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2021 REACH CODE

COST-EFFECTIVENESS ANALYSIS:

Non-Residential Alterations

Prepared by:
TRC, P2S Engineers

Prepared for:
Jay Madden, Codes and Standards Program, Southern California Edison Company
Kelly Cunningham, Codes and Standards Program, Pacific Gas and Electric Company

Legal Notice

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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

ESA CAM – Energy Savings Assistance Common Area Measures Program

EUI – Energy Use Index

FDD – Fault Detection and Diagnostics

FSR – Full Service Restaurant

GHG - Greenhouse Gas

GPM – Gallons Per Minute

HE – High efficiency

HRMF – Nonresidential and High-Rise Multifamily

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

PCE – Peninsula Clean Energy

PNNL – Pacific Northwest National Laboratory

POU – Publicly Owned Utility

PSI – Per Square Inch

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)**
1/27/2022	Original Release	NA

Table of Contents

LIST OF FIGURES

1 Introduction

The California Building Energy Efficiency Standards Title 24, Part 6 (Title 24) (CEC, 2019) is maintained and updated every three years by two state agencies: the California Energy Commission (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). Local jurisdictions must demonstrate that the requirements of the proposed ordinance are cost-effective and do not result in buildings consuming more energy than is permitted by Title 24. In addition, the jurisdiction must obtain approval from the Energy Commission and file the ordinance with the BSC for the ordinance to be legally enforceable.

This report documents cost-effective combinations of measures that exceed the minimum state requirements, the 2019 Building Energy Efficiency Standards, effective January 1, 2020, for alterations to nonresidential and high-rise multifamily (HRMF) buildings. This report was developed in coordination with the California Statewide Investor-Owned Utilities (IOU) Codes and Standards Program, key consultants, and engaged cities—collectively known as the Reach Code Team.

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

2 Methodology

The Reach Code Team used the following cost-effectiveness methodology to analyze prototype alteration measures.

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*) *energy* 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 valuated:

- **On-Bill:** Focusing on the estimated bill impacts is a customer-centric 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 for nonresidential buildings and a 30-year duration for the HRMF building, accounting for a 3% discount rate and energy cost inflation per Appendix 7.2.
- **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. With the TDV approach, electricity used (or saved) during peak periods has a much higher value than electricity used (or saved) during off-peak periods. This metric values energy use 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 (E3 2016).

The Reach Code Team performed energy simulations using the most recent software available for 2019 Title 24 code compliance analysis, California Building Energy Code Compliance (CBECC-Com) 2019.1.3. The Team also simulated packages in 2022 research version software to test the impact of 2022 TDV multipliers and weather files on cost-effectiveness.

2.1.2 Costs

The Reach Code Team assessed the incremental costs and savings of the energy packages over 15 years for nonresidential prototypes and 30 years for the HRMF prototype. Incremental costs represent the equipment, installation, replacements, and maintenance costs of the proposed measure relative to the 2019 Title 24 Standards minimum requirements. Where applicable, The Reach Code Team accounted for demolition costs, such as cutting, framing, and patching an exterior wall to install a new packaged terminal heat pump (PTHP). The Team obtained measure costs from engineering cost estimators, manufacturer distributors, contractors, literature review, and online sources such as Home Depot and RS Means. The Team added taxes and contractor markups where appropriate.

A limitation of this study is the fact that the Reach Code Team only sourced one cost estimate for mechanical equipment and associated labor costs. The costs were provided from Western Allied Mechanical, an experienced and well-established design-build contractor located in the San Francisco Bay Area. The costs provided were for hypothetical projects located in Sacramento, CA. Costs were estimated using the contractor and Reach Codes Team's previous experience, and there may be different cost estimates from other experts or from field data. The Reach Code Team attempted to control for geographic variation using multipliers derived from RS Means, Nonetheless, the study findings will improve in precision as further cost data from real projects or other estimators become available for public use. Cost data specified in Section 3 will continue to be scrutinized and updated in future iterations of this study. Similarly, the electrical design, prototype characteristic assumptions, and associated costs were performed in detail with P2S Engineers, a mechanical, electrical, and plumbing design firm. The specific assumptions around electrical design may differ from one engineering expert to another.

2.1.3 Metrics

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

- **NPV**: The Reach Code Team uses net savings (NPV benefits *minus* NPV costs) as the cost-effectiveness metric. If the net savings of a measure or package is positive, it is considered cost effective. Negative savings represent net costs. A measure that has negative energy cost benefits (energy cost *increase*) can still be cost effective if the costs to implement the measure are even more negative (i.e., construction and maintenance cost savings).
- **B/C Ratio**: Ratio of the present value of all benefits to the present value of all costs over 15 or 30 years (NPV benefits *divided by* NPV costs). The criterion for cost effectiveness is a B/C greater than 1.0, representing a positive return on investment. A value of 1.0 indicates the savings over the life of the measure are equivalent to the incremental cost of that measure.

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

2.1.4 Utility Rates

In coordination with staff from the IOUs and the publicly-available information for several publicly-owned utilities (POUs), the Reach Code Team determined appropriate utility rate schedule for each prototype and package (see Appendix 7.2 for details). The Team determined utility rate schedule based on the annual load profile of each prototype, the corresponding package, the most prevalent rate in each territory, and assurance that there were no plans for the rate to be phased out in the near term. For some prototypes, there are multiple options for rates because of the varying load profiles of mixed-fuel buildings versus all-electric buildings. If more than one rate schedule is applicable for a particular load profile, the Reach Code Team did not compare or test a variety of tariffs to determine their impact on cost effectiveness. The team applied utility rate schedules to each climate zone based on the IOU serving the majority of the population in each zone according to Figure 1 for the nonresidential buildings analysis and according to Figure 2 for HRMF.

The team applied a time-of-use (TOU) rate to all cases. 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. For cases with solar photovoltaic (PV) generation, the team applied the approved NEM2 (net energy metering) tariffs along with minimum daily use billing and mandatory non-bypassable charges. Future changes to the NEM tariffs are likely and the CPUC has issued a proposed decision with suggested changes that is expected to be finalized in 2022. For the PV cases, annual electric production was always less than annual electricity consumption; therefore, no credits for surplus generation were necessary.

Figure 1. Utility Tariffs Used Based on Climate Zone (Nonresidential)

Climate Zones	Electric / Gas Utility	Electricity (TOU)	Natural Gas
IOUs			
1-5,11-13,16	Pacific Gas and Electric Company (PG&E)	B-1 / B-10	G-NR1
5	PG&E / Southern California Gas Company (SCG)	B-1 / B-10	G-10 (GN-10)
6, 8-10, 14, 15	Southern California Edison (SCE) / 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)	TOU-A+EECC / AL-TOU+EECC	GN-3
POUs			
3	Peninsula Clean Energy (PCE)	B-1 / B-10	G-NR1
4	City of Palo Alto (CPAU)	E-2 / E-4 TOU	G-2
12	Sacramento Municipal Utility District (SMUD) / PG&E	GSN / GSS	G-NR1
6, 8, 9, 16	Los Angeles Department of Water and Power (LADWP) / SCG	A-1 / A-2	G-10 (GN-10)

Figure 2. Utility Tariffs used based on Climate Zone (HRMF)

Climate Zones	Electric / Gas Utility	Electricity (TOU)	Natural Gas
IOUs			
1-5,11-13,16	PG&E	E-TOU Option C	G-1
6, 8-10, 14, 15	SCE / SCG	TOU-D Option 4-9	GM-E
7, 10, 14	SDG&E	TOU-DR-1	GM
POUs			
3	PCE / PG&E	E-TOU Option C	G-1
4	CPAU	E-1	G-1
12	SMUD / PG&E	R TOD	G-1
6, 8, 9, 16	LADWP / SCG	R-1	GM-E

For commercial buildings, the Reach Code Team's analysis assumes that utility rates escalate over time, using assumptions from research conducted by Energy and Environmental Economics (E3) in the 2019 study *Residential Building Electrification in California* (Energy & Environmental Economics, 2019) and escalation rates used in the development of the 2022 TDV multipliers (Energy & Environmental Economics, 2021). Escalation of electricity rates from 2020 through 2023 is assumed to be 2% per year above inflation, based on E3 assumptions. After 2023, escalation rates for electric rates are assumed, per the 2022 TDV report, to drop to a more conservative escalation rate between 0.2% and 0.7%, before dropping to a steady 0.6% escalation per year above inflation for long-term rate trajectories, beginning in 2030 through end of analysis duration. Natural gas is assumed to escalate at a relatively higher rate for commercial buildings, peaking at 7.7% in 2024, then escalating more slowly to a rate of approximately 2% in the latter years of the analysis period. As stated by E3, this latter assumption "does not presuppose specific new investments, changes in load and gas throughput, or other measures associated with complying with California's climate policy goals" (i.e., business-as-usual).

For residential buildings such as HRMF, the Reach Code Team's analysis assumes that utility rates escalate over time using assumptions from an En-Banc study (CPUC, 2021) from 2020 to 2030 and 2022 TDV report for the rest of the analysis period. Escalation of electricity rates from 2020 to 2030 is assumed to be 1.8%, 1.6% and 2.8% per year above inflation for PG&E, SCE and SDG&E territory respectively. The electricity escalation rate is assumed to be a constant 0.6% from 2030 onwards. Escalation for natural gas is assumed to be 4.6% per year above inflation from 2020 to 2030, after which the escalation rates are between 1.2% and 2.5% for the remainder of the analysis period.

See Appendix B – Utility Rate Schedules for additional details.

2.2 Prototype Characteristics

The Reach Code Team used modified versions of the following seven DOE building prototypes to evaluate cost effectiveness of measure packages in the occupancy types listed below:

- Medium Office
- Stand-alone Retail
- Warehouse
- Quick-service Restaurant (QSR) and Full-service Restaurant (FSR)
- HRMF
- Small Hotel

The Team created three vintages of each building prototype by leveraging data and methodologies from IOU studies, Senate Bill 350 (SB350) analysis, and Commercial Building Energy Consumption Survey (CBECS) to identify appropriate characteristics (ITRON, 2014; CEC, 2017; U.S. Energy Information Administration, 2021). These datasets include estimates of retrofits/upgrades to older buildings as well as field data on existing conditions. The three vintages that the Reach Code Team analyzed include:

- 1980s: represents buildings built prior to 1990 (reference year 1982).
- 1990s: represents buildings built during the 1990 era (reference year 1992).
- 2000s: represents buildings built during the 2000 era (reference year 2006).

The analysis presented in this report assumes a certain set of existing conditions within each prototype, and buildings operate as-intended. Real building existing conditions are often a variety of old and new components, and equipment performance degrades over time. The analysis assumes some equipment replacement over time, based primarily on the SB350 analysis. The rate of replacement varies by building system and by envelope component.

The Reach Code Team's prototypes and cost-effectiveness results represent a range of vintages to account for the variety of existing conditions in real buildings in a simplified way. Jurisdictions should consider how the Reach Code Team's measure-specific findings would apply to the existing conditions in the jurisdictions' building stock and in what instances they would be applicable.

Figure 3 summarizes the existing building prototype characteristics, with more detail available in Appendix 7.3.

Figure 3. Existing Building Prototype Summaries

Building Type	Conditioned Floor Area (ft^2)	# Of Floors	Existing Heating, Ventilation, and Air Conditioning (HVAC) Distribution System	Existing Hot Water System
Medium Office: All vintages	53,628	3	(3) Packaged multizone Variable Air Volume (VAV) reheat + boilers	Central Gas Storage
Stand-alone Retail: All vintages	24,563	1	(4) Packaged single zone (SZ) Constant Air Volume (CAV) + gas furnace	Central Gas Storage
Warehouse: All vintages	17,548	1	Warehouse: Gas furnace serving 10% of floor area, exhaust-only ventilation Office: (1) Packaged SZ CAV + gas furnace	Central Gas Storage
QSR: All vintages	2,500	1	(2) Packaged SZ CAV + gas furnace units	Central Gas Storage
FSR: All vintages	5,000			
HRMF: 1980s vintage	100,400 residential floor area (117 Dwelling Units)	10	Packaged terminal air conditioning (PTAC) + boilers serving heating-only baseboard No cooling scenario: Boilers serving heating-only baseboard	Central gas Storage
HRMF: 1990s vintage			PTAC + boilers serving heating-only fan coils No cooling scenario: Boilers serving heating-only fan coils	
HRMF: 2000s vintage			Split air conditioner (AC) + gas furnace	
Small Hotel: 1980s vintage	42,552	4	PTAC + gas wall furnace	Central gas Storage
Small Hotel: 1990s vintage				
Small Hotel: 2000s vintage			SZAC + furnace	

The HRMF prototype included additional complexities for analysis:

- The Reach Code Team tested the sensitivity of the HRMF prototype results by varying the existing HVAC system by vintage based on data from PG&E (TRC, 2018).
- Within the 1980s and 1990s vintages, the Team tested packages against two existing buildings, the first including both existing mechanical cooling and electric cooking and the second including no cooling and gas cooking. Many existing residential dwelling units do not have cooling systems as they are not required.
- The nonresidential first-floor space in the HRMF prototype was not tested for cost effectiveness, as it represents a minority of the conditioned floor area, and the results are being captured through separate analysis of the office and retail prototypes in this study. The energy savings impacts of the nonresidential first floor were removed during post-processing.

2.3 Greenhouse Gas Emissions

The analysis uses the greenhouse gas (GHG) emission multipliers developed by E3 (E3, 2021) to support development of compliance metrics for use in the 2022 California energy code. There are 8,760 hourly multipliers accounting for time dependent energy use and carbon emissions based on source emissions, including renewable portfolio standard projections. For the 2022 code cycle, the multipliers also 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 Climate Zone and each fuel type (metric tons of CO2 per kWh for electricity and metric tons of CO2 per therm for natural gas). The Reach Code Team used the multipliers to calculate emissions from both the 2019 and 2022 results.

3 Measure Packages and Costs

The Reach Code Team analyzed the electrification retrofit, efficiency, solar PV, and battery measures described in this section.

3.1 Electrification retrofit

The Reach Code Team examined the potential for electrification retrofits of HVAC, hot water, cooking, and clothes drying where applicable. In some scenarios, partial electrification retrofits were considered.

The Reach Code Team received cost estimates for all packages from Western Allied Mechanical, a San Francisco Bay Area mechanical contractor for the HVAC and water heating systems. The mechanical contractor provided labor costs for typical new installations and noted that retrofit labor costs are highly variable. Building-specific considerations such as tight conditions, prepping surfaces, elevated work, material handling, specialty rigging, and protecting existing finishes can vary building to building. These details can have a large labor cost impact, and it is difficult to define a typical condition. Because of this variation, the Reach Code Team increased new construction labor costs with multipliers ranging from 25 to 50% depending on assumptions for the building physical characteristics and scope of retrofit, as described later in this section. See further limitations described in Section 2.1.2.

For each electrification retrofit, the Team considered the mechanical equipment impact at the central system, distribution, and zone levels. The Team assigned a retrofit labor multiplier separately to the central system equipment, distribution equipment, and zonal equipment based on challenges the installers are likely to encounter. The Team estimated a different multiplier for the mixed fuel retrofit as well as the electrification retrofit for each prototype. The final multipliers range from 25 to 50%, with lower multipliers typical of like-for-like replacements such as replacing a packaged SZ unit and higher multipliers where additional demolition, physical space, and coordination may be needed.

The Team determined electrical upgrades required for each electrification retrofit and the cost of the upgrade through design engineering coordination with P2S Engineers and costs from RSMeans. The team intended to capture all components of electrical upgrades, from receptacles to transformers. Costs for utility service upgrades were out of the scope of this study. For the HRMF prototype 80s and 90s vintages, the Team assumed that the electrical equipment in the building is obsolete and requires complete replacement, which is commonly required in buildings over 40 years old. The Reach Code Team made this assumption to avoid exorbitant incremental costs for electrical upgrades in the HRMF prototype for packages that included no mechanical cooling and gas cooking.

The Team assumed that all HVAC and service hot water (SHW) equipment has a 15-year useful life and, therefore, did not consider replacements in either the mixed-fuel or the all-electric scenario for all nonresidential building types. For the HRMF building type, the Team assumed that the HVAC and domestic hot water (DHW) equipment is replaced at the end of its useful life (at 15 years) for both the mixed-fuel and all-electric scenarios. The Team assumed that the maintenance requirements would be the same in the mixed-fuel and all-electric scenarios and, therefore, did not consider incremental maintenance costs except as noted.

3.1.1 Medium Office

The existing HVAC system is a VAV reheat system that includes one gas hot water boiler, one packaged rooftop unit per floor, and VAV hot water reheat boxes. The existing SHW design includes one gas storage water heater.

To replace the incumbent gas-fired boiler for the Medium Office electrification retrofit, the Reach Code Team selected a central heat pump water heater with a storage tank and electric resistance booster, only to be used during peak heating demand periods. This approach utilizes the existing hydronic plumbing infrastructure, VAV reheat terminal units, and lower supply water temperature, except during peak heating demand periods. To replace the existing gas storage SHW heater for the electrification retrofit, the Team selected a heat pump with storage tank. The HVAC and

SHW electrification retrofit systems present higher costs compared to the mixed-fuel replacements due to the increased equipment costs and electrical infrastructure needs.

For a mixed-fuel retrofit baseline, the Team assumed the gas boiler and gas water heater replacements are a one-to-one replacement of equipment at the system level, with no demolition required, and a labor retrofit multiplier of 25%. For the electrification retrofit, the Team assumed a labor retrofit multiplier of 35% for both HVAC and SHW to account for installation of additional components and floor area required for the heat pump and storage tank. No distribution or zonal equipment changes are required as part of the electrification retrofit.

Figure 4 shows the costs for Medium Office averaged across all Climate Zones.

Figure 4. Medium Office Electrification Retrofit Costs

Mixed-Fuel Measure	Mixed-Fuel Cost	Electrification Retrofit Measure	All-Electric Cost	All-Electric Incremental Cost	Source
Boilers	$45,508	Central heat pump water heater with electric resistance booster	$157,070	$111,562	Cost estimator
Service Water Heater	$73,479	Central heat pump water heater	$88,762	$15,283	Cost estimator
Electrical upgrades	$0	Wiring, distribution boards, and transformers to serve central HVAC and SHW systems	$31,233	$31,233	Design engineer, RSMeans
Total	$118,987		$277,065	$158,078	

3.1.2 Stand-Alone Retail

The existing HVAC system includes four packaged single zone rooftop ACs with gas furnaces. The existing SHW design includes one gas storage water heater.

To replace the existing packaged rooftop units for the Stand-alone Retail electrification retrofit, the Reach Code Team selected packaged heat pumps. To replace the existing gas storage water heater for the electrification retrofit, the Team selected one electric resistance point of use water heater for each of the three sinks.

The team assumed a labor retrofit multiplier of 25% for both the mixed fuel and the all-electric HVAC retrofits. This is the low end of retrofit labor multipliers, because in both the mixed-fuel case and the all-electric case, the packaged units are drop-in replacements at the system level, with no demolition required. No HVAC distribution or zonal equipment changes are required as part of the electrification retrofit. For a mixed-fuel SHW retrofit baseline, the team assumed a labor retrofit multiplier of 25% because the water heater is a drop-in replacement of the existing water heater. For the SHW electrification retrofit, the team assumed a labor retrofit multiplier of 35% to account for installing equipment in three different locations.

Figure 5 shows the cost data for Stand-alone Retail averaged across all Climate Zones.

Figure 5. Standalone Retail Electrification Retrofit Costs

Mixed-Fuel Measure	Mixed-Fuel Cost	Electrification Retrofit Measure	All-Electric Cost	All-Electric Incremental Cost	Source
HVAC: Packaged SZ AC + gas furnace	$176,229	Packaged SZ heat pump	$173,617	-$2,612	Cost estimator
SWH: Gas storage	$1,255	Point of use electric resistance	$1,723	$468	Cost estimator
Electrical upgrades	$0	Wiring for SHW	$2,007	$2,007	Design engineer, RSMeans
Total	$177,484		$177,347	-$137	

3.1.3 Warehouse

The baseline HVAC system includes one packaged single zone rooftop AC with gas furnace, which serves the office. The warehouse space does not have cooling, but approximately 10% of the floor area is heated by a ceiling-suspended gas unit heater. Exhaust fans provide stand-alone ventilation and are not included in the measure packages. The existing SHW design includes one gas storage water heater.

To replace the existing packaged rooftop unit for the office space, the Reach Code Team selected a packaged heat pump. For the warehouse space, where 10% of the floor area is heated, the team selected an electric radiant heater[1] to replace the gas unit heater. To replace the existing gas storage water heater for the electrification retrofit, the Team selected one electric resistance point of use water heater for the sink.

The Team assumed a labor retrofit multiplier of 25% for both the mixed fuel and the all-electric office HVAC retrofits, as well as the warehouse space mixed fuel retrofit. Similar to the Retail prototype, the equipment represents drop-in replacements without significant demolition. For the all-electric warehouse space HVAC retrofit, the Team also assumed 25% because the electrification retrofit requires little space and only requires hanging equipment in an open area. For a mixed-fuel SHW retrofit baseline, the Team assumed a labor retrofit multiplier of 25% because the water heater is a drop-in replacement of the existing water heater. For the SHW electrification retrofit, the Team assumed a labor retrofit multiplier of 35% to account for installing equipment in a different location than the existing water heater.

Figure 6 shows the cost data for Warehouse averaged across all Climate Zones.

[1] Example electric radiant heater: https://www.reverberray.com/products/international-230v/electric-infrared/sw2-series/

Figure 6. Warehouse Electrification Retrofit Costs

Mixed-Fuel Measure	Mixed-Fuel Cost	Electrification Retrofit Measure	All-Electric Cost	All-Electric Incremental Cost	Source
Office HVAC: Packaged SZ AC + Gas Furnace	$56,013	Packaged SZ Heat Pump	$60,462	$4,449	Cost estimator
Warehouse HVAC: Gas heaters. Exhaust-only Ventilation	$6,529	Electric radiant heaters. Exhaust only ventilation	$10,958	$4,429	Cost estimator
SWH: Gas Storage	$1,255	Point of use electric resistance	$1,149	-$106	Cost estimator
Electrical Upgrades	$0	Wiring for warehouse HVAC and SHW	$6,231	$6,231	Design engineer, RSMeans
Total	$63,797		$78,800	$15,003	

3.1.4 Quick-Service and Full-Service Restaurants

The Reach Code Team analyzed two prototypes, QSR and FSR, to discern the variance in analysis results depending on the type of restaurant. The Reach Code Team developed a basis-of-design (BOD) for kitchen cooking equipment, HVAC, and service water heating (SWH) for mixed-fuel kitchens and all-electric kitchens. The BOD served as the foundation for modeling inputs and cost assumptions for the cost-effectiveness analysis. Appendix 7.3 provides an overview of the methodology for developing the BODs, as well as the BODs for the mixed-fuel code minimum baseline, mixed-fuel energy efficient appliances, and all-electric kitchen designs including kitchen exhaust hood and SHW. None of the cooking appliances examined in this study are subject to federal energy efficiency requirements.

The Team determined cost estimates for kitchen appliances from online retailers. Whenever possible, costs were gathered from three different appliance retailers and the average was used for the analysis. The Team adjusted material and labor costs for each Climate Zone based on weighting factors from RS Means.

The Reach Code Team compared the incremental differences in equipment selection and associated costs from a mixed-fuel baseline to all-electric restaurants for HVAC, SWH, kitchen process equipment, and gas/electrical infrastructure.

For replacement and maintenance costs, the Team assumed all cooking appliance replacement at year 10. Based on interviews with subject matter experts, a typical mixed-fuel kitchen needs regular maintenance ten times a year, whereas an all-electric kitchen would require maintenance five times a year without the need for plumbing maintenance. We assumed each visit would cost $150. Figure 7 and Figure 8 show the costs for QSR and FSR, respectively, averaged across all Climate Zones.

Figure 7. Alterations Quick Service Restaurant All-Electric Construction Costs

Mixed-Fuel Measure	Mixed-Fuel Cost	Electrification Retrofit Measure	All-Electric Cost	All-Electric Incremental Cost
Mechanical Equipment				
HVAC: Packaged Furnace, Direct Expansion A/C	$120,811	HVAC: Packaged heat pump	$128,154	$7,343
SWH: Gas Storage Water Heater - One 150 kBtu/hr Heater - One 100-gallon Tank	$21,860	SWH: Heat pump water heaters with storage tank - A.O. Smith CHP-120 - One 120-gallon tank	$27,963	$6,103
Kitchen Appliances				
Gas Appliances: - French Fryer (4) - Griddle, Single-sided (2) Electric Appliances: - Half-size Electric Convection Oven (1)	$21,291	French fryer (4) Griddle, single sided (2) Half-size electric convection oven (1)	$42,815	$21,524
Maintenance Costs: - $1,500/yr - Assuming 15 years lifetime	$22,500	Maintenance costs: - $750/yr - Assuming 15 Years Lifetime	$11,250	$11,250
Infrastructure Upgrades				
n/a	$0	Electrical	$25,865	$25,865
Total	**$186,462**		**$236,047**	**$49,585**

Figure 8. Alterations Full Service Restaurant All-Electric Construction Costs

Mixed-Fuel Measure	Mixed-Fuel Cost	Electrification Retrofit Measure	All-Electric Cost	All-Electric Incremental Cost
Mechanical Equipment				
HVAC: Packaged Furnace, Direct Expansion A/C	$160,889	HVAC: Packaged heat pump	$161,013	$123
SWH: Gas Storage Water Heater with recirculation loop - 400 kBtu/hr heater (2) - 200-gallon tank (1)	$38,088	SWH: Heat pump water heaters with storage tank - Four Colmac CxV-5 - Total 750-gallons of primary storage - One 5 kW electric resistance loop heater - One 120-gallon loop tank	$161,943	$123,855
Kitchen Appliances				
Gas Appliances: - Underfired Broiler (1) - French Fryer (2) - Griddle, Single-sided (1) - Broiler, Salamander (1) - Oven, Convection Double Deck (1) - Oven, Range (2) - Range, Six Open Burners (2) - Range, Stock Pot (2)	$52,383	Electric appliances: - Chain broiler (1) - French fryer (2) - Griddle, single sided (1) - Broiler, salamander (1) - Oven, convection double - deck (1) - Oven, induction range (2) - Range, six-burner induction cooktop (2) - Range, induction stock pot (2)	$99,959	$47,576
Maintenance Costs: - $1,500/yr - Assuming 15 Years Lifetime	$22,500	Maintenance costs: - $750/yr - Assuming 15 years lifetime	$11,250	-$11,250
Infrastructure Upgrades				
N/A	$0	Electrical	$37,213	$37,213
Total	**$273,860**		**$471,378**	**$197,518**

3.1.5 High-Rise Multifamily

The existing HVAC system varies by vintage, and the electrification retrofit system varies depends upon the existing HVAC system. A description of the mixed-fuel retrofit system and the all-electric retrofit systems for each vintage are shown in Figure 8 through Figure 10.

The existing DHW design for all vintages is a central gas storage water heating system. For the all-electric design, the Reach Code Team selected heat pump water heaters with storage to replace the gas water heaters.

In the 1980s vintage, the existing HVAC system consists of hydronic baseboard heaters in each dwelling unit, which are served by a gas boiler. The dwelling units each have PTACs for cooling. For the all-electric HVAC design, the Reach Code Team selected PTHPs to provide both heating and cooling to the dwelling units. The PTHP fits directly into the PTAC housing. The team assumed a weighted labor retrofit multiplier of 28% in the all-electric design and a 25% for the mixed-fuel design.

For cooking, the Team assumed 1) existing electric cooking in scenarios where there is existing cooling (Figure 8 through Figure 10) and 2) existing gas cooking in scenarios where there is no existing cooling (Figure 11and Figure 12). These assumptions intend to represent the wide range of potential electrical infrastructure upgrades required (high to low, respectively). For clothes drying, the Team selected a 120-volt combination washer and dryer that replaces the existing washer and dryer without any electrical upgrade.[2]

Figure 8 shows the cost data for the 1980s vintage averaged across all Climate Zones.

