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2022 Cost-Effectiveness Study: Multifamily New Construction

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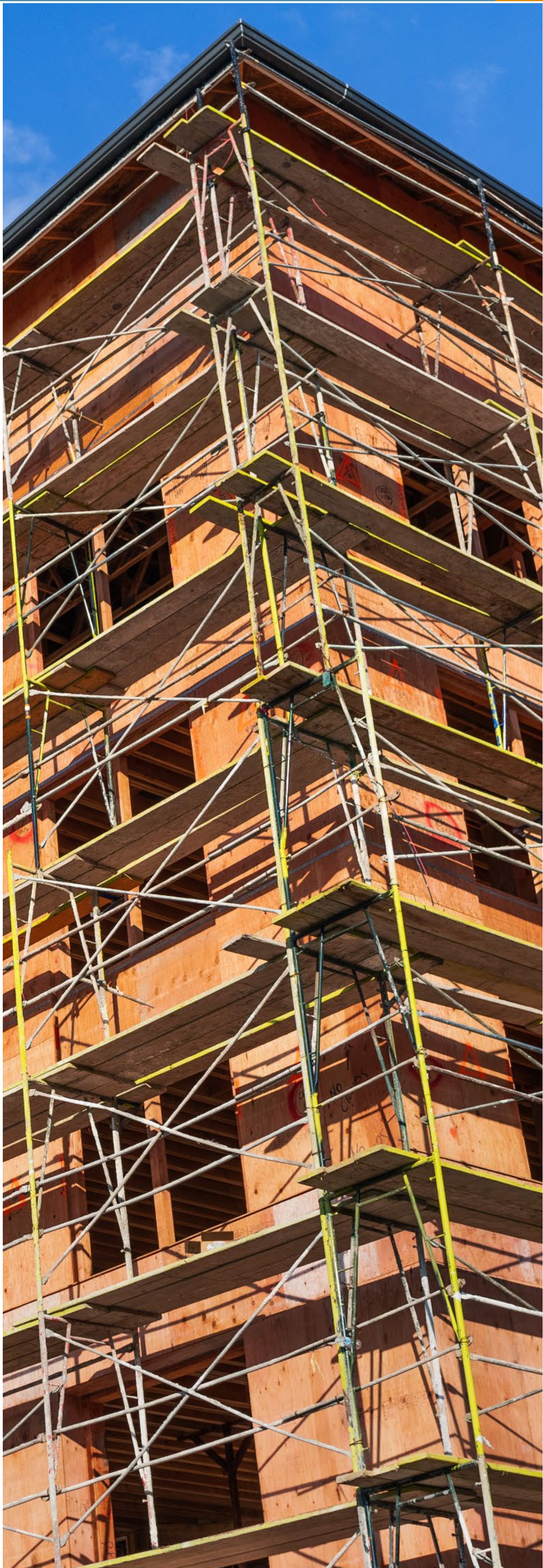

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Acronym List

2023 PV$ – Present value costs in 2023

ACH50 – Air Changes per Hour at 50 pascals pressure differential

ACM – Alternative Calculation Method

ADU – Accessory Dwelling Unit

AFUE – Annual Fuel Utilization Efficiency

B/C – Lifecycle Benefit-to-Cost Ratio

BEopt – Building Energy Optimization Tool

BSC – Building Standards Commission

CA IOUs – California Investor-Owned Utilities

CASE – Codes and Standards Enhancement

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

CFI – California Flexible Installation

CFM – Cubic Feet per Minute

CO_2 – Carbon Dioxide

CPAU – City of Palo Alto Utilities

CPUC – California Public Utilities Commission

CZ – California Climate Zone

DHW – Domestic Hot Water

DOE – Department of Energy

DWHR – Drain Water Heat Recovery

EDR – Energy Design Rating

EER – Energy Efficiency Ratio

EF – Energy Factor

GHG – Greenhouse Gas

HERS Rater – Home Energy Rating System Rater

HPA – High Performance Attic

HPWH – Heat Pump Water Heater

HSPF – Heating Seasonal Performance Factor

HVAC – Heating, Ventilation, and Air Conditioning

IECC – International Energy Conservation Code

IOU – Investor Owned Utility

kBtu – kilo-British thermal unit

kWh – Kilowatt Hour

LBNL – *Lawrence Berkeley National Laboratory*

LCC – Lifecycle Cost

LLAHU – Low Leakage Air Handler Unit

VLLDCS – Verified Low Leakage Ducts in Conditioned Space

MF – Multifamily

NEEA – Northwest Energy Efficiency Alliance

NEM – Net Energy Metering

NPV – Net Present Value

NREL – *National Renewable Energy Laboratory*

PG&E – Pacific Gas and Electric Company

POU – Publicly-Owned-Utilities

PV – Photovoltaic

SCE – Southern California Edison

SDG&E – San Diego Gas and Electric

SEER – Seasonal Energy Efficiency Ratio

SF – Single Family

SMUD – Sacramento Municipal Utility District

SoCalGas – Southern California Gas Company

TDV – Time Dependent Valuation

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

Title 24 – Title 24, Part 6

TOU – Time-Of-Use

UEF – Uniform Energy Factor

ZNE – Zero-net Energy

Summary Of Revisions

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

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Executive Summary

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

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

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

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

The following summarizes key results from the study:

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

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

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

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

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

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

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

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

1 Introduction

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

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

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

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

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

2 Methodology and Assumptions

2.1 Analysis for Reach Codes

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

2.1.1 Modeling

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

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

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

2.1.2 Cost-Effectiveness

2.1.2.1 Benefits

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

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

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

2.1.2.2 Costs

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

2.1.2.3 Metrics

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

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

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

Equation 1

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

Equation 2

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

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

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

Equation 3

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

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

Where:

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

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

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

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

Equation 4

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

2.1.3 Utility Rates

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

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

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

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

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

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

Table 1. Utility Tariffs Used Based on Climate Zone

IOUs

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

POUs

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

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

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

2.2 2022 T24 Compliance Metrics

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

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

2.3 Greenhouse Gas Emissions

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

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

3 Prototypes, Measure Packages, and Costs

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

3.1 Prototype Characteristics

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

Table 2 describes the basic characteristics of each prototype.

Table 2. Prototype Characteristics

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

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

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

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

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

Table 3. Base Case Characteristics of the Prototypes

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

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

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

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

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

3.2 Measure Definitions and Costs

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

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

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

3.2.1 Efficiency, Solar PV, and Batteries

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

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

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

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

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

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

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

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

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

Table 5. Incremental Cost Assumptions

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

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

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

3.2.2 All-Electric

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

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

3.2.2.1 Water Heating

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

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

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

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

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

3.2.2.2 Space Heating

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

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

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

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

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

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

3.2.2.3 Natural Gas Infrastructure

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

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

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

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

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

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

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

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

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

Table 10. Multifamily IOU Total Natural Gas Infrastructure Costs

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

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

Table 11. Multifamily CPAU Total Natural Gas Infrastructure Costs

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

3.3 Measure Packages

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

1. All-Electric Prescriptive Code: This package meets all the prescriptive requirements of the 2022 Energy Code.
2. All-Electric Prescriptive Code + PV: Using the code minimum package as a starting point, PV capacity was added to offset 100 percent of the estimated annual electricity use.
3. Mixed Fuel Efficiency Only: This package uses only efficiency measures that do not trigger federal preemption including envelope and duct distribution efficiency measures.

