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CALIFORNIA ENERGY CODES & STANDARDS
A STATEWIDE UTILITY PROGRAM

2022 Cost-Effectiveness Study: Single Family New Construction

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Acronym List

2023 PV$ – Present value costs in 2023

ACH50 – Air Changes per Hour at 50 pascals pressure differential

ACM – Alternative Calculation Method

ADU – Accessory Dwelling Unit

AFUE – Annual Fuel Utilization Efficiency

B/C – Lifecycle Benefit-to-Cost Ratio

BEopt – Building Energy Optimization Tool

BSC – Building Standards Commission

CA IOUs – California Investor-Owned Utilities

CASE – Codes and Standards Enhancement

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

CFI – California Flexible Installation

CFM – Cubic Feet per Minute

CO_2 – Carbon Dioxide

CPAU – City of Palo Alto Utilities

CPUC – California Public Utilities Commission

CZ – California Climate Zone

DHW – Domestic Hot Water

DOE – Department of Energy

DWHR – Drain Water Heat Recovery

EDR – Energy Design Rating

EER – Energy Efficiency Ratio

EF – Energy Factor

GHG – Greenhouse Gas

HERS Rater – Home Energy Rating System Rater

HPA – High Performance Attic

HPWH – Heat Pump Water Heater

HSPF – Heating Seasonal Performance Factor

IECC – International Energy Conservation Code

IOU – Investor Owned Utility

kBtu – kilo-British thermal unit

kWh – Kilowatt Hour

LBNL – *Lawrence Berkeley National Laboratory*

LCC – Lifecycle Cost

LLAHU – Low Leakage Air Handler Unit

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

MF – Multifamily

NEEA – Northwest Energy Efficiency Alliance

NEM – Net Energy Metering

NPV – Net Present Value

NREL – *National Renewable Energy Laboratory*

PG&E – Pacific Gas and Electric Company

POU – Publicly-Owned-Utilities

PV – Photovoltaic

SCE – Southern California Edison

SDG&E – San Diego Gas and Electric

SEER – Seasonal Energy Efficiency Ratio

SF – Single Family

SMUD – Sacramento Municipal Utility District

SoCalGas – Southern California Gas Company

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

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

Title 24 – Title 24, Part 6

TOU – Time-Of-Use

UEF – Uniform Energy Factor

VLLDCS – Verified Low Leakage Ducts in Conditioned Space

ZNE – Zero-net Energy

Summary of Revisions

Date	Description	Reference (page or section)
9/12/2022	Original Release (1.0)	N/A
3/25/2024	Updated analysis (1.1)	• New simulation results with latest CBECC-Res version (Section 2.1.1) • Updated utility cost estimates using recent utility tariff and net billing tariff (Section 2.1.3) • New measure costs for heat pumps, batteries, and PV (Section 3.3) • Revised packages (Section 3.4) • Revised Results, Summary, References, and Appendices (Sections 4-7)
4/26/2024	Corrected errors (1.2)	• Corrected incorrect results in Tables 16-19, 23, 26
5/30/2024	Corrected errors (1.3)	• Corrected incorrect results in Tables 15-18, 22-28

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Executive Summary

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

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

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

The following are key takeaways and recommendations from the analysis.

<u>Conclusions and Discussion:</u>

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

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

- Under the Net Biling Tariff (NBT)[2], utility cost savings for increasing PV system size beyond code minimum are substantially less than what they were under prior net energy metering rules (NEM 2.0); however, savings are sufficient to be On-Bill cost-effective in all climate zones for the all-electric single family home except climate zones 1, 3, and 16. Coupling PV with battery systems increases utility cost savings as a result of improved on-site utilization of PV generation and fewer exports to the grid.
- Applying California Alternate Rates for Energy (CARE) rates in the IOU territories improves On-Bill cost-effectiveness for all-electric buildings, as compared to the same case under standard rates, due to higher utility cost savings compared to a code compliant mixed fuel building also on a CARE rate. This is due to the CARE discount on electricity being higher than that on gas.
- If gas tariffs are assumed to increase substantially over time, in line with the escalation assumption from the 2025 LSC development, all-electric new construction was found to be On-Bill cost-effective in almost all single family and most ADU scenarios over the 30-year analysis period. There is much uncertainty surrounding future tariff structures as well as escalation values. While it's clear that gas rates are anticipated to increase, how much and how quickly is not known. Electricity tariff structures are expected to evolve over time, and the California Public Utilities Commission (CPUC) has an active proceeding to adopt an income-graduated fixed charge that benefits low-income customers and supports electrification measures[3]. The CPUC will make a decision in mid-2024 and the new rates are expected to be in place later that year or in 2025. While the anticipated impact of this rate change is lower volumetric electricity rates, the rate design is not finalized. While lower volumetric electricity rates provide many benefits like incentivizing electrification, it also will make building efficiency measures harder to justify as cost-effective due to lower utility bill cost savings.

<u>Recommendations:</u>

- A reach code with a single performance target based on source energy (EDR1) can be structured to strongly encourage electrification. This approach requires equivalent performance for all buildings and allows mixed fuel buildings which minimizes the risk of violating federal preemption. Below are examples of how a reach code for single family homes could be set up based on the results summarized in Table 27.
    - A jurisdiction in Climate Zone 12 could set a performance target at an EDR1 margin of 11.5 (the EDR1 margin for the all-electric Code Minimum package). Any all-electric home meeting or exceeding the prescriptive requirements would comply, and a mixed fuel home would likely need to incorporate a combination of efficiency measures and a battery system to comply.
    - Similarly, a jurisdiction in Climate Zone 7 may consider setting a performance target of 2.8 EDR1 margin (also the EDR1 margin for the all-electric Code Minimum package). Any all-electric home meeting or exceeding the prescriptive requirements would comply, but a mixed fuel home would likely be able to comply with only a suite of above-code efficiency measures (no battery). Alternatively, a higher EDR1 margin target of 5 would incentivize more energy efficiency or additional PV for all-electric construction, and mixed fuel construction would likely need to incorporate a battery system to comply.
    - A jurisdiction in Climate Zone 16 may want to set a performance target at an EDR1 margin of 20.4 (the EDR1 margin for the mixed fuel efficiency + PV + battery package). This would establish a target that a mixed fuel home could On-Bill cost-effectively meet, likely only after incorporating a combination of efficiency measures and a battery system, and that an all-electric home could easily meet.
- The 2022 Title 24 code's new source energy metric combined with the heat pump baseline encourage all-electric construction, providing an incentive that allows for some amount of prescriptively required building efficiency to be traded off, still meeting minimum code compliance. This compliance benefit for all-electric homes highlights a unique opportunity for jurisdictions to incorporate efficiency into all-electric reach codes. Efficiency and electrification have symbiotic benefits and are both critical for decarbonization of buildings. As demand on the electric grid is increased through electrification, efficiency can reduce the negative impacts of

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

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

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

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

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

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

1 Introduction

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

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

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

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

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

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

2 Methodology and Assumptions

2.1 Analysis for Reach Codes

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

2.1.1 Modeling

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

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

2.1.2 Cost-effectiveness

2.1.2.1 Benefits

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

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

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

2.1.2.2 Costs

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

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

2.1.2.3 Metrics

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

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

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

Equation 1

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

Equation 2

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

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

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

Equation 3

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

Where: n = analysis term in years

$r = discount\ rate$

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

Analysis term of 30 years
Real discount rate of three percent

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

Equation 4

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

2.1.3 Utility Rates

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

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

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

Table 1: Utility Tariffs Used Based on Climate Zone

IOUs

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

POUs

Climate Zones	Electric / Gas Utility	Electricity Tariff	Natural Gas Tariff
4	CPAU / CPAU	E-1	G1
12	SMUD / PG&E	R-TOD	G1

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

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

utility rate escalation sensitivity analysis, presented in Section 4.6.3, was based on those used within the 2025 Long-term System Cost (LSC) factors (LSC replaces TDV in the 2025 code cycle) which assumed steep increases in gas rates in the latter half of the analysis period. See Appendix 7.2.7 Fuel Escalation Assumptions for details.

