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CALIFORNIA ENERGY CODES & STANDARDS
A STATEWIDE UTILITY PROGRAM

2019 Cost-Effectiveness Study:
Existing Single Family Residential Building Upgrades
Climate Zone 2 Results

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Acronym List

ACH50	Air Changes per Hour at 50 pascals pressure differential
AC	Air Conditioner
ACM	Alternative Calculation Method
AFUE	Annual Fuel Utilization Efficiency
A	Ampere
B/C	Benefits-to Cost; as in Lifecycle Benefit-to-Cost Ratio
BSC	Building Standards Commission
Btu	British thermal units
CALGreen	Title 24, Part 11
CASE	Codes and Standards Enhancement
CBECC-Res	California Building Energy Code Compliance – Residential: 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
CFL	Compact Fluorescent Lamp
CO_2e	Carbon Dioxide (CO_2)-equivalent
CPAU	City of Palo Alto Utilities
CRRC	Cool Roof Rating Council
CZ	California Climate Zone
DHW	Domestic Hot Water
E3	Energy and Environmental Economics
EDR	Energy Design Rating
EER	Energy Efficiency Ratio
ft^2	Square foot
GHG	Greenhouse Gas
GRC	General Rate Case
gpm	Gallons per minute
HERS Rater	Home Energy Rating System Rater
HPWH	Heat Pump Water Heater
HSPF	Heating Seasonal Performance Factor
HVAC	Heating, Ventilation, and Air Conditioning
IC	Insulation Contact
IOU	Investor-Owned Utility
ITC	Income Tax Credit (federal)

kWh	Kilowatt-hour
kW_{DC}	Kilowatt Direct Current; nominal rated power of a photovoltaic system
lb(s)	Pound(s)
LCC	Lifecycle Cost
LED	Light-Emitting Diode
MF	Multifamily
NEEA	Northwest Energy Efficiency Alliance
NEM	Net Energy Metering
NPV	Net Present Value
PG&E	Pacific Gas and Electric Company
PV	Photovoltaic
SCE	Southern California Edison
SDG&E	San Diego Gas and Electric
SEER	Seasonal Energy Efficiency Ratio
SHGC	Solar Heat Gain Coefficient
SMUD	Sacramento Municipal Utility District
TDV	Time Dependent Valuation
therm	Unit for quantity of heat that equals 100,000 Btu
Title 24	Title 24, Part 6
TOU	Time-of-Use
UEF	Uniform Energy Factor
V	Volt
W	Watt
W_{DC}	Watt Direct Current

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1 Overview

The California Statewide Codes and Standards Reach Codes Team (Statewide Reach Code Team) has updated the prior cost-effectiveness study for existing building upgrades completed in February 2020 (Statewide Reach Codes Team, 2020). This analysis evaluates the feasibility and cost effectiveness of retrofit measures in California existing single family homes built before 2010. A lifecycle cost (LCC) approach to evaluating cost effectiveness was applied quantifying the savings associated with energy efficiency measures compared to measure costs. The focus of this study was to revisit the recommended retrofit efficiency measure and package cost effectiveness based on latest utility rates, updated measure costs and evaluate cost effectiveness of additional efficiency and grid integration measures, including:

- Revisit base case assumptions for different vintages.
- Additional efficiency upgrade options including:
    - High-efficiency equipment replacement as alternative to non-preempted upgrade measures.
    - Higher ceiling insulation requirements.
    - Improved duct insulation and reduced duct leakage.
- PV system installation.
- Evaluation of electrification measures at equipment change-out and electrification-ready measures.
- Electrification measures tied to installation of PV system.
- Battery storage measures.

2 Introduction

The California Codes and Standards 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 and greenhouse gas 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. Local jurisdictions that are considering adopting ordinances may contact the program for support through its website, LocalEnergyCodes.com.

The California Building Energy Efficiency Standards, or Title 24, Part 6 (Title 24) (California Energy Commission, 2018) 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 result in buildings consuming less energy than is permitted by Title 24. In addition, the jurisdiction must obtain approval from the Energy Commission and file the ordinance with the BSC for the ordinance to be legally enforceable.

This report documents cost-effective combinations of measures that exceed the minimum state requirements, the 2019 Building Energy Efficiency Standards, effective January 1, 2020. Local jurisdictions in California may consider adopting local energy ordinances to achieve energy savings beyond what will be accomplished by enforcing building efficiency requirements that apply statewide. This report was developed in coordination with the California Statewide Investor-Owned Utilities (IOUs) Codes and Standards Program, key consultants, and engaged cities—collectively known as the Statewide Reach Code Team.

The focus of this study is on existing single family buildings. This analysis does not apply to low- or high-rise multifamily buildings. Each jurisdiction must establish the appropriate structure and threshold for triggering the requirements. Some common structures include triggering the requirements at major remodels, additions, or date-certain (upgrades must be completed by a specific date). Some of these measures could be triggered with a permit for another specific measure, such as a reroof. The analysis includes scenarios of individual measures, as well as package upgrades, and identifies cost-effective options based on the existing conditions of the building in all 16 California Climate Zones (CZ) (see Appendix A: Map of California Climate Zones for a graphical depiction of climate zone locations).

This analysis does not evaluate the impact of retrofit measures on Title 24 compliance margins, as the proposed measures are required in addition to achieving compliance with all codes.

3 Methodology and Assumptions

This analysis uses 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 On-Bill savings using electricity and natural gas utility rate schedules over a 30-year duration accounting for discount rate and energy cost inflation.
- **Time Dependent Valuation (TDV)**: Energy Commission LCC methodology, which is intended to capture the societal value or cost of energy use including 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. Electricity used (or saved) during peak periods has a much higher value than electricity used (or saved) during off-peak periods (Horii et al., 2014). This is the methodology used by the Energy Commission in evaluating cost effectiveness for efficiency measures in Title 24. Both 2019 and 2022 TDV multipliers are evaluated and documented in this analysis.

The general approach applied in this analysis is to evaluate performance and determine cost effectiveness of various energy retrofit measures, individually and as packages, in single family homes. Three unique building vintages are considered: pre-1978, 1978-1991, and 1992-2010. The vintages were defined based on review of historic Title 24 code requirements and selecting year ranges with distinguishing features. The applied approach establishes recommendations based on existing conditions and cost effectiveness of each measure or package.

The California Building Energy Code Compliance – Residential (CBECC-Res) 2019.1.2 and 2022.0.1 compliance simulation tools were used to evaluate energy savings for most measures, with the exception of those outside the code compliance scope. In these cases, a combination of the Department of Energy's BEopt software and EnergyPlus v9.3. simulation engine was used.