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

4. Mixed Fuel Efficiency + PV + Battery: Using the Efficiency Package as a starting point, PV capacity was added to offset 100 percent of the estimated annual electricity use. A battery system was also added. This package only applies to the 3-story prototype. The 5-story prototype includes a battery system in the baseline per the 2022 prescriptive requirements.
5. Mixed Fuel Efficiency + PV: Using the Efficiency Package as a starting point, PV capacity was added to offset 100 percent of the estimated annual electricity use. This package only applies to the 5-story prototype.

4 Results

Cost-effectiveness results are presented per prototype and measure packages described in Section 3.3. The TDV and On-Bill based cost-effectiveness results are presented in terms of B/C ratio and NPV. Energy savings, compliance margin, utility bill savings, and incremental costs are also shown.

In the following figures, green highlighting indicates that the case is cost-effective with a B/C ratio greater than or equal to 1 and a NPV greater than or equal to 0. Red highlighting indicates the case is not cost-effective.

Compliance margins are presented as percentages both for the efficiency TDV and the source energy metrics. A compliance margin that is equal to or greater than 0 indicates the case is code compliant.

4.1 All-Electric Prescriptive Code

Table 12 and Table 13 shows results for the multifamily all-electric prescriptive code case compared to the 2022 baseline. For both prototypes this scenario is cost-effective based on TDV in all climate zones. This scenario is only On-Bill cost-effective in a few climate zones. The 3-story all-electric case is cost-effective On-Bill in Climate Zones 1 through 3, 4 in CPAU territory, 12 in SMUD territory, and 16. The 5-story all-electric case is cost-effective On-Bill in Climate Zones 1, 4, 12 in SMUD territory, and 16.

In most cases there is a small net increase in utility cost in the first year.

There is an incremental cost for the central heat pump water heater ranging from $361 to $697 per dwelling unit.

The all-electric packages applied to the 3-story prototype in Climate Zone 16 and the 5-story prototype in Climate Zones 1 and 16 incorporate both gas to electric water heating and gas to electric space heating measures. In these cases, there are significant cost savings due to the avoided first costs of installing a gas furnace as compared to a heat pump. As a result, these cases are On-Bill cost-effective.

These results reflect a CO_2 refrigerant based central heat pump water heating system. The 5-story prototype was also evaluated with a R-134a refrigerant based central heat pump water heater and these results are shown in Appendix 7.5 Central Heat Pump Water Heater Comparison.

Table 12. 3-Story Cost-Effectiveness Results per Dwelling Unit: All-Electric Prescriptive Code

Climate Zone	Electric /Gas Utility	Efficiency TDV Comp Margin	Source Comp Margin	Annual Elec Savings (kWh)	Annual Gas Savings (therms)	Utility Cost Savings		Incremental Cost		On-Bill		TDV	
						First Year	Lifecycle (2022$)	First Year	Lifecycle (2022$)	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	26%	15%	-904	135	($19)	$1,676	$97	$429	3.9	$1,247	>1	$4,158
CZ02	PGE	20%	11%	-801	115	($30)	$1,061	$697	$1,029	1.0	$32	9.9	$2,998
CZ03	PGE	21%	10%	-789	115	($26)	$1,148	$697	$1,029	1.1	$119	9.9	$2,990
CZ04	PGE	18%	9%	-759	109	($31)	$922	$697	$1,029	0.9	($108)	9.2	$2,767
CZ04	CPAU	18%	9%	-759	109	$233	$8,191	$765	$1,097	7.5	$7,094	7.7	$2,700
CZ05	PGE	23%	9%	-789	112	($30)	$1,009	$697	$1,029	0.98	($21)	9.3	$2,782
CZ05	PGE/SCG	23%	9%	-789	112	($79)	($515)	$697	$1,029	0.0	($1,545)	9.3	$2,782
CZ06	SCE/SCG	18%	7%	-709	100	($61)	($226)	$697	$1,029	0.0	($1,255)	8.6	$2,551
CZ07	SDGE	20%	8%	-704	102	($69)	($427)	$697	$1,029	0.0	($1,456)	9.1	$2,712
CZ08	SCE/SCG	13%	6%	-689	96	($61)	($302)	$697	$1,029	0.0	($1,331)	8.2	$2,432
CZ09	SCE	13%	5%	-698	96	($64)	($351)	$697	$1,029	0.0	($1,380)	8.0	$2,363
CZ10	SCE/SCG	14%	7%	-701	83	($88)	($1,109)	$446	$649	0.0	($1,758)	>1	$1,959
CZ10	SDGE	14%	7%	-701	83	($112)	($1,803)	$446	$649	0.0	($2,452)	>1	$1,959
CZ11	PGE	14%	10%	-740	91	($64)	($177)	$446	$649	0.0	($826)	>1	$2,212
CZ12	PGE	17%	11%	-755	94	($62)	($70)	$446	$649	0.0	($719)	>1	$2,297
CZ12	SMUD/PGE	17%	11%	-755	94	$68	$2,942	$446	$649	4.5	$2,293	>1	$2,297
CZ13	PGE	13%	9%	-717	86	($65)	($291)	$446	$649	0.0	($940)	>1	$2,050
CZ14	SCE/SCG	13%	7%	-748	83	($102)	($1,413)	$446	$649	0.0	($2,063)	>1	$1,759
CZ14	SDGE	13%	7%	-748	83	($128)	($2,191)	$446	$649	0.0	($2,841)	>1	$1,759
CZ15	SCE/SCG	5%	2%	-607	64	($89)	($1,403)	$446	$649	0.0	($2,053)	>1	$1,305
CZ16	PG&E	24%	29%	-1,928	185	($178)	($1,066)	($4,045)	($2,983)	2.8	$1,917	>1	$4,352

Table 13. 5-Story Cost-Effectiveness Results per Dwelling Unit: All-Electric Prescriptive Code