2.2 Greenhouse Gas Emissions

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

2.3 Energy Design Rating

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

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

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

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

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

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

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

Equation 5

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

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

3 Prototypes, Measure Packages, and Costs

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

3.1 Prior Reach Code Research

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

3.2 Prototype Characteristics

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

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

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

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

Table 2: Prototype Characteristics

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

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

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

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

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

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

Table 3: Base case Characteristics of the Prototypes

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

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

[2] AFUE = annual fuel utilization efficiency. SEER = seasonal energy efficiency ratio. EER = energy efficiency ratio. HSPF = heating seasonal performance factor. UEF = uniform energy factor.

[3] This version of CBECC-Res used in this analysis did not have the capability to directly model ducted HPWHs even though this configuration is called out as the Standard Design in the 2022 ACM (California Energy Commission, 2022). This was modeled by indicating that the tank is located within the conditioned space with the compressor unit located outside.

[4] Exception 2 to Section 150.1(I)14 states that “no PV system is required when the minimum PV system size specified by section 150.1(c)14 is less than 1.8 kWdc.” In this analysis this exception is applied based on the sizes calculated per Equation150.1-C of Section 150.1(c)14. The performance software sizes the PV system based on the estimated energy use, which differs slightly from the prescriptive sizing. As a result, the baseline PV capacity from the performance software for Climate Zone 10 is less than 1.8 kWdc.

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

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

3.3 Measure Definitions and Costs

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

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

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

3.3.1 Efficiency, Solar PV, and Batteries

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.3.2 Electrification

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

3.3.2.1 Utility Infrastructure

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

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

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

Table 6: Single Family IOU Total Natural Gas Infrastructure Costs

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

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

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

Table 7: Single Family CPAU Total Natural Gas Infrastructure Costs

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

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

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

Table 8: ADU Utility Infrastructure Total and Incremental Costs

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

3.3.2.2 Equipment

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

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

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

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

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

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

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

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

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

Table 10: Space Conditioning System Nominal Capacities

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Table 13: Single Family All-Electric Appliance Incremental Costs

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

3.4 Measure Packages

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

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

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

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

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

4 Results

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

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

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

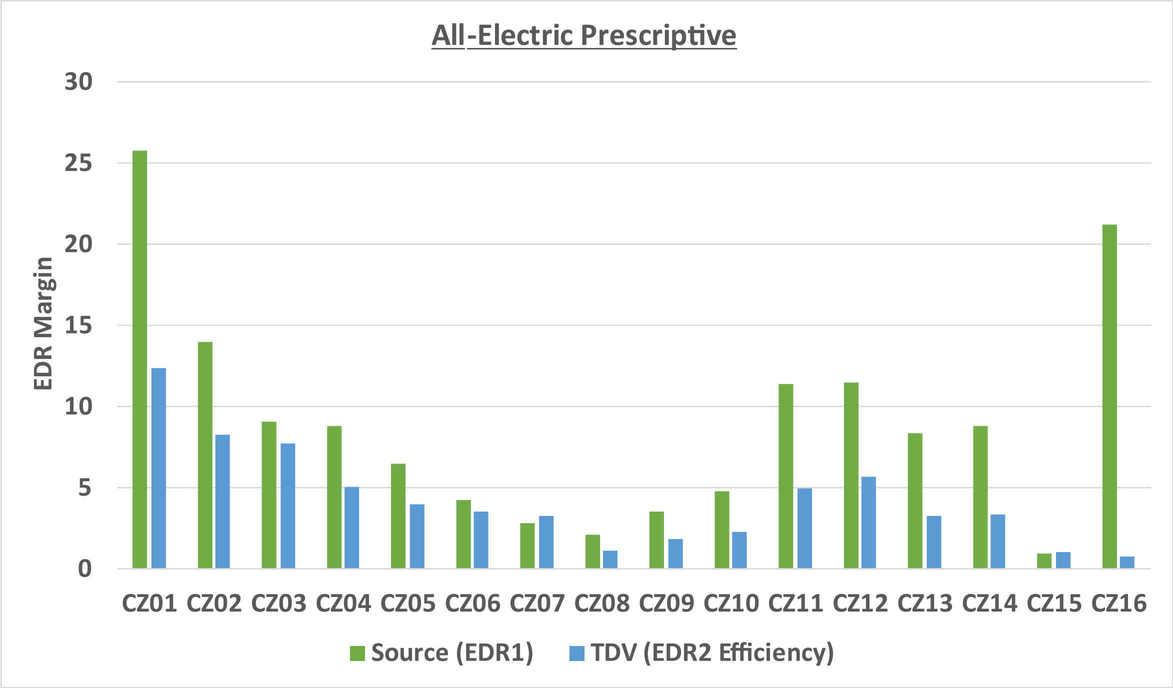

Figure 1: Single family all-electric home compliance impacts.

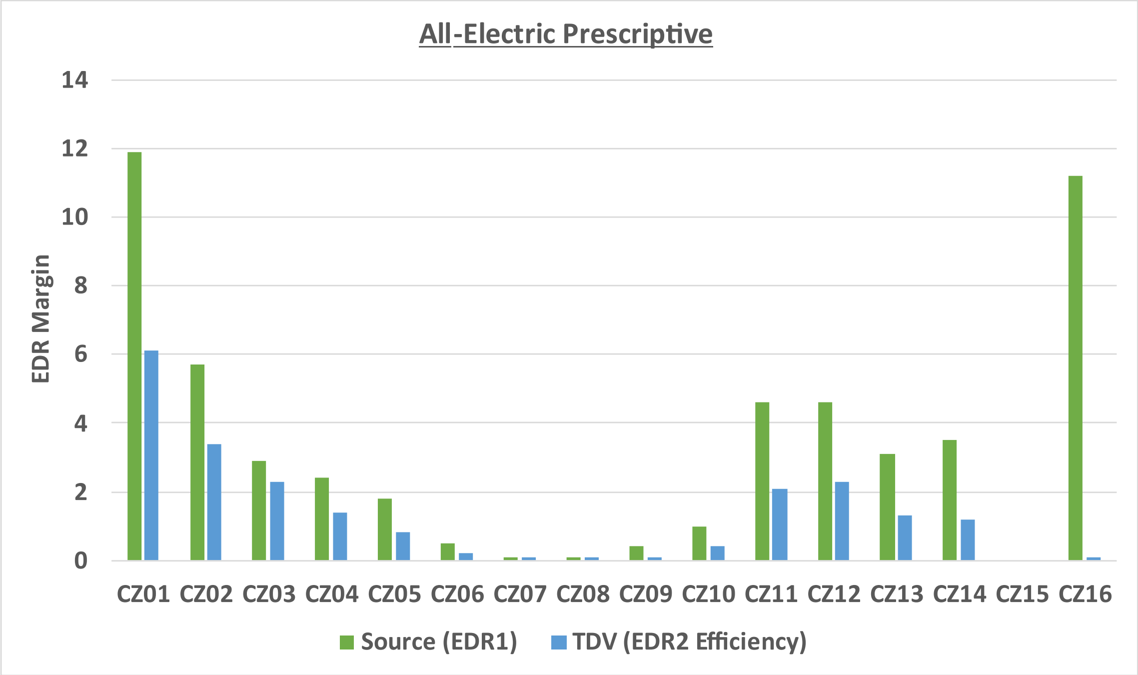

Figure 2: ADU all-electric home compliance impacts.