This analysis builds on the work completed earlier in 2020 for the 2019 Title 24 (Statewide Reach Codes Team, 2020) and has been updated to reflect changes in measure costs over time as well as current utility tariffs. Energy simulations were re-evaluated in CBECC-Res 2019 to evaluate cost effectiveness from a TDV perspective under the 2019 Title 24. TDV cost effectiveness was also completed using the 2022 TDV and weather files to evaluate cost effectiveness with the latest version of the software for future code cycles.

3.1 Building Prototypes

The Energy Commission defines building prototypes which it uses to evaluate the cost effectiveness of proposed changes to Title 24 requirements. Average home size has steadily increased over time,[1] and the Energy Commission single family new construction prototypes are larger than many existing single family homes across California. For this analysis, an existing home prototype developed by the Energy Commission for residential ACM testing[2] was used with the following revisions. The original prototype includes an existing 1,440 square foot (ft^2) space and a 225 ft^2 addition. For this analysis, the entire 1,665 ft^2 was evaluated as existing space and features (i.e., insulation levels, glazing) were applied consistently across the entire building consistent with the existing home specifications in Table 2. Additions are not evaluated in this analysis as they are already addressed in Section 150.2 of Title 24, Part 6. Table 1 describes the basic characteristics of the single family prototype.

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[1] https://www.census.gov/const/C25Ann/sftotalmedavgsqft.pdf

[2] Residential ACM test U12 can be accessed at the following website: http://www.bwilcox.com/BEES/cbecc2016.html

Table 1: Prototype Characteristics

	Single Family
Existing Conditioned Floor Area	1,665 ft^2
Num. of Stories	1
Num. of Bedrooms	3
Window-to-Floor Area Ratio	13%
Attached Garage	2-car garage

Three building vintages were evaluated to determine sensitivity of existing building performance on cost effectiveness of upgrades. For example, it is widely recognized that adding attic insulation in an older home with no insulation is cost-effective, however, newer homes will likely have at least some existing insulation in the attic reducing the potential savings from the measure. The building characteristics for each vintage were determined based on either prescriptive requirements from Title 24 that were in effect or standard construction practice during that time period. Homes built under 2001 Title 24 are subject to prescriptive envelope code requirements very similar to homes built under the 2005 code cycle, which was in effect until January 1, 2010.

Table 2 summarizes the assumptions for each of the three vintages. Additionally, the analysis assumed the following features when modeling the prototype buildings:

- Individual space conditioning and water heating systems, one per single family building.
- Split-system air conditioner with natural gas furnace. Efficiency defined by year of the most recent equipment replacement (based on standard equipment lifetime).
- Small storage natural gas water heater. Efficiency defined by year of most recent equipment replacement (based on standard equipment lifetime).
- Gas cooktop, oven, and clothes dryer.

Table 2: Efficiency Characteristics for Three Vintage Cases

Building Component Efficiency Feature	Pre-1978	1978-1991	1992-2010
Envelope	-	-	-
Exterior Walls	2x4, 16 inch on center wood frame, R-0[a]	2x4 16inch on center wood frame, R-11	2x4 16inch on center wood frame, R-13
Foundation Type & Insulation	Uninsulated slab (CZ 2-15) Raised floor, R-0 (CZ 1 & 16)	Uninsulated slab (CZ 2-15) Raised floor, R-0 (CZ 1 & 16)	Uninsulated slab (CZ 2-15) Raised floor, R-19 (CZ 1 & 16)
Ceiling Insulation & Attic Type	Vented attic, R-11 @ ceiling level Vented attic, R-5 @ ceiling level (CZ 6 & 7)	Vented attic, R-19 @ ceiling level	Vented attic, R-30 @ ceiling level
Roofing Material & Color	Asphalt shingles, dark (0.10 reflectance, 0.85 emittance)	Asphalt shingles, dark (0.10 reflectance, 0.85 emittance)	Asphalt shingles, dark (0.10 reflectance, 0.85 emittance)
Radiant Barrier	No	No	No
Window Type: U-factor/SHGC[b]	Metal, single pane: 1.16/0.76	Metal, dual pane: 0.79/0.70	Vinyl, dual pane Low-E: 0.55/0.40
House Infiltration	15 ACH50	10 ACH50	7 ACH50
HVAC Equipment	-	-	-
Heating Efficiency	78 AFUE (assumes 2 replacements)	78 AFUE (assumes 1 replacement)	78 AFUE
Cooling Efficiency	10 SEER (assumes 2 replacements)	10 SEER (assumes 1 replacement)	13 SEER, 11 EER
Duct Location & Details	Attic, R-2.1, 30% leakage	Attic, R-2.1, 25% leakage	Attic, R-4.2, 15% leakage
Whole Building Mechanical Ventilation	None	None	None
Water Heating Equipment	-	-	-
Water Heater Efficiency	0.575 Energy Factor (assumes 2 replacements)	0.575 Energy Factor (assumes 1 replacement)	0.575 Energy Factor
Water Heater Tank	40-gallon uninsulated tank	40-gallon uninsulated tank	40-gallon uninsulated tank
Pipe Insulation	None	None	None
Hot Water Fixtures	Standard, non-low flow	Standard, non-low flow	Standard, non-low flow

[a] Pre-1978 wall modeled with R-5 cavity insulation to better simulate uninsulated wall performance with field data and not overestimate energy use.

[b] Window type selections were made based on conversations with window industry expert, Ken Nittler. If a technology was entering the market during the time period (e.g., Low-E during 1992-2010 or dual pane during 1978-1991) that technology was included in the analysis. This provides a conservative assumption for overall building performance and additional measures may be cost-effective for buildings with lower performing windows, for example buildings with metal single pane windows in the 1978-1991 vintage.

3.2 Efficiency Measures

The methodology used in the analyses for each of the prototypical building types begins with a design that matches the specifications as described in Table 2 for each of the three vintages. Prospective energy efficiency measures were modeled in each of the prototypes to determine the projected electricity and natural gas energy savings relative to the baseline vintage. In some cases, where logical, measures were packaged together. Unless specified otherwise, all measures were evaluated using CBECC-Res.

All measures are evaluated assuming they are not otherwise required by Title 24. For example, duct sealing is required by code whenever HVAC equipment is altered. For this analysis duct sealing was evaluated for those projects where it is not already triggered by code (i.e., no changes to the heating or cooling equipment). Where appropriate, measure requirements align with those defined in Title 24. In some cases, cost-effective measures were identified that exceed Title 24 requirements, such as attic insulation, cool roofs, and duct sealing.

Following are descriptions of each of the efficiency upgrade measures applied in this analysis.