Climate Zone	Electric /Gas Utility	Efficiency TDV Comp Margin	Source Comp Margin	Annual Elec Savings (kWh)	Annual Gas Savings (therms)	Utility Cost Savings		Incremental Cost		On-Bill		TDV	
						First Year	Lifecycle (2022$)	First Year	Lifecycle (2022$)	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	14%	9%	-1,146	147	($49)	$1,209	($4,639)	($5,788)	>1	$6,998	>1	$9,816
CZ02	PGE	9%	6%	-888	120	($45)	$809	$608	$1,185	0.7	($375)	3.0	$2,270
CZ03	PGE	11%	7%	-874	120	($46)	$778	$608	$1,185	0.7	($407)	3.1	$2,421
CZ04	PGE	9%	6%	-824	113	$18	$2,130	$608	$1,185	1.8	$945	3.1	$2,393
CZ04	CPAU	9%	6%	-824	113	$230	$8,205	$635	$1,211	6.8	$6,994	3.0	$2,367
CZ05	PGE	12%	6%	-871	117	($47)	$706	$608	$1,185	0.6	($479)	2.8	$2,065
CZ05	PGE/SCG	12%	6%	-871	117	($99)	($919)	$608	$1,185	0.0	($2,103)	2.8	$2,065
CZ06	SCE/SCG	9%	5%	-739	104	($10)	$986	$608	$1,185	0.8	($199)	2.9	$2,183
CZ07	SDGE	11%	6%	-735	106	($74)	($500)	$608	$1,185	0.0	($1,685)	2.9	$2,215
CZ08	SCE/SCG	8%	4%	-710	100	($79)	($644)	$608	$1,185	0.0	($1,829)	3.0	$2,259
CZ09	SCE	7%	4%	-725	100	($53)	($51)	$608	$1,185	0.0	($1,236)	3.0	$2,274
CZ10	SCE/SCG	7%	4%	-729	84	($111)	($1,615)	$361	$831	0.0	($2,445)	2.7	$1,374
CZ10	SDGE	7%	4%	-729	84	($137)	($2,404)	$361	$831	0.0	($3,234)	2.7	$1,374
CZ11	PGE	8%	5%	-790	92	($86)	($663)	$361	$831	0.0	($1,494)	3.1	$1,656
CZ12	PGE	9%	6%	-809	96	($83)	($527)	$361	$831	0.0	($1,358)	3.0	$1,620
CZ12	SMUD/PGE	9%	6%	-809	96	$62	$2,831	$361	$831	3.4	$2,000	3.0	$1,620
CZ13	PGE	7%	5%	-754	88	($83)	($686)	$361	$831	0.0	($1,517)	3.0	$1,570
CZ14	SCE/SCG	6%	3%	-803	84	($131)	($2,085)	$361	$831	0.0	($2,916)	2.2	$928
CZ14	SDGE	6%	3%	-803	84	($165)	($3,106)	$361	$831	0.0	($3,937)	2.2	$928
CZ15	SCE/SCG	3%	1%	-602	65	($105)	($1,775)	$361	$831	0.0	($2,606)	1.9	$695
CZ16	PG&E	9%	11%	-1,388	142	($127)	($675)	($4,886)	($6,142)	9.1	$5,467	>1	$6,704

4.2 All-Electric Plus PV

Table 14 and Table 15 present cost-effectiveness results for the all-electric plus PV packages for the 3-story and 5-story prototypes, respectively. All cases are cost-effective both On-Bill and based on TDV.

Table 14. 3-Story Cost-Effectiveness Results per Dwelling Unit: All-Electric 100% PV

Climate Zone	Electric /Gas Utility	Efficiency TDV Comp Margin	Source Comp Margin	Annual Elec Savings (kWh)	Annual Gas Savings (therms)	Utility Cost Savings		Incremental Cost		On-Bill		TDV	
						First Year	Lifecycle (2022$)	First Year	Lifecycle (2022$)	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	26%	24%	2,127	135	$782	$20,242	$3,638	$5,034	4.0	$15,208	3.2	$9,448
CZ02	PGE	20%	20%	1,835	115	$653	$16,910	$3,294	$4,406	3.8	$12,504	3.3	$8,632
CZ03	PGE	21%	20%	1,711	115	$614	$15,998	$3,076	$4,123	3.9	$11,875	3.4	$8,209
CZ04	PGE	18%	18%	1,558	109	$559	$14,587	$2,841	$3,818	3.8	$10,770	3.6	$8,230
CZ04	CPAU	18%	18%	1,558	109	$489	$14,138	$2,909	$3,886	3.6	$10,253	3.6	$8,162
CZ05	PGE	23%	20%	1,604	112	$579	$15,137	$2,826	$3,798	4.0	$11,338	3.6	$8,026
CZ05	PGE/SCG	23%	20%	1,604	112	$531	$13,613	$2,826	$3,798	3.6	$9,814	3.6	$8,026
CZ06	SCE/SCG	18%	17%	1,207	100	$378	$9,795	$2,364	$3,197	3.1	$6,598	3.8	$7,092
CZ07	SDGE	20%	21%	1,528	102	$723	$19,318	$2,777	$3,734	5.2	$15,584	3.5	$7,623
CZ08	SCE/SCG	13%	17%	1,393	96	$426	$10,842	$2,569	$3,464	3.1	$7,378	3.9	$7,908
CZ09	SCE	13%	15%	1,204	96	$379	$9,756	$2,335	$3,160	3.1	$6,596	3.9	$7,158
CZ10	SCE/SCG	14%	18%	1,381	83	$404	$10,130	$2,237	$2,978	3.4	$7,152	4.1	$7,031
CZ10	SDGE	14%	18%	1,381	83	$621	$16,493	$2,237	$2,978	5.5	$13,514	4.1	$7,031
CZ11	PGE	14%	19%	1,843	91	$625	$15,782	$2,940	$3,893	4.1	$11,889	3.4	$7,748
CZ12	PGE	17%	19%	1,704	94	$579	$14,777	$2,756	$3,654	4.0	$11,124	3.6	$7,607
CZ12	SMUD/PGE	17%	19%	1,704	94	$399	$10,615	$2,756	$3,654	2.9	$6,961	3.6	$7,607
CZ13	PGE	13%	17%	1,572	86	$544	$13,822	$2,567	$3,408	4.1	$10,415	3.6	$7,148
CZ14	SCE/SCG	13%	18%	1,572	83	$449	$11,152	$2,300	$3,060	3.6	$8,092	4.2	$7,668
CZ14	SDGE	13%	18%	1,572	83	$688	$18,158	$2,300	$3,060	5.9	$15,098	4.2	$7,668
CZ15	SCE/SCG	5%	11%	1,163	64	$330	$8,164	$1,966	$2,626	3.1	$5,539	3.9	$5,567
CZ16	PG&E	24%	38%	1,371	185	$700	$19,307	($1,064)	$894	21.6	$18,412	58.9	$11,596

Table 15. 5-Story Cost-Effectiveness Results per Dwelling Unit: All-Electric 100% PV