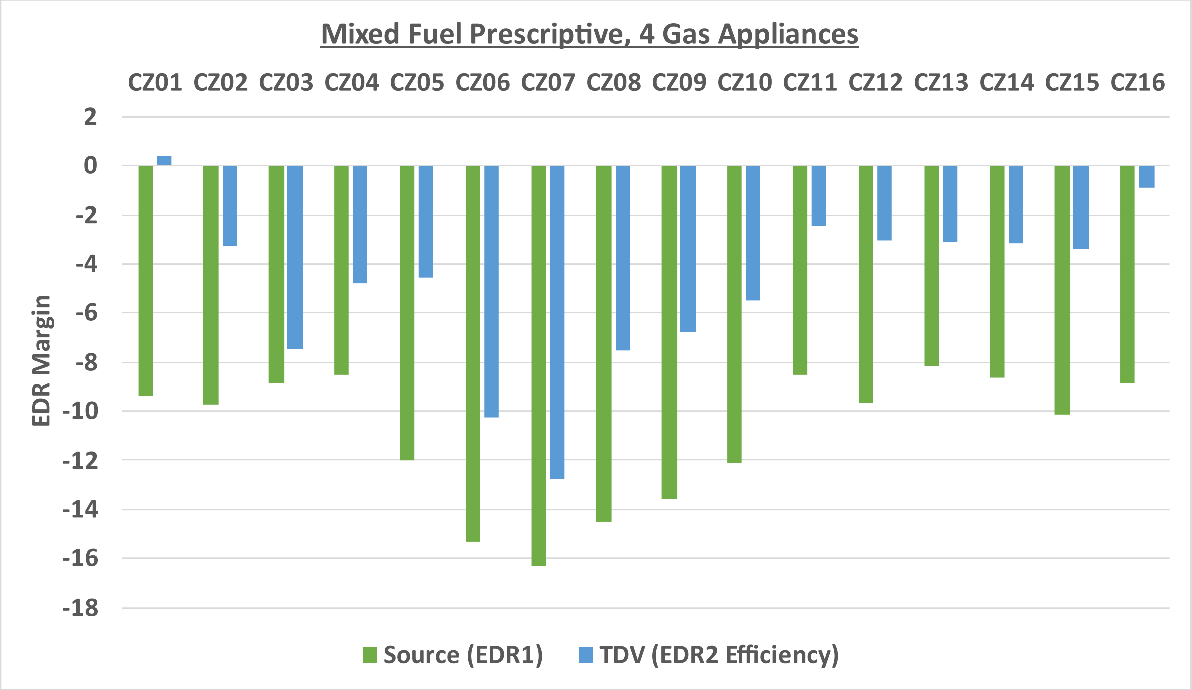

Figure 3: Single family four gas appliance home compliance impacts.

This analysis illustrates a couple of interesting points:

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

4.2 All-Electric Code Minimum Results

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

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

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

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

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

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

Climate Zone	Electric /Gas Utility	Total EDR1 Margin	Efficiency EDR2 Margin	Annual Elec Savings (kWh)	Annual Gas Savings (therms)	Utility Cost Savings		Incremental Cost[1]		On-Bill		TDV	
						First Year	Lifecycle (2022$)	First Year	Lifecycle (2022$)	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	11.9	6.1	(1,641)	114	($353)	($6,682)	($4,692)	($4,605)	0.7	($2,077)	3.9	$2,986
CZ02	PGE	5.7	3.4	(1,245)	75	($312)	($6,347)	($4,692)	($4,605)	0.7	($1,742)	2.7	$2,515
CZ03	PGE	2.9	2.3	(1,672)	123	($377)	($7,138)	($863)	$442	0.0	($7,581)	0.0	($1,489)
CZ04	PGE	2.4	1.4	(1,612)	118	($366)	($6,964)	($863)	$442	0.0	($7,406)	0.0	($801)
CZ04	CPAU	2.4	1.4	(1,612)	118	$25	$3,035	($863)	$442	6.9	$2,592	0.0	($801)
CZ05	PGE	1.8	0.8	(1,026)	49	($302)	($6,517)	($4,692)	($4,605)	0.7	($1,912)	2.0	$2,021
CZ05	PGE/SCG	1.8	0.8	(1,026)	49	($257)	($5,178)	($4,692)	($4,605)	0.9	($574)	2.0	$2,021
CZ06	SCE/SCG	0.5	0.2	(904)	38	($243)	($4,923)	($4,692)	($4,605)	0.9	($318)	2.1	$2,135
CZ07	SDGE	0.1	0.1	(884)	37	($337)	($7,903)	($4,692)	($4,605)	0.6	($3,298)	2.2	$2,205
CZ08	SCE/SCG	0.1	0.1	(878)	36	($241)	($4,894)	($4,692)	($4,605)	0.9	($289)	2.3	$2,274
CZ09	SCE	0.4	0.1	(903)	38	($243)	($4,914)	($4,692)	($4,605)	0.9	($310)	2.4	$2,321
CZ10	SCE/SCG	1.0	0.4	(952)	43	($189)	($3,629)	($4,692)	($4,605)	1.3	$976	2.8	$2,577
CZ10	SDGE	1.0	0.4	(952)	43	($249)	($5,689)	($4,692)	($4,605)	0.8	($1,084)	2.8	$2,577
CZ11	PGE	4.6	2.1	(1,209)	71	($224)	($4,405)	($4,692)	($4,605)	1.1	$200	3.5	$2,870
CZ12	PGE	4.6	2.3	(1,183)	69	($306)	($6,315)	($4,692)	($4,605)	0.7	($1,710)	3.0	$2,684
CZ12	SMUD/PGE	4.6	2.3	(1,183)	69	($65)	($808)	($4,692)	($4,605)	5.7	$3,797	3.0	$2,684
CZ13	PGE	3.1	1.3	(1,611)	112	($218)	($3,689)	($863)	$442	0.0	($4,131)	0.0	($858)
CZ14	SCE/SCG	3.5	1.2	(1,714)	115	($375)	($6,933)	($863)	$442	0.0	($7,375)	0.0	($1,089)
CZ14	SDGE	3.5	1.2	(1,714)	115	($483)	($10,348)	($863)	$442	0.0	($10,790)	0.0	($1,089)
CZ15	SCE/SCG	0.0	0.0	(864)	36	($172)	($3,359)	($4,692)	($4,605)	1.4	$1,246	2.6	$2,477
CZ16	PG&E	11.2	0.1	(1,781)	122	($379)	($7,167)	($4,692)	($4,605)	0.6	($2,562)	2.1	$2,133

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

4.3 All-Electric Efficiency, PV, and Battery Results

Table 16 and Table 17 compare cost-effectiveness results for the all-electric packages for the single family and ADU prototypes, respectively, with the exception of the all-electric Efficiency + High Efficiency (Preempted) Equipment package (cost-effectiveness was not evaluated for this package but see Table 27 and Table 28 for a comparison of compliance impacts). In almost all cases the single family packages are cost-effective based on TDV. For ADUs, all climate zones show an increase in TDV-cost effectiveness for the Efficiency + PV case but a decrease when a battery is added. On-Bill cost-effectiveness generally improves with the addition of efficiency measures for single family, but not for ADUs, which generally follows the same trend as TDV cost-effectiveness . A summary of measures included in each package is provided in Appendix 7.3 Summary of Measures by Package. The efficiency measures added to the all-electric package to meet minimum code requirements are described in Table 39 and Table 41.

