.7	($1,401)	4.3	$1,936	0.0	($1,079)	15.1	$3,840	1.4	$6,523	1.1	$940
CZ11	PGE	1.0	$200	3.5	$2,870	1.1	$290	>1	$2,875	0.9	($216)	3.9	$4,381	1.0	($600)	1.2	$2,983
CZ12	PGE	0.7	($1,710)	3.0	$2,684	0.5	($2,152)	>1	$2,222	1.6	$5,030	2.0	$7,018	1.2	$3,451	1.3	$5,859
CZ12	SMUD/PGE	5.7	$3,797	3.0	$2,684	15.3	$2,366	>1	$2,222	1.8	$6,123	2.0	$7,018	0.6	($8,899)	1.2	$4,809
CZ13	PGE	0.0	($4,131)	0.0	($858)	0.0	($4,116)	0.6	($879)	0.3	($4,374)	1.1	$649	0.8	($3,872)	1.0	$456
CZ14	SCE/SCG	0.0	($7,375)	0.0	($1,089)	0.0	($7,543)	0.5	($1,340)	1.2	$1,941	1.6	$6,279	1.1	$1,496	1.2	$4,644
CZ14	SDGE	0.0	($10,790)	0.0	($1,089)	0.0	($10,889)	0.5	($1,340)	1.3	$3,342	1.6	$6,279	1.4	$11,396	1.2	$4,644
CZ15	SCE/SCG	1.4	$1,246	2.6	$2,477	2.8	$1,629	>1	$2,686	>1	$2,115	>1	$3,904	1.2	$2,922	1.2	$2,135
CZ16	PG&E	0.6	($2,562)	2.1	$2,133	0.6	($1,707)	>1	$2,879	1.7	$5,819	2.1	$8,219	1.2	$4,345	1.3	$6,454

4.4 Mixed Fuel Results

Table 18 and Table 19 show results for the mixed fuel Efficiency + PV + Battery package for Single Family and ADU prototypes, respectively. On a TDV basis, this package is cost-effective only in Climate Zone 1 for single family and in no cases for ADUs. However, this package is cost-effective On-Bill for the single family home in all climate zones except 4 in CPAU territory and 12 in SMUD/PG&E territory. On-Bill cost-effectiveness for the ADU home, on the other hand, is seen only in Climate Zones 2, 5, 7 through 9, 10 in SDG&E territory, 14, and 16.

Table 18: Single Family Cost-Effectiveness: Mixed Fuel Efficiency + PV + Battery

Climate Zone	Electric /Gas Utility	Total EDR1 Margin	Efficiency EDR2 Margin	Annual Elec Savings (kWh)	Annual Gas Savings (therms)	Utility Cost Savings		Incremental Cost		On-Bill		TDV	
						First Year	Lifecycle (2022$)	First Year	Lifecycle (2022$)	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	22.6	18.8	1,571	116	$1,084	$26,667	$11,160	$20,166	1.3	$6,501	1.0	$500
CZ02	PGE	14.1	7.4	1,257	34	$913	$21,353	$10,268	$18,868	1.1	$2,486	0.9	($1,282)
CZ03	PGE	12.8	4.3	858	7	$785	$18,003	$8,708	$16,900	1.1	$1,104	0.7	($4,777)
CZ04	PGE	13.2	4.3	790	6	$803	$18,394	$9,623	$17,938	1.0	$456	0.8	($3,925)
CZ04	CPAU	13.2	4.3	790	6	$123	$2,877	$10,673	$19,172	0.2	($16,295)	0.7	($4,975)
CZ05	PGE	14.8	4.9	1,178	13	$905	$20,821	$10,021	$18,536	1.1	$2,285	0.8	($4,048)
CZ05	PGE/SCG	14.8	4.9	1,178	13	$900	$20,690	$10,021	$18,536	1.1	$2,154	0.8	($4,048)
CZ06	SCE/SCG	18.3	5.5	888	6	$864	$19,539	$9,266	$17,587	1.1	$1,951	0.8	($3,941)
CZ07	SDGE	18.7	4.8	832	4	$1,134	$27,505	$9,302	$17,636	1.6	$9,869	0.7	($4,905)
CZ08	SCE/SCG	17.1	3.0	777	2	$920	$20,754	$9,134	$17,410	1.2	$3,344	0.7	($4,341)
CZ09	SCE	16.2	3.1	833	3	$922	$20,804	$9,152	$17,435	1.2	$3,369	0.8	($3,839)
CZ10	SCE/SCG	14.4	2.7	846	2	$958	$21,608	$8,828	$17,062	1.3	$4,546	0.7	($4,146)
CZ10	SDGE	14.4	2.7	846	2	$1,288	$31,210	$8,828	$17,062	1.8	$14,148	0.7	($4,146)
CZ11	PGE	12.9	5.1	1,025	26	$1,031	$23,949	$9,099	$17,426	1.4	$6,523	0.98	($285)
CZ12	PGE	13.2	4.8	1,098	23	$923	$21,415	$9,485	$17,964	1.2	$3,451	0.96	($614)
CZ12	SMUD/PGE	13.2	4.8	1,098	23	$253	$6,133	$10,535	$19,199	0.3	($13,066)	0.9	($1,664)
CZ13	PGE	12.3	4.2	1,006	5	$1,016	$23,250	$9,251	$17,585	1.3	$5,665	0.9	($1,774)
CZ14	SCE/SCG	13.4	5.4	1,514	6	$1,093	$24,697	$10,214	$18,751	1.3	$5,945	0.9	($1,383)
CZ14	SDGE	13.4	5.4	1,514	6	$1,421	$34,477	$10,214	$18,751	1.8	$15,726	0.9	($1,383)
CZ15	SCE/SCG	13.5	3.8	531	2	$1,140	$25,708	$8,586	$16,630	1.5	$9,078	0.6	($5,490)
CZ16	PG&E	20.4	14.2	1,228	114	$1,070	$26,218	$12,086	$20,964	1.3	$5,254	0.98	($444)

Table 19: ADU Cost-Effectiveness: Mixed Fuel Efficiency + PV + Battery

Climate Zone	Electric /Gas Utility	Total EDR1 Margin	Efficiency EDR2 Margin	Annual Elec Savings (kWh)	Annual Gas Savings (therms)	Utility Cost Savings		Incremental Cost		On-Bill		TDV	
						First Year	Lifecycle (2022$)	First Year	Lifecycle (2022$)	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	18.5	7.7	3,666	20	$1,078	$24,880	$15,088	$25,533	1.0	($654)	0.7	($6,375)
CZ02	PGE	16.6	3.5	3,472	11	$1,042	$23,928	$13,502	$23,404	1.0	$524	0.8	($3,785)
CZ03	PGE	11.8	1.2	2,679	0	$781	$17,816	$11,433	$20,715	0.9	($2,899)	0.7	($6,381)
CZ04	PGE	13.3	1.6	2,799	0	$859	$19,588	$11,869	$21,212	0.9	($1,625)	0.7	($4,962)
CZ04	CPAU	13.3	1.6	2,799	0	$391	$8,911	$12,919	$22,447	0.4	($13,536)	0.7	($6,012)
CZ05	PGE	16.9	1.1	3,309	2	$1,031	$23,539	$12,222	$21,774	1.1	$1,765	0.8	($4,320)
CZ05	PGE/SCG	16.9	1.1	3,309	2	$1,031	$23,520	$12,222	$21,774	1.1	$1,746	0.8	($4,320)
CZ06	SCE/SCG	19.8	1.2	3,285	1	$953	$21,468	$12,050	$21,543	1.0	($75)	0.8	($3,431)
CZ07	SDGE	20.3	1.2	3,278	0	$1,296	$31,370	$12,424	$22,045	1.4	$9,325	0.8	($4,187)
CZ08	SCE/SCG	20.4	0.5	3,505	0	$1,040	$23,434	$12,609	$22,292	1.1	$1,141	0.8	($3,179)
CZ09	SCE	19.6	0.5	3,497	0	$1,030	$23,213	$12,347	$21,941	1.1	$1,272	0.8	($2,974)
CZ10	SCE/SCG	19.0	0.6	729	0	$537	$12,107	$8,092	$16,220	0.7	($4,113)	0.5	($7,000)
CZ10	SDGE	19.0	0.6	729	0	$813	$19,671	$8,092	$16,220	1.2	$3,451	0.5	($7,000)
CZ11	PGE	17.6	3.0	871	10	$663	$15,273	$8,874	$17,182	0.9	($1,909)	0.7	($5,184)
CZ12	PGE	16.7	2.7	3,594	9	$1,112	$25,496	$13,450	$23,324	1.1	$2,172	0.9	($2,978)
CZ12	SMUD/PGE	16.7	2.7	3,594	9	$537	$12,380	$14,500	$24,558	0.5	($12,178)	0.8	($4,028)
CZ13	PGE	14.5	2.2	273	0	$551	$12,569	$7,635	$15,518	0.8	($2,949)	0.5	($6,560)
CZ14	SCE/SCG	14.5	3.2	3,499	0	$1,006	$22,671	$12,471	$21,939	1.0	$732	0.8	($3,079)
CZ14	SDGE	14.5	3.2	3,499	0	$1,351	$32,711	$12,471	$21,939	1.5	$10,772	0.8	($3,079)
CZ15	SCE/SCG	19.2	1.8	551	0	$683	$15,387	$8,134	$16,188	1.0	($801)	0.5	($6,677)
CZ16	PG&E	18.3	6.3	3,680	24	$1,117	$25,838	$13,274	$23,130	1.1	$2,708	0.8	($3,161)

4.5 Greenhouse Gas Reductions

Table 20 and Table 21 present greenhouse gas reductions for the single family and ADU prototypes, respectively. Savings represent average annual savings over the 30-year lifetime of the analysis. Greenhouse gas reductions are greatest for the all-electric Efficiency + PV + Battery package in all cases. For the single family homes, the all-electric Code Minimum case reduces greenhouse gas emissions as much or greater than the mixed fuel Efficiency + PV + Battery package in Climate Zones 1 through 4, 11 through 13, and 16—showcasing the benefit of all-electric construction over even the most ambitious of mixed fuel construction packages evaluated in this study. The trend differs for the ADU where the mixed fuel Efficiency + PV + Battery package results in more greenhouse gas savings than the all-electric Code Minimum in all climate zones except Climate Zones 3, 4, and 13. In most of the climate zones (1, 2, 5 through 12, 15, and 16) the all-electric ADU involves electrification of space heating, cooking, and clothes drying. The space heating loads for the ADU are very low, even in the colder climates, and as a result the greenhouse gas savings from efficiency measures, PV and battery are greater than just code minimum electrification. This is also the case for single family homes in Climate Zones 5 through 10, and 15 where space heating loads are low.

Table 20: Single Family Greenhouse Gas Reductions (metric tons)

Climate Zone	Single Family All-Electric					Single Family Mixed Fuel	
	Code Minimum	Efficiency Only	Efficiency + High Efficiency Equipment	Efficiency + PV	Efficiency + PV + Battery	Efficiency + High Efficiency Equipment	Efficiency + PV + Battery
CZ01	1.5	1.7	1.8	1.8	2.3	0.8	1.1
CZ02	0.9	1.0	1.1	1.1	1.6	0.5	0.7
CZ03	0.7	0.7	0.8	0.8	1.3	0.2	0.5
CZ04	0.7	0.7	0.8	0.8	1.3	0.2	0.5
CZ05	0.4	0.5	0.6	0.6	1.1	0.2	0.6
CZ06	0.3	0.3	0.3	0.4	0.9	0.1	0.5
CZ07	0.2	0.2	0.3	0.3	0.8	0.1	0.5
CZ08	0.2	0.2	0.3	0.3	0.8	0.1	0.5
CZ09	0.3	0.3	0.3	0.4	0.9	0.1	0.5
CZ10	0.3	0.4	0.4	0.5	1.0	0.1	0.5
CZ11	0.8	0.9	1.0	1.0	1.5	0.4	0.7
CZ12	0.7	0.8	0.9	0.9	1.4	0.4	0.6
CZ13	0.6	0.7	0.8	0.8	1.3	0.2	0.6
CZ14	0.6	0.7	0.8	0.9	1.4	0.2	0.6
CZ15	0.2	0.2	0.3	0.3	0.7	0.1	0.5
CZ16	1.4	1.7	1.7	1.9	2.3	1.0	1.1

Table 21: ADU Greenhouse Gas Reductions (metric tons)

Climate Zone	ADU All-Electric					ADU Mixed Fuel	
	Code Minimum	Efficiency Only	Efficiency + High Efficiency Equipment	Efficiency + PV	Efficiency + PV + Battery	Efficiency + High Efficiency Equipment	Efficiency + PV + Battery
CZ01	0.4	0.5	0.5	0.6	1.0	0.2	0.5
CZ02	0.2	0.3	0.3	0.4	0.8	0.1	0.5
CZ03	0.5	0.5	0.6	0.7	1.0	0.1	0.3
CZ04	0.5	0.5	0.5	0.7	1.0	0.1	0.4
CZ05	0.1	0.2	0.2	0.3	0.7	0.0	0.4
CZ06	0.1	0.1	0.1	0.3	0.6	0.0	0.4
CZ07	0.1	0.1	0.1	0.3	0.6	0.0	0.4
CZ08	0.1	0.1	0.1	0.3	0.6	0.0	0.5
CZ09	0.1	0.1	0.1	0.3	0.7	0.0	0.5
CZ10	0.1	0.1	0.2	0.2	0.6	0.0	0.4
CZ11	0.2	0.3	0.3	0.3	0.7	0.1	0.4
CZ12	0.2	0.3	0.3	0.4	0.7	0.1	0.5
CZ13	0.4	0.5	0.5	0.5	0.9	0.1	0.3
CZ14	0.4	0.5	0.5	0.7	1.1	0.1	0.5
CZ15	0.1	0.1	0.1	0.2	0.6	0.0	0.4
CZ16	0.4	0.5	0.5	0.7	1.0	0.2	0.6

4.6 Sensitivity Analysis

In response to jurisdictional interest, several cases were evaluated under circumstances different than those presented above in order to assess their impact on cost-effectiveness. Altered circumstances include:

1. CARE versus standard tariffs. This comparison is presented for the all-electric Code Minimum and the mixed fuel Efficiency + PV+ Battery packages and shows the impact on On-Bill cost-effectiveness for income qualified utility customers.
2. Infill versus new subdivision single family developments. This comparison applied to the all-electric Code Minimum package demonstrates how cost-effectiveness is impacted due to the magnitude of cost savings for all-electric construction from elimination of the natural gas infrastructure.
3. Utility rate escalation factors. The impact on On-Bill cost-effectiveness is presented for the all-electric Code Minimum package from varying the assumptions for escalation of electricity and natural gas utility rates over the 30-year analysis period.

4.6.1 CARE Rate Comparison

Table 22 and Table 23 present a comparison of On-Bill cost-effectiveness results for CARE tariffs relative to standard IOU tariffs for the all-electric Code Minimum package for the single family and ADU prototypes, respectively. Applying the CARE rates lowers both electric and gas utility bills for the consumer. In the case of the all-electric home, the net impact of CARE rates is improved cost-effectiveness relative to the standard tariffs. This is because the discount on electricity is greater than that for natural gas. The opposite trend occurs for the mixed fuel packages, where the lower CARE rates result in lower utility cost savings and subsequently lower benefit-to-cost ratios.

Table 22: On-Bill Cost-Effectiveness with CARE Tariffs: All-Electric Code Minimum

Climate Zone	Electric /Gas Utility	Single Family				ADU			
		Standard		CARE		Standard		CARE	
		B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	0.9	($268)	>1	$3,886	0.7	($2,077)	1.2	$696
CZ02	PGE	1.6	$2,355	5.1	$5,107	0.7	($1,742)	1.1	$580
CZ03	PGE	1.0	($90)	1.7	$1,968	0.0	($7,581)	0.0	($4,596)
CZ04	PGE	1.3	$979	2.3	$2,619	0.0	($7,406)	0.0	($4,526)
CZ05	PGE	1.3	$1,373	2.2	$3,467	0.7	($1,912)	1.1	$237
CZ05	PGE/SCG	1.4	$1,823	2.5	$3,841	0.9	($574)	1.4	$1,321
CZ06	SCE/SCG	1.6	$2,339	2.3	$3,535	0.9	($318)	1.4	$1,225
CZ07	SDGE	1.1	$624	2.1	$3,309	0.6	($3,298)	0.9	($627)
CZ08	SCE/SCG	1.7	$2,792	2.3	$3,945	0.9	($289)	1.4	$1,231
CZ09	SCE	1.7	$2,831	2.4	$4,074	0.9	($310)	1.4	$1,230
CZ10	SCE/SCG	1.6	$2,642	2.4	$4,083	1.3	$976	1.7	$1,923
CZ10	SDGE	1.4	$1,825	3.0	$4,642	0.8	($1,084)	1.3	$1,114
CZ11	PGE	1.7	$2,552	5.0	$5,077	1.0	$200	1.6	$1,634
CZ12	PGE	1.9	$3,210	5.0	$5,587	0.7	($1,710)	1.1	$545
CZ13	PGE	1.5	$1,480	2.7	$2,924	0.0	($4,131)	0.0	($2,754)
CZ14	SCE/SCG	0.9	($522)	1.3	$1,191	0.0	($7,375)	0.0	($4,754)
CZ14	SDGE	0.7	($1,717)	2.0	$2,295	0.0	($10,790)	0.0	($6,496)
CZ15	SCE/SCG	1.4	$1,791	1.9	$2,831	1.4	$1,246	1.8	$2,031
CZ16	PG&E	0.2	($5,394)	0.8	($351)	0.6	($2,562)	1.1	$453

Table 23: On-Bill Cost-Effectiveness with CARE Tariffs: Mixed Fuel Efficiency + PV+ Battery Package

Climate Zone	Electric /Gas Utility	Single Family				ADU			
		Standard		CARE		Standard		CARE	
		B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	1.3	$6,501	0.9	($2,072)	0.97	($654)	0.7	($8,623)
CZ02	PGE	1.1	$2,486	0.7	($5,286)	1.0	$524	0.7	($7,297)
CZ03	PGE	1.1	$1,104	0.6	($5,980)	0.9	($2,899)	0.6	($8,788)
CZ04	PGE	1.0	$456	0.6	($6,790)	0.9	($1,625)	0.6	($8,200)
CZ05	PGE	1.1	$2,285	0.7	($5,646)	1.1	$1,765	0.7	($6,142)
CZ05	PGE/SCG	1.1	$2,154	0.7	($5,751)	1.1	$1,746	0.7	($6,157)
CZ06	SCE/SCG	1.1	$1,951	0.7	($5,232)	0.997	($75)	0.7	($5,476)
CZ07	SDGE	1.6	$9,869	1.1	$1,502	1.4	$9,325	0.9	($1,935)
CZ08	SCE/SCG	1.2	$3,344	0.7	($4,574)	1.1	$1,141	0.8	($4,945)
CZ09	SCE	1.2	$3,369	0.7	($4,547)	1.1	$1,272	0.8	($4,812)
CZ10	SCE/SCG	1.3	$4,546	0.8	($3,683)	0.7	($4,113)	0.5	($7,624)
CZ10	SDGE	1.8	$14,148	1.3	$4,461	1.2	$3,451	0.8	($2,615)
CZ11	PGE	1.4	$6,523	0.9	($2,487)	0.9	($1,909)	0.6	($7,688)
CZ12	PGE	1.2	$3,451	0.7	($4,560)	1.1	$2,172	0.7	($6,267)
CZ13	PGE	1.3	$5,665	0.8	($3,372)	0.8	($2,949)	0.5	($8,111)
CZ14	SCE/SCG	1.3	$5,945	0.8	($3,074)	1.0	$732	0.8	($5,341)
CZ14	SDGE	1.8	$15,726	1.3	$4,718	1.5	$10,772	1.0	($1,007)
CZ15	SCE/SCG	1.5	$9,078	0.9	($877)	0.95	($801)	0.6	($6,322)
CZ16	PG&E	1.3	$5,254	0.8	($3,523)	1.1	$2,708	0.8	($5,611)

4.6.2 Utility Infrastructure Cost Sensitivity

Table 24 compares cost-effectiveness results for the natural gas service line extension cost scenarios that inform the average values presented in Table 8. The average cost scenario reflects the cost-effectiveness results for the single family all-electric Code Minimum package presented in Table 16. Relative to a new subdivision, gas infrastructure cost savings are higher for the infill development case, which translates to higher cost-effectiveness. This is shown by positive cost-effectiveness in all metrics except one – On-Bill for Climate Zone 16 – for infill development. Compared to the average cost scenario, there are two cases – On-Bill for Climate Zone 4 in PG&E territory and Climate Zone 7 – where the all-electric Code Minimum package is no longer cost-effective based on the new subdivision costs.

Table 24: Single Family Cost-Effectiveness Comparison with Range of Natural Gas Utility Infrastructure Costs: All-Electric Code Minimum

Climate Zone	Electric /Gas Utility	Average				New Subdivision				Infill Development			
		On-Bill		TDV		On-Bill		TDV		On-Bill		TDV	
		B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	0.9	($268)	>1	$5,702	0.6	($1,492)	>1	$4,612	2.2	$4,628	>1	$10,062
CZ02	PGE	1.6	$2,355	>1	$7,711	1.3	$1,131	>1	$6,621	2.8	$7,250	>1	$12,071
CZ03	PGE	0.98	($90)	25.3	$3,887	0.7	($1,314)	18.5	$2,797	2.0	$4,806	52.6	$8,247
CZ04	PGE	1.3	$979	>1	$4,494	0.9	($245)	>1	$3,404	2.6	$5,875	>1	$8,854
CZ04	CPAU	>1	$10,437	>1	$7,762	>1	$10,437	>1	$7,762	>1	$10,437	>1	$7,762
CZ05	PGE	1.3	$1,373	6.1	$4,633	1.0	$149	4.9	$3,543	2.3	$6,269	11.0	$8,993
CZ05	PGE/SCG	1.4	$1,823	6.1	$4,633	1.1	$599	4.9	$3,543	2.5	$6,719	11.0	$8,993
CZ06	SCE/SCG	1.6	$2,339	4.7	$4,353	1.3	$1,115	3.8	$3,263	2.8	$7,235	8.4	$8,713
CZ07	SDGE	1.1	$624	4.2	$4,211	0.9	($600)	3.4	$3,121	2.0	$5,519	7.5	$8,571
CZ08	SCE/SCG	1.7	$2,792	4.2	$4,674	1.4	$1,568	3.5	$3,584	2.8	$7,687	7.3	$9,034
CZ09	SCE	1.7	$2,831	5.5	$5,013	1.4	$1,607	4.6	$3,923	2.9	$7,726	9.5	$9,373
CZ10	SCE/SCG	1.6	$2,642	7.4	$5,287	1.3	$1,418	6.1	$4,197	2.7	$7,537	12.6	$9,647
CZ10	SDGE	1.4	$1,825	7.4	$5,287	1.1	$601	6.1	$4,197	2.3	$6,721	12.6	$9,647
CZ11	PGE	1.7	$2,552	>1	$7,153	1.3	$1,328	>1	$6,063	3.0	$7,448	>1	$11,513
CZ12	PGE	1.9	$3,210	>1	$7,504	1.5	$1,986	>1	$6,414	3.1	$8,106	>1	$11,864
CZ12	SMUD/PGE	>1	$11,714	>1	$7,504	>1	$10,490	>1	$6,414	>1	$16,610	>1	$11,864
CZ13	PGE	1.5	$1,480	>1	$4,490	1.1	$256	>1	$3,400	3.0	$6,376	>1	$8,850
CZ14	SCE/SCG	0.9	($522)	>1	$4,105	0.7	($1,746)	>1	$3,015	1.8	$4,374	>1	$8,465
CZ14	SDGE	0.7	($1,717)	>1	$4,105	0.5	($2,941)	>1	$3,015	1.5	$3,179	>1	$8,465
CZ15	SCE/SCG	1.4	$1,791	3.0	$3,439	1.1	$567	2.4	$2,349	2.6	$6,687	5.6	$7,799
CZ16	PG&E	0.2	($5,394)	0.4	($1,339)	0.0	($6,618)	0.0	($2,429)	0.9	($498)	2.4	$3,021

4.6.3 Utility Rate Escalation

In this sensitivity analysis, an alternative set of annual utility escalation rates was applied to the gas and electricity savings in select measure packages to show the impact that utility cost changes over time have on cost-effectiveness. This set of rates, detailed in Section 7.2.7, reflects those used by the Energy Commission in their development of the LSC factors for the 2025 code cycle (LSC replaces TDV in the 2025 code cycle). The rates assume steep increases in gas rates starting in 2030. Increased gas rates range from 2% to 6.7% higher than annual rates used in the 2022 code cycle; electricity rates are only marginally (about 0.5%) higher each year.

On-Bill cost-effectiveness results are shown for in Table 25 for the all-electric Code Minimum scenario and Table 26 for the mixed fuel Efficiency + PV + Battery measure package. The alternative rates described above ("2025 LSC") are shown alongside those reported elsewhere in this report ("CPUC / 2022 TDV", described in Section 2.1.3) for comparison. In all cases, the 2025 LSC escalation rates improve cost-effectiveness. In some cases, this improvement is enough to change the result from not cost-effective to cost-effective, these cases are summarized below:

- All-Electric Code Minimum package
    - Climate Zones 1, 3, 14, and 16 for the single family home
    - Climate Zones 1, 5 in PG&E/SCG territory, 6, 8, 9, 10 in SDG&E territory, and 16 for the ADU home
- Mixed fuel Efficiency + PV + Battery package
    - Climate Zones 1, 6, and 15 for the ADU home

Table 25: Cost-Effectiveness, 2025 LSC Basis: All-Electric Code Minimum

Climate Zone	Electric /Gas Utility	Single Family				ADU			
		CPUC / 2022 TDV		2025 LSC		CPUC / 2022 TDV		2025 LSC	
		B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	0.9	($268)	>1	$13,867	0.7	($2,077)	1.2	$833
CZ02	PGE	1.6	$2,355	>1	$10,458	0.7	($1,742)	0.95	($228)
CZ03	PGE	0.98	($90)	>1	$4,883	0.0	($7,581)	0.0	($4,465)
CZ04	PGE	1.3	$979	>1	$5,728	0.0	($7,406)	0.0	($4,466)
CZ04	CPAU	>1	$10,437	>1	$17,647	6.9	$2,592	20.7	$8,704
CZ05	PGE	1.3	$1,373	5.3	$5,148	0.7	($1,912)	0.8	($1,386)
CZ05	PGE/SCG	1.4	$1,823	13.5	$5,884	0.9	($574)	1.2	$807
CZ06	SCE/SCG	1.6	$2,339	4.0	$4,751	0.9	($318)	1.2	$630
CZ07	SDGE	1.1	$624	1.9	$3,008	0.6	($3,298)	0.7	($2,394)
CZ08	SCE/SCG	1.7	$2,792	3.0	$4,650	0.9	($289)	1.1	$591
CZ09	SCE	1.7	$2,831	4.0	$5,233	0.9	($310)	1.2	$634
CZ10	SCE/SCG	1.6	$2,642	5.4	$5,700	1.3	$976	1.9	$2,147
CZ10	SDGE	1.4	$1,825	7.4	$6,038	0.8	($1,084)	1.0	$102
CZ11	PGE	1.7	$2,552	>1	$9,997	1.0	$200	1.6	$1,669
CZ12	PGE	1.9	$3,210	>1	$10,077	0.7	($1,710)	0.9	($430)
CZ12	SMUD/PGE	>1	$11,714	>1	$19,028	5.7	$3,797	>1	$5,367
CZ13	PGE	1.5	$1,480	>1	$5,987	0.0	($4,131)	0.0	($1,228)
CZ14	SCE/SCG	0.9	($522)	6.0	$3,876	0.0	($7,375)	0.0	($4,363)
CZ14	SDGE	0.7	($1,717)	>1	$4,799	0.0	($10,790)	0.0	($6,285)
CZ15	SCE/SCG	1.4	$1,791	2.2	$3,214	1.4	$1,246	1.9	$2,210
CZ16	PG&E	0.2	($5,394)	>1	$8,516	0.6	($2,562)	1.2	$629

Table 26: Cost-Effectiveness, 2025 LSC Basis: Mixed Fuel Efficiency + PV + Battery

Climate Zone	Electric /Gas Utility	Single Family				ADU			
		CPUC / 2022 TDV		2025 LSC		CPUC / 2022 TDV		2025 LSC	
		B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	1.3	$6,501	1.6	$12,598	1.0	($654)	1.1	$1,379
CZ02	PGE	1.1	$2,486	1.3	$4,914	1.0	$524	1.1	$2,202
CZ03	PGE	1.1	$1,104	1.1	$2,287	0.9	($2,899)	0.9	($1,962)
CZ04	PGE	1.0	$456	1.1	$1,645	0.9	($1,625)	0.97	($594)
CZ04	CPAU	0.2	($16,295)	0.2	($15,990)	0.4	($13,536)	0.4	($13,067)
CZ05	PGE	1.1	$2,285	1.2	$3,855	1.1	$1,765	1.1	$3,074
CZ05	PGE/SCG	1.1	$2,154	1.2	$3,639	1.1	$1,746	1.1	$3,043
CZ06	SCE/SCG	1.1	$1,951	1.2	$3,420	1.0	($75)	1.1	$1,347
CZ07	SDGE	1.6	$9,869	1.6	$9,831	1.4	$9,325	1.4	$9,070
CZ08	SCE/SCG	1.2	$3,344	1.3	$4,750	1.1	$1,141	1.1	$2,674
CZ09	SCE	1.2	$3,369	1.3	$4,812	1.1	$1,272	1.1	$2,793
CZ10	SCE/SCG	1.3	$4,546	1.4	$6,006	0.7	($4,113)	0.8	($3,317)
CZ10	SDGE	1.8	$14,148	1.8	$13,960	1.2	$3,451	1.2	$3,290
CZ11	PGE	1.4	$6,523	1.5	$8,837	0.9	($1,909)	0.96	($740)
CZ12	PGE	1.2	$3,451	1.3	$5,457	1.1	$2,172	1.2	$3,844
CZ12	SMUD/PGE	0.3	($13,066)	0.4	($11,864)	0.5	($12,178)	0.5	($11,196)
CZ13	PGE	1.3	$5,665	1.4	$7,099	0.8	($2,949)	0.9	($2,288)
CZ14	SCE/SCG	1.3	$5,945	1.4	$7,729	1.0	$732	1.1	$2,213
CZ14	SDGE	1.8	$15,726	1.8	$15,707	1.5	$10,772	1.5	$10,493
CZ15	SCE/SCG	1.5	$9,078	1.7	$10,819	1.0	($801)	1.0	$204
CZ16	PG&E	1.3	$5,254	1.5	$10,999	1.1	$2,708	1.2	$4,956

5 Summary

The purpose of this study was to examine and document the code compliance and cost-effectiveness impacts of improving performance among single family new construction – both standard sized homes and ADUs. To this end, the Reach Codes Team evaluated packages of energy efficiency measures as well as packages combining energy efficiency with solar PV generation and battery storage, simulated them in building modeling software, and gathered costs to determine the cost-effectiveness of multiple scenarios. The Reach Codes Team coordinated with multiple utilities, cities, and building community experts to develop a set of assumptions considered reasonable in the current market. Changing assumptions, such as the period of analysis, measure selection, cost assumptions, energy escalation rates, or utility tariffs are likely to change results.

Table 27 (single family) and Table 28 (ADU) summarize results for each prototype and depict the EDR1 compliance margins achieved for each climate zone and package. Because local reach codes must both exceed the energy code (i.e., have a positive compliance margin in the performance approach) and be cost-effective, the Reach Codes Team highlighted cells meeting these two requirements to help clarify the upper boundary for potential reach code policies. All results presented in this study have a positive compliance margin.

- Cells highlighted in **green** depict a positive compliance margin and cost-effective results using both On-Bill and TDV approaches.
- Cells highlighted in **yellow** depict a positive compliance and cost-effective results using either the On-Bill or TDV approach.
- Cells **not highlighted** depict a package that was not cost-effective using either the On-Bill or TDV approach.
- Cells highlighted in **grey** depict the high efficiency equipment packages where cost-effectiveness was not evaluated.

The following are key takeaways and recommendations from the analysis.