3.2.1 Building Envelope/Non-Preempted Measures

Attic Insulation: Add attic insulation in buildings with vented attic spaces to meet R-49. For pre-1992 vintage homes this measure was also evaluated to include retrofitting of existing recessed can luminaires that are not rated for insulation contact (IC) to be airtight and allow for insulation contact. This can be accomplished by installing a recessed light cover over existing non-compliant luminaires and sealing the covers to the ceiling plane with foam or replacing non-IC-rated luminaires with IC-rated luminaires. The energy analysis includes savings from adding insulation and upgrading compact fluorescent lamp (CFL) recessed cans to LED lighting but does not include any reduced infiltration benefits. Newer vintage homes are assumed to have IC-rated recessed light luminaires that can be covered in insulation.

Air Sealing and Weather-stripping: Apply air sealing practices throughout all accessible areas of the building. For this study, it was assumed that older vintage homes would be leakier than newer buildings and that approximately 30 percent improvement in air leakage was achievable through air sealing of all accessible areas. For modeling purposes, it was assumed that air sealing can reduce infiltration levels from 15 to ten air changes per hour at 50 Pascals pressure difference (ACH50) in the oldest vintages (pre-1978), from ten to seven ACH50 for the 1978 to 1991 vintage, and from seven to five ACH50 in the 1992 to 2010 vintage.

Cool Roof: For steep slope roofs, install a roofing product rated by the Cool Roof Rating Council (CRRC) with an aged solar reflectance of 0.25 or higher and thermal emittance of 0.75 or higher. This measure only applies to buildings that are installing a new roof as part of the scope of the remodel; the cost and energy savings associated with this upgrade reflects the incremental step between a standard roofing product with one that is CRRC rated with an aged solar reflectance of 0.25. This is similar to cool roof requirements in 2019 Title 24 Section 150.2(b)1Ii but assumes a higher solar reflectance.

Raised Floor Insulation: In existing homes with raised floors and no insulation, add R-19 insulation.

Wall Insulation: Blow-in R-13 wall insulation in existing homes that currently have no insulation in the walls (pre-1978 vintages).

Window Replacement: Replace existing metal-frame windows with a non-metal dual-pane product, which has a U-factor equal to 0.30 Btu/hour-ft^2-°F or lower and a Solar Heat Gain Coefficient (SHGC) equal to 0.23 or lower, except in heating dominated climates (Climate Zones 1, 3, 5, and 16) where an SHGC of 0.35 was evaluated. This measure was only evaluated for the two older vintages, pre-1992, which are assumed to have either single- or dual-pane, metal-frame windows. This aligns with new window requirements in 2019 Title 24.

Duct Sealing, New Ducts, and Duct Insulation: Air seal all ductwork to meet the requirements of the 2019 Title 24, Part 6 Section 150.2(b)1E. For this analysis, final duct leakage values of both 15 percent (which corresponds to Option i in the Title 24 section referenced), and ten percent (proposed revised leakage rate for 2022 Title 24) were evaluated. Replacing existing ductwork with entirely new ductwork to meet Sections 150.2(b)1Di and 150.2(b)1Diia of the 2019 Title 24 was also evaluated. This assumed new ducts meet five percent duct leakage and R-8 duct insulation in all climates.

Water Heater Blanket: Add R-6 insulation to the exterior of existing residential tank storage water heaters. For the analysis, the water heater was modeled within conditioned space, which is a typical configuration for older homes. This assumption is conservative since a water heater located in unconditioned space will tend to have higher tank losses and installing a water heater blanket in those situations will result in additional savings. The energy savings for this measure reflect water heating energy savings only, and do not include any impacts to the space conditioning load, which reduces space cooling loads and increases space heating loads. The impact on space conditioning energy used is minimal and in most climate zones, except for heating dominated ones, the combination of these two impacts results in net energy savings. This measure was evaluated using EnergyPlus for individual water heaters only and does not apply to central water heating systems.

Hot Water Pipe Insulation: Insulate all accessible hot water pipes with R-3 pipe insulation. In certain buildings such as those with slab on grade construction where the majority of pipes are located either underground or within the walls, most of the pipes are inaccessible. For the purposes of this analysis a conservative assumption that only ten percent of the pipes could be insulated was applied. In buildings where pipes are located in the attic, crawlspace, or are otherwise more accessible, energy savings will be higher than those presented in this analysis. This measure was evaluated using BEopt and EnergyPlus.

Low-Flow Fixtures: Upgrade sink and shower fittings to meet current Title 24, Part 11 (CALGreen) requirements, which require maximum flow rates of 1.8 gallons per minute (gpm) for showerheads and kitchen faucets, and 1.2 gpm for bathroom faucets. Baseline whole house hot water use was based on BEopt assumptions and this measure assumed the upgraded fixtures reduce flow rates by ten percent for showerheads and 20 percent for all faucets based on a 2010 water use study (ConSol, 2010). This measure was evaluated using BEopt and EnergyPlus.

LED Lighting: Replace screw-in (A-based for lamps) incandescent lamps and CFLs with light-emitting diode (LED) A-lamps. This analysis was conducted external to the energy model and evaluated replacement of a 13 W CFL lamp with an 11 W LED lamp operating 620 hours annually. Annual hour estimates were based on whole building average hours of operation from a 2010 lighting study by KEMA (KEMA, 2010). Lifetime assumptions were 10,000 hours for CFLs and 25,000 hours for LED lamps. For incremental cost calculations it was assumed CFLs have a lifetime of 15 years, are installed five years prior to the retrofit, and would need to be replaced at year ten and 25.

Exterior Lighting Controls: Evaluation of exterior lighting controls was completed on a per-luminaire basis external to the energy model and assumes a screw-in photosensor control is installed in outdoor lighting luminaires. Energy savings of 12.1 kWh per year was applied based on analysis done by the Consortium for Energy Efficiency, assuming LED lamps, 2.6 hours per day of operation, and that photosensor controls reduce operating hours on average 20 percent each day (CEE, 2014). Energy savings will be higher for incandescent or CFL luminaires.

3.2.2 Photovoltaics (PV) and Battery Measures

PV: Installation of on-site PV is required in the 2019 residential code for new construction but not for additions or alterations to existing buildings. This report does not focus on optimizing PV system sizing for each prototype and climate zone. For this study, the PV system was sized to the 2019 new construction standards for a 1,665 ft^2 home or sized to offset 100 percent of annual building electricity use, whichever was smaller. Based on prior studies, PV system cost effectiveness was not sensitive to system sizing up to 90 percent of annual electricity use (Statewide Reach Codes Team, 2019). The system is sized to offset a portion of annual building electricity use for a new construction home and avoid oversizing which would violate net energy metering (NEM) rules. In only one case was the PV system downsized to ensure that over-generation did not occur. In all cases, PV is evaluated in CBECC-Res according to the California Flexible Installation (CFI) assumptions. Table 3 summarizes the PV sizing used in the analysis.