Climate Zone	Electric /Gas Utility	Efficiency TDV Comp Margin	Source Comp Margin	Annual Elec Savings (kWh)	Annual Gas Savings (therms)	Utility Cost Savings		Incremental Cost		On-Bill		TDV	
						First Year	Lifecycle (2022$)	First Year	Lifecycle (2022$)	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	14%	21%	1,437	147	$629	$16,919	($1,574)	($1,803)	>1	$18,721	>1	$18,222
CZ02	PGE	9%	14%	428	120	$262	$7,918	$1,930	$2,904	2.7	$5,015	4.0	$8,679
CZ03	PGE	11%	16%	682	120	$327	$9,417	$2,121	$3,152	3.0	$6,265	4.0	$9,285
CZ04	PGE	9%	13%	92	113	$207	$6,524	$1,476	$2,313	2.8	$4,211	4.1	$7,054
CZ04	CPAU	9%	13%	92	113	$337	$10,667	$1,502	$2,340	4.6	$8,327	4.0	$7,027
CZ05	PGE	12%	16%	451	117	$259	$7,806	$1,815	$2,754	2.8	$5,052	4.0	$8,096
CZ05	PGE/SCG	12%	16%	451	117	$207	$6,182	$1,815	$2,754	2.2	$3,427	4.0	$8,096
CZ06	SCE/SCG	9%	12%	-163	104	$98	$3,449	$1,127	$1,859	1.9	$1,590	3.8	$5,035
CZ07	SDGE	11%	15%	74	106	$192	$6,131	$1,387	$2,198	2.8	$3,934	3.9	$6,204
CZ08	SCE/SCG	8%	14%	265	100	$154	$4,666	$1,516	$2,365	2.0	$2,301	4.0	$7,053
CZ09	SCE	7%	12%	60	100	$122	$3,930	$1,307	$2,093	1.9	$1,837	3.7	$5,636
CZ10	SCE/SCG	7%	13%	289	84	$131	$3,912	$1,266	$2,007	1.9	$1,905	3.9	$5,749
CZ10	SDGE	7%	13%	289	84	$238	$6,951	$1,266	$2,007	3.5	$4,945	3.9	$5,749
CZ11	PGE	8%	17%	1,091	92	$417	$10,990	$2,226	$3,256	3.4	$7,734	4.2	$10,472
CZ12	PGE	9%	16%	594	96	$263	$7,487	$1,712	$2,587	2.9	$4,901	4.3	$8,544
CZ12	SMUD/PGE	9%	16%	594	96	$260	$7,419	$1,712	$2,587	2.9	$4,889	4.3	$8,544
CZ13	PGE	7%	17%	1,036	88	$398	$10,479	$2,064	$3,045	3.4	$7,434	4.2	$9,715
CZ14	SCE/SCG	6%	11%	182	84	$102	$3,250	$1,170	$1,883	1.7	$1,368	4.0	$5,515
CZ14	SDGE	6%	11%	182	84	$194	$5,858	$1,170	$1,883	3.1	$3,975	4.0	$5,515
CZ15	SCE/SCG	3%	10%	387	65	$153	$4,119	$1,238	$1,971	2.1	$2,148	3.6	$4,998
CZ16	PG&E	9%	23%	1,007	142	$501	$13,864	($2,682)	($3,275)	>1	$17,139	>1	$16,140

4.3 Mixed Fuel Efficiency

Table 16 and Table 17 show results for the Mixed Fuel Efficiency packages. The packages are cost-effective based on at least one of the two metrics in Climate Zones 1, 2, 4, and 8 through 16 for the 3-story prototype and in Climate Zones 2, 4, 6, and 8 through 15 for the 5-story prototype. In all cases the NPV values, whether negative or positive, are small. The compliance impacts are also small.

A summary of measures included in each package is provided in Appendix 7.6 Summary of Measures by Package.

Table 16. 3-Story Cost-Effectiveness Results per Dwelling Unit: Mixed Fuel Efficiency

Climate Zone	Electric /Gas Utility	Efficiency TDV Comp Margin	Source Comp Margin	Annual Elec Savings (kWh)	Annual Gas Savings (therms)	Utility Cost Savings		Incremental Cost		On-Bill		TDV	
						First Year	Lifecycle (2022$)	First Year	Lifecycle (2022$)	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	1%	1%	41	0	$12	$273	$176	$176	1.6	$98	1.2	$38
CZ02	PGE	1%	0%	24	0	$7	$162	$132	$132	1.2	$30	1.5	$62
CZ03	PGE	1%	0%	17	0	$5	$111	$132	$132	0.8	($21)	0.8	($27)
CZ04	PGE	1%	0%	21	0	$6	$141	$132	$132	1.1	$9	1.3	$46
CZ04	CPAU	1%	0%	21	0	$3	$74	$132	$132	0.6	($58)	1.3	$46
CZ05	PGE	1%	0%	19	0	$5	$123	$132	$132	0.9	($9)	0.8	($32)
CZ05	PGE/SCG	1%	0%	19	0	$5	$123	$132	$132	0.9	($9)	0.8	($32)
CZ06	SCE/SCG	1%	0%	9	0	$2	$56	$132	$132	0.4	($75)	0.7	($44)
CZ07	SDGE	0%	0%	7	0	$3	$72	$132	$132	0.5	($60)	0.4	($81)
CZ08	SCE/SCG	1%	0%	20	0	$6	$140	$132	$132	1.1	$9	1.5	$59
CZ09	SCE	1%	0%	28	0	$8	$192	$146	$156	1.2	$36	1.6	$88
CZ10	SCE/SCG	3%	1%	65	0	$20	$447	$190	$199	2.2	$247	2.4	$277
CZ10	SDGE	3%	1%	65	0	$27	$683	$190	$199	3.4	$484	2.4	$277
CZ11	PGE	3%	1%	91	0	$30	$699	$190	$199	3.5	$499	3.5	$489
CZ12	PGE	2%	0%	98	0	$33	$766	$381	$514	1.5	$252	1.5	$273
CZ12	SMUD/PGE	2%	0%	98	0	$17	$396	$381	$514	0.8	($118)	1.5	$273
CZ13	PGE	4%	1%	99	0	$33	$765	$190	$199	3.8	$566	3.9	$574
CZ14	SCE/SCG	3%	1%	88	0	$26	$585	$190	$199	2.9	$385	3.1	$427
CZ14	SDGE	3%	1%	88	0	$36	$886	$190	$199	4.4	$686	3.1	$427
CZ15	SCE/SCG	5%	2%	182	0	$54	$1,226	$190	$199	6.1	$1,026	5.8	$957
CZ16	PG&E	5%	4%	16	12	$34	$1,012	$712	$712	1.4	$300	1.3	$184

Table 17. 5-Story Cost-Effectiveness Results per Dwelling Unit: Mixed Fuel Efficiency