Conclusions and Discussion:

- All-electric buildings have lower GHG emissions than mixed fuel buildings, due to the clean power sources currently available from California's power providers as well as accounting for increased penetration of renewables in the future. Almost all the all-electric packages evaluated resulted in greater GHG emission savings than the mixed fuel packages, with the exception of the mixed fuel package with battery storage in climate zones with low heating loads. The Reach Codes Team found code-compliant, all-electric new construction to be feasible and cost-effective based on TDV for single family homes in all cases except Climate Zone 16.
- All-electric single family new construction was On-Bill cost-effective in all cases except Climate Zones 1, 3, 14, and 16.
- The all-electric ADU home was cost-effective based on TDV in all cases except in Climate Zones 3, 4, 13, and 14 where the higher cost of installing a ducted HPWH instead of the prescriptively required gas tankless water heater outweigh the resulting energy cost savings. In the other climate zones there were first cost savings for installing a heat pump space heater instead of gas furnace, contributing to an overall TDV cost-effective result.
- Few cases were cost-effective On-Bill for the ADU.
- All-electric code minimum construction results in an increase in first year utility costs relative to a mixed fuel home, except for CPAU and SMUD where electricity rates are much lower than for the IOUs. The addition of efficiency measures, market dominant HPWHs that meet NEEA's Advanced Water Heating Specification, high efficiency heat pumps, increased PV, and batteries all reduce utility costs, and a combination of these options was found to reduce annual utility costs relative to a mixed fuel home in all cases.
- Under NBT, utility cost savings for increasing PV system size beyond code minimum are substantially less than under prior net energy metering rules (NEM 2.0); however, savings are sufficient to be On-Bill cost-effective in all climate zones for the all-electric single family home. Coupling PV with battery systems increases utility cost savings as a result of improved on-site utilization of PV generation and fewer exports to the grid.

- Applying CARE rates in the IOU territories increases improves On-Bill cost-effectiveness for all-electric buildings, as compared to the same case under standard rates, due to higher utility cost savings compared to a code compliant mixed fuel building also on a CARE rate, improving On-Bill cost-effectiveness. This is due to the CARE discount on electricity being higher than that on gas.
- If gas tariffs are assumed to increase substantially over time, in-line with the escalation assumption from the 2025 LSC development, all-electric new construction was found to be On-Bill cost-effective in almost all scenarios over the 30-year analysis period. There is much uncertainty surrounding future tariff structures as well as escalation values. While it's clear that gas rates will increase, how much and how quickly is not known. Electricity tariff structures are expected to evolve over time, and the CPUC has an active proceeding to adopt an income-graduated fixed charge that benefits low-income customers and supports electrification measures.[21] The CPUC will make a decision in mid-2024 and the new rates are expected to be in place later that year or in 2025. While the anticipated impact of this rate change is lower volumetric electricity rates, the rate design is not finalized. While lower volumetric electricity rates provide many benefits including incentivizing electrification, it also will make building efficiency measures harder to justify as cost-effective due to lower utility bill cost savings.

Recommendations:

- A reach code with a single performance target based on source energy (EDR1) can be structured to strongly encourage electrification. This approach requires equivalent performance for all buildings and allows mixed fuel buildings which minimizes the risk of violating federal preemption. Below are examples of how a reach code for single family homes could be setup based on the results summarized in Table 27.
  - A jurisdiction in Climate Zone 12 could set a performance target at an EDR1 margin of 11.5 (the EDR1 margin for the all-electric Code Minimum package). Any all-electric home meeting or exceeding the prescriptive requirements would comply, and a mixed fuel home would likely need to incorporate a combination of efficiency measures and a battery system to comply.
  - Similarly, a jurisdiction in Climate Zone 7 may consider setting a performance target of 2.8 EDR1 margin (also the EDR1 margin for the all-electric Code Minimum package). Any all-electric home meeting or exceeding the prescriptive requirements would comply, but a mixed fuel home would likely be able to comply with only a suite of above-code efficiency measures (no battery). Alternatively, a higher EDR1 margin target of 5 would incentivize more energy efficiency or additional PV for all-electric construction, and mixed fuel construction would likely need to incorporate a battery system to comply.
  - A jurisdiction in Climate Zone 16 may want to set a performance target at an EDR1 margin of 20.5 (the EDR1 margin for the mixed fuel efficiency + PV + battery package). This would establish a target that a mixed fuel home could cost-effectively meet, likely only after incorporating a combination of efficiency measures and a battery system, and that an all-electric home could easily meet.
- The 2022 Title 24 code's new source energy metric combined with the heat pump baseline encourage all-electric construction, providing an incentive that allows for some amount of prescriptively required building efficiency to be traded off, still meeting minimum code compliance. This compliance benefit for all-electric homes highlights a unique opportunity for jurisdictions to incorporate efficiency into all-electric reach codes. Efficiency and electrification have symbiotic benefits and are both critical for decarbonization of buildings. As demand on the electric grid is increased through electrification, efficiency can reduce the negative impacts of additional electricity demand on the grid, reducing the need for increased generation and storage capacity, as well as the need to upgrade upstream transmission and distribution equipment. The Reach Codes Team recommends that jurisdictions adopting a reach code for single family buildings also include an efficiency requirement with EDR1 margins at minimum consistent with the all-electric code minimum package results in Table 27.

[21] https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-costs/demand-response-dr/demand-flexibility-rulemaking

- The code compliance margins for the ADU all-electric code minimum package are lower than for the single family prototype; code compliance and cost-effectiveness can be more challenging for smaller dwelling units. As a result, the Reach Codes Team does not recommend EDR1 targets above those reported for the all-electric Code Minimum package in Table 28.

Local jurisdictions may also adopt ordinances that amend different Parts of the California Building Standards Code or may elect to amend other state or municipal codes. The decision regarding which code to amend will determine the specific requirements that must be followed for an ordinance to be legally enforceable. For example, jurisdictions may amend Part 11 instead of Part 6 of the CA Building Code requiring review and approval by the BSC but not the Energy Commission. Reach codes that amend Part 6 of the CA Building Code and require energy performance beyond state code minimums must demonstrate the proposed changes are cost-effective and obtain approval from the Energy Commission.

This report documents the key results and conclusions from the Reach Codes Team analysis. A full dataset of all results can be downloaded at https://localenergycodes.com/content/resources. Results alongside policy options can also be explored using the Cost-effectiveness Explorer at https://explorer.localenergycodes.com/.

Table 27: Summary of Single Family EDR1 Margins and Cost-Effectiveness

Climate Zone	Electric /Gas Utility	All-Electric					Mixed Fuel	
		Code Minimum	Efficiency	Efficiency + High Efficiency Equipment	Efficiency + PV	Efficiency + PV + Battery	Efficiency + High Efficiency Equipment	Efficiency + PV + Battery
CZ01	PGE	25.8	29.1	31.4	32.6	41.4	14.8	22.6
CZ02	PGE	14.0	16.3	18.0	18.9	28.3	9.1	14.1
CZ03	PGE	9.1	10.6	12.2	13.1	24.2	3.6	12.8
CZ04	PGE	8.8	10.4	11.9	12.8	24.6	3.8	13.2
CZ04	CPAU	8.8	10.4	11.9	12.8	24.6	3.8	13.2
CZ05	PGE	6.5	7.9	10.2	10.8	23.3	5.2	14.8
CZ05	PGE/SCG	6.5	7.9	10.2	10.8	23.3	5.2	14.8
CZ06	SCE/SCG	4.2	5.3	6.6	8.4	24.6	4.0	18.3
CZ07	SDGE	2.8	3.6	4.8	6.9	23.6	3.2	18.7
CZ08	SCE/SCG	2.1	2.9	4.2	5.6	21.3	2.7	17.1
CZ09	SCE/SCG	3.6	4.4	5.7	7.1	21.8	3.2	16.2
CZ10	SCE/SCG	4.8	5.8	7.2	8.5	21.9	3.9	14.4
CZ10	SDGE	4.8	5.8	7.2	8.5	21.9	3.9	14.4
CZ11	PGE	11.4	13.4	15.0	15.6	24.5	7.7	12.9
CZ12	PGE	11.5	13.3	14.8	15.5	25.2	7.2	13.2
CZ12	SMUD/PGE	11.5	13.3	14.8	15.5	25.2	7.2	13.2
CZ13	PGE	8.3	10.3	11.9	12.3	22.3	4.1	12.3
CZ14	SCE/SCG	8.8	11.5	13.2	14.3	24.7	4.6	13.4
CZ14	SDGE	8.8	11.5	13.2	14.3	24.7	4.6	13.4
CZ15	SCE/SCG	0.9	2.4	3.7	3.8	15.7	3.5	13.5
CZ16	PG&E	21.3	25.6	27.0	29.1	37.5	16.3	20.4

Table 28: Summary of ADU EDR1 Margins and Cost-Effectiveness

Climate Zone	Electric /Gas Utility	All-Electric					Mixed Fuel	
		Code Minimum	Efficiency	Efficiency + High Efficiency Equipment	Efficiency + PV	Efficiency + PV + Battery	Efficiency + High Efficiency Equipment	Efficiency + PV + Battery
CZ01	PGE	11.9	15.7	18.5	19.3	33.7	2.9	18.5
CZ02	PGE	5.7	7.9	9.7	10.8	25.6	-4.7	16.6
CZ03	PGE	2.9	4.0	5.9	7.1	23.2	4.0	11.8
CZ04	PGE	2.4	3.9	5.5	6.8	23.6	4.2	13.3
CZ04	CPAU	2.4	3.9	5.5	6.8	23.6	4.2	13.3
CZ05	PGE	1.8	2.9	4.8	6.4	24.0	-12.1	16.9
CZ05	PGE/SCG	1.8	2.9	4.8	6.4	24.0	-12.1	16.9
CZ06	SCE/SCG	0.5	1.3	2.6	5.0	25.7	-15.6	19.8
CZ07	SDGE	0.1	0.9	2.1	5.0	26.4	-16.5	20.3
CZ08	SCE/SCG	0.1	0.7	1.8	4.2	25.1	-15.3	20.4
CZ09	SCE	0.4	1.1	2.3	4.5	25.0	-14.4	19.6
CZ10	SCE/SCG	1.0	2.0	3.5	5.4	25.3	-11.9	19.0
CZ10	SDGE	1.0	2.0	3.5	5.4	25.3	-11.9	19.0
CZ11	PGE	4.6	7.0	8.6	9.6	25.1	-3.5	17.6
CZ12	PGE	4.6	6.6	8.3	9.3	24.5	-5.6	16.7
CZ12	SMUD/PGE	4.6	6.6	8.3	9.3	24.5	-5.6	16.7
CZ13	PGE	3.1	5.5	6.9	7.8	25.2	4.4	14.5
CZ14	SCE/SCG	3.5	6.3	8.0	9.6	26.9	5.1	14.5
CZ14	SDGE	3.5	6.3	8.0	9.6	26.9	5.1	14.5
CZ15	SCE/SCG	0.0	2.2	2.6	4.4	25.3	-9.3	19.2
CZ16	PG&E	11.2	14.7	15.7	18.3	33.7	2.9	18.3

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Get In Touch

The adoption of reach codes can differentiate jurisdictions as efficiency leaders and help accelerate the adoption of new equipment, technologies, code compliance, and energy savings strategies.

As part of the Statewide Codes & Standards Program, the Reach Codes Subprogram is a resource available to any local jurisdiction located throughout the state of California.

Our experts develop robust toolkits as well as provide specific technical assistance to local jurisdictions (cities and counties) considering adopting energy reach codes. These include cost-effectiveness research and analysis, model ordinance language and other code development and implementation tools, and specific technical assistance throughout the code adoption process.

If you are interested in finding out more about local energy reach codes, the Reach Codes Team stands ready to assist jurisdictions at any stage of a reach code project.

Visit LocalEnergyCodes.com to access our resources and sign up for newsletters.

Contact info@localenergycodes.com for no-charge assistance from expert Reach Code advisors.

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2022 Cost-Effectiveness Study: Multifamily New Construction

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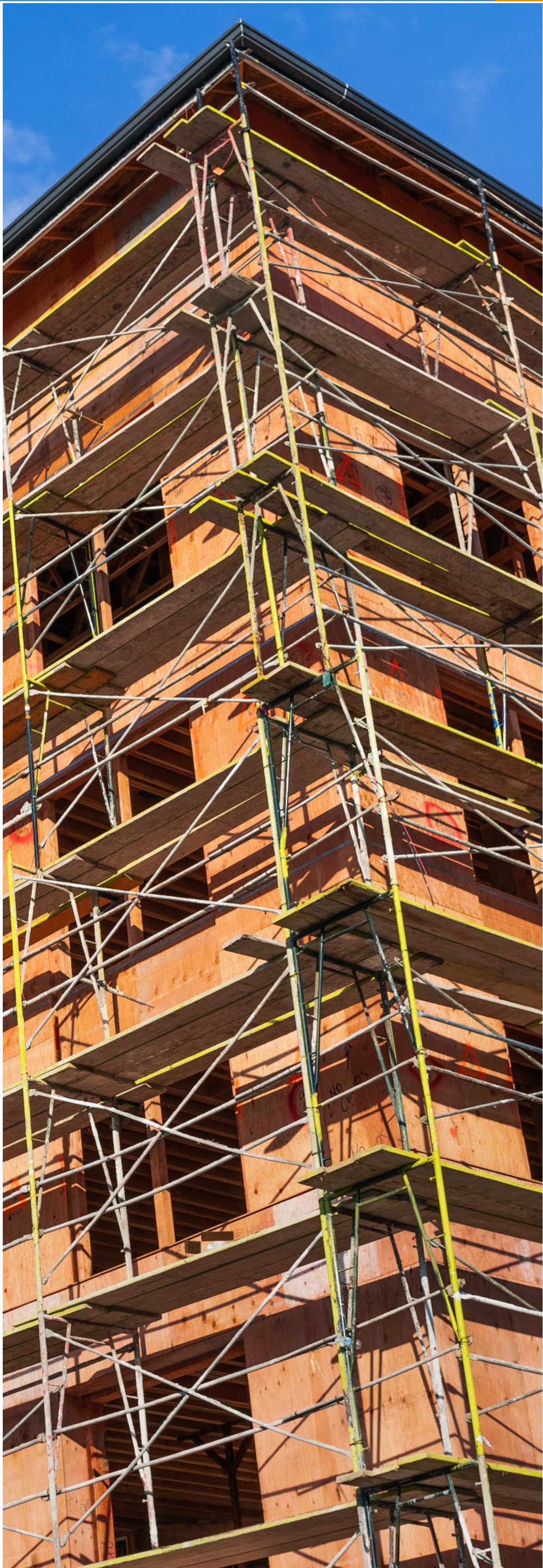
Legal Notice

This report was prepared by Pacific Gas and Electric Company and funded by the California utility customers under the auspices of the California Public Utilities Commission.



Acronym List

2023 PV$ – Present value costs in 2023

ACH50 – Air Changes per Hour at 50 pascals pressure differential

ACM – Alternative Calculation Method

ADU – Accessory Dwelling Unit

AFUE – Annual Fuel Utilization Efficiency

B/C – Lifecycle Benefit-to-Cost Ratio

BEopt – Building Energy Optimization Tool

BSC – Building Standards Commission

CA IOUs – California Investor-Owned Utilities

CASE – Codes and Standards Enhancement

CBECC-Res – Computer program developed by the California Energy Commission for use in demonstrating compliance with the California Residential Building Energy Efficiency Standards

CFI – California Flexible Installation

CFM – Cubic Feet per Minute

CO_2 – Carbon Dioxide

CPAU – City of Palo Alto Utilities

CPUC – California Public Utilities Commission

CZ – California Climate Zone

DHW – Domestic Hot Water

DOE – Department of Energy

DWHR – Drain Water Heat Recovery

EDR – Energy Design Rating

EER – Energy Efficiency Ratio

EF – Energy Factor

GHG – Greenhouse Gas

HERS Rater – Home Energy Rating System Rater

HPA – High Performance Attic

HPWH – Heat Pump Water Heater

HSPF – Heating Seasonal Performance Factor

HVAC – Heating, Ventilation, and Air Conditioning

IECC – International Energy Conservation Code

IOU – Investor Owned Utility

kBtu – kilo-British thermal unit

kWh – Kilowatt Hour

LBNL – *Lawrence Berkeley National Laboratory*

LCC – Lifecycle Cost

LLAHU – Low Leakage Air Handler Unit

VLLDCS – Verified Low Leakage Ducts in Conditioned Space

MF – Multifamily

NEEA – Northwest Energy Efficiency Alliance

NEM – Net Energy Metering

NPV – Net Present Value

NREL – *National Renewable Energy Laboratory*

PG&E – Pacific Gas and Electric Company

POU – Publicly-Owned-Utilities

PV – Photovoltaic

SCE – Southern California Edison

SDG&E – San Diego Gas and Electric

SEER – Seasonal Energy Efficiency Ratio

SF – Single Family

SMUD – Sacramento Municipal Utility District

SoCalGas – Southern California Gas Company

TDV – Time Dependent Valuation

Therm – Unit for quantity of heat that equals 100,000 British thermal units

Title 24 – Title 24, Part 6

TOU – Time-Of-Use

UEF – Uniform Energy Factor

ZNE – Zero-net Energy

Summary Of Revisions

Date	Description	Reference (page or section)
2/28/2022	Original Release	N/A
6/20/2023	Minor revisions to content; no change to results	2, 3, 32, 33

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Executive Summary

The California Codes and Standards (C&S) Reach Codes program provides technical support to local governments considering adopting a local ordinance (reach code) intended to support meeting local and/or statewide energy efficiency and greenhouse gas (GHG) reduction goals. The program facilitates adoption and implementation of the code when requested by local jurisdictions by providing resources such as cost-effectiveness studies, model language, sample findings, and other supporting documentation.

This report documents cost-effective combinations of measures that exceed the minimum state requirements, the 2022 Building Energy Efficiency Standards (Title 24, Part 6 or Energy Code), effective January 1, 2023, for newly constructed multifamily buildings. The analysis considers low-rise and mid-rise multifamily building types and evaluates mixed fuel and all-electric package options in all sixteen California climate zones (CZs) Packages include a code compliant electrification package and a mixed fuel efficiency package, as well as the addition of above-code on-site solar photovoltaic (PV) capacity and battery energy storage. The 2022 Energy Code established electric heat pumps as the prescriptive baseline for space heating in most climate zones. As a result, this analysis primarily focuses on the electrification of central water heating. Space heating electrification was also evaluated where the prescriptive heat pump baseline didn’t apply: In Climate Zone 16 for multifamily buildings three habitable stories or fewer, and Climate Zones 1 and 16 for multifamily buildings greater than three habitable stories.

This analysis used two different metrics to assess the cost-effectiveness of the proposed upgrades. Both methodologies require estimating and quantifying the incremental costs and energy savings associated with each energy efficiency measure over a 30-year analysis period. On-Bill cost-effectiveness is a customer-based lifecycle cost (LCC) approach that values energy based upon estimated site energy usage and customer utility bill savings using today’s electricity and natural gas utility tariffs. Time Dependent Valuation (TDV) is the California Energy Commission’s LCC methodology, which is intended to capture the long-term projected cost of energy including costs for providing energy during peak periods of demand, carbon emissions, grid transmission and distribution impacts. This is the methodology used by the Energy Commission in evaluating cost-effectiveness for efficiency measures in Title 24, Part 6.

Two multifamily prototypes were evaluated in this study. A 3-story loaded corridor and a 5-story mixed use prototype, which combined are estimated to represent 91 percent of new multifamily construction in California.

The following summarizes key results from the study:

- The Reach Codes Team found all-electric new construction to be feasible and cost-effective based on the California Energy Commission’s Time Dependent Valuation (TDV) metric in all cases. In many cases all-electric prescriptive code construction results in an increase in utility costs and is not cost-effective On-Bill. Some exceptions include the SMUD and CPAU territories where lower electricity rates relative to gas rates result in lower overall utility bills.
- All-electric packages have lower GHG emissions than mixed fuel packages in all cases, due to the clean power sources currently available from California’s power providers.
- The 2022 Energy Code’s new source energy metric combined with the heat pump space heating baseline in most climate zones encourages all-electric construction. While the code does not include an electric baseline for water heating, the penalty for central electric water heating observed in the performance approach in past code cycles has been removed and a credit is provided for well-designed central heat pump water heaters in most cases.
- Electrification combined with increased PV capacity results in utility cost savings and was found to be On-Bill cost-effective in all cases.
- The results in this study are based on today’s net energy metering (NEM 2.0) rules and do not account for recently approved changes to the NEM tariff (referred to as the net billing tariff). The net billing tariff decreases the value of PV to the consumer as compared to NEM 2.0. As a result, the cost-effectiveness of the packages that include above-code PV capacity is expected to be less under the net billing tariff. Conversely, the net

billing tariff is expected to increase On-Bill cost-effectiveness of the all-electric prescriptive code scenario. An all-electric home has better on-site utilization of generated electricity from PV than a mixed fuel home with a similar sized PV system, and as a result exports less electricity to the grid. Since the net-billing tariff values exports less than under NEM 2.0, the relative impact on annual utility costs to the mixed fuel baseline is greater.

- This analysis does justify a modest reach based on either efficiency TDV or source energy for all-electric buildings. However, this may be challenging for some projects given the recent changes to which the industry must adapt, including the efficiency updates and multifamily restructuring in the 2022 Title 24, Part 6 code. While project compliance margins using a CO_2 refrigerant heat pump water heating system are high, the Reach Code Team found lower compliance margins using other heat pump water heater system designs. Focusing on supporting projects to electrify water heating is expected to support the market shift towards more central heat pump water heaters.
- For jurisdictions interested in a reach code that allows for mixed fuel buildings, a mixed fuel efficiency and PV package (and battery for the 3-story prototype) was found to be cost-effective based on TDV in all cases and cost-effective On-Bill in most climate zones. This path, referred to as "Electric-Preferred", allows for mixed fuel buildings but requires a higher building performance than for all-electric buildings. The efficiency measures evaluated in this study did not provide significant compliance benefit. As a result, the Reach Codes Team recommends establishing a compliance margin target based on source energy or total TDV. This would allow for PV and battery above minimum code requirements to be used to meet the target.
- Jurisdictions interested in increasing affordable multifamily housing should know that applying the CARE rates has the overall impact of increasing utility cost savings for an all-electric building in most climate zones compared to a code compliant mixed fuel building, improving On-Bill cost-effectiveness.

Table ES-1 summarizes results for each prototype and depicts the efficiency TDV compliance margins achieved for each climate zone and package. All results presented in the table have a positive compliance margin (greater than zero percent). Cells highlighted in **green** depict cases with a positive compliance margin and cost-effective results using both On-Bill and TDV approaches. Cells highlighted in **yellow** depict cases with a positive compliance margin and cost-effective results using either the On-Bill or TDV approach. Cells **not highlighted** depict cases with a positive compliance margin but that were not cost-effective using either the On-Bill or TDV approach.

Table ES-1. Summary of Efficiency TDV Compliance Margins and Cost-Effectiveness

Climate Zone	Electric /Gas Utility	3-Story				5-Story			
		All-Electric Prescriptive Code	All-Electric + PV	Mixed Fuel Efficiency	Mixed Fuel Efficiency + PV + Battery	All-Electric Prescriptive Code	All-Electric + PV	Mixed Fuel Efficiency	Mixed Fuel Efficiency + PV
CZ01	PGE	26%	26%	1%	1%	14%	14%	0%	0%
CZ02	PGE	20%	20%	1%	1%	9%	9%	1%	1%
CZ03	PGE	21%	21%	1%	1%	11%	11%	0%	0%
CZ04	PGE	18%	18%	1%	1%	9%	9%	1%	1%
CZ04	CPAU	18%	18%	1%	1%	9%	9%	1%	1%
CZ05	PGE	23%	23%	1%	1%	12%	12%	0%	0%
CZ05	PGE/SCG	23%	23%	1%	1%	12%	12%	0%	0%
CZ06	SCE/SCG	18%	18%	1%	1%	9%	9%	0%	0%
CZ07	SDGE	20%	20%	0%	0%	11%	11%	0%	0%
CZ08	SCE/SCG	13%	13%	1%	1%	8%	8%	1%	1%
CZ09	SCE	13%	13%	1%	1%	7%	7%	1%	1%
CZ10	SCE/SCG	14%	14%	3%	3%	7%	7%	2%	2%
CZ10	SDGE	14%	14%	3%	3%	7%	7%	2%	2%
CZ11	PGE	14%	14%	3%	3%	8%	8%	2%	2%
CZ12	PGE	17%	17%	2%	2%	9%	9%	2%	2%
CZ12	SMUD/PGE	17%	17%	2%	2%	9%	9%	2%	2%
CZ13	PGE	13%	13%	4%	4%	7%	7%	2%	2%
CZ14	SCE/SCG	13%	13%	3%	3%	6%	6%	2%	2%
CZ14	SDGE	13%	13%	3%	3%	6%	6%	2%	2%
CZ15	SCE/SCG	5%	5%	5%	5%	3%	3%	3%	3%
CZ16	PG&E	24%	24%	5%	5%	9%	9%	2%	2%

Local jurisdictions may also adopt ordinances that amend different Parts of the California Building Standards Code or may elect to amend other state or municipal codes. The decision regarding which code to amend will determine the specific requirements that must be followed for an ordinance to be legally enforceable. Reach codes that amend Part 6 of the CA Building Code and require energy performance (including PV and storage) beyond state code minimums must demonstrate that the proposed changes are cost-effective and obtain approval from the Energy Commission prior to filing with the BSC.

Model ordinance language and other resources are posted on the C&S Reach Codes Program website at LocalEnergyCodes.com. Local jurisdictions that are considering adopting an ordinance may contact the program for further technical support at info@localenergycodes.com.

1 Introduction

This report documents cost-effective combinations of measures that exceed the minimum state requirements, the 2022 Building Energy Efficiency Standards, effective January 1, 2023, for newly constructed multifamily buildings. This report was developed in coordination with the California Statewide Investor-Owned Utilities (CA IOUs) Codes and Standards Program, key consultants, and engaged cities—collectively known as the Reach Codes Team. The CA IOU Codes and Standards Program is comprised of IOUs representatives from Pacific Gas and Electric (PG&E), Southern California Edison (SCE) and San Diego Gas and Electric (SDG&E) and two Publicly-Owned-Utilities (POUs) – Sacramento Municipal Utility District (SMUD) and City of Palo Alto Utilities (CPAU),

The analysis considers low-rise and mid-rise multifamily building types and evaluates mixed fuel and all-electric package options in all sixteen California climate zones (CZs)[1] Packages include combinations of efficiency measures, on-site renewable energy, and battery energy storage.

The California Building Energy Efficiency Standards Title 24, Part 6 (Energy Code) (California Energy Commission, 2022a) is maintained and updated every three years by two state agencies: the California Energy Commission (Energy Commission) and the Building Standards Commission (BSC). In addition to enforcing the code, local jurisdictions have the authority to adopt local energy efficiency ordinances—or reach codes—that exceed the minimum standards defined by Title 24 (as established by Public Resources Code Section 25402.1(h)2 and Section 10-106 of the Building Energy Efficiency Standards (California Energy Commission, 2022a)). Local jurisdictions must demonstrate that the requirements of the proposed ordinance are cost-effective and do not result in buildings consuming more energy than is permitted by Title 24. In addition, the jurisdiction must obtain approval from the Energy Commission and file the ordinance with the BSC for the ordinance to be legally enforceable.

The Department of Energy (DOE) sets minimum efficiency standards for equipment and appliances that are federally regulated under the National Appliance Energy Conservation Act, including heating, cooling, and water heating equipment (E-CFR, 2020). Since state and local governments are prohibited from adopting higher minimum efficiencies than the federal standards require, the focus of this study is to identify and evaluate cost-effective packages that do not include high efficiency heating, cooling, and water heating equipment. High efficiency appliances are often the easiest and most affordable measures to increase energy performance. While federal preemption limits reach code mandatory requirements for covered appliances, in practice, builders may install any package of compliant measures to achieve the performance requirements.

[1] See Appendix 7.1 Map of California Climate Zones for a graphical depiction of climate zone locations.

2 Methodology and Assumptions

2.1 Analysis for Reach Codes

This section describes the approach to calculating cost-effectiveness including benefits, costs, metrics, and utility rate selection.

2.1.1 Modeling

The Reach Codes Team performed energy simulations using software approved for 2022 Title 24 Code compliance analysis, CBECC 2022.2.0.

Using the 2022 baseline as the starting point, prospective energy efficiency measures were identified and modeled to determine the projected site energy (therm and kWh) and compliance impacts. Annual utility costs were calculated using hourly data output from CBECC, and electricity and natural gas tariffs for each of the investor-owned utilities (IOUs).

This analysis focused on residential apartments only (a prior study and report analyzed the cost-effectiveness of above code packages for nonresidential buildings (Statewide Reach Codes Team, 2022b). The Statewide Reach Codes Team selected measures for evaluation based on the single family 2022 reach code analysis (Statewide Reach Codes Team, 2022a) and the multifamily 2019 reach code analysis [(Statewide Reach Codes Team, 2020), (Statewide Reach Codes Team, 2021)] as well as experience with and outreach to architects, builders, and engineers.

2.1.2 Cost-Effectiveness

2.1.2.1 Benefits

This analysis used two different metrics to assess the cost-effectiveness of the proposed upgrades. Both methodologies require estimating and quantifying the incremental costs and energy savings associated with each energy efficiency measure. The main difference between the methodologies is the manner in which they value energy and thus the cost savings of reduced or avoided energy use:

Utility Bill Impacts (On-Bill): This customer-based lifecycle cost (LCC) approach values energy based upon estimated site energy usage and customer utility bill savings using the latest electricity and natural gas utility tariffs available at the time of writing this report. Total savings are estimated over a 30-year duration and include discounting of future utility costs and energy cost inflation.

Time Dependent Valuation (TDV): This reflects the Energy Commission's current LCC methodology, which is intended to capture the total value or cost of energy use over 30 years. This method accounts for long-term projected costs, such as the cost of providing energy during peak periods of demand, costs for carbon emissions, and grid transmission and distribution impacts. This metric values energy use differently depending on the fuel source (natural gas, electricity, and propane), time of day, and season. Electricity used (or saved) during peak periods has a much higher value than electricity used (or saved) during off-peak periods due to the less inefficient energy generation sources providing peak electricity (Horii, Cutter, Kapur, Arent, & Conotyannis, 2014). This is the methodology used by the Energy Commission in evaluating cost-effectiveness for efficiency measures in the 2022 Energy Code.

2.1.2.2 Costs

The Reach Codes Team assessed the incremental costs of the measures and packages over a 30-year lifecycle. Incremental costs represent the equipment, installation, replacements, and maintenance costs of the proposed measure relative to the 2022 Energy Code minimum requirements or standard industry practices. Present value of replacement cost is included for measures with lifetimes less than the evaluation period.

2.1.2.3 Metrics

Cost-effectiveness is presented using net present value (NPV) and benefit-to-cost (B/C) ratio metrics.

NPV: The lifetime NPV is reported as a cost-effectiveness metric, Equation 1 demonstrates how this is calculated. If the NPV of a measure or package is positive, it is considered cost-effective. A negative values represent net costs.

B/C Ratio: This is the ratio of the present value (PV) of all benefits to the present value of all costs over 30 years (PV benefits divided by PV costs). The criteria benchmark for cost-effectiveness is a B/C ratio greater than one. A value of one indicates the NPV of the savings over the life of the measure is equivalent to the NPV of the lifetime incremental cost of that measure. A value greater than one represents a positive return on investment. The B/C ratio is calculated according to Equation 2.

Equation 1

$$NPV = PV\ of\ lifetime\ benefit - PV\ of\ lifetime\ cost$$

Equation 2

$$Benefit - to - Cost\ Ratio = \frac{PV\ of\ lifetime\ benefit}{PV\ of\ lifetime\ cost}$$

Improving the efficiency of a project often requires an initial incremental investment. In most cases the benefit is represented by annual On-Bill utility or TDV savings, and the cost is represented by incremental first cost and replacement costs. Some packages result in initial construction cost savings (negative incremental cost), and either energy cost savings (positive benefits), or increased energy costs (negative benefits). In cases where both construction costs and energy-related savings are negative, the construction cost savings are treated as the 'benefit' while the increased energy costs are the 'cost.' In cases where a measure or package is cost-effective immediately (i.e., upfront construction cost savings and lifetime energy cost savings), B/C ratio cost-effectiveness is represented by ">1".