Figure 8. High Rise Multifamily Electrification Retrofit Costs, 1980s Vintage

	Mixed-Fuel Measure	Mixed-Fuel Cost	Electrification Retrofit Measure	All-Electric Cost	All-Electric Incremental Cost	Source
HVAC	Replace PTACs and boilers. Baseboards remain in place.	$616,741	Replace PTACs with PTHPs. Decommission boilers and baseboards.	$610,651	-$6,090	Cost estimator
DHW	Gas water heater with storage	$55,037	Heat pump water heater with storage.	$275,352	$220,315	Cost estimator
Appliances	Electric cooking, gas dryer	$479,700	Electric cooking, electric dryer.	$526,500	$46,800	Online retailers, E3 report (E3, 2019)
Infrastructure	Wiring and distribution replacements, like for like replacement	$312	Wiring and distribution for central DHW heat pump water heater.	$8,552	$8,240	Design engineer, RSMeans
Total		**$1,151,791**		**$1,421,056**	**$269,265**	

In the 1990s vintage, the existing HVAC system consists of heating-only fan coils in each dwelling unit, which are served by a gas boiler. The dwelling units each have PTACs for cooling. The team assumed the same all-electric HVAC design as the 1980s vintage.

Figure 9 shows the cost data for the 1990s vintage averaged across all Climate Zones.

[2] Examples available in: https://www.redwoodenergy.tech/wp-content/uploads/2019/11/Multifamily-ZNC-Guide-7-10-19-sa-clean.pdf

Figure 9. High Rise Multifamily Electrification Retrofit Costs, 1990s Vintage

	Mixed-Fuel Measure	Mixed-Fuel Cost	Electrification Retrofit Measure	All-Electric Cost	All-Electric Incremental Cost	Source
HVAC	Replace PTACs, fan coils, and boilers	$1,075,630	Replace PTACs with PTHPs. Decommission boilers and fan coils.	$605,149	-$470,481	Cost estimator
DHW	Gas water heater with storage	$55,037	Heat pump water heater with storage.	$275,352	$220,315	Cost estimator
Appliances	Electric cooking, gas dryer	$479,700	Electric cooking, electric dryer.	$526,500	$46,800	
Infrastructure	Wiring and distribution replacements, like for like replacement	$312	Wiring and distribution for central DHW heat pump water heater.	$8,552	$8,240	Design engineer, RSMeans
Total		**$1,610,679**		**$1,415,554**	**-$195,126**	

In the 2000s vintage, the existing HVAC system consists of central furnaces and split ACs. For the all-electric HVAC design, the Reach Code Team selected split heat pumps to provide both heating and cooling to the dwelling units. The team assumed a weighted labor retrofit multiplier of 25% in the all-electric and mixed fuel designs

Figure 10 shows the cost data for the 2000s vintage averaged across all Climate Zones.

Figure 10. High Rise Multifamily Electrification Retrofit Costs, 2000s Vintage

	Mixed-Fuel Measure	Mixed-Fuel Cost	Electrification Retrofit Measure	All-Electric Cost	All-Electric Incremental Cost	Source
HVAC	Central furnace + Split AC	$1,183,585	Split heat pump	$1,023,382	-$160,203	Cost estimator
DHW	Gas water heater with storage	$55,037	Heat pump water heater with storage	$275,352	$220,315	Cost estimator
Appliances	Electric cooking, gas dryer	$479,700	Electric cooking, electric dryer	$526,500	$46,800	
Infrastructure	None	$0	Wiring and distribution for central DHW heat pump water heater	$8,552	$8,552	Design Engineer, RSMeans
Total		**$1,718,322**		**$1,833,786**	**$115,464**	

The Team also analyzed a 1980s vintage where the existing system serving the dwelling units does not include cooling and have gas cooking. The existing HVAC system consists of hydronic baseboard heaters in each dwelling unit. For the all-electric HVAC design, the Reach Code Team selected PTHPs to provide both heating and cooling to the dwelling units. This all-electric retrofit requires cutting out a section of the wall to house the PTHP. In the mixed fuel retrofit, the boilers are replaced, and no cooling is added. The Team assumed a weighted labor retrofit multiplier of 48% in the all-electric design and a 25% for the mixed fuel design.

Figure 11 shows the cost data for the 1980s vintage without existing cooling averaged across all Climate Zones.

Figure 11. High Rise Multifamily Electrification Retrofit Costs, 1980s Vintage Without Existing Cooling and Gas Cooking

	Mixed-Fuel Measure	Mixed-Fuel Cost	Electrification retrofit Measure	All-Electric Cost	All-Electric Incremental Cost	Source
HVAC	Replace boilers. Baseboards remain in place.	$55,787	Install PTHPs. Decommission boilers and baseboards + demolition	$1,232,054	$1,176,267	Cost estimator
DHW	Gas water heater with storage	$55,037	Heat pump water heater with storage	$275,352	$220,315	Cost estimator
Appliances	Gas cooking, gas dryer	$456,300	Electric cooking, electric dryer	$526,500	$70,200	
Infrastructure	Wiring and distribution replacements, like for like replacement	$301,038	Wiring and distribution for HVAC, DHW, and cooking.	$469,540	$168,502	Design engineer, RSMeans
Total		**$868,163**		**$2,503,447**	**$1,635,284**	

The Team also analyzed a 1990s vintage where the dwelling units do not have cooling, and similar to the 1980s vintage, assumed an all-electric design with PTHP. Figure 12 shows the cost data for the 1990s vintage without existing cooling, averaged across all Climate Zones.

Figure 12. HRMF Electrification retrofit Costs, 1990s Vintage Without Cooling

	Mixed-Fuel Measure	Mixed-Fuel Cost	Electrification retrofit Measure	All-Electric Cost	All-Electric Incremental Cost	Source
HVAC	Replace boilers and fan coils + demolition	$514,676	Install PTHPs, Decommission boilers and fan coils + demolition	$1,272,014	$757,338	Cost estimator
DHW	Gas water heater with storage	$55,037	Heat pump water heater with storage	$275,352	$220,315	Cost estimator
Appliances	Gas cooking, gas dryer	$456,300	Electric cooking, electric dryer	$526,500	$70,200	
Infrastructure	Wiring and distribution replacements, like for like replacement	$301,038	Wiring and distribution for HVAC, DHW, and cooking.	$469,540	$168,502	RSMeans
Total		**$1,327,051**		**$2,543,407**	**$1,216,356**	

The Team did not analyze a 2000s vintage prototype without cooling or with gas cooking. Based on a PG&E study that found that approximately 30 percent of multifamily projects participating in an upgrade program had existing space cooling systems, and that space cooling is more prevalent in newer buildings, the Team assumed that high rise multifamily buildings built within the last 20 years typically have cooling and electric cooking. (TRC, 2018)

3.1.6 Small Hotel

The existing HVAC system varies by vintage, and the electrification retrofit system varies depending upon the existing HVAC systems. A description of the existing system, the mixed-fuel retrofit system, and the all-electric retrofit systems for each vintage are shown in Figure 13 through Figure 14.

The existing DHW design for all vintages is a gas storage water heater. For the all-electric design, the Reach Code Team selected heat pump water heaters with storage to replace the gas water heaters.

In the 1980s and 1990s vintage, the existing HVAC system in the guest rooms is gas wall furnace for space heating and PTACs for cooling. For the all-electric HVAC design, the Reach Code Team selected PTHPs to provide both heating and cooling to the dwelling units. The PTHP fits directly into the PTAC housing. The team assumed a weighted labor retrofit multiplier of 25% in both all-electric and the mixed fuel design.

Figure 13 shows the cost data for the 1980s and 1990s vintage averaged across all Climate Zones.

Figure 13. Small Hotel Electrification Retrofit Costs, 1980s and 1990s Vintage

	Mixed-Fuel Measure	Mixed-Fuel Cost	Electrification Retrofit Measure	All-Electric Cost	All-Electric Incremental Cost	Source
HVAC	Replace PTACs and wall furnaces	$408,151	Replace PTACs with PTHPs. Decommission wall furnaces.	$227,317	-$180,834	Cost estimator, Online retailers
DHW	Gas water heater with storage	$36,303	Heat pump water heater with storage	$101,446	$64,842	Cost estimator, HRMF New Construction C/E Study (Frontier Energy, 2021)
Infrastructure	None	$0	Wiring and distribution for central DHW heat pump water heater.	$8,240	$8,240	RSMeans
Total		**$444,754**		**$337,003**	**-$107,751**	

In the 2000s vintage, the existing HVAC system in guest rooms consists of central furnaces and split ACs. For the all-electric HVAC design, the Reach Code Team selected split heat pumps to provide both heating and cooling to the guest rooms. The team assumed a weighted labor retrofit multiplier of 25% in the all-electric and mixed fuel designs.

Figure 14 shows the cost data for the 2000s vintage averaged across all Climate Zones.

Figure 14. Small Hotel Electrification Retrofit Costs, 2000s Vintage

	Mixed-Fuel Measure	Mixed-Fuel Cost	Electrification Retrofit Measure	All-Electric Cost	All-Electric Incremental Cost	Source
HVAC	Central furnace + Split AC	$699,398	Split heat pump	$611,888	-$87,510	Cost estimator
DHW	Gas water heater with storage	$36,603	Heat pump water heater with storage	$101,446	$64,842	Cost estimator, HRMF New Construction C/E Study
Infrastructure	None	$0	Wiring and distribution for central DHW heat pump water heater	$8,240	$8,240	RSMeans
Total		**$736,002**		**$721,573**	**-$14,428**	

3.2 Efficiency Measures

The Reach Code Team identified and investigated potential alterations efficiency measures from a variety of sources:

- 2019 T24 alterations requirements and new construction measures as they might apply to alterations.

- Potential measures for 2022 Title 24 (California Energy Commission, 2021)
- DOE study on measures in commercial building retrofits (PNNL, 2011)
- ASHRAE 90.1 and ASHRAE 189.1 (ASHRAE, 2021)

The team dropped measures with low impact potential, low analysis feasibility, and low implementation feasibility. The measures selected for analysis fall into one of two categories:

1. Higher efficiency requirements than required by Title 24 Part 6 for the planned renovation scope.
2. Requirements for additional improvements beyond the planned renovation scope. These measures can be considered *common sense* measures that are relatively easy to implement with low costs and/or a high likelihood that appropriate installation personnel are on-site.

The Reach Code Team developed the final measure list based on iterative modeling and discussions with designers and contractors.

3.2.1 Measure Descriptions

3.2.1.1 Envelope

- **Cool roof:** This measure specifies solar reflectance exceeding 2019 Title 24 Part 6 Section 141.0(b)2.B for low-sloped and steep-sloped roof requirements when the renovation scope already includes replacing the roof. (Title 24 Stakeholders, 2020).
  - For Medium Office, Stand-Alone Retail, Warehouse, QSR, FSR:
    - For steep-sloped roofs, Climate Zones 2 and 4 through 16: The minimum aged solar reflectance is increased from 0.20 to 0.25.
    - For low-sloped roofs, Climate Zones 2 and 4 through 16: The minimum aged solar reflectance is increased from 0.63 to 0.70.
  - For HRMF and Small Hotel: Climate Zones 2, 4, and 6 through 15: The minimum aged solar reflectance is increased from 0.55 to 0.63.
  - All building types: Climate Zones 1 and 3: No proposed roof measure.
- **Window film:** This measure reduces window SHGC of existing windows to 0.39 by adding window film as a *common sense* measure. Existing window SHGC varies by building type, Climate Zone, and by vintage, and it can be found in Appendix 7.37.3.
- **Roof Alterations:** This measure specifies roof insulation requirements that exceed 2019 Title 24 Part 6 roof alteration requirements when the renovation scope already includes replacing the roof. (Title 24 Stakeholders, 2020)
  - For Medium Office, Stand-Alone Retail, Warehouse, QSR, FSR:
    - For Climate Zones 1, 3, 4, 5, and 9, the maximum assembly U-factor is decreased from 0.082 to 0.043.
    - For Climate Zones 2 and 10 through 16, the maximum assembly U-factor is decreased from 0.055 to 0.043.
    - For Climate Zones 6 through 8, the maximum assembly U-factor is decreased from 0.082 to 0.059.
  - For Small Hotel:
    - For Climate Zones 1 and 11 through 16, the maximum assembly U-factor is decreased from 0.054 to 0.037.
    - For Climate Zones 2 and 10, the maximum assembly U-factor is decreased from 0.055 to 0.037.
    - For Climate Zones 3 through 5 and 9, the maximum assembly U-factor is decreased from 0.057 to 0.037.

    - For Climate Zones 6 through 8, the maximum assembly U-factor is decreased from 0.057 to 0.047.

3.2.1.2 Domestic and & Service Hot Water

- **Solar thermal water heating:** This measure requires installing a solar thermal water heating when the project scope includes other mechanical projects in the HRMF prototype, such as those involving HVAC or plumbing. The system shall have a solar savings fraction of 0.50.
- **Faucet Aerators:** This *common sense* measure requires adding faucet aerators to older faucets to meet California Title 20 Standards in the QSR and FSR. A public lavatory faucet must have a flow rate less than 0.5 gallons per minute (gpm) at 60 pounds per square inch (psi) and a kitchen faucet must have a flow rate less than 1.8 gpm at 60 psi.
- **Low-flow water fixtures**: This measure specifies commercial dishwashers that use 20 percent less water than ENERGY STAR specifications and uses pre-rinse spray valves (PRSV) qualified for IOU rebates. In addition, the dishwasher includes heat recovery function such that it only needs connection to cold water and reduces hot water demand and sizes of the central SHW system. When this measure is combined with the *Faucet Aerators* measure for FSR, the SHW equipment can be down-sized from four (4) Colmac CxV 5 to two (2) AO Smith CHP-120 due to reduced hot water demand. This results in upfront cost savings and improved cost effectiveness for all-electric packages that include these efficiency measures. Please see Appendix 7.4.3 for more detail.
- **Recirculating pump control:** This measure requires on-demand recirculating pump controls in existing recirculation domestic hot water systems in multifamily high-rise buildings as a *common sense* measure under certain circumstances (e.g., if a technician is performing an alteration to the direct digital control system). The existing HRMF DHW system has a recirculation loop where hot water is constantly pumped through a loop around the building. The measure is to install recirculating pump controls to reduce energy by only circulating hot water according to demand.

3.2.1.3 Heating Ventilation, and Air Conditioning

- **Operational Efficiency in Small Capacity HVAC:** This measure expands 2019 Title 24 prescriptive requirements per the following (not rated efficiency):
    - Reduces the Section 140.4 (e)1 threshold for an economizer from 54,000 Btu/hr to 33,000 Btu/hr.
    - Reduces the Section 140.4 (e)2.E threshold requiring a minimum of two stages of mechanical cooling capacity for direct expansion units from 65,000 Btu/hr to 33,000 Btu/hr.
    - Reduces the Section 140.4 (m)1 threshold requiring a minimum fan speed ratio of 0.5 from 65,000 Btu/h to 33,000 Btu/hr.
- **Economizer repair and fault detection and diagnostics (FDD).** This *common sense* measure restores existing economizers to be fully functional and also installs standalone economizer FDD on existing air handling units greater than 54,000 Btu/hr in cooling capacity with economizers. The measure recognizes that existing economizers are often non-functional, with the dampers often either failed closed or partially open (DNV KEMA, 2013).

  Economizer faults are common in existing buildings and often result from malfunctioning economizer dampers. T24 requires an economizer FDD system on units greater than 54,000 Btu/hr in cooling capacity that detect when a fault occurs, diagnose the cause of the fault, and report the fault occurrence. Several manufacturers build standalone economizer FDD systems that are intended to be integrated into existing rooftop systems and to detect, diagnose, and report faults. Alterations Section 141.0(b)2 requires economizer FDD (per Section 120.2(i)) only on newly-installed air handling equipment serving an alteration.
- **Transfer air for commercial kitchens:** This measure expands the Section 140.9 (b)2 requirements for kitchen ventilation per the following:
    - Reduces the transfer air requirement for kitchens with exhaust hoods to air flows greater than 2,000 ft^3/min from 5,000 ft^3/min. For exhaust hoods with air flow rate greater than 2000 ft^3/min but lower than 5000 ft^3/min, this measure would require at least 15% of all replacement air come from transfer air in the dining space, which would otherwise be exhausted. This measure only applies to the QSR.
    - For exhaust hoods with an air flow rate greater than 5,000 ft^3/min for FSR:
        - Use transfer air for at least 25% of all replacement air that would otherwise be exhausted, and

    - Demand ventilation systems meeting Title 24 Section 140.9 (b)2.B.ii

- **Building Automation System Retrofit**: This *common sense* measure replaces all controller hardware and updates the programming. This hardware update includes the front end, equipment controllers (including system- and zone-level), and some sensors. The programming update features the following controls measures:
    - Reheat control to be updated to *Dual Maximum* from *Single Maximum*
    - Supply temperature control to be updated from *Other* to *DDC to zone*
    - Optimum start
- **VAV Deadband Airflow**: This measure reduces VAV box minimum airflows from the current T24 prescriptive requirement of 20% of maximum (design) airflow to the T24 zone ventilation minimums. This measure increases the efficiency when the renovation scope already includes re-programming the zone minimum airflows.

3.2.1.4 Lighting

- **Above code interior Lighting Power Density (LPD)**: Upon a lighting replacement, this measure reduces the LPD requirement from the existing Title 24 requirement for alterations in select areas as follows using the Area Category Method. The Reach Code Team designed this measure to ensure that illumination will meet IES guidelines and provide ample light for the tasks performed in the space.

Figure 15. Above-Code Lighting Power Density Efficiency Measure Specifications

Prototype	Space	Baseline LPD (W/sqft)	LPD (W/ft^2)
Medium Office	Office Areas >250 square feet	0.65	0.60
Standalone Retail	Retail Merchandise Sales Area	1.00	0.95
QSR and FSR	Dining Area (Bar/Lounge and Fine Dining)	0.55	0.45

- **Lighting retrofit**: As with all other *common sense* measures, this measure is an additional improvement beyond the planned renovation scope. This *common sense* measure replaces the existing luminaires (whose wattages vary based on building type, space type, and building vintage) to reduce the existing LPD in select areas to the following, representing 2019 code-minimum upgrades using the Area Category Method.:

Figure 16. Lighting Retrofit Lighting Power Density Efficiency Measure Specifications

Prototype	Space	LPD (W/ft^2)
Medium Office	Open plan office	0.60
Standalone Retail	Commercial/Industrial Storage	1.00
	Retail Merchandise Sales	1.00
Warehouse	Commercial/Industrial Storage	0.45
QSR	Dining Area: Cafeteria/Fast Food	0.40
	Kitchen/Food Preparation Area	0.95
FSR	Dining Area: Bar/Lounge and Fine Dining	0.55

	Kitchen/Food Preparation Area	0.95

Occupancy sensing and daylighting controls are mandatory requirements, so there is no compliance credit. Energy savings and cost-effectiveness ratios are conservative.

3.2.1.5 Process

- **Energy efficient commercial cooking appliances:** For the QSR and FSR, this measure specifies cooking appliances that meet ENERGY STAR™ specifications or are qualified for IOU rebates, compared to a mixed-fuel baseline of appliances that are not ENERGY STAR or qualified for rebates. All-electric packages only contain ENERGY STAR or rebate-qualified cooking appliances.

3.2.2 Measure Applicability and Costs

The incremental measure costs for these measures are provided in Figure 17 below.

Figure 17. Energy Efficiency Measures: Specification and Cost

Measure	Applicability to Existing Buildings	**Measure Applicability** ● Cost-effectiveness included in Section 4 * Included in Common Sense Package + Included in All-Electric + Efficiency Package — Not analyzed						Incremental Cost	Sources & Notes
		Med Office	Retail	Ware-house	QSR & FSR	HRMF	Small Hotel		
Envelope									
Cool Roofs	Renovation scope includes roof replacement	●	●	-	●	●	●	Steep slope: $0.02/ft^2 of roof; Low slope: $0.04/ft^2 of roof	2022 Nonresidential High Performance Envelope CASE report (Energy Solutions and Determinant, 2020)
Window film	Common sense	●*	●*+	-	●*+	-	●	$1.82/ ft^2	Energy Savings Assistance Common Area Measures Program (ESA CAM)
Roof alterations	Renovation scope includes roof replacement	-	●	-	●	-	●	$0.43 - $1.26 / ft^2, varies by vintage and CZ	2022 Nonresidential High Performance Envelope CASE report (Energy Solutions and Determinant, 2020)
DHW & SHW									
Solar thermal water heating	Renovation scope includes other mechanical projects	-	-	-	-	●	-	$166,500	2022 Multi-family Domestic Hot Water Draft CASE report (TRC and Noresco)
Faucet aerators	Common sense	-	-	-	●*+	-	-	$8/unit	Online retailers
Low-flow water fixtures	Renovation scope includes water heater replacement	-	-	-	+	-	-	FSR: $45,420	Costs from online retailers

Measure	Applicability to Existing Buildings	Measure Applicability ● Cost-effectiveness included in Section 4 * Included in Common Sense Package + Included in All-Electric + Efficiency Package — Not analyzed						Incremental Cost	Sources & Notes
		Med Office	Retail	Ware-house	QSR & FSR	HRMF	Small Hotel		
									- HE door-type high temperature dishwasher: $5,056 - HE undercounter-type high temperature dishwasher: $4,460 - PRSV: $22 -Two AO Smith CHP-120: $73,969 result in an incremental cost of $35,881 in comparison to a mixed-fuel baseline
Recirculating pump control	Common sense	-	-	-	-	●	●	$2,159	Controls vendors
HVAC									
Operational efficiency in lower capacity HVAC units	Renovation scope includes HVAC system replacement	-	●	-	●	-	-	$2,857/unit	(TRC and EnergySoft, 2019)
Economizer repair and FDD	Common sense	●*	●*	-	●*	-	-	$126.78/ton	SCE work paper (Southern California Edison, 2019)
Transfer air for commercial kitchens	Renovation scope includes other mechanical projects	-	-	-	●+	-	-	$0	
BAS Retrofit	Common sense	●	-	-	-	-	-	$6.40 / ft^2	Average of project costs collected from industry

Measure	Applicability to Existing Buildings	Measure Applicability ● Cost-effectiveness included in Section 4 * Included in Common Sense Package + Included in All-Electric + Efficiency Package — Not analyzed						Incremental Cost	Sources & Notes
		Med Office	Retail	Ware-house	QSR & FSR	HRMF	Small Hotel		
VAV Deadband Airflow	Renovation scope includes re-programming the zone minimum airflows	●*	-	-	-	-	-	$0	2022 Nonresidential HVAC Controls CASE report (Energy Solutions and Red Car Analytics, 2020)
Lighting									
Above code reduced interior LPD	Renovation scope includes lighting replacement	●	●	●	●	-	-	Warehouse: $1,918 All other prototypes: $0	2022 Nonresidential Indoor Lighting CASE report (Energy Solutions, 2020)
Lighting retrofit	Common sense	●*	●*+	●	●*+	-	-	Varies by prototype and vintage	Lighting designer
Process									
Energy efficient cooking appliances	Renovation scope includes cooking appliance replacement	-	-	-	●	-	-	QSR: $21,886 FSR: $48,376	Online retailers

3.3 Solar PV

The Reach Code Team estimated 50% of the roof area is available to install PV and has solar access, with a capacity of 15 W/ft². This approach assumes that a maximum of 50% of the roof is available for skylights, mechanical equipment, and walking paths. PV energy output is built into CBECC-Com and is based on the National Renewable Energy Lab's PVWatts calculator, which includes long-term performance degradation estimates.[3]

The costs for PV include first cost to purchase and install the system, inverter replacement costs, and annual maintenance costs, summarized in Figure 18. Upfront solar PV system costs are reduced by the Federal Income Tax Credit, approximately 26% due to a phased reduction in the credit through the year 2022.[4]

Figure 18. PV Construction Costs

		Unit Cost	Useful Life (yrs.)	Source
Solar PV System	Small NR <100kW (QSR, FSR, Warehouse, HRMF)	$3.20 / Wdc	30	LBNL – Tracking the Sun (Lawrence Berkeley National Laboratory, 2019)
	Large NR >100kW (Medium Office, Retail)	$2.50 / Wdc		
Inverter Replacement (at Year 11)		$0.15 / Wdc	10	E3 Rooftop Solar PV System Report (E3, 2017)
Inverter Replacement (at Year 21)		$0.12 / Wdc	10	
Annual Maintenance Costs		$0.02 / Wdc	1	

3.4 Battery

This measure includes installation of batteries to allow energy generated through PV to be stored and used later, providing utility cost benefits. The Reach Code Team applied battery measures to only the QSR and FSR prototypes, because these prototypes have significant electrical loads during peak periods (i.e., 4:00 – 9:00 PM). Although the multifamily prototype includes a similar ramp-up period, the Team assumed that an existing building storage measure would be exceedingly complex to implement as a load-shifting measure for all dwelling unit end-uses. The Team has not yet examined load-shifting a portion of the end-uses, such as hot water generation or common area loads.

The Reach Code Team ran test simulations to assess the impact of battery sizes and control algorithms on TDV savings. The Team optimized the battery size for each prototype to offset the majority of the peak period load. The Team used the *Ranked Day Demand Response* control method, which assumes batteries are charged anytime PV generation is greater than the building load, but they discharge to the electric grid beginning on the highest priced hour of the day. This control algorithm uses the relative ranking of the highest TDV for a day to determine its rank instead of a specific TDV value as threshold. This control option is not reflective of the current products on the market and represents an ideally controlled condition where there is real-time pricing of electricity. While this control strategy is being used in the analysis, there would be no mandate on the control strategy used in practice. The Team analyzed Time-of-Use (TOU) battery control option, but the savings were better optimized for Ranked Day DR Control as suggested by software development team. The current simulation software has approximations of performance characteristics changes due to environmental conditions, charge/discharge rates, and degradation with age and use.

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[3] More information available at: https://pvwatts.nrel.gov/downloads/pvwattsv5.pdf

[4] The federal credit drops to 26% in 2020, and 26% in 2021 before dropping permanently to 10% for commercial projects. More information on federal Investment Tax Credits available at: https://www.seia.org/initiatives/solar-investment-tax-credit-itc; https://www.seia.org/sites/default/files/2021-01/SEIA-ITC-Factsheet-2021-Jan.pdf

The Reach Code Team used costs of $1,000 kWh based on preliminary findings from concurrent research by the IOU Codes and Standards Program, using data from the Self Generation Incentive Program (Itron, 2019). Batteries are also eligible for the Federal Income Tax Credit if they are installed at the same time as the renewable generation source, and at least 75% of the energy is used to charge the battery comes from a renewable source. Thus, the Reach Code Team applied a 26% cost reduction to battery costs.

3.5 Measure Packaging

The Reach Code Team examined the following packages:

- **All-electric Code Min:** Replace any gas equipment with electric, code-minimum equipment, including HVAC, SHW, and appliances. Upgrade electrical infrastructure as-required. The baseline for this package is a gas code-minimum equipment replacement, including HVAC, SHW, and appliances.
- **All-electric Code Min (2022 TDV):** *All-electric Code Min*, with cost-effectiveness calculations done using 2022 TDV multipliers. The baseline for this package is the same as the all-electric Code Min Baseline, except with 2022 TDV multipliers.
- **All-electric + PV:** *All-electric Code Min*, including a solar PV array, plus battery storage for FSR and QSR only. The Baseline for this package is the same as the All-electric Code Min Baseline.
- **All-electric + PV (2022 TDV):** *All-electric + PV*, with cost-effectiveness calculations done using 2022 TDV multipliers. The baseline for this package is the same as the *All-electric Code Min* Baseline, except with 2022 TDV multipliers.
- **Electric HVAC and SHW:** This package is specifically for the restaurant prototypes, and it replaces gas space and water heating equipment with electric code-minimum equipment. Kitchen appliance electrification is excluded.
- **All-Electric + Efficiency:** Adds efficiency measures to the *All-Electric Code Min* package, except in restaurants where it adds efficiency measures to the *Electric HVAC and SHW* package. The baseline for this package is the gas-code minimum equipment replacement.
- **Existing buildings + Common Sense measures**: Common sense efficiency measures that are relatively easy to implement due to having low cost and/or the appropriate personnel on-site applied to the existing mixed-fuel building with existing HVAC and SHW equipment.