Climate Zone	Electric /Gas Utility	Efficiency TDV Comp Margin	Source Comp Margin	Annual Elec Savings (kWh)	Annual Gas Savings (therms)	Utility Cost Savings		Incremental Cost		On-Bill		TDV	
						First Year	Lifecycle (2022$)	First Year	Lifecycle (2022$)	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	0%	0%	5	0	$2	$39	$176	$176	0.2	($137)	0.2	($136)
CZ02	PGE	1%	0%	11	0	$2	$38	$132	$132	0.3	($94)	1.9	$118
CZ03	PGE	0%	0%	7	0	$2	$46	$132	$132	0.3	($86)	0.8	($23)
CZ04	PGE	1%	0%	12	0	$2	$40	$132	$132	0.3	($92)	1.9	$114
CZ04	CPAU	1%	0%	12	0	$2	$39	$132	$132	0.3	($93)	1.9	$114
CZ05	PGE	0%	0%	6	0	$1	$17	$132	$132	0.1	($114)	0.4	($73)
CZ05	PGE/SCG	0%	0%	6	0	$1	$17	$132	$132	0.1	($114)	0.4	($73)
CZ06	SCE/SCG	0%	0%	12	0	$2	$51	$132	$132	0.4	($81)	1.4	$49
CZ07	SDGE	0%	0%	10	0	$0	$0	$132	$132	0.0	($132)	0.9	($7)
CZ08	SCE/SCG	1%	0%	24	0	$8	$184	$132	$132	1.4	$53	2.2	$152
CZ09	SCE	1%	0%	28	0	$4	$96	$142	$149	0.6	($52)	2.1	$163
CZ10	SCE/SCG	2%	1%	66	0	$21	$491	$186	$192	2.6	$298	3.2	$425
CZ10	SDGE	2%	1%	66	0	$30	$751	$186	$192	3.9	$558	3.2	$425
CZ11	PGE	2%	1%	83	0	$29	$665	$186	$192	3.5	$473	4.2	$621
CZ12	PGE	2%	0%	84	0	$29	$681	$321	$414	1.6	$267	2.3	$546
CZ12	SMUD/PGE	2%	0%	84	0	$16	$372	$321	$414	0.9	($42)	2.3	$546
CZ13	PGE	2%	1%	95	0	$33	$765	$186	$192	4.0	$573	4.9	$742
CZ14	SCE/SCG	2%	1%	75	0	$11	$246	$186	$192	1.3	$54	3.9	$561
CZ14	SDGE	2%	1%	75	0	$34	$847	$186	$192	4.4	$654	3.9	$561
CZ15	SCE/SCG	3%	2%	172	0	$55	$1,257	$186	$192	6.5	$1,065	7.3	$1,212
CZ16	PG&E	2%	2%	40	4	$23	$616	$665	$665	0.9	($49)	0.999	($0)

4.4 Mixed Fuel Plus PV (Plus Battery for the 3-Story Prototype)

Table 18 presents the Mixed Fuel Efficiency + PV + Battery package for the 3-story prototype. The battery system is a 100kWh battery. This scenario is cost-effective for all climate zones and under both metrics except for On-Bill in Climate Zone 4 in CPAU territory. Table 19 presents the Mixed Fuel Efficiency + PV package for the 5-story prototype. This package is cost-effective under TDV in all climate zones and cost-effective On-Bill everywhere except in Climate Zones 6 and 7. In the cases where it is not cost-effective, it is very close to being so with small negative NPV. In Climate Zone 6 in the 5-story prototype there is no upgrade to the PV system capacity as the prescriptive PV system already offset all of the estimated electricity use.

Table 18. 3-Story Cost-Effectiveness Results per Dwelling Unit: Mixed Fuel Efficiency + PV + Battery

Climate Zone	Electric /Gas Utility	Efficiency TDV Comp Margin	Source Comp Margin	Annual Elec Savings (kWh)	Annual Gas Savings (therms)	Utility Cost Savings		Incremental Cost		On-Bill		TDV	
						First Year	Lifecycle (2022$)	First Year	Lifecycle (2022$)	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	1%	16%	2,068	0	$543	$12,588	$4,603	$6,917	1.8	$5,671	1.5	$3,724
CZ02	PGE	1%	16%	1,757	0	$462	$10,718	$3,881	$5,990	1.8	$4,728	1.6	$3,820
CZ03	PGE	1%	17%	1,624	0	$423	$9,797	$3,700	$5,754	1.7	$4,043	1.5	$3,157
CZ04	PGE	1%	17%	1,476	0	$383	$8,878	$3,518	$5,518	1.6	$3,360	1.6	$3,067
CZ04	CPAU	1%	17%	1,476	0	$171	$3,967	$3,518	$5,518	0.7	($1,551)	1.6	$3,067
CZ05	PGE	1%	18%	1,520	0	$393	$9,107	$3,503	$5,498	1.7	$3,609	1.6	$3,526
CZ05	PGE/SCG	1%	18%	1,520	0	$393	$9,107	$3,503	$5,498	1.7	$3,609	1.6	$3,526
CZ06	SCE/SCG	1%	18%	1,112	0	$336	$7,677	$3,127	$5,009	1.5	$2,668	1.4	$1,917
CZ07	SDGE	0%	20%	1,431	0	$550	$13,713	$3,498	$5,493	2.5	$8,220	1.6	$3,159
CZ08	SCE/SCG	1%	18%	1,311	0	$413	$9,427	$3,328	$5,270	1.8	$4,156	1.4	$2,277
CZ09	SCE	1%	17%	1,129	0	$367	$8,375	$3,129	$5,017	1.7	$3,359	1.4	$1,937
CZ10	SCE/SCG	3%	19%	1,342	0	$420	$9,584	$3,321	$5,254	1.8	$4,331	1.5	$2,588
CZ10	SDGE	3%	19%	1,342	0	$533	$13,303	$3,321	$5,254	2.5	$8,049	1.5	$2,588
CZ11	PGE	3%	17%	1,833	0	$500	$11,587	$3,914	$6,025	1.9	$5,562	1.6	$3,852
CZ12	PGE	2%	17%	1,701	0	$442	$10,239	$3,926	$6,105	1.7	$4,133	1.6	$3,583
CZ12	SMUD/PGE	2%	17%	1,701	0	$285	$6,609	$3,926	$6,105	1.1	$503	1.6	$3,583
CZ13	PGE	4%	17%	1,568	0	$431	$9,983	$3,594	$5,609	1.8	$4,374	1.7	$3,944
CZ14	SCE/SCG	3%	19%	1,556	0	$477	$10,886	$3,388	$5,341	2.0	$5,545	1.6	$3,434
CZ14	SDGE	3%	19%	1,556	0	$607	$15,155	$3,388	$5,341	2.8	$9,815	1.6	$3,434
CZ15	SCE/SCG	5%	19%	1,241	0	$421	$9,616	$3,136	$5,013	1.9	$4,603	1.6	$3,076
CZ16	PG&E	5%	17%	1,286	12	$357	$8,508	$3,894	$5,833	1.5	$2,674	1.6	$3,219