Table 3: Single Family PV Sizing for 1,665 ft^2 home by Climate Zone (kW_{DC})

CA Climate Zone	PV Capacity (kW_{DC})[a]	CA Climate Zone	PV Capacity (kW_{DC})[a]
1	2.59	**9**	2.38
2	2.25	**10**	2.45
3	2.17	**11**	2.83
4	2.19	**12**	2.42
5	2.03	**13**	3.00
6	2.22 (2.19 1992-2010 vintage)[b]	**14**	2.49
7	2.10	**15**	4.07
8	2.35	**16**	2.20

[a] PV system sized using residential new construction sizing methodology based on climate zone and house size.

[b] PV system was downsized for this vintage to prevent over-generation of PV.

<u>Energy Storage (Batteries):</u> This measure includes installation of batteries to allow energy generated through PV to be stored and used later, providing energy cost and resiliency benefits. This report does not focus on optimizing battery sizes or controls for each prototype and climate zone. A ten kWh battery system was evaluated in CBECC-Res in conjunction with a PV system sized to the 2019 new construction standards, with control type set to “Time of Use” (TOU) and with default efficiencies of 95 percent for both charging and discharging (round trip efficiency of 90 percent). The TOU option assumes batteries are charged anytime PV generation is greater than the house load but controls when the battery storage system discharges. During the summer months (July – September) the battery begins to discharge at the beginning of the peak period at a maximum rate until fully discharged. During discharge the battery first serves the house load but will discharge to the electric grid if there is excess energy available. During other months, the battery discharges whenever the PV system does not cover the entire house load and does not discharge to the electric grid. This control option is considered to be most reflective of the current products on the market. This control option requires an input for the “First Hour of the Summer Peak” and the Statewide Reach Codes Team applied the default hour in CBECC-Res which differs by climate zone (either a 6pm or 7pm start).

3.2.3 Equipment Fuel Substitution Measures – Heat Pump Replacements

The baseline for the retrofit analysis assumed a mixed-fuel baseline for all cases, with natural gas-fired furnaces for space heating and natural gas storage tank water heaters for domestic hot water (DHW). For fuel substitution cases, the natural gas appliances were assumed to be replaced with heat pump technology at the end of equipment life, when the equipment is being replaced.

<u>Ducted Heat Pump:</u> Replace existing ducted natural gas furnace and air conditioner (AC) with an electric heat pump. Minimum federal efficiency (14 SEER, 11.7 EER, 8.2 HSPF) and higher efficiency (21 SEER, 13.5 EER, 11 HSPF) heat pumps were evaluated as replacements to existing equipment. Savings are relative to a new ducted natural gas furnace/AC (14 SEER, 11.7 EER, 80 AFUE).

<u>Heat Pump Water Heater (HPWH):</u> Replace existing natural gas storage tank water heater with either a minimum efficiency (UEF 2.0) 50-gallon HPWH, or a HPWH that meets the Northwest Energy Efficiency Alliance

(NEEA)[3] Tier 3 rating. The evaluated NEEA HPWH is an 80-gallon unit with a UEF of 3.45. Savings are relative to a new 50-gallon natural gas storage water heater (UEF 0.63).

3.3 Efficiency Packages

Some of the measures described above were also evaluated as packages.

3.3.1 Envelope and Duct Packages

Five envelope and duct packages were developed as described below. Air sealing and attic insulation are very often applied as a package in building retrofits. From a performance perspective, air sealing of the boundary between the attic and living space should be addressed any time there is significant work in the attic, such as adding attic insulation and sealing or replacing ductwork. When the building shell is being improved, air sealing is an important component to be addressed. The boundary between the living space and vented attics is where a significant amount of building air leakage can occur and sealing these areas prior to covering the attic floor with insulation is both practical and effective. These measures also directly address occupant comfort, as they reduce heat transfer, and result in more even temperatures within the building. When ductwork is located in the attic there are synergies with addressing all three of these building aspects at the same time.

1. **R-49 Attic Insulation and Air Sealing:** This package includes attic insulation and air sealing measures, as described below:
   - R-49 attic insulation installed in attic.
   - Air sealing and weatherstripping to reduce total building air leakage by 30 percent. Target air leakage assumptions are ten ACH50 for pre-1978 vintage, seven ACH50 for 1978 to 1991 vintage, and five ACH50 for the 1992 to 2010 vintage.
   - Retrofitting all non-IC-rated recessed light luminaires to be airtight and allow for coverage by insulation. This submeasure only applies to homes without IC-rated recessed can luminaires.
2. **R-49 Attic Insulation and Duct Sealing:** This package includes attic insulation and duct sealing measures, as described below:
   - R-49 attic insulation installed in attic.
   - Ductwork sealed to ten percent of nominal airflow.
   - Retrofitting all non-IC-rated recessed light luminaires to be airtight and allow for coverage by insulation. This submeasure only applies to homes without IC-rated recessed can luminaires.
3. **R-49 Attic Insulation, Air Sealing, and Duct Sealing:** This package includes attic insulation, air sealing, and duct sealing measures, as described below:
   - R-49 attic insulation installed in attic.
   - Ductwork sealed to ten percent of nominal airflow.
   - Air sealing and weatherstripping to reduce total building air leakage by 30 percent. Target air leakage assumptions are ten ACH50 for pre-1978 vintage, seven ACH50 for 1978 to 1991 vintage, and five ACH50 for the 1992 to 2010 vintage.
   - Retrofitting all non-IC-rated recessed light luminaires to be airtight and allow for coverage by insulation. This submeasure only applies to homes without IC-rated recessed can luminaires.

[3] 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 an Energy Factor equal to the ENERGY STAR® performance level and includes requirements regarding noise and prioritizing heat pump use over supplemental electric resistance heating.

- This combination of measures is common when a whole building performance upgrade is done in combination with HVAC equipment replacement. Incorporating these measures can allow for contractor to downsize HVAC equipment by lowering heating and cooling loads in the house.