4 Results

Results are presented in this section as per the prototype-specific 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 section. What constitutes a benefit or a cost varies with the scenarios because both energy savings and incremental construction costs may be negative depending on the package. Typically, utility bill savings are categorized as a benefit, while incremental construction costs are treated as costs. In cases where both construction costs are negative and utility bill savings are negative, the construction cost savings are treated as the benefit, while the utility bill negative savings are as the cost. In the result figures Figure 19 through Figure 34, the result **Both** (shown in green shading) indicates that the result is cost-effective in both On-Bill and TDV. The result ***On-Bill*** or ***TDV*** (shown in yellow shading) indicates that the result is either cost-effective in On-Bill or TDV, respectively. The result **-** (results with no shading) indicates that the result is cost-effective neither in On-Bill or TDV. Results that are **blank** (shown in gray shading) indicate that the package or measure is not applicable.

Overarching factors to keep in mind when reviewing the results include:

- Electrification retrofit packages will have lower GHG emissions that mixed-fuel packages in all cases, due to the clean power sources currently available from California's power providers.
- To pass the Energy Commission's application process, local reach codes must both be cost effective compared to the mixed-fuel baseline package and exceed the energy performance budget using TDV (i.e., have a positive compliance margin) compared to the standard model in the compliance software. To emphasize these two important factors, the figures in this section highlight in green the modeling results that have demonstrated **either** TDV savings or are cost effective. This will allow readers to identify whether a scenario is fully or partially supportive of a reach code and the opportunities/challenges that the scenario presents.
- As mentioned in Section 2.1.4, The Reach Code Team coordinated with utilities to select tariffs for each prototype given the annual energy demand profile 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.
- As a point of comparison, mixed-fuel existing building energy figures are provided in Appendix 7.3.

For each prototype, the Reach Code Team assessed the viability of achieving a cost-effective outcome when combining efficiency measures with all-electric packages (i.e., the *All-Electric + Efficiency* packages) based on the NPVs achieved from each individually. The Team determined that testing All-Electric + Efficiency may be most successful for the Standalone Retail, QSR, and FSR prototypes, and these results are presented below.

Similarly, the Team determined that Common Sense measure packages would be most appropriate for the Medium Office, Standalone Retail, QSR, and FSR prototypes due to the quantity and type of efficiency measures applicable to these prototypes.

4.1 Medium Office

Figure 19 shows the results of the Medium Office packages all-electric and common-sense measure packages. The *All-electric Code Min* package is not cost-effective in terms of TDV or On-Bill in any vintage or CZ partly due to the large incremental first cost of switching to an all-electric HVAC system. The all-electric HVAC system is a heat pump with supplemental electric resistance covering between 0 percent and 9 percent of the heating load, depending upon vintage and CZ. Adding PV improves cost-effectiveness enough to make the package On-Bill cost-effective in most CZs of TDV in the 1980s and 1990s vintages. Using CBECC-Com 2022 software made the *All-electric + PV* package TDV cost-effective in some additional climate zones as well.

The *Existing buildings + Common Sense Measures* package is cost-effective in terms of TDV and On-Bill across most of the CZs and vintages. Electrification retrofits become cost effective in most CZs when including *common-sense* measures and PV.

Figure 19. Medium Office Package Results

Climate Zone		CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Package	Utility / **Vintage**	PG&E	PG&E	PG&E / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	PG&E / LADWP	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
All-electric Code Min	1980's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	1990's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	2000's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
All-electric Code Min (2022 TDV)	1980's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	1990's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	2000's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
All-electric+PV	1980's	–	On-Bill	On-Bill / On-Bill	On-Bill / On-Bill	On-Bill / –	– / –	–	TDV / TDV	TDV / TDV	On-Bill / –	On-Bill	On-Bill / –	On-Bill	Both / TDV	–	– / –
	1990's	–	–	– / –	On-Bill / On-Bill	On-Bill / –	– / –	–	– / –	– / –	On-Bill / –	–	– / –	–	TDV / TDV	–	– / –
	2000's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
All-electric+PV (2022 TDV)	1980's	–	On-Bill	On-Bill / On-Bill	On-Bill / On-Bill	On-Bill / –	– / –	–	TDV / TDV	TDV / TDV	Both / TDV	On-Bill	On-Bill / –	On-Bill	Both / TDV	–	– / –
	1990's	–	–	– / –	On-Bill / –	On-Bill / On-Bill	– / –	On-Bill	– / –	– / –	On-Bill / –	–	– / –	–	– / –	–	– / –
	2000's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –

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 / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	PG&E / LADWP	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
Package	**Vintage**																
Existing Building + Common Sense Measures	1980's	On-Bill	Both	Both / Both	Both / TDV	Both / Both	TDV / TDV	Both	TDV / TDV	Both / Both	Both / TDV	Both	Both / TDV	Both	Both / TDV	Both	Both / TDV
	1990's	Both	Both	Both / Both	Both / Both	Both / Both	Both / TDV	Both	Both / TDV	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / TDV
	2000's	Both	Both	Both / Both	Both / Both	Both / Both	Both / TDV	Both	Both / Both	Both / TDV	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / TDV
All-electric + Common Sense Measures + PV	1980's	–	Both	Both / Both	Both / Both	Both / Both	TDV / TDV	Both	TDV / TDV	TDV / TDV	Both / TDV	Both	Both / TDV	Both	Both / TDV	TDV	On-Bill / –
	1990's	–	Both	Both / Both	Both / Both	Both / Both	TDV / TDV	Both	TDV / TDV	TDV / TDV	Both / TDV	Both	Both / TDV	Both	Both / TDV	TDV	On-Bill / –
	2000's	–	–	On-Bill / On-Bill	On-Bill / –	On-Bill / On-Bill	TDV / TDV	Both	TDV / TDV	TDV / TDV	On-Bill / –	–	– / –	–	Both / TDV	TDV	– / –
All-electric + Common Sense Measures + PV (2022 TDV)	1980's	–	Both	On-Bill / On-Bill	Both / Both	On-Bill / On-Bill	TDV / TDV	On-Bill	TDV / TDV	TDV / TDV	Both / TDV	Both	On-Bill / –	On-Bill	Both / TDV	TDV	On-Bill / –
	1990's	–	Both	On-Bill / On-Bill	Both / Both	On-Bill / On-Bill	TDV / TDV	Both	TDV / TDV	TDV / TDV	Both / TDV	On-Bill	On-Bill / –	On-Bill	Both / TDV	TDV	On-Bill / –
	2000's	–	–	On-Bill / On-Bill	On-Bill / –	On-Bill / On-Bill	– / –	On-Bill	TDV / TDV	– / –	On-Bill / –	–	On-Bill / –	On-Bill	On-Bill / –	–	– / –

Figure 20 shows results of individual efficiency measures applied to the existing Medium Office prototype. The *Cool Roof*, *Window Film*, *Roof Alterations*, *Above Code Interior LPD*, *Lighting Retrofit*, *VAV Deadband Airflow*, and *BAS Retrofit* measures are On-Bill and TDV cost-effective in most CZs and vintages where they are applicable. The *Economizer Repair and FDD* measure is cost-effective in only a small number of scenarios.

Figure 20. Medium Office Individual Efficiency Measure Results

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 / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	PG&E / LADWP	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
Measure	**Vintage**																
Cool Roof	**1980's**		Both		Both / TDV	Both / Both	– / –	On-Bill	TDV / TDV	– / –	On-Bill / –	Both	TDV / TDV	–	Both / TDV	Both	Both / Both
	1990's		Both		Both / TDV	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / TDV	Both	Both / Both	Both	Both / Both
	2000's		Both		Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / TDV	Both	Both / Both	Both	Both / Both	Both	Both / Both
Window Film	**1980's**	–	–	– / –	Both / TDV	– / On-Bill	TDV / TDV	Both	TDV / TDV	Both / TDV	Both / Both	Both	Both / TDV	Both	Both / TDV	Both	– / –
	1990's	–	Both	On-Bill / On-Bill	Both / TDV	On-Bill / On-Bill	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / TDV	Both	Both / Both	Both	On-Bill / –
	2000's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
Roof Alterations	**1980's**	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	1990's	On-Bill	On-Bill	– / –	On-Bill / –	On-Bill / –	Both / TDV	On-Bill	Both / Both	TDV / Both	Both / Both	Both	Both / Both	Both	Both / TDV	TDV	Both / Both
	2000's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
Economizer Repair and FDD	**1980's**	–	–	– / –	– / –	– / –	– / On-Bill	On-Bill	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	1990's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	2000's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	On-Bill	– / –

Climate Zone		CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Measure	Utility / Vintage	PG&E	PG&E	PG&E / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	PG&E / LADWP	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
Above Code Interior LPD	1980's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	1990's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	2000's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
Lighting Retrofit	1980's	Both	Both	Both / Both	Both / Both	Both / Both	TDV / TDV	Both	TDV / TDV	TDV / TDV	Both / TDV	Both	Both / TDV	Both	Both / TDV	TDV	Both / TDV
	1990's	Both	Both	Both / Both	Both / Both	Both / Both	Both / TDV	Both	Both / TDV	Both / TDV	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / TDV
	2000's	Both	Both	Both / Both	Both / Both	Both / Both	TDV / TDV	Both	TDV / TDV	TDV / TDV	Both / TDV	Both	Both / TDV	Both	Both / TDV	TDV	Both / TDV
VAV Deadband Airflow	1980's																
	1990's																
	2000's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
BAS Retrofit	1980's	Both	Both	Both / Both	Both / Both	Both / Both	TDV / TDV	Both	TDV / TDV	TDV / TDV	TDV / TDV	On-Bill	On-Bill / –	–	– / –	–	– / –
	1990's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	2000's																

4.2 Standalone Retail

Figure 21 shows results of the Standalone Retail packages. The *All-electric Code Min* package is only cost-effective On-Bill in CPAU and LADWP territory. Adding PV significantly improves TDV cost-effectiveness across all CZs except 1. Using 2022 software produces similar results for the *All-electric Code Min* package and the *All-electric + PV* package as the 2019 software, though slightly fewer CZs are TDV cost-effective.

The *All-electric + Efficiency* package is cost-effective in terms of TDV and On-Bill across most CZs and vintages. The *Existing Buildings + Common sense measures* package is cost-effective in terms of TDV across all CZs, and both TDV and On-Bill metrics in Climate Zones 3 to 5 across all vintages.

Figure 21. Standalone Retail Package Results

Climate Zone		CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Package	Utility / **Vintage**	PG&E	PG&E	PG&E / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	SCE / LADWP	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
All-electric Code Min	1980's	–	–	– / –	– / On-Bill	– / –	– / –	–	– / On-Bill	– / On-Bill	– / –	–	– / –	–	– / –	On-Bill	– / –
	1990's	–	–	– / –	– / On-Bill	– / –	– / On-Bill	–	– / On-Bill	– / On-Bill	– / –	–	– / –	–	– / –	–	– / –
	2000's	–	–	– / –	– / On-Bill	– / –	– / –	–	– / On-Bill	– / On-Bill	– / –	–	– / –	–	– / –	–	– / –
All-electric Code Min (2022 TDV)	1980's	–	–	– / –	– / On-Bill	– / –	– / On-Bill	–	– / On-Bill	– / On-Bill	– / –	–	– / On-Bill	–	– / –	On-Bill	– / –
	1990's	On-Bill	–	– / –	– / On-Bill	– / –	– / –	–	– / On-Bill	– / On-Bill	– / –	–	– / On-Bill	–	– / –	–	– / –
	2000's	–	–	– / –	– / On-Bill	– / –	– / On-Bill	–	– / On-Bill	– / On-Bill	– / –	–	– / On-Bill	–	– / –	–	– / –
All-electric+PV	1980's	–	TDV	TDV / TDV	TDV / Both	Both / TDV	TDV / TDV	TDV	TDV / TDV	TDV / TDV	TDV / TDV	TDV	TDV / TDV	TDV	TDV / TDV	TDV	– / –
	1990's	–	TDV	TDV / TDV	Both / Both	Both / Both	TDV / TDV	TDV	TDV / TDV	TDV / TDV	TDV / TDV	TDV	TDV / TDV	TDV	TDV / TDV	TDV	TDV / TDV
	2000's	–	TDV	Both / Both	TDV / Both	Both / Both	TDV / TDV	TDV	TDV / TDV	TDV / TDV	TDV / TDV	TDV	TDV / –	TDV	TDV / TDV	TDV	TDV / –
All-electric+PV (2022 TDV)	1980's	–	–	– / –	TDV / Both	On-Bill / On-Bill	TDV / TDV	–	TDV / TDV	TDV / TDV	TDV / TDV	–	– / –	–	TDV / TDV	TDV	– / –
	1990's	On-Bill	–	– / –	TDV / Both	On-Bill / On-Bill	TDV / TDV	–	TDV / TDV	TDV / TDV	TDV / TDV	–	– / –	–	TDV / TDV	TDV	– / –
	2000's	–	–	– / –	TDV / Both	On-Bill / On-Bill	TDV / TDV	–	TDV / TDV	TDV / TDV	TDV / TDV	–	– / –	–	TDV / TDV	TDV	– / –

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 / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	SCE / LADWP	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
Package	Vintage																
All Electric + Efficiency	1980's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	On-Bill / On-Bill
	1990's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	On-Bill / –
	2000's	On-Bill	Both	Both / Both	Both / Both	Both / Both	TDV / TDV	Both	Both / Both	TDV / Both	Both / TDV	Both	Both / Both	Both	Both / TDV	Both	– / –
Existing Buildings + Common sense measures	1980's	TDV	Both	Both / Both	Both / Both	Both / Both	Both / TDV	TDV	Both / TDV	Both / TDV	TDV / Both	Both	Both / Both	Both	TDV / Both	Both	Both / TDV
	1990's	TDV	Both	Both / Both	Both / Both	Both / Both	Both / TDV	TDV	Both / TDV	Both / TDV	TDV / Both	Both	Both / TDV	Both	TDV / Both	Both	Both / TDV
	2000's	TDV	TDV	Both / Both	Both / Both	Both / Both	TDV / TDV	TDV	TDV / TDV	TDV / TDV	TDV / TDV	TDV	TDV / TDV	TDV	TDV / TDV	TDV	TDV / TDV

Figure 22 shows results of individual efficiency measures applied to the existing Standalone Retail prototype. The *Window Film*, *Above Code Interior LPD*, and *Lighting Retrofit* measures are all cost-effective in terms of On-Bill and TDV across nearly all vintages and CZs. The *Cool Roof* measure is cost-effective in terms of On-Bill and TDV across a majority of vintages and CZs. The *Economizer Repair FDD* measure is TDV cost-effective in all vintages and Climate Zones.

Figure 22. Standalone Retail Individual Efficiency Measure Results

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 / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	SCE / LADWP	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
Measure	Vintage																
Cool Roof	1980's		–		Both / Both	– / –	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	– / –
Cool Roof	1990's		–		Both / Both	– / –	Both / Both	Both	Both / Both	Both / Both	Both / TDV	Both	Both / Both	Both	Both / Both	Both	– / –
Cool Roof	2000's		–		Both / TDV	– / –	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / TDV	Both	Both / Both	Both	– / –
Window Film	1980's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	– / –
Window Film	1990's	–	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	– / –
Window Film	2000's																
Roof Alterations	1980's	On-Bill	–	– / –	– / –	– / –	On-Bill / On-Bill	–	TDV / Both	TDV / Both	Both / Both	Both	On-Bill / –	Both	Both / Both	Both	Both / Both
Roof Alterations	1990's	–	On-Bill	– / –	– / –	– / –	– / –	On-Bill	TDV / TDV	TDV / TDV	Both / TDV	Both	Both / TDV	Both	Both / Both	TDV	Both / Both
Roof Alterations	2000's	–	–	– / –	– / –	– / –	– / –	On-Bill	TDV / TDV	Both / Both	– / –	–	– / –	–	– / –	–	Both / TDV
Small Capacity HVAC Efficiency	1980's	Both	Both	Both / Both	Both / Both	Both / Both	TDV / TDV	Both	TDV / TDV	TDV / TDV	– / –	–	On-Bill / –	–	On-Bill / –	–	Both / TDV
Small Capacity HVAC Efficiency	1990's	Both	Both	Both / Both	Both / Both	Both / Both	TDV / TDV	Both	TDV / TDV	TDV / TDV	– / –	–	Both / TDV	–	On-Bill / –	–	Both / TDV
Small Capacity HVAC Efficiency	2000's	Both	Both	Both / Both	Both / Both	Both / Both	TDV / TDV	Both	TDV / TDV	TDV / TDV	TDV / TDV	–	– / –	–	– / –	–	On-Bill / –

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 / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	SCE / LADWP	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
Measure	**Vintage**																
Economizer repair and FDD	1980's	TDV	TDV	TDV / TDV	TDV / Both	TDV / TDV	TDV / TDV	TDV	TDV / TDV	TDV / TDV	TDV / TDV	TDV	TDV / TDV	TDV	TDV / TDV	TDV	TDV / TDV
	1990's	TDV	TDV	TDV / TDV	TDV / Both	TDV / TDV	TDV / TDV	TDV	TDV / TDV	TDV / TDV	TDV / TDV	TDV	TDV / TDV	TDV	TDV / TDV	TDV	TDV / TDV
	2000's	TDV	TDV	TDV / TDV	TDV / Both	TDV / TDV	TDV / TDV	TDV	TDV / TDV	TDV / TDV	TDV / TDV	TDV	TDV / TDV	TDV	TDV / TDV	TDV	TDV / TDV
Above Code Interior LPD	1980's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	1990's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	2000's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
Lighting Retrofit	1980's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	1990's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	2000's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both

4.3 Warehouse

Figure 23 shows results of the Warehouse packages. The *All-electric Code Min* package is not cost-effective in terms of TDV or On-Bill in any of the vintages or CZs. Adding PV improves cost-effectiveness, with the package being cost-effective in terms of either TDV or On-Bill across CZs 3 through 9 and 12 through 16 for the 1990s and 2000s vintages. For the 1980s vintage, adding PV only saw On-Bill cost-effectiveness for Climate Zones 4, 5, and 12 in PG&E territory. Using the 2022 software slightly decreased cost-effectiveness of the *All-electric + PV* package compared to using the 2019 software. This may be due to the different weather files in the software. There are no *common sense* measures for Warehouse, so no *Existing buildings + Common Sense* package is presented.

Figure 23. Warehouse Package Results

Package	Vintage	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
	Utility	PG&E	PG&E	PG&E / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	SCE / LADWP	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
All-electric Code Min	1980's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
All-electric Code Min	1990's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
All-electric Code Min	2000's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
All-electric Code Min (2022 TDV)	1980's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
All-electric Code Min (2022 TDV)	1990's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
All-electric Code Min (2022 TDV)	2000's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
All-electric+PV	1980's	–	–	– / –	On-Bill / –	On-Bill / On-Bill	– / –	–	– / –	– / –	– / –	–	On-Bill / –	–	– / –	–	– / –
All-electric+PV	1990's	–	On-Bill	On-Bill / On-Bill	On-Bill / On-Bill	Both / Both	TDV / TDV	TDV	TDV / TDV	TDV / TDV	– / –	On-Bill	Both / TDV	On-Bill	TDV / TDV	TDV	On-Bill / –
All-electric+PV	2000's	–	–	On-Bill / On-Bill	On-Bill / –	On-Bill / On-Bill	TDV / TDV	TDV	TDV / TDV	TDV / TDV	– / –	–	Both / TDV	On-Bill	TDV / TDV	TDV	On-Bill / –
All-electric+PV (2022 TDV)	1980's	–	–	On-Bill / –	On-Bill / –	On-Bill / On-Bill	– / –	–	– / –	– / –	– / –	–	On-Bill / –	–	– / –	–	– / –
All-electric+PV (2022 TDV)	1990's	–	On-Bill	On-Bill / On-Bill	On-Bill / On-Bill	On-Bill / On-Bill	TDV / TDV	TDV	TDV / TDV	TDV / TDV	– / –	On-Bill	On-Bill / –	On-Bill	– / –	–	On-Bill / –
All-electric+PV (2022 TDV)	2000's	–	–	On-Bill / On-Bill	On-Bill / –	On-Bill / On-Bill	TDV / TDV	TDV	TDV / TDV	– / –	– / –	–	On-Bill / –	On-Bill	– / –	–	On-Bill / –

Figure 24 shows results for individual efficiency measures for the warehouse prototype. The Reach Code Team analyzed only lighting measures for the warehouse. The *Above Code Interior LPD* measure is both TDV and On-Bill cost effective in all CZs and vintages. The *Lighting Retrofit* measure, however, is only On-Bill cost effectiveness in the 1980s vintages for most CZs..

Figure 24. Warehouse Individual Efficiency Measure Results

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 / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	SCE / LADWP	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
Measure	Vintage																
Above Code Interior LPD	1980's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	1990's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	2000's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
Lighting Retrofit	1980's	On-Bill	On-Bill	On-Bill / On-Bill	On-Bill / –	On-Bill / On-Bill	– / –	On-Bill	– / –	– / –	On-Bill / –	On-Bill	On-Bill / –	On-Bill	On-Bill / –	–	On-Bill / –
	1990's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	2000's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –

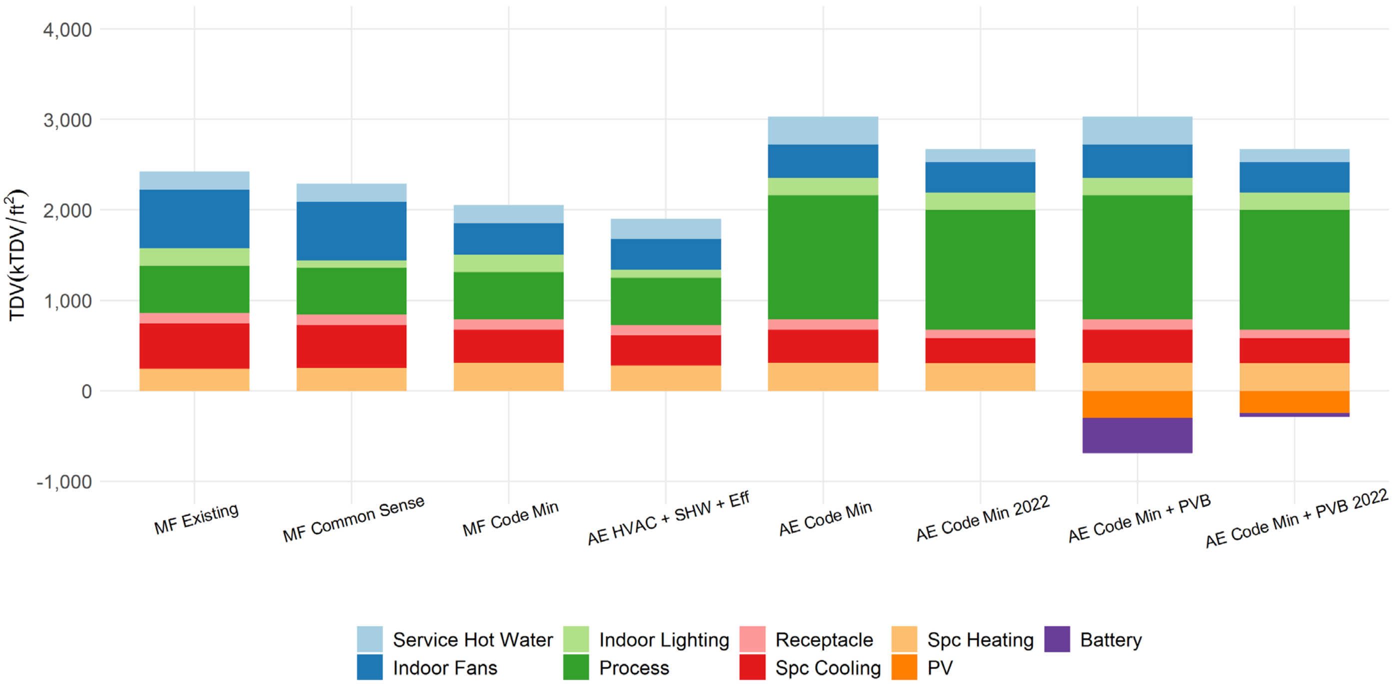
4.4 Full Service Restaurants and Quick Service Restaurants

The Reach Code Team analyzed two different restaurant prototypes, FSR and QSR, and provided results for each prototype separately. The Reach Code Team developed the commercial kitchen and hot water characteristics through a literature review and interviews (see Section 7.4 for more detail) and is presenting the simulation outcomes of this research in more detail than other prototypes due to the significant commercial kitchen process loads.

4.4.1 Full Service Restaurants

The TDV end-use breakdowns shown in Figure 25 for the FSR in Climate Zone 12 for the 1990s vintage indicate that the all-electric packages have a higher TDV energy usage than the mixed-fuel baseline primarily due to the process loads (cooking equipment). Results are presented 2019 TDV except where 2022 is indicated in the column label. The primary opportunity to reduce the TDV energy consumption of an all-electric commercial kitchen is to offset with solar PV generation and battery storage, as shown by the negative TDV values in the figure. The only all-electric package with a lower TDV than the mixed-fuel packages is the All-electric HVAC + SHW + Eff, which only includes electrification retrofits for the space and water heating and a package of efficiency measures.

Figure 25. Full Service Restaurant Packages Annual TDV Results: CZ 12, 1990s Vintage



To optimize size and operation of the battery storage system, the Reach Code Team analyzed the cooking appliance load profiles developed through research described in Section 7.4. Figure 26 shows the 24-hour load profiles of the FSR in Climate Zone 12 on June 15th. The all-electric packages have substantially higher lunchtime and dinnertime kWh loads than the mixed-fuel baselines, which are steady throughout the day. In the 2019 software, battery operation reduces the load during peak dinner hours, which can be seen in the kWh and TDV graphs. When the battery operates in the 2022 software, the electrical load of the all-electric reduces to negative values due to the simulation software control of the battery (the 'Ranked Day Demand Response' controls options is not yet available in 2022 software).