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

Climate Zone	Electric /Gas Utility	All-Electric Code Minimum				All-Electric Efficiency Only				All-Electric-Efficiency + PV				All-Electric Efficiency + PV + Battery			
		On-Bill		TDV		On-Bill		TDV		On-Bill		TDV		On-Bill		TDV	
		B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	0.9	($268)	>1	$5,702	>1	$2,945	>1	$8,168	0.9	($1,313)	1.8	$9,817	1.0	$1,012	1.2	$4,391
CZ02	PGE	1.6	$2,355	>1	$7,711	8.9	$3,870	>1	$9,325	1.5	$2,242	4.2	$12,452	1.3	$4,962	1.5	$8,190
CZ03	PGE	0.98	($90)	25.3	$3,887	1.1	$168	>1	$3,939	0.8	($903)	2.8	$6,465	1.1	$2,114	1.1	$1,347
CZ04	PGE	1.3	$979	>1	$4,494	1.7	$1,054	>1	$4,849	1.1	$204	3.5	$7,893	1.2	$3,709	1.3	$4,506
CZ04	CPAU	>1	$10,437	>1	$7,762	>1	$10,021	>1	$8,117	>1	$14,776	>1	$11,161	0.9	($1,076)	1.5	$6,724
CZ05	PGE	1.3	$1,373	6.1	$4,633	1.6	$1,975	>1	$4,985	2.2	$1,457	8.5	$7,927	1.3	$5,551	1.2	$3,296
CZ05	PGE/SCG	1.4	$1,823	6.1	$4,633	1.9	$2,424	>1	$4,985	2.6	$1,907	8.5	$7,927	1.4	$6,001	1.2	$3,296
CZ06	SCE/SCG	1.6	$2,339	4.7	$4,353	1.6	$1,813	>1	$4,119	109.5	$2,638	152.4	$6,727	1.5	$7,153	1.2	$2,276
CZ07	SDGE	1.1	$624	4.2	$4,211	1.2	$839	8.3	$4,070	5.7	$469	>1	$6,079	2.0	$13,798	1.1	$1,186
CZ08	SCE/SCG	1.7	$2,792	4.2	$4,674	1.8	$2,574	17.7	$4,642	>1	$3,329	>1	$7,492	1.7	$8,899	1.2	$2,085
CZ09	SCE	1.7	$2,831	5.5	$5,013	1.9	$2,699	>1	$5,087	>1	$3,634	>1	$8,007	1.7	$9,151	1.3	$3,630
CZ10	SCE/SCG	1.6	$2,642	7.4	$5,287	2.0	$2,668	>1	$5,376	>1	$3,765	>1	$8,347	1.7	$10,088	1.3	$3,901
CZ10	SDGE	1.4	$1,825	7.4	$5,287	1.8	$2,438	>1	$5,376	>1	$2,539	>1	$8,347	2.4	$19,463	1.3	$3,901
CZ11	PGE	1.7	$2,552	>1	$7,153	>1	$4,159	>1	$8,524	1.8	$2,984	4.6	$11,310	1.4	$7,781	1.5	$8,757
CZ12	PGE	1.9	$3,210	>1	$7,504	4.6	$3,742	>1	$8,084	1.9	$2,561	5.5	$11,063	1.3	$6,021	1.5	$8,216
CZ12	SMUD/PGE	>1	$11,714	>1	$7,504	>1	$10,665	>1	$8,084	5.8	$13,407	5.5	$11,063	0.9	($1,237)	1.4	$7,166
CZ13	PGE	1.5	$1,480	>1	$4,490	>1	$2,876	>1	$5,773	1.7	$2,334	3.7	$8,341	1.4	$7,848	1.4	$7,005
CZ14	SCE/SCG	0.9	($522)	>1	$4,105	1.8	$811	>1	$5,461	1.6	$2,558	3.6	$9,965	1.6	$10,569	1.4	$6,204
CZ14	SDGE	0.7	($1,717)	>1	$4,105	1.5	$643	>1	$5,461	1.2	$922	3.6	$9,965	2.1	$20,099	1.4	$6,204
CZ15	SCE/SCG	1.4	$1,791	3.0	$3,439	8.0	$3,267	>1	$4,669	>1	$3,940	>1	$6,120	2.0	$13,576	0.99	($80)
CZ16	PG&E	0.2	($5,394)	0.4	($1,339)	0.2	($1,946)	1.7	$1,894	0.8	($3,199)	1.6	$6,711	1.0	$206	1.1	$1,690

Table 17: ADU Cost-Effectiveness: Comparison of All-Electric Efficiency Only, PV, and Battery Packages

Climate Zone	Electric /Gas Utility	All-Electric Code Minimum				All-Electric Efficiency Only				All-Electric Efficiency + PV				All-Electric Efficiency + PV + Battery			
		On-Bill		TDV		On-Bill		TDV		On-Bill		TDV		On-Bill		TDV	
		B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	0.7	($2,077)	3.9	$2,986	0.6	($1,727)	>1	$2,900	1.2	$2,003	1.5	$5,010	0.997	($79)	0.9	($2,884)
CZ02	PGE	0.7	($1,742)	2.7	$2,515	0.5	($2,541)	>1	$1,945	1.4	$3,532	1.8	$6,360	1.1	$1,302	0.98	($410)
CZ03	PGE	0.0	($7,581)	0.0	($1,489)	0.0	($8,981)	0.0	($2,680)	0.8	($2,489)	1.1	$1,436	0.8	($4,949)	0.8	($5,369)
CZ04	PGE	0.0	($7,406)	0.0	($801)	0.0	($8,705)	0.4	($1,762)	0.9	($1,480)	1.3	$3,589	0.9	($3,501)	0.8	($3,849)
CZ04	CPAU	6.9	$2,592	0.0	($801)	1.3	$944	0.4	($1,762)	1.7	$8,498	1.3	$3,589	0.7	($9,161)	0.8	($4,899)
CZ05	PGE	0.7	($1,912)	2.0	$2,021	0.4	($3,310)	1.4	$650	1.6	$4,015	1.9	$5,436	1.1	$1,265	0.9	($1,611)
CZ05	PGE/SCG	0.9	($574)	2.0	$2,021	0.6	($1,972)	1.4	$650	1.8	$5,353	1.9	$5,436	1.2	$3,836	0.9	($1,611)
CZ06	SCE/SCG	0.9	($318)	2.1	$2,135	0.6	($1,579)	2.1	$1,103	2.0	$5,866	2.2	$6,551	1.1	$2,799	0.95	($852)
CZ07	SDGE	0.6	($3,298)	2.2	$2,205	0.4	($4,255)	1.8	$941	1.8	$5,667	1.9	$5,493	1.5	$10,358	0.9	($1,804)
CZ08	SCE/SCG	0.9	($289)	2.3	$2,274	0.6	($1,432)	2.1	$1,179	2.0	$6,364	2.3	$7,936	1.2	$4,058	0.97	($609)
CZ09	SCE	0.9	($310)	2.4	$2,321	0.6	($1,494)	2.3	$1,280	2.0	$6,568	2.4	$7,709	1.2	$4,314	0.99	($279)
CZ10	SCE/SCG	1.3	$976	2.8	$2,577	0.96	($106)	3.7	$1,593	2.2	$734	6.7	$3,496	0.9	($860)	0.7	($3,944)
CZ10	SDGE	0.8	($1,084)	2.8	$2,577	0.6	($1,787)	3.7	$1,593	0.0	($1,465)	6.7	$3,496	1.3	$5,079	0.7	($3,944)
CZ11	PGE	1.1	$200	3.5	$2,870	0.96	($96)	>1	$2,531	0.7	($602)	3.2	$4,037	0.9	($1,125)	0.9	($1,893)
CZ12	PGE	0.7	($1,710)	3.0	$2,684	0.5	($2,538)	>1	$1,878	1.6	$4,644	1.9	$6,675	1.1	$2,970	1.0	$178
CZ12	SMUD/PGE	5.7	$3,797	3.0	$2,684	13	$1,980	>1	$1,878	1.7	$5,737	1.9	$6,675	0.6	($9,432)	0.96	($872)
CZ13	PGE	0.0	($4,131)	0.0	($858)	0.0	($4,502)	0.6	($1,223)	0.3	($4,759)	1.1	$305	0.8	($4,729)	0.7	($5,491)
CZ14	SCE/SCG	0.0	($7,375)	0.0	($1,089)	0.0	($7,929)	0.5	($1,684)	1.1	$1,555	1.5	$5,935	1.0	$1,222	0.9	($1,525)
CZ14	SDGE	0.0	($10,790)	0.0	($1,089)	0.0	($10,375)	0.5	($1,684)	1.2	$2,956	1.5	$5,935	1.4	$10,678	0.9	($1,525)
CZ15	SCE/SCG	1.4	$1,246	2.6	$2,477	2.4	$1,243	>1	$2,342	>1	$1,729	52.2	$3,560	1.2	$2,631	0.8	($2,812)
CZ16	PG&E	0.6	($2,562)	2.1	$2,133	0.5	($2,378)	>1	$2,282	1.6	$5,433	2.0	$7,875	1.2	$3,618	1.0	$611