4. **R-49 Attic Insulation, Air Sealing, and Entirely New Ducts:** This package is similar to Package 3 above but assumes that all existing ductwork is replaced with new R-8 ducts and sealed to new construction standards (five percent total leakage). This package assumes that if an existing HVAC system is being replaced with new ductwork, the area between the vented attic and conditioned space be air sealed and insulation added to the attic.
   - R-49 attic insulation installed in attic.
   - New R-8 ductwork sealed to five percent of nominal airflow.
   - Air sealing and weatherstripping to reduce total building air leakage by 30 percent. Target air leakage assumptions are ten ACH50 for pre-1978 vintage, seven ACH50 for 1978 to 1991 vintage, and five ACH50 for the 1992 to 2010 vintage.
   - Retrofitting all non-IC-rated recessed light luminaires to be airtight and allow for coverage by insulation. This submeasure only applies to homes without IC-rated recessed can luminaires.
   - This combination of measures is common when a whole building performance upgrade is done in combination with HVAC equipment replacement. Incorporating these measures can allow for contractor to downsize HVAC equipment by lowering heating and cooling loads in the house.
5. **Advanced Envelope Package: Attic Insulation, Recessed Cans, Air and Duct Sealing, plus Wall Insulation and New Windows:** This package includes all the measures in Package 3, in addition to insulating exterior walls, and replacing existing single-pane windows with improved high-performance windows. This package only applies to older vintage homes with no wall cavity insulation and single-pane windows.
   - R-49 attic insulation installed in attic.
   - Ductwork sealed to ten percent of nominal airflow.
   - Air sealing and weatherstripping to reduce total building air leakage by 30 percent. Target air leakage assumptions are ten ACH50 for pre-1978 vintage, seven ACH50 for 1978 to 1991 vintage, and five ACH50 for the 1992 to 2010 vintage.
   - Retrofitting all non-IC-rated recessed light luminaires to be airtight and allow for coverage by insulation. This submeasure only applies to homes without IC-rated recessed can luminaires.
   - Insulate exterior walls to R-13.
   - New windows with 0.30 U-factor and 0.23 SHGC (0.35 SHGC in Climate Zones 1, 3, 5, and 16).
   - This combination of measures is common when a whole building performance upgrade is done in combination with HVAC equipment replacement. Incorporating these measures can allow for contractor to downsize HVAC equipment by lowering heating and cooling loads in the house.

3.3.2 Additional Packages

Water Heating Package: Includes water heater blanket, hot water pipe insulation, and low-flow fixtures: These three water heating measures are all relatively low cost and work together to reduce building hot water energy use. Additional water savings measures and model language are documented on the LocalEnergyCodes.com website.[4]

PV plus Batteries: PV sized to Residential New Construction Standards and a ten kWh battery system with TOU control.

[4] https://localenergycodes.com/

PV plus Heat Pump: PV sized to Residential New Construction Standards and one fuel substitution measure, either a ducted heat pump for space heating or heat pump water heater.

PV plus Heat Pump plus Panel Upgrade: The PV plus Heat Pump package with the additional cost included for upgrading the electric panel.

PV plus Electric Ready Measures: Includes adding electric ready measures for future replacement of natural gas furnace and water heater with heat pumps, along with installation of an on-site PV system. The electric ready measures include prewiring 240 V power to the furnace location in the attic and the water heater location in the garage, and panel upgrade to allow for installation of future electric appliances at a future date.

3.4 Measure Cost

Measure costs were obtained from various sources, including prior reach code studies, past Title 24 Codes and Standards Enhancement (CASE) work, local contractors, internet searches, past projects, and technical reports.

3.4.1 Building Envelope/Non-Preempted Measures

Table 4 summarizes the cost assumptions for the building envelope and non-preempted HVAC measures evaluated.

3.4.2 PV and Battery Measures

The costs for installing PV and batteries are summarized in Table 5. For PV, they include first cost to purchase and install the system, inverter replacement costs, and annual maintenance costs. Upfront solar PV system costs are reduced by the federal income tax credit (ITC) by 26 percent based on renewal of the credit through the year 2023.

Costs for batteries include first cost and replacement at year 10 and 20, assuming a 10 year battery life. Batteries are also eligible for the ITC if they are installed at the same time as the renewable generation source and at least 75 percent of the energy used to charge the battery comes from a renewable source.

Table 4: Measure Descriptions & Cost Assumptions - Non-Preempted Measures[a]

Table 4A – Building Envelope Measures

Measure	Performance Level	Incremental Cost – Single Family Building			Source	Notes
		Pre 1978	1978 – 1991	1992 - 2010		
Wall Insulation	R-13	$3,360	N/A	N/A	Retrofit contractor[b]	$2.14/ ft^2 exterior wall area. Drill 2-inch holes from outside.
Raised Floor Insulation	R-19	$3,147	N/A	N/A	Retrofit contractor[b]	$1.89/ ft^2 of raised floor area. Assumes installation of R-19 batt insulation when existing condition is no insulation.
Attic Insulation	R-49	$2,851	$2,393	$1,852	2022 Alterations CASE Report (Statewide CASE Team, 2020)	$1.71/ ft^2 ceiling area to add insulation to existing R-11 insulation. $1.44/ ft^2 to add insulation to existing R-19 insulation.
	R-49 + Recessed Can Retrofit	$3,332	$2,874	$2,333		Added cost of $0.29/ ft^2 ceiling area to retrofit non-IC-rated to be airtight and allow coverage with insulation and seal the covers to the ceiling plane with foam. Added cost used for pre-1992 homes.
Air Sealing	10 ACH50	$1,474	N/A	N/A	Retrofit contractor[b]	Based on contractor quote to seal building shell and reduce building air leakage by 30%. Assumes all accessible leaks are sealed and assumes existing attic insulation is not removed.
	7 ACH50	N/A	$1,474	N/A		
	5 ACH50	N/A	N/A	$1,474		
Cool Roof	Aged Solar Reflectance ≥ 0.25	$778	$778	$778	2022 Alterations CASE Report (Statewide CASE Team, 2020)	Based on $0.32/ ft^2 roof area first incremental cost for cool asphalt shingle product. 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
Window U-factor/SHGC	0.30 U-factor. 0.23 SHGC in CZs 2,4,6-15. 0.35 SHGC in CZs 1,3,5,16	$9,810	N/A	N/A	Retrofit contractor[c]	Based on $45/ ft^2 window area installed cost.

[a] Costs include contractor overhead and profit.

[b] Source: Retrofit contractor pricing. 2020. Phone outreach.

[c] Source: Retrofit contractor pricing obtained by Davis Energy Group through the Stockton Energy Challenge neighborhood retrofit program (DEG, 2017).