Figure 26. Full Service Restaurant Hourly Load Profile on June 15th: CZ 12, 1990s Vintage

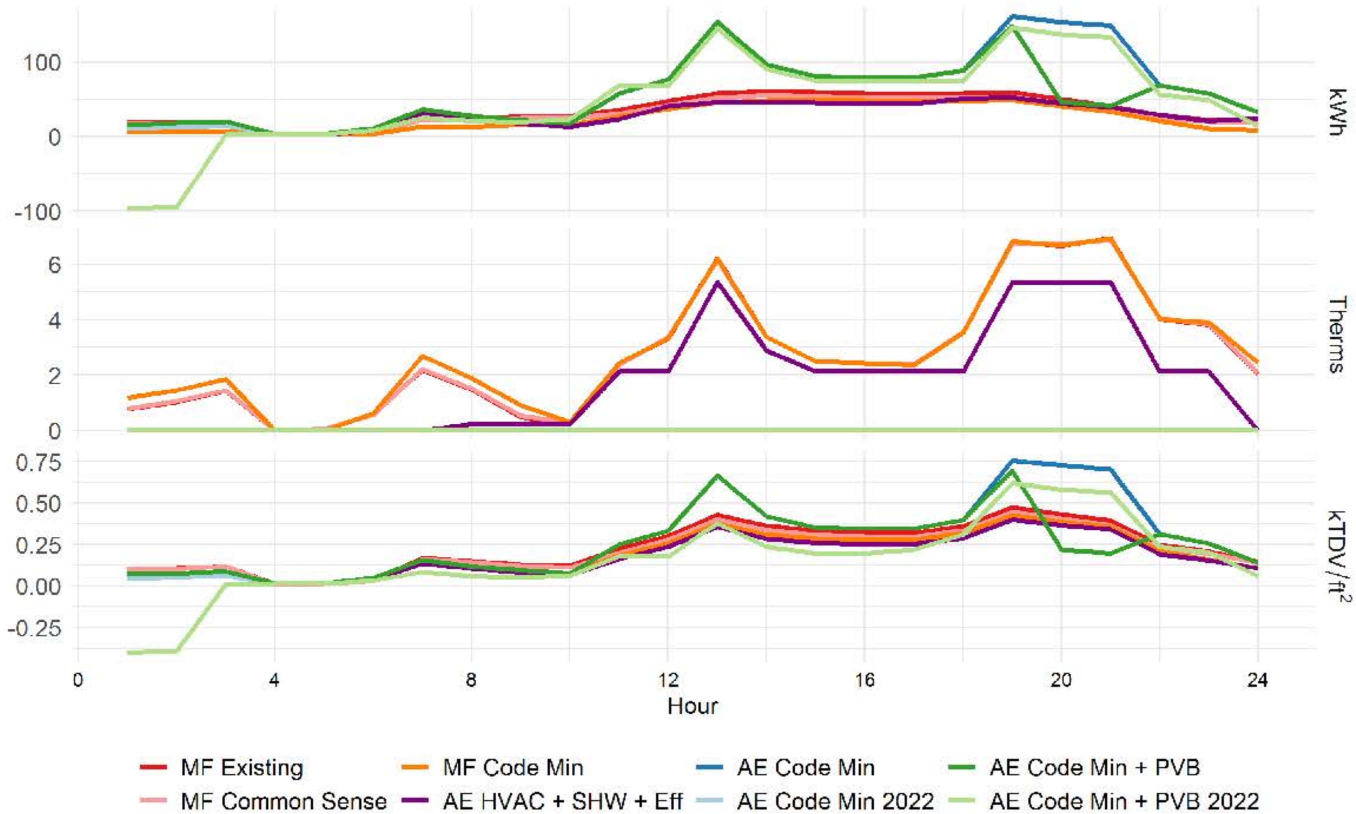


Figure 27 shows the results of the FSR packages. Most of the all-electric packages, including the *All-electric Code Min*, *All-electric Code Min (2022 TDV)*, *All-electric + PV + B*, *All-electric + PV +B (2022 TDV)*, and *Electric HVAC + SHW,* are not TDV or On-Bill cost-effective. While adding PV and battery and using the 2022 TDV multipliers improved cost-effectiveness compared to the *All-Electric Code Min* package, they did not improve enough to make an all-electric package cost-effective This is partly due to the incremental first cost of the all-electric SWH and cooking appliances. The *All-Electric + Efficiency* package is cost-effective in terms of TDV or On-Bill for Climate Zones 4 and 6 through 16. Adding efficiency measures such as low-flow water fixtures, allows the usage of a smaller and less expensive heat pump water heater plant, and improves cost-effectiveness. The package *Existing buildings + Common Sense* is cost-effective in terms of TDV and On-Bill across all Climate Zones and vintages.

Figure 27. Full Service Restaurant Package Results

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 / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	SCE / LADWP	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
Package	**Vintage**																
All-electric Code Min	1980's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	1990's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	2000's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
All-electric Code Min (2022 TDV)	1980's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	1990's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	2000's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
All-electric+PV+B	1980's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	1990's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	2000's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
All-electric+PV+B (2022 TDV)	1980's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	1990's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	2000's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –

In two-utility zones, each cell gives the first utility's result, then " / ", then the second utility's result.

Climate Zone		CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
	Utility																
Package	Vintage	PG&E	PG&E	PG&E / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	SCE / LADWP	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
Electric HVAC and SHW	1980's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	1990's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	2000's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
All Electric + Efficiency	1980's	–	–	– / –	TDV / Both	– / –	TDV / Both	TDV	Both / Both	Both / Both	TDV / TDV	Both	TDV / Both	TDV	TDV / TDV	Both	– / On-Bill
	1990's	–	–	– / –	– / On-Bill	– / –	TDV / Both	TDV	Both / Both	Both / Both	TDV / TDV	Both	TDV / Both	TDV	TDV / TDV	Both	– / On-Bill
	2000's	–	–	– / –	– / On-Bill	– / –	– / On-Bill	–	– / On-Bill	TDV / Both	TDV / TDV	TDV	– / On-Bill	–	– / –	TDV	– / On-Bill
Existing Buildings + Common sense measures	1980's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	1990's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	2000's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both

Figure 28 shows results of individual efficiency measures on the existing building. The *Faucet Aerators, Small Capacity HVAC Efficiency*, *Economizer Repair and FDD, Above Code Interior LPD*, *Lighting Retrofit*, and *Transfer Air for Commercial Kitchens* measures are cost effective across almost all vintages and Climate Zones. The *Cool Roof* measure is cost effective in terms of both metrics in all CZs where it is applicable, except 4, 5 (1990s and 2000s vintage) and 16. The *Window Film* measure is mostly cost effective for all Climate Zones except for CZ 1 and is not applicable to the 2000s vintage. The *Roof Alterations* measure is cost-effective in the 1980s vintage in CZs 6 through 16 and largely not cost effective in the other vintages. The *Energy Efficient Cooking Appliances* measure has mixed results but is largely cost effective in terms of TDV in Climate Zones 5 through 15 across all vintages.

Figure 28. Full Service Restaurant Individual Efficiency Measure Results

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 / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	SCE / LADWP	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
Measure	Vintage																
Faucet Aerators	1980's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	1990's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	2000's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
Cool Roof	1980's		Both		Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	1990's		Both		Both / TDV	– / –	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / TDV
	2000's		Both		Both / TDV	– / –	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	On-Bill / –
Window Film	1980's	–	Both	Both / Both	TDV / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	1990's	–	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / TDV
	2000's																
Roof Alterations	1980's	–	On-Bill	– / –	– / –	– / –	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / TDV	Both	Both / Both
	1990's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	On-Bill / –	–	– / –	TDV	– / –	TDV	On-Bill / –
	2000's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	On-Bill / –

Climate Zone		CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Measure	Utility / Vintage	PG&E	PG&E	PG&E / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	SCE / LADWP	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
Small Capacity HVAC Efficiency	1980's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	1990's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / TDV	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	2000's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / TDV	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
Economizer repair and FDD	1980's	On-Bill	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / TDV	Both / TDV	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / TDV
	1990's	–	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / TDV	Both / TDV	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / TDV
	2000's	–	Both	Both / Both	Both / Both	Both / Both	Both / TDV	Both	Both / TDV	TDV / TDV	Both / TDV	Both	Both / TDV	Both	Both / TDV	TDV	Both / TDV
Above Code Interior LPD	1980's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	1990's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	2000's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
Lighting Retrofit	1980's	Both	Both	Both / Both	TDV / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	1990's	Both	TDV	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	2000's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both

Climate Zone		CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Measure	**Utility / Vintage**	PG&E	PG&E	PG&E / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	SCE / LADWP	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
Energy Efficient Cooking Appliances	1980's	–	Both	On-Bill / On-Bill	TDV / Both	On-Bill / –	Both / TDV	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / TDV
Energy Efficient Cooking Appliances	1990's	–	Both	– / –	Both / Both	– / –	TDV / TDV	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / TDV
Energy Efficient Cooking Appliances	2000's	–	Both	– / –	Both / Both	– / –	TDV / TDV	Both	TDV / TDV	Both / TDV	Both / Both	Both	Both / Both	Both	Both / TDV	Both	On-Bill / –
Transfer Air for Commercial Kitchens	1980's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
Transfer Air for Commercial Kitchens	1990's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
Transfer Air for Commercial Kitchens	2000's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both

4.4.2 Quick Service Restaurants

Figure 29 shows the results of the QSR packages. None of the all-electric packages, including the *All-electric Code Min*, *All-electric Code Min (2022 TDV)*, *All-electric + PV + B*, and *All-electric + PV +B (2022 TDV)* were found to be cost effective TDV or On-Bill. While adding PV and battery and using the 2022 TDV multipliers improves cost effectiveness compared to the *All-Electric Code Min* package, they did not improve enough to make an all-electric package cost effective. This is partly due to the incremental first cost of the all-electric SWH and appliances. The package *Electric HVAC + SHW* is largely not cost-effective in terms of TDV or On-Bill, except in CZs 6 and 9 for the 1980s vintage where it is On-Bill cost-effective. The package *All-electric + Efficiency* is largely not cost effective in terms of TDV or On-Bill, except for in some vintages in CZs 7 through 9, 12 and 16.

Unlike the FSR prototype where there are cost savings since the high-efficiency heat pump water heater would be significantly less expensive than the code-minimum heat pump water heater, the *All-electric + Efficiency* package for QSR did not include the low-flow water fixtures measure because there is less water use and the impact on the heat pump water heater plant would not result in cost savings. This results in the *All-electric + Efficiency* package being more cost-effective for FSR than QSR. The package *Existing buildings + Common Sense* is mostly cost-effective in terms of TDV and On-Bill across all Climate Zones and vintages, though not On-Bill cost-effective in select Climate Zones and territories.

Figure 29. Quick Service Restaurant Package Results

Climate Zone		CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Package	Utility / Vintage	PG&E	PG&E	PG&E / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	SCE / LADWP	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
All-electric Code Min	1980's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	1990's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	2000's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
All-electric Code Min (2022 TDV)	1980's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	1990's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	2000's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
All-electric+PV+B	1980's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	1990's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	2000's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
All-electric+PV+B (2022 TDV)	1980's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	1990's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	2000's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –

Climate Zone		CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Plot Area	Utility	PG&E	PG&E	PG&E / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	SCE / LADWP	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
Package	**Vintage**																
Electric HVAC and SHW	**1980's**	–	–	– / –	– / –	– / –	– / On-Bill	–	– / –	– / On-Bill	– / –	–	– / –	–	– / –	–	– / –
	1990's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	2000's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
All Electric + Efficiency	**1980's**	–	–	– / –	– / –	– / –	– / –	TDV	TDV / TDV	– / On-Bill	– / –	–	– / –	–	– / –	–	– / –
	1990's	–	–	– / –	– / –	– / –	– / –	TDV	TDV / Both	– / On-Bill	– / –	–	– / On-Bill	–	– / –	–	– / On-Bill
	2000's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / On-Bill	– / –	–	– / –	–	– / –	–	– / –
Existing Buildings + Common sense measures	**1980's**	–	Both	Both / Both	Both / Both	Both / Both	Both / TDV	Both	Both / TDV	Both / TDV	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	1990's	On-Bill	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	2000's	–	Both	Both / Both	Both / Both	Both / Both	TDV / TDV	Both	Both / TDV	Both / TDV	Both / Both	Both	Both / TDV	Both	Both / Both	Both	Both / TDV

Figure 30 shows results of individual efficiency measures on the existing building. The *Faucet Aerators, Above Code Interior LPD, Lighting Retrofit, Energy Efficient Cooking Appliances and Transfer Air for Commercial Kitchens* measures are cost effective across almost all vintages and CZs. The *Cool Roof* measure is mostly cost effective in terms of both metrics across the vintages in CZs 2, 4, and 6 through 15, while the *Window Film* measure is cost effective in CZs 2 to 15 in applicable vintage 1980s and 1990s. The *Roof Alterations* measure is cost effective in the 1980s vintage in some CZs, and it is largely not cost effective in the other vintages. The *Small Capacity HVAC Efficiency* is mostly not cost effective in the 1980s vintage but is mostly cost effective in the 1990s and 2000s vintages. The *Economizer Repair FDD* is mostly only cost effective in the 1990s vintage, and in limited CZs.

Figure 30. Quick Service Restaurant Individual Efficiency Measure Results

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 / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	SCE / LADWP	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
Measure	Vintage																
Faucet Aerators	1980's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
Faucet Aerators	1990's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
Faucet Aerators	2000's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
Cool Roof	1980's		Both		Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
Cool Roof	1990's		Both		Both / TDV	– / –	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / TDV
Cool Roof	2000's		Both		Both / TDV	– / On-Bill	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / TDV	Both	Both / TDV	Both	On-Bill / –
Window Film	1980's	On Bill	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
Window Film	1990's	–	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / TDV
Window Film	2000's																
Roof Alterations	1980's	On-Bill	Both	/ –	/ On-Bill	On Bill / –	Both / Both	On-Bill	Both / Both	TDV / Both	Both / Both	Both	Both / Both	Both	Both / TDV	TDV	Both / Both
Roof Alterations	1990's	On-Bill	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
Roof Alterations	2000's	On-Bill	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –

Measure	Vintage	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
	Utility	PG&E	PG&E	PG&E / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	SCE / LADWP	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
Small Capacity HVAC Efficiency	1980's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	1990's	Both	Both	Both / Both	Both / Both	Both / Both	Both / TDV	Both	Both / TDV	Both / TDV	Both / Both	Both	Both / Both	Both	Both / Both	TDV	Both / TDV
	2000's	Both	Both	Both / Both	Both / Both	Both / Both	Both / TDV	Both	Both / TDV	Both / TDV	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / TDV
Economizer repair and FDD	1980's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	Both / TDV
	1990's	–	–	– / –	On-Bill / –	– / On-Bill	TDV / TDV	Both	TDV / TDV	– / –	Both / TDV	–	– / –	–	Both / TDV	TDV	Both / TDV
	2000's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	On-Bill / –
Above Code Interior LPD	1980's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	1990's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	2000's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
Lighting Retrofit	1980's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	1990's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	2000's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both

Climate Zone		CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Measure	Utility / Vintage	PG&E	PG&E	PG&E / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	SCE / LADWP	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
Energy Efficient Cooking Appliances	1980's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	1990's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	2000's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / TDV
Transfer Air for Commercial Kitchens	1980's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	1990's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	2000's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both

4.5 High-rise Multifamily

Figure 31 shows the results of the HRMF packages. The *All-electric Code Min* package is cost effective for the 1990s vintage in terms of TDV in CZs 1, 3, 4, and 5, and On-Bill in several municipal utility territories. Adding PV improves cost-effectiveness, making the 1990s vintage cost effective in terms of both TDV and On-Bill in all CZs and making the 2000s vintage cost-effective in terms of TDV in all Climate Zones. The cost-effectiveness in the 1990s vintage is related to the all-electric HVAC retrofit having significantly lower first cost than the mixed-fuel retrofit, making the overall all-electric package lower cost than the mixed-fuel package. Using the 2022 CBECC-Com software reduces On-Bill cost effectiveness for the 1990's vintage for the *All-Electric + PV* package. The *All-electric Code Min* package, when evaluated against a mixed fuel code-minimum equipment replacement in the 1980s and 1990s vintages where there is no existing cooling system, is not cost effective in any climate zone.

Figure 31. High Rise Multifamily Package Results

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 / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	PG&E / CPAU	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
Package	**Vintage**																
All-electric Code Min	1980's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	1990's	TDV	–	TDV / TDV	TDV / Both	TDV / TDV	– / On-Bill	–	– / On-Bill	– / On-Bill	– / –	–	– / On-Bill	–	– / –	–	– / On-Bill
	2000's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / On-Bill
All-electric Code Min (2022 TDV)	1980's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	1990's	TDV	TDV	TDV / TDV	TDV / TDV	– / –	– / On-Bill	–	– / On-Bill	– / On-Bill	– / –	TDV	TDV / TDV	TDV	TDV / TDV	–	TDV / Both
	2000's	TDV	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	TDV	– / –	–	TDV / TDV	–	TDV / Both
All-electric+PV	1980's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	1990's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	2000's	TDV	TDV	TDV / TDV	TDV / TDV	TDV / TDV	TDV / –	Both	TDV / –	TDV / –	Both / –	TDV	TDV / –	TDV	Both / TDV	TDV	TDV / Both
All-electric+PV (2022 TDV)	1980's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	1990's	TDV	TDV	TDV / TDV	TDV / TDV	TDV / TDV	TDV / Both	TDV	TDV / Both	TDV / Both	TDV / TDV	TDV	TDV / TDV	TDV	TDV / TDV	TDV	TDV / Both
	2000's	TDV	TDV	TDV / TDV	TDV / TDV	TDV / TDV	– / –	–	– / –	– / –	– / –	TDV	– / –	TDV	TDV / TDV	–	TDV / Both

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 / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	PG&E / CPAU	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
Package	Vintage																
All-electric Code Min (no cooling)	1980's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	1990's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	2000's																
All-electric Code Min (no cooling, 2022 TDV)	1980's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	1990's	–	–	– / –	– / –	– / –	– / –	–	– / –	– / –	– / –	–	– / –	–	– / –	–	– / –
	2000's																

Figure 32 shows results of individual efficiency measures applied to existing HRMF prototype. The *Solar Thermal* measure is On-Bill cost effective in all CZs except 13 across all vintages, but it is not cost effective in terms of TDV in any scenario. The *Recirculating Pump Control* measure is cost-effective both in terms of TDV and On-Bill across all vintages and CZs. The *Cool Roof* measure is mostly cost effective in terms of both TDV and On-Bill across all CZ where applicable except in the 1990s vintage of CZs 2, 13, and 14.

Figure 32. High Rise Multifamily Individual Efficiency Measure Results

Climate Zone		CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Measure	Utility / Vintage	PG&E	PG&E	PG&E / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	PG&E / CPAU	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
Solar Thermal	1980's	On-Bill	On-Bill	On-Bill / On-Bill	On-Bill / On-Bill	On-Bill / On-Bill	On-Bill / On-Bill	On-Bill	On-Bill / On-Bill	On-Bill / On-Bill	On-Bill / On-Bill	On-Bill	On-Bill / On-Bill	–	On-Bill / On-Bill	On-Bill	On-Bill / On-Bill
	1990's	On-Bill	On-Bill	On-Bill / On-Bill	On-Bill / On-Bill	On-Bill / On-Bill	On-Bill / On-Bill	On-Bill	On-Bill / On-Bill	On-Bill / On-Bill	On-Bill / On-Bill	On-Bill	On-Bill / On-Bill	–	On-Bill / On-Bill	On-Bill	On-Bill / On-Bill
	2000's	On-Bill	On-Bill	On-Bill / On-Bill	On-Bill / On-Bill	On-Bill / On-Bill	On-Bill / On-Bill	On-Bill	On-Bill / On-Bill	On-Bill / On-Bill	On-Bill / On-Bill	On-Bill	On-Bill / On-Bill	–	On-Bill / On-Bill	On-Bill	On-Bill / On-Bill
Return Temp Pump Control	1980's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	1990's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	2000's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
Cool Roof	1980's		Both		Both / Both		Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	
	1990's		–		Both / Both		Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	–	– / –	Both	
	2000's		Both		Both / Both		Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	

4.6 Small Hotel

Figure 33 shows the results of the Small Hotel packages. The *All-electric Code Min* package is cost-effective in all CZs and vintages in terms of TDV except for 2000s vintage CZs 1, 10, 15, and 16. The package is also On-Bill cost effective in many CZs and vintages. These cost-effective results are because the all-electric retrofit has a lower first cost than the mixed fuel retrofit due to the HVAC cost savings. Adding PV slightly improves cost effectiveness to make the *All-electric + PV* package On-Bill and TDV cost effective in more CZs and vintages than the *All-electric Code Min* package.

Figure 33. Small Hotel Package Results

Package	Climate Zone / Vintage	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
	Utility	PG&E	PG&E	PG&E / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	PG&E / LADWP	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
All-electric Code Min	1980's	Both	Both	Both / Both	Both / Both	Both / TDV	Both / Both	TDV	Both / Both	Both / Both	TDV / Both	Both	Both / Both	Both	TDV / Both	Both	Both / Both
	1990's	Both	Both	Both / Both	Both / Both	Both / TDV	Both / Both	TDV	Both / Both	Both / Both	TDV / Both	Both	Both / Both	Both	TDV / Both	Both	Both / Both
	2000's	–	TDV	TDV / TDV	Both / Both	TDV / TDV	TDV / Both	TDV	Both / Both	Both / Both	– / –	TDV	TDV / Both	TDV	TDV / TDV	On-Bill	– / –
All-electric+PV	1980's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / TDV
	1990's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	TDV	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / TDV
	2000's	–	Both	Both / Both	Both / Both	Both / Both	TDV / TDV	TDV	TDV / TDV	TDV / TDV	TDV / TDV	Both	Both / Both	Both	TDV / TDV	TDV	– / –

Figure 34 shows results of individual efficiency measures applied to existing Small Hotel prototype. The *Recirculating Pump Control* measure is cost effective in terms of TDV and On-Bill across all vintages and CZs. The *Cool Roof* measure is largely cost-effective where the measure is applicable on an On-Bill or TDV basis, except in some vintages of CZs 2, 4, and 6. The *Window Film* measure results are mixed, with it being largely cost effective on On-Bill or TDV basis in CZs 6 through 10, 14, and 15. The *Roof Alterations* measure is only applicable to the 1980’s vintage, where it is cost effective in all CZs except Climate Zones 1 and 3.

Figure 34. Small Hotel Individual Efficiency Measure Results

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 / PCE	PG&E / CPAU	PG&E / SCG	SCE / LADWP	SDG&E	PG&E / LADWP	SCE / LADWP	SDG&E / SCE	PG&E	PG&E / SMUD	PG&E	SDG&E / SCE	SCE	PG&E / LADWP
Measure	Vintage																
Return Temp Pump Control	1980's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	1990's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	2000's	Both	Both	Both / Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
Cool Roof	1980's		On-Bill		Both / TDV		Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	
	1990's		On-Bill		– / –		Both / Both	Both	Both / Both	Both / Both	Both / Both	Both	Both / TDV	Both	Both / Both	Both	
	2000's		–		– / –		– / –	On-Bill	Both / Both	Both / Both	Both / Both	Both	Both / TDV	Both	Both / TDV	Both	
Window Film	1980's	–	–	– / –	TDV / TDV	– / –	TDV / TDV	Both	Both / TDV	Both / TDV	Both / Both	Both	TDV / TDV	Both	Both / TDV	TDV	– / –
	1990's	–	–	– / –	– / –	– / –	TDV / TDV	Both	TDV / TDV	TDV / TDV	Both / TDV	–	– / –	–	On-Bill / –	TDV	– / –
	2000's																
Roof Alterations	1980's	–	Both	– / –	Both / Both	On-Bill / –	TDV / TDV	On-Bill	TDV / Both	Both / Both	Both / Both	Both	Both / Both	Both	Both / Both	Both	Both / Both
	1990's																
	2000's																

5 Conclusions and Next Steps

The Reach Code Team developed a set of electrification retrofit and efficiency measure packages for a set of existing building prototypes, attained costs, ran simulations, and performed financial analysis to assess cost effectiveness. Generally, jurisdictions statewide can adopt a variety of building reach codes using the results in this report. While results are nuanced by vintage, Climate Zone, and utility, the overarching takeaways by prototype using the assumptions in this report are summarized below:

- **Medium Office:** Code minimum electrification retrofits are cost effective when combined with PV, with more widespread cost effectiveness using 2022 Title 24 compliance software. There are several cost-effective efficiency measures, including cool roof, window films, and interior lighting upgrades, as well as the common-sense efficiency packages described in Section 3.2 Efficiency Measures.
- **Standalone Retail:** Code minimum electrification retrofits are cost effective when combined with efficiency measures (window film and lighting retrofit) or PV. There are several cost-effective efficiency measures, including cool roof, window films, roof alterations, and interior lighting upgrades, as well as a common-sense efficiency package.
- **Warehouse:** Code minimum electrification retrofits are cost effective when combined with PV. The Team only found lighting efficiency measures to be cost effective, partially due to the limited range of efficiency measures applicable to warehouse spaces.
- **FSR:** The Team identified cost-effective electrification retrofit packages when excluding kitchen electrification measures and employing significant hot water efficiency measures to reduce the heat pump service hot water plant design. A common-sense package of efficiency measures, as well as ten individual efficiency measures, are cost effective for most Climate Zones statewide, depending on the vintage.
- **QSR:** The Team did not identify any cost-effective electrification retrofit packages, except for the *All Electric + Efficiency* package (which excludes kitchen electrification) in limited Climate Zones. A common-sense package of efficiency measures, as well as seven individual efficiency measures, are cost effective for most Climate Zones statewide, depending on the vintage.
- **HRMF:** Electrification retrofits can be cost effective depending on the vintage and associated existing HVAC system. The *All-Electric Code Min* package is cost effective in the 1990's vintage in most Climate Zones, and improves in cost-effectiveness when adding PV, largely due to cost savings from replacing PTACs with PTHPs and decommissioning standalone heating systems.
- **Small Hotel:** Electrification retrofits are cost effective in all Climate Zones due to the existing HVAC system having separate heating and cooling systems in all vintages. The *All-Electric Code Min* package is cost effective in all vintages and improves in cost effectiveness when adding PV, largely due to cost savings from replacing PTACs with PTHPs and decommissioning standalone heating systems.

The challenges with cost-effective electrification retrofits in commercial buildings identified in this report align with a publication from the American Council for an Energy Efficient Economy, which identified that electrifying heating results in a simple payback of less than 10 years for about 27% of commercial floor space heated with fossil fuel systems (Nadel, S., and C. Perry., 2021).

Nonetheless, the Reach Code Team has identified the following potential policies that jurisdictions in most CZs and utility territories may consider adopting based on cost-effectiveness. The trigger for such policies may vary across jurisdiction and should likely consider the cost of the submitted alteration permit scope versus the cost of the additional requirements.

1. **Require several individual efficiency measures and *common-sense* efficiency measures** across all types of nonresidential buildings. Efficiency measures that are consistently cost-effective across most prototypes, CZs, and vintages include:

   a. Cool roof
   b. Window film
   c. Above-code interior LPD
   d. Lighting retrofit
   e. Restaurant measures, including Faucet aerators, Small capacity HVAC efficiency, Economizer repair, Energy efficient cooking appliances, and Transfer air for commercial kitchens.
   f. Central DHW measures, including Solar thermal, and Return temperature pump control.
2. **Require electrification retrofits for HVAC and SHW** alongside either efficiency measures or solar PV:
   a. Offices and Retail are fully electrified combined with either efficiency measures or solar PV.
   b. Warehouses are fully electrified combined with solar PV.
   c. Restaurants perform electrification retrofits of gas-fueled HVAC and SHW simultaneously, combined with efficiency measures.
   d. HRMF dwellings with gas-fueled space heating, water heating, cooking, and laundry are fully electrified combined with solar PV
   e. Hotel with gas-fueled HVAC and SHW are electrified simultaneously, and in a few cases combined with solar PV.

In the course of performing the work, the Reach Code Team was not able to perform the following steps for the Small Hotel, and has listed them as potential next steps:

1. Analyze a variation of the prototype that assumes that PTHPs are already installed in the newer vintages, which may reduce cost effectiveness.
2. Further troubleshoot to produce results in the 2022 Title 24 compliance software. The Reach Code Team encountered modeling challenges with the central HPWH when using the 2022 software.
3. Include on-premises laundry electrification retrofits, which may reduce cost effectiveness.
4. Include occupancy sensing thermostat controls as an efficiency measure for guest rooms.