4.4 Mixed Fuel Results

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

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

Climate Zone	Electric /Gas Utility	Total EDR1 Margin	Efficiency EDR2 Margin	Annual Elec Savings (kWh)	Annual Gas Savings (therms)	Utility Cost Savings		Incremental Cost		On-Bill		TDV	
						First Year	Lifecycle (2022$)	First Year	Lifecycle (2022$)	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	22.6	18.8	1,571	116	$1,084	$26,667	$11,160	$20,166	1.3	$6,501	1.0	$500
CZ02	PGE	14.1	7.4	1,257	34	$913	$21,353	$10,268	$18,868	1.1	$2,486	0.9	($1,282)
CZ03	PGE	12.8	4.3	858	7	$785	$18,003	$8,708	$16,900	1.1	$1,104	0.7	($4,777)
CZ04	PGE	13.2	4.3	790	6	$803	$18,394	$9,623	$17,938	1.0	$456	0.8	($3,925)
CZ04	CPAU	13.2	4.3	790	6	$123	$2,877	$10,673	$19,172	0.2	($16,295)	0.7	($4,975)
CZ05	PGE	14.8	4.9	1,178	13	$905	$20,821	$9,441	$17,885	1.2	$2,936	0.8	($3,468)
CZ05	PGE/SCG	14.8	4.9	1,178	13	$900	$20,690	$9,441	$17,885	1.2	$2,805	0.8	($3,468)
CZ06	SCE/SCG	18.3	5.5	888	6	$864	$19,539	$9,266	$17,587	1.1	$1,951	0.8	($3,941)
CZ07	SDGE	18.7	4.8	832	4	$1,134	$27,505	$9,214	$17,537	1.6	$9,867	0.7	($4,817)
CZ08	SCE/SCG	17.1	3.0	777	2	$920	$20,754	$9,134	$17,410	1.2	$3,344	0.7	($4,341)
CZ09	SCE	16.2	3.1	833	3	$922	$20,804	$9,152	$17,435	1.2	$3,369	0.8	($3,839)
CZ10	SCE/SCG	14.4	2.7	846	2	$958	$21,608	$8,489	$16,733	1.3	$4,875	0.7	($3,859)
CZ10	SDGE	14.4	2.7	846	2	$1,288	$31,210	$8,489	$16,733	1.9	$14,477	0.7	($3,859)
CZ11	PGE	12.9	5.1	1,025	26	$1,031	$23,949	$9,828	$18,296	1.3	$5,653	0.9	($1,066)
CZ12	PGE	13.2	4.8	1,098	23	$923	$21,415	$10,065	$18,616	1.2	$2,800	0.9	($1,194)
CZ12	SMUD/PGE	13.2	4.8	1,098	23	$253	$6,133	$11,115	$19,850	0.3	($13,717)	0.9	($2,244)
CZ13	PGE	12.3	4.2	1,006	5	$1,016	$23,250	$9,831	$18,236	1.3	$5,013	0.9	($2,354)
CZ14	SCE/SCG	13.4	5.4	1,514	6	$1,093	$24,697	$10,741	$19,342	1.3	$5,354	0.9	($1,910)
CZ14	SDGE	13.4	5.4	1,514	6	$1,421	$34,477	$10,741	$19,342	1.8	$15,135	0.9	($1,910)
CZ15	SCE/SCG	13.5	3.8	531	2	$1,140	$25,708	$8,586	$16,630	1.6	$9,078	0.6	($5,490)
CZ16	PG&E	20.4	14.2	1,228	114	$1,070	$26,218	$12,086	$20,964	1.3	$5,254	0.98	($444)

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

Climate Zone	Electric /Gas Utility	Total EDR1 Margin	Efficiency EDR2 Margin	Annual Elec Savings (kWh)	Annual Gas Savings (therms)	Utility Cost Savings		Incremental Cost		On-Bill		TDV	
						First Year	Lifecycle (2022$)	First Year	Lifecycle (2022$)	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	18.5	7.7	3,666	20	$1,078	$24,880	$15,432	$25,919	0.96	($1,040)	0.7	($6,719)
CZ02	PGE	16.6	3.5	3,472	11	$1,042	$23,928	$13,846	$23,790	1.0	$138	0.8	($4,128)
CZ03	PGE	11.8	1.2	2,679	0	$781	$17,816	$11,879	$21,215	0.8	($3,399)	0.6	($6,826)
CZ04	PGE	13.3	1.6	2,799	0	$859	$19,588	$12,213	$21,598	0.9	($2,011)	0.7	($5,306)
CZ04	CPAU	13.3	1.6	2,799	0	$391	$8,911	$13,263	$22,833	0.4	($13,922)	0.7	($6,356)
CZ05	PGE	16.9	1.1	3,309	2	$1,031	$23,539	$12,668	$22,274	1.1	$1,265	0.8	($4,765)
CZ05	PGE/SCG	16.9	1.1	3,309	2	$1,031	$23,520	$12,668	$22,274	1.1	$1,246	0.8	($4,765)
CZ06	SCE/SCG	19.8	1.2	3,285	1	$953	$21,468	$12,496	$22,043	0.97	($575)	0.8	($3,877)
CZ07	SDGE	20.3	1.2	3,278	0	$1,296	$31,370	$12,869	$22,545	1.4	$8,825	0.8	($4,633)
CZ08	SCE/SCG	20.4	0.5	3,505	0	$1,040	$23,434	$12,952	$22,678	1.0	$755	0.8	($3,522)
CZ09	SCE	19.6	0.5	3,497	0	$1,030	$23,213	$12,691	$22,327	1.0	$886	0.8	($3,318)
CZ10	SCE/SCG	19.0	0.6	729	0	$537	$12,107	$8,436	$16,606	0.7	($4,499)	0.5	($7,344)
CZ10	SDGE	19.0	0.6	729	0	$813	$19,671	$8,436	$16,606	1.2	$3,065	0.5	($7,344)
CZ11	PGE	17.6	3.0	871	10	$663	$15,273	$9,218	$17,568	0.9	($2,295)	0.7	($5,528)
CZ12	PGE	16.7	2.7	3,594	9	$1,112	$25,496	$13,764	$23,710	1.1	$1,786	0.8	($3,321)
CZ12	SMUD/PGE	16.7	2.7	3,594	9	$537	$12,380	$14,844	$24,944	0.5	($12,564)	0.8	($4,371)
CZ13	PGE	14.5	2.2	273	0	$551	$12,569	$7,979	$15,904	0.8	($3,335)	0.5	($6,903)
CZ14	SCE/SCG	14.5	3.2	3,499	0	$1,006	$22,671	$12,815	$22,325	1.0	$346	0.8	($3,423)
CZ14	SDGE	14.5	3.2	3,499	0	$1,351	$32,711	$12,815	$22,325	1.5	$10,386	0.8	($3,423)
CZ15	SCE/SCG	19.2	1.8	551	0	$683	$15,387	$8,478	$16,574	0.9	($1,187)	0.5	($7,021)
CZ16	PG&E	18.3	6.3	3,680	24	$1,117	$25,838	$13,872	$23,801	1.1	$2,037	0.8	($3,759)