Table 4B – HVAC/DHW and Lighting Measures

Measure	Performance Level	Incremental Cost – Single Family Building All vintages	Source	Notes
Duct Sealing	15% nominal airflow	$423 (Pre-1978, 1978–1991) N/A (1992-2010)	HVAC contractor	Assume ducts in attic with 5 wye branches, 8 supplies & 1 return. $223 in labor (~2 hours at $120/hour) and $20 material for 15% leakage from a starting point of 25-30% and for 10% from a starting point of 15%. $463 in labor (~4 hours at $120/hour) and $40 material for 10% leakage from a starting point of 25-30%. $180 for HERS Rater.
Duct Sealing	10% nominal airflow	$683 (Pre-1978, 1978-1991) $423 (1992-2010)	HVAC contractor	Assume ducts in attic with 5 wye branches, 8 supplies & 1 return. $223 in labor (~2 hours at $120/hour) and $20 material for 15% leakage from a starting point of 25-30% and for 10% from a starting point of 15%. $463 in labor (~4 hours at $120/hour) and $40 material for 10% leakage from a starting point of 25-30%. $180 for HERS Rater.
Entirely New Ducts	R-8 ducts; 5% duct leakage	$3,986	Retrofit contractor[b]	Based on duct layout provided for prototype single story model, and all ducts located in attic.
Water Heater Blanket	R-6	$40	Internet search	$20 blanket + ½-hour labor ($40.30/hour laborer rate).[d] Six-year life assuming that the water heater will need to be replaced after 6 years on average.
Hot Water Pipe Insulation	3/4 inch (R-3)	$42	Internet search	$0.20/ft of ¾ inch pipe insulation. 10ft total + 1-hour labor ($40.30/hour common labor rate).[d] 15-year life assumed.
Low-flow Fixtures	CALGreen	$126	Retrofit contractor[c]	Showerheads at $34.74 each + sink aerators at $5.37 each + 1-hour labor ($40.30/hour common labor rate).[d] 2 showerheads & 3 aerators assumed for single family. 15-year life assumed.
LED Lamp	11 W screw-in lamp	$3.99/luminaire	Internet search	$3.99 for LED dimmable A19 lamp 60 W equivalent. $1.83 for an equivalent CFL product which was used to estimate total replacement costs at years 10 and 25. Cost based on a single LED lamp replacement.
Exterior Lighting Controls	Photocell control with motion sensor	$10.50/device	Internet search	Incremental cost of $10.50, based on a screw-in photosensor control, was obtained from an on-line product search of available products. A five-year lifetime for this type of control was assumed.

Table 5: Measure Descriptions & Cost Assumptions – PV and Batteries[a]

Measure	Performance Level	Incremental Cost – Single Family Building All vintages	Source	Notes
PV	Sized to 2019 New Construction Standards: System size varies by climate (2.03-4.07 kW)	$\$3.18/W_{DC}$ $6,467 - $12,933	(LBNL, 2019)	First costs are from LBNL's Tracking the Sun 2019 costs (Barbose et al., 2019) and represent costs for the first half of 2019 of $\$3.70/W_{DC}$ for residential systems. These costs were reduced by 26% for the solar ITC, which is the average credit over years 2021-2022. Inverter replacement cost of $\$0.14/W_{DC}$ present value includes replacements at year 11 at $\$0.15/W_{DC}$ (nominal) and at year 21 at $\$0.12/W_{DC}$ (nominal) per the 2019 PV CASE Report (California Energy Commission, 2017). System maintenance costs of $\$0.31/W_{DC}$ present value assume $\$0.02/W_{DC}$ (nominal) annually per the 2019 PV CASE Report (California Energy Commission, 2017).
Batteries	10 kWh, TOU controls	$11,372 $1,137/kWh	(SGIP, 2020), (E Source Companies, 2020).	$1,000/kWh first cost in 2020 based on Self-Generation Incentive Program residential participant cost data. To estimate the first cost in future years this was reduced by 7% annually based on SDG&E's Behind-the-Meter Battery Market Study (E Source Companies, 2020). The first cost is reduced by the Residential Storage Step 7 SGIP incentive of $0.15/Wh and the solar ITC of 26%. Costs are presented as the average of 2021 and 2022. Replacement cost at year 10 and 20 calculated based on the 2020 cost of $1,000/kWh reduced by 7% annually over the next 11 years for a future value cost of $450 (present value of $335 in year 10 and $249 in year 20).

[a] Costs include contractor overhead and profit.

3.4.3 Equipment Fuel Substitution Measures – Heat Pump Equipment

The cost assumptions used for fuel substitution measures are summarized in Table 6 and Table 7. Incremental costs for the heat pump replacement measures were obtained from several sources, including a 2019 report on residential building electrification in California (Energy & Environmental Economics, 2019), pricing information provided from Sacramento Municipal Utility District's (SMUD's) electric appliance incentive program (SMUD, 2020), online equipment pricing, and contractor outreach. Both material and labor costs are included, assuming that existing natural gas equipment is being replaced with heat pumps at the end of equipment life, at time of equipment replacement.

For both the space heating and water heating cases, costs for service panel upgrades are not included as it is assumed many existing homes have the service capacity to support converting one appliance from gas to electric. In some homes and in cases where multiple end uses are electrified, a larger electrical panel may be necessary. Cost assumptions for electric ready measures including panel upgrade for future equipment fuel substitution measures are included in Table 8.

Ducted Heat Pump: The base case assumes that an existing AC is replaced. In mild climates, where AC may not be installed, there will be additional costs for installing an outdoor unit, refrigerant lines, and condensate drain pan.

Table 6 presents estimated costs to replace existing equipment with a heat pump instead of a minimum efficiency natural gas furnace and AC. It is assumed there is no incremental labor except in providing new 240 V electrical service to the air handler location.

The lifetime for the heat pump, furnace, and air conditioner are based on the Database for Energy Efficient Resources (DEER) (California Public Utilities Commission, 2021). In DEER, heat pump and air conditioner measures are assigned an effective useful lifetime (EUL) of 15 years and a furnace an EUL of 20 years. The heating and cooling system components are typically replaced at the same time when one reaches the end of its life and the other is near it. Therefore, it is assumed that both the furnace and air conditioner are replaced at the same time at year 17.5, halfway between 15 and 20 years. Present value replacement costs are included in the LCC.

The base case assumes that an existing AC is replaced. In mild climates, where AC may not be installed, there will be additional costs for installing an outdoor unit, refrigerant lines, and condensate drain pan.

Table 6: HVAC Measure Cost Assumptions – Electric Replacements

	Gas Furnace/ AC	14 SEER Heat Pump	21 SEER Heat Pump	Notes
First Cost	$8,738	$9,101	$11,247	Equipment costs from on-line sources and HVAC contractors. Other supply and labor costs from 2019 report on residential building electrification in California (Energy & Environmental Economics, 2019). First cost includes disposal, electrical upgrade, and labor costs.
Replacement Cost (Future Value)	$8,738	$6,729	$8,445	Future total replacement costs for the heat pumps are reduced by 20% to account for cost reductions because of a maturing market and electrical upgrade costs are removed.
Replacement Cost (Present Value)	$5,209	$4,319	$5,421	Based on 17.5-year lifetime for gas furnace/AC, 15-year lifetime for heat pumps, and 3% discount rate.
Remaining Value at Year 30	($1,029)	$0	$0	Residual value of the gas furnace/AC to account for the remaining life at end of 30-year analysis period.
Total Lifecycle Cost	$12,918	$13,419	$16,667	
Incremental Cost	**-**	***$501***	***$3,749***	

Heat Pump Water Heater (HPWH): Table 7 presents estimated costs for the replacement of a natural gas storage water heater located in a garage with a HPWH. Costs include all material and installation labor including providing new 240 V electrical service to the water heater location. Total installed costs are based on data from SMUD's HPWH incentive program between 2018 and 2020 (SMUD, 2020). Equipment replacement costs are included based on an equipment life of 15 years for both the base case gas water heater and the HPWH. Present value replacement costs are included in the LCC.

