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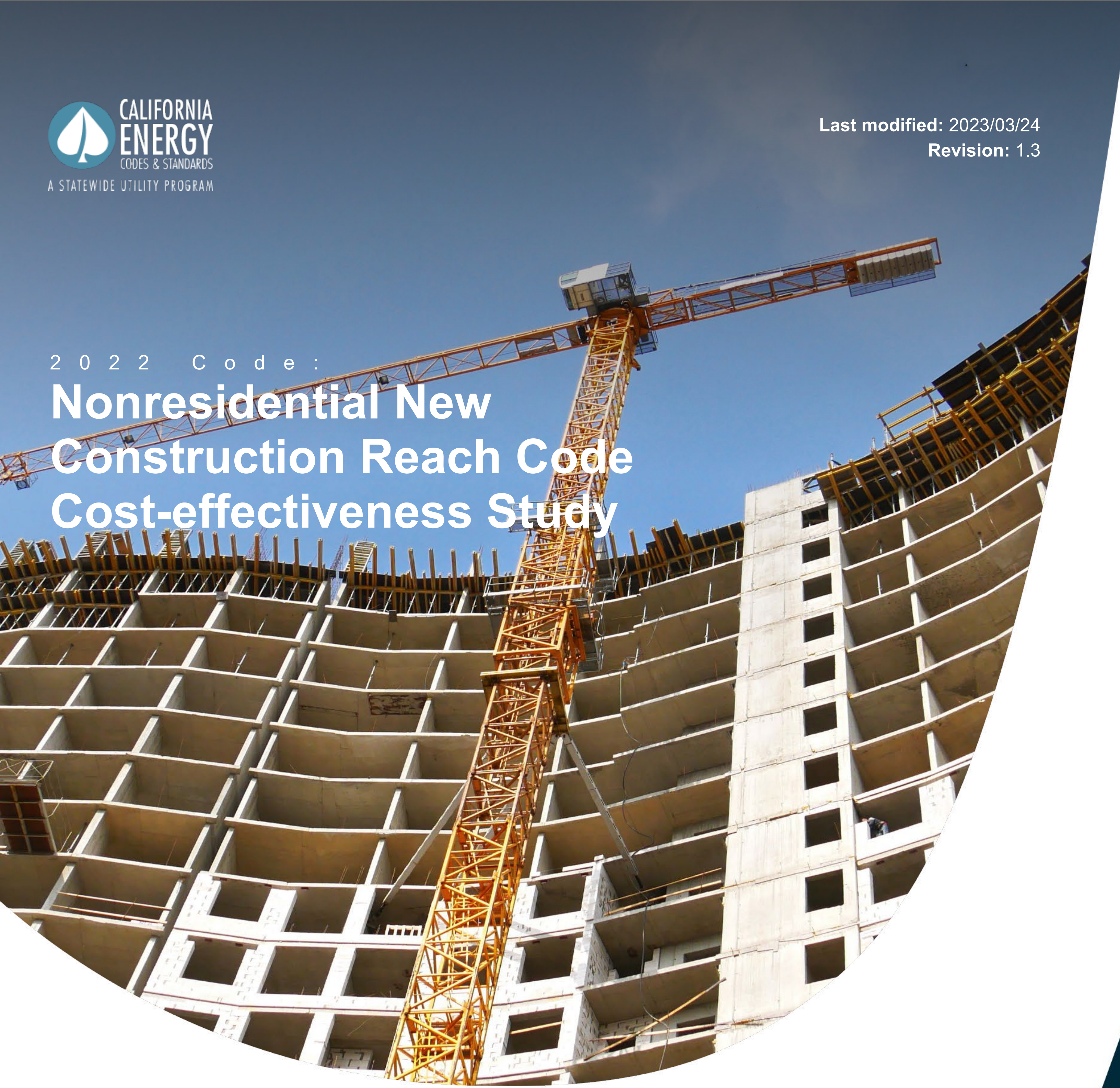

CALIFORNIA ENERGY CODES & STANDARDS
A STATEWIDE UTILITY PROGRAM

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Nonresidential New Construction Reach Code Cost-effectiveness Study

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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/ft²) 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/ft²

Medium Retail

- Storage: 0.36 W/ft²
- Retail sales: 0.86 W/ft²
- Main entry lobby: 0.63 W/ft²

QSR

- Dining: 0.41 W/ft²
- Kitchen: 0.86 W/ft²

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
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
Retail (RE)	Mixed Fuel Code Minimum	Both	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	On-Bill	On-Bill	–	On-Bill
Retail (RE)	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
Retail (RE)	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	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																
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
	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	–
	All Electric Energy Efficiency	TDV	TDV	TDV	Both Both	TDV TDV	TDV	TDV	TDV	TDV	TDV TDV	TDV	TDV Both	TDV	TDV TDV	TDV	–
	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	–
	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
(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 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
(grey)	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
(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 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
(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 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.

7 References

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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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