4.5 Greenhouse Gas Reductions

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

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

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

Table 21: ADU Greenhouse Gas Reductions (metric tons)

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

4.6 Sensitivity Analysis

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

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

4.6.1 CARE Rate Comparison

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

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

Climate Zone	Electric /Gas Utility	Single Family				ADU			
		Standard		CARE		Standard		CARE	
		B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	0.9	($268)	>1	$3,886	0.7	($2,077)	1.2	$696
CZ02	PGE	1.6	$2,355	5.1	$5,107	0.7	($1,742)	1.1	$580
CZ03	PGE	0.98	($90)	1.7	$1,968	0.0	($7,581)	0.0	($4,596)
CZ04	PGE	1.3	$979	2.3	$2,619	0.0	($7,406)	0.0	($4,526)
CZ05	PGE	1.3	$1,373	2.2	$3,467	0.7	($1,912)	1.1	$237
CZ05	PGE/SCG	1.4	$1,823	2.5	$3,841	0.9	($574)	1.4	$1,321
CZ06	SCE/SCG	1.6	$2,339	2.3	$3,535	0.9	($318)	1.4	$1,225
CZ07	SDGE	1.1	$624	2.1	$3,309	0.6	($3,298)	0.9	($627)
CZ08	SCE/SCG	1.7	$2,792	2.3	$3,945	0.9	($289)	1.4	$1,231
CZ09	SCE	1.7	$2,831	2.4	$4,074	0.9	($310)	1.4	$1,230
CZ10	SCE/SCG	1.6	$2,642	2.4	$4,083	1.3	$976	1.7	$1,923
CZ10	SDGE	1.4	$1,825	3.0	$4,642	0.8	($1,084)	1.3	$1,114
CZ11	PGE	1.7	$2,552	5.0	$5,077	1.1	$200	1.6	$1,634
CZ12	PGE	1.9	$3,210	5.0	$5,587	0.7	($1,710)	1.1	$545
CZ13	PGE	1.5	$1,480	2.7	$2,924	0.0	($4,131)	0.0	($2,754)
CZ14	SCE/SCG	0.9	($522)	1.3	$1,191	0.0	($7,375)	0.0	($4,754)
CZ14	SDGE	0.7	($1,717)	2.0	$2,295	0.0	($10,790)	0.0	($6,496)
CZ15	SCE/SCG	1.4	$1,791	1.9	$2,831	1.4	$1,246	1.8	$2,031
CZ16	PG&E	0.2	($5,394)	0.8	($351)	0.6	($2,562)	1.1	$453

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

Climate Zone	Electric /Gas Utility	Single Family				ADU			
		Standard		CARE		Standard		CARE	
		B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	1.3	$6,501	0.9	($2,072)	0.96	($1,040)	0.7	($9,009)
CZ02	PGE	1.1	$2,486	0.7	($5,286)	1.0	$138	0.7	($7,683)
CZ03	PGE	1.1	$1,104	0.6	($5,980)	0.8	($3,399)	0.6	($9,288)
CZ04	PGE	1.0	$456	0.6	($6,790)	0.9	($2,011)	0.6	($8,586)
CZ05	PGE	1.2	$2,936	0.7	($4,995)	1.1	$1,265	0.7	($6,642)
CZ05	PGE/SCG	1.2	$2,805	0.7	($5,100)	1.1	$1,246	0.7	($6,657)
CZ06	SCE/SCG	1.1	$1,951	0.7	($5,232)	0.97	($575)	0.7	($5,976)
CZ07	SDGE	1.6	$9,867	1.1	$1,601	1.4	$8,825	0.9	($2,435)
CZ08	SCE/SCG	1.2	$3,344	0.7	($4,574)	1.0	$755	0.8	($5,331)
CZ09	SCE	1.2	$3,369	0.7	($4,547)	1.0	$886	0.8	($5,198)
CZ10	SCE/SCG	1.3	$4,875	0.8	($3,354)	0.7	($4,499)	0.5	($8,010)
CZ10	SDGE	1.9	$14,477	1.3	$4,789	1.2	$3,065	0.8	($3,001)
CZ11	PGE	1.3	$5,653	0.8	($3,358)	0.9	($2,295)	0.5	($8,074)
CZ12	PGE	1.2	$2,800	0.7	($5,212)	1.1	$1,786	0.7	($6,653)
CZ13	PGE	1.3	$5,013	0.8	($4,024)	0.8	($3,335)	0.5	($8,497)
CZ14	SCE/SCG	1.3	$5,354	0.8	($3,665)	1.0	$346	0.7	($5,727)
CZ14	SDGE	1.8	$15,135	1.2	$4,127	1.5	$10,386	0.9	($1,393)
CZ15	SCE/SCG	1.6	$9,078	0.95	($877)	0.93	($1,187)	0.6	($6,708)
CZ16	PG&E	1.3	$5,254	0.8	($3,523)	1.1	$2,037	0.7	($6,282)

4.6.2 Utility Infrastructure Cost Sensitivity

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

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

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

4.6.3 Utility Rate Escalation

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

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

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

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

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

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

Climate Zone	Electric /Gas Utility	Single Family				ADU			
		CPUC / 2022 TDV		2025 LSC		CPUC / 2022 TDV		2025 LSC	
		B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV
CZ01	PGE	1.3	$6,501	1.6	$12,598	0.96	($1,040)	1.0	$993
CZ02	PGE	1.1	$2,486	1.3	$4,914	1.0	$138	1.1	$1,816
CZ03	PGE	1.1	$1,104	1.1	$2,287	0.8	($3,399)	0.9	($2,462)
CZ04	PGE	1.0	$456	1.1	$1,645	0.9	($2,011)	0.95	($980)
CZ04	CPAU	0.2	($16,295)	0.2	($15,990)	0.4	($13,922)	0.4	($13,453)
CZ05	PGE	1.2	$2,936	1.3	$4,506	1.1	$1,265	1.1	$2,574
CZ05	PGE/SCG	1.2	$2,805	1.2	$4,291	1.1	$1,246	1.1	$2,543
CZ06	SCE/SCG	1.1	$1,951	1.2	$3,420	0.97	($575)	1.0	$847
CZ07	SDGE	1.6	$9,867	1.6	$9,930	1.4	$8,825	1.4	$8,570
CZ08	SCE/SCG	1.2	$3,344	1.3	$4,750	1.0	$755	1.1	$2,288
CZ09	SCE	1.2	$3,369	1.3	$4,812	1.0	$886	1.1	$2,407
CZ10	SCE/SCG	1.3	$4,875	1.4	$6,334	0.7	($4,499)	0.8	($3,703)
CZ10	SDGE	1.9	$14,477	1.9	$14,289	1.2	$3,065	1.2	$2,904
CZ11	PGE	1.3	$5,653	1.4	$7,967	0.9	($2,295)	0.94	($1,126)
CZ12	PGE	1.2	$2,800	1.3	$4,806	1.1	$1,786	1.1	$3,458
CZ12	SMUD/PGE	0.3	($13,717)	0.4	($12,515)	0.5	($12,564)	0.5	($11,582)
CZ13	PGE	1.3	$5,013	1.4	$6,448	0.8	($3,335)	0.8	($2,674)
CZ14	SCE/SCG	1.3	$5,354	1.4	$7,138	1.0	$346	1.1	$1,827
CZ14	SDGE	1.8	$15,135	1.8	$15,116	1.5	$10,386	1.5	$10,107
CZ15	SCE/SCG	1.6	$9,078	1.7	$10,819	0.9	($1,187)	0.99	($182)
CZ16	PG&E	1.3	$5,254	1.5	$10,999	1.1	$2,037	1.2	$4,285

5 Summary

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

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

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

The following are key takeaways and recommendations from the analysis.