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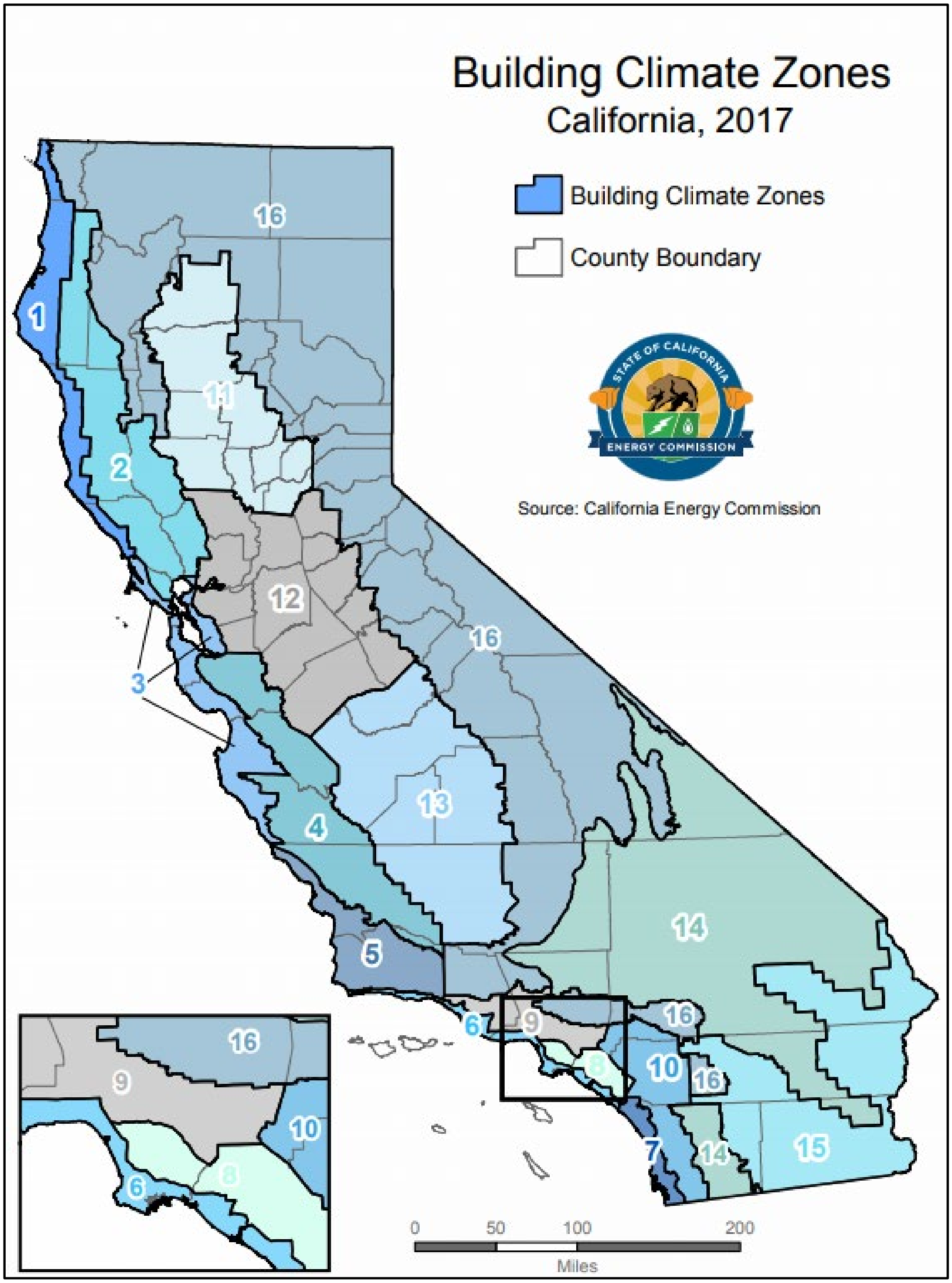
7 Appendices

7.1 Map of California Climate Zones

Climate Zone geographical boundaries are depicted in Figure 35. The map in Figure 35, along with a zip-code search directory, is available at: https://ww2.energy.ca.gov/maps/renewable/building_climate_zones.html

Figure 35. Map of California Climate Zones



7.2 Utility Rate Schedules

The Reach Code Team used the IOU rate tariffs listed in Figure 36 to determine the On-Bill savings for each prototype.

Figure 36. Utility Tariffs Analyzed Based on Climate Zone: Detailed View

Climate Zones	Electric / Gas Utility	Electricity (TOU)							Natural Gas	
		MO	RE	WA	QSR	FSR	HRMF	SH	HRMF	Others
CZ01	PG&E	B-10	B-1 or B-10	B-1	B-1 or B-10	B-1 or B-10	E-TOU C	B-1 or B-10	G-1	G-NR1
CZ02	PG&E	B-10	B-1 or B-10	B-1	B-1 or B-10	B-1 or B-10	E-TOU C	B-1 or B-10	G-1	G-NR1
CZ03	PG&E	B-10	B-1 or B-10	B-1	B-1 or B-10	B-1 or B-10	E-TOU C	B-1 or B-10	G-1	G-NR1
CZ03-2	PCE/PG&E	B-10	B-1 or B-10	B-1	B-1 or B-10	B-1 or B-10	E-TOU C	B-1 or B-10	G-1	G-NR1
CZ04	PG&E	B-10	B-1 or B-10	B-1	B-1 or B-10	B-1 or B-10	E-TOU C	B-1 or B-10	G-1	G-NR1
CZ04-2	CPAU	E-2	E-2	E-2	E-2	E-2	E-1	E-2	G-1	G-2
CZ05	PG&E	B-10	B-1 or B-10	B-1	B-1 or B-10	B-1 or B-10	E-TOU C	B-1 or B-10	G-1	G-NR1
CZ05-2	PG&E/SCG	B-10	B-1 or B-10	B-1	B-1 or B-10	B-1 or B-10	E-TOU C	B-1 or B-10	G-1	G-10 (GN-10)
CZ06	SCE/SCG	TOU-GS-3	TOU-GS-2	TOU-GS-2	TOU-GS-2	TOU-GS-2	TOU-D	TOU-GS-2	GM-E	G-10 (GN-10)
CZ06-2	LADWP/SCG	A-2	A-2	A-2	A-1 or A-2	A-2	R-1	A-2	GM-E	G-10 (GN-10)
CZ07	SDG&E	AL-TOU	AL-TOU	AL-TOU	AL-TOU	AL-TOU	TOU-DR-1	AL-TOU	GM	GN-3
CZ08	SCE/SCG	TOU-GS-3	TOU-GS-2	TOU-GS-2	TOU-GS-2	TOU-GS-2	TOU-D	TOU-GS-2	GM-E	G-10 (GN-10)
CZ08-2	LADWP/SCG	A-2	A-2	A-2	A-2	A-2	R-1	A-2	GM-E	G-10 (GN-10)
CZ09	SCE/SCG	TOU-GS-3	TOU-GS-2 or TOU-GS-3	TOU-GS-2	TOU-GS-2	TOU-GS-2	TOU-D	TOU-GS-2	GM-E	G-10 (GN-10)
CZ09-2	LADWP/SCG	A-2	A-2	A-2	A-2	A-2	R-1	A-2	GM-E	G-10 (GN-10)
CZ10	SDG&E	AL-TOU	AL-TOU	AL-TOU	AL-TOU	AL-TOU	TOU-DR-1	AL-TOU	GM	GN-3
CZ10-2	SCE/SCG	TOU-GS-3	TOU-GS-2 or TOU-GS-3	TOU-GS-2	TOU-GS-2	TOU-GS-2	TOU-D	TOU-GS-2	GM-E	G-10 (GN-10)
CZ11	PG&E	B-10	B-10	B-1	B-1 or B-10	B-1 or B-10	E-TOU C	B-10	G-1	G-NR1
CZ12	PG&E	B-10	B-10	B-1	B-1 or B-10	B-1 or B-10	E-TOU C	B-10	G-1	G-NR1
CZ12-2	SMUD/PG&E	GSN OR GSS	GSS	GSS	GSS	GSS	R TOD	GSS	G-1	G-NR1
CZ13	PG&E	B-10	B-10	B-1	B-1 or B-10	B-1 or B-10	E-TOU C	B-10	G-1	G-NR1
CZ14	SDG&E	AL-TOU	AL-TOU	AL-TOU	AL-TOU	AL-TOU	TOU-DR-1	AL-TOU	GM	GN-3
CZ14-2	SCE/SCG	TOU-GS-3	TOU-GS-2 or TOU-GS-3	TOU-GS-2	TOU-GS-2	TOU-GS-2	TOU-D	TOU-GS-2	GM-E	G-10 (GN-10)
CZ15	SCE/SCG	TOU-GS-3	TOU-GS-2 or TOU-GS-3	TOU-GS-2	TOU-GS-2	TOU-GS-2	TOU-D	TOU-GS-2	GM-E	G-10 (GN-10)
CZ16	PG&E	B-10	B-1 or B-10	B-1	B-1 or B-10	B-1 or B-10	E-TOU C	B-1 or B-10	G-1	G-NR1
CZ16-2	LADWP/SCG	A-2	A-1 or A-2	A-2	A-1 or A-2	A-2	R-1	A-2	GM-E	G-10 (GN-10)

Utility rates are assumed to escalate over time, using assumptions from research conducted by Energy and Environmental Economics (E3) in the 2019 study Residential Building Electrification in California (Energy & Environmental Economics, 2019) and escalation rates used in the development of the 2022 TDV multipliers. Figure 37 and Figure 38 below demonstrate the escalation rates used for nonresidential and residential (HRMF) buildings respectively. Residential escalation rates for both electricity and gas applied for life cycle cost analysis of HRMF prototype are based on En Banc Session[5] from 2020 to 2030 and forecasts of 2022 TDV report for the rest of the analysis period.

[5] En Banc meeting at February 24,2021 on CPUC white paper “Utility Costs and Affordability of the Grid of the Future”

Figure 37. Real Utility Rate Escalation Rate Assumptions Above Inflation: Nonresidential

Year	Source	Statewide Electric Nonresidential Average Rate (%/year, real)	Natural Gas Nonresidential Core Rate (%/year, real)
2020	E3 2019	2.0%	4.3%
2021	E3 2019	2.0%	4.3%
2022	E3 2019	2.0%	2.7%
2023	E3 2019	2.0%	4.0%
2024	2022 TDV	0.7%	7.7%
2025	2022 TDV	0.5%	5.5%
2026	2022 TDV	0.7%	5.6%
2027	2022 TDV	0.2%	5.6%
2028	2022 TDV	0.6%	5.7%
2029	2022 TDV	0.7%	5.7%
2030	2022 TDV	0.6%	5.8%
2031	2022 TDV	0.6%	3.3%
2032	2022 TDV	0.6%	3.6%
2033	2022 TDV	0.6%	3.4%
2034	2022 TDV	0.6%	3.4%
2035	2022 TDV	0.6%	3.2%
2036	2022 TDV	0.6%	3.2%
2037	2022 TDV	0.6%	3.1%
2038	2022 TDV	0.6%	2.9%
2039	2022 TDV	0.6%	3.2%
2040	2022 TDV	0.6%	2.9%
2041	2022 TDV	0.6%	3.5%
2042	2022 TDV	0.6%	3.4%
2043	2022 TDV	0.6%	3.4%
2044	2022 TDV	0.6%	3.4%
2045	2022 TDV	0.6%	3.5%
2046	2022 TDV	0.6%	2.0%
2047	2022 TDV	0.6%	1.8%
2048	2022 TDV	0.6%	2.1%
2049	2022 TDV	0.6%	1.7%
2050	2022 TDV	0.6%	2.1%
2035	2022 TDV	0.6%	3.2%
2036	2022 TDV	0.6%	3.2%
2037	2022 TDV	0.6%	3.1%
2038	2022 TDV	0.6%	2.9%
2039	2022 TDV	0.6%	3.2%
2040	2022 TDV	0.6%	2.9%
2041	2022 TDV	0.6%	3.5%
2042	2022 TDV	0.6%	3.4%
2043	2022 TDV	0.6%	3.4%
2044	2022 TDV	0.6%	3.4%
2045	2022 TDV	0.6%	3.5%
2046	2022 TDV	0.6%	2.0%
2047	2022 TDV	0.6%	1.8%
2048	2022 TDV	0.6%	2.1%
2049	2022 TDV	0.6%	1.7%
2050	2022 TDV	0.6%	2.1%

Figure 38. Utility Rate Escalation Rate Assumptions Above Inflation: Residential

Year	Source	Electric Residential Rate (%/yr escalation, real)			Statewide Natural Gas Residential Average Rate (%/year, real)
		PG&E	SoCalGas	SDG&E	
2020	En-Banc	1.8%	1.6%	2.8%	4.6%
2021	En-Banc	1.8%	1.6%	2.8%	4.6%
2022	En-Banc	1.8%	1.6%	2.8%	4.6%
2023	En-Banc	1.8%	1.6%	2.8%	4.6%
2024	En-Banc	1.8%	1.6%	2.8%	4.6%
2025	En-Banc	1.8%	1.6%	2.8%	4.6%
2026	En-Banc	1.8%	1.6%	2.8%	4.6%
2027	En-Banc	1.8%	1.6%	2.8%	4.6%
2028	En-Banc	1.8%	1.6%	2.8%	4.6%
2029	En-Banc	1.8%	1.6%	2.8%	4.6%
2030	En-Banc	1.8%	1.6%	2.8%	4.6%
2031	2022 TDV	0.6%	0.6%	0.6%	2.0%
2032	2022 TDV	0.6%	0.6%	0.6%	2.4%
2033	2022 TDV	0.6%	0.6%	0.6%	2.1%
2034	2022 TDV	0.6%	0.6%	0.6%	1.9%
2035	2022 TDV	0.6%	0.6%	0.6%	1.9%
2036	2022 TDV	0.6%	0.6%	0.6%	1.8%
2037	2022 TDV	0.6%	0.6%	0.6%	1.7%
2038	2022 TDV	0.6%	0.6%	0.6%	1.6%
2039	2022 TDV	0.6%	0.6%	0.6%	2.1%
2040	2022 TDV	0.6%	0.6%	0.6%	1.6%
2041	2022 TDV	0.6%	0.6%	0.6%	2.2%
2042	2022 TDV	0.6%	0.6%	0.6%	2.2%
2043	2022 TDV	0.6%	0.6%	0.6%	2.3%
2044	2022 TDV	0.6%	0.6%	0.6%	2.4%
2045	2022 TDV	0.6%	0.6%	0.6%	2.5%
2046	2022 TDV	0.6%	0.6%	0.6%	1.5%
2047	2022 TDV	0.6%	0.6%	0.6%	1.3%
2048	2022 TDV	0.6%	0.6%	0.6%	1.6%
2049	2022 TDV	0.6%	0.6%	0.6%	1.3%
2050	2022 TDV	0.6%	0.6%	0.6%	1.5%

7.3 Prototype Characteristics

Figure 39 through Figure 66 show the annual electricity and natural gas consumption and cost, compliance TDV, and GHG emissions for each prototype under the mixed fuel design baseline for the earliest vintage (1980s). End-use energy charts for the 1990s vintages have been omitted in recognition that the energy trends can be interpolated between the 1980s and 2000s vintages.

7.3.1 Medium Office

Figure 39. Medium Office Prototype Characteristics by Vintage

Vintage	1980s	1990s	2000s
Cooling System	PVAV 7.99 EER	PVAV 8.43 EER	PVAV 9.51 EER
Heating System	Boiler 65.5% TE	Boiler 78.5% TE	Boiler 78.5% TE
Conditioned Thermal Zones	15 zones	15 zones	15 zones
Service Hot Water Heating	0.535 EF	0.533 EF	0.575 EF
Roof Insulation (U-Value)	0.076 – 0.090	0.057 – 0.078	0.051 - 0.076
Low-Sloped Roof Solar Reflectance	0.18	0.17	0.55
Metal-Framed Wall Insulation (U-Value)	0.102 – 0.248	0.182 - 0.189	0.217 - 0.224
Windows	U-Factor: 1.14 – 1.21 SHGC: 0.57 – 0.73 VT: 0.36	U-Factor: 0.69 - 1.17 SHGC: 0.55 - 0.67 VT: 0.38	U-Factor: 0.47 – 0.76 SHGC: 0.39 - 0.41 VT: 0.4
LPD	1.4 W/sqft	1.4 W/sqft	1.2 W/sqft

Figure 40. Medium Office Prototype End-Use Energy Use, 1980s Vintage

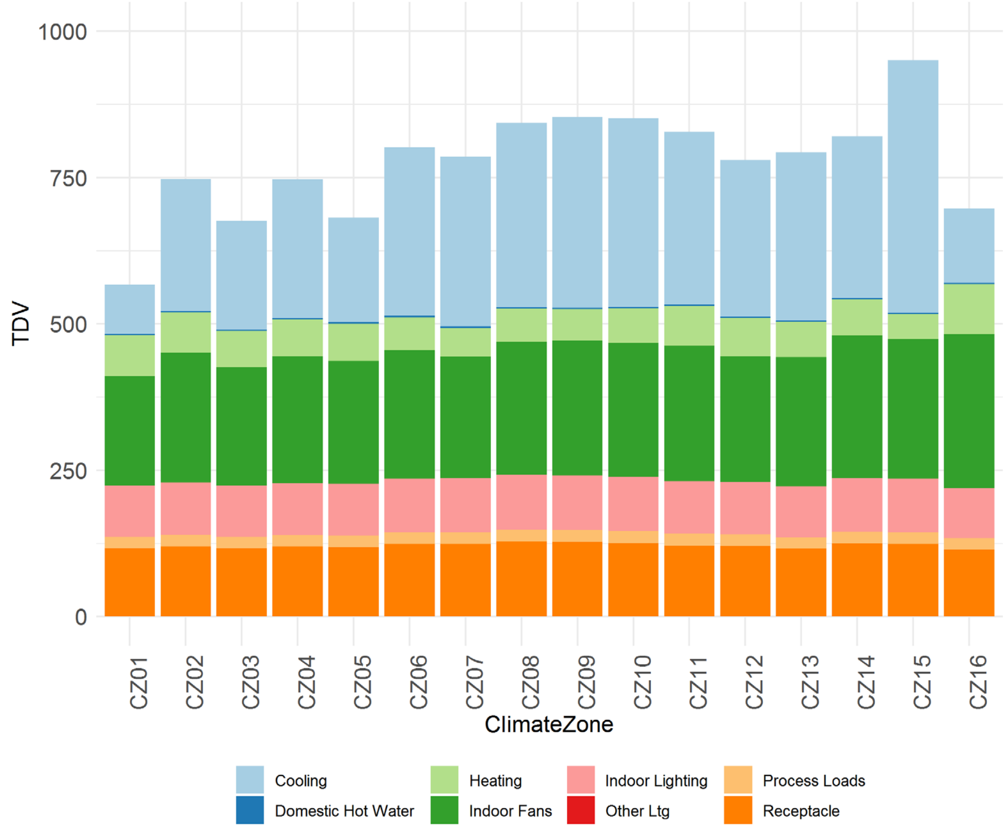


Figure 41. Medium Office Prototype End-Use Energy Use, 2000s Vintage

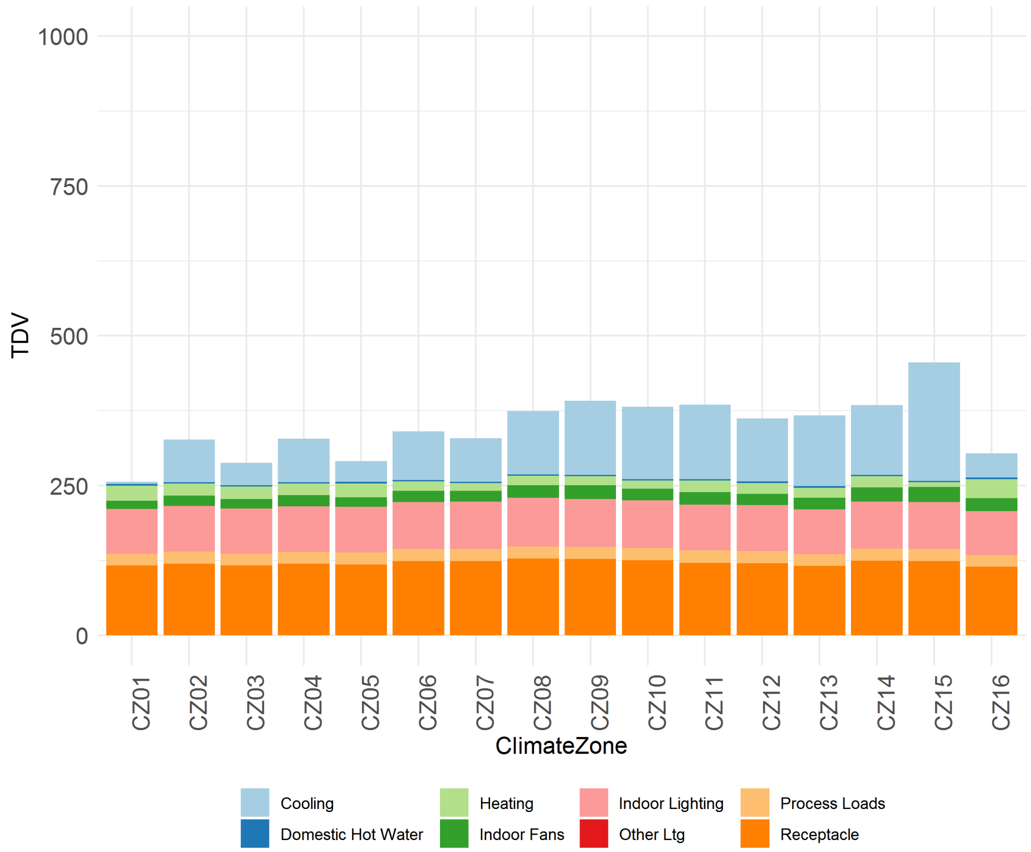


Figure 42. Medium Office Mixed Fuel Baseline, 1980s Vintage

Climate Zone	Utility	Electricity Consumption (kWh)	Natural Gas Consumption (Therms)	Electricity Cost	Natural Gas Cost	GHG Emissions (mton)
CZ01	PG&E	939,922	20,130	$218,062	$22,194	246
CZ02	PG&E	1,185,651	19,663	$278,092	$21,798	275
CZ03	PG&E	1,121,189	17,789	$258,515	$19,710	256
CZ03-2	PCE	1,121,189	17,789	$261,564	$19,710	256
CZ04	PG&E	1,215,114	18,060	$280,928	$20,045	271
CZ04-2	CPAU	1,215,114	18,060	$209,720	$22,426	271
CZ05	PG&E	1,130,859	18,514	$261,244	$20,382	258
CZ05-2	SCG	1,130,859	18,514	$261,244	$14,261	258
CZ06	SCE	1,334,013	16,312	$159,366	$12,714	279
CZ06-2	LA	1,334,013	16,312	$114,358	$12,714	279
CZ07	SDG&E	1,315,903	14,393	$328,602	$11,736	269
CZ08	SCE	1,374,679	16,341	$165,357	$12,734	285
CZ08-2	LA	1,374,679	16,341	$119,509	$12,734	285
CZ09	SCE	1,361,734	15,516	$166,127	$12,154	279
CZ09-2	LA	1,361,734	15,516	$120,967	$12,154	279
CZ10	SDG&E	1,362,613	16,952	$357,048	$13,326	285
CZ10-2	SCE	1,362,613	16,952	$166,258	$13,164	285
CZ11	PG&E	1,293,386	19,124	$300,513	$21,451	290
CZ12	PG&E	1,220,674	18,529	$284,532	$20,702	274
CZ12-2	SMUD	1,220,674	18,529	$170,505	$20,702	274
CZ13	PG&E	1,290,383	16,981	$300,055	$19,126	275
CZ14	SDG&E	1,305,251	17,195	$342,719	$13,294	279
CZ14-2	SCE	1,305,251	17,195	$159,271	$13,335	279
CZ15	SCE	1,567,785	11,923	$188,002	$9,629	286
CZ16	PG&E	1,157,350	23,808	$262,891	$26,400	302
CZ16-2	LA	1,157,350	23,808	$99,388	$17,983	302

7.3.2 Stand-alone Retail

Figure 43. Stand-alone Retail Prototype Characteristics by Vintage

Vintage	1980s	1990s	2000s
Cooling System	PCAV 8.2 EER (≥ 65 and < 135 kBtu/h) 8.1 EER (≥ 135 and < 240 kBtu/h) 8.0 EER (≥ 240 and < 760 kBtu/h)	PCAV 8.8 EER (≥ 65 and < 135 kBtu/h) 8.7 EER (≥ 135 and < 240 kBtu/h) 8.4 EER (≥ 240 and < 760 kBtu/h)	PVAV 10.3 EER (≥ 65 and < 135 kBtu/h) 9.7 EER (≥ 135 and < 240 kBtu/h) 9.5 EER (≥ 240 and < 760 kBtu/h)
Heating System	67.5% AFUE (< 225 kBtu/h) 78.6% ET (≥ 78.6%)	78.1% AFUE (< 225 kBtu/h) 80.0% ET (≥ 78.6%)	78.1% AFUE (< 225 kBtu/h) 80.0% ET (≥ 78.6%)
Conditioned Thermal Zones	5 zones	5 zones	5 zones
Service Hot Water Heating	0.535 EF	0.533 EF	0.575 EF
Roof Insulation (U-Value)	0.076 - 0.093	0.055 – 0.076	0.051 – 0.076
Low-Sloped Roof Solar Reflectance	0.18	0.17	0.5518
Metal-Framed Wall Insulation (U-Value)	0.276 – 0.401	0.182 – 0.189	0.217 – 0.223
Windows	U-Factor: 1.14 – 1.21 SHGC: 0.56 – 0.73 VT: 0.36	U-Factor: 0.69 – 1.17 SHGC: 0.54 – 0.67 VT: 0.38	U-Factor: 0.47 – 0.76 SHGC: 0.36 – 0.43 VT: 0.4
LPD	2.3 W/sqft	2.0 W/sqft	1.7 W/sqft