The lifetime costs or benefits are calculated according to Equation 3.

Equation 3

$$PV\ of\ lifetime\ cost\ or\ benefit = \sum_{t=0}^{n} \frac{(Annual\ cost\ or\ benefit)_t}{(1+r)^t}$$

$$Present\ value\ of\ lifetime\ cost\ or\ benefit = \sum_{t=0}^{n} \frac{(Annual\ cost\ or\ benefit)_t}{(1+r)^t}$$

Where:

- n = analysis term in years
- r = discount rate

The following summarizes the assumptions applied in this analysis to both methodologies.

- Analysis term of 30 years
- Real discount rate of three percent

TDV is a normalized monetary format and there is a unique procedure for calculating the present value benefit of TDV energy savings. The present value of the energy cost savings in dollars is calculated by multiplying the TDV savings (reported by the CBECC simulation software) by a NPV factor developed by the Energy Commission (see E3's 2022 TDV report for details (Energy + Environmental Economics, 2020)). The 30-year residential NPV factor is \$0.173/kTDV for the 2022 Energy Code.

Equation 4

$$TDV\ PV\ of\ lifetime\ benefit = TDV\ energy\ savings * NPV\ factor$$

2.1.3 Utility Rates

In coordination with the CA IOU rate team (comprised of representatives from PG&E, SCE, SDG&E, SMUD, and CPAU), the Reach Codes Team determined appropriate utility rates for each climate zone in order to calculate utility costs and determine On-Bill cost-effectiveness for the proposed measures and packages. The utility tariffs, summarized in Table 1, were determined based on the most prevalent active rate in each territory. Utility rates were applied to each climate zone based on the predominant IOU serving the population of each zone, with a few climate zones evaluated multiple times under different utility scenarios. Climate Zones 10 and 14 were evaluated with both SCE for electricity and Southern California Gas Company (SoCalGas) for gas and SDG&E tariffs for both electricity and gas since each utility has customers within these climate zones. Climate Zone 5 is evaluated under both PG&E and SoCalGas natural gas rates. Two POU or municipal utility rates were also evaluated: SMUD in Climate Zone 12 and CPAU in Climate Zone 4.

For the IOUs in-unit gas was evaluated under the G1 rate and central gas for water heating was evaluated under the relevant master metered gas tariff, GM. Electricity use for central water heating was evaluated using the residential TOU rates. The water heating utility bill was calculated separately from the in-unit electricity bill. Photovoltaic (PV) and battery energy storage benefits were applied according to virtual net energy metering (VNEM) rules.[2] PV was first assigned to the central water heating meter to offset 100 percent of the electricity use. The remaining PV and all of the battery impacts were then split evenly across the apartment meters. The same approach was applied for CPAU and SMUD using the rates described in Table 1.

The multifamily prototypes used in this analysis include common area spaces that serve the residents (lobby, leasing office, corridors, etc.). Most of the energy use for these spaces could not be separated from that for the dwelling units within the CBECC model. As a result, average per dwelling unit hourly energy use was calculated to include both the dwelling unit and common space energy use.

First-year utility costs were calculated using hourly electricity and natural gas output from CBECC and applying the utility tariffs summarized in Table 1. Annual costs were also estimated for customers eligible for the CARE tariff discounts on both electricity and natural gas bills. The CARE tariff was only applied to the in-unit apartment meters. Appendix 7.2 Utility Rate Schedules includes details of each utility tariff.

For cases with PV generation, the approved NEM 2.0 tariffs were applied along with minimum daily use billing and mandatory non-bypassable charges. In December the California Public Utilities Commission (CPUC) issued a decision adopting a net billing tariff (NBT) as a successor to NEM 2.0 that will go into effect April of 2023[3] Given the recent timing of this decision there was not time to incorporate these changes into this analysis. The Reach Codes Team conducted a limited sensitivity analysis on the impacts of NBT relative to NEM 2.0 on utility bills. It was found that utility costs will increase for all homes with PV systems; however, the increase was less for an all-electric building compared to a mixed fuel building with a similarly sized PV system. As a result of better onsite utilization of PV generation and thus fewer exports to the grid, the Reach Codes Team expects the cost-effectiveness for the electrification scenarios for the all-electric home evaluated in this report to improve under NBT. Conversely, cost-effectiveness of increasing PV capacity is expected to be reduced under NBT.

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[2] PG&E: https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_SCHEDS_NEM2V.pdf
SDG&E: https://tariff.sdge.com/tm2/pdf/tariffs/ELEC_ELEC-SCHEDS_NEM-V-ST.pdf
SCE:
https://edisonintl.sharepoint.com/teams/Public/TM2/Shared%20Documents/Forms/AllItems.aspx?ga=1&id=%2Fteams%2FPublic%2FTM2%2FShared%20Documents%2FPublic%2FRegulatory%2FTariff%2DSCE%20Tariff%20Books%2FElectric%2FSchedules%2FOther%20Rates%2FELECTRIC%5FSCHEDULES%5FNEM%2DV%2DST%2Epdf&parent=%2Fteams%2FPublic%2FTM2%2FShared%20Documents%2FPublic%2FRegulatory%2FTariff%2DSCE%20Tariff%20Books%2FElectric%2FSchedules%2FOther%20Rates

[3] https://www.cpuc.ca.gov/nemrevisit

Table 1. Utility Tariffs Used Based on Climate Zone

IOUs

Climate Zones	Electric / Gas Utility	Electricity	Natural Gas
1-5,11-13,16	PG&E / PG&E	E-TOU Option C	G1 (in-unit) & GM (central water heating)[1]
5	PG&E / SoCalGas	E-TOU Option C	GM
6, 8-10, 14, 15	SCE / SoCalGas	TOU-D Option 4-9	GM
7, 10, 14	SDG&E / SDG&E	TOU-DR-1	GM

POUs

Climate Zones	Electric / Gas Utility	Electricity	Natural Gas
4	CPAU / CPAU	E-1 (in-unit) & E-2 (central water heating)	G-2
12	SMUD / PG&E	R-TOD, RT02 (in-unit) & RSMM (central water heating)	GM

[1]G1 rate applied to gas use within the apartment units, which only occurs in Climate Zones 1 and 16, see Section 3 for details. GM rate applied to gas use for central water heating.

Utility rates are assumed to escalate over time according to the assumptions from the CPUC 2021 En Banc hearings on utility costs through 2030 (California Public Utilities Commission, 2021a). Escalation rates through the remainder of the 30-year evaluation period are based on the escalation rate assumptions within the 2022 TDV factors. See Appendix 7.2.7 Fuel Escalation Assumptions for details.

2.2 2022 T24 Compliance Metrics

2022 Title 24, Part 6 Section 170.1 defines the energy budget of the building based on source energy and TDV energy for space-conditioning, indoor lighting, mechanical ventilation, PV and battery storage systems, service water heating and covered process loads. In 2022, the Energy Commission introduced the new compliance metric of source energy, which differs by fuel source (as does TDV) and is a reasonable proxy for greenhouse gas emissions. Additionally, for multifamily buildings four habitable stories and higher prescriptive requirements for PV and battery systems were also introduced. This led to the need to differentiate an efficiency compliance metric, which ensured that the building met minimum efficiency standards, and a total energy compliance metric which incorporated the PV and battery standards. In order to be compliant with the building code a building needs to comply with all three compliance metrics described below:

- **Efficiency TDV**. Efficiency TDV accounts for all regulated end-uses but does not include the impacts of PV and battery storage.
- **Total TDV**. Total TDV includes regulated end-uses and accounts for PV and battery storage contributions.
- **Source Energy**. Source energy is based on fuel used for power generation and distribution.

2.3 Greenhouse Gas Emissions

The analysis reports the greenhouse gas (GHG) emission estimates based on assumptions within CBECC. There are 8,760 hourly multipliers accounting for time dependent energy use and carbon based on source emissions, including renewable portfolio standard projections. There are two series of multipliers—one for Northern California climate zones, and another for Southern California climate zones.[4] GHG emissions are reported as average annual metric tons of CO_2 equivalent over the 30-year building lifetime.

[4] CBECC multipliers are the same for CZs 1-5 and 11-13 (Northern California), while there is another set of multipliers for CZs 6-10 and 14-16 (Southern California).

3 Prototypes, Measure Packages, and Costs

This section describes the prototypes, measures, costs, and the scope of analysis drawing from previous reach code research where appropriate.

3.1 Prototype Characteristics

The Energy Commission defines building prototypes which it uses to evaluate the cost-effectiveness of proposed changes to Title 24 requirements. There are 4 multifamily prototypes used in code development: a 2-story garden style, a 3-story loaded corridor, a 5-story mixed use and a 10-story mixed use. Based on work completed for the 2022 Title 24 code development, the 3-story and the 5-story represent 33 percent and 58 percent, respectively, of new multifamily construction in California. As a result, these two prototypes are used in this analysis. Additional details on all four prototypes can be found in the Multifamily Prototypes Report (TRC, 2019).

Table 2 describes the basic characteristics of each prototype.

Table 2. Prototype Characteristics

Characteristic	3-Story Loaded Corridor	5-Story Mixed Use
Conditioned Floor Area	39,372 ft^2	113,100 ft^2 total: 33,660 ft^2 nonresidential 79,440 ft^2 residential
Num. of Stories	3	6 Stories total: 1 story parking garage (below grade) 1 story of nonresidential space 4 stories of residential space
Num. of Bedrooms	(6) Studio (12) 1-bed (12) 2-bed (6) 3-bed	(8) studios (40) 1-bed units (32) 2-bed units (8) 3-bed units
Window-to-Wall Area Ratio	25%	25%
Wall Type	Wood framed	Wood frame over a first-floor concrete podium
Roof Type	Flat roof	Flat roof
Foundation	Slab-on-grade	Concrete podium with underground parking

The methodology used in the analyses for each of the prototypical building types begins with a design that precisely meets the minimum 2022 prescriptive requirements.[5] Table 170.2-A and 170.2-B in the 2022 Standards (California Energy Commission, 2022a) list the prescriptive measures that determine the baseline design in each climate zone. Other features are designed to meet, but not exceed, the minimum requirements and are consistent with the Standard Design in the ACM Reference Manual (California Energy Commission, 2022c). The analysis also assumed electric resistance cooking in the apartment units to reflect current market data. The 3-story building prototype includes a central laundry facility, and the 5-story assumes laundry in the units. Laundry equipment was assumed to be electric in all cases; electrification of laundry equipment was not addressed in this study. The nonresidential 2022 reach code analysis (Statewide Reach Codes Team, 2022b) did consider electrification of central laundry facilities within the small hotel prototype.

Table 3 describes characteristics as they were applied to the base case energy model in this analysis. In a shift from the 2019 Standards, the 2022 Standards define a prescriptive fuel source for space heating establishing an electric

[5]Due to planned software updates to how the prescriptive requirements are applied in the Standard Design and challenges for certain space types with sizing heating and cooling equipment the same in the Proposed Design as in the Standards, the results compliance margins for the base case models were not exactly zero percent..

heat pump baseline in all climate zones except 16 for multifamily buildings three habitable stories and fewer and 1 and 16 for multifamily buildings four habitable stories and greater.

Table 3. Base Case Characteristics of the Prototypes

Characteristic	3-Story Loaded Corridor	5-story Mixed Use
Space Heating/Cooling[1]	Individual split systems with ducts in conditioned space CZ 1-15: Heat pump CZ 16: Natural gas furnace with air conditioner	Individual split systems with ducts in conditioned space CZ2-15: Heat pump CZ1, 16: Dual-fuel heat pump with natural gas backup
Ventilation	Individual balanced fans, continuously operating	Individual balanced fans, continuously operating
Water Heater[1]	Natural gas central boiler with solar thermal sized to meet the prescriptive requirements by climate zone.	Natural gas central boiler with solar thermal sized to meet the prescriptive requirements by climate zone.
Hot Water Distribution	Central recirculation	Central recirculation
Cooking	Electric	Electric
Clothes Drying	Electric (central)	Electric (in-unit)
PV System	Sized according to the prescriptive requirements in Equation 170.2-C of the 2022 Title 24 Standards. Size differs by climate zone ranging from 1.60 kW to 2.90 kW per dwelling unit, see Table 4.	Sized according to the prescriptive requirements in Equation 170.2-D of the 2022 Title 24 Standards. Size differs by climate zone ranging from 2.26 kW to 3.34 kW per dwelling unit, see Table 4.
Battery System	None	None

[1] Equipment efficiencies are equal to minimum federal appliance efficiency standards.

Table 4 summarizes the PV capacities for the base case packages.

Table 4. Base Package PV Capacities (kW-DC)

Climate Zone	Base Package	
	3-Story	5-Story
CZ01	2.00	2.26
CZ02	1.79	2.68
CZ03	1.70	2.26
CZ04	1.75	2.68
CZ05	1.60	2.26
CZ06	1.77	2.68
CZ07	1.67	2.68
CZ08	1.91	2.68
CZ09	1.92	2.68
CZ10	1.98	2.68
CZ11	2.21	2.68
CZ12	1.96	2.68
CZ13	2.33	2.68
CZ14	1.94	2.68
CZ15	2.90	3.34
CZ16	1.76	2.26

3.2 Measure Definitions and Costs

Measures evaluated in this study fall into two categories: those associated with general efficiency, onsite generation, and demand flexibility and those associated with building electrification. The Reach Codes Team selected measures based on cost-effectiveness as well as decades of experience with residential architects, builders, and engineers along with general knowledge of the relative consumer acceptance of many measures. This analysis focused on measures that impacted the residential dwelling units only.

The following sections describe the details and incremental cost assumptions for each of the measures. Incremental costs represent the equipment, installation, replacement, and maintenance costs of the proposed measures relative to the base case. Replacement costs are applied for roofs, mechanical equipment, PV inverters and battery systems over the 30-year evaluation period. Incremental maintenance costs are estimated for PV systems, but not any other measures. Costs were estimated to reflect costs to the building owner. All costs are provided as present value in 2023 (2023 PV$).

The Reach Codes Team obtained measure costs from distributors, contractors, literature review, and online sources such as Home Depot and RS Means. Contractor markups are incorporated. These are the Reach Codes Team best estimate of average costs statewide. Regional variation in costs is not accounted for, although it's recognized that local costs may differ. Cost increases due to recent high inflation rates and supply chain delays are not included.

3.2.1 Efficiency, Solar PV, and Batteries

The following are descriptions of each of the efficiency, PV, and battery measures evaluated under this analysis and applied in at least one of the packages presented in this report. Table 5 summarizes the incremental cost assumptions for each of these measures. These measures were evaluated for all climate zones but were ultimately adopted in a subset of climate zones based on cost-effectiveness outcomes.

Lower U-Factor Fenestration: Reduce window U-factor to 0.24. The prescriptive U-factor is 0.30 in all climate zones except Climate Zones 7 and 8 where it is 0.34. This measure is included in Climate Zone 16 only.

Cool Roof: Install a roofing product that's rated by the Cool Roof Rating Council to have an aged solar reflectance (ASR) equal to or greater than 0.70. Low-sloped roofs were assumed in all cases. The 2022 Title 24 specifies a prescriptive ASR of 0.63 for Climate Zones 9 through 11 and 13 through 15. This measure is included in Climate Zones 9 through 15.

Low Pressure Drop Ducts: Upgrade the duct distribution system to reduce external static pressure and meet a maximum fan efficacy of 0.35 Watts per cfm. This may involve upsizing ductwork, reducing the total effective length of ducts, and/or selecting low pressure drop components such as filters. Fan watt draw must be verified by a HERS rater according to the procedures outlined in the 2022 Reference Appendices RA3.3 (California Energy Commission, 2022b). This measure is included in Climate Zones 1 and 10 through 16.

Verified Low Leakage Ducts in Conditioned Space: Seal the ducts to achieve a measured leakage no greater than 25 cfm leakage to outside. This may be verified using a guarded blower door test to isolate leakage to outside. Alternatively, this can also be satisfied by demonstrating that total leakage is not greater than 25 cfm. Ducts are assumed to already be located in conditioned space in the baseline. This measure is included in all climate zones.

Solar PV: Installation of on-site PV is required in the 2022 residential code unless an exception is met. The PV sizing methodology in each package was developed to offset annual building electricity use and avoid oversizing which would violate net energy metering (NEM) rules.[6] In all cases, PV is evaluated in CBECC according to the California Flexible Installation (CFI) assumptions. This measure is included in all climate zones.

Battery Energy Storage: A battery system was evaluated in CBECC-Res with control type set to "Time-of-Use" and with default efficiencies of 95% for both charging and discharging. This control option assumes the battery system will

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

charge or discharge based on a utility tariff time-of use signal. To qualify, the battery system must meet the requirements outlined in the 2022 Reference Appendices JA12.2.3.2 (California Energy Commission, 2022b). This measure is included in all climate zones but only for the 3-story prototype. A 100kWh battery was applied following the battery sizing requirements for multifamily buildings more than three habitable stories per Equation 170.2-E of the 2022 Energy Code.

Table 5. Incremental Cost Assumptions

Measure	Performance Level	Incremental Cost per Dwelling Unit (2023 PV$)		Source & Notes
		3-Story	5-Story	
Non-Preempted Measures				
Window U-factor	0.24 vs 0.30	$536	$489	$4.23/ft² of window area based on analysis conducted for the 2019 and 2022 Title 24 cycles (Statewide CASE Team, 2018).
Low-Sloped Cool Roof Aged Solar Reflectance	0.63 vs 0.10	$314	$222	$0.525/ft² of roof area first incremental cost based on the 2022 Residential Additions and Alterations CASE Report (Statewide CASE Team, 2020b).Total costs assume present value of replacement at year 15.
	0.70 vs 0.63	$24	$17	$0.04/ft² of roof area first incremental cost based on the 2022 Nonresidential High Performance Envelope CASE Report (Statewide CASE Team, 2020a). Costs assume a blended average across roofing product types. Total costs assume present value of replacement at year 15.
Low Pressure Drop Ducts	0.35 vs 0.45 W/cfm	$44	$44	Costs assume half-hour labor per multifamily dwelling unit. Labor rate of $88 per hour is from 2022 RS Means for sheet metal workers and includes a weighted average City Cost Index for labor for California.
Verified Low Leakage Ducts in Conditioned Space	≤25 cfm leakage to outside	$132	$132	Costs assume half-hour labor per multifamily dwelling unit and a $100 HERS Rater fee. Labor rate of $88 per hour is from 2022 RS Means for sheet metal workers and includes a weighted average City Cost Index for labor for California. Ducts are already assumed to be located in conditioned space and the incremental costs reflect additional sealing and testing only.
PV + Battery				
PV System	First Cost	$1.47/W	$1.47/W	First costs from LBNL's Tracking the Sun 2022 costs (Barbose, Darghouth, O'Shaughnessy, & Forrester, 2022) and represent median costs in California in 2021 of $2.10/WDC for nonresidential greater than 100kWDC systems. The first cost was reduced by the solar energy Investment Tax Credit (ITC) of 30%.[1] Costs are presented as the average of 2023, 2024, and 2025.
	Inverter replacement	$0.14/W	$0.14/W	Inverter replacement cost of $0.14/WDC present value includes replacements at year 11 at $0.15/WDC (nominal) and at year 21 at $0.12/WDC (nominal) per the 2019 PV CASE Report (California Energy Commission, 2017).
	Maintenance	$0.31/W	$0.31/W	System maintenance costs of $0.31/WDC present value assume $0.02/WDC (nominal) annually per the 2019 PV CASE Report (California Energy Commission, 2017).

Measure	Performance Level	Incremental Cost per Dwelling Unit (2023 PV$)		Source & Notes
		3-Story	5-Story	
Battery	First cost	$700/kWh	n/a	First cost of $1,000/kWh from LBNL's Tracking the Sun 2022 costs (Barbose, Darghouth, O'Shaughnessy, & Forrester, 2022) for residential systems > 30kWh. The report derived costs from California's Self-Generation Incentive Program (SGIP) residential participant cost data. First cost is reduced by the solar energy ITC of 30%.[1] No SGIP incentives are included. Costs are assumed to remain consistent at $1,000/kWh through 2025 and then reduced by 7% annually based on SDG&E's Behind-the-Meter Battery Market Study (E-Source companies, 2020) over a 10 year period. Replacement is assumed at years 10 and 20. At year 10 the replacement cost is based on the average of expected 2033, 2034, and 2035 costs after applying the ITC for a future value cost of $435. Replacement cost at year 20 is based on a future value cost of $484 and does not include any ITC reduction.
	Replacement cost	$564/kWh	n/a	

[1]As part of the Inflation Reduction Act in August 2022 the Section 25D Investment Tax Credit was extended and raised to 30% through 2032 with a step-down to 26% in 2033 and 22% in 2034. It's assumed that the ITC is not renewed and is 0% starting in 2035. https://www.irs.gov/pub/taxpros/fs-2022-40.pdf.

3.2.2 All-Electric

This analysis compared a code compliant mixed fuel prototype, which uses natural gas for water heating only in most climate zones, with a code compliant all-electric prototype. In these cases, the relative costs between natural gas and electric appliances and natural gas infrastructure and the associated infrastructure costs for not providing natural gas to the building were included.

To estimate costs the Reach Codes Team leveraged costs from the 2022 Multifamily All-Electric CASE Report (Statewide CASE Team, 2020c) and the 2019 reach code multifamily cost-effectiveness studies ((Statewide Reach Codes Team, 2020), (Statewide Reach Codes Team, 2021)), and online equipment research. Present value replacement costs are included in the total lifetime incremental costs.

3.2.2.1 Water Heating

Federal regulations establish minimum efficiency requirements for heat pump water heaters with rated storage volume less than 120 gallons. While some heat pump water heaters falling into this regulated category can be used in a central water heater design, they are not required and therefore this measure does not trigger federal preemption and heat pump equipment of any efficiency level may be used for this analysis to justify the basis of a reach code.

For the central heat pump water heating system in the 3-story prototype the system design was based on the 2022 All-Electric Multifamily CASE Report (Statewide CASE Team, 2020c) and used CO_2 refrigerant based heat pump water heaters (four Sanden GS3-45HPA-US units), 525 gallons of storage, and a 250 gallon electric resistance swing tank. The 2022 CASE work based the 5-story system design on Colmac R-134a refrigerant heat pump water heaters. While this is an acceptable design, R-134a or R-410a refrigerant heat pump water heaters were found to be less cost-effective for the prototypes evaluated in this analysis due to higher incremental costs and lower overall performance relative to CO_2 refrigerant products. As such, the Reach Codes Team evaluated a CO_2 refrigerant system for the 5-story prototype for this analysis. As part of the 2025 Energy Code update cycle, designs for both multifamily prototypes are being reexamined using CO_2 refrigerant heat pump water heaters. While full design and cost information was not yet available for this analysis, preliminary design data was used to inform sizing of a Sanden system for this prototype. The system used 10 heat pump water heaters (Sanden GS3-45HPA-US units), 800 gallons of storage, and a 200 gallon electric resistance swing tank.

Table 6 reports costs for the central heat pump water heating systems relative to a gas boiler system with solar thermal that meets the prescriptive requirements of 20% solar fraction in Climate Zones 1 through 9 and 35% solar fraction in Climate Zones 10 through 16. Costs include equipment and labor, gas piping within the building for the boiler system, and additional electrical service necessary for the heat pump system. Replacement costs are based on an effective useful life of 15 years for the water heaters and tanks, and 20 years for the solar thermal collectors. For the solar thermal systems, it’s also assumed that the glycol is replaced at years 9, 18 and 27. Additional details on cost assumptions are presented in Appendix 7.3 Cost Details.

Table 6. Heat Pump Water Heater Incremental System Costs (Present Value (2023$))

Item		3-Story		5-Story		Source & Notes
		Central Gas Boiler	Central Heat Pump	Central Gas Boiler	Central Heat Pump	
First Cost	CZs 1-9	$173,772	$211,531	$279,163	$343,920	3-story costs directly from 2022 Multifamily All-Electric CASE Report. 5-story costs estimated based on component costs for the 3-story from the CASE report.
	CZs 10-16	$182,810		$300,883		
Replacement Cost	CZs 1-9	$32,297	$44,263	$59,930	$110,659	
	CZs 10-16	$36,943		$69,361		
Total Incremental Cost	**CZs 1-9**	n/a	**$49,725**	n/a	**$115,486**	
	CZs 10-16		**$36,041**		**$84,335**	
Incremental Cost per Dwelling Unit	**CZs 1-9**		**$1,381**		**$1,312**	
	CZs 10-16		**$1,001**		**$958**	

3.2.2.2 Space Heating

Table 7 presents the costs for heat pump space heater conversion from gas equipment. In most climate zones the baseline per the 2022 Energy Code is a heat pump space heater, so these costs are only applied in a couple of instances. For the 3-story prototype the baseline in Climate Zone 16 is a gas furnace and air conditioner. For the 5-story prototype the baseline in Climate Zones 1 and 16 is a dual fuel heat pump with a gas furnace as backup. Costs include equipment and labor, gas piping within the building for the boiler system, and additional electrical service necessary for the heat pump system. Most of the cost difference between the two systems is attributed to higher labor costs to install the gas system as a result of gas piping and venting. Additional details on cost assumptions are presented in Appendix 7.3 Cost Details.

Table 7. Heat Pump Space Heater Costs per Dwelling Unit (Present Value (2023$)

Item	3-Story		5-Story		Source & Notes
	Furnace + Split AC	Heat Pump	Furnace + Split HP	Heat Pump	
First Cost	$20,667	$16,776	$21,245	$16,597	Costs largely based on the 2022 Multifamily All-Electric CASE Report with some updates to reflect online equipment cost research and labor cost alignments.
Replacement Cost	$8,059	$7,326	$9,052	$7,326	See lifetimes referenced in Table 8. Residual value at the end of the 30-year analysis period was accounted for to represent the remaining life of any equipment.
Residual Value	($1,591)	$0	$0	$0	
Total	$27,135	$24,102	$30,296	$23,924	
Incremental Cost		**($3,032)**		**($6,373)**	

Equipment lifetimes applied in this analysis for the space conditioning measures are summarized in Table 8. The lifetime for the heat pump, furnace, and air conditioner are based on the Database for Energy Efficient Resources (DEER) (California Public Utilities Commission, 2021b). In DEER, heat pump and air conditioner measures are assigned an effective useful lifetime (EUL) of 15 years and a furnace an EUL of 20 years. The heating and cooling system components are typically replaced at the same time when one reaches the end of its life and the other is near it. Therefore, it is assumed that both the furnace and air conditioner are replaced at the same time at year 17.5, halfway between 15 and 20 years. For HVAC system costing, air-conditioning is included in all cases in both the base case and proposed models.

Table 8. Lifetime of Water Heating & Space Conditioning Equipment Measures

Measure	Lifetime
Gas Furnace	17.5
Air Conditioner	17.5
Heat Pump	15
Dual Fuel Heat Pump	15

3.2.2.3 Natural Gas Infrastructure

Eliminating natural gas to a building saves costs associated with connecting a service line from the street main to the building, piping distribution within the building, and monthly meter customer charges from the utility. This section focuses on the first item, not connecting gas service to the building. The latter two are captured in the appliance costs and the utility bill analysis. Cost savings for removing natural gas infrastructure to a multifamily building in IOU territory are presented in Table 9 and Table 10. These costs are applied as cost savings for the all-electric case when compared to the mixed fuel baseline.

These costs are project dependent and may be significantly impacted by such factors as utility territory, site characteristics, distance to the nearest natural gas main and main location, joint trenching, whether work is conducted by the utility or a private contractor, and number of dwelling units per development. All gas utilities participating in this study were solicited for cost information.

Service Extension: Service extension costs to the building were taken from a PG&E memo dated December 5, 2019 to Energy Commission staff (see Appendix 7.4 PG&E Gas Infrastructure Cost Memo for a copy of the memo). The estimated cost of $6,750 excludes costs for trenching and assumes nonresidential new construction within a developed area. For the 5-story building the cost is apportioned between the residential and nonresidential spaces in the building based on associated conditioned floor areas where 84 percent is residential. All of the spaces in the 3-story building are residential based.

Today, total costs are reduced to account for deductions per the Utility Gas Main Extensions rules.[7] These rules categorize distribution line extensions as “refundable” costs, which are offset or subsidized by all other ratepayers. The CPUC issued a Decision in September 2022 that eliminates the subsidies effective July 1, 2023 (California Public Utilities Commission, 2022). Since most of the development that will occur during the three-year 2022 code cycle (2023-2025) will not be subject to these deduction allowances they are not included in this analysis.

Meter: Cost per meter provided by PG&E of $3,600 for a commercial meter to serve the central water heating and $600 per multifamily dwelling unit. The $600 dwelling unit meter is only applied in Climate Zone 16 for the 3-story prototype and Climate Zones 1 and 16 for the 5-story prototypes where gas is used either for primary or backup space heating. Two scenarios are presented in the tables. One is the case with electric space heating, no in-unit gas and the only residential gas use is to serve the central water heating system. The other case represents the scenario where there is in-unit gas to service space heating.

[7] PG&E Rule 15: https://www.pge.com/tariffs/assets/pdf/tariffbook/GAS_RULES_15.pdf.
SoCalGas Rule 20: https://www.socalgas.com/regulatory/tariffs/tm2/pdf/20.pdf.
SDG&E Rule 15: https://tariff.sdge.com/tm2/pdf/GAS_GAS-RULES_GRULE15.pdf.

Natural Gas Plan Review: Total costs are based on TRC's 2019 reach code analysis for Palo Alto (TRC, 2018). The cost for the 5-story prototype is apportioned between the residential and nonresidential spaces in the building in the same way as was done for the service extension costs.

Table 9. IOU Natural Gas Infrastructure Cost Savings for All-Electric Building

Item		3-Story	5-Story
Service Extension		$6,750	$5,695
Meter	No In-Unit Gas (Gas DHW only)	$3,600	$3,600
	In-Unit Gas	$25,200	$56,400
Plan Review		$2,316	$1,954

Table 10. Multifamily IOU Total Natural Gas Infrastructure Costs

Prototype	Scenario	Total Building	Per Dwelling Unit
3-Story	No In-Unit Gas	$12,666	$352
	In-Unit Gas	$34,266	$952
5-Story	No In-Unit Gas	$11,248	$128
	In-Unit Gas	$64,048	$728

CPAU provides gas service to its customers and therefore separate costs were evaluated based on CPAU gas service connection fees.[8] Table 11 presents the breakdown of gas infrastructure costs used in this analysis for CPAU. The same approach to apportioning the total building costs to the residential spaces as described in the IOU section was applied here for the service extension and plan review costs for the 5-story prototype. Meter costs were based on $1,772 for an 800 cubic foot per hour commercial meter for the central water heating system.

Table 11. Multifamily CPAU Total Natural Gas Infrastructure Costs

Item	3-Story	5-Story
Service Extension	$5,892	$4,971
Meter	$1,772	$1,772
Plan Review	$2,557	$2,157

3.3 Measure Packages

The Reach Codes Team evaluated three packages for mixed fuel homes and five packages for all-electric homes for each prototype and climate zone, as described below.

1. All-Electric Prescriptive Code: This package meets all the prescriptive requirements of the 2022 Energy Code.
2. All-Electric Prescriptive Code + PV: Using the code minimum package as a starting point, PV capacity was added to offset 100 percent of the estimated annual electricity use.
3. Mixed Fuel Efficiency Only: This package uses only efficiency measures that do not trigger federal preemption including envelope and duct distribution efficiency measures.

[8] CPAU Schedule G-5 effective 09-01-2019: https://www.cityofpaloalto.org/files/assets/public/utilities/utilities-engineering/general-specifications/gas-service-connection-fees.pdf

4. Mixed Fuel Efficiency + PV + Battery: Using the Efficiency Package as a starting point, PV capacity was added to offset 100 percent of the estimated annual electricity use. A battery system was also added. This package only applies to the 3-story prototype. The 5-story prototype includes a battery system in the baseline per the 2022 prescriptive requirements.
5. Mixed Fuel Efficiency + PV: Using the Efficiency Package as a starting point, PV capacity was added to offset 100 percent of the estimated annual electricity use. This package only applies to the 5-story prototype.