Conclusions and Discussion:

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

effective in all climate zones for the all-electric single family home except climate zones 1, 3, and 16. Coupling PV with battery systems increases utility cost savings as a result of improved on-site utilization of PV generation and fewer exports to the grid.

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

Recommendations:

- A reach code with a single performance target based on source energy (EDR1) can be structured to strongly encourage electrification. This approach requires equivalent performance for all buildings and allows mixed fuel buildings which minimizes the risk of violating federal preemption. Below are examples of how a reach code for single family homes could be setup based on the results summarized in Table 27.
  - A jurisdiction in Climate Zone 12 could set a performance target at an EDR1 margin of 11.5 (the EDR1 margin for the all-electric Code Minimum package). Any all-electric home meeting or exceeding the prescriptive requirements would comply, and a mixed fuel home would likely need to incorporate a combination of efficiency measures and a battery system to comply.
  - Similarly, a jurisdiction in Climate Zone 7 may consider setting a performance target of 2.8 EDR1 margin (also the EDR1 margin for the all-electric Code Minimum package). Any all-electric home meeting or exceeding the prescriptive requirements would comply, but a mixed fuel home would likely be able to comply with only a suite of above-code efficiency measures (no battery). Alternatively, a higher EDR1 margin target of 5 would incentivize more energy efficiency or additional PV for all-electric construction, and mixed fuel construction would likely need to incorporate a battery system to comply.
  - A jurisdiction in Climate Zone 16 may want to set a performance target at an EDR1 margin of 20.4 (the EDR1 margin for the mixed fuel efficiency + PV + battery package). This would establish a target that a mixed fuel home could On-Bill cost-effectively meet, likely only after incorporating a combination of efficiency measures and a battery system, and that an all-electric home could easily meet.
- The 2022 Title 24 code's new source energy metric combined with the heat pump baseline encourage all-electric construction, providing an incentive that allows for some amount of prescriptively required building efficiency to be traded off, still meeting minimum code compliance. This compliance benefit for all-electric homes highlights a unique opportunity for jurisdictions to incorporate efficiency into all-electric reach codes. Efficiency and electrification have symbiotic benefits and are both critical for decarbonization of buildings. As demand on the electric grid is increased through electrification, efficiency can reduce the negative impacts of additional electricity demand on the grid, reducing the need for increased generation and storage capacity, as well as the need to upgrade upstream transmission and distribution equipment. The Reach Codes Team recommends that jurisdictions adopting a reach code for single family buildings also include an efficiency

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

requirement with EDR1 margins at minimum consistent with the all-electric code minimum package results in Table 27.

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

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

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

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

Climate Zone	Electric /Gas Utility	All-Electric					Mixed Fuel	
		Code Minimum	Efficiency	Efficiency + High Efficiency Equipment	Efficiency + PV	Efficiency + PV + Battery	Efficiency + High Efficiency Equipment	Efficiency + PV + Battery
CZ01	PGE	25.8	29.1	31.4	32.6	41.4	14.8	22.6
CZ02	PGE	14.0	16.3	18.0	18.9	28.3	9.1	14.1
CZ03	PGE	9.1	10.6	12.2	13.1	24.2	3.6	12.8
CZ04	PGE	8.8	10.4	11.9	12.8	24.6	3.8	13.2
CZ04	CPAU	8.8	10.4	11.9	12.8	24.6	3.8	13.2
CZ05	PGE	6.5	7.9	10.2	10.8	23.3	5.2	14.8
CZ05	PGE/SCG	6.5	7.9	10.2	10.8	23.3	5.2	14.8
CZ06	SCE/SCG	4.2	5.3	6.6	8.4	24.6	4.0	18.3
CZ07	SDGE	2.8	3.6	4.9	6.9	23.6	3.2	18.7
CZ08	SCE/SCG	2.1	2.9	4.2	5.6	21.3	2.7	17.1
CZ09	SCE/SCG	3.6	4.4	5.7	7.1	21.8	3.2	16.2
CZ10	SCE/SCG	4.8	5.8	7.2	8.5	21.9	3.9	14.4
CZ10	SDGE	4.8	5.8	7.2	8.5	21.9	3.9	14.4
CZ11	PGE	11.4	13.4	15.0	15.6	24.5	7.7	12.9
CZ12	PGE	11.5	13.3	14.8	15.5	25.2	7.2	13.2
CZ12	SMUD/PGE	11.5	13.3	14.8	15.5	25.2	7.2	13.2
CZ13	PGE	8.3	10.3	11.9	12.3	22.3	4.1	12.3
CZ14	SCE/SCG	8.8	11.5	13.2	14.3	24.7	4.7	13.4
CZ14	SDGE	8.8	11.5	13.2	14.3	24.7	4.7	13.4
CZ15	SCE/SCG	0.9	2.4	3.7	3.8	15.7	3.5	13.5
CZ16	PG&E	21.3	25.6	27.0	29.1	37.5	16.3	20.4

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

Climate Zone	Electric /Gas Utility	All-Electric					Mixed Fuel	
		Code Minimum	Efficiency	Efficiency + High Efficiency Equipment	Efficiency + PV	Efficiency + PV + Battery	Efficiency + High Efficiency Equipment	Efficiency + PV + Battery
CZ01	PGE	11.9	15.7	18.5	19.3	33.5	9.9	18.5
CZ02	PGE	5.7	7.9	9.7	10.8	25.4	5.6	16.6
CZ03	PGE	2.9	4.0	5.9	7.1	22.8	3.0	11.8
CZ04	PGE	2.4	3.9	5.5	6.8	23.5	3.7	13.3
CZ04	CPAU	2.4	3.9	5.5	6.8	23.5	3.7	13.3
CZ05	PGE	1.8	2.9	4.8	6.4	23.6	2.7	16.9
CZ05	PGE/SCG	1.8	2.9	4.8	6.4	23.6	2.7	16.9
CZ06	SCE/SCG	0.5	1.3	2.6	5.0	25.4	1.8	19.8
CZ07	SDGE	0.1	0.9	2.1	5.0	25.9	1.5	20.3
CZ08	SCE/SCG	0.1	0.7	1.8	4.2	25.4	1.6	20.4
CZ09	SCE	0.4	1.1	2.3	4.5	24.9	1.9	19.6
CZ10	SCE/SCG	1.0	2.0	3.5	5.4	25.3	2.5	19.0
CZ10	SDGE	1.0	2.0	3.5	5.4	25.3	2.5	19.0
CZ11	PGE	4.6	7.0	8.6	9.6	25.0	5.4	17.6
CZ12	PGE	4.6	6.6	8.3	9.3	24.4	5.0	16.7
CZ12	SMUD/PGE	4.6	6.6	8.3	9.3	24.4	5.0	16.7
CZ13	PGE	3.1	5.5	6.9	7.8	25.1	3.9	14.5
CZ14	SCE/SCG	3.5	6.3	8.0	9.6	26.8	4.3	14.5
CZ14	SDGE	3.5	6.3	8.0	9.6	26.8	4.3	14.5
CZ15	SCE/SCG	0.0	2.2	2.6	4.4	24.8	2.3	19.2
CZ16	PG&E	11.2	14.7	15.7	18.3	32.0	8.3	18.3