Figure 44. Stand-alone Retail Prototype End-Use Energy Use, 1980s Vintages

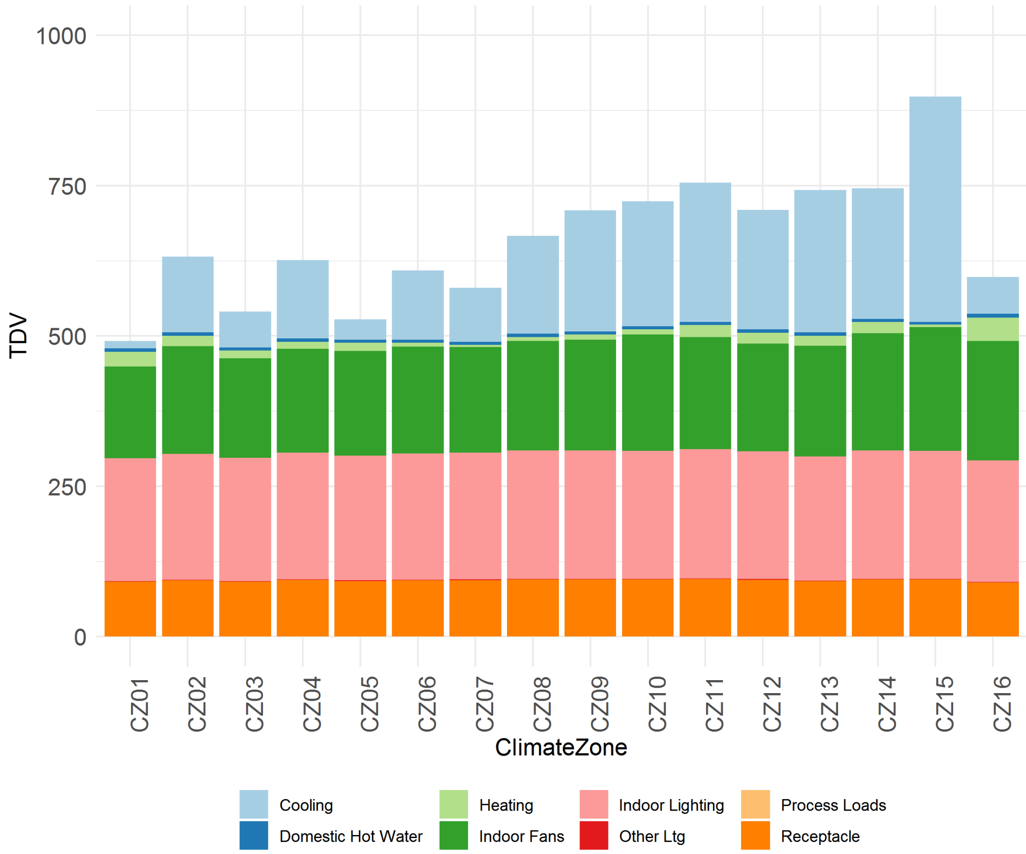


Figure 45. Stand-alone Retail Prototype End-Use Energy Use, 2000s Vintages

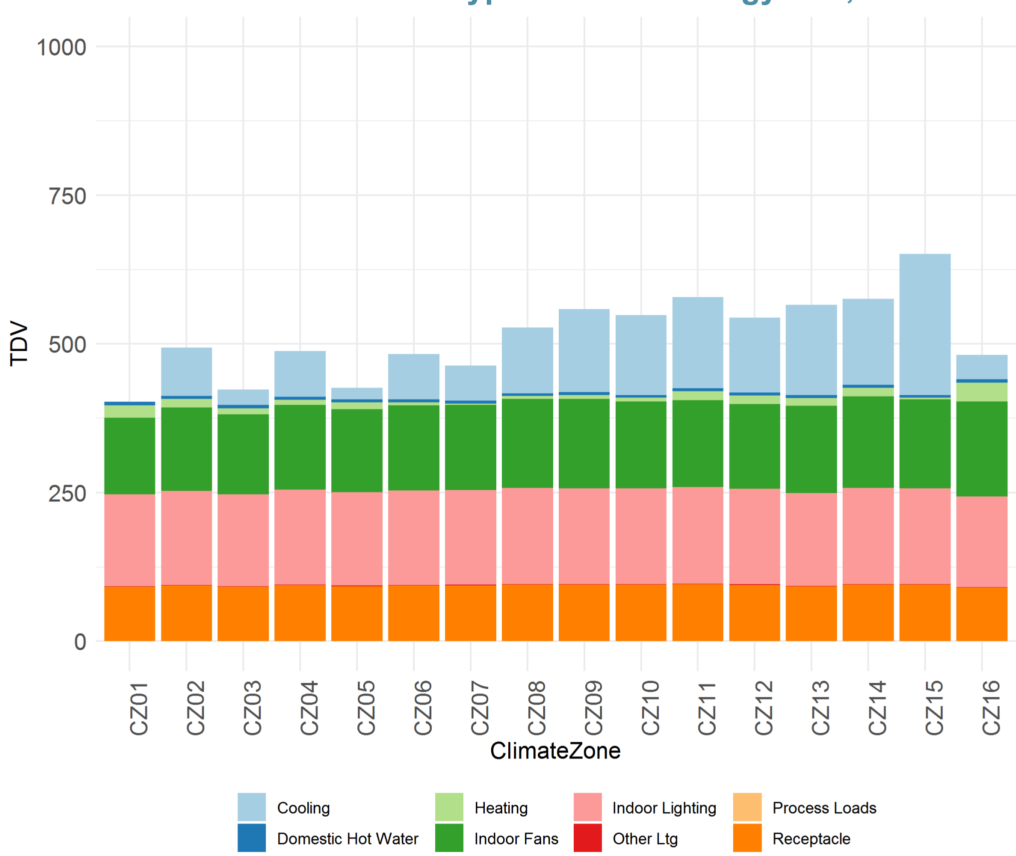


Figure 46. Standalone Retail Mixed Fuel Baseline, 1980s Vintage

Climate Zone	Utility	Electricity Consumption (kWh)	Natural Gas Consumption (Therms)	Electricity Cost	Natural Gas Cost	GHG Emissions (mton)
CZ01	PG&E	391,411	3,798	$90,579	$4,361	72.2
CZ02	PG&E	464,613	2,921	$112,704	$3,426	76.1
CZ03	PG&E	427,281	2,335	$101,812	$2,770	67.7
CZ03-2	PCE	427,281	2,335	$102,987	$2,770	67.7
CZ04	PG&E	466,342	2,119	$111,751	$2,533	70.9
CZ04-2	CPAU	466,342	2,119	$81,061	$3,649	70.9
CZ05	PG&E	418,323	2,432	$100,449	$2,864	67.1
CZ05-2	SCG	418,323	2,432	$100,449	$2,003	67.1
CZ06	SCE	467,764	1,484	$61,860	$1,026	66.4
CZ06-2	LA	467,764	1,484	$45,714	$1,026	66.4
CZ07	SDG&E	445,887	1,103	$126,507	$1,047	62.7
CZ08	SCE	495,089	1,463	$65,805	$1,020	70.2
CZ08-2	LA	495,089	1,463	$48,879	$1,020	70.2
CZ09	SCE	509,481	1,686	$69,527	$1,285	74.0
CZ09-2	LA	509,481	1,686	$50,869	$1,285	74.0
CZ10	SDG&E	528,530	1,718	$152,205	$1,565	76.3
CZ10-2	SCE	528,530	1,718	$71,447	$1,301	76.3
CZ11	PG&E	527,378	3,127	$127,676	$3,682	85.9
CZ12	PG&E	503,543	2,890	$121,273	$3,415	80.7
CZ12-2	SMUD	503,543	2,890	$72,727	$3,415	80.7
CZ13	PG&E	539,628	2,713	$129,703	$3,223	83.9
CZ14	SDG&E	538,392	2,952	$148,259	$2,602	85.0
CZ14-2	SCE	538,392	2,952	$70,701	$2,558	85.0
CZ15	SCE	666,905	1,118	$86,596	$699	90.7
CZ16	PG&E	463,765	5,567	$107,755	$6,357	92.6
CZ16-2	LA	463,765	5,567	$41,834	$4,599	92.6

7.3.3 Warehouse

Figure 47. Warehouse Prototype Characteristics by Vintage

Vintage	1980s	1990s	2000s
Cooling System (Office only)	SZAC 8.2 EER	SZAC 8.8 EER	SZAC 10.3 EER
Heating System (Office + Storage area)	Furnace 67.5% AFUE	Furnace 78.1% AFUE	Furnace 78.1% AFUE
Conditioned Thermal Zones	3 zones	3 zones	3 zones
Domestic Hot Water Heating	0.535 EF	0.533 EF	0.575 EF
Roof Insulation (U-Value)	0.076 – 0.09	0.055 – 0.076	0.051 – 0.076
Low-Sloped Roof Solar Reflectance	0.55	0.17	0.18
Metal-Framed Wall Insulation (U-Value)	0.333 - 0.451	0.182 - 0.189	0.217 - 0.223
Windows	U-Factor: 1.14 - 1.21 SHGC: 0.56 - 0.73 VT: 0.36	U-Factor: 0.69 - 1.17 SHGC: 0.54 - 0.67 VT: 0.38	U-Factor: 0.47 - 0.76 SHGC: 0.36 – 0.43 VT: 0.4
LPD	1.4 W/sqft (Office) 0.8 W/sqft (Storage)	1.4 W/sqft (Office) 0.6 W/sqft (Storage)	1.2 W/sqft (Office) 0.6 W/sqft (Storage)

Figure 48. Warehouse Prototype End-Use Energy Use, 1980s Vintage

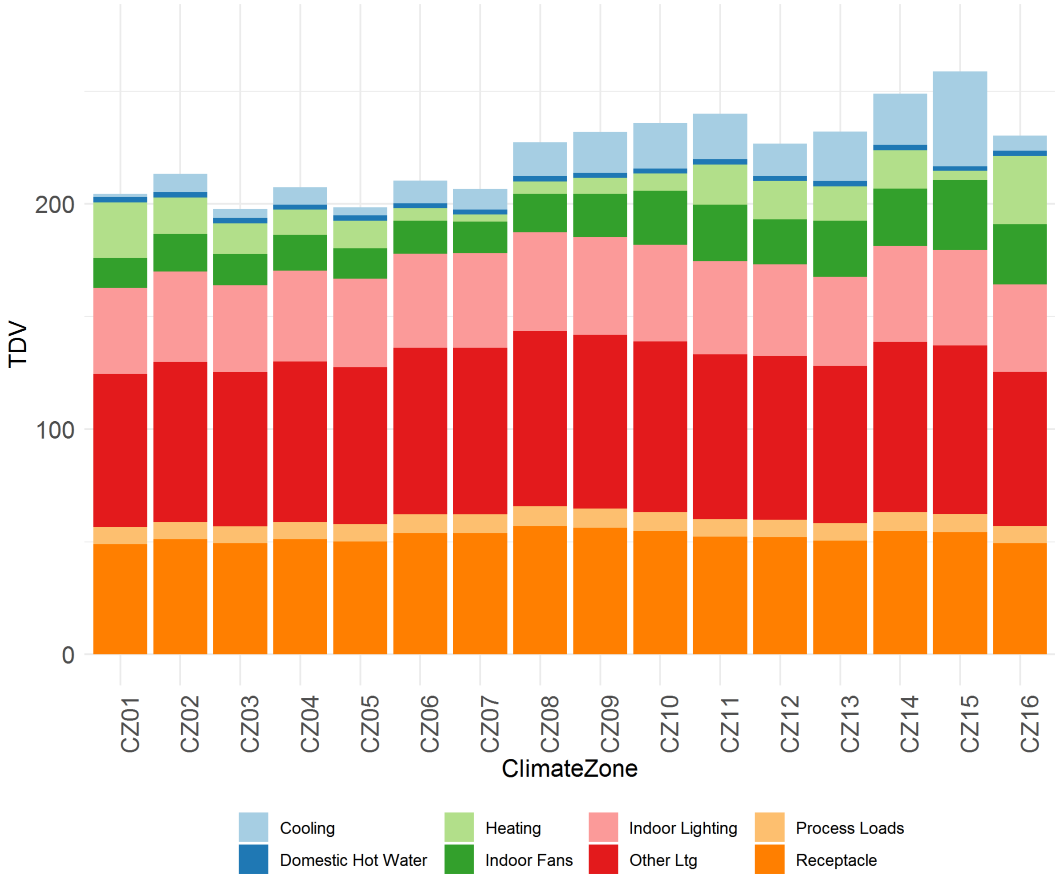


Figure 49. Warehouse Prototype End-Use Energy Use, 2000s Vintage

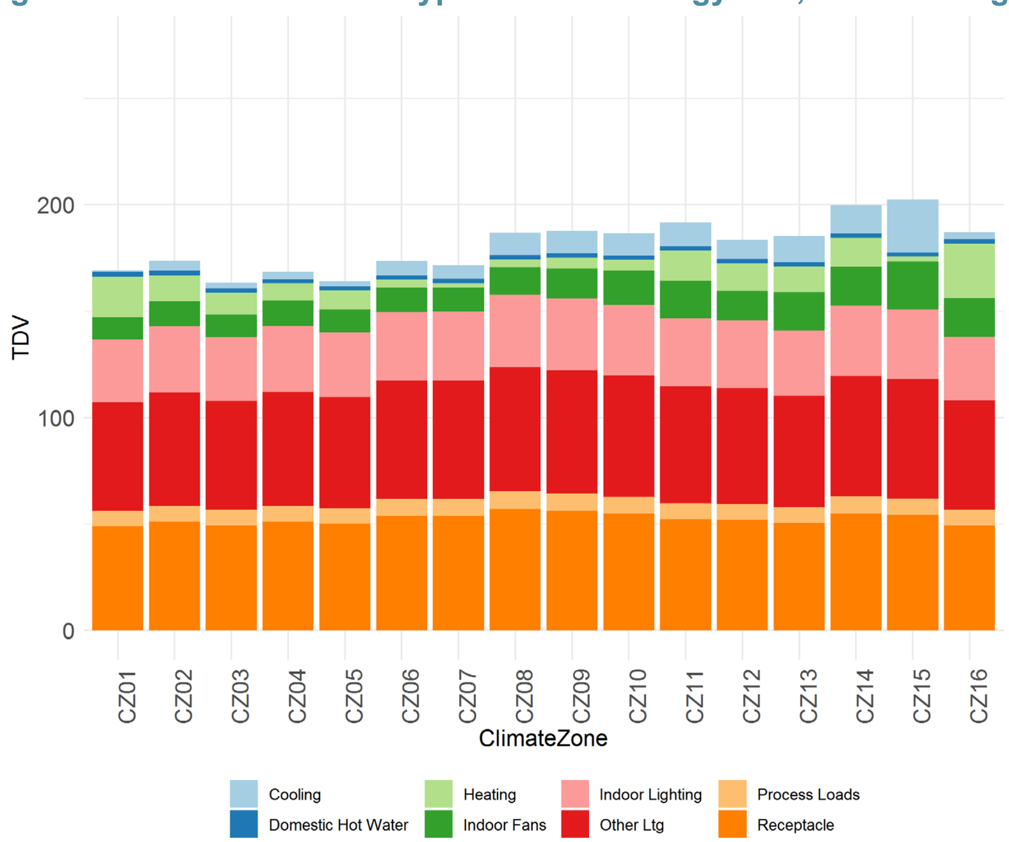


Figure 50. Warehouse Mixed Fuel Baseline, 1980s Vintage

Climate Zone	Utility	Electricity Consumption (kWh)	Natural Gas Consumption (Therms)	Electricity Cost	Natural Gas Cost	GHG Emissions (mton)
CZ01	PG&E	122,720	2,438	$30,939	$2,889	26.0
CZ02	PG&E	128,022	1,612	$32,294	$1,912	21.6
CZ03	PG&E	125,077	1,403	$31,528	$1,673	20.2
CZ03-2	PCE	125,077	1,403	$30,876	$1,673	20.2
CZ04	PG&E	128,186	1,173	$32,323	$1,415	19.1
CZ04-2	CPAU	128,186	1,173	$22,569	$2,535	19.1
CZ05	PG&E	124,531	1,300	$31,381	$1,549	19.5
CZ05-2	SCG	124,531	1,300	$31,381	$1,099	19.5
CZ06	SCE	127,746	692	$18,077	$501	16.3
CZ06-2	LA	127,746	692	$13,121	$501	16.3
CZ07	SDG&E	127,206	479	$40,314	$523	15.0
CZ08	SCE	130,127	695	$18,459	$503	16.5
CZ08-2	LA	130,127	695	$13,466	$503	16.5
CZ09	SCE	131,856	824	$18,722	$562	17.5
CZ09-2	LA	131,856	824	$13,687	$562	17.5
CZ10	SDG&E	136,471	862	$43,587	$845	18.2
CZ10-2	SCE	136,471	862	$19,296	$580	18.2
CZ11	PG&E	138,193	1,743	$35,087	$2,064	24.0
CZ12	PG&E	131,657	1,655	$33,278	$1,967	22.4
CZ12-2	SMUD	131,657	1,655	$19,404	$1,967	22.4
CZ13	PG&E	138,805	1,517	$35,229	$1,813	22.8
CZ14	SDG&E	138,721	1,663	$43,170	$1,518	23.6
CZ14-2	SCE	138,721	1,663	$19,365	$1,478	23.6
CZ15	SCE	154,269	538	$21,111	$430	19.3
CZ16	PG&E	134,176	2,881	$33,836	$3,394	30.0
CZ16-2	LA	134,176	2,881	$13,399	$2,654	30.0

7.3.4 Quick-service Restaurant

Figure 51. Quick Service Restaurant Prototype Characteristics by Vintage

Vintage	1980s	1990s	2000s
Cooling System (Kitchen Space)	SZAC 8.1 EER	SZAC 8.7 EER	SZAC 9.7 EER
Cooling System (Dining Space)	SZAC 8.2 EER	SZAC 8.8 EER	SZAC 10.3 EER
Heating System	Furnace 67.5% AFUE	Furnace 78.1% AFUE	Furnace 78.1% AFUE
Conditioned Thermal Zones	2 zones	2 zones	2 zones
Domestic Hot Water Heating	75.7% TE*	75.6% TE*	78.1% TE*
Roof Insulation (U-Value)	0.76-0.90	0.57-0.78	0.51-0.76
Steep-Sloped Roof Solar Reflectance	CZ01: 0.105 CZ02-16: 0.117	CZ01: 0.104 CZ02-16: 0.114	CZ01: 0.102 CZ02-16: 0.2
Metal-Framed Wall Insulation (U-Value)	0.217-0.351	0.182-0.189	0.217-0.224
Windows	U-Factor: 1.144-1.209 SHGC: 0.561-0.73 VT: 0.36	U-Factor: 1.143-0.689 SHGC: 0.544-0.67 VT: 0.383	U-Factor: 0.468-0.763 SHGC: 0.358-0.427 VT: 0.4
LPD (Dining Space)	1.2 W/ft^2	1.2 W/ft^2	1.1 W/ft^2
LPD (Kitchen Space)	2.0 W/ft^2	2.0 W/ft^2	1.6 W/ft^2

**Due to a bug in the CBECC-Com 2019 software, The Reach Code Team is unable to model thermal efficiency below 80%.*

Figure 52. Quick Service Restaurant Prototype End-Use Energy Use, 1980s Vintages

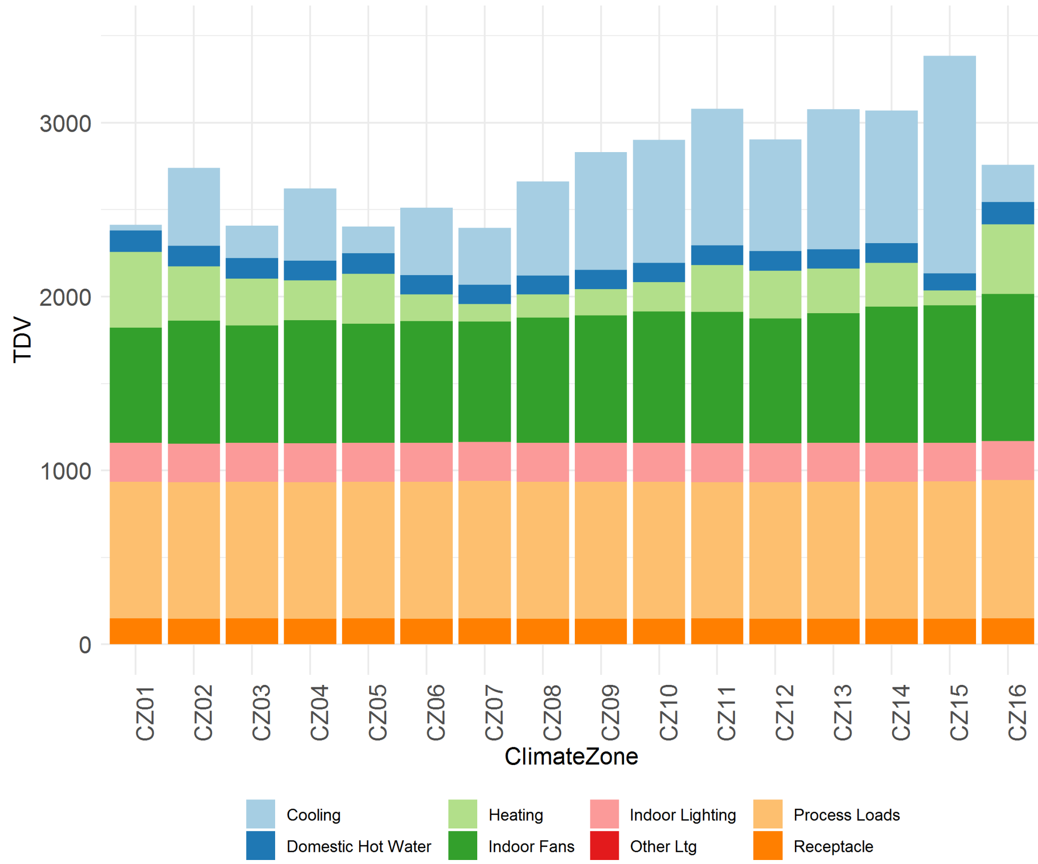


Figure 53. Quick Service Restaurant Prototype End-Use Energy Use, 2000s Vintages

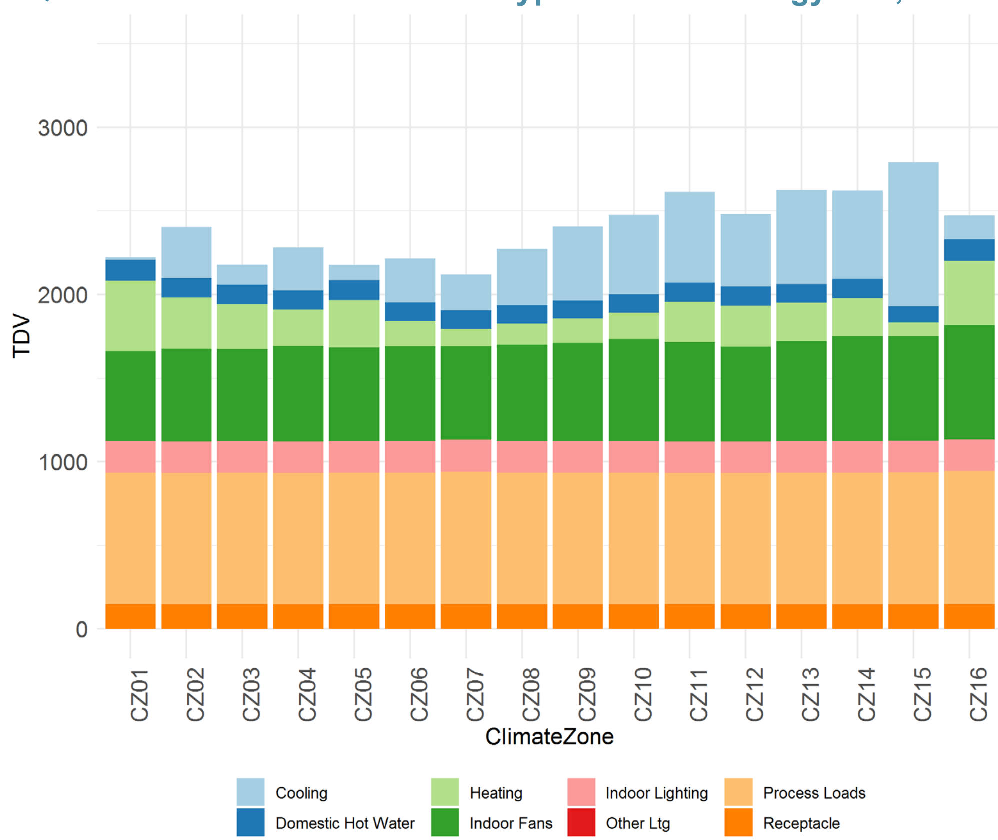


Figure 54. Quick Service Restaurant Mixed Fuel Baseline, 1980s Vintage

Climate Zone	Utility	Electricity Consumption (kWh)	Natural Gas Consumption (Therms)	Electricity Cost	Natural Gas Cost	GHG Emissions (mton)
CZ01	PG&E	115,242	14,122	$30,191	$15,420	98.8
CZ02	PG&E	138,883	12,335	$36,791	$13,563	92.1
CZ03	PG&E	123,870	11,758	$32,548	$12,942	86.7
CZ03-2	PCE	123,870	11,758	$31,852	$12,942	86.7
CZ04	PG&E	136,421	11,151	$36,043	$12,300	85.2
CZ04-2	CPAU	136,421	11,151	$23,689	$14,287	85.2
CZ05	PG&E	124,723	12,074	$32,634	$13,229	88.4
CZ05-2	SCG	124,723	12,074	$32,634	$9,735	88.4
CZ06	SCE	138,777	10,126	$18,819	$8,366	88.4
CZ06-2	LA	138,777	10,126	$12,115	$8,366	88.4
CZ07	SDG&E	134,011	9,443	$33,186	$8,060	75.5
CZ08	SCE	149,010	9,826	$20,199	$8,155	79.6
CZ08-2	LA	149,010	9,826	$13,165	$8,155	79.6
CZ09	SCE	156,426	10,075	$21,130	$8,331	82.4
CZ09-2	LA	156,426	10,075	$13,828	$8,331	82.4
CZ10	SDG&E	161,951	10,297	$42,099	$8,749	84.3
CZ10-2	SCE	161,951	10,297	$21,778	$8,486	84.3
CZ11	PG&E	165,907	11,603	$44,463	$12,847	92.9
CZ12	PG&E	150,427	11,674	$40,110	$12,914	90.4
CZ12-2	SMUD	150,427	11,674	$20,684	$12,914	90.4
CZ13	PG&E	166,426	11,369	$44,530	$12,607	91.5
CZ14	SDG&E	168,777	11,324	$41,400	$9,452	91.3
CZ14-2	SCE	168,777	11,324	$21,979	$9,208	91.3
CZ15	SCE	212,393	9,146	$26,792	$7,677	86.2
CZ16	PG&E	142,792	13,420	$37,630	$14,800	99.5
CZ16-2	LA	142,792	13,420	$11,427	$10,681	99.5

7.3.5 Full Service Restaurant

Figure 55. Full Service Restaurant Prototype Characteristics by Vintage

Vintage	1980s	.1990s	2000s
Cooling System (Kitchen Space)	SZAC 8.0 EER	SZAC 8.4 EER	SZAC 9.5 EER
Cooling System (Dining Space)	SZAC 8.1 EER	SZAC 8.7 EER	SZAC 9.7 EER
Heating System	Furnace 78.6% TE	Furnace 80% TE	Furnace 80% TE
Conditioned Thermal Zones	2 zones	2 zones	2 zones
Domestic Hot Water Heating	65.5% TE*	78.6% TE*	78.5% TE*
Roof Insulation (U-Value)	0.76-0.90	0.57-0.78	0.51-0.76
Steep-Sloped Roof Solar Reflectance	CZ01: 0.105 CZ02-16: 0.117	CZ01: 0.104 CZ02-16: 0.114	CZ01: 0.102 CZ02-16: 0.2
Metal-Framed Wall Insulation (U-Value)	0.217-0.351	0.182-0.189	0.217-0.224
Windows	U-Factor: 1.144-1.209 SHGC: 0.561-0.73 VT: 0.36	U-Factor: 0.689-1.168 SHGC: 0.544- 0.67 VT: 0.383	U-Factor: 0.427-0.763 SHGC: 0.358-0.427 VT: 0.4
LPD (Dining Space)	1.2 W/ft^2	1.2 W/ft^2	1.1 W/ft^2
LPD (Kitchen Space)	2.0 W/ft^2	2.0 W/ft^2	1.6 W/ft^2