4 Results

Cost-effectiveness results are presented per prototype and measure packages described in Section 3.3. The TDV and On-Bill based cost-effectiveness results are presented in terms of B/C ratio and NPV. Energy savings, compliance margin, utility bill savings, and incremental costs are also shown.

In the following figures, green highlighting indicates that the case is cost-effective with a B/C ratio greater than or equal to 1 and a NPV greater than or equal to 0. Red highlighting indicates the case is not cost-effective.

Compliance margins are presented as percentages both for the efficiency TDV and the source energy metrics. A compliance margin that is equal to or greater than 0 indicates the case is code compliant.

4.1 All-Electric Prescriptive Code

Table 12 and Table 13 shows results for the multifamily all-electric prescriptive code case compared to the 2022 baseline. For both prototypes this scenario is cost-effective based on TDV in all climate zones. This scenario is only On-Bill cost-effective in a few climate zones. The 3-story all-electric case is cost-effective On-Bill in Climate Zones 1 through 3, 4 in CPAU territory, 12 in SMUD territory, and 16. The 5-story all-electric case is cost-effective On-Bill in Climate Zones 1, 4, 12 in SMUD territory, and 16.

In most cases there is a small net increase in utility cost in the first year.

There is an incremental cost for the central heat pump water heater ranging from $361 to $697 per dwelling unit.

The all-electric packages applied to the 3-story prototype in Climate Zone 16 and the 5-story prototype in Climate Zones 1 and 16 incorporate both gas to electric water heating and gas to electric space heating measures. In these cases, there are significant cost savings due to the avoided first costs of installing a gas furnace as compared to a heat pump. As a result, these cases are On-Bill cost-effective.

These results reflect a CO_2 refrigerant based central heat pump water heating system. The 5-story prototype was also evaluated with a R-134a refrigerant based central heat pump water heater and these results are shown in Appendix 7.5 Central Heat Pump Water Heater Comparison.

Table 12. 3-Story Cost-Effectiveness Results per Dwelling Unit: All-Electric Prescriptive Code

Climate Zone	Electric /Gas Utility	Efficiency TDV Comp Margin	Source Comp Margin	Annual Elec Savings (kWh)	Annual Gas Savings (therms)	Utility Cost Savings		Incremental Cost		On-Bill		TDV	
						First Year	Lifecycle (2022$)	First Year	Lifecycle (2022$)	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	26%	15%	-904	135	($19)	$1,676	$97	$429	3.9	$1,247	>1	$4,158
CZ02	PGE	20%	11%	-801	115	($30)	$1,061	$697	$1,029	1.0	$32	9.9	$2,998
CZ03	PGE	21%	10%	-789	115	($26)	$1,148	$697	$1,029	1.1	$119	9.9	$2,990
CZ04	PGE	18%	9%	-759	109	($31)	$922	$697	$1,029	0.9	($108)	9.2	$2,767
CZ04	CPAU	18%	9%	-759	109	$233	$8,191	$765	$1,097	7.5	$7,094	7.7	$2,700
CZ05	PGE	23%	9%	-789	112	($30)	$1,009	$697	$1,029	0.98	($21)	9.3	$2,782
CZ05	PGE/SCG	23%	9%	-789	112	($79)	($515)	$697	$1,029	0.0	($1,545)	9.3	$2,782
CZ06	SCE/SCG	18%	7%	-709	100	($61)	($226)	$697	$1,029	0.0	($1,255)	8.6	$2,551
CZ07	SDGE	20%	8%	-704	102	($69)	($427)	$697	$1,029	0.0	($1,456)	9.1	$2,712
CZ08	SCE/SCG	13%	6%	-689	96	($61)	($302)	$697	$1,029	0.0	($1,331)	8.2	$2,432
CZ09	SCE	13%	5%	-698	96	($64)	($351)	$697	$1,029	0.0	($1,380)	8.0	$2,363
CZ10	SCE/SCG	14%	7%	-701	83	($88)	($1,109)	$446	$649	0.0	($1,758)	>1	$1,959
CZ10	SDGE	14%	7%	-701	83	($112)	($1,803)	$446	$649	0.0	($2,452)	>1	$1,959
CZ11	PGE	14%	10%	-740	91	($64)	($177)	$446	$649	0.0	($826)	>1	$2,212
CZ12	PGE	17%	11%	-755	94	($62)	($70)	$446	$649	0.0	($719)	>1	$2,297
CZ12	SMUD/PGE	17%	11%	-755	94	$68	$2,942	$446	$649	4.5	$2,293	>1	$2,297
CZ13	PGE	13%	9%	-717	86	($65)	($291)	$446	$649	0.0	($940)	>1	$2,050
CZ14	SCE/SCG	13%	7%	-748	83	($102)	($1,413)	$446	$649	0.0	($2,063)	>1	$1,759
CZ14	SDGE	13%	7%	-748	83	($128)	($2,191)	$446	$649	0.0	($2,841)	>1	$1,759
CZ15	SCE/SCG	5%	2%	-607	64	($89)	($1,403)	$446	$649	0.0	($2,053)	>1	$1,305
CZ16	PG&E	24%	29%	-1,928	185	($178)	($1,066)	($4,045)	($2,983)	2.8	$1,917	>1	$4,352

Table 13. 5-Story Cost-Effectiveness Results per Dwelling Unit: All-Electric Prescriptive Code

Climate Zone	Electric /Gas Utility	Efficiency TDV Comp Margin	Source Comp Margin	Annual Elec Savings (kWh)	Annual Gas Savings (therms)	Utility Cost Savings		Incremental Cost		On-Bill		TDV	
						First Year	Lifecycle (2022$)	First Year	Lifecycle (2022$)	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	14%	9%	-1,146	147	($49)	$1,209	($4,639)	($5,788)	>1	$6,998	>1	$9,816
CZ02	PGE	9%	6%	-888	120	($45)	$809	$608	$1,185	0.7	($375)	3.0	$2,270
CZ03	PGE	11%	7%	-874	120	($46)	$778	$608	$1,185	0.7	($407)	3.1	$2,421
CZ04	PGE	9%	6%	-824	113	$18	$2,130	$608	$1,185	1.8	$945	3.1	$2,393
CZ04	CPAU	9%	6%	-824	113	$230	$8,205	$635	$1,211	6.8	$6,994	3.0	$2,367
CZ05	PGE	12%	6%	-871	117	($47)	$706	$608	$1,185	0.6	($479)	2.8	$2,065
CZ05	PGE/SCG	12%	6%	-871	117	($99)	($919)	$608	$1,185	0.0	($2,103)	2.8	$2,065
CZ06	SCE/SCG	9%	5%	-739	104	($10)	$986	$608	$1,185	0.8	($199)	2.9	$2,183
CZ07	SDGE	11%	6%	-735	106	($74)	($500)	$608	$1,185	0.0	($1,685)	2.9	$2,215
CZ08	SCE/SCG	8%	4%	-710	100	($79)	($644)	$608	$1,185	0.0	($1,829)	3.0	$2,259
CZ09	SCE	7%	4%	-725	100	($53)	($51)	$608	$1,185	0.0	($1,236)	3.0	$2,274
CZ10	SCE/SCG	7%	4%	-729	84	($111)	($1,615)	$361	$831	0.0	($2,445)	2.7	$1,374
CZ10	SDGE	7%	4%	-729	84	($137)	($2,404)	$361	$831	0.0	($3,234)	2.7	$1,374
CZ11	PGE	8%	5%	-790	92	($86)	($663)	$361	$831	0.0	($1,494)	3.1	$1,656
CZ12	PGE	9%	6%	-809	96	($83)	($527)	$361	$831	0.0	($1,358)	3.0	$1,620
CZ12	SMUD/PGE	9%	6%	-809	96	$62	$2,831	$361	$831	3.4	$2,000	3.0	$1,620
CZ13	PGE	7%	5%	-754	88	($83)	($686)	$361	$831	0.0	($1,517)	3.0	$1,570
CZ14	SCE/SCG	6%	3%	-803	84	($131)	($2,085)	$361	$831	0.0	($2,916)	2.2	$928
CZ14	SDGE	6%	3%	-803	84	($165)	($3,106)	$361	$831	0.0	($3,937)	2.2	$928
CZ15	SCE/SCG	3%	1%	-602	65	($105)	($1,775)	$361	$831	0.0	($2,606)	1.9	$695
CZ16	PG&E	9%	11%	-1,388	142	($127)	($675)	($4,886)	($6,142)	9.1	$5,467	>1	$6,704

4.2 All-Electric Plus PV

Table 14 and Table 15 present cost-effectiveness results for the all-electric plus PV packages for the 3-story and 5-story prototypes, respectively. All cases are cost-effective both On-Bill and based on TDV.

Table 14. 3-Story Cost-Effectiveness Results per Dwelling Unit: All-Electric 100% PV

Climate Zone	Electric /Gas Utility	Efficiency TDV Comp Margin	Source Comp Margin	Annual Elec Savings (kWh)	Annual Gas Savings (therms)	Utility Cost Savings		Incremental Cost		On-Bill		TDV	
						First Year	Lifecycle (2022$)	First Year	Lifecycle (2022$)	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	26%	24%	2,127	135	$782	$20,242	$3,638	$5,034	4.0	$15,208	3.2	$9,448
CZ02	PGE	20%	20%	1,835	115	$653	$16,910	$3,294	$4,406	3.8	$12,504	3.3	$8,632
CZ03	PGE	21%	20%	1,711	115	$614	$15,998	$3,076	$4,123	3.9	$11,875	3.4	$8,209
CZ04	PGE	18%	18%	1,558	109	$559	$14,587	$2,841	$3,818	3.8	$10,770	3.6	$8,230
CZ04	CPAU	18%	18%	1,558	109	$489	$14,138	$2,909	$3,886	3.6	$10,253	3.6	$8,162
CZ05	PGE	23%	20%	1,604	112	$579	$15,137	$2,826	$3,798	4.0	$11,338	3.6	$8,026
CZ05	PGE/SCG	23%	20%	1,604	112	$531	$13,613	$2,826	$3,798	3.6	$9,814	3.6	$8,026
CZ06	SCE/SCG	18%	17%	1,207	100	$378	$9,795	$2,364	$3,197	3.1	$6,598	3.8	$7,092
CZ07	SDGE	20%	21%	1,528	102	$723	$19,318	$2,777	$3,734	5.2	$15,584	3.5	$7,623
CZ08	SCE/SCG	13%	17%	1,393	96	$426	$10,842	$2,569	$3,464	3.1	$7,378	3.9	$7,908
CZ09	SCE	13%	15%	1,204	96	$379	$9,756	$2,335	$3,160	3.1	$6,596	3.9	$7,158
CZ10	SCE/SCG	14%	18%	1,381	83	$404	$10,130	$2,237	$2,978	3.4	$7,152	4.1	$7,031
CZ10	SDGE	14%	18%	1,381	83	$621	$16,493	$2,237	$2,978	5.5	$13,514	4.1	$7,031
CZ11	PGE	14%	19%	1,843	91	$625	$15,782	$2,940	$3,893	4.1	$11,889	3.4	$7,748
CZ12	PGE	17%	19%	1,704	94	$579	$14,777	$2,756	$3,654	4.0	$11,124	3.6	$7,607
CZ12	SMUD/PGE	17%	19%	1,704	94	$399	$10,615	$2,756	$3,654	2.9	$6,961	3.6	$7,607
CZ13	PGE	13%	17%	1,572	86	$544	$13,822	$2,567	$3,408	4.1	$10,415	3.6	$7,148
CZ14	SCE/SCG	13%	18%	1,572	83	$449	$11,152	$2,300	$3,060	3.6	$8,092	4.2	$7,668
CZ14	SDGE	13%	18%	1,572	83	$688	$18,158	$2,300	$3,060	5.9	$15,098	4.2	$7,668
CZ15	SCE/SCG	5%	11%	1,163	64	$330	$8,164	$1,966	$2,626	3.1	$5,539	3.9	$5,567
CZ16	PG&E	24%	38%	1,371	185	$700	$19,307	($1,064)	$894	21.6	$18,412	58.9	$11,596

Table 15. 5-Story Cost-Effectiveness Results per Dwelling Unit: All-Electric 100% PV

Climate Zone	Electric /Gas Utility	Efficiency TDV Comp Margin	Source Comp Margin	Annual Elec Savings (kWh)	Annual Gas Savings (therms)	Utility Cost Savings		Incremental Cost		On-Bill		TDV	
						First Year	Lifecycle (2022$)	First Year	Lifecycle (2022$)	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	14%	21%	1,437	147	$629	$16,919	($1,574)	($1,803)	>1	$18,721	>1	$18,222
CZ02	PGE	9%	14%	428	120	$262	$7,918	$1,930	$2,904	2.7	$5,015	4.0	$8,679
CZ03	PGE	11%	16%	682	120	$327	$9,417	$2,121	$3,152	3.0	$6,265	4.0	$9,285
CZ04	PGE	9%	13%	92	113	$207	$6,524	$1,476	$2,313	2.8	$4,211	4.1	$7,054
CZ04	CPAU	9%	13%	92	113	$337	$10,667	$1,502	$2,340	4.6	$8,327	4.0	$7,027
CZ05	PGE	12%	16%	451	117	$259	$7,806	$1,815	$2,754	2.8	$5,052	4.0	$8,096
CZ05	PGE/SCG	12%	16%	451	117	$207	$6,182	$1,815	$2,754	2.2	$3,427	4.0	$8,096
CZ06	SCE/SCG	9%	12%	-163	104	$98	$3,449	$1,127	$1,859	1.9	$1,590	3.8	$5,035
CZ07	SDGE	11%	15%	74	106	$192	$6,131	$1,387	$2,198	2.8	$3,934	3.9	$6,204
CZ08	SCE/SCG	8%	14%	265	100	$154	$4,666	$1,516	$2,365	2.0	$2,301	4.0	$7,053
CZ09	SCE	7%	12%	60	100	$122	$3,930	$1,307	$2,093	1.9	$1,837	3.7	$5,636
CZ10	SCE/SCG	7%	13%	289	84	$131	$3,912	$1,266	$2,007	1.9	$1,905	3.9	$5,749
CZ10	SDGE	7%	13%	289	84	$238	$6,951	$1,266	$2,007	3.5	$4,945	3.9	$5,749
CZ11	PGE	8%	17%	1,091	92	$417	$10,990	$2,226	$3,256	3.4	$7,734	4.2	$10,472
CZ12	PGE	9%	16%	594	96	$263	$7,487	$1,712	$2,587	2.9	$4,901	4.3	$8,544
CZ12	SMUD/PGE	9%	16%	594	96	$260	$7,419	$1,712	$2,587	2.9	$4,889	4.3	$8,544
CZ13	PGE	7%	17%	1,036	88	$398	$10,479	$2,064	$3,045	3.4	$7,434	4.2	$9,715
CZ14	SCE/SCG	6%	11%	182	84	$102	$3,250	$1,170	$1,883	1.7	$1,368	4.0	$5,515
CZ14	SDGE	6%	11%	182	84	$194	$5,858	$1,170	$1,883	3.1	$3,975	4.0	$5,515
CZ15	SCE/SCG	3%	10%	387	65	$153	$4,119	$1,238	$1,971	2.1	$2,148	3.6	$4,998
CZ16	PG&E	9%	23%	1,007	142	$501	$13,864	($2,682)	($3,275)	>1	$17,139	>1	$16,140

4.3 Mixed Fuel Efficiency

Table 16 and Table 17 show results for the Mixed Fuel Efficiency packages. The packages are cost-effective based on at least one of the two metrics in Climate Zones 1, 2, 4, and 8 through 16 for the 3-story prototype and in Climate Zones 2, 4, 6, and 8 through 15 for the 5-story prototype. In all cases the NPV values, whether negative or positive, are small. The compliance impacts are also small.

A summary of measures included in each package is provided in Appendix 7.6 Summary of Measures by Package.

Table 16. 3-Story Cost-Effectiveness Results per Dwelling Unit: Mixed Fuel Efficiency

Climate Zone	Electric /Gas Utility	Efficiency TDV Comp Margin	Source Comp Margin	Annual Elec Savings (kWh)	Annual Gas Savings (therms)	Utility Cost Savings		Incremental Cost		On-Bill		TDV	
						First Year	Lifecycle (2022$)	First Year	Lifecycle (2022$)	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	1%	1%	41	0	$12	$273	$176	$176	1.6	$98	1.2	$38
CZ02	PGE	1%	0%	24	0	$7	$162	$132	$132	1.2	$30	1.5	$62
CZ03	PGE	1%	0%	17	0	$5	$111	$132	$132	0.8	($21)	0.8	($27)
CZ04	PGE	1%	0%	21	0	$6	$141	$132	$132	1.1	$9	1.3	$46
CZ04	CPAU	1%	0%	21	0	$3	$74	$132	$132	0.6	($58)	1.3	$46
CZ05	PGE	1%	0%	19	0	$5	$123	$132	$132	0.9	($9)	0.8	($32)
CZ05	PGE/SCG	1%	0%	19	0	$5	$123	$132	$132	0.9	($9)	0.8	($32)
CZ06	SCE/SCG	1%	0%	9	0	$2	$56	$132	$132	0.4	($75)	0.7	($44)
CZ07	SDGE	0%	0%	7	0	$3	$72	$132	$132	0.5	($60)	0.4	($81)
CZ08	SCE/SCG	1%	0%	20	0	$6	$140	$132	$132	1.1	$9	1.5	$59
CZ09	SCE	1%	0%	28	0	$8	$192	$146	$156	1.2	$36	1.6	$88
CZ10	SCE/SCG	3%	1%	65	0	$20	$447	$190	$199	2.2	$247	2.4	$277
CZ10	SDGE	3%	1%	65	0	$27	$683	$190	$199	3.4	$484	2.4	$277
CZ11	PGE	3%	1%	91	0	$30	$699	$190	$199	3.5	$499	3.5	$489
CZ12	PGE	2%	0%	98	0	$33	$766	$381	$514	1.5	$252	1.5	$273
CZ12	SMUD/PGE	2%	0%	98	0	$17	$396	$381	$514	0.8	($118)	1.5	$273
CZ13	PGE	4%	1%	99	0	$33	$765	$190	$199	3.8	$566	3.9	$574
CZ14	SCE/SCG	3%	1%	88	0	$26	$585	$190	$199	2.9	$385	3.1	$427
CZ14	SDGE	3%	1%	88	0	$36	$886	$190	$199	4.4	$686	3.1	$427
CZ15	SCE/SCG	5%	2%	182	0	$54	$1,226	$190	$199	6.1	$1,026	5.8	$957
CZ16	PG&E	5%	4%	16	12	$34	$1,012	$712	$712	1.4	$300	1.3	$184

Table 17. 5-Story Cost-Effectiveness Results per Dwelling Unit: Mixed Fuel Efficiency

Climate Zone	Electric /Gas Utility	Efficiency TDV Comp Margin	Source Comp Margin	Annual Elec Savings (kWh)	Annual Gas Savings (therms)	Utility Cost Savings		Incremental Cost		On-Bill		TDV	
						First Year	Lifecycle (2022$)	First Year	Lifecycle (2022$)	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	0%	0%	5	0	$2	$39	$176	$176	0.2	($137)	0.2	($136)
CZ02	PGE	1%	0%	11	0	$2	$38	$132	$132	0.3	($94)	1.9	$118
CZ03	PGE	0%	0%	7	0	$2	$46	$132	$132	0.3	($86)	0.8	($23)
CZ04	PGE	1%	0%	12	0	$2	$40	$132	$132	0.3	($92)	1.9	$114
CZ04	CPAU	1%	0%	12	0	$2	$39	$132	$132	0.3	($93)	1.9	$114
CZ05	PGE	0%	0%	6	0	$1	$17	$132	$132	0.1	($114)	0.4	($73)
CZ05	PGE/SCG	0%	0%	6	0	$1	$17	$132	$132	0.1	($114)	0.4	($73)
CZ06	SCE/SCG	0%	0%	12	0	$2	$51	$132	$132	0.4	($81)	1.4	$49
CZ07	SDGE	0%	0%	10	0	$0	$0	$132	$132	0.0	($132)	0.9	($7)
CZ08	SCE/SCG	1%	0%	24	0	$8	$184	$132	$132	1.4	$53	2.2	$152
CZ09	SCE	1%	0%	28	0	$4	$96	$142	$149	0.6	($52)	2.1	$163
CZ10	SCE/SCG	2%	1%	66	0	$21	$491	$186	$192	2.6	$298	3.2	$425
CZ10	SDGE	2%	1%	66	0	$30	$751	$186	$192	3.9	$558	3.2	$425
CZ11	PGE	2%	1%	83	0	$29	$665	$186	$192	3.5	$473	4.2	$621
CZ12	PGE	2%	0%	84	0	$29	$681	$321	$414	1.6	$267	2.3	$546
CZ12	SMUD/PGE	2%	0%	84	0	$16	$372	$321	$414	0.9	($42)	2.3	$546
CZ13	PGE	2%	1%	95	0	$33	$765	$186	$192	4.0	$573	4.9	$742
CZ14	SCE/SCG	2%	1%	75	0	$11	$246	$186	$192	1.3	$54	3.9	$561
CZ14	SDGE	2%	1%	75	0	$34	$847	$186	$192	4.4	$654	3.9	$561
CZ15	SCE/SCG	3%	2%	172	0	$55	$1,257	$186	$192	6.5	$1,065	7.3	$1,212
CZ16	PG&E	2%	2%	40	4	$23	$616	$665	$665	0.9	($49)	0.999	($0)

4.4 Mixed Fuel Plus PV (Plus Battery for the 3-Story Prototype)

Table 18 presents the Mixed Fuel Efficiency + PV + Battery package for the 3-story prototype. The battery system is a 100kWh battery. This scenario is cost-effective for all climate zones and under both metrics except for On-Bill in Climate Zone 4 in CPAU territory. Table 19 presents the Mixed Fuel Efficiency + PV package for the 5-story prototype. This package is cost-effective under TDV in all climate zones and cost-effective On-Bill everywhere except in Climate Zones 6 and 7. In the cases where it is not cost-effective, it is very close to being so with small negative NPV. In Climate Zone 6 in the 5-story prototype there is no upgrade to the PV system capacity as the prescriptive PV system already offset all of the estimated electricity use.

Table 18. 3-Story Cost-Effectiveness Results per Dwelling Unit: Mixed Fuel Efficiency + PV + Battery

Climate Zone	Electric /Gas Utility	Efficiency TDV Comp Margin	Source Comp Margin	Annual Elec Savings (kWh)	Annual Gas Savings (therms)	Utility Cost Savings		Incremental Cost		On-Bill		TDV	
						First Year	Lifecycle (2022$)	First Year	Lifecycle (2022$)	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	1%	16%	2,068	0	$543	$12,588	$4,603	$6,917	1.8	$5,671	1.5	$3,724
CZ02	PGE	1%	16%	1,757	0	$462	$10,718	$3,881	$5,990	1.8	$4,728	1.6	$3,820
CZ03	PGE	1%	17%	1,624	0	$423	$9,797	$3,700	$5,754	1.7	$4,043	1.5	$3,157
CZ04	PGE	1%	17%	1,476	0	$383	$8,878	$3,518	$5,518	1.6	$3,360	1.6	$3,067
CZ04	CPAU	1%	17%	1,476	0	$171	$3,967	$3,518	$5,518	0.7	($1,551)	1.6	$3,067
CZ05	PGE	1%	18%	1,520	0	$393	$9,107	$3,503	$5,498	1.7	$3,609	1.6	$3,526
CZ05	PGE/SCG	1%	18%	1,520	0	$393	$9,107	$3,503	$5,498	1.7	$3,609	1.6	$3,526
CZ06	SCE/SCG	1%	18%	1,112	0	$336	$7,677	$3,127	$5,009	1.5	$2,668	1.4	$1,917
CZ07	SDGE	0%	20%	1,431	0	$550	$13,713	$3,498	$5,493	2.5	$8,220	1.6	$3,159
CZ08	SCE/SCG	1%	18%	1,311	0	$413	$9,427	$3,328	$5,270	1.8	$4,156	1.4	$2,277
CZ09	SCE	1%	17%	1,129	0	$367	$8,375	$3,129	$5,017	1.7	$3,359	1.4	$1,937
CZ10	SCE/SCG	3%	19%	1,342	0	$420	$9,584	$3,321	$5,254	1.8	$4,331	1.5	$2,588
CZ10	SDGE	3%	19%	1,342	0	$533	$13,303	$3,321	$5,254	2.5	$8,049	1.5	$2,588
CZ11	PGE	3%	17%	1,833	0	$500	$11,587	$3,914	$6,025	1.9	$5,562	1.6	$3,852
CZ12	PGE	2%	17%	1,701	0	$442	$10,239	$3,926	$6,105	1.7	$4,133	1.6	$3,583
CZ12	SMUD/PGE	2%	17%	1,701	0	$285	$6,609	$3,926	$6,105	1.1	$503	1.6	$3,583
CZ13	PGE	4%	17%	1,568	0	$431	$9,983	$3,594	$5,609	1.8	$4,374	1.7	$3,944
CZ14	SCE/SCG	3%	19%	1,556	0	$477	$10,886	$3,388	$5,341	2.0	$5,545	1.6	$3,434
CZ14	SDGE	3%	19%	1,556	0	$607	$15,155	$3,388	$5,341	2.8	$9,815	1.6	$3,434
CZ15	SCE/SCG	5%	19%	1,241	0	$421	$9,616	$3,136	$5,013	1.9	$4,603	1.6	$3,076
CZ16	PG&E	5%	17%	1,286	12	$357	$8,508	$3,894	$5,833	1.5	$2,674	1.6	$3,219

Table 19. 5-Story Cost-Effectiveness Results per Dwelling Unit: Mixed Fuel Efficiency + PV

Climate Zone	Electric /Gas Utility	Efficiency TDV Comp Margin	Source Comp Margin	Annual Elec Savings (kWh)	Annual Gas Savings (therms)	Utility Cost Savings		Incremental Cost		On-Bill		TDV	
						First Year	Lifecycle (2022$)	First Year	Lifecycle (2022$)	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	0%	5%	1,446	0	$341	$7,917	$1,889	$2,403	3.3	$5,514	3.0	$4,757
CZ02	PGE	1%	2%	444	0	$55	$1,275	$567	$697	1.8	$578	4.4	$2,365
CZ03	PGE	0%	4%	693	0	$119	$2,766	$801	$1,002	2.8	$1,764	4.4	$3,423
CZ04	PGE	1%	1%	112	0	$14	$324	$226	$254	1.3	$69	3.5	$632
CZ04	CPAU	1%	1%	112	0	$13	$307	$226	$254	1.2	$53	3.5	$632
CZ05	PGE	0%	3%	464	0	$56	$1,310	$550	$676	1.9	$634	4.2	$2,165
CZ05	PGE/SCG	0%	3%	464	0	$56	$1,310	$550	$676	1.9	$634	4.2	$2,165
CZ06	SCE/SCG	0%	0%	12	0	$2	$51	$132	$132	0.4	($81)	1.4	$49
CZ07	SDGE	0%	1%	95	0	$0	$0	$212	$237	0.0	($237)	2.8	$423
CZ08	SCE/SCG	1%	3%	299	0	$42	$968	$388	$465	2.1	$504	4.3	$1,527
CZ09	SCE	1%	1%	99	0	$12	$284	$204	$230	1.2	$54	3.0	$465
CZ10	SCE/SCG	2%	3%	364	0	$57	$1,296	$450	$536	2.4	$759	4.2	$1,720
CZ10	SDGE	2%	3%	364	0	$103	$2,566	$450	$536	4.8	$2,030	4.2	$1,720
CZ11	PGE	2%	7%	1,178	0	$281	$6,521	$1,276	$1,610	4.1	$4,911	4.8	$6,162
CZ12	PGE	2%	4%	683	0	$120	$2,791	$898	$1,164	2.4	$1,627	4.2	$3,716
CZ12	SMUD/PGE	2%	4%	683	0	$102	$2,362	$898	$1,164	2.0	$1,198	4.2	$3,716
CZ13	PGE	2%	7%	1,137	0	$274	$6,347	$1,179	$1,484	4.3	$4,863	4.8	$5,599
CZ14	SCE/SCG	2%	2%	266	0	$33	$748	$342	$395	1.9	$353	4.7	$1,447
CZ14	SDGE	2%	2%	266	0	$62	$1,554	$342	$395	3.9	$1,158	4.7	$1,447
CZ15	SCE/SCG	3%	5%	567	0	$125	$2,851	$535	$646	4.4	$2,204	5.6	$2,994
CZ16	PG&E	2%	6%	1,051	4	$237	$5,569	$1,601	$1,883	3.0	$3,686	3.1	$4,011

4.5 CARE Rate Comparison

Table 20 presents a comparison of On-Bill cost-effectiveness results for CARE tariffs relative to standard tariffs for the all-electric prescriptive code case. The CARE rates apply to the apartment meters only and don't impact the central water heating utility costs. Applying the CARE rates lowers both electric and gas utility bills for the consumer and the net impact for an all-electric building in most climate zones is lower overall bills and improved cost-effectiveness relative to the standard tariffs. Although not presented here, the all-electric + PV packages are all still On-Bill cost-effective using the CARE tariffs.

Table 20. On-Bill IOU Cost-Effectiveness Comparison with CARE Tariffs, Results per Dwelling Unit: All-Electric Prescriptive Code

Climate Zone	Electric /Gas Utility	3-Story				5-Story			
		Standard		CARE		Standard		CARE	
		B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	3.9	$1,247	9.5	$3,637	>1	$6,998	>1	$10,045
CZ02	PGE	1.0	$32	3.1	$2,139	0.7	($375)	2.5	$1,831
CZ03	PGE	1.1	$119	3.1	$2,187	0.7	($407)	2.6	$1,901
CZ04	PGE	0.9	($108)	2.8	$1,884	1.8	$945	2.9	$2,218
CZ05	PGE	0.98	($21)	3.0	$2,041	0.6	($479)	2.5	$1,773
CZ05	PGE/SCG	0.0	($1,545)	1.5	$517	0.0	($2,103)	1.1	$148
CZ06	SCE/SCG	0.0	($1,255)	0.9	($57)	0.8	($199)	2.1	$1,349
CZ07	SDGE	0.0	($1,456)	1.8	$856	0.0	($1,685)	1.3	$343
CZ08	SCE/SCG	0.0	($1,331)	0.8	($165)	0.0	($1,829)	1.2	$271
CZ09	SCE	0.0	($1,380)	0.8	($204)	0.0	($1,236)	1.6	$750
CZ10	SCE/SCG	0.0	($1,758)	0.1	($574)	0.0	($2,445)	0.5	($447)
CZ10	SDGE	0.0	($2,452)	0.8	($162)	0.0	($3,234)	0.0	($1,590)
CZ11	PGE	0.0	($826)	2.7	$1,119	0.0	($1,494)	1.7	$616
CZ12	PGE	0.0	($719)	2.9	$1,263	0.0	($1,358)	2.0	$793
CZ13	PGE	0.0	($940)	2.4	$936	0.0	($1,517)	1.6	$491
CZ14	SCE/SCG	0.0	($2,063)	0.0	($803)	0.0	($2,916)	0.3	($613)
CZ14	SDGE	0.0	($2,841)	0.0	($3,407)	0.0	($3,937)	1.1	$61
CZ15	SCE/SCG	0.0	($2,053)	0.0	($1,036)	0.0	($2,606)	0.0	($1,452)
CZ16	PG&E	2.8	$1,917	>1	$5,527	9.1	$5,467	>1	$8,557

Error! Not a valid bookmark self-reference. presents the comparison for the mixed fuel efficiency and PV packages. Generally, the opposite trend occurs here for the mixed fuel packages where the CARE rate lowers utility cost savings and the benefit-to-cost ratios decline.