6 References

Barbose, G., Darghouth, N., O'Shaughnessy, E., & Forrester, S. (2021, October). *Tracking the Sun. Pricing and Design Trends for Distributed Photovoltaic Systems in the United States 2021 Edition.* Retrieved from https://emp.lbl.gov/tracking-the-sun

Barbose, Galen; Darghouth, Naim; O'Shaughnessy, Eric; Forrester, Sydney. (2022). *Tracking the Sun: Pricing and Design Trends for Distributed Photovoltaic Systems in the United States 2022 Edition.* Retrieved from https://emp.lbl.gov/tracking-the-sun

California Energy Commission. (2017). Rooftop Solar PV System. Measure number: 2019-Res-PV-D Prepared by Energy and Environmental Economics, Inc. Retrieved from https://efiling.energy.ca.gov/getdocument.aspx?tn=221366

California Energy Commission. (2018). *2019 Alternative Calculation Method Approval Manual for the 2019 Building Energy Efficiency Standards.* Retrieved from https://www.energy.ca.gov/publications/2018/2019-alternative-calculation-method-approval-manual-2019-building-energy

California Energy Commission. (2021a). *Express Terms for the Proposed Revisions to 2022 Title 24, Part 1 and Part 6.* Retrieved from https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=21-BSTD-01

California Energy Commission. (2021b). *Final Express Terms for the Proposed Revisions to the 2022 Energy Code Reference Appendices.* Retrieved from https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=21-BSTD-01

California Energy Commission. (2022, Feb). *2022 Single-Family Residential Alternative Calculation Method Reference Manual.* Retrieved from https://www.energy.ca.gov/publications/2022/2022-single-family-residential-alternative-calculation-method-reference-manual

California Public Utilities Commission. (2021a). *Utility Costs and Affordability of the Grid of the Future: An Evaluation of Electric Costs, Rates, and Equity Issues Pursuant to P.U. Code Section 913.1.* Retrieved from https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/office-of-governmental-affairs-division/reports/2021/senate-bill-695-report-2021-and-en-banc-whitepaper_final_04302021.pdf

California Public Utilities Commission. (2021b). *Database for Energy-Efficient resources (DEER2021 Update).* Retrieved April 13, 2021, from http://www.deeresources.com/index.php/deer-versions/deer2021

California Public Utilities Commission. (2022). *Proposed Decision of Commissioner Rechtschaffen: PHASE III DECISION ELIMINATING GAS LINE EXTENSION ALLOWANCES, TEN-YEAR REFUNDABLE PAYMENT OPTION, AND FIFTY PERCENT DISCOUNT PAYMENT OPTION UNDER GAS LINE EXTENSION RULES.*

Department of Energy. (2022). *Preliminary Analysis Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment.* Retrieved from https://www.regulations.gov/document/EERE-2017-BT-STD-0019-0018

E-CFR. (2020). *https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=8de751f141aaa1c1c9833b36156faf67&mc=true&n=pt10.3.431&r=PART&ty=HTML#se10.3.431_197*. Retrieved from Electronic Code of Federal Regulations: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=8de751f141aaa1c1c9833b36156faf67&mc=true&n=pt10.3.431&r=PART&ty=HTML#se10.3.431_197

Energy & Environmental Economics. (2019). *Residential Building Electrification in California.* Retrieved from https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf

Energy + Environmental Economics. (2020). *Time Dependent Valuation of Energy for Developing Building Efficiency Standards: 2022 Time Dependent Valuation (TDV) and Source Energy Metric Data Sources and Inputs.*

E-Source companies. (2020). *Behind-the-Meter Battery Market Study.* Prepared for San Diego Gas & Electric. Retrieved from https://www.etcc-ca.com/reports/behind-meter-battery-market-study?dl=1582149166

Horii, B., Cutter, E., Kapur, N., Arent, J., & Conotyannis, D. (2014). *Time Dependent Valuation of Energy for Developing Building Energy Efficiency Standards.*

Proctor, J., Wilcox, B., & Chitwood, R. (2018). *Central Valley Research Homes Project.* California Energy Commission. Retrieved from https://www.researchgate.net/publication/342135376_Central_Valley_Research_Homes_Project_--_Final_CEC_Report

RSMeans. (2022). Cost data obtained from the 2022 RSMeans online database.

Statewide CASE Team. (2017). *Residential High Performance Windows & Doors Codes and Standards Enhancement (CASE) Initiative 2019 California Energy Code.* Retrieved from http://title24stakeholders.com/wp-content/uploads/2017/09/2019-T24-CASE-Report_Res-Windows-and-Doors_Final_September-2017.pdf

Statewide CASE Team. (2018). *Energy Savings Potential and Cost-Effectiveness Analysis of High Efficiency Windows in California.* Prepared by Frontier Energy. Retrieved from https://www.etcc-ca.com/reports/energy-savings-potential-and-cost-effectiveness-analysis-high-efficiency-windows-california

Statewide CASE Team. (2020a). *Nonresidential High Performance Envelope Codes and Standards Enhancement (CASE) Initiative 2022 California Energy Code.* Prepared by Energy Solutions. Retrieved from https://title24stakeholders.com/wp-content/uploads/2020/10/2020-T24-NR-HP-Envelope-Final-CASE-Report.pdf

Statewide CASE Team. (2020b). *Residential Energy Savings and Process Improvements for Additions and Alterations Codes and Standards Enhancement (CASE) Initiative 2022 California Energy Code.* Prepared by Frontier Energy. Retrieved from https://title24stakeholders.com/wp-content/uploads/2020/08/SF-Additions-and-Alterations_Final_-CASE-Report_Statewide-CASE-Team.pdf

Statewide CASE Team. (2020c). *Multifamily All-Electric Codes and Standards Enhancement (CASE) Initiative 2022 California Energy Code.* Prepared by TRC.

Statewide Reach Codes Team. (2019, August). *2019 Cost-effectiveness Study: Low-Rise Residential New Construction. Prepared for Pacific Gas and Electric Company.* Prepared by Frontier Energy. Retrieved from https://localenergycodes.com/download/800/file_path/fieldList/2019%20Res%20NC%20Reach%20Codes

Statewide Reach Codes Team. (2021a). *Cost-Effectiveness Analysis: Batteries in Single Family Homes.* Prepared by Frontier Energy. Retrieved from https://localenergycodes.com/download/930/file_path/fieldList/Single%20Family%20Battery%20Cost-eff%20Report.pdf

Statewide Reach Codes Team. (2021b). *2020 Reach Code Cost-Effectiveness Analysis: Detached Accessory Dwelling Units.* Prepared by TRC. Retrieved from https://localenergycodes.com/download/760/file_path/fieldList/2019%20New%20Detached%20ADUs%20Cost-effectiveness%20Report.pdf

Statewide Reach Codes Team. (tbd). *2022 Cost-Effectiveness Study: Existing Single Family Building Upgrades.* Prepared by Frontier Energy. Not yet published.

TRC, P. E. (2021). *2020 Reach Code Cost-Effectiveness Analysis: Detached Accessory Dwelling Units.*

UC Berkeley Center for Community Innovation. (2021). *Implementing the Backyard Revolution: Perspectives of California's ADU Owners.*

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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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