Table 7: Water Heating Measure Cost Assumptions – Electric Replacements

Item	Gas Storage Water Heater	2.0 UEF HPWH	NEEA Tier 3 HPWH	Notes
First Cost	$1,600	$4,018	$4,155	First cost based on 2018-2020 costs from SMUD incentive program for NEEA Tier 3 HPWH (SMUD, 2020). 2.0 UEF first cost assumes 90% of equipment cost compared to NEEA Tier 3 unit based on on-line product research. Includes equipment cost, electrical upgrade, permitting, and labor.
Replacement Cost (Future Value)	$1,600	$1,874	$1,943	Future replacement cost assumes the same labor for the gas and HPWH case. HPWH replacement equipment costs are reduced by 50% to account for cost reductions because of a maturing market.
Replacement Cost (Present Value)	$1,027	$1,203	$1,247	Based on 15-year lifetime and 3% discount rate.
Total Lifecycle Cost	$2,627	$5,221	$5,402	
Incremental Cost	-	***$2,594***	***$2,775***	

Electric Ready: Table 8 presents electric ready measure costs. Appliance pre-wiring costs assume materials and labor for prewiring 240 V, 30 A dedicated circuits to the existing furnace location in the attic and the water heater location in the garage. Panel upgrade costs are based on upgrading from 100 A to 200 A service to allow for electric appliance installation at a future date.

Table 8: Electric Ready Measure Cost Assumptions

Measure	Incremental Cost	Notes
Appliance pre-wire	$455 per appliance. $910 total for space and water heating	$125 parts, $330 labor. (E3, 2019)
Panel upgrade	$3,181	(TRC, 2016)

3.5 Cost Effectiveness

Cost effectiveness was evaluated for all climate zones and is presented based on both TDV energy, using the Energy Commission's LCC methodology, and an On-Bill, customer-based approach using residential customer utility rates. Both methodologies require estimating and quantifying the value of the energy impact associated with energy efficiency measures over the life of the measures (30 years) as compared to the prescriptive Title 24 requirements.

Additional analysis included evaluating the measures using both the 2019 and proposed 2022 TDV multipliers. The proposed 2022 weather files were also used to evaluate On-Bill energy performance. The 2022 weather files were updated in 2019 and are considered to better represent conditions now and in the future. They tend to increase cooling and reduce space heating energy use, based on recent warming trends throughout the state.

Cost effectiveness is presented using both lifecycle NPV savings and benefit-to-cost (B/C) ratio metrics, which represent the cost effectiveness of a measure over a 30-year lifetime taking into account discounting of future savings and costs and financing of incremental first costs.

- **NPV Savings:** NPV benefits minus NPV costs is reported as a cost-effectiveness metric. If the net savings of a measure or package is positive, it is considered cost-effective. Negative savings represent net costs. A measure that has negative energy cost benefits (energy cost increase) can still be cost-effective if the costs to implement the measure are more negative (i.e., material and maintenance cost savings).
- **B/C Ratio:** Ratio of the present value of all benefits to the present value of all costs over 30 years (NPV benefits divided by NPV costs). The criteria for cost effectiveness is a B/C ratio greater than one. A value of one indicates the NPV of the savings over the life of the measure is equivalent to the NPV of the lifetime incremental cost of that measure. A value greater than one represents a positive return on investment. The B/C ratio is calculated according to Equation 1.

Equation 1

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

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 by incremental first cost and replacement costs. However, some packages result in initial construction cost savings (negative incremental cost), and either energy cost savings (positive benefits), or increased energy costs (negative benefits). In cases where both construction costs and energy-related savings are negative, the construction cost savings are treated as the 'benefit' while the increased energy costs are the 'cost.' In cases where a measure or package is cost-effective immediately (i.e., upfront construction cost savings and lifetime energy cost savings), B/C ratio cost effectiveness is represented by ">1". Because of these situations, NPV savings are also reported, which, in these cases, are positive values.

The lifetime costs or benefits are calculated according to Equation 2.

Equation 2

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

Where:

- n = analysis term
- r = discount rate

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

- Analysis term of 30 years
  - 15-year analysis term for the water heating package
  - Five-year analysis term for the exterior light controls
- Real discount rate of three percent

3.5.1 On-Bill LCC

Residential utility rates at the time of the analysis were applied to calculate utility costs for all cases and determine On-Bill cost effectiveness for the proposed measures and packages. The Statewide Reach Code Team obtained the recommended utility rates from each IOU based on the assumption that the reach codes go into effect in 2020. First-year utility costs were calculated using hourly electricity and natural gas output from CBECC-Res and applying the utility tariffs summarized in Table 9. Appendix B: Utility Rate Schedules includes details on the utility rate schedules used for this study. The applicable residential TOU rate was applied to all cases. For cases with PV generation, the approved NEM2 tariffs were applied along with minimum daily use billing and mandatory non-bypassable charges. For the PV cases annual electric production was always less than annual electricity consumption; and therefore, no credits for surplus generation were necessary. Future changes to the NEM tariffs are likely; however, there is uncertainty about what those changes will be and if they will become effective during the 2019 Title 24 code cycle (2020-2022).

Utility rates were applied to each climate zone based on the predominant IOU serving the population of each zone according to Table 9. Climate Zones 10 and 14 are 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 municipal utility rates were also evaluated: SMUD in Climate Zone 12 and City of Palo Alto Utilities (CPAU) in Climate Zone 4.

Table 9: IOU Utility Tariffs Applied Based on Climate Zone

Climate Zones	Electric/Gas Utility	Electricity	Natural Gas
1-5, 11-13, 16	PG&E	E-TOU-C	G1
5	PG&E/SoCalGas	E-TOU-C	GR
6, 8-10, 14, 15	SCE/SoCalGas	TOU-D-4-9	GR
7, 10, 14	SDG&E	D TOU-DR1	GR
12	SMUD/PG&E	R-TOD (RT02)	G1
4	CPAU	E-1	G-2

Source: Utility websites, see Appendix B: Utility Rate Schedules for details on the tariffs applied

Utility rates are assumed to escalate over time, using assumptions from research conducted by Energy and Environmental Economics (E3) in the 2019 study Residential Building Electrification in California study (Energy & Environmental Economics, 2019). Escalation of natural gas rates between 2019 and 2022 is based on the currently filed General Rate Cases (GRCs) for PG&E, SoCalGas, and SDG&E. From 2023 through 2025, natural gas rates are assumed to escalate at four percent per year above inflation, which reflects historical rate increases between 2013 and 2018. Escalation of electricity rates from 2019 through 2025 is assumed to be two percent per year above inflation, based on electric utility estimates. After 2025, escalation rates for both natural gas and electric rates are assumed to drop to a more conservative one percent escalation per year above inflation for long-term rate trajectories beginning in 2026 through 2050. See Appendix B: Utility Rate Schedules – Escalation Assumptions for additional details.