Table 21. On-Bill IOU Cost-Effectiveness Comparison with CARE Tariffs, Results per Dwelling Unit: Mixed Fuel Packages

Climate Zone	Electric /Gas Utility	3-Story (Efficiency + PV + Battery)				5-Story (Efficiency + PV)			
		Standard		CARE		Standard		CARE	
		B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	1.8	$5,671	1.2	$1,113	3.3	$5,514	2.2	$2,765
CZ02	PGE	1.8	$4,728	1.2	$907	1.8	$578	1.5	$337
CZ03	PGE	1.7	$4,043	1.1	$579	2.8	$1,764	2.0	$1,028
CZ04	PGE	1.6	$3,360	1.0	$259	1.3	$69	0.8	($44)
CZ05	PGE	1.7	$3,609	1.1	$414	1.9	$634	1.7	$442
CZ05	PGE/SCG	1.7	$3,609	1.1	$414	1.9	$634	1.7	$442
CZ06	SCE/SCG	1.5	$2,668	0.9	($515)	0.4	($81)	0.3	($92)
CZ07	SDGE	2.5	$8,220	1.7	$4,106	0.0	($237)	0.0	($237)
CZ08	SCE/SCG	1.8	$4,156	1.1	$446	2.1	$504	1.3	$137
CZ09	SCE	1.7	$3,359	0.99	($26)	1.2	$54	0.9	($28)
CZ10	SCE/SCG	1.8	$4,331	1.1	$577	2.4	$759	1.3	$180
CZ10	SDGE	2.5	$8,049	1.8	$4,180	4.8	$2,030	0.0	($536)
CZ11	PGE	1.9	$5,562	1.2	$1,435	4.1	$4,911	2.7	$2,744
CZ12	PGE	1.7	$4,133	1.1	$517	2.4	$1,627	1.8	$905
CZ13	PGE	1.8	$4,374	1.2	$883	4.3	$4,863	2.9	$2,777
CZ14	SCE/SCG	2.0	$5,545	1.3	$1,395	1.9	$353	1.3	$136
CZ14	SDGE	2.8	$9,815	1.4	$2,292	3.9	$1,158	0.0	($395)
CZ15	SCE/SCG	1.9	$4,603	1.2	$887	4.4	$2,204	1.9	$586
CZ16	PG&E	1.5	$2,674	0.97	($162)	3.0	$3,686	2.0	$1,908

4.6 Greenhouse Gas Reductions

Figure 1 and Figure 2 compare greenhouse gas reductions across all the packages for the multifamily 3-story and 5-story prototypes, respectively. Savings represent average annual savings per dwelling unit over the 30-year lifetime of the analysis. Electrification of gas uses represents the greatest greenhouse gas reductions, followed by PV. Greenhouse gas reductions are greatest for the all-electric + PV package.

Figure 1. 3-Story greenhouse gas reductions (metric tons) per dwelling unit

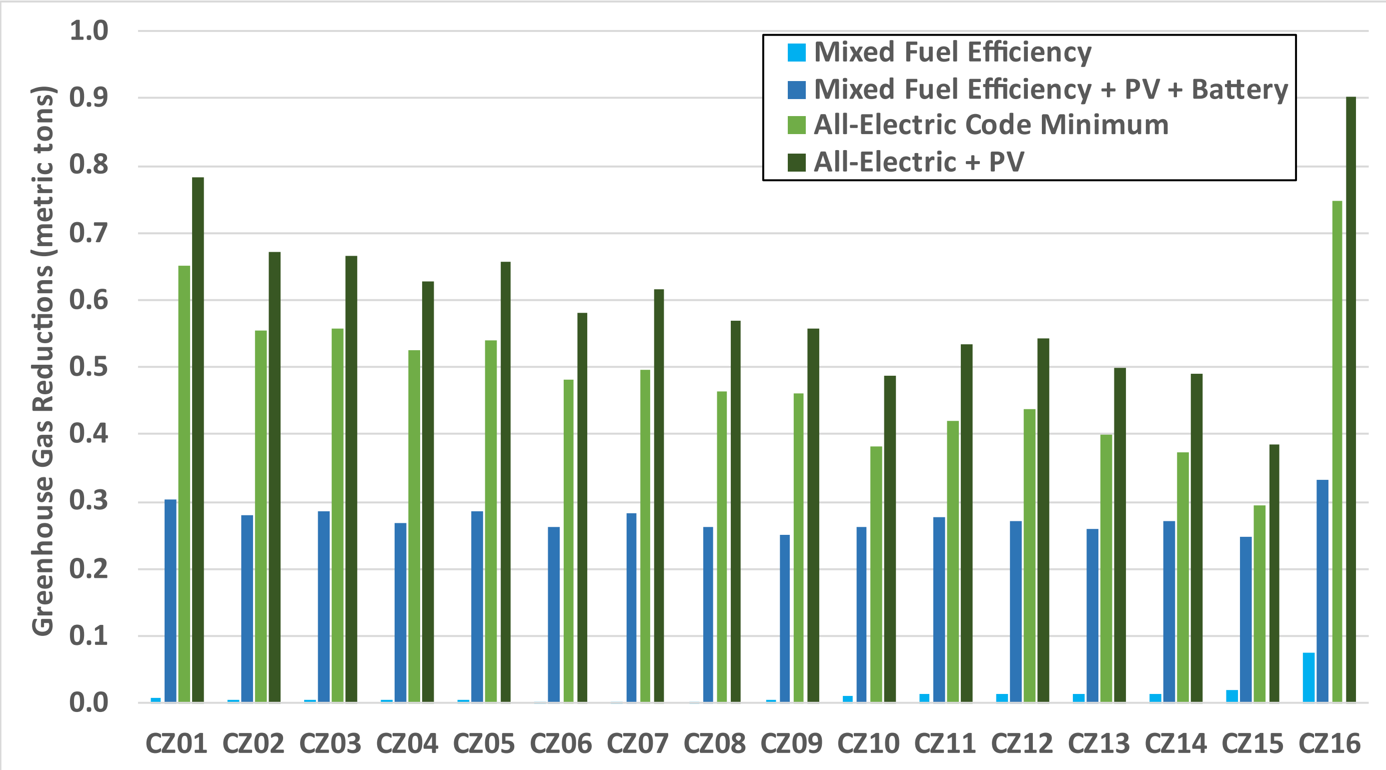
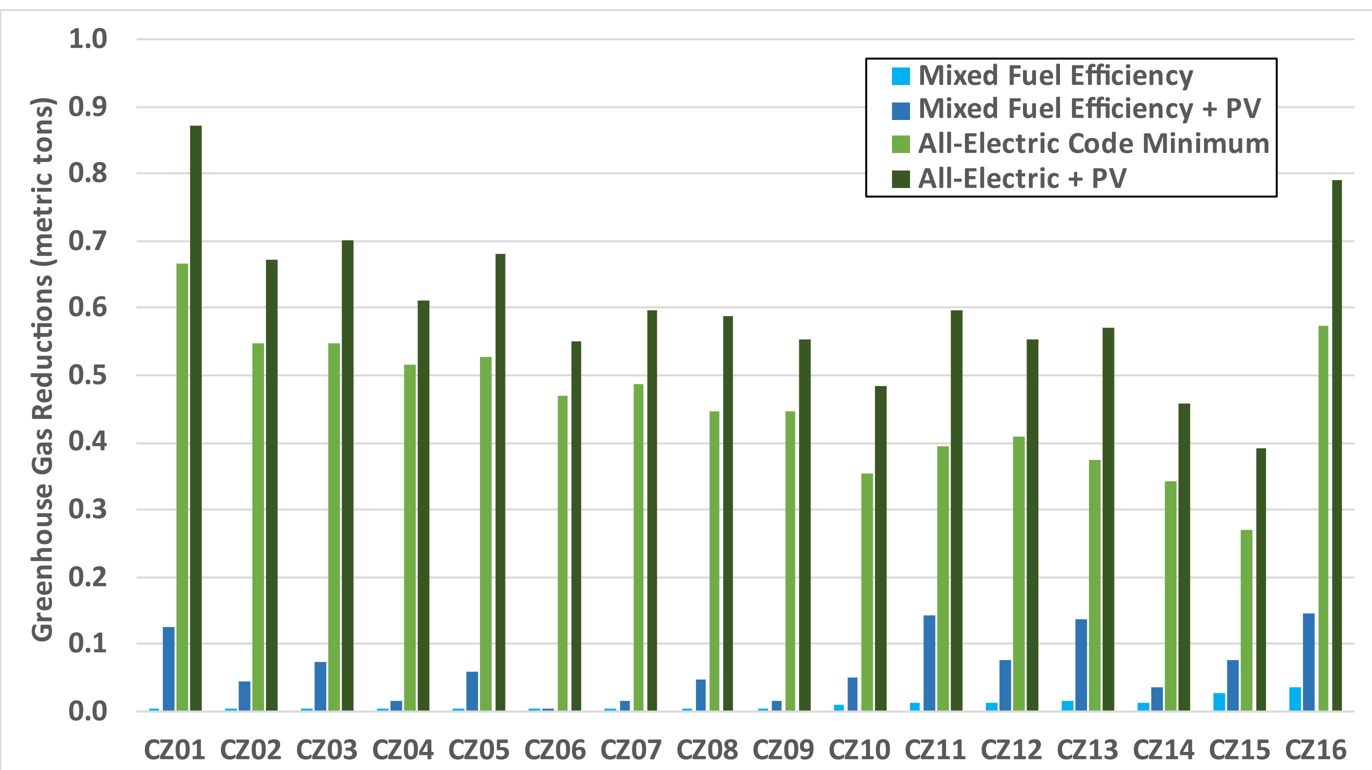


Figure 2. 5-Story greenhouse gas savings (metric tons) per dwelling unit



5 Summary

The Reach Codes Team identified packages of electrification and energy efficiency measures as well as packages combining these measures with solar PV generation and battery storage, simulated them using building modeling software, and gathered costs to determine the cost-effectiveness of multiple scenarios. The Reach Codes Team coordinated with multiple utilities, cities, and building community experts to develop a set of assumptions considered reasonable in the current market. Changing assumptions, such as the period of analysis, measure selection, cost assumptions, energy escalation rates, or utility tariffs are likely to change results.

Table 22 summarizes results for each prototype and depicts the efficiency TDV compliance margins achieved for each climate zone and package. Because local reach codes must both exceed the Energy Commission performance budget (i.e., have a positive compliance margin) and be cost-effective, the Reach Codes Team highlighted cells meeting these two requirements to help clarify the upper boundary for potential reach code policies. All results presented in this study have a positive compliance margin.

- Cells highlighted in **green** depict cases with a positive compliance margin and cost-effective results using both On-Bill and TDV approaches.
- Cells highlighted in **yellow** depict cases with a positive compliance margin and cost-effective results using either the On-Bill or TDV approach.
- Cells **not highlighted** depict cases with a positive compliance margin but that were not cost-effective using either the On-Bill or TDV approach.

Following are key takeaways and recommendations from the analysis.

- The Reach Codes Team found all-electric new construction to be feasible and cost-effective based on the California Energy Commission's Time Dependent Valuation (TDV) metric in all cases. In many cases all-electric prescriptive code construction results in an increase in utility costs and is not cost-effective On-Bill. Some exceptions include the SMUD and CPAU territories where lower electricity rates relative to gas rates result in lower overall utility bills.
- All-electric packages have lower GHG emissions than mixed fuel packages in all cases, due to the clean power sources currently available from California's power providers.
- The 2022 Energy Code's new source energy metric combined with the heat pump space heating baseline in most climate zones encourages all-electric construction. While the code does not include an electric baseline for water heating, the penalty for central electric water heating observed in the performance approach in past code cycles has been removed and a credit is provided for well-designed central heat pump water heaters in most cases.
- Electrification combined with increased PV capacity results in utility cost savings and was found to be On-Bill cost-effective in all cases.
- The results in this study are based on today's net energy metering (NEM 2.0) rules and do not account for recently approved changes to the NEM tariff (referred to as the net billing tariff). The net billing tariff decreases the value of PV to the consumer as compared to NEM 2.0. As a result, the cost-effectiveness of the packages that include above-code PV capacity is expected to be less under the net billing tariff. Conversely, the net billing tariff is expected to increase On-Bill cost-effectiveness of the all-electric prescriptive code scenario. An all-electric home has better on-site utilization of generated electricity from PV than a mixed fuel home with a similar sized PV system, and as a result exports less electricity to the grid. Since the net-billing tariff values exports less than under NEM 2.0, the relative impact on annual utility costs to the mixed fuel baseline is greater.
- This analysis does justify requiring a modest reach based on either efficiency TDV or source energy for all-electric buildings. However, this may be challenging for some projects given the recent changes to which the industry must adapt, including the efficiency updates and multifamily restructuring in the 2022 Title 24, Part 6 code. While project compliance margins using a CO_2 refrigerant heat pump water heating system are high, the Reach Code Team found lower compliance margins using other heat pump water heater system designs.

Focusing on supporting projects to electrify water heating is expected to support the market shift towards more central heat pump water heaters.

- For jurisdictions interested in a reach code that allows for mixed fuel buildings, a mixed fuel efficiency and PV package (and battery for the 3-story prototype) was found to be cost-effective based on TDV in all cases and cost-effective On-Bill in most climate zones. This path, referred to as "Electric-Preferred", allows for mixed fuel buildings but requires a higher building performance than for all-electric buildings. The efficiency measures evaluated in this study did not provide significant compliance benefit. As a result, the Reach Codes Team recommends establishing a compliance margin target based on source energy or total TDV. This would allow for PV and battery above minimum code requirements to be used to meet the target.
- Jurisdictions interested in increasing affordable multifamily housing should know that applying the CARE rates has the overall impact of increasing utility cost savings for an all-electric building in most climate zones compared to a code compliant mixed fuel building, improving On-Bill cost-effectiveness.

Local jurisdictions may also adopt ordinances that amend different parts of the California Building Standards Code or may elect to amend other state or municipal codes. The decision regarding which code to amend will determine the specific requirements that must be followed for an ordinance to be legally enforceable. Reach codes that amend Part 6 of the California Building Code and require energy performance beyond state code minimums must demonstrate the proposed changes are cost-effective and obtain approval from the Energy Commission.

Table 22. Summary of Efficiency TDV Compliance Margins and Cost-Effectiveness

Climate Zone	Electric /Gas Utility	3-Story				5-Story			
		All-Electric Prescriptive Code	All-Electric + PV	Mixed Fuel Efficiency	Mixed Fuel Efficiency + PV + Battery	All-Electric Prescriptive Code	All-Electric + PV	Mixed Fuel Efficiency	Mixed Fuel Efficiency + PV
CZ01	PGE	26%	26%	1%	1%	14%	14%	0%	0%
CZ02	PGE	20%	20%	1%	1%	9%	9%	1%	1%
CZ03	PGE	21%	21%	1%	1%	11%	11%	0%	0%
CZ04	PGE	18%	18%	1%	1%	9%	9%	1%	1%
CZ04	CPAU	18%	18%	1%	1%	9%	9%	1%	1%
CZ05	PGE	23%	23%	1%	1%	12%	12%	0%	0%
CZ05	PGE/SCG	23%	23%	1%	1%	12%	12%	0%	0%
CZ06	SCE/SCG	18%	18%	1%	1%	9%	9%	0%	0%
CZ07	SDGE	20%	20%	0%	0%	11%	11%	0%	0%
CZ08	SCE/SCG	13%	13%	1%	1%	8%	8%	1%	1%
CZ09	SCE	13%	13%	1%	1%	7%	7%	1%	1%
CZ10	SCE/SCG	14%	14%	3%	3%	7%	7%	2%	2%
CZ10	SDGE	14%	14%	3%	3%	7%	7%	2%	2%
CZ11	PGE	14%	14%	3%	3%	8%	8%	2%	2%
CZ12	PGE	17%	17%	2%	2%	9%	9%	2%	2%
CZ12	SMUD/PGE	17%	17%	2%	2%	9%	9%	2%	2%
CZ13	PGE	13%	13%	4%	4%	7%	7%	2%	2%
CZ14	SCE/SCG	13%	13%	3%	3%	6%	6%	2%	2%
CZ14	SDGE	13%	13%	3%	3%	6%	6%	2%	2%
CZ15	SCE/SCG	5%	5%	5%	5%	3%	3%	3%	3%
CZ16	PG&E	24%	24%	5%	5%	9%	9%	2%	2%

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The adoption of reach codes can differentiate jurisdictions as efficiency leaders and help accelerate the adoption of new equipment, technologies, code compliance, and energy savings strategies.

As part of the Statewide Codes & Standards Program, the Reach Codes Subprogram is a resource available to any local jurisdiction located throughout the state of California.

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2022 Code:

Nonresidential New Construction Reach Code Cost-effectiveness Study

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Legal Notice

Acronym List

AC – Air Conditioner

ASHRAE - American Society of Heating, Refrigerating and Air-Conditioning Engineers

B/C – Benefit-to-Cost Ratio

BOD – Basis of Design

BSC – Building Standards Commission

Btu – British thermal unit

CAV – Constant Air Volume

CBECC - California Building Energy Code Compliance

CBECS - Commercial Building Energy Consumption Survey

CBSC - California Building Standards Commission

CEC - California Energy Commission

CPAU – City of Palo Alto Utilities

CZ – Climate Zone

DCKV – Demand-Controlled Kitchen Ventilation

DHW – Domestic Hot Water

DEER – Database for Energy Efficient Resources

DOE – U.S. Department of Energy

E3 – Energy and Environmental Economics

EUI – Energy Use Index

FDD – Fault Detection and Diagnostics

GHG - Greenhouse Gas

GPM – Gallons Per Minute

HVAC – Heating, Ventilation, and Air Conditioning

IOU – Investor-Owned Utility

kWh – Kilowatt Hour

LADWP – Los Angeles Department of Water and Power

LBNL – Lawrence Berkeley National Lab

LPD – Lighting Power Density

NPV – Net Present Value

QSR – Quick-Service Restaurant

PNNL – Pacific Northwest National Laboratory

POU – Publicly Owned Utility

PTHP – Packaged Terminal Heat Pump

PG&E – Pacific Gas & Electric (utility)

PTAC – Packaged Terminal Air Conditioning

PV - Solar Photovoltaic

SCE – Southern California Edison (utility)

SCG – Southern California Gas (utility)

SDG&E – San Diego Gas & Electric (utility)

SHW – Service Hot Water

SMUD – Sacramento Municipal Utility District

SZ – Single Zone

TDV – Time Dependent Valuation

VAV – Variable Air Volume

TDV - Time Dependent Valuation

Title 24 – California Code of Regulations Title 24, Part 6

TOU – Time of Use

Summary of Revisions

Date	Description	Reference (page or section)
11/16/2022	Original Release	-
01/31/2023	Minor changes to reflect efficiency compliance margin calculation updates in workbook and report tables	Section 5
03/24/2023	Minor changes in narrative of quick service restaurant in reach code considerations	Section 5

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Executive Summary

The California Codes and Standards (C&S) Reach Codes program provides technical support to local governments considering adopting a local ordinance, also known as a reach code, intended to support meeting local and/or statewide energy efficiency and greenhouse gas (GHG) reduction goals. The program facilitates the adoption and implementation of reach codes when requested by local jurisdictions by providing resources such as cost-effectiveness studies, model language, sample findings, and other supporting documentation.

The Reach Code Team (the Team) provides this report and accompanying Reach Code Results Workbook to present measures and measure packages that local jurisdictions can adopt to achieve energy savings and emissions reductions beyond what will be accomplished by enforcing the minimum state requirements according to the 2022 Building Energy Efficiency Standards (Title 24, Part 6), effective January 1, 2023. This report documents a variety of above-code electrification, energy efficiency, load flexibility, and solar photovoltaic (PV) packages applied to a set of four nonresidential building prototypes: Medium Office, Standalone Retail, Quick-Service Restaurant, and Small Hotel.

The Team evaluated energy simulation results and code compliance using the CBECC v1.0 software version released in June 2022. Results may change with future software versions. Results across all prototypes indicate the efficiency measures included in the analysis, both On-Bill and TDV, are cost-effective across all climate zones when added to the prescriptive baseline prototype. In all cases all-electric packages are capable of achieving the greatest greenhouse gas emissions reductions as compared to mixed-fuel buildings.

These results, including the attached Reach Code Results Workbook, indicate that all-electric packages can achieve the greatest greenhouse gas emissions reductions as compared to mixed-fuel buildings. Results align with the decarbonization objectives set by California Energy Commission (Energy Commission), and several new construction new construction ordinances focusing on all-electric design. The results of this study by prototype are summarized below:

Medium Office: Due to the lack of a prescriptive compliance pathway and performance modeling approach in CBECC, all-electric space heating is simulated as electric-resistance variable-air-volume reheat. This system selection limits operational benefits, energy code compliance, and cost-effectiveness. All-electric packages are cost-effective with energy efficiency and load flexibility measures in many climate zones, but do not achieve code compliance across all three metrics—with efficiency TDV margin being the most challenging. Results will be updated in the first half of 2023 when central heat pump boilers can be simulated in CBECC. Jurisdictions may adopt reach codes that exempt building systems that do not have a prescriptive pathway in the energy code and cannot be modeled to comply using the performance approach. Efficiency packages over the mixed-fuel baseline are cost-effective and compliant across all climate zones.

Medium Retail: All-electric is prescriptively required in most scenarios in Retail buildings. The Team identified cost-effective and code compliant packages with energy efficiency measures over an all-electric baseline in most climate zones. This study analyzed mixed-fuel retail buildings with large (>240 kBtuh) gas furnace packaged units replacing the smaller (<240 kBtuh) packaged heat pumps. The mixed-fuel building is neither cost-effective nor code compliant in most climate zones.

Quick-Service Restaurant: The Team identified cost-effective, *nearly* cost-effective, and code compliant packages in several climate zones for all-electric space conditioning and service water heating when including energy efficiency and solar PV measures. The Team could not identify cost-effective packages including all-electric commercial cooking equipment except for City of Palo Alto Utility (CPAU) territory. Also, when including energy efficiency measures, restaurants with all-electric cooking achieve compliance and are *nearly* On-Bill cost-effective in Sacramento Municipal Utility District (SMUD) territory as well. Jurisdictions may adopt All-Electric reach codes that exempt commercial cooking equipment or require energy efficiency for either mixed-fuel and/or all-electric buildings, in many climate zones.

Small Hotel: All-electric packages are cost-effective and code-compliant in most climate zones. The remaining climate zones are very close to meeting the TDV Efficiency compliance criteria and may achieve compliance by re-evaluating nonresidential-area modeling using central heat pump boiler instead of electric resistance VAV systems. In addition to electrification packages that include single-zone packaged heat pumps, the Team analyzed an alternative scenario with packaged terminal heat pumps (PTHPs) that improved all-electric code minimum cost-effectiveness due to high first-cost savings, but PTHPs do not achieve TDV Efficiency compliance. Mixed-fuel plus energy efficiency is code compliant and cost-effective across all climate zones.

Jurisdictions may use these results for amending Part 6, Part 11, other parts of the California building code, or their municipal code as determined appropriate for the given jurisdiction. A cost-effectiveness study is required to amend Part 6 of the California building code or when adopting energy efficiency or energy conservation measures, including solar PV or batteries. The Energy Commission has previously concluded that all-electric requirements do not constitute an energy efficiency or energy conservation standard and are outside the scope of Public Resources Code section 25402.1(h)(2).[1] Jurisdictions may adopt an All-Electric reach code when amending Part 11 or their municipal code. Even reach code policies that only require electrification, and do not require energy efficiency or conservation, will benefit from findings in this study to inform potential economic impacts of a policy decision. This study documents the estimated costs, benefits, energy impacts and GHG emission reductions that may result from implementing an ordinance based on the results to help residents, local leadership, and other stakeholders make informed policy decisions.

Model ordinance language and other resources are posted on the C&S Reach Codes Program website at www.localenergycodes.com. Local jurisdictions that are considering adopting an ordinance are encouraged to contact the program for further technical support at info@localenergycodes.com.

[1] CEC Letter to South San Francisco 2021: https://bayareareachcodes.org/wp-content/uploads/2022/10/CEC-Letter-to-SSF-Signed.pdf

1 Introduction

This report documents cost-effective combinations of measures that exceed the minimum state requirements, the 2022 California Building Energy Efficiency Standards Title 24, Part 6 (Title 24) (CEC 2022), effective January 1, 2023, for newly constructed nonresidential buildings. This report was developed in coordination with the California Statewide Investor-Owned Utilities (CA IOUs) Codes and Standards Program, key consultants, and engaged cities—collectively known as the Reach Code Team (or "the Team" for short). The objectives of this report are to inform discourse for local reach code adoption and, where applicable, support approval of local energy code amendments from the California Energy Commission (the Energy Commission).

The Reach Code Team performed cost-effectiveness analysis for the following scenarios above prescriptive 2022 Title 24 code requirements in all 16 California climate zones (CZs):

- Fuel substitution with federal code-minimum efficiency appliances, compared to a prescriptive minimum design compliance pathway.
    - For the retail building type, the prescriptive code minimum is all-electric. Fuel substitution packages revert to mixed-fuel appliances.
    - For all other building types, the prescriptive code minimum is mixed-fuel. Fuel substitution packages switch to all-electric appliances.
- Energy efficiency measures
- Load flexibility measures
- Solar PV and Battery

The Reach Code Team analyzed four prototypes—Medium Office, Medium Retail, Quick-Service Restaurant, and Small Hotel—to represent common nonresidential new construction buildings in the California. The selected building types align with the requests received from dozens of jurisdictions seeking to adopt reach codes. The results of this cost-effectiveness study could potentially be extrapolated to other building types that have similar properties such as occupancy pattern, HVAC design and layout. These results were attained using the first version of California Building Energy Compliance Calculator (CBECC) software that is approved by CEC for 2022 code compliance. There are a few gaps in functionalities and standard design assumptions in this software version, described in Section 2.5, the Reach Code team has been actively coordinating with the CBECC software team to inform future software updates.

Title 24 is maintained and updated every three years by two state agencies: the Energy Commission and the Building Standards Commission (BSC). In addition to enforcing the code, local jurisdictions have the authority to adopt local energy efficiency ordinances—or reach codes—that exceed the minimum standards defined by Title 24 (as established by Public Resources Code Section 25402.1(h)2 and Section 10-106 of the Building Energy Efficiency Standards). When adopting local energy efficiency or conservation ordinances, local jurisdictions must demonstrate that the requirements of the proposed ordinance are cost-effective and do not result in buildings consuming more energy than is permitted by Title 24. In addition, the jurisdiction must obtain formal approval from the Energy Commission and file the ordinance with the BSC for the ordinance to be legally enforceable. Local jurisdictions do not require Energy Commission approval when adopting ordinances that do not require efficiency or conservation, such as only electrification-required ordinances.

The Department of Energy (DOE) sets minimum efficiency standards for equipment and appliances that are federally regulated under the National Appliance Energy Conservation Act, including heating, cooling, and water heating equipment (E-CFR 2020). Since state and local governments are prohibited from adopting higher minimum equipment efficiencies than the federal standards require, the focus of this study is to identify and evaluate cost-effective packages that do not include high efficiency heating, cooling, and water heating equipment. High efficiency appliances are often the easiest and most affordable measures to increase energy performance. While federal preemption limits reach code mandatory requirements for covered appliances, in practice, builders may install any package of compliant measures to achieve the performance requirements.

This study references the statewide reach code study performed in 2019 for newly constructed nonresidential buildings as a starting point for additional measure definitions. Importantly, the current 2022 cost-effectiveness report introduced a new restaurant building type and updated the modeling and cost assumptions.

2 Methodology and Assumptions

The Reach Code Team analyzed four prototypes—Medium Office, Medium Retail, Quick-Service Restaurant, and Small Hotel—using the cost-effectiveness methodology detailed in this section below.

2.1 Cost-effectiveness

This section describes the approach to calculating cost-effectiveness including benefits, costs, metrics, and utility rate selection.

2.1.1 Benefits

This analysis used both On-Bill and time dependent valuation (TDV) of energy-based approaches to evaluate cost-effectiveness. Both On-Bill and TDV require estimating and quantifying the energy savings and costs associated with energy measures. The primary difference between On-Bill and TDV is how energy is valued:

- **On-Bill:** Customer-based lifecycle cost approach that values energy based upon estimated site energy usage and customer On-Bill savings using electricity and natural gas utility rate schedules over a 15-year duration accounting for a three percent discount rate and energy cost inflation per Appendix 8.2.
- **TDV:** TDV was developed by the Energy Commission to reflect the time dependent value of energy, including long-term projected costs of energy such as the cost of providing energy during peak periods of demand and other societal costs including projected costs for carbon emissions and grid transmission impacts. This metric values energy uses differently depending on the fuel source (gas, electricity, and propane), time of day, and season. Electricity used (or saved) during peak periods has a much higher value than electricity used (or saved) during off-peak periods. This refers to the "Total TDV" that includes all the energy end uses such as space-conditioning, mechanical ventilation, service water heating indoor lighting, photovoltaic (PV) and battery storage systems, and covered process loads.

2.1.2 Costs

The Reach Code Team assessed the incremental costs and savings of the energy packages over a 15 year lifecycle. Incremental costs represent the equipment, installation, replacements, and maintenance costs of the proposed measure relative to the 2022 Title 24 standards minimum requirements or standard industry practices. The Reach Code Team obtained baseline and measure costs from manufacturer distributors, contractors, literature review, and online sources such as RS Means.

For heating, ventilation, and air conditioning (HVAC) and water heating baseline and measure costs, including gas and electrical infrastructure, the Reach Code Team contracted two different firms, one mechanical contractor (Western Allied Mechanical, based in Menlo Park) and one mechanical designer (P2S Engineering, based in Irvine) to provide cost data. The Reach Code Team developed a basis of design for all prototypes described in section 3.1 and worked with the mechanical contractor and designer to get cost estimates. The Reach Code Team determined HVAC design heating and cooling loads and capacities by climate zone from the energy models. For each HVAC system type, the Reach Code Team requested costs for the smallest capacity unit required and the largest capacity unit required and specified federal minimum equipment efficiency.

The mechanical contractor and mechanical designer collected equipment costs and labor assumptions from their vendors and manufacturers' representatives, as well as through their own recent projects. The mechanical contractor and designer provided material and labor cost estimates for the entire HVAC and DHW systems, disaggregated by the HVAC and DHW equipment itself; refrigerant piping; structural; electrical supply; gas supply; controls; commissioning and startup; general conditions and overhead; design and engineering; permit, testing, and inspection; and a contractor profit or market factor. The mechanical contractor and designer provided costs for each of the system capacities, based on which the Reach Code Team developed a relationship between HVAC system capacity and cost to calculate the cost for each building in each climate zone. In most cases, the analysis uses the average of the costs provided by the contractor and the costs provided by the designer. In some limited cases where costs provided by one source were unlikely to be representative of the measure, costs from only the other source were used. The Reach Code Team added taxes, contractor markups, maintenance costs, and replacement costs where needed, and adjusted material and labor costs for each climate zone based on weighting factors from RS Means (presented in Appendix 8.3).

Actual project costs vary widely based on a range of real-building considerations. The costs that the Reach Code Team determined through contractors are likely costs for the given prototypes and are not representative of all projects.

2.1.3 Metrics

Cost-effectiveness is presented using net present value (NPV) and benefit-to-cost (B/C) ratio metrics.

- **NPV:** Net savings (NPV benefits minus NPV costs). If the net savings of a measure or package is positive over a lifetime of 15 years, it is considered cost-effective. Negative net savings represent net costs to the consumer. A measure that has negative energy cost benefits (energy cost increase) can still be cost-effective if the incremental costs to implement the measure (i.e., construction and maintenance cost savings) outweigh the negative energy cost impacts.
- **B/C Ratio:** Ratio of the present value of all benefits to the present value of all costs over 15 years (NPV benefits divided by NPV costs). The criterion for cost-effectiveness is a B/C greater than 1.0. A value of one indicates the savings over the life of the measure are equivalent to the incremental cost of that measure. A value greater than one represents a positive return on investment.

Improving the energy performance of a building often requires an initial capital investment, though in some cases an energy measure may be cost neutral or have a lower cost. In most cases the benefit is represented by annual On-Bill utility or TDV savings and the cost by incremental first cost and replacement costs. In cases where both construction costs and energy-related savings are negative, the construction cost savings are treated as the benefit while the increased energy costs are the cost.

In cases where a measure or package is cost-effective immediately (i.e., shows positive upfront construction cost savings and lifetime energy cost savings), B/C ratio cost-effectiveness is represented by “>1”. Because of these situations, NPV savings are also reported, which, in these cases, are positive values.

2.1.4 Utility Rates

In coordination with the IOU and POU rate teams the Reach Code Team determined appropriate utility rates for each CZ and package as of October 2022. The utility tariffs, summarized in Table 1, were determined based on the annual load profile of each prototype and the corresponding package, the most prevalent rate in each utility territory, and information indicating that the rates were unlikely to be phased out during the code cycle.