Figure 56. Full Service Restaurant Prototype End-Use Energy Use, 1980s Vintages

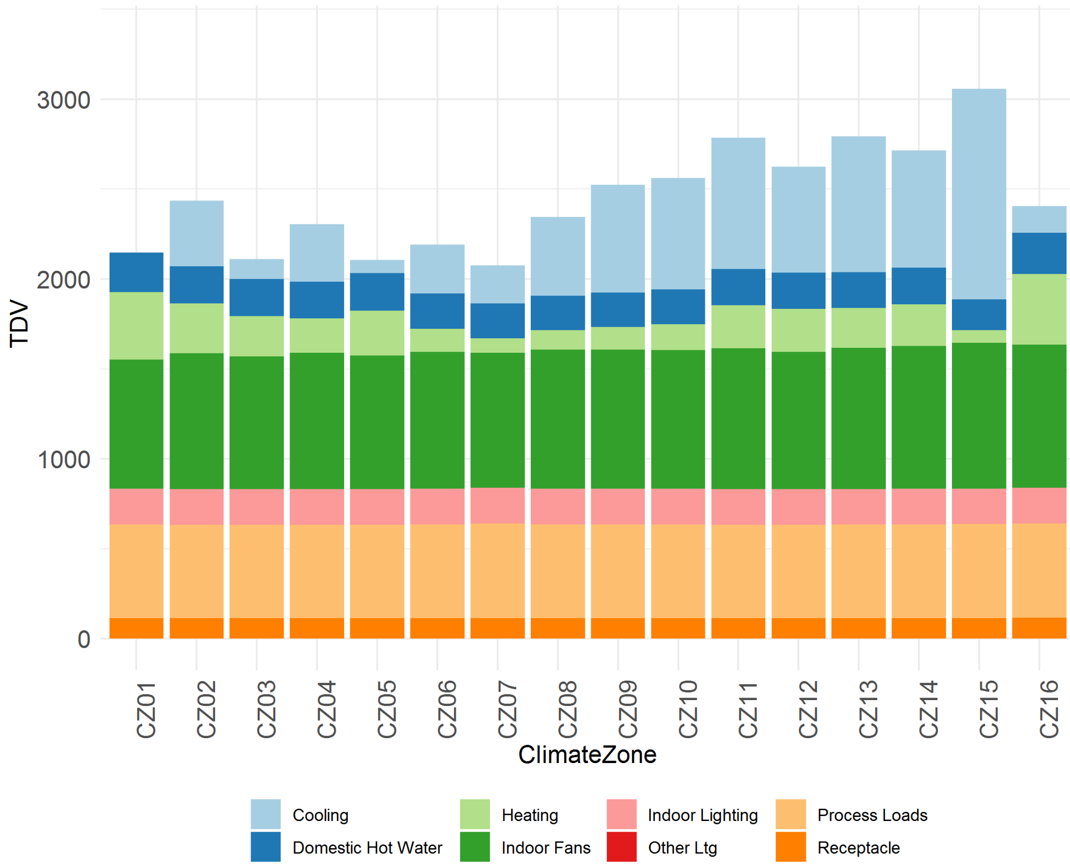


Figure 57. Full Service Restaurant Prototype End-Use Energy Use, 2000s Vintage

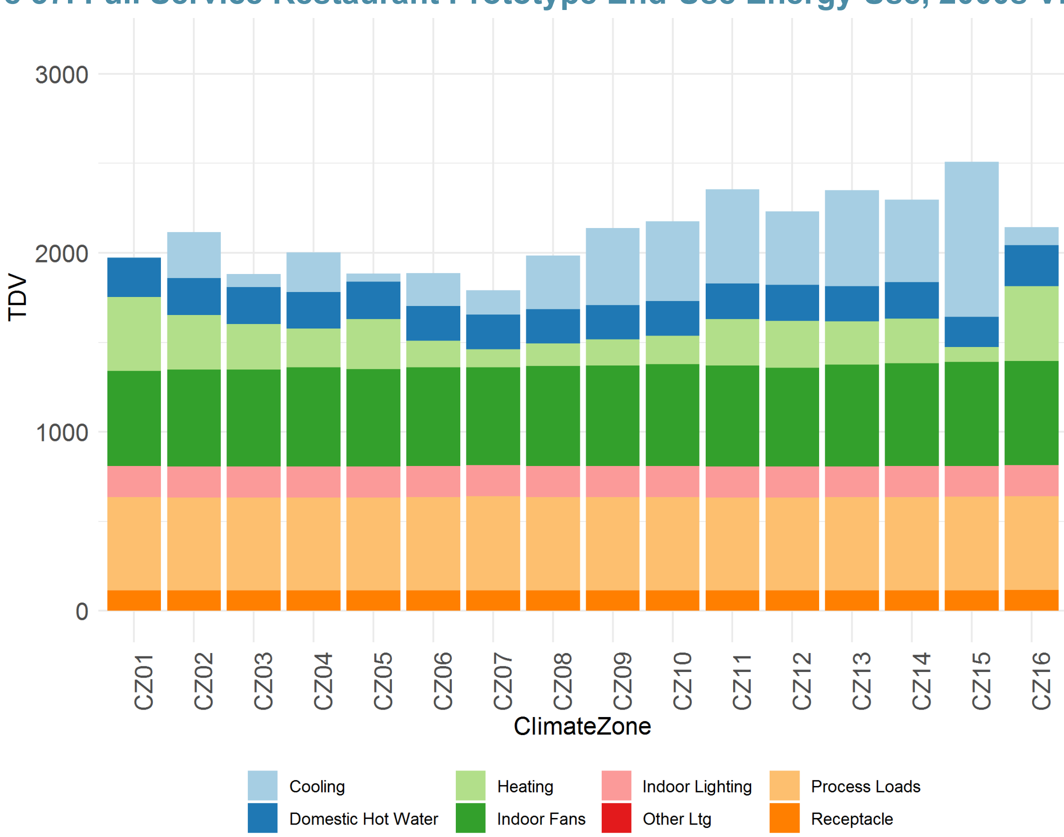


Figure 58. Full Service Restaurant Mixed Fuel Baseline, 1980s Vintage

Climate Zone	Utility	Electricity Consumption (kWh)	Natural Gas Consumption (Therms)	Electricity Cost	Natural Gas Cost	GHG Emissions (mton)
CZ01	PG&E	212,861	26,781	$54,504	$29,211	186
CZ02	PG&E	255,325	23,595	$57,680	$25,901	175
CZ03	PG&E	225,670	22,005	$57,740	$24,169	161
CZ03-2	PCE	225,670	22,005	$56,535	$24,169	161
CZ04	PG&E	248,789	21,037	$55,719	$23,148	159
CZ04-2	CPAU	248,789	21,037	$43,211	$25,932	159
CZ05	PG&E	225,610	22,931	$57,726	$25,096	166
CZ05-2	SCG	225,610	22,931	$57,726	$17,366	166
CZ06	SCE	250,335	19,106	$32,246	$14,678	148
CZ06-2	LA	250,335	19,106	$20,975	$14,678	148
CZ07	SDG&E	238,620	17,745	$50,637	$13,906	140
CZ08	SCE	272,572	18,464	$35,161	$14,226	148
CZ08-2	LA	272,572	18,464	$23,388	$14,226	148
CZ09	SCE	287,899	18,988	$37,167	$14,595	154
CZ09-2	LA	287,899	18,988	$25,296	$14,595	154
CZ10	SDG&E	296,266	19,478	$65,445	$15,021	158
CZ10-2	SCE	296,266	19,478	$37,823	$14,939	158
CZ11	PG&E	310,322	22,151	$69,524	$24,477	176
CZ12	PG&E	281,256	22,208	$62,876	$24,515	171
CZ12-2	SMUD	281,256	22,208	$37,153	$24,515	171
CZ13	PG&E	313,561	21,628	$69,773	$23,931	174
CZ14	SDG&E	309,152	21,891	$66,171	$16,574	174
CZ14-2	SCE	309,152	21,891	$38,198	$16,635	174
CZ15	SCE	403,341	17,258	$48,815	$13,379	163
CZ16	PG&E	246,551	26,763	$63,270	$29,467	192
CZ16-2	LA	246,551	26,763	$18,728	$20,060	192

7.3.6 High-rise Multifamily

Figure 59. High Rise Multifamily Prototype Characteristics by Vintage

Vintage	1980s	1990s	2000s
Cooling System: Apartment Units	Packaged terminal air conditioning (PTAC)	Packaged terminal air conditioning (PTAC)	Split AC
Cooling System: Apartment Units Efficiency	7.9 EER	7.9 EER	10.3 EER
Cooling System: Common Areas	PVAV 9.8 EER, 11.4 SEER	PVAV 9.8 EER, 11.4 SEER	PVAV 9.8 EER, 11.4 SEER
Heating System: Apartment Units	Boilers serving heating only base-board	Boilers serving heating only fan coils	Gas furnace
Heating System: Apartment Units Efficiency	65.5% TE	78.6% TE	78.1% AFUE
Heating System: Common Areas	VAV Reheat served by boiler 65.5% TE	VAV Reheat served by boiler 78.6% TE	VAV Reheat served by boiler 78.1% TE
Conditioned Thermal Zones	40 zones	40 zones	40 zones
Domestic Hot Water Heating	0.8 TE	0.8 TE	0.8 TE
Roof Insulation (U-Value)	0.055 - 0.057	0.037 - 0.051	0.036 - 0.051
Low-Sloped Roof Solar Reflectance	0.1	0.17	0.55
Metal-Framed Wall Insulation (U-Value)	0.117 - 0.236	0.140 - 0.181	0.181 - 0.223
Windows	U-Factor: 1.14 - 1.21 SHGC: 0.56 - 0.74 VT: 0.36	U-Factor: 0.69 - 1.17 SHGC: 0.54 - 0.67 VT: 0.38	U-Factor: 0.47 - 0.77 SHGC: 0.36 - 0.43 VT: 0.4
Residential LPD	0.5 W/sqft	0.5 W/sqft	0.5 W/sqft

Figure 60. High Rise Multifamily Prototype End-Use Energy Use, 1980s Vintage

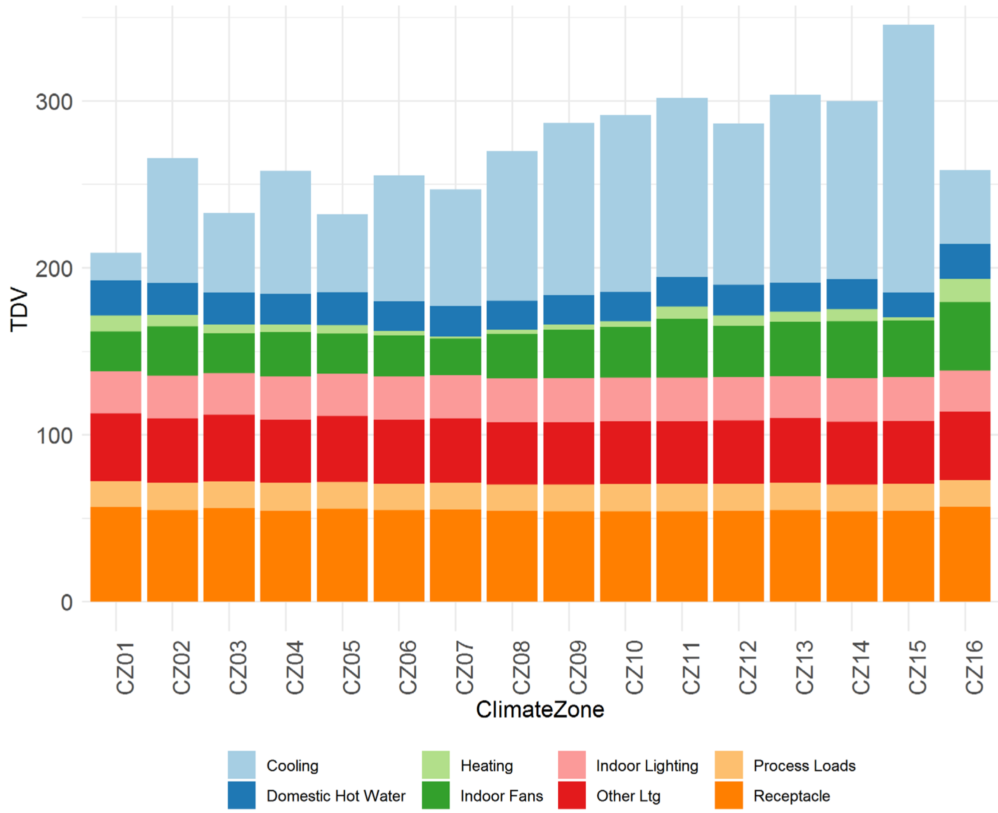


Figure 61. High Rise Multifamily Prototype End-Use Energy Use, 2000s Vintage

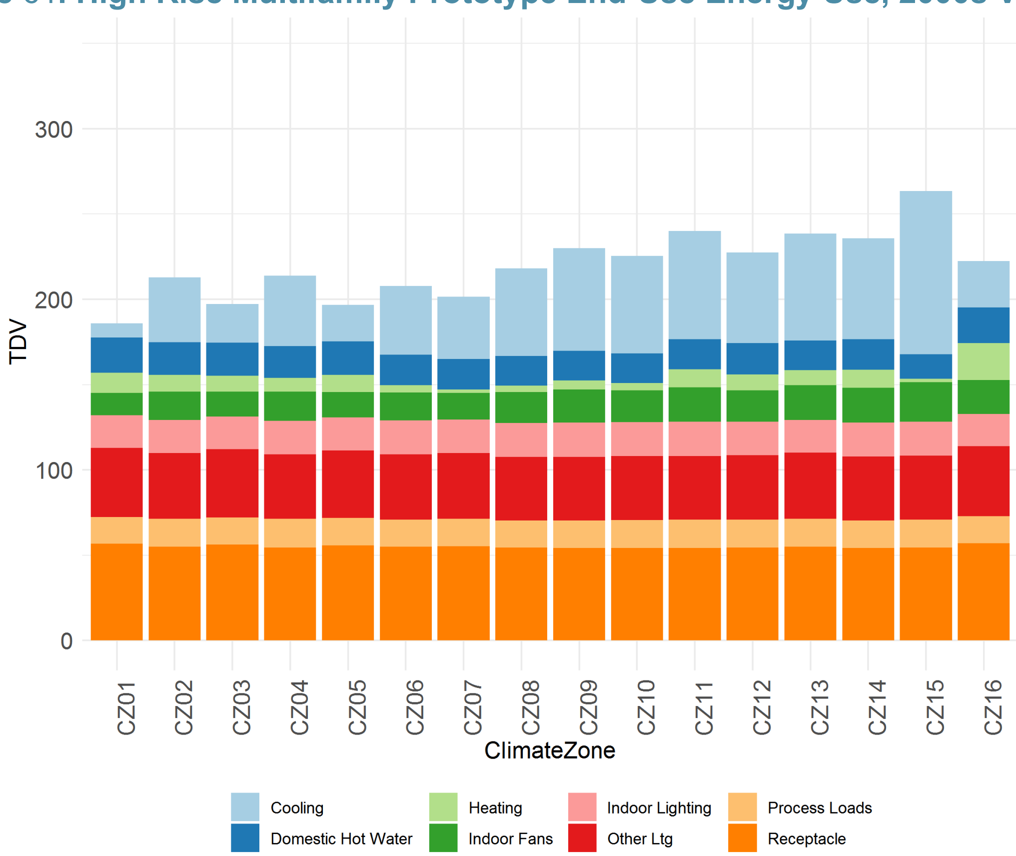


Figure 62. High Rise Multifamily Mixed Fuel Baseline, 1980s Vintage

Climate Zone	Utility	Electricity Consumption (kWh)	Natural Gas Consumption (Therms)*	Electricity Cost	Natural Gas Cost	GHG Emissions (mtons)
CZ01	PG&E	735,647	19,057	$220,051	$33,671	240
CZ02	PG&E	918,504	16,909	$277,890	$29,201	236
CZ03	PG&E	841,146	16,616	$251,380	$27,698	221
CZ03-2	PCE	841,146	16,616	$247,977	$27,698	221
CZ04	PG&E	908,977	15,873	$285,832	$26,307	221
CZ04-2	CPAU	908,977	15,873	$176,042	$33,600	221
CZ05	PG&E	851,645	16,838	$252,455	$28,350	225
CZ05-2	SCG	851,645	16,838	$252,455	$27,970	225
CZ06	SCE	930,061	15,283	$225,192	$25,115	214
CZ06-2	LA	930,061	15,283	$84,825	$25,115	214
CZ07	SDG&E	911,251	14,691	$294,988	$27,109	207
CZ08	SCE	963,313	14,824	$235,334	$24,544	214
CZ08-2	LA	963,313	14,824	$88,136	$24,544	214
CZ09	SCE	993,592	14,954	$237,397	$24,913	221
CZ09-2	LA	993,592	14,954	$90,950	$24,913	221
CZ10	SDG&E	1,023,203	15,000	$337,673	$28,817	225
CZ10-2	SCE	1,023,203	15,000	$242,593	$25,132	225
CZ11	PG&E	1,012,273	16,300	$303,877	$28,495	246
CZ12	PG&E	949,215	16,244	$282,116	$28,118	236
CZ12-2	SMUD	949,215	16,244	$123,369	$28,118	236
CZ13	PG&E	1,034,647	15,557	$309,434	$26,914	239
CZ14	SDG&E	1,041,362	16,406	$334,648	$33,094	245
CZ14-2	SCE	1,041,362	16,406	$250,314	$27,805	245
CZ15	SCE	1,258,012	12,557	$290,609	$21,904	234
CZ16	PG&E	914,096	19,950	$275,157	$37,047	273
CZ16-2	LA	914,096	19,950	$82,352	$43,931	273

*Includes natural gas consumption from residential areas only.

7.3.7 Small Hotel

Figure 63. Small Hotel Prototype Characteristics by Vintage

Vintage	1980s	1990s	2000s
Cooling System: Guest Rooms	Packaged terminal air conditioning (PTAC)	Packaged terminal air conditioning (PTAC)	Split AC
Cooling System: Guest Rooms Efficiency	7.9 EER	7.9 EER	13 SEER
Cooling System: Common Areas	PVAV 9.8 EER, 11.4 SEER	PVAV 9.8 EER, 11.4 SEER	PVAV 9.8 EER, 11.4 SEER
Heating System: Guest Rooms	Gas wall furnace	Gas wall furnace	Gas furnace
Heating System: Guest Rooms Efficiency	67.5% AFUE	78.1% AFUE	78.1% AFUE
Heating System: Common Areas	VAV Reheat served by boiler 65.5% TE	VAV Reheat served by boiler 78.6% TE	VAV Reheat served by boiler 78.5% TE
Conditioned Thermal Zones	35 zones	35 zones	35 zones
Domestic Hot Water Heating	0.8 TE	0.8 TE	0.8 TE
Roof Insulation (U-Value)	0.055 - 0.057	0.037 - 0.051	0.036 - 0.051
Low-Sloped Roof Solar Reflectance	0.1	0.17	0.55
Metal-Framed Wall Insulation (U-Value)	0.117 - 0.236	0.140 - 0.181	0.181 - 0.223
Windows	U-Factor: 1.14 - 1.21 SHGC: 0.56 - 0.74 VT: 0.36	U-Factor: 0.69 - 1.17 SHGC: 0.54 - 0.67 VT: 0.38	U-Factor: 0.47 - 0.77 SHGC: 0.36 - 0.43 VT: 0.4
Residential LPD	0.5 W/sqft	0.5 W/sqft	0.5 W/sqft

Figure 64. Small Hotel Prototype End-Use Energy Use, 1980s Vintage

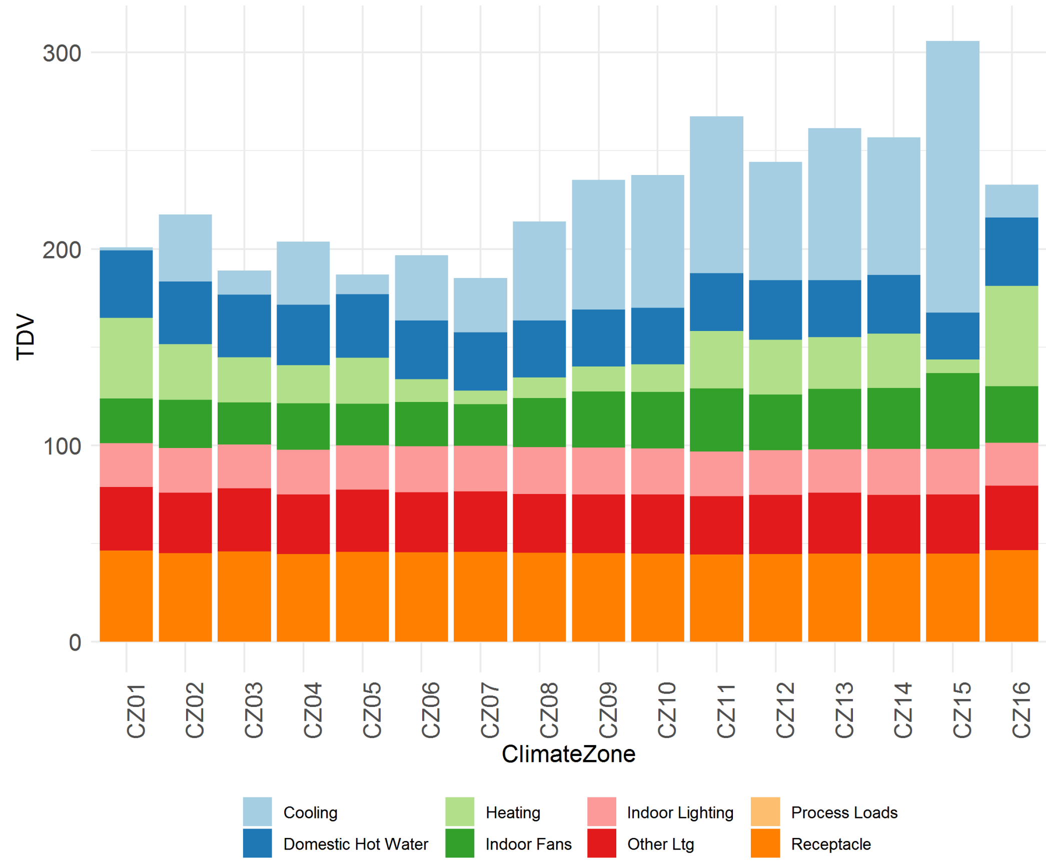


Figure 65. Small Hotel Prototype End-Use Energy Use, 2000s Vintage

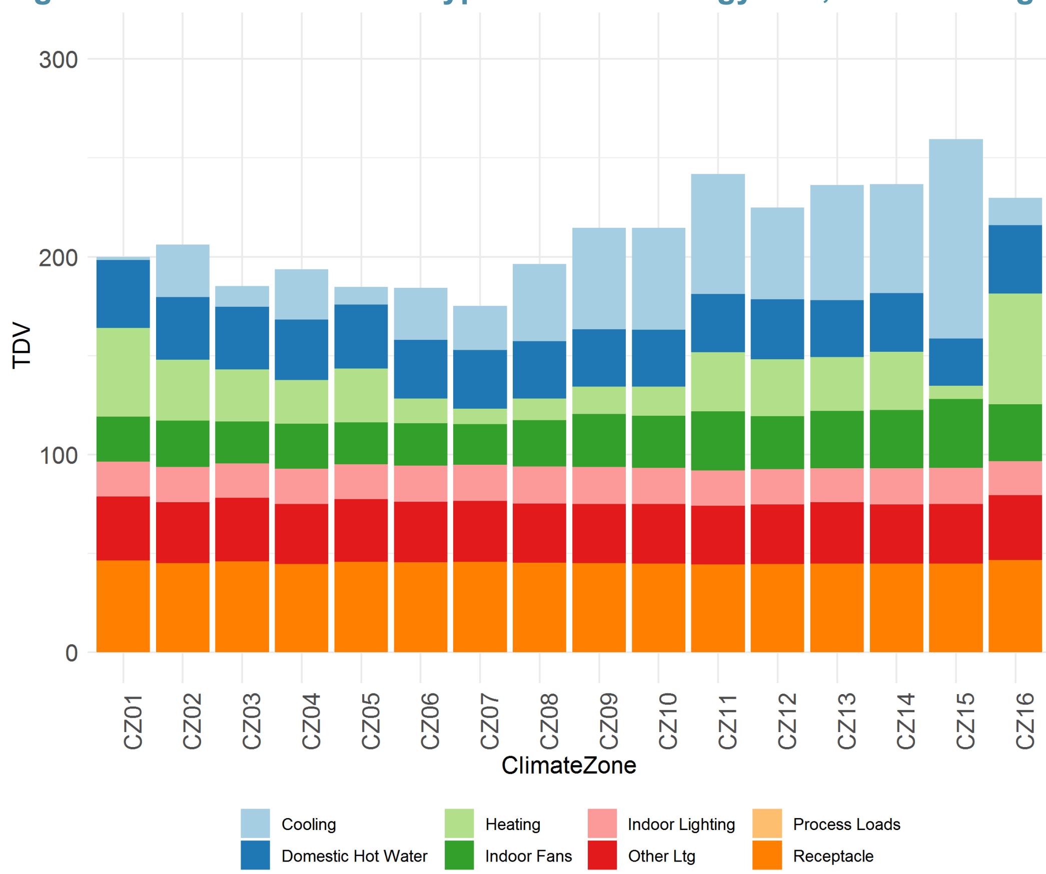


Figure 66. Small Hotel Mixed Fuel Baseline, 1980s Vintage

Climate Zone	Utility	Electricity Consumption (kWh)	Natural Gas Consumption (Therms)*	Electricity Cost	Natural Gas Cost	GHG Emissions (mtons)
CZ01	PG&E	183,189	12,985	$47,742	$19,198	128
CZ02	PG&E	207,910	10,553	$51,096	$15,090	110
CZ03	PCE	191,068	9,770	$49,963	$13,807	101
CZ03-2	PG&E	191,068	9,770	$48,893	$13,807	101
CZ04	PG&E	205,581	9,097	$54,042	$12,676	97
CZ04-2	CPAU	205,581	9,097	$35,794	$14,548	97
CZ05	PG&E	190,938	9,950	$49,753	$14,103	103
CZ05-2	SCG	190,938	9,950	$49,753	$10,218	103
CZ06	SCE	211,619	7,765	$28,296	$7,870	87
CZ06-2	LA	211,619	7,765	$19,169	$7,870	87
CZ07	SDG&E	205,225	7,092	$52,621	$7,125	80
CZ08	SCE	225,271	7,429	$31,027	$7,518	86
CZ08-2	LA	225,271	7,429	$21,652	$7,518	86
CZ09	SCE	235,206	7,753	$32,953	$7,861	90
CZ09-2	LA	235,206	7,753	$23,416	$7,861	90
CZ10	SDG&E	242,404	7,890	$71,105	$8,129	92
CZ10-2	SCE	242,404	7,890	$33,655	$8,026	92
CZ11	PG&E	257,274	10,033	$63,440	$14,514	114
CZ12	PG&E	230,277	10,073	$56,919	$14,443	110
CZ12-2	SMUD	230,277	10,073	$32,734	$14,443	110
CZ13	PG&E	260,901	9,558	$64,064	$13,733	110
CZ14	SDG&E	255,610	9,812	$71,501	$10,042	111
CZ14-2	SCE	255,610	9,812	$34,630	$10,099	111
CZ15	SCE	351,705	5,841	$46,097	$6,085	93
CZ16	PG&E	208,827	14,089	$54,766	$21,368	142
CZ16-2	LA	208,827	14,089	$17,675	$14,632	142

*Includes natural gas consumption from guest rooms only.

7.4 Basis of Design for Full Service and Quick Service Restaurants

The Reach Code Team developed these bases of designs for restaurants after exhaustive literature review and interviews and used them to develop simulation inputs. Note that where '***' is used in the model name and number, it is a placeholder representing multiple model options.

7.4.1 Kitchen Hooded Cooking Appliances

The BOD for kitchen hooded cooking appliances covers three scenarios:

- Baseline gas appliances
- High-efficiency gas appliances, defined as either ENERGY STAR® compliant or qualified for IOU rebates
- All-electric appliances, also selected to be high efficiency

For cooking appliances, the Reach Code Team focused on gas cooking appliances that require a Type I exhaust hood. Compared to appliances needing a Type II exhaust hood, Type I appliances present the biggest challenges for electrification and have large impacts on process load and HVAC load. Most appliances requiring Type II are already electrical appliances, and the amount of exhaust air required is small. The Team determined the type and number of cooking appliances appropriate for the QSR and FSR based on data collected from more than 100 restaurants presented in the report by PG&E and Fisher-Nickel (PG&E & Fisher-Nickel, 2014). The Reach Code Team selected specific models of cooking appliances and developed typical hourly energy load profiles for each appliance based on information collected through:

- Literature review, including Database for Energy Efficient Resources (DEER) workpapers (DEER, 2020), ASHRAE RP 1362 (ASHRAE, 2008), the IOU rebate product list (California Energy Wise, 2020), GTI and Fisher-Nickel (GTI and Fisher-Nickel, 2013), and ENERGY STAR commercial kitchen product criteria.
- Interviews and BOD reviews with food service technology subject matter experts, including SCE, SCG, SDG&E, and Frontier Energy (formerly Fisher-Nickel).
- Market research, including product specification review.