Table 19. 5-Story Cost-Effectiveness Results per Dwelling Unit: Mixed Fuel Efficiency + PV

Climate Zone	Electric /Gas Utility	Efficiency TDV Comp Margin	Source Comp Margin	Annual Elec Savings (kWh)	Annual Gas Savings (therms)	Utility Cost Savings		Incremental Cost		On-Bill		TDV	
						First Year	Lifecycle (2022$)	First Year	Lifecycle (2022$)	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	0%	5%	1,446	0	$341	$7,917	$1,889	$2,403	3.3	$5,514	3.0	$4,757
CZ02	PGE	1%	2%	444	0	$55	$1,275	$567	$697	1.8	$578	4.4	$2,365
CZ03	PGE	0%	4%	693	0	$119	$2,766	$801	$1,002	2.8	$1,764	4.4	$3,423
CZ04	PGE	1%	1%	112	0	$14	$324	$226	$254	1.3	$69	3.5	$632
CZ04	CPAU	1%	1%	112	0	$13	$307	$226	$254	1.2	$53	3.5	$632
CZ05	PGE	0%	3%	464	0	$56	$1,310	$550	$676	1.9	$634	4.2	$2,165
CZ05	PGE/SCG	0%	3%	464	0	$56	$1,310	$550	$676	1.9	$634	4.2	$2,165
CZ06	SCE/SCG	0%	0%	12	0	$2	$51	$132	$132	0.4	($81)	1.4	$49
CZ07	SDGE	0%	1%	95	0	$0	$0	$212	$237	0.0	($237)	2.8	$423
CZ08	SCE/SCG	1%	3%	299	0	$42	$968	$388	$465	2.1	$504	4.3	$1,527
CZ09	SCE	1%	1%	99	0	$12	$284	$204	$230	1.2	$54	3.0	$465
CZ10	SCE/SCG	2%	3%	364	0	$57	$1,296	$450	$536	2.4	$759	4.2	$1,720
CZ10	SDGE	2%	3%	364	0	$103	$2,566	$450	$536	4.8	$2,030	4.2	$1,720
CZ11	PGE	2%	7%	1,178	0	$281	$6,521	$1,276	$1,610	4.1	$4,911	4.8	$6,162
CZ12	PGE	2%	4%	683	0	$120	$2,791	$898	$1,164	2.4	$1,627	4.2	$3,716
CZ12	SMUD/PGE	2%	4%	683	0	$102	$2,362	$898	$1,164	2.0	$1,198	4.2	$3,716
CZ13	PGE	2%	7%	1,137	0	$274	$6,347	$1,179	$1,484	4.3	$4,863	4.8	$5,599
CZ14	SCE/SCG	2%	2%	266	0	$33	$748	$342	$395	1.9	$353	4.7	$1,447
CZ14	SDGE	2%	2%	266	0	$62	$1,554	$342	$395	3.9	$1,158	4.7	$1,447
CZ15	SCE/SCG	3%	5%	567	0	$125	$2,851	$535	$646	4.4	$2,204	5.6	$2,994
CZ16	PG&E	2%	6%	1,051	4	$237	$5,569	$1,601	$1,883	3.0	$3,686	3.1	$4,011

4.5 CARE Rate Comparison

Table 20 presents a comparison of On-Bill cost-effectiveness results for CARE tariffs relative to standard tariffs for the all-electric prescriptive code case. The CARE rates apply to the apartment meters only and don't impact the central water heating utility costs. Applying the CARE rates lowers both electric and gas utility bills for the consumer and the net impact for an all-electric building in most climate zones is lower overall bills and improved cost-effectiveness relative to the standard tariffs. Although not presented here, the all-electric + PV packages are all still On-Bill cost-effective using the CARE tariffs.

Table 20. On-Bill IOU Cost-Effectiveness Comparison with CARE Tariffs, Results per Dwelling Unit: All-Electric Prescriptive Code

Climate Zone	Electric /Gas Utility	3-Story				5-Story			
		Standard		CARE		Standard		CARE	
		B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	3.9	$1,247	9.5	$3,637	>1	$6,998	>1	$10,045
CZ02	PGE	1.0	$32	3.1	$2,139	0.7	($375)	2.5	$1,831
CZ03	PGE	1.1	$119	3.1	$2,187	0.7	($407)	2.6	$1,901
CZ04	PGE	0.9	($108)	2.8	$1,884	1.8	$945	2.9	$2,218
CZ05	PGE	0.98	($21)	3.0	$2,041	0.6	($479)	2.5	$1,773
CZ05	PGE/SCG	0.0	($1,545)	1.5	$517	0.0	($2,103)	1.1	$148
CZ06	SCE/SCG	0.0	($1,255)	0.9	($57)	0.8	($199)	2.1	$1,349
CZ07	SDGE	0.0	($1,456)	1.8	$856	0.0	($1,685)	1.3	$343
CZ08	SCE/SCG	0.0	($1,331)	0.8	($165)	0.0	($1,829)	1.2	$271
CZ09	SCE	0.0	($1,380)	0.8	($204)	0.0	($1,236)	1.6	$750
CZ10	SCE/SCG	0.0	($1,758)	0.1	($574)	0.0	($2,445)	0.5	($447)
CZ10	SDGE	0.0	($2,452)	0.8	($162)	0.0	($3,234)	0.0	($1,590)
CZ11	PGE	0.0	($826)	2.7	$1,119	0.0	($1,494)	1.7	$616
CZ12	PGE	0.0	($719)	2.9	$1,263	0.0	($1,358)	2.0	$793
CZ13	PGE	0.0	($940)	2.4	$936	0.0	($1,517)	1.6	$491
CZ14	SCE/SCG	0.0	($2,063)	0.0	($803)	0.0	($2,916)	0.3	($613)
CZ14	SDGE	0.0	($2,841)	0.0	($3,407)	0.0	($3,937)	1.1	$61
CZ15	SCE/SCG	0.0	($2,053)	0.0	($1,036)	0.0	($2,606)	0.0	($1,452)
CZ16	PG&E	2.8	$1,917	>1	$5,527	9.1	$5,467	>1	$8,557

Error! Not a valid bookmark self-reference. presents the comparison for the mixed fuel efficiency and PV packages. Generally, the opposite trend occurs here for the mixed fuel packages where the CARE rate lowers utility cost savings and the benefit-to-cost ratios decline.