A time-of-use (TOU) rate was applied to most cases, some POUs may not have TOU rates. In addition to energy consumption charges, there are kW demand charges for monthly peak loads. Utilities calculate the peak load by the highest kW of the 15-minute interval readings in the month. However, the energy modeling software produces results on hourly intervals; hence, the Team calculated the demand charges by multiplying the highest load of all hourly loads in a month with the corresponding demand charge per kW. The utility rates applicable to a prototype may vary by package and CZ especially between a mixed fuel and all-electric package if the monthly peak demand loads exceed the applicable threshold.

The Reach Code Team coordinated with utilities to select tariffs for each prototype given the annual energy demand profile of each specific prototype, climate zone, and measure package and the most prevalent rates in each utility territory. The Reach Code Team did not compare a variety of tariffs to determine their impact on cost-effectiveness. Utility rate updates can affect cost-effectiveness results. For a more detailed breakdown of the rates selected, refer to Appendix 8.2.

For packages with PV generation, the approved Net Energy Metering (NEM) 2.0 tariffs were applied along with minimum daily use billing and mandatory non-bypassable charges. For the PV cases, annual electric production was always less than the modeled annual electricity consumption; therefore, no credits for surplus generation were necessary.

The analysis assumes that utility rates escalate over time for commercial buildings, as described in Appendix 8.2. Escalation rates above inflation for electricity beyond 2023 are assumed to be between 0.2% and 0.7%, before dropping to a steady 0.6% escalation per year in 2030. Natural gas is assumed to escalate at a relatively higher rate, peaking at 7.7% in 2024, then escalating more slowly to a rate of approximately 2% in the latter years of the analysis period.

Table 1. Utility Tariffs Used Based on CZ (October 2022)

1A: Investor-Owned Utilities

CZs	Electric / Gas Utility	Electricity	Natural Gas
1-5,11-13,16	Pacific Gas & Electric Company (PG&E)	B-1 / B-10	G-NR1
6, 8-10, 14, 15	Southern California Edison (SCE) / Southern California Gas (SCG)	TOU-GS-1 / TOU-GS-2 /TOU-GS-3	G-10 (GN-10)
7, 10, 14	San Diego Gas and Electric Company (SDG&E)	AL-TOU + EECC (AL-TOU)	GN-3

1A: Publicly-Owned Utilities

CZs	Electric / Gas Utility	Electricity	Natural Gas
4	City of Palo Alto Utilities (CPAU)	E-2	G-2
12	Sacramento Municipal Utilities District (SMUD)	CI-TOD 1 (CITS-0 /CITS-1)	G-NR1

2.2 Energy Simulations

The Reach Code Team performed energy simulations using California's Building Energy Code Compliance Software CBECC 2022.1.0 (1250) with ruleset version BEMCmpMgr 2022.1.0 (7361) (California Building Energy Code Compliance 2022).[2] This is the first 2022 Title 24 code compliance software approved by Energy Commission for compliance of nonresidential buildings on June 8, 2022. The CBECC software combined the capabilities of CBECC-Com and CBECC-Res software into one to model both nonresidential and multifamily building prototypes in one interface.

The Reach Code Team set up parametric simulations using Modelkit software to run thousands of measure packages for each prototype in all California's CZs. Individual measures were simulated separately and combined into cost-effective measure packages for each CZ. Where necessary, the Reach Code Team employed minor ruleset changes, such as load flexibility measures that alter thermostat setpoint schedules, to improve the cost-effectiveness of measure packages. While these measures produce operational savings, they may not be used to achieve code compliance without further software upgrades.

[2] Prior to the CBECC software, the Reach Code Team used CBECC-Com 2022 and CBECC 2022.0.8 Beta to model nonresidential prototypes for the 2022 reach code analysis. The Reach Code Team noted the changes in results due to updates in functionalities and standard design assumptions.

2.3 2022 T24 Compliance Metrics

2022 Title 24 Section 140.1 defines the energy budget of the building based on source energy and TDV energy for space-conditioning, indoor lighting, mechanical ventilation, photovoltaic (PV) and battery storage systems, and service water heating and covered process loads. CEC has introduced two new compliance metrics in addition to Total Compliance TDV Margin for 2022 code cycle. A building needs to comply with all three compliance metrics below:

- **Efficiency TDV.** Efficiency TDV accounts for all regulated end-uses but does not include the impacts of PV and battery storage.
- **Total TDV**. Total TDV Compliance metric includes regulated end-uses accounting for PV and battery storage contributions.
- **Source Energy.** Source energy is based on fuel used for power generation, assuming utilities meet all Renewable Portfolio Standard (RPS) goals and other obligations projected over 15-year lifecycle.

2.4 GHG Emissions

The analysis uses the GHG emissions estimates built into CBECC. The GHG emission multipliers were developed by Energy + Environmental Economics (E3) to support development of compliance metrics for use in the 2022 California energy code (E3 2021). There are 8,760 hourly multipliers accounting for time dependent energy use and carbon emissions based on source emissions, including RPS projections. For the 2022 code cycle, the multipliers incorporate GHG from methane and refrigerant leakage, which are two significant sources of GHG emissions (NORESCO 2020). There are 32 strings of multipliers, with a different string for each California CZ and each fuel type (metric tons of CO_2 per kWh for electricity and metric tons of CO_2 per therm for natural gas).

2.5 Limitations and Further Considerations

The Team encountered some modeling limitations, outside of the Team's control that should be noted while using these results to inform reach code policies,

- **CBECC Software:**
    - The Reach Code Team coordinated with the CBECC software development team on potential differences in our understanding of 2022 code requirements and its implementation in standard design such as battery controls. The version of 2022 CBECC software v1.0, described in Section 2.2, available to the Reach Code Team at the time of the analysis has limited functionalities and could not model heat pump hydronic system or other measures like drain water heat recovery. As the software evolves, some results may look different.
    - The most likely all-electric replacement for a central gas boiler serving a variable air volume reheat system would be a central heat pump boiler; however, this system cannot be modeled in CBECC at the time of the writing of this report. The Reach Code Team is treating this analysis as temporary until a compliance pathway is established for a central heat pump boiler in the Energy Code and results can be updated accordingly.
    - The team identified some apparent anomalies in software-reported compliance margins when they became available in June 2022. The Reach Code Team is in the midst of discussing outputs and ramifications with software development team specifically related to ventilation such as fan power and heat recovery, among other modeling methods. Results may change with future software versions. In the interim, the Reach Code Team manually calculated the compliance margins using the mixed fuel baseline model created in this study based on our best understanding.

- **Prototype Building:** The cost-effectiveness analysis is based on standard prototypical buildings, which may differ from actual buildings being constructed. Jurisdictions should keep this in mind while extrapolating to the buildings in their territory.
- **System Cost Assumptions:** The incremental electrification and additional measure costs are based on specific system selection and assumptions made by experienced professionals. These costs can vary based on contractor, system design and specifications, and regional variation.

The Team will re-evaluate packages with central heat pump boiler system in Medium Office and Small Hotel in early 2023. In addition to the packages assessed in the report, there are other future potential enhancements that can be considered for more cost-effective or compliant packages:

- Adding more solar PV than already analyzed if the building has more roof space to accommodate.
- Adding battery at higher levels than prescriptively required in 2022 Title 24 with more advanced controls.
- Adding energy efficiency measures as software capability evolves such as drain water heat recovery.
- Applying federally pre-emptive (high) efficiency energy systems or appliances.

3 Prototypes, Measure Packages, and Costs

This section describes the prototype characteristics and the scope of analysis including measures and their corresponding costs. The Reach Code Team used versions of the following four DOE building prototypes to evaluate cost-effectiveness of measure packages in the occupancy types listed below:

- Medium Office
- Medium Retail
- Quick-Service Restaurant (QSR)
- Small Hotel

The Reach Code Team designed the baseline prototypes to be mixed fuel based on 2022 Title 24 Final Express Terms requirements. The Reach Code Team reviewed the 2022 T24 ACM HVAC system map to ensure alignment as applicable for most cases, differences if any are discussed in subsequent sections. The Team built new construction prototypes to have compliance margins as close to zero as possible to reflect a prescriptively compliant new construction building in each CZ. The code compliance is based on the first publicly available CBECC v1.0 compliance software as described in Section 2.2. Misalignments have been reported back to the software team for future software iterations, as described in Section 2.5.

3.1 Prototype Characteristics

The DOE provides building prototype models which, when modified to comply with 2022 Title 24 requirements, can be used to evaluate the cost-effectiveness of efficiency measures (U.S. Department of Energy 2022 A). These prototypes have historically been used by the Energy Commission to assess potential code enhancements. The selection of four building types for this analysis is based on the priority suggested by a group of California cities. The cost-effectiveness results of this study could potentially be extrapolated to other building types that have similar properties such as occupancy pattern, HVAC design and layout.

Water heating includes both service hot water (SHW) for office and retail buildings and domestic hot water for hotel guest rooms. In this report, water heating or SHW is used to refer to both. The compliance software assumes a Standard Design, where HVAC and SHW systems are based on the system maps included in 2022 Nonresidential ACM Reference Manual. However, the Reach Code Team applied both 2022 Title 24 prescriptive requirements and 2022 ACM system map for baseline mixed fuel model, HVAC and SHW system characteristics as described below.

- **Medium Office**
  - The HVAC design is a variable air volume (VAV) reheat system with two gas hot water boilers, three packaged rooftop units (one serving each floor), and VAV terminal units with hot water reheat coils.
  - The SHW design includes one 8.7 kW electric resistance hot water heater with a 5-gallon storage tank.
- **Medium Retail**
  - For CZs 2 to 15, the 2022 Title 24 ACM System Map Standard Design informed the baseline model to have three packaged Single Zone Heat Pump (SZHP) systems for the smaller capacity (<240 kBtuh) thermal zones, in alignment with 2022 Title 24 prescriptive code requirements.[3] The large (>240 kBtuh) core thermal zone has two smaller (<240 kBtuh) SZHPs with VAV fans instead of one large SZHP, since larger rooftop packaged heat pumps are not available in the market. The 2022 Title24 ACM Standard Design assumes a large SZHP for larger zones as well, however this deviation does not impact the results considerably.[3]

[3] https://www.energy.ca.gov/publications/2022/2022-nonresidential-and-multifamily-alternative-calculation-method-reference

  - For CZs 1 and 16, the baseline model assumed all-electric packaged single zone heat pumps similar to CZs 2-15. The assumption deviates from 2022 Title24 ACM System Map that suggests a single zone dual fuel heat pump. Presumably this will not impact results significantly because the dual fuel system will be in heat-pump mode most times.
  - The SHW design includes one 8.7 kW electric resistance hot water heater with a 5-gallon storage tank.

- **Quick-Service Restaurant**
  - HVAC includes two SZAC (VAV or constant volume, depending on capacity) with gas furnace, one for kitchen and another for dining area. An exhaust fan is applied for kitchens in all climates based on prescriptive requirements in 2022 Title 24 code.
  - The SHW design includes a gas storage water heater with a 100-gallon storage tank.
- **Small Hotel**
  - The nonresidential HVAC design is a VAV reheat system with two gas hot water boilers, four packaged rooftop units (one serving each floor), and VAV terminal units with hot water reheat coils. The SHW design includes a small electric resistance water heater with 30-gallon storage tank.
  - The guest room HVAC design includes one packaged SZAC unit with gas furnace serving each guest room. The water heating design includes a central gas water heater with a 250-gallon storage tank and recirculation pump, serving all guest rooms.

Table 2 summarizes the baseline mixed-fuel prototype characteristics, based on prescriptive 2022 Title 24 new construction requirements.

Table 2. Baseline Prototype Characteristics

	Medium Office	Medium Retail	Quick-Service Restaurant	Small Hotel
Conditioned floor area (ft²)	53,628	24,563	2,501	42,554 (77 guest rooms) (Nonresidential area: 15,282 (36%))
Number of stories	3	1	1	4
Window-to-Wall Area ratio	0.33	0.07	0.11	0.14
Window U-factor/SHGC	U-factor: CZ 1-8, 10, 16 – 0.36 CZ 9, 11-15 – 0.34 SHGC: CZ 1-8, 10, 16 – 0.25 CZ 9, 11-15 – 0.22	U-factor: CZ 1-8, 10, 16 – 0.36 CZ 9, 11-15 – 0.34 SHGC: CZ 1-8, 10, 16 – 0.25 CZ 9, 11-15 – 0.22	U-factor: CZ 1-8, 10, 16 – 0.36 CZ 9, 11-15 – 0.34 SHGC: CZ 1-8, 10, 16 – 0.25 CZ 9, 11-15 – 0.22	Nonresidential: U-factor: CZ 1-8,10,16 – 0.36 CZ 9, 11-15 –0.34 SHGC: CZ 1-8,10,16 – 0.25 CZ 9, 11-15 – 0.22 Guest Rooms: U-factor: 0.36 SHGC: 0.25
Solar PV size	123 kW – 204 kW Depending on CZ	64 kW – 87 kW Depending on CZ	None	17 kW – 25 kW Depending on CZ
Battery Storage	217 kWh – 360 kWh Depending on CZ	70 kWh – 94 kWh Depending on CZ	None	16 kWh – 24 kWh Depending on CZ

	Medium Office	Medium Retail	Quick-Service Restaurant	Small Hotel
HVAC System	VAV reheat system with packaged rooftop units, gas boilers, VAV terminal units with hot water reheat	CZ 1 Heat recovery for Core Retail space only < 65 kBtu/h: SZHP > 65 kBtu/h and < 240 kBtu/h: SZHP VAV > 240 kBtu/h: SZHP VAV	< 65 kBtu/h: SZAC + gas furnace > 65 kBtu/h: SZAC VAV	Nonresidential and Laundry: VAV reheat system with packaged rooftop units, gas boilers, VAV terminal units with hot water reheat Guest Rooms: SZAC with gas furnaces
SHW System	5-gallon electric resistance water heater	5-gallon electric resistance water heater	100-gallon gas water heater	Nonresidential: 30-gallon electric resistance water heater Laundry Room: 120-gal gas storage water heater Guest rooms: Central gas water heater, 250 gallons storage, recirculation loop

3.2 Measure Definitions and Costs

The measures evaluated in the analysis fall into four different categories:

Fuel Substitution

- Heat pump or electric space heating or gas furnace
- Heat pump or electric water heaters
- Electric cooking
- Electric clothes dryer
- Electrical panel capacity
- Natural gas infrastructure

Energy Efficiency

- Envelope
- Mechanical equipment (HVAC and SHW)
- Lighting

Load Flexibility

- Peak Load shedding
- Load shift

Additional solar PV and/or battery storage.

These measures are detailed further in this section.

3.2.1 Fuel Substitution

The Reach Code Team investigated the cost and performance impacts and associated infrastructure costs associated with changing the mixed-fuel baseline HVAC and water heating systems to all-electric equipment for all prototypes except Medium Retail where the baseline is already an all-electric design.

For Medium Office, Quick Service Restaurant and Small Hotel, the fuel substitution measure entails electrification including heat pump space heating, electric resistance re-heat coils, electric water heaters with storage tank, heat pump water heating, increasing electrical capacity, and eliminating natural gas connections that would have been present in mixed-fuel new construction.

For Medium Retail with all-electric baseline, the fuel substitution measure entails mixed-fuel space conditioning system including single zone packaged AC with gas furnace, dual fuel heat pump, adding gas infrastructure costs and eliminating any additional electric infrastructure.

3.2.1.1 HVAC and Water Heating

The 2022 T24 nonresidential standards analysis uses a mixed-fuel baseline for most of the Standard Design mechanical equipment, primarily gas for space heating, except for some heat pump scenarios in Retail prototype (see Table 2). Quick-Service Restaurant has a gas storage water heater in baseline, and heat pump water heater in all-electric scenario. The Small Hotel has a central gas water heating system serving the guest rooms and a separate gas storage water heater for laundry room. In the all-electric scenario, gas equipment serving HVAC and water heating end-uses is replaced with electric equipment. Full details of HVAC and water heating systems in baseline and proposed fuel substitution measure package are described in Table 3.

Regions of California covered by the South Coast Air Quality Management District have emissions restrictions imposed on mechanical equipment. The Reach Code Team investigated the potential cost implications of meeting these requirements for gas furnaces and boilers but found that costs are minimal for mechanical systems under 2,000,000 Btu/h, and therefore did not include them. All gas-fired mechanical systems in this study are under 2,000,000 Btu/h and are subject to only an initial permitting fee, while larger systems require additional permitting costs and annual renewals.

Table 3. HVAC and Water Heating Characteristics Summary

		Medium Office	Medium Retail	Quick-Service Restaurant	Small Hotel
HVAC	Baseline	Packaged DX + VAV with hot water reheat. Central **gas** boilers.	All zones and CZs: Single zone packaged **heat pumps**	Packaged SZAC + **gas** furnace	Nonresidential: Packaged DX + VAV with hot water reheat. Central **gas** boilers. Guest Rooms: Packaged SZAC + **gas** furnaces
	Proposed – Fuel Substitution	Packaged DX + VAV with electric **resistance** reheat.	Core zone (>30 ton): Packaged SZAC + VAV + **gas** furnace Other small zones: SZHP, or dual fuel heat pump for CZ 1 and 16	Single zone packaged **heat pumps**	Nonresidential: Packaged DX + VAV with electric **resistance** reheat Guest Rooms: SZHPs
SHW	Baseline	Electric **resistance** with storage	Electric **resistance** with storage	**Gas** storage water heater	Nonresidential: Electric **resistance** storage Guest Rooms: Central **gas** storage with recirculation
	Proposed – Fuel Substitution			Unitary **heat pump** water heater	Nonresidential: Electric **resistance** storage Guest Rooms: Central **heat pump water heater** with recirculation

The Reach Code Team received cost data for mechanical equipment from two experienced mechanical design firms including equipment and material, labor, subcontractors (for example, HVAC and SHW control systems), and contractor overhead.

3.2.1.1.1 Medium Office

For the Medium Office all-electric HVAC design, the Reach Code Team investigated several potential all-electric design options, including variable refrigerant flow, packaged heat pumps, and variable volume and temperature systems. The most likely all-electric replacement for a central gas boiler serving a variable air volume reheat system would be a central heat pump boiler; however, this system cannot be modeled in CBECC at the time of writing of this report. As such, Reach Code Team is treating this analysis as temporary until a compliance pathway is established for a central heat pump boiler in the Energy Code and results can be updated accordingly. This modeling capability is anticipated by Q1 2023 according to discussions with the CBECC software development team, and the cost-effectiveness analysis should become available in the first half of 2023.

After seeking feedback from the design community and considering the software modeling constraints, the Reach Code Team determined that the most feasible all-electric HVAC system is a VAV system with an electric resistance reheat instead of hot water reheat coil. A parallel fan-powered box (PFPB) implementation of electric resistance reheat would further improve efficiency due to reducing ventilation requirements, but an accurate implementation of PFPBs is not currently available in compliance software.

The actual gas consumption for the VAV hot water reheat baseline may be higher than the current simulation results due to a combination of boiler and hot water distribution losses. A recent research study shows that the total losses can account for as high as 80 percent of the boiler energy use.[4] If these losses are considered savings for the electric resistance reheat (which has zero associated distribution loss), cost-effectiveness may be higher than presented.

The all-electric SHW system remains the same electric resistance water heater as the baseline and has no associated incremental costs. Cost data for Medium Office designs are presented in Table 4. The all-electric HVAC system presents cost savings compared to the hot water reheat system from elimination of the hot water boiler and associated hot water piping distribution. CZ10 and CZ15 all-electric design costs are slightly higher because they require larger size rooftop heat pumps than the other CZs.

Table 4. Medium Office Average Mechanical System Costs

Components (HVAC Only)	Baseline – Mixed Fuel	Proposed – All-electric	Incremental Cost
Description	Packaged units, boilers, hot water piping, VAV boxes, ductwork, grilles	Packaged units, electric resistance VAV boxes, electric circuitry, ductwork, grilles	VAV Boxes, electric infrastructure
Material	$491,630	$438,555	$(53,075)
Labor	$173,816	$102,120	$(71,696)
Electric Infrastructure	$0	$112,340	$112,340
Gas Infrastructure	$17,895	$0	$(17,895)
Overhead & CZ adjustment **	$267,052	$250,114	$(16,938)
TOTAL	**$950,393**	**$903,129**	**$(47,264)**

** The overhead and CZ adjustment factors are presented in Section 8.3.

3.2.1.1.2 Medium Retail

The baseline HVAC system includes five packaged single zone heat pumps. Based on fan control requirements in Section 140.4(m), units with cooling capacity ≥ 65,000 Btu/h have variable air volume fans, while smaller units have constant volume fans. For the Medium Retail proposed fuel substitution scenario, the Reach Code Team assumed one large Single Zone Packaged ACs with gas furnaces to replace the two smaller packaged heat pumps in the large core thermal zone. The all-electric SHW system remains the same electric resistance water heater as the baseline and has no associated incremental costs. In addition, according to the prescriptive requirement in Section 140.4 (q), the air system of Core Retail Zone in CZ1 meets the requirement in Table 140.4 J, which should include exhaust air heat recovery. Cost data for Medium Retail designs are presented in Table 5. Costs for rooftop air-conditioning systems are very similar to rooftop heat pump systems.

[4] Raftery, P., A. Geronazzo, H. Cheng, and G. Paliaga. 2018. Quantifying energy losses in hot water reheat systems. Energy and Buildings, 179: 183-199. November. https://doi.org/10.1016/j.enbuild.2018.09.020. Retrieved from https://escholarship.org/uc/item/3qs8f8qx

For climate zones 2 to 15, the proposed fuel substitution HVAC design includes three SZHP units (VAV or constant volume, depending on capacity) based on prescriptive requirements and one large SZAC that is between 35-45 tons for the core zone.

For climate zones 1 and 16, the smaller capacity (<240 kBtuh) thermal zones may have either of dual-fuel SZHPs or SZACs, depending on capacity. The core zone with 35-to-45-ton cooling capacity is assumed to have one large SZAC. CZ 1 also assumes an exhaust air heat recovery system for core zone based on prescriptive requirement in Title 24 Part 6 Section 140.4.

Table 5. Medium Retail Average Mechanical System Costs

Components (HVAC Only)	Baseline – All-electric	Proposed – Mixed Fuel	Incremental Cost
Description	SZHPs	Single zone AC + furnace, SZHP, or dual fuel SZHP, depending upon capacity and CZ	SZAC with gas furnace, Added gas infrastructure cost
HVAC – Material	$189,160	$183,157	$(6,003)
HVAC – Labor	$54,785	$52,886	$(1,899)
Electric Infrastructure	$0	$0	-
Gas Infrastructure	$0	$17,895	$17,895
Overhead & CZ adjustment **	$94,600	$98,519	$3,919
TOTAL	**$338,546**	**$352,458**	**$13,912**

** The overhead and CZ adjustment factors are presented in Section 8.3.

3.2.1.1.3 Quick-Service Restaurant

The baseline HVAC system includes two packaged single zone rooftop ACs with gas furnaces. Based on fan control requirements in Section 140.4(m), units with cooling capacity ≥ 65,000 Btu/h have variable air volume fans, while smaller units have constant volume fans. The SHW design includes one central gas storage water heater with 150 kBtu/h input capacity and a 100-gallon storage tank. For the QSR all-electric design, the Reach Code Team assumed packaged heat pumps and an A.O. Smith CHP-120 heat pump water heater with a 120-gallon storage tank. Cost data for the QSR designs are presented in Table 6, which shows the costs for full electrification of the HVAC and water heating equipment.

The Team has not included costs of electrifying the cooking equipment because of the negative impact on cost-effectiveness, as demonstrated in a 2021 Restaurants cost-effectiveness study (TRC, P2S Engineers, and Western Allied Mechanical 2022). The HVAC and SHW electrification packages are referred to as the HS package to reflect all-electric HVAC and SHW.

Table 6. Quick-Service Restaurant Average Mechanical System Costs - HS Package

Components	Baseline – Mixed Fuel	Proposed – All-electric	Incremental Cost
Description	Single zone AC + furnace, gas storage water heater	SZHP, heat pump water heater	HVAC +SHW electrification
HVAC Material	$50,065	$52,785	$2,719
HVAC Labor	$6,748	$6,249	$(499)
SHW – Material	$10,198	$13,720	$3,523
SHW – Labor	$2,650	$2,529	$(121)
Electric Infrastructure	$0	$12,960	$12,960

Gas Infrastructure	$17,895	$15,878	-$2,017
Overhead & CZ adjustment **	$41,633	$47,612	$5,979
TOTAL	**$150,838**	**$173,382**	**$22,544**

** The overhead and CZ adjustment factors are presented in Section 8.3.

3.2.1.1.4 Small Hotel

The Small Hotel has two different baseline equipment systems, one for the nonresidential spaces and one for the guest rooms. The nonresidential HVAC system includes two gas hot water boilers, four packaged rooftop units, and twenty-eight VAV terminal boxes with hot water reheat coil. The SHW design includes a small electric water heater with storage tank for nonresidential areas and gas storage water heater dedicated to laundry room. The guest rooms HVAC design includes one single-zone AC unit with gas furnace for each guest room, and the water heating design includes one central gas storage water heater with a recirculation pump for all guest rooms.

For the Small Hotel all-electric design, the Reach Code Team assumed the nonresidential HVAC system to be packaged heat pumps with electric resistance VAV terminal units, and the SHW system will remain a small electric resistance water heater. As described in Section 3.2.1.1.1 above, a central heat pump boiler may be the most commonly employed system type but was not evaluated in this study because of modeling limitations. For the guest room all-electric HVAC system, the Team assumed SZHPs and a central heat pump water heater serving all guest rooms. For the laundry room, all-electric HVAC system is same as other nonresidential areas and all-electric water heating is a split heat pump water heater. The central heat pump water heater includes a temperature maintenance loop with an electric resistance backup heater.

Cost data for Small Hotel designs are presented in Table 7. The all-electric design presents substantial cost savings because there is no hot water plant or piping distribution system serving the nonresidential spaces. The incremental cost savings are further enhanced considerably if packaged terminal heat pumps (PTHPs) are used instead of SZHPs in guest rooms compared to split DX/furnace systems with individual flues.

Table 7. Small Hotel HVAC and Water Heating System Costs

Components	Baseline – Mixed Fuel	Proposed – All-electric	Incremental Cost
Description	Non-residential spaces: Packaged units, boilers, hot water piping, VAV boxes, ductwork, grilles, gas water heater for laundry Guest rooms: SZAC + furnace, central gas water heater	Non-residential spaces: Packaged units, electric resistance VAV boxes, electric circuitry, ductwork, grilles, heat pump water heater for laundry Guest rooms: SZHP, central heat pump water heater	HVAC (NR and Guest Rooms) Electrification SHW (Laundry Room and Guest Rooms)
HVAC - Material	$802,004	$625,642	$(176,361)
HVAC - Labor	$366,733	$282,394	$(84,339)
SHW - Material	$55,829	$139,087	$83,258
SHW - Labor	$11,780	$15,080	$3,300
Electric Infrastructure	$-	$119,625	$119,625
Gas Infrastructure	$74,943	$-	$(74,943)
Overhead & CZ adjustment **	$518,741	$461,001	$(57,739)
TOTAL	**$1,830,029**	**$1,642,830**	**$(187,199)**
TOTAL HVAC (PTHP option)	**$1,830,029**	**$1,161,178**	**($668,851)**

** The overhead and CZ adjustment factors are presented in 8.3.

3.2.1.2 Commercial Cooking Equipment

For Quick-Service Restaurant prototype, the Reach Code Team evaluated electrification of commercial cooking equipment extensively in 2019 Restaurants Cost Effectiveness analysis and leveraged it for cost and other specifications for the this study. It assumes a Type I exhaust hood and shows high incremental cost affecting the cost-effectiveness of this measure. Table 8 summarizes the quick-service restaurant cooking equipment costs for both mixed-fuel and all-electric scenarios.

Table 8. Quick-Service Restaurant Cooking Equipment Costs

Components	Baseline – Mixed Fuel	Proposed – All-electric (non "HS" scenario)	Incremental Cost
Description	Gas based appliances	Electric cooking appliance	Cooking appliance electrification
Cooking equipment cost	$21,649	$43,534	$21,886
TOTAL	**$21,649**	**$43,534**	**$21,886**

This measure also adds electric infrastructure cost as detailed in Table 10 below.

3.2.1.3 Commercial Clothes Dryer

For the all-electric measure, the Reach Code Team assumed electric resistance clothes dryers for Small Hotel prototype. Commercial-scale heat pump clothes dryers take significantly longer time to dry compared to a conventional gas or electric dryer and are not common in the United States On-Premise Laundry (OPL) market, where labor is relatively expensive and use of heat pump dryers implies hotels may need to require more than one shift to perform laundry duties. Most commercial clothes dryers are available in models that use either gas or electricity as the fuel source, so there is negligible incremental cost for electric resistance dryers. Table 9 summarizes the Small Hotel construction costs for both mixed-fuel and all-electric OPL scenarios.

Table 9. Small Hotel Clothes Dryer Costs

Components	Baseline – Mixed Fuel	Proposed – All-electric	Incremental Cost
Description	Gas clothes dryer	Electric resistance clothes dryer	-
Clothes Dryer cost	$29,342	$29,342	$0
TOTAL	**$29,342**	**$29,342**	**$(0)**

This measure also adds electric infrastructure cost as detailed in Table 10 below.

3.2.1.4 Infrastructure Impacts

3.2.1.4.1 Electrical infrastructure

Electric heating appliances and equipment often require a larger electrical connection than an equivalent gas appliance because of the higher voltage and amperage necessary to electrically generate heat. Thus, many buildings may require larger electrical capacity than a comparable building with natural gas appliances. This includes:

- Electric resistance VAV space heating in the medium office and common area spaces of the small hotel.
- Heat pump water heating for the guest room spaces of the small hotel.

Table 10 details the cost impact of additional electrical panel sizing and wiring required for all-electric scenarios as compared to their corresponding mixed-fuel scenario The costs are based on estimates from one contractor. The Reach Code Team excluded costs associated with electrical service connection upgrades because these costs are very often rate-based and highly complex.

Table 10. Electrical Infrastructure Costs

	Mixed-Fuel Equipment	All-electric Equipment	Electrical Infrastructure Impact	Incremental Cost
Medium Office	Hot water reheat system with gas boiler plant and VAV boxes with hot water reheat coils	VAV boxes with electric resistance reheat coils	Upgraded transformers, transformer feeders, switchboards, and branch circuits	$ 112,340
Medium Retail	Mix of SZHPs and single zone AC plus furnace serving all zones	SZHPs serving all zones	Electrical requirements are driven by cooling capacity, so no impact.	$0
Quick-Service Restaurant	Gas water heater	Heat pump water heater	Upgraded switchboard, transformer feeder, and branch circuits	$12,960
	Gas Water heater, Gas cooking	Heat pump water heater, Electric cooking	Upgraded switchboard, transformer feeder, and branch circuits	$95,260
Small Hotel	Guest rooms HVAC: Single zone AC plus furnace Non-residential spaces HVAC: Hot water reheat system with gas boiler plant and VAV boxes with hot water reheat coils. Water heating: Gas water heating serving both laundry and guest rooms. Process: Gas dryers.	Guest rooms HVAC: SZHPs Non-residential spaces HVAC: VAV boxes with electric resistance reheat coils. Water heating: Heat pump water heating serving both laundry and guest rooms. Process: Electric resistance dryers.	Upgraded transformers, transformer feeders, switchboards, and branch circuits	$119,625

3.2.1.4.2 Gas Piping

The Reach Code Team assumes that gas would not be supplied to the site in an all-electric new construction scenario. Eliminating natural gas in new construction would save costs associated with connecting a service line from the street main to the building, piping distribution within the building, and monthly connection charges by the utility.

The Reach Code Team determined that for a new construction building with natural gas piping, there is a service line (branch connection) from the natural gas main to the building meter. Table 11 gives a summary of the gas infrastructure costs by component, assuming 1-inch corrugated stainless-steel tubing (CSST) material is used for the plumbing distribution. The Reach Code Team assumes that the gas meter costs vary depending on the gas load. Based on typical space heating loads for all building types, the Reach Code Team categorized CZs 1 and 16 as 'High-load CZs' and CZs 2-15 as 'Low-load CZs'. The Reach Code Team assumed an interior plumbing distribution length based on the expected layout. Table 12 gives the total gas infrastructure cost by building type. The costs are based on estimates from one contractor.