The Reach Code Team developed two BODs for the QSR, a burger diner, and a taqueria. The Team verified that both are technically feasible0 and used the burger diner for cost-effectiveness analysis, though cost-effectiveness results are not expected to be significantly different for the taqueria. The FSR BOD represents a fine dining restaurant serving American cuisine. Both the QSR and FSR have wall-mounted canopy exhaust hoods that overhang appliances by six inches on each side, per ASHRAE 154 (ASHRAE, 2020). The total exhaust rate is the maximum airflow allowed by Title 24 2019 Table 140.9 for the appropriate equipment duty level. The Reach Code Team includes demand-controlled kitchen ventilation (DCKV) per Title 24 2019 prescriptive requirements in the FSR due to the exhaust rate exceeding 5000 ft^3/min.

7.4.1.1 QSR: Burger Diner

Figure 67. Hooded Cooking Appliances for QSR: Baseline Gas Appliance

Hooded Cooking Appliances	Number of units	Model	Width (ft)	Nameplate power (Btu/hr)	Idle energy (Btu/hr)	Duty (ASHRAE, 2020)	Source
French Fryer, Small	4	Frymaster GF40	1.3	122,000	9,000	Medium	Market data
Griddle, Single Sided	2	Imperial ITG-36	3	90,000	20,400	Medium	Market data
Oven, Half-Size Electric Convection*	1	Montague Vectaire EK8	2.5	26,955	5,390	Light	Market data

*Interviewees suggested that a half-size electric oven is commonly used for gas QSR, with no exhaust hood is required.

Figure 68. Hooded Cooking Appliances for QSR: High Efficiency Gas Appliance

Hooded Cooking Appliances	Number	Model	Width (ft)	Nameplate power (Btu/hr)	Idle energy (Btu/hr)	Duty	Source
French Fryer, Small	4	Frymaster H55	**1**	80,000	5,604	Medium	IOU Rebate
Griddle, Single Sided	2	AccuTemp GGF1201A3650	3	70,000	7,900	Medium	IOU Rebate
Oven, Half-Size Electric Convection*	1	Montague Vectaire EK8	2.5	26,955	5390	Light	Market data

Figure 69. Hooded Cooking Appliances for QSR: Electric Appliance

Hooded Cooking Appliances	Number of units	Model	Width (ft)	Nameplate power (Watt)	Idle energy (Watt)	Duty	Source
French Fryer, Small	4	Frymaster RE14***	1	14,000	620	Medium	IOU Rebate
Griddle, Single Sided	2	AccuTemp EGF****A3650	3	15,250	2,034	Medium	IOU Rebate
Oven, Convection	1	Blodgett CBT	2.5	5600	300	Light	IOU Rebate

7.4.1.2 QSR: Taqueria

Figure 70. Hooded Cooking Appliances for QSR: Baseline Gas Appliance

Hooded Cooking Appliances	Number of units	Model	Width (ft)	Nameplate power (Btu/hr)	Idle energy (Btu/hr)	Duty	Source
Broiler, Underfired	1	Vulcan HGB34	3	96,000	73,900	Heavy	RP 1362
French Fryer, Small	1	Frymaster GF40	1.3	122000	9000	Medium	Market data
Griddle, Single Sided	1	Imperial ITG-36	3	90,000	20,400	Medium	Market data
Oven, Half-Size Electric Convection	1	Montague Vectaire EK8	2.5	26955	5390	Light	Market data
Oven, Range	1	Wolf C36C -6, oven	3	25,000	7,400	Light	RP 1362
Range, Open Burner	1	Wolf C36C -6	3.0	180,000	181,800	Medium	GTI and Fisher Nickel (2013) Table 12

Figure 71. Hooded Cooking Appliances for QSR: High Efficiency Gas Appliance

Hooded Cooking Appliances	Number	Model	Width (ft)	Nameplate power (Btu/hr)	Idle energy (Btu/hr)	Duty	Source
Broiler, Underfired	1	Vulcan VTEC36	3	66,000	51,000	Heavy	DEER
French Fryer, Small	1	Frymaster H55	**1**	80,000	5,604	Medium	IOU Rebate
Griddle, Single Sided	1	AccuTemp GGF1201A3650	3	70,000	7,900	Medium	IOU Rebate
Oven, Half-Size Electric Convection*	1	Montague Vectaire EK8	2.5	26,955	5,390	Light	Market data
Oven, Range	1	Southbend C0300, oven	3	25,000	7,400	Light	RP 1362
Range, Open Burner With Turbo Pot	1	Montague 136-5	3	120,000	121,200	Medium	GTI and Fisher Nickel (2013) Table 13

Figure 72. Hooded Cooking Appliances for QSR: Electric Appliance

Hooded Cooking Appliances	Number of units	Model	Width (ft)	Nameplate power (Watt)	Idle energy (Watt)	Duty	Source
Broiler, Chain	1	Nieco JF63	3	18,000	15,120	Medium	Market data
French Fryer, Small	1	Frymaster RE14***	1	14,000	620	Medium	IOU Rebate
Griddle, Single Sided	1	AccuTemp EGF****A3650	3	15,250	2,034	Medium	IOU Rebate
Oven, Convection	1	Blodgett CBT	2.5	5600	300	Light	IOU Rebate
Oven, Range	1	Garland GME36-I20C Oven	3	5,100	1,224	Light	Market data
Range, Open Burner	1	CookTek Six-Burner Range	3	21,000	0	Light	Market data

7.4.1.3 FSR

Figure 73. Hooded Cooking Appliance for FSR - Baseline Gas Appliance

Hooded Cooking Appliances	Number of units	Model	Width	Name plate power (Btu/hr)	Idle energy (Btu/hr)	Duty	Source
Broiler, Underfired	1	Vulcan HGB34	3	96,000	73,900	Heavy	Market data
French Fryer	2	Frymaster GF40	1.3	122000	9000	Medium	Market data
Griddle, Single Sided	1	Imperial ITG-36	3	90,000	20,400	Medium	Market data

Hooded Cooking Appliances	Number of units	Model	Width	Name plate power (Btu/hr)	Idle energy (Btu/hr)	Duty	Source
Broiler, Salamander	1	Vulcan Sar 34R	2.8	35,000	33,300	Light	RP 1362
Oven, Convection	2	Montague Vectaire R85	3.188	85000	12000	Light	Market data
Oven, Range	2	Wolf C36C -6, oven	3	25,000	7,400	Light	RP 1362
Range, Open Burner	2	Wolf C36C -6	3.0	180,000	181,800	Medium	GTI and Fisher Nickel (2013) Table 12
Range, Stock Pot	2	Royal RSP18	1.5	90,000	90,900	Medium	Market data

Figure 74. Hooded cooking appliance for FSR: High Efficiency Gas Appliance

Hooded Cooking Appliances	Number of units	Model	Width	Name plate power (Btu/hr)	Idle energy (Btu/hr)	Duty	Source
Broiler, Underfired	1	Vulcan VTEC36	3	66,000	51,000	Heavy	DEER[6]
French Fryer	2	Frymaster H55	**1**	80,000	5,604	Medium	IOU Rebate
Griddle, Single Sided	1	AccuTemp GGF1201A3650	3	70,000	11,850	Medium	IOU Rebate
Broiler, Salamander	1	Vulcan Sar 34R	2.8	35,000	33,300	Light	RP 1362
Oven, Convection	2	Blodgett HVH100G	3.2	60,000	9,082	Light	IOU Rebate
Oven, Range	2	Southbend C0300, oven	3	25,000	7,400	Light	RP 1362
Range, Open Burner[7] With Turbo Pot	2	Montague 136-5	3	120,000	121,200	Medium	GTI and Fisher Nickel (2013) Table 13
Range, Stock Pot	2	Royal RSP18	1.5	90,000	90,900	Medium	Market data

Figure 75. Hooded cooking appliance for FSR: Electric Appliance

Hooded Cooking Appliances	Number of units	Model	Width	Nameplate power (Watt)	Idle energy (Watt)	Duty	Source
Broiler, Chain	1	Nieco JF63	3	18,000	15,120	Medium	Market data
French Fryer	2	Frymaster RE14***	1	14,000	620	Medium	IOU Rebate

[6] Efficiency is based on DEER commercial underfired broiler workpaper for IR Plate Broiler with 17 kbtu/hr/ft idle rate
[7] High efficiency gas scenario includes replacing high-input burners with low-input burners in combination with turbo pot

Hooded Cooking Appliances	Number of units	Model	Width	Nameplate power (Watt)	Idle energy (Watt)	Duty	Source
Griddle, Single Sided	1	AccuTemp EGF****A3650	3	15,250	2,034	Medium	IOU Rebate
Broiler, Salamander	1	Garland SERC	2.8	7,003	6,827	Light	RP 1362
Oven, Convection	2	Blodgett Zephaire-100-E	3.2	11,000	1,400	Light	IOU Rebate
Oven, Range	2	Garland GME36-I20C Oven	3	5,100	1,224	Light	Market data
Range, Open Burner Induction	2	CookTek Six-Burner Range	3	21,000	0	Light	Market data
Range, Stock Pot Induction	2	CookTek MSP7000-200	1.8	7,000	0	Light	Market data

7.4.1.4 Annual Cooking Energy Use

The Reach Code Team used a bottom-up approach to estimate annual cooking energy usage. The Team developed hourly load profiles for each appliance based on occupancy schedule, equipment nameplate power, idle energy rate and energy input as a function of appliance cooking state if data is available.

Figure 76 shows the aggregated cooking appliances load profile for the QSR-Burger. The annual energy uses for each scenario are:

- **Baseline gas appliances:** 293 kBtu/ft^2 for gas consumption and 3.3 kwh/ ft^2 for electric convection oven
- **High-efficient gas appliances:** 190.5 kBtu/ft^2 for gas consumption and 3.3 kwh/ ft^2 for electric convection oven
- **All-electric appliances:** 42.3 kWh/ ft^2 (144 kBtu/ft^2)

Figure 76. QSR Weekday Cooking Appliance Load Profiles, Percent of Total Capacity

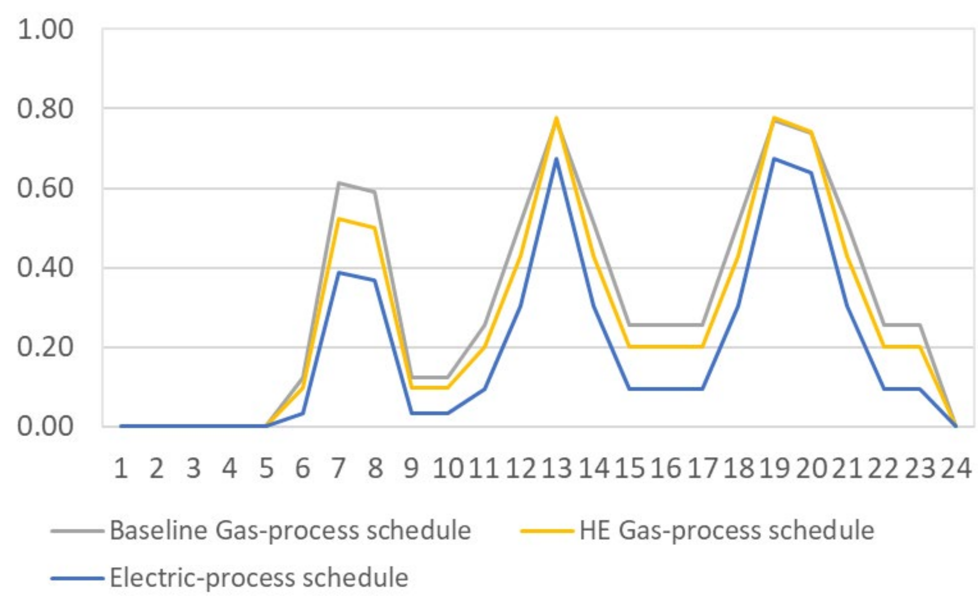
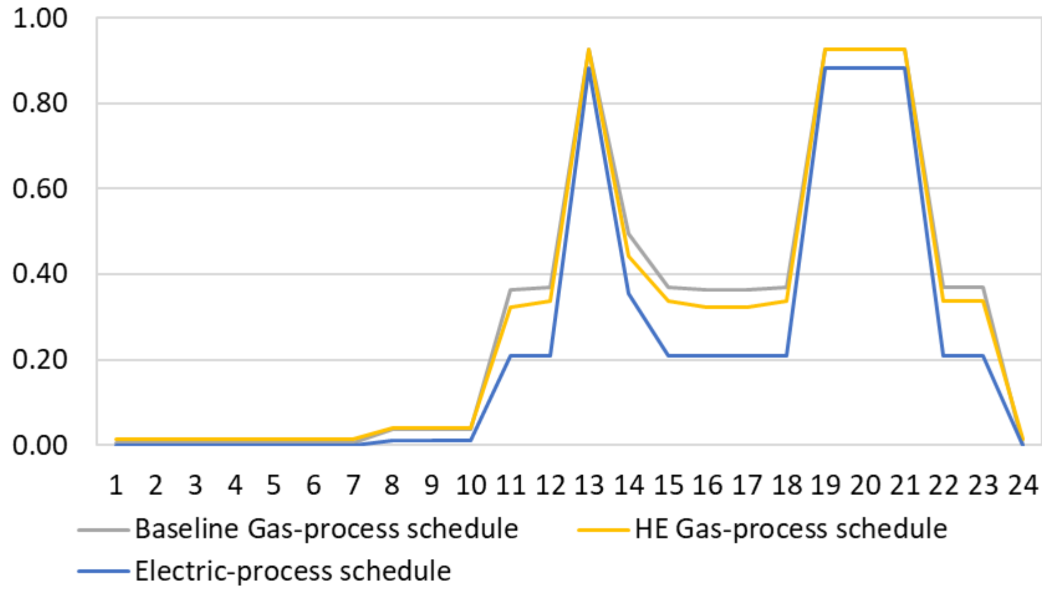


Figure 77 shows the aggregated cooking appliances load profile for the FSR. The annual energy use for each scenario is:

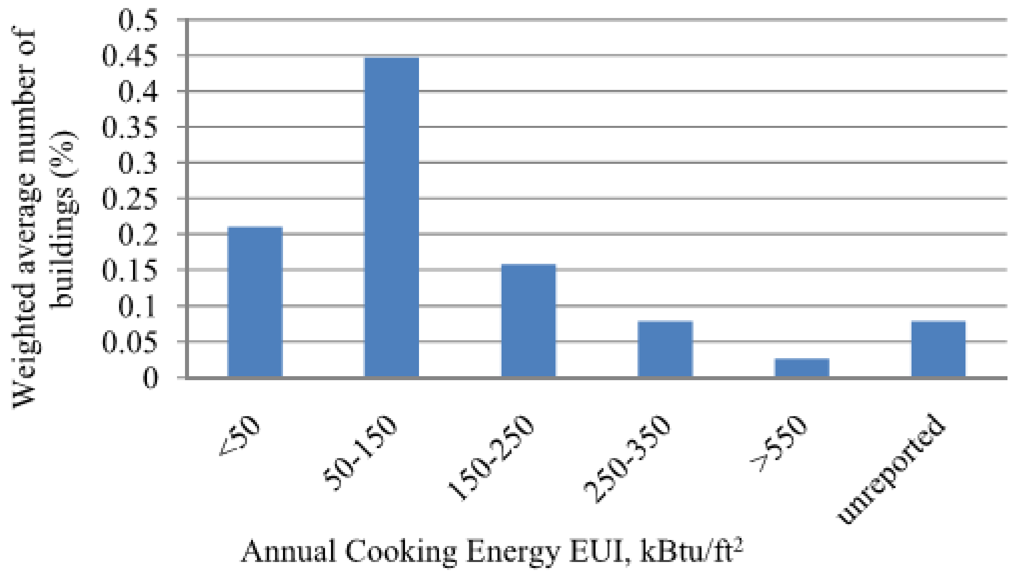
- **Baseline gas appliances:** 247 kBtu/ft^2
- **High-efficiency gas appliances:** 183 kBtu/ft^2
- **All-electric appliances:** 32 kWh/ ft^2 (110 kBtu/ft^2)

Figure 77. FSR Weekday Cooking Appliance Load Profiles, Percent of Total Capacity



As a reference, 2003 CBECS results for annual cooking energy use index (EUI) for restaurants has a wide range, as shown in Figure 78. CBECS data includes restaurants serving different menus, like sandwich or cafés, which use much less energy than a burger restaurant. A Pacific Northwest National Laboratory (PNNL) report suggests a cooking EUI of 400 to 450 kBtu/ft^2 as reasonable for a burger QSR (PNNL, 2010). Thus, the annual energy use the Reach Code Team developed for the QSR and FSR baseline scenarios are appropriately on the higher-end of PNNL's EUI findings, because they represent energy use by a busy burger restaurant.

Figure 78. Annual Cooking Energy EUI of Post-1980 Restaurants from CBECS 2003 (PNNL 2010)



7.4.2 Kitchen Exhaust Hood

The Reach Code Team determined the exhaust hood length by adding all appliance widths and six inches of overhang on each side. This is the approach used in the ASHRAE 154 Appendix example.

Total exhaust rate is the maximum airflow allowed by Title 24 2019 Table 140.9.

For control, if total exhaust rate exceeds 5000 ft^3/min, DCKV is specified per Title 24 2019 prescriptive requirement.

Figure 79. Quick Service Restaurant Type I Exhaust Hood Design

	Length (ft)	Exhaust rate (ft^3/min)	Equipment Duty	Control
Gas Baseline	13	2,730	Medium	Constant
High-efficiency Gas	13	2,730	Medium	Constant
Electric	13	2,730	Medium	Constant

Figure 80. Full Service Restaurant Type I Exhaust Hood Design

	Length (ft)	Exhaust rate	Equipment Duty	Control
Gas Baseline	26	7,280	Heavy	DCKV
High-efficiency Gas	26	7,280	Heavy	DCKV
Electric	26	5,460	Medium	DCKV

7.4.3 Hot Water System

For SWH design, the Team reviewed a 2010 PG&E and Fisher-Nickel report and California Energy Wise design guide to determine the SWH design parameters and load profiles for both the QSR and FSR and worked with commercial heat pump water heater manufacturers on system designs (Fisher-Nickel and PG&E, 2010) (California Energy Wise, 2020). The baseline scenarios represent design practice with typical hot water use appliances and fixtures for a medium QSR and medium FSR. Fixture types and counts assumed in the FSR and QSR are presented in Figure 81.

Figure 81. Fixture Type and Counts Included in the FSR and QSR Baselines

Fixture type	FSR	QSR
Restroom sinks	4	2
Hand sinks	6	2
3-comp sink (18"x18")	2	1
Dishwasher - Undercounter	1	0
Dishwasher - door type	1	0
Pre-rinse valve	1	0
Mop sink	1	1
Utility sink	2	1
Dipper well	1	0

Hot water use in restaurants features high demand for an extended period, which can be very challenging for a cost-effective heat pump water design. Heat pump water heaters have low recovery rate compared to gas heaters, and their capacity reduces significantly when there is a large difference between supply hot water temperature and incoming cold-water temperature.

For the baseline scenario with typical hot water design load, the design uses large capacity split heat pump (i.e., Colmac), which are much more expensive than a gas storage water heater. Alternatively, the design can use integrated heat pumps (i.e., AO Smith), which are less expensive than the split heat pumps. However, the high hot water demand in a restaurant, in particularly for FSR, would require several integrated heat pumps supplemented by an electric resistance heater, which may not be a practical design solution.

To address these issues, the team investigated high efficiency SHW design approaches to drastically reduce hot water demand and supply hot water temperature requirement, which are critical to improve the feasibility and cost effectiveness of a heat pump water heater design. The measures investigated include the following:

- **Low-flow pre-rinse valves**: Specifies pre-rinse spray valves (PRSV) qualified for IOU rebates. This reduces design flowrate from 45 gallon per hour (gph) to 24 gph.
- **Low-flow restroom and hand sinks**: Specifies highly efficient restroom and hand sinks that reduced design flowrate by 40-50%. Specifies adding a 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 at most 1.8 gpm.
- **Heat recovery dishwasher in the FSR**: For the FSR design, specifies dishwasher that includes heat recovery function such that it only needs connection to cold water and reduces hot water demand and sizes of the central SHW system. Typical design supply hot water temperature for FSR is 140°F for both high-temperature and low-temperature dishwasher types. With heat recovery function at dishwasher, the central house SHW system only needs to provide 125°F hot water to meet other demands. The lowered temperature significantly improves the practicality of

an all-electric solution that uses heat pump water heater, which has much lower output capacity when supplying a higher supply temperature especially during the winter when the design temperature rise is at the highest. Although market penetration of heat recovery dishwasher is low, they appear to be a critical piece to electrify SHW in restaurant.

- **Highly efficient dishwasher in QSR**: QSRs typically specify a three-compartment sink for dishwashing, this measure would add a dishwasher to reduce total hot water load.
- **Compact design to avoid recirculation loop in FSR**: the team investigated this measure but did not include it in the final package. Recirculation loops are typically included in designs where hot water end use locations are far away from the water heater. For example, when the restroom hand sinks are far away from the heater, the hot water delivery time between heater and sink would be unacceptable (30 seconds or greater) without a recirculation loop. The need for a recirculation loop depends on the architectural floor layout, which is not within the scope of the study. Designers could consider the use of a point-of-use heater for far-away end uses, such as the restroom, to eliminate recirculation loop. The energy impact would be about the same for the baseline and all-electric design scenarios, so the Reach Code Team decided to not analyze this scenario.

Design parameters for the hot water systems are presented in Figure 82.

Figure 82. Design Parameters for Hot Water Systems

Design Parameters	FSR Baseline	QSR Baseline	FSR – Low-Demand	QSR – Low-Demand
Daily hot water usage (gal)	2000	500	1450	420
Minimum recovery rate gallons per hour (gph)	240	66	170	55
Hot water supply temperature (°F)	140	125	125	125
Winter cold water inlet temperature (°F)	50	50	50	50
Design temperature rise (°F)	90	75	75	75

The gas baseline design is based on report by PG&E and Fisher-Nickel (2010), and electric HPWH design is based on communication with representatives from COLMAC[8].

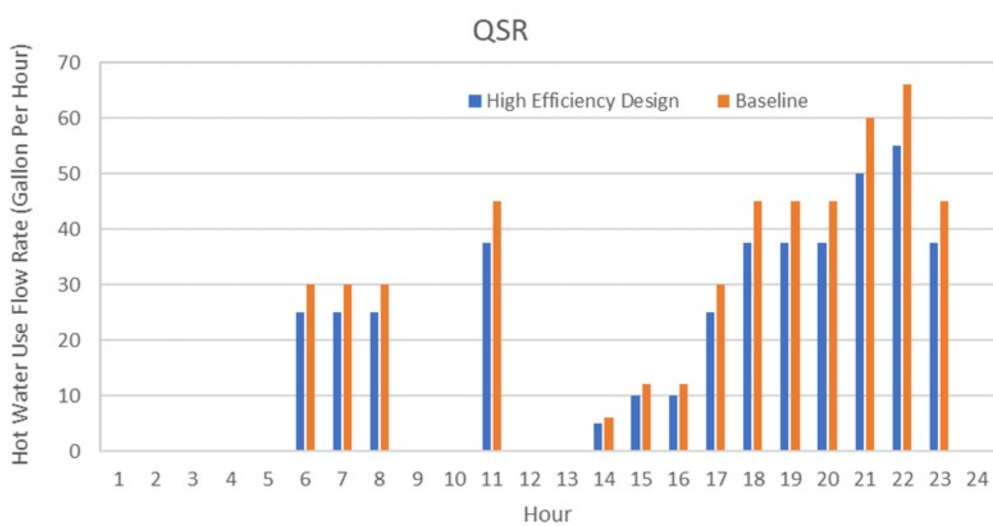
Figure 83. Hot Water System Specifications

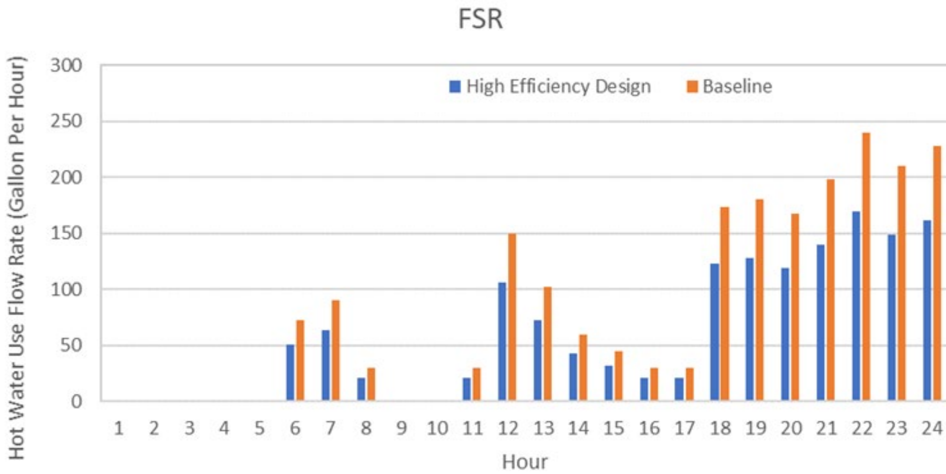
Measure	HW System	QSR	FSR
Gas Baseline Water Heater	Type	Storage water heater	Storage water heater
	Number of heaters	1	2
	Heater Product	Bosch Buderus G234X/38	Bosch Buderus G234X/55
	Total rated input rate (kBtu/hr)	150	400

[8] COLMAC Water Heater.

Measure	HW System	QSR	FSR
	Storage capacity (gal)	100	150
	Storage Product	Niles S-24-062-TC (119gal)	Niles S-28-079-TC (200gal)
	Distribution system	No recirculation	Recirculation system with recirculation pump
Electric Water Heater	Type	HPWH with storage	HPWH with storage
	HPWH Model	1 A.O. Smith CHP 120, with 12 KW built-in resistive electric element	4 Colmac CxV-5 or 2 CxV-15
	HPWH recovery rate, gph	120	240
	Electric resistance heater	n/a	5 kW
	Primary storage capacity (gal)	120	500
	Storage product	Niles S-24-062-TC (119gal)	1x Niles S-48-073-TC 1 Niles S-30-063-TC
	Recirculation tank, gal	n/a	120
	Distribution system	No recirculation	Recirculation system with recirculation pump
Low-demand electric water heater	Type	HPWH with storage	HPWH with storage
	HPWH Model	1	2
	HPWH recovery rate, gph	1 A.O. Smith CHP 120	2 A.O. Smith CHP 120, each with 12 KW built-in resistive electric element
	Electric resistance heater	55	170
	Primary storage capacity (gal)	n/a	12 kW
	Storage product	120	240
	Recirculation tank, gal	n/a	120
	Distribution system	No recirculation	Recirculation system with recirculation pump

Figure 84: Hot Water Daily Usage Profile (based on Fisher and Pietrucha, 2008 (Fisher, Fisher-Nickel, Pietrucha, & PG&E, 2008) and interview)





Like energy use for cooking, hot water consumption in restaurants varies significantly depending on the food they serve, their operation schedule, and number of customers. Figure 85 compares monitored daily hot water use in several national chain restaurants and the assumptions used for the reach code analysis. For FSR, designers must carefully select hot water appliances and fixtures and use design approach that can achieve deep hot water savings to enable cost-effective HPWH solutions.

Figure 85. Monitored Daily Hot Water Use in Full-service Restaurants vs. Daily Hot Water Use in Reach Code FSR Prototype (Fisher-Nickel and PG&E 2010)