Table 21. On-Bill IOU Cost-Effectiveness Comparison with CARE Tariffs, Results per Dwelling Unit: Mixed Fuel Packages

Climate Zone	Electric /Gas Utility	3-Story (Efficiency + PV + Battery)				5-Story (Efficiency + PV)			
		Standard		CARE		Standard		CARE	
		B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	1.8	$5,671	1.2	$1,113	3.3	$5,514	2.2	$2,765
CZ02	PGE	1.8	$4,728	1.2	$907	1.8	$578	1.5	$337
CZ03	PGE	1.7	$4,043	1.1	$579	2.8	$1,764	2.0	$1,028
CZ04	PGE	1.6	$3,360	1.0	$259	1.3	$69	0.8	($44)
CZ05	PGE	1.7	$3,609	1.1	$414	1.9	$634	1.7	$442
CZ05	PGE/SCG	1.7	$3,609	1.1	$414	1.9	$634	1.7	$442
CZ06	SCE/SCG	1.5	$2,668	0.9	($515)	0.4	($81)	0.3	($92)
CZ07	SDGE	2.5	$8,220	1.7	$4,106	0.0	($237)	0.0	($237)
CZ08	SCE/SCG	1.8	$4,156	1.1	$446	2.1	$504	1.3	$137
CZ09	SCE	1.7	$3,359	0.99	($26)	1.2	$54	0.9	($28)
CZ10	SCE/SCG	1.8	$4,331	1.1	$577	2.4	$759	1.3	$180
CZ10	SDGE	2.5	$8,049	1.8	$4,180	4.8	$2,030	0.0	($536)
CZ11	PGE	1.9	$5,562	1.2	$1,435	4.1	$4,911	2.7	$2,744
CZ12	PGE	1.7	$4,133	1.1	$517	2.4	$1,627	1.8	$905
CZ13	PGE	1.8	$4,374	1.2	$883	4.3	$4,863	2.9	$2,777
CZ14	SCE/SCG	2.0	$5,545	1.3	$1,395	1.9	$353	1.3	$136
CZ14	SDGE	2.8	$9,815	1.4	$2,292	3.9	$1,158	0.0	($395)
CZ15	SCE/SCG	1.9	$4,603	1.2	$887	4.4	$2,204	1.9	$586
CZ16	PG&E	1.5	$2,674	0.97	($162)	3.0	$3,686	2.0	$1,908

4.6 Greenhouse Gas Reductions

Figure 1 and Figure 2 compare greenhouse gas reductions across all the packages for the multifamily 3-story and 5-story prototypes, respectively. Savings represent average annual savings per dwelling unit over the 30-year lifetime of the analysis. Electrification of gas uses represents the greatest greenhouse gas reductions, followed by PV. Greenhouse gas reductions are greatest for the all-electric + PV package.

Figure 1. 3-Story greenhouse gas reductions (metric tons) per dwelling unit

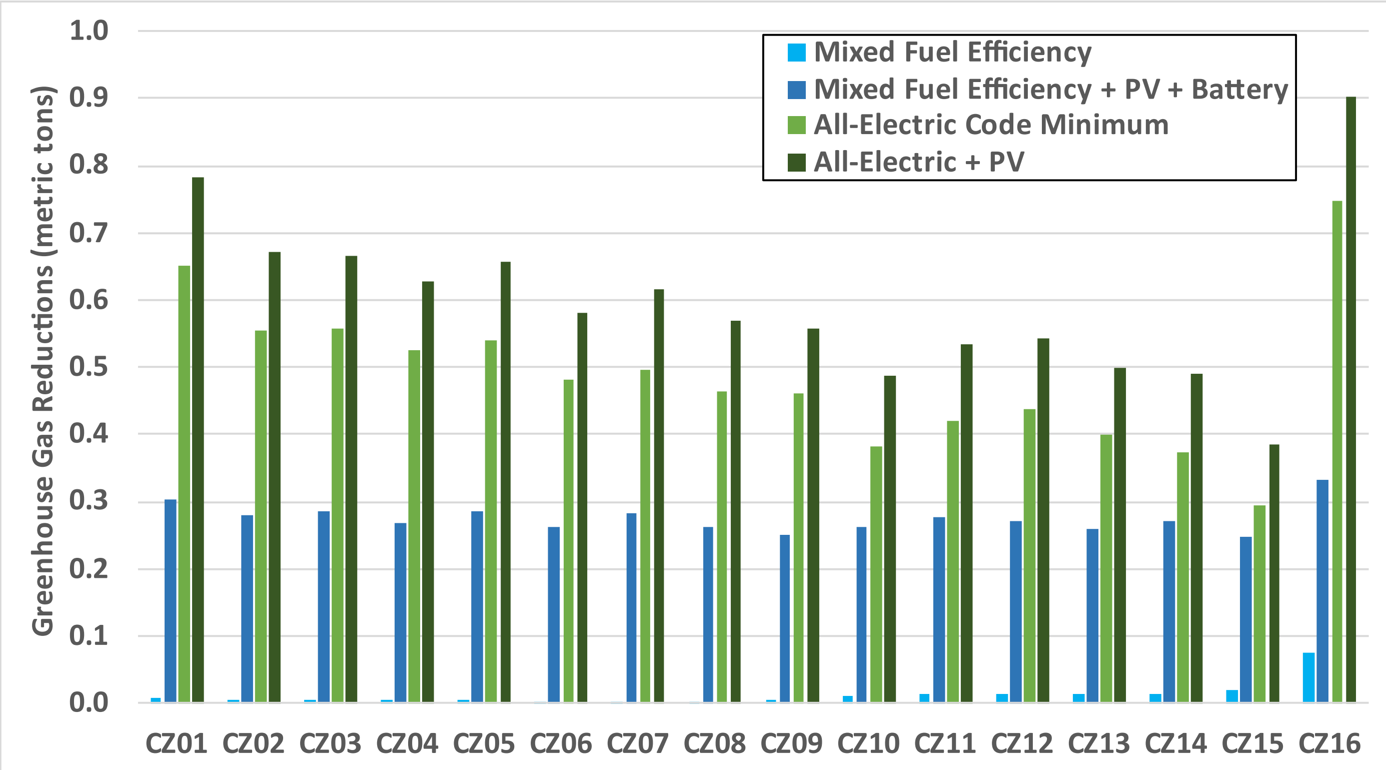
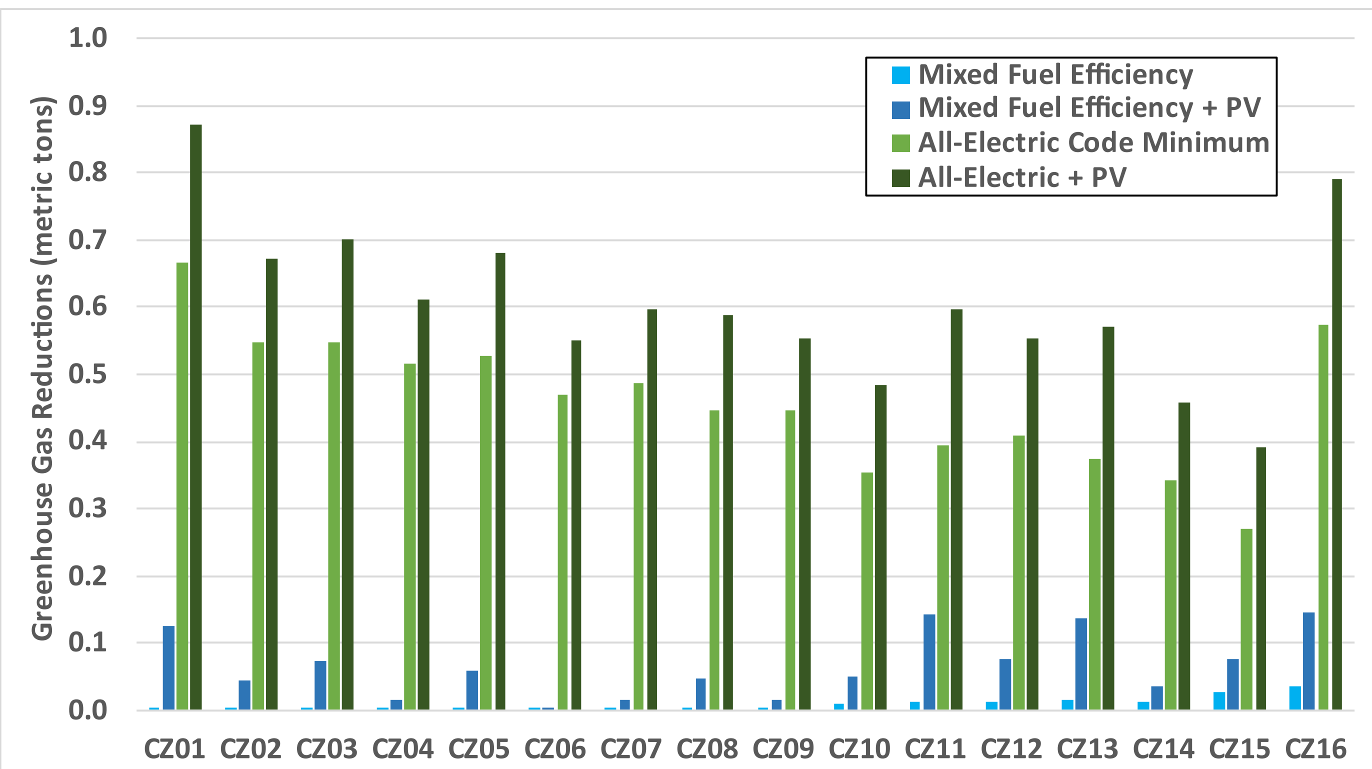