Table 11. Gas Infrastructure Costs by Component

Component	Details	Cost
Meter, including Pressure Regulator, and Earthquake Valve	Low load CZ (CZ 2-15)	$11,056
	High load CZ (CZ 1,16)	$15,756
Gas lateral	Cost per linear foot of 1" CSST	$40
Connection charges	Includes street cut and plan review	$1,015
Interior plumbing distribution	Cost per linear foot of 1" CSST	$40

Table 12. Total Gas Infrastructure Cost Estimates by Building Type

		Total gas infrastructure cost	
Building Prototype	**Interior plumbing distribution length (ft)**	**Low load CZ**	**High load CZ**
Medium Office	100	$17,307	$22,007
Medium Retail	100	$17,307	$22,007
Quick-Service Restaurant	100	$2,017*	
Small Hotel	1,412	$70,243	$74,943

*The Quick-Service Restaurant package includes gas cooking appliances, which will require a gas lateral and meter. These costs represent only the interior plumbing distribution costs that would have served the HVAC and SHW systems.

3.2.2 Efficiency

The Reach Code Team started with a potential list of energy efficiency measures proposed for the 2025 Title 24 energy code update by the Statewide Building Codes Advocacy program (CASE Team)[5], which initially included over 500 options. Other options originated in previous energy code cycles or were drawn from other codes or standards (examples: ASHRAE 90.1 and International Energy Conservation Code [IECC]), literature reviews, or expert recommendations. The Reach Code Team leveraged the CASE Team's assessment tools for the 2025 Cycle, focusing on measures prioritized by the CASE Team. The Reach Code Team filtered the list of potential measures based on building type (to remove measures that applied to building types not covered in this study), measure category (to remove end-uses and loads that are not relevant to the prototypes) and impacts to new construction. Based on this filtering, the Team was left with around 100 measures to consider. The Reach Code Team ranked this list of potential measures based on applicability to the prototypes in this study, ability to model in simulation software, demonstrated energy savings potential, and market readiness.

Please note that the **measures requiring a ruleset update cannot currently be modeled for compliance purposes**. The modeling method for each efficiency measure is defined in their respective measure descriptions in Section 3.2.2.1 and if the ruleset amendment was applied. Please refer to Section 2.5 for further details.

The subsections below describe the energy efficiency measures that the Team analyzed, including description, modeling approach, and specification.

3.2.2.1 Envelope

1. **Cool Roof:** Requires higher reflectance and emittance values for the Medium Office building only. This measure was not shown to produce substantial savings in the other prototypes.

[5] https://title24stakeholders.com/

Modeling: Modeled cool roof measure in efficiency measures package by updating Aged Solar Reflectance (ASR) and/or Thermal Emittance (TE) in CBECC software.
Specification: Increased ASR from 0.63 to 0.70 with a TE of 0.85 in CZs 4 and 6-15.

2. **Efficient Vertical Fenestration:** Requires lower U-factor and Solar Heat Gain Coefficient (SHGC) for windows in select climate zones for three building types (Medium Office, Retail, and Small Hotel). The measure details and the climate zone selection are based on the proposition of 2022 NR CASE Report (Statewide CASE Team 2020 B).

   Modeling: Modeled high performance windows in efficiency measures package by updating U-factor and SHGC inputs in CBECC software.
   Specification: Reduced U-factor from 0.36 to 0.34 and SHGC from 0.25 to 0.22 in CZs 2, 6, 7 and 8 for Medium Office and Retail, Reduced U-factor from 0.36 to 0.34 and SHGC from 0.25 to 0.22 in all CZs for Small Hotel.

3. **Vertical Fenestration as a Function of Orientation:** Limit the amount of fenestration area as a function of orientation for the Medium Office. East-facing and west-facing windows are each limited to one-half of the average amount of north-facing and south-facing windows.

   Modeling: Change z-coordinate input of windows in CBECC software for Medium Office to increase or decrease fenestration area for the Medium Office.
   Specification: Decreased east-facing and west-facing fenestration area from 468 to 390 square feet. Increased north-facing and south-facing fenestration area from 703 to 781 square feet.

3.2.2.2 Mechanical Equipment (SHW and HVAC)

4. **Water Efficient Fixtures in Kitchen:** Specifies commercial dishwashers that use 20% less water than ENERGY STAR® specifications. In addition, the dishwasher includes heat recovery function such that it only needs connection to cold water and reduces hot water demand and central SHW system capacity. For QSRs, which typically specify a three-compartment sink for dishwashing, this measure would replace or add a dishwasher to reduce total hot water load. The measure also adds 1.0 gallon per minute (GPM) faucet aerators to hand-washing sinks in the kitchen to reduce water usage. Title 20 requires kitchen sinks to have a flow rate of 1.8 GPM at most. The reduced hot water load from the water efficient fixtures above allows the heat pump water heater (HPWH) to operate without an electric resistance back-up.

   Modeling: Reduced water usage in the ruleset based on calculations of expected water usage from literature review and fixture specifications. HPWH coefficient of performance (COP) is increased since there is no electric resistance back-up.
   Specification: Decreased hot water usage by 26% in the software ruleset (13.4 gallons per person to 9.9 gallons per person) and increased HPWH COP from 3.1 to 4.2.

5. **Ozone Washing Machines:** Adds an ozone system to the large on-premises washing machines. The ozone laundry system generates ozone, which helps clean fabrics by chemically reacting with soils in cold water. This measure saves energy by reducing hot water usage and by reducing cycle time for laundry systems. Refer to DEER Deemed measure SWAP005-01 for more information (California Public Utilites Commission 2022).

   Modeling: Reduced the total runtime of each cycle and hot water hourly usage per person (gallons per hour per person) for laundry area in software ruleset.
   Specification: Reduced hot water usage by 85%, from 48.4 to 7.3 gal/hour-person based on the deemed measure data from the California electronic Technical Reference Manual (California Technical Forum 2022).

6. **Efficient Hot Water Distribution:** Reduces domestic hot water (DHW) distribution system pipe heat losses in two ways. First, the Team used pipe sizing requirements in Appendix M of the California Plumbing Code instead of Appendix A. Appendix M reduces pipe diameters for the cold and hot water supply lines based on advancements made in water efficiency standards for plumbing fixtures found in hotel bathrooms. Second, the Team added more stringent pipe insulation thickness requirements for hotels to match that of single and multifamily dwellings using Title 24 Table 160.4-A *Pipe Insulation Thickness Requirements for Multifamily DHW Systems* instead of Table 120.3-A.

   Modeling*:* The Team calculated the pipe heat loss savings for the Small Hotel prototype by following the modelling methodology applied to the low-rise loaded corridor multi-family building prototype in the *2022 CASE Multifamily Domestic Hot Water Distribution* report (Statewide CASE Team 2020 A). The Team designed a riser distribution system for the Small Hotel prototype building using the baseline Appendix A and modern Appendix M pipe sizing tables. The pipe design and total pipe surface area of the supply and return lines for the Small Hotel closely matched the Low-Rise Loader Corridor Building prototype. The hotel insulated pipe heat loss for both Appendix A and M was approximated from the multifamily building heat loss modelling results for the 16 CZs and water heater energy savings calculated for the two sub-measures.

   Specification*:* (a) Pipe diameter decreased from Appendix A requirements to Appendix M multifamily plumbing requirements (b) For pipe diameters at or above 1.5 inches, increase the insulation thickness from 1.5 to two inches thick for fluids operating in the 105-140ºF temperature range. . The Team reduced the DHW energy consumption by 0.4 – 0.7% depending on CZ in a post-processing of the model.

7. **Demand Control Ventilation (DCV) and Transfer Air:** The California Energy Code requires kitchen exhaust to have DCV if the exhaust rate is greater than 5,000 cfm. This measure expands this requirement and applies DCV regardless of the exhaust rate for the QSR. Additionally, the kitchen makeup air supply is decreased by requiring at least 15% of replacement air to come from the transfer air in the dining space that would otherwise be exhausted.

   Modeling: Changed exhaust fan from constant speed fan to variable speed and reduce kitchen ventilation airflow rate for the QSR.

   Specification: Changed Kitchen Exhaust Fan Control Method to Variable Flow Variable Speed Drive, reduced kitchen ventilation from 2,730 cfm to 2,293 cfm.

8. **Guest Room Ventilation and Fan Power:** Uses the 2021 IECC fan power limitation requirements for ventilation fans under 1/12 horsepower, and approximates the ASHRAE 90.1 Small Hotel guestroom control requirements, which require shutting off ventilation within five minutes of all occupants leaving the room and changing the cooling setpoint to at least 80ºF and heating setpoint to at most 60ºF.

   Modeling*:* Since variable occupancy cannot be modeled in CBECC, the Reach Code Team revised the software ruleset ventilation schedule and setpoints from 8:00 AM to 7:00 PM—the time range where the CBECC software assumed occupancy to be less than half for all guestrooms.

   Specification: Heating setpoint reduced from 68°F to 66°F, cooling setpoint increased from 78°F to 80°F PM, and ventilation shut off from 8:00 AM to 7:00 PM. Guestroom ventilation fans have fan efficacy of 0.263 W/cfm.

9. **Variable speed Fans:** Require variable speed fans at lower capacities than required by Title 24 Part 6 Section 140.4(m), currently at 65,000 Btu/hr. This measure is based on the 2022 Title 24 Part 6, Section 140.4(m),

where direct expansion units greater than 65,000 Btu/hr that control the capacity of the mechanical cooling directly shall have a minimum of two stages of mechanical cooling capacity and variable speed fan control.

Modeling: Reduced the cooling capacity threshold from 65,000 Btu/hr to 48,000 Btu/hr. Changed the supply fan control from constant speed to variable speed for zones that have cooling capacity > 48,000 Btu/hr and < 65,000 Btu/hr in the Medium Retail and QSR.

Specification: Changed the supply fan control from Constant Volume to Variable Speed Drive for the Front Retail and Point-of-Sale thermal zones in Medium Retail prototype and the Dining Zone in the QSR prototype.

3.2.2.3 Lighting

10. **Interior lighting reduced lighting power density:** Update lighting power densities (LPD, measured as Watts/ft^2) requirements based on technology advances (e.g., optical efficiency, thermal management, and improved bandgap materials). Identify spaces with opportunities for more savings from lowered LPDs—not all spaces are subject to LPD reductions. Take into consideration IES recommended practices and biological effectiveness metrics (such as WELL) when developing the proposed LPD values (WELL 2022).

The 2022 Indoor Lighting CASE Study (Statewide CASE Team 2021 D) provided a survey of 2x2 troffer products available in the Design Lights Consortium Qualified Products List (DLC-QPL) and the efficacy level each measured. This study indicated that at the time of the report approximately 20% of available DLC-QPL products exceeded the performance level of the ‘Standard’ DLC-QPL listing by approximately 15%, meeting the ‘Premium’ listing criteria. The Title 24 2022 CASE Report uses the ‘Standard’ designation performance level as the design baseline for all the LPD calculations in the code. This document proposes using the ‘Premium’ designation performance as the basis of the LPD allowances.

A DOE study on solid-state light sources (LEDs) provides projections of efficacy improvement for LED light sources that are in the range of 2.5 to 3% per year, continuing for the next five or ten years (U.S. Department of Energy 2019 B). So, the products offered for sale by the luminaire manufacturers are improving as older products are discontinued and newer ones are introduced. Even in just three years, the overall performance of the products available can improve by 7 to 9%.

A recent Navigant LED pricing study shows a slightly negative cost to efficacy correlation, indicating that higher performing products may be slightly lower in cost (Navigant Consulting 2018). This is likely to be in part caused by the decreasing cost of the LED chips with each subsequent generation produced. There is likely to be no cost associated with employing higher performing LED luminaires.

Modeling: Reduce LPDs by approximately 13% in each space listed below under regulated lighting below Title 24 prescriptive requirements.

Specification: Medium Office

- All spaces: 0.52 W/ft^2

Medium Retail

- Storage: 0.36 W/ft^2
- Retail sales: 0.86 W/ft^2
- Main entry lobby: 0.63 W/ft^2

QSR

- Dining: 0.41 W/ft^2
- Kitchen: 0.86 W/ft^2

Small Hotel

Stairs: 0.54 W/ft^2
Corridor: 0.36 W/ft^2
Lounge: 0.50 W/ft^2

The measures are summarized below by building type, including measure costs, in Table 13.

Table 13. Efficiency Measures Applicability, Costs, and Sources

Measure Applicability

- • Included in packages with energy efficiency measures
- \- Not Applicable

Measure	Baseline T24 Requirement	Proposed Measure	Med Office	Med Retail	Quick-Service Restaurant	Small Hotel: *Guest Rooms*	Small Hotel: *Nonresidential*	Incremental Cost	Sources & Notes
Envelope									
1. Cool Roof	For low slope roofs: ASR = 0.63 TE = 0.75	For low slope roofs: ASR = 0.7 TE = 0.85	•	–	–	–	–	$0.04/ft^2	Final Nonresidential High Performance Envelope Case Report (Statewide CASE Team 2020 B)
2. Efficient Vertical Fenestration	U-factor = 0.36 SHGC = 0.25	U-factor = 0.34 SHGC = 0.22	•	•	–	•	•	$1.75/ft^2	Final Nonresidential High Performance Envelope Case Report (Statewide CASE Team 2020 B)
3. Vertical Fenestration as a Function of Orientation	40% window-to-wall ratio in each orientation per Title 24 Table 140.3-B.	Redistribute window areas by orientation	•	–	–	–	–	$0	No additional cost. This measure is a design consideration.
HVAC and SHW									
4. Water Efficient Fixtures in Kitchen	Kitchen faucet max flow rate is 1.8 GPM (Title 20)	Kitchen faucet flow rate is 1 GPM	–	–	•	–	–	High efficiency, door-type, high temperature dishwasher: $7,633/unit Faucet aerator: $8/unit	Combination of literature review, online sources such as Home Depot and manufacturer websites
5.Ozone Washing Machine	Not required	Reduced hot water use	–	–	–	–	•	$25,469/unit	DEER Deemed measure SWAP005-01 (California Public Utilites Commission 2022)

Measure	Baseline T24 Requirement	Proposed Measure	Med Office	Med Retail	Quick-Service Restaurant	Small Hotel: *Guest Rooms*	Small Hotel: *Nonresidential*	Incremental Cost	Sources & Notes
Measure Applicability • Included in packages with energy efficiency measures - Not Applicable									
6. Efficient Hot Water Distribution	Appendix A Pipe Sizing with standard pipe insulation thickness 1.5''	Appendix M pipe sizing with 2" pipe insulation thickness	–	–	–	•	–	$5,819	Multifamily Domestic Hot Water Final CASE Report
7. DCV & Transfer Air	DCV required in kitchen for exhaust air rate > 5000 cfm	DCV for all exhaust fans	–	–	•	–	–	$8,500	Mechanical contractor cost estimate
8. Guest Room Ventilation, Temperature Setback, and Fan Power	Guest rooms required to have occupancy sensing zone controls, but no ventilation fan power requirement.	Updated fan power and HVAC schedules	–	–	–	•	–	$0	No cost increase, as guest rooms already have controls.
9. Variable Speed Fans	Variable speed required if cooling capacity is greater than 65,000 Btu/h	Variable speed control for smaller capacity systems	–	•	•	–	–	$6,390/unit	Mechanical contractor cost estimate
Lighting									
10. Interior Lighting Reduced LPD	Per Area Category Method, varies by Primary Function Area.	Top 20% of market products	•	•	•	–	•	$0	Industry report on LED pricing analysis shows that costs are not correlated with efficacy. (Navigant Consulting 2018)

3.2.3 Load Flexibility

The Reach Code Team investigated a range of high-impact demand flexibility strategies potentially applicable to the four prototypes. The list of strategies is informed by DOE's Grid-interactive Efficient Buildings efforts and the 2022 Nonresidential Grid Integration CASE report (U.S. Department of Energy 2021, Statewide CASE Team 2020). The Team selected the three measures based on their load flexibility potential, cost, compliance software modeling capabilities, savings potential and the ease of project implementation and field verification:

Please note that these measures require a ruleset update and cannot be modeled currently for compliance purposes.

11. **Temperature Setback using Smart Thermostat:** This measure leverages the existing mandatory requirement for HVAC zone thermostatic controls to pre-condition spaces prior to, and to shed demand during, peak period. This measure introduces a setback in temperature setpoint during peak period and incurs no additional cost because Occupant-Controlled Smart Thermostats (OCSTs) are already required for buildings similar to the Medium Office prototype.

    Modeling: Instead of utilizing the demand responsive features, OCST would be used to change temperature setpoints and setpoint schedules. These changes were integrated by altering the setpoint schedules directly in the backend ruleset files of CBECC software.

    Specification: In the base case, the Medium Office prototype HVAC equipment schedules dictate "on" hours (at desired temperature) from 6:00 AM through 12:00 AM on weekdays and 6:00 AM – 7:00 PM on Saturdays. All Sunday hours are "off." Cooling setpoints are 75°F during "on" and 85°F when "off" hours; heat setpoints are 70°F during "on" and 60°F during "off" hours. The Team modified this schedule such that the "on" setpoints are stepped back by 2°F from 4:00 PM through 12:00 AM on weekdays; and from 4:00 PM – 7:00 PM on Saturdays.

12. **Demand Response Capable HPWH:** The Reach Code Team modeled a measure intended to reduce the peak demand of the significant hot water loads in the QSR prototype. The measure increases costs due to adding a 100-gallon storage tank and plumbing hardware. The additional hot water storage enables pre-heating water ahead of demand by effectively increasing the HPWH's thermal storage capacity. The extra plumbing hardware is needed to keep the stored hot water stratified to maintain efficient HPWH operations. The Team did not directly address the issue of storage tank location but assumed floor plan design would be able to accommodate it.

    Modeling: The measure uses the HPWH and additional storage tank capacity to produce and store hot water ahead of actual use during evening peak period. QSR hot water baseline schedule exhibits a low morning load (6:00 AM – 8:00 AM), moderate load near lunch time (11:00 AM), and a peak evening load (4:00 PM – 11:00 PM). These changes were made by changing the hot water load fraction in the ruleset.

    Specification: Implements an early pre-heat that starts at 12:00 PM and finishes by 7:00 PM, avoiding the super peak hours of 7:00 PM – 9:00 PM.

13. **Demand Response Lighting:** This measure extends existing Title 24 mandatory requirements for demand responsive lighting by shedding demand during peak hours. There are no additional measure costs because demand responsive control capability is already required for nonresidential buildings with more than 4kW of total lighting load. This measure does not require additional commissioning.

    Modeling: The baseline lighting schedule exhibits a plateau of 0.65 load fraction from 8:00 AM – 8:00 PM and trails off after 8:00 PM through the end of the day for weekdays. The Team altered the ruleset to reduce the load fraction during 4:00 PM – 9:00 PM.

    Specification: The Team implemented a 10% setback during the 4-9pm peak hours.

The load flexibility measure applications to each prototype are summarized in Table 14.

Table 14. Load Flexibility Measure Summary

Measure	Med Office	Med Retail	QSR	Small Hotel	Incremental Cost	Other Notes
11. Smart Thermostat	●	-	-	-	$0	Capability already required
12. Demand Control HPWH	-	-	●	-	$5,400	An additional 100-gallon tank, plumbing hardware, and related labor hours
13. Demand Response Lighting	●	-	-	-	$0	Capability already required

None of the measures apply to the Medium Retail or Small Hotel prototypes. While the Small Hotel contains some office space and common areas, the Medium Office load flexibility measures were not applied to the Small Hotel spaces because of the potential for unpopular impacts, varying occupancy schedules, difficult field maintenance, and limited energy impacts. Team also explored the impact of load flexibility in all-electric clothes dryer scenario but did not see enough savings impact, hence the measure was not included in the package.

3.2.4 Additional Solar PV and Battery Storage

The Reach Code Team considered additional solar PV and battery storage measures that exceed the 2022 Title 24 prescriptive requirements to improve the cost-effectiveness of proposed scenarios. For Medium Office and Retail, the prescriptive solar PV sizes are large enough to occupy the entirety of the available roof space. Additional rooftop solar PV could not be considered for the two prototypes. For the Quick-Service Restaurant, solar PV is not prescriptively required since the prototype qualifies for the exception and the Reach Code Team considered adding solar PV to improve cost-effectiveness. For Small Hotel, the required PV size in the code-compliant models did not occupy the entire available roof space. Additional PV system capacity was considered as a measure to improve cost-effectiveness.

For the cost-effectiveness analysis, the Team evaluated additional solar PV for all-electric scenarios for the two building types, Quick Service Restaurant and Small Hotel. The additional PV size is calculated based on available roof space, assuming the maximum available space is 50% of total roof space and 15 Watt per square foot panel size.

Modeling: Updated PV capacity (kW) input in CBECC software.

Specification: Baseline requirement is 0 kW and 22-32.6 (depending on climate zone) kW for Quick-Service Restaurant and Small Hotel respectively. Proposed measure specification is 18.8 kW and 79.8 kW for Quick-Service Restaurant and Small Hotel respectively.

The costs for PV include first cost to purchase and install the system, inverter replacement costs, and annual maintenance costs. A summary of incremental costs and sources is given in Table 15 below.

Table 15. Additional Solar PV Measure Summary

Measure	Med Office	Med Retail	QSR	Small Hotel	Incremental Cost	Cost Source
Solar PV	-	-	●	●	First Cost: $3.20/W Inverter replacement cost at 10-yr: $0.15/W Annual Maintenance Cost: $0.02/W ITC Federal Incentive: 30%	National Renewable Energy Laboratory (NREL) Q1 2016 (National Renewable Energy Laboratory 2016) E3 Rooftop Solar PV System Report (Energy and Environmental Economics, Inc. 2017)

Upfront solar PV system costs are lowered because of the federal income tax credit (ITC)—approximately 30 percent based on the passage of Inflation Reduction Act. PV energy output is built into CBECC and is based on NREL's PVWatts calculator, which includes long term performance degradation estimates.

A battery storage system is prescriptively required for three prototypes: Medium Office, Medium Retail, and Small Hotel. The current software, CBECC v1.0, applies the appropriate prescriptive battery size (kWh) and capacity (kW) in the standard design. However, the control assumed in standard design is "Basic Control", which does not function for optimum battery use. The Team did not evaluate additional battery measures because the compliance software does not apply the "Time of Use" battery control method in standard design, which impacts the incremental energy costs and TDV benefits.

3.3 Measure Packages

The Reach Code Team compared a baseline Title 24 prescriptive package to mixed-fuel packages and two to four electrification packages depending on applicability of building type. Note that *most* QSR all-electric packages exclude kitchen electrification, while the Small Hotel all-electric package does include electric laundry cost and energy impacts.

- **Mixed Fuel Code Minimum:** Mixed-fuel prescriptive building per 2022 Title 24 requirements.
- **Mixed Fuel + Efficiency Measures**: Mixed-fuel prescriptive building per 2022 Title 24 requirements, including additional efficiency measures.
- **All-electric Code Minimum Efficiency:** All-electric building to minimum Title 24 prescriptive standards and *federal* minimum efficiency standards. This package has the same PV size as mixed-fuel prescriptive baseline.
- **All-electric Energy Efficiency:** All-electric building with added energy efficiency measures related to HVAC, SHW, lighting or envelope.
- **All-electric Energy Efficiency + Load Flexibility:** All-electric building with added energy efficiency and load flexibility measures.
- **All-electric Energy Efficiency + Solar PV:** All-electric building with added energy efficiency and additional Solar PV. The added PV size is larger than prescriptive 2022 Title 24 code requirements and accounts for roof space availability.

For QSR, the Reach Code Team has analyzed two scenarios for all-electric packages, one with electric cooking and the one with gas cooking (the latter of which is referred to as the "HS" package to reflect all-electric HVAC and SHW). The results section includes results for both scenarios since all-electric package with electric cooking appliance can be cost-effective in POU territories. This study did not evaluate pre-empted package with all-electric HVAC and SHW to have higher efficiency than required by federal regulations, that will potentially enhance cost-effectiveness and/or compliance margins.

For Small Hotel, the Reach Code Team also analyzed an alternative scenario with PTHP instead of SZHP in all-electric scenario. It is denoted by the “PTHP” in parenthesis in package name.

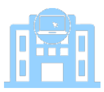
4 Cost-Effectiveness Results

Cost-effectiveness results are presented in this section and the attached workbook per prototype and measure packages described in Section 3. The TDV and On-Bill based cost-effectiveness results are presented in terms of B/C ratio and NPV.

In the following figures, the result **Both** (shown in green shading) indicates that the result is cost-effective on both On-Bill and (Total) TDV basis. The result ***On-Bill*** or ***TDV*** (shown in yellow shading) indicates that the result is either cost-effective on On-Bill or (Total) TDV basis, respectively. The result " - " (results with no shading) indicates that the result is not cost-effective on either an On-Bill basis or (Total) TDV basis.

Across all prototypes and climate zones, efficiency measures improve cost-effectiveness when added to the mixed-fuel baseline prototype and all-electric federal code minimum designs.

All-electric cost-effectiveness results by prototype can be summarized as:



Medium Office (Figure 1): All-electric space heating is predominantly achieved through electric resistance due to modeling limitations, which limits operational benefits. Efficiency measures yield some On-Bill cost-effective all-electric packages in milder climate zones. Adding load flexibility measures increases the cost-effectiveness to most climates.

Medium Retail (Figure 2): All-electric packages are cost-effective in all climate zones with added efficiency measures over all-electric baseline. Proposed mixed-fuel packages are cost-effective too with added efficiency measures in most climate zones primarily driven by cost-equivalency in the all-electric package compared to a mixed-fuel package.

Quick-Service Restaurant (

Figure 3)**:** All-electric package with and without cooking electrification is cost-effective in CPAU and SMUD territories only, On-Bill. All-electric HVAC and SHW package with added efficiency measures is On-Bill cost-effective in CZs 1, 3-5 and 12. Adding efficiency and solar PV is On-Bill cost-effective in CZs 1-5, 11-13, and 16. While not depicted in

Figure 3, the Results Workbook indicates that all-electric HVAC and SHW plus efficiency packages are *nearly* cost-effective (greater than
-$350/month) in all climate zones using On-Bill Net Present Values.

Small Hotel (Error! Reference source not found.)**:** The all-electric hotel has tremendous cost savings compared to a mixed-fuel package, primarily due to the avoidance of gas infrastructure to each guest room. All-electric packages achieve TDV cost-effectiveness in all CZs except 16. On-Bill cost-effectiveness is limited to CZs 2-5, 12 and 15 with single zone ducted heat pumps, but nearly all CZs with a packaged terminal heat pump.

4.1 Medium Office

In the all-electric Medium Office building, the upfront cost savings associated with avoiding boiler and gas infrastructure supports cost-effective packages in several climate zones, particularly with additional efficiency and load flexibility measures.

- Adding energy efficiency measures over mixed fuel code minimum is On-Bill cost-effective in all climate zones.
- The all-electric code minimum efficiency package is cost-effective for CZs 4 (CPAU), 6-10, 12 (SMUD) and 15.
- Adding energy efficiency measures to the all-electric code minimum package extends On-Bill cost-effectiveness to CZ 3 as well.
- All-electric energy efficiency along with load flexibility measure package is On-Bill cost-effective in most climate zones except 1, 11 and 16.

Figure 1. Medium Office Cost-Effectiveness Summary

Climate Zone		CZ1	CZ2	CZ3	CZ4		CZ5		CZ6	CZ7	CZ8	CZ9	CZ10		CZ11	CZ12		CZ13	CZ14		CZ15	CZ16
Prototype	Utility / Package	PG&E	PG&E	PG&E	PG&E	CPAU	PG&E	SCG	SCE	SDG&E	PG&E	SCE	SDG&E	SCE	PG&E	PG&E	SMUD	PG&E	SDG&E	SCE	SCE	PG&E
Medium Office (MO)	Mixed Fuel + Efficiency Measures	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both
Medium Office (MO)	All Electric Code Minimum Efficiency	–	–	–	On-Bill	On-Bill	–	–	Both	Both	Both	On-Bill	On-Bill	On-Bill	–	–	On-Bill	–	–	–	Both	–
Medium Office (MO)	All Electric Energy Efficiency	–	–	On-Bill	Both	Both	–	–	Both	Both	Both	Both	Both	Both	–	–	On-Bill	–	–	–	Both	–
Medium Office (MO)	All-Electric Energy Efficiency + Load Flexibility	–	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	On-Bill	Both	Both	Both	On-Bill	On-Bill	Both	–

4.2 Medium Retail

2022 Title 24 code prescriptively requires heat pumps in most scenarios already. This report evaluates added energy efficiency measures over the baseline all-electric scenario and proposed mixed-fuel packages.

- The mixed-fuel code minimum is not cost-effective by itself in most climate zones.
- Adding energy efficiency measures to the mixed-fuel code minimum package is On-Bill and/or TDV cost-effective in most climate zones.
- Adding energy efficiency measures over prescriptive all-electric package is also cost-effective in most climate zones except CZ16 using TDV.

Figure 2. Medium Retail Cost-effectiveness Summary

Climate Zone		CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
	Utility	PG&E	PG&E	PG&E	PG&E CPAU	PG&E SCG	SCE	SDG&E	PG&E	SCE	SDG&E SCE	PG&E	PG&E SMUD	PG&E	SDG&E SCE	SCE	PG&E
Prototype	Package																
Retail (RE)	Mixed Fuel Code Minimum	Both	–	–	– –	– –	–	–	–	–	– –	–	– –	–	On-Bill On-Bill	–	On-Bill
	Mixed Fuel + Efficiency Measures	Both	Both	Both	Both TDV	Both Both	Both	Both	Both	TDV	On-Bill –	On-Bill	Both TDV	Both	Both Both	Both	On-Bill
	All Electric Energy Efficiency	Both	Both	Both	Both Both	Both Both	Both	Both	Both	Both	Both Both	Both	Both Both	Both	Both Both	Both	On-Bill

4.3 Quick-Service Restaurant (QSR)

High incremental cost for HVAC and SHW electrification (“HS” package) makes restaurant electrification challenging. Because cooking electrification packages are very expensive – both upfront and operationally in IOU territories – the Team evaluated HS packages that do not consider cooking equipment electrification. This affects cost-effectiveness as gas infrastructure cost savings do not materialize.

- Adding energy efficiency measures over mixed fuel code minimum is On-Bill cost-effective in all climate zones.
- All-electric HVAC and SHW “HS” package is On-Bill cost-effective in CZ4 (CPAU) and CZ12 (SMUD) territory only.
- Adding energy efficiency and load flexibility measures extends On-Bill cost-effectiveness to CZs 1, 3 and 5.
- All-electric HVAC and SHW “HS” package with energy efficiency and solar PV measure is On-Bill cost-effective in climate zones 1-5, 11-13 and 16.
- All-electric package including cooking electrification is On-Bill cost-effective in CZ 4 (CPAU) territory only.
- The Results Workbook indicates that all-electric HVAC and SHW plus efficiency packages are nearly cost-effective (greater than -$350/month) in all climate zones using On-Bill Net Present Values.

Figure 3. QSR Cost-effectiveness Summary

Climate Zone		CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
	Utility	PG&E	PG&E	PG&E	PG&E CPAU	PG&E SCG	SCE	SDG&E	PG&E	SCE	SDG&E SCE	PG&E	PG&E SMUD	PG&E	SDG&E SCE	SCE	PG&E
Prototype	Package																
Quick-Service Restaurant (QSR)	Mixed Fuel + Efficiency Measures	Both	Both	Both	Both Both	Both Both	Both	Both	Both	Both	Both Both	Both	Both Both	Both	Both Both	Both	Both
	All Electric HS Code Minimum Efficiency	–	–	–	– On-Bill	– –	–	–	–	–	– –	–	– On-Bill	–	– –	–	–
	All Electric HS Energy Efficiency	On-Bill	–	On-Bill	– On-Bill	On-Bill –	–	–	–	–	– –	–	– On-Bill	–	– –	–	–
	All-Electric HS Energy Efficiency + Load Flexibility	On-Bill	–	On-Bill	– On-Bill	– –	–	–	–	–	– –	–	– On-Bill	–	– –	–	–
	All Electric HS Energy Efficiency + Solar PV	On-Bill	On-Bill	On-Bill	On-Bill On-Bill	On-Bill On-Bill	–	–	–	–	– –	On-Bill	On-Bill On-Bill	On-Bill	– –	–	On-Bill
	All Electric Code Minimum Efficiency	–	–	–	– On-Bill	– –	–	–	–	–	– –	–	– –	–	– –	–	–
	All Electric Energy Efficiency	–	–	–	– On-Bill	– –	–	–	–	–	– –	–	– –	–	– –	–	–

4.4 Small Hotel

The all-electric hotel has cost savings compared to a mixed-fuel package, primarily due to the avoidance of boilers and gas infrastructure to each guest room. The analysis assumes single zone ducted heat pump for all all-electric scenarios; however, the Team analyzed a Packaged Terminal Heat Pump (PTHP) scenario as well. PTHP shows higher incremental cost *savings* as compared to a baseline of mixed fuel single zone packaged system and hence are cost-effective in many climate zones.

- Adding energy efficiency measures over mixed fuel code minimum is On-Bill cost-effective in all climate zones.
- All-electric code minimum packages with or without energy efficiency measure packages are TDV cost-effective in all climate zones except 16, and On-Bill cost-effective in CZ4 (CPAU) and CZ12 (SMUD) due to relatively lower electricity costs.
- Additional solar PV over all-electric energy efficiency package extends On-Bill cost-effectiveness to CZs 2, 3, 4 (PG&E), 5 and 15.
- The alternative all-electric scenario with PTHP is cost-effective in all climates, On-Bill in most CZs except 7,10 and 14 SDG&E territories.

Figure 4. Small Hotel Cost-effectiveness Summary

Climate Zone		CZ1	CZ2	CZ3	CZ4	CZ4	CZ5	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ10	CZ11	CZ12	CZ12	CZ13	CZ14	CZ14	CZ15	CZ16
Prototype	Utility / Package	PG&E	PG&E	PG&E	PG&E	CPAU	PG&E	SCG	SCE	SDG&E	PG&E	SCE	SDG&E	SCE	PG&E	PG&E	SMUD	PG&E	SDG&E	SCE	SCE	PG&E
Small Hotel (SH)	Mixed Fuel + Efficiency Measures	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both	Both
Small Hotel (SH)	All Electric Code Minimum Efficiency	TDV	TDV	TDV	TDV	Both	TDV	TDV	TDV	TDV	TDV	TDV	TDV	TDV	TDV	TDV	Both	TDV	TDV	TDV	TDV	–
Small Hotel (SH)	All Electric Energy Efficiency	TDV	TDV	TDV	Both	Both	TDV	TDV	TDV	TDV	TDV	TDV	TDV	TDV	TDV	TDV	Both	TDV	TDV	TDV	TDV	–
Small Hotel (SH)	All Electric Energy Efficiency + Solar PV	TDV	Both	Both	Both	Both	Both	TDV	TDV	TDV	TDV	TDV	TDV	TDV	TDV	TDV	Both	TDV	TDV	TDV	Both	–
Small Hotel (SH)	All Electric Code Minimum Efficiency (PTHP)	Both	Both	Both	Both	Both	Both	Both	Both	TDV	Both	Both	TDV	Both	Both	Both	Both	Both	TDV	Both	Both	Both

5 Energy Code Compliance Results and Reach Code Considerations

This section combines the cost-effectiveness and 2022 Title 24 energy code compliance metric results — efficiency TDV, total TDV, and source energy, described in Section 2.3 — to highlight the viable reach code options for local jurisdictions. The Reach Code Team calculated metrics using both:

1. Software outputs using the ACM standard design and
2. Manually by subtraction against the baseline model because of software limitations that are beyond the Reach Code Team's control.[6]

All Efficiency TDV margins presented in this section are the lower of the two approaches, Software output and Manual, to be conservative and inform the minimum compliance margins that can be met by a typical modeler. Full details of compliance margins and cost-effectiveness results are presented in the Final Results Workbook for reference.

Importantly, the workbook shows that for all prototypes, all-electric packages are capable of achieving greater greenhouse savings as compared to mixed-fuel buildings. Below is a summary of how compliance results as well as cost-effectiveness for each prototype and package could influence reach code options. The Reach Code Team outlines recommendations using the following framework, based on reach codes that were adopted across California under the 2019 building code cycle:

- **Mixed fuel buildings are allowed, with efficiency.** Local amendments governing efficiency and conservation must be performed in the Title 24 Part 6 Building Energy Efficiency Standards and be approved by the Energy Commission.
    - *Energy Efficiency* — Require energy efficiency for buildings regardless of fuel type. A jurisdiction can require different compliance thresholds for all-electric and/or mixed-fuel. The thresholds should be set considering how they may affect mixed-fuel or all-electric buildings.
    - *Electric-Preferred* — Allow mixed-fuel appliances but require a higher building performance via efficiency, total, or source compliance metric (for example, (Milpitas 2019), section 140.1).[7] Applies only to mixed-fuel buildings.
- **Mixed fuel buildings are not allowed.** Local amendments governing green building requirements may be performed in the Title 24 Part 11 Green Building Standards Code and must be filed with the Building Standards Commission. Alternatively, the local amendment may be performed in a municipal code chapter of their respective jurisdictions.
    - *All-Electric* — Require certain all-electric only appliances, with exceptions (for example (Menlo Park 2019). Does not involve efficiency or conservation measures, and cost-effectiveness is a not a legal requirement.[8] Local amendments may be performed through other building code sections, such as Part 11. See discussion on Exceptions below.
    - *All-Electric + Efficiency* — Require certain all-electric appliances, but with a higher building performance via efficiency, total, or source compliance metric. Also requires amendment to Title 24 Part 6 and approval by the Energy Commission.

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[6] The difference between the two methods of calculating TDV margins occurs due to various software limitations. The Team had challenges modeling a baseline showing zero-percent (exactly compliant) compliance margin, and differing interpretations of 2022 Title 24 code regarding fan power, exhaust fan, heat recovery, battery control, and other aspects. Most scenarios show similar trends between software calculated compliance margin and the Team's manual subtraction against baseline model, with a difference in magnitude. For example, if the Total TDV Compliance margin as shown by software directly is negative, it is typically negative per manual calculation as well. Nonetheless, modeling limitations introduce error into the calculations, which may affect results. Many scenarios have very low negative compliance margin and are very close to being zero. While this uncertainty in error may lead to imprecision in results, relative performance across packages can yield information helpful for decision-making.

[7] Note Milpitas has since adopted an All-electric with Exceptions code for the 2022 code cycle.

[8] See letter from CEC to South San Francisco for reference.

Exceptions enable reach codes to broadly require electrification except for specific building systems. These systems may have uncertainty on energy code compliance, building industry electrification approaches, or other related impacts on economic development. During the 2019 code cycle, cities developed exemptions based on discussions with local stakeholders, resulting in a wide array of exemption types.[9] For the four prototypes in this study, the Team has determined two exemptions that may be necessary for cities passing All-Electric reach codes.

- **Building systems without a prescriptive compliance pathway in the energy code.** This exemption considers that all-electric central space heating does not have a prescriptive pathway in Title 24, and central heat pump boilers cannot be currently modeled, which has impacted compliance results for the Medium Office and Small Hotel. This exemption has broad precedence and can apply to other large nonresidential buildings (e.g., (Berkeley 2019), section 12.80.040.A Exception 1). These exemptions typically state that the building is also not able to comply via the performance approach using commercially available technology.
- **Commercial cooking**. Cooking electrification does not considerably impact code compliance but is not nearly cost-effective against a mixed-fuel baseline. To account for this challenge, cities may wish to adopt reach codes that exempt commercial kitchen cooking appliances (e.g., (Menlo Park 2019) 100.0(e)2.A Exception 4).

[9] See list of exemptions on Bay Area Reach Codes.

Table 16. Reach Code Pathway Considerations

Prototype	Compliance and Cost-Effectiveness Results Summary	Energy Efficiency	Electric-Preferred	All-Electric	All-Electric + Efficiency
Medium Office	The Team could not identify any all-electric package that complies with all three compliance metrics, with the Efficiency TDV Compliance margin being the most challenging. Future iterations of this study will re-evaluate the Medium Office with a central heat pump boiler, an anticipated compliance software capability in early 2023, instead of electric resistance VAVs.	To Be Determined. Modeling constraints impacted achievable compliance margins for all-electric packages.	All CZs.	Exempt building systems without a prescriptive pathway in the energy code.	To Be Determined. Modeling constraints impacted achievable compliance margins for all-electric packages
Medium Retail	The Team identified cost-effective and code compliant packages of all-electric + energy efficiency measures across most CZs. Mixed-fuel + efficiency was cost-effective but not code compliant in most CZs.	CZs 7 and 9.	CZs 7 and 9.	CZs 2-15. 2022 T24 prescriptive baseline	CZs 1-10, 12-14.
Quick-Service Restaurant	The Mixed-fuel + efficiency package is cost-effective and compliant in many climate zones. Code compliance and cost-effectiveness results support reach code adoption for all-electric space conditioning and service water heating when adding efficiency and solar PV for CZs 1 and 3-5, many others are likely to be compliant with future modeling input updates. Cost-effectiveness is achieved or *nearly* achieved (Net Present Value is greater than -$350/month) On-Bill in all CZs. Cooking electrification does not impact code compliance but is not cost-effective against a mixed-fuel baseline except for CPAU territory.	CZs 1, 3-7.	CZs 1-7, 13.	CZs 1, 3-7. Exempt commercial kitchen appliances, except CZ4 (CPAU). Nearly all remaining CZs have a *nearly* cost-effective and/or nearly compliant pathway for HVAC and SHW only.	CZs 1, 3-5.
Small Hotel	Results support Electric-Preferred reach code for all CZs. The all-electric packages are *near* compliant and TDV cost-effective for most CZs when including energy efficiency measures and additional solar PV. They are *likely* to be compliant with future modeling iterations. Future iterations of this study will re-evaluate the nonresidential areas of the hotel with a central heat pump boiler, as mentioned for the Medium Office, which can potentially improve code compliance.	To Be Determined. Modeling constraints impacted achievable compliance margins for all-electric packages.	All CZs.	Exempt building systems without a prescriptive pathway in the energy code.	To Be Determined. Modeling constraints impacted achievable compliance margins for all-electric packages.

The combined result of cost-effectiveness and code compliance across all climate zones and packages are detailed in Section 0 through 5.4 below. The tables are formatted to show:

- Cost-effectiveness results with color highlight:
  - **Green** highlight — for scenarios that are cost-effective on both On-Bill and TDV metrics, may or may not be compliant.
  - **Yellow** highlight — for scenarios that are cost-effective on either one of the On-Bill/TDV metrics, may or may not be compliant.
  - **Gray** highlight — for scenarios that are not cost-effective on either metric, either compliant currently or likely to be compliant in future.
  - White highlight — for scenarios that are not cost-effective on either metric and are not compliant.
- Compliance results with cell values:
  - "EffTDV Margin" percentages — for scenarios that are compliant, across both Manual and CBECC software output, the reported value is the minimum of the two.
  - "-" for scenarios that do not comply across any one code compliance metric.

"TBD" – for scenarios that are likely to be compliant with modeling updates or software versions in future, maybe compliant across either one of the Manual or CBECC software output approach or has a system type modeling limitation such as central heat pump boiler for Medium Office and Small Hotel. The package names in table results columns are as follows, as defined in Section 3.3:

- **Mixed fuel — Code Min**: Mixed Fuel Code Minimum Efficiency
- **Mixed fuel — EE**: Mixed Fuel + Efficiency Measures
- **All-electric — Code Min**: All-electric Code Minimum Efficiency
- **All-electric — EE**: All-electric Energy Efficiency
- **All-electric — EE + LF**: All-electric Energy Efficiency and Load Flexibility
- **All-electric — EE + PV**: All-electric Energy Efficiency and Solar PV

The QSR has two electrification scenarios, with and without cooking appliance electrification, which is denoted by "HS" prefix.

The Small Hotel has an extra package that evaluates a different HVAC type in the all-electric Code Minimum Efficiency package, a Packaged Terminal Heat Pump (PTHP) instead of a Single Zone Heat Pump.

5.1 Medium Office

For Medium Office, the Reach Code Team analyzed EE measures over mixed fuel baseline model and three electrification packages: 1) Code Min, 2) EE and 3) EE + LF packages, results shown in Table 17.

The most likely all-electric replacement for a central gas boiler serving a VAV reheat system would be a central heat pump boiler; however, this system cannot be modeled in CBECC at the time of the writing of this report. As such, the Reach Code Team is treating this analysis as temporary until a compliance pathway is established for a central heat pump boiler in the Energy Code and results can be updated accordingly. This modeling capability is anticipated in early 2023 according to discussions with the CBECC software development team, and the cost-effectiveness analysis should become available in the first half of 2023. Heat pump systems are multiple times more efficient, but may also be multiple times more costly, than the electric resistance reheat systems currently analyzed.

- Results support reach code adoption for energy efficiency measures over mixed fuel baseline, also known as the “Electric-Preferred”. A compliance margin of 4–5% is achievable depending on the climate zone.
- No all-electric package complies with all three-compliance metrics, with the efficiency compliance TDV margin being the most challenging. The Reach Code Team explored other efficiency measures that reduce the efficiency compliance TDV margin, but not enough to make the TDV margin positive. The compliance values are labeled as “TBD” for all-electric packages, as they are likely to be compliant with future modeling and/or software updates. Some climate zones are compliant currently on either one of the Software output or Manual compliance approaches.

Table 17. Cost-effectiveness and Compliance Summary – Medium Office

CZ	Utility	Mixed Fuel	All-electric		
		EE	Code Min	EE	EE + LF
cz01	PG&E	4%	TBD	TBD	TBD
cz02	PG&E	5%	TBD	TBD	TBD
cz03	PG&E	5%	TBD	TBD	TBD
cz04	PG&E	4%	TBD	TBD	TBD
cz04-2	CPAU	4%	TBD	TBD	TBD
cz05	PG&E	5%	TBD	TBD	TBD
cz05-2	SCG	5%	TBD	TBD	TBD
cz06	SCE	6%	TBD	TBD	TBD
cz07	SDG&E	7%	TBD	TBD	TBD
cz08	SCE	6%	TBD	TBD	TBD
cz09	SCE	4%	TBD	TBD	TBD
cz10	SDG&E	4%	TBD	TBD	TBD
cz10-2	SCE	4%	TBD	TBD	TBD
cz11	PG&E	3%	TBD	TBD	TBD
cz12	PG&E	4%	TBD	TBD	TBD
cz12-2	SMUD	4%	TBD	TBD	TBD
cz13	PG&E	4%	TBD	TBD	TBD
cz14	SDG&E	4%	TBD	TBD	TBD
cz14-2	SCE	4%	TBD	TBD	TBD
cz15	SCE	3%	TBD	TBD	TBD
cz16	PG&E	4%	TBD	TBD	TBD

* These results will be re-evaluated with central heat pump boiler system instead of electric resistance VAV systems, which largely are unable to achieve energy code compliance.

KEY

Cell Color	
(green)	Cost effective on both TDV/On-Bill metrics
(yellow)	Cost effective on either TDV/On-Bill metrics
(gray)	Compliant, not cost effective
	Not compliant nor cost effective
Cell Value	
X%	EffTDV Compliance Margin percentages (Lowest common) Compliant on both Manual and Software output approaches
TBD	Likely to comply with future modeling updates or software versions, maybe compliant on either Manual or Software output approach presently
-	Not compliant on either approach

5.2 Medium Retail

For Medium Retail, the Team analyzed EE measure package over an all-electric baseline model and two mixed fuel packages — Code Min and EE, with results in Table 18.

- Results support reach code adoption for energy efficiency measures over mixed fuel code minimum package, also known as "Electric-Preferred" or "Energy Efficiency" reach code pathways in climate zones 7 and 9.
- Results also support "All-Electric + Efficiency" reach code option, with compliance margins of 4-14% above the all-electric code minimum baseline in climate zones 1-10 and 12-14.
- For some scenarios in climate zone 6, 8, 11, 15 and 16, labeled as "TBD", the package is cost-effective and likely to be compliant in future with modeling input and/or software version updates.

Table 18. Cost-effectiveness and Compliance Summary – Medium Retail

CZ	Utility	Mixed Fuel		All-electric
		Code Min	EE	EE
cz01	PG&E	-	-	6%
cz02	PG&E	-	-	4%
cz03	PG&E	-	-	12%
cz04	PG&E	-	-	11%
cz04-2	CPAU	-	-	11%
cz05	PG&E	-	-	12%
cz05-2	SCG	-	-	12%
cz06	SCE	-	TBD	9%
cz07	SDG&E	-	12%	14%
cz08	SCE	-	TBD	8%
cz09	SCE	-	11%	12%
cz10	SDG&E	-	-	3%
cz10-2	SCE	-	-	3%
cz11	PG&E	-	-	TBD
cz12	PG&E	-	-	10%
cz12-2	SMUD	-	-	10%
cz13	PG&E	-	-	4%
cz14	SDG&E	-	-	7%
cz14-2	SCE	-	-	7%
cz15	SCE	-	-	TBD
cz16	PG&E	-	-	TBD

KEY

Cell Color	
(green)	Cost effective on both TDV/On-Bill metrics
(yellow)	Cost effective on either TDV/On-Bill metrics
(gray)	Compliant, not cost effective
(white)	Not compliant nor cost effective

Cell Value	
X%	EffTDV Compliance Margin percentages (Lowest common) Compliant on both Manual and Software output approaches
TBD	Likely to comply with future modeling updates or software versions, maybe compliant on either Manual or Software output approach presently
-	Not compliant on either approach

5.3 Quick-Service Restaurant (QSR)

The Team analyzed efficiency measures over a mixed fuel baseline and electrification packages, with and without cooking appliance electrification. For the "HS" scenario including HVAC and SHW electrification only, packages with EE, EE + LF and EE + PV were analyzed, with results in Table 19.

- Results support reach code adoption for energy efficiency measures over a mixed fuel baseline, also known as "Electric-Preferred" in climate zones 1 to 7 and 13, or "Energy Efficiency" in CZs 1 and 3 to 7.
- All-electric "HS" HVAC and SHW electrification can be adopted in CZs 1 and 3-7 since it is code compliant and *nearly* cost effective on at least one metric when energy efficiency measures and/or load flexibility or solar PV measure is added, demonstrated by yellow or gray cells.
- All-electric "HS" HVAC and SHW option with additional efficiency measures can be adopted in CZs 1 and 3-5. Adding solar PV makes the package on-bill cost-effective on at least one metric marked as yellow cells..
- Packages labeled as "TBD" may or may not be cost-effective but are likely to be compliant in the future with modeling input and/or software updates.

Table 19. Cost-effectiveness and Compliance Summary – Quick-Service Restaurant (without cooking electrification)

CZ	Utility	Mixed Fuel	All-electric "HS" (HVAC+SHW)			
		EE	Code Min	EE	EE + LF	EE + PV
cz01	PG&E	16%	-	6%	16%	6%
cz02	PG&E	6%	-	TBD	TBD	TBD
cz03	PG&E	18%	-	8%	13%	8%
cz04	PG&E	16%	-	5%	8%	5%
cz04-2	CPAU	16%	-	5%	8%	5%
cz05	PG&E	18%	-	8%	15%	8%
cz05-2	SCG	18%	-	8%	15%	8%
cz06	SCE	16%	-	3%	6%	3%
cz07	SDG&E	21%	-	9%	13%	9%
cz08	SCE	TBD	-	-	-	-
cz09	SCE	TBD	-	TBD	TBD	TBD
cz10	SDG&E	TBD	-	-	-	-
cz10-2	SCE	TBD	-	-	-	-
cz11	PG&E	TBD	-	TBD	TBD	TBD
cz12	PG&E	TBD	-	TBD	TBD	TBD
cz12-2	SMUD	TBD	-	TBD	TBD	TBD
cz13	PG&E	7%	-	TBD	TBD	TBD
cz14	SDG&E	TBD	-	TBD	TBD	TBD
cz14-2	SCE	TBD	-	TBD	TBD	TBD
cz15	SCE	TBD	-	TBD	TBD	TBD
cz16	PG&E	TBD	-	-	TBD	-

KEY

Cell Color	
(green)	Cost effective on both TDV/On-Bill metrics
(yellow)	Cost effective on either TDV/On-Bill metrics
(gray)	Compliant, not cost effective
	Not compliant nor cost effective
Cell Value	
X%	EffTDV Compliance Margin percentages (Lowest common) Compliant on both Manual and Software output approaches
TBD	Likely to comply with future modeling updates or software versions, maybe compliant on either Manual or Software output approach presently
-	Not compliant on either approach

The Reach Code Team analyzed a completely all-electric package including cooking appliances, results shown in Table 20, which show compliance in many climate zones with added efficiency and load flexibility. Remaining CZs are "TBD", except climate zone 16, which comply on either one of the Manual or Software output approaches currently and are likely to show compliance with future modeling updates. However, the all-electric package is cost-effective in CZ4 CPAU territory only and very close to being cost-effective in SMUD territory. Cooking electrification is expensive and challenging to show cost-effective.

Table 20. Cost-effectiveness and Compliance Summary – Quick-Service Restaurant (with cooking electrification)

CZ	Utility	All-electric		
		Code Min	EE	EE + LF
cz01	PG&E	-	6%	15%
cz02	PG&E	-	TBD	2%
cz03	PG&E	-	10%	14%
cz04	PG&E	-	8%	10%
cz04-2	CPAU	-	8%	10%
cz05	PG&E	-	10%	17%
cz05-2	SCG	-	10%	17%
cz06	SCE	-	6%	10%
cz07	SDG&E	-	11%	14%
cz08	SCE	-	TBD	TBD
cz09	SCE	-	TBD	TBD
cz10	SDG&E	-	TBD	TBD
cz10-2	SCE	-	TBD	TBD
cz11	PG&E	-	TBD	0%
cz12	PG&E	-	TBD	TBD
cz12-2	SMUD	-	TBD	TBD
cz13	PG&E	-	TBD	TBD
cz14	SDG&E	-	TBD	TBD
cz14-2	SCE	-	TBD	TBD
cz15	SCE	-	TBD	2%
cz16	PG&E	-	-	-

KEY

Cell Color	
(green)	Cost effective on both TDV/On-Bill metrics
(yellow)	Cost effective on either TDV/On-Bill metrics
(gray)	Compliant, not cost effective
(white)	Not compliant nor cost effective
Cell Value	
X%	EffTDV Compliance Margin percentages (Lowest common) Compliant on both Manual and Software output approaches
TBD	Likely to comply with future modeling updates or software versions, maybe compliant on either Manual or Software output approach presently
-	Not compliant on either approach

5.4 Small Hotel

The Team analyzed EE package over mixed fuel baseline and three electrification packages - Code Min, EE, EE+PV, with results in Table 21.

- Results support reach code adoption for energy efficiency measures over mixed fuel baseline, also known as "Electric-Preferred" reach code pathway with 2-5% compliance margin.
- All-electric packages with efficiency measures and/or solar PV in most CZs are cost-effective and likely to be compliant in future with modeling and/or software version updates. Some climate zones are compliant currently across either one of the Manual or Software output approaches.
- All all-electric scenarios are labeled as "TBD" because 36% of conditioned floor area is nonresidential space and has the same system type limitation as Medium Office (see Section 5.1). Hence, the Small Hotel will be re-evaluated as well with a central heat pump boiler system instead of electric resistance VAV system in early 2023. The current results show compliance on either one of the Manual or Software output approaches in some climate zones with efficiency measures and solar PV, still labeled as "TBD" until the software inconsistencies are resolved.

Table 21. Cost-effectiveness and Compliance Summary – Small Hotel.

CZ	Utility	Mixed Fuel	All-electric		
		EE	Code Min	EE	EE + PV
cz01	PG&E	5%	TBD	TBD	TBD
cz02	PG&E	4%	TBD	TBD	TBD
cz03	PG&E	5%	TBD	TBD	TBD
cz04	PG&E	5%	TBD	TBD	TBD
cz04-2	CPAU	5%	TBD	TBD	TBD
cz05	PG&E	5%	TBD	TBD	TBD
cz05-2	SCG	5%	TBD	TBD	TBD
cz06	SCE	5%	TBD	TBD	TBD
cz07	SDG&E	4%	TBD	TBD	TBD
cz08	SCE	5%	TBD	TBD	TBD
cz09	SCE	5%	TBD	TBD	TBD
cz10	SDG&E	5%	TBD	TBD	TBD
cz10-2	SCE	5%	TBD	TBD	TBD
cz11	PG&E	3%	TBD	TBD	TBD
cz12	PG&E	4%	TBD	TBD	TBD
cz12-2	SMUD	4%	TBD	TBD	TBD
cz13	PG&E	3%	TBD	TBD	TBD
cz14	SDG&E	4%	TBD	TBD	TBD
cz14-2	SCE	4%	TBD	TBD	TBD
cz15	SCE	5%	TBD	TBD	TBD
cz16	PG&E	2%	TBD	TBD	TBD

KEY

Cell Color	
(green)	Cost effective on both TDV/On-Bill metrics
(yellow)	Cost effective on either TDV/On-Bill metrics
(gray)	Compliant, not cost effective

	Not compliant nor cost effective
Cell Value	
X%	EffTDV Compliance Margin percentages (Lowest common) Compliant on both Manual and Software output approaches
TBD	Likely to comply with future modeling updates or software versions, maybe compliant on either Manual or Software output approach presently
-	Not compliant on either approach

The Team analyzed an additional scenario that proposes PTHP compared to the same SZAC mixed fuel baseline model, results shown in Table 22. Though PTHP is a much cheaper alternative than SZHP, it is not compliant by itself.

Table 22. Cost-effectiveness and Compliance Summary – Small Hotel (PTHP)

CZ	Utility	All-electric
		Code Min (PTHP)
cz01	PG&E	-
cz02	PG&E	-
cz03	PG&E	-
cz04	PG&E	-
cz04-2	CPAU	-
cz05	PG&E	-
cz05-2	SCG	-
cz06	SCE	-
cz07	SDG&E	TBD
cz08	SCE	TBD
cz09	SCE	TBD
cz10	SDG&E	-
cz10-2	SCE	-
cz11	PG&E	-
cz12	PG&E	-
cz12-2	SMUD	-
cz13	PG&E	-
cz14	SDG&E	-
cz14-2	SCE	-
cz15	SCE	-
cz16	PG&E	-

KEY

Cell Color	
(green)	Cost effective on both TDV/On-Bill metrics
(yellow)	Cost effective on either TDV/On-Bill metrics
(grey)	Compliant, not cost effective
	Not compliant nor cost effective
Cell Value	
X%	EffTDV Compliance Margin percentages (Lowest common) Compliant on both Manual and Software output approaches

TBD	Likely to comply with future modelling updates or software versions, maybe compliant on either Manual or Software output approach presently
-	Not compliant on either approach

6 Conclusions

The Reach Code Team developed a variety of packages involving fuel substitution, energy efficiency, load flexibility, and solar PV, simulated them in building modeling software, and gathered costs to determine the cost-effectiveness of multiple scenarios. The Team coordinated with multiple utilities, cities, and building community experts to develop a set of assumptions considered reasonable in the current market. Changing assumptions, such as the period of analysis, measure selection, fuel costs, other costs, energy escalation rates, software or utility tariffs may change the results.

These results, including the attached Reach Code Results Workbook, indicate all-electric packages are capable of achieving the greatest GHG savings as compared to mixed-fuel buildings, see Appendix 8.5. Jurisdictions may adopt a variety of reach codes such as “Energy Efficiency”, “Electric-Preferred”, “All-Electric” or “All-Electric + Efficiency.” In summary:

- The Reach Code Team has identified a cost-effective and code compliant energy efficiency measure package for most prototypes and climate zones analyzed, which supports an “Electric-Preferred” and/or “Energy Efficiency” reach code pathways for jurisdictions.
- “All-Electric” reach codes are feasible for all building types and climate zones when Part 11 is modified, including some exceptions.
    - All-electric HVAC consisting of packaged single zone systems, including rooftop units in the Medium Retail and Quick-Service Restaurant, and single zone heat pumps in the Small Hotel guest rooms, are widely shown to be cost-effective and energy code compliant, with exceptions in CZs 1 and 16.
    - All-electric SHW systems have a prescriptive pathway for all building types and have not been shown to be an impediment to cost-effectiveness or energy code compliance of all-electric packages in this study.
    - All-electric laundry in the Small Hotel can be cost-effective with added energy efficiency and additional solar PV than required prescriptively by 2022 Title 24 code.
    - Medium Office all-electric packages are cost-effective with energy efficiency and load flexibility measures, but not code compliant due to the use of electric resistance VAV reheat systems. The Small Hotel faces a similar issue for its smaller nonresidential area HVAC systems in some climate zones. This indicates that further efficiency measures would need to be added to achieve energy code compliance which may not be cost-effective. As described in Sections 5.1 and 5.4, modeling limitations impacted the code compliance results for the medium office and nonresidential portion of the small hotel. These prototypes will be re-evaluated using a more appropriate central heat pump boiler HVAC system, likely available in compliance software in early 2023. In the meantime, jurisdictions can choose to exempt building systems that do not have a prescriptive compliance pathway in the energy code. See Berkeley’s all-electric ordinance (Berkeley 2019) section 12.80.040.A Exception 1 for an example.
- Commercial kitchen electrification is challenging to design cost-effectively currently. These results align with a previous study focusing on restaurants (Statewide IOU Team 2022). Jurisdictions may choose to exempt cooking appliances until cost-effectiveness factors improve. See Menlo Park's ordinance (Menlo Park 2019) 100.0(e)2.A Exception 4 for an example.
- For the Medium Retail prototype in CZs 2 to 15, there is already a prescriptive pathway to comply with packaged single zone heat pumps in smaller (<240 kBtuh) thermal zones. This study supports an “All-Electric + Efficiency” reach code pathway for many climates. However, mixed-fuel scenarios with SZAC and gas furnaces for larger (>240 kBtuh) thermal zones are challenging to show cost-effectiveness and/or code compliance, except for climate zones 7 and 9, when including efficiency measures.

Further discussion is required at the jurisdiction and community members to review results and determine appropriate reach code pathways. Please refer to the limitations of this study, described in Section 2.5, while using them to inform reach code policies. Of note:

- The Team employed several CBECC ruleset modifications to support achieving cost-effective packages, especially load flexibility measures. Ruleset modifications cannot be used by the building industry for code compliance without supporting justification or alternate methods. Where jurisdictions want to encourage the adoption of Load Flexibility measures through modeling estimates, the Reach Code Team can support cities and building applicants by providing modeling approximations that may achieve similar energy and compliance total impacts, in coordination with the Energy Commission. For example, for the Demand Response Lighting measure, the Team may be able to share a TDV/ft^2 impact of the measure in that climate zone or provide guidance to the building applicant's energy consultant on appropriate modeling and documentation.
- Results are predominantly based on the code compliance metrics that are manually calculated based on the mixed fuel baseline model and not the standard design model assumed by the current software version. The Team also provided software reported compliance metrics in the workbook for reference. The Team is in communication with software development team to resolve differences in future iterations of this study and the software and improve code compliance reporting.

Even considering the limitations, this study has identified a set of reach code pathways for all climate zones, and jurisdictions have broad discretion on how to interpret the study's findings. Jurisdictions can adopt reach codes requiring energy efficiency via a Title 24 Part 6 local amendment, or electrification via a Title 24 Part 11 (or municipal code) amendment, or both. Jurisdictions may choose to except particular building systems from certain reach codes pathways.

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The adoption of reach codes can differentiate jurisdictions as efficiency leaders and help accelerate the adoption of new equipment, technologies, code compliance, and energy savings strategies.

As part of the Statewide Codes & Standards Program, the Reach Codes Subprogram is a resource available to any local jurisdiction located throughout the state of California.

Our experts develop robust toolkits as well as provide specific technical assistance to local jurisdictions (cities and counties) considering adopting energy reach codes. These include cost-effectiveness research and analysis, model ordinance language and other code development and implementation tools, and specific technical assistance throughout the code adoption process.

If you are interested in finding out more about local energy reach codes, the Reach Code Team stands ready to assist jurisdictions at any stage of a reach code project.

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