Figure 2. 5-Story greenhouse gas savings (metric tons) per dwelling unit



5 Summary

The Reach Codes Team identified packages of electrification and energy efficiency measures as well as packages combining these measures with solar PV generation and battery storage, simulated them using building modeling software, and gathered costs to determine the cost-effectiveness of multiple scenarios. The Reach Codes Team coordinated with multiple utilities, cities, and building community experts to develop a set of assumptions considered reasonable in the current market. Changing assumptions, such as the period of analysis, measure selection, cost assumptions, energy escalation rates, or utility tariffs are likely to change results.

Table 22 summarizes results for each prototype and depicts the efficiency TDV compliance margins achieved for each climate zone and package. Because local reach codes must both exceed the Energy Commission performance budget (i.e., have a positive compliance margin) and be cost-effective, the Reach Codes Team highlighted cells meeting these two requirements to help clarify the upper boundary for potential reach code policies. All results presented in this study have a positive compliance margin.

- Cells highlighted in **green** depict cases with a positive compliance margin and cost-effective results using both On-Bill and TDV approaches.
- Cells highlighted in **yellow** depict cases with a positive compliance margin and cost-effective results using either the On-Bill or TDV approach.
- Cells **not highlighted** depict cases with a positive compliance margin but that were not cost-effective using either the On-Bill or TDV approach.

Following are key takeaways and recommendations from the analysis.

- The Reach Codes Team found all-electric new construction to be feasible and cost-effective based on the California Energy Commission's Time Dependent Valuation (TDV) metric in all cases. In many cases all-electric prescriptive code construction results in an increase in utility costs and is not cost-effective On-Bill. Some exceptions include the SMUD and CPAU territories where lower electricity rates relative to gas rates result in lower overall utility bills.
- All-electric packages have lower GHG emissions than mixed fuel packages in all cases, due to the clean power sources currently available from California's power providers.
- The 2022 Energy Code's new source energy metric combined with the heat pump space heating baseline in most climate zones encourages all-electric construction. While the code does not include an electric baseline for water heating, the penalty for central electric water heating observed in the performance approach in past code cycles has been removed and a credit is provided for well-designed central heat pump water heaters in most cases.
- Electrification combined with increased PV capacity results in utility cost savings and was found to be On-Bill cost-effective in all cases.
- The results in this study are based on today's net energy metering (NEM 2.0) rules and do not account for recently approved changes to the NEM tariff (referred to as the net billing tariff). The net billing tariff decreases the value of PV to the consumer as compared to NEM 2.0. As a result, the cost-effectiveness of the packages that include above-code PV capacity is expected to be less under the net billing tariff. Conversely, the net billing tariff is expected to increase On-Bill cost-effectiveness of the all-electric prescriptive code scenario. An all-electric home has better on-site utilization of generated electricity from PV than a mixed fuel home with a similar sized PV system, and as a result exports less electricity to the grid. Since the net-billing tariff values exports less than under NEM 2.0, the relative impact on annual utility costs to the mixed fuel baseline is greater.
- This analysis does justify requiring a modest reach based on either efficiency TDV or source energy for all-electric buildings. However, this may be challenging for some projects given the recent changes to which the industry must adapt, including the efficiency updates and multifamily restructuring in the 2022 Title 24, Part 6 code. While project compliance margins using a CO_2 refrigerant heat pump water heating system are high, the Reach Code Team found lower compliance margins using other heat pump water heater system designs.

Focusing on supporting projects to electrify water heating is expected to support the market shift towards more central heat pump water heaters.

- For jurisdictions interested in a reach code that allows for mixed fuel buildings, a mixed fuel efficiency and PV package (and battery for the 3-story prototype) was found to be cost-effective based on TDV in all cases and cost-effective On-Bill in most climate zones. This path, referred to as "Electric-Preferred", allows for mixed fuel buildings but requires a higher building performance than for all-electric buildings. The efficiency measures evaluated in this study did not provide significant compliance benefit. As a result, the Reach Codes Team recommends establishing a compliance margin target based on source energy or total TDV. This would allow for PV and battery above minimum code requirements to be used to meet the target.
- Jurisdictions interested in increasing affordable multifamily housing should know that applying the CARE rates has the overall impact of increasing utility cost savings for an all-electric building in most climate zones compared to a code compliant mixed fuel building, improving On-Bill cost-effectiveness.

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

Table 22. Summary of Efficiency TDV Compliance Margins and Cost-Effectiveness

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

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

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

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

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

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