In calculating On-Bill cost effectiveness, incremental first costs are assumed to be financed into a mortgage or loan with a 30-year loan term and four percent interest rate. The only exceptions are the lighting measures. These are low-cost measures that are more likely than the other measures evaluated to be installed by the homeowner and are not assumed to be financed. Present value of replacement cost is included for measures with equipment lifetimes less than the evaluation period.

3.5.2 TDV LCC

Cost effectiveness was also assessed using the Energy Commission's TDV LCC methodology. TDV is a normalized monetary format developed and used by the Energy Commission for comparing electricity and natural gas savings, and it considers the cost of electricity and natural gas consumed during different times of the day and year. Both 2019 and proposed 2022 TDV values were used and are based on long term discounted costs of 30 years for all residential measures. The CBECC-Res simulation software results are expressed in terms of TDV kBtu. The present value of the energy cost savings in dollars is calculated by multiplying the TDV kBtu savings by a NPV factor, also developed by the Energy Commission. The 30-year

NPV factor $0.173/TDV kBtu, used for both 2019 and 2022 Title 24 code cycles for residential buildings, was used.

Like the customer B/C ratio, a TDV B/C ratio value of one indicates the savings over the life of the measure are equivalent to the incremental cost of that measure. A value greater than one represents a positive return on investment. The ratio is calculated according to Equation 3. In calculating TDV cost effectiveness, incremental first costs were not assumed to be financed into a mortgage or loan.

Equation 3

$$TDV\ Benefit-to-Cost\ Ratio = \frac{TDV\ energy\ savings\ *\ NPV\ factor}{NPV\ of\ lifetime\ incremental\ cost}$$

3.5.2.1 2019 and 2022 TDV Differences

There were key changes to the 2022 TDV methodology as compared to the 2019 TDV, including the major updates below:

- Updated weather files to reflect historical data from recent years.
- New load profiles representing building and transportation electrification and renewable generation.
- Addition of internalized cost streams to account for carbon emissions.
- Shaped retail rate adjustment partially scaled to hourly marginal cost of service.
- Addition of non-combustion emissions from methane and refrigerant leakage.

The impact of these key changes for electricity TDV are lower values during the mid-day that correspond with an abundance of solar production and a shift of the peak TDV to later in the day as a result of increasing levels of rooftop PV systems. However, the overall magnitude of the 2022 TDV does not increase significantly relative to 2019 TDV. For natural gas TDV there is a large increase in magnitude with the 2022 TDV being roughly 70 percent higher than in 2019. This is driven by the new retail rate forecast, increased fixed costs for maintaining the distribution system, and the new carbon cost component. Additional details about 2022 TDV are described in the final 2022 TDV methodology report (Energy & Environmental Economics, 2020).

The updated weather files represent an updated dataset based on historical weather sampled from recent years (1998-2017) to reflect the impacts of climate change. Cooling loads increase significantly, particularly for the mild climates zones where cooling energy use was previously low. Heating loads decrease on average 30 percent across all climate zones. The weather files used for the 2019 code cycle had not been updated since the 2013 code cycle and represented data only up until 2009. The Energy Commission and the Statewide Reach Codes Team contend that the updated 2022 weather files better reflect changing climate conditions in California. Therefore, the 2022 files are used for all the analysis reported in this study.

3.6 Greenhouse Gas (GHG) Emissions Reductions

Equivalent CO_2 emission reductions were calculated based on outputs from the CBECC-Res 2022.0.1 simulation software. Electricity emissions vary by region and by hour of the year. CBECC-Res applies two distinct hourly profiles, one for Climate Zones 1 through 5 and 11 through 13 and another for Climate Zones 6 through 10 and 14 through 16. For natural gas, a fixed factor of 9.9 pounds (lbs) per therm is used. To compare the mixed-fuel and all-electric cases side-by-side, GHG emissions are presented as lbs CO_2-equivalent (CO_2e) emissions for the 1,665 ft^2 prototype.

3.7 Energy Performance Equivalency of Retrofit Measures and Packages

Efficiency measures were evaluated based on three distinct vintage homes with typical characteristics applied to each. However, the existing building stock is quite varied, and year of construction is not always an accurate indicator of efficiency and performance as homes may have been upgraded over time. To provide flexibility in the ordinance structure, the Statewide Reach Codes Team developed an energy performance equivalency methodology where the efficiency characteristics of a home and upgrades are valued relative to one another. This provides a flexible approach in two forms:

1) Where retrofit requirements are based on home vintage, applicants can value upgrades that may have been completed on their home (HERS Rater verified) to determine the closest vintage bin their house falls into, providing credit for improvements made to the house after it was constructed.
2) Applicants can pick from a menu of efficiency upgrades that in combination result in equivalent performance as a prescriptive package of measures or single measure that may be required as part of a retrofit reach code.

Energy performance equivalency is based on the source energy use metric (Energy Design Rating (EDR) 1) developed for the 2022 code cycle and is calculated by climate zone relative to the pre-1978 prototype home used in this analysis. The scoring is unique to each climate zone where different heating and cooling loads contribute to distinct values for various upgrades. For example, high efficiency heating equipment has a greater impact on score in heating dominated climates such as Climate Zone 1 and 16 as compared to Climate Zone 15, a cooling dominated climate.

As an example, the pre-1978 prototype home in Climate Zone 12 has an EDR1 score of 39 kBtu/ft^2-year and the pre-1978 prototype home with upgraded R-49 attic insulation has an EDR1 score of 36 kBtu/ft^2-year, the equivalent energy performance for R-49 insulation in Climate Zone 12 is valued at 3. The same approach is applied to packages of measures. Equivalent energy performance was calculated for most of the retrofit measures and packages described in Section 3.2 and Section 3.3, as well as a variety of additional building efficiency characteristics (see Appendix E – Details on Energy Performance Equivalency for a complete list).

4 Results

The primary objective of the evaluation is to identify cost-effective energy upgrade measures and packages for existing single family buildings, to support the design of local ordinances requiring upgrades, which may be triggered by different events, such as at the time of a significant remodel or addition. Cost-effectiveness analysis was completed for all climate zones based on single family prototype designs representing buildings features commonly used during each of three vintages.

Table 11 through Table 14 summarize cost effectiveness of efficiency measures and packages. Cost-effectiveness analysis was evaluated using both On-Bill and TDV cost-effectiveness criteria described in Section 3.5. Detailed cost-effectiveness analysis results, along with energy savings are presented in Appendix D – Measure Cost-Effectiveness Tables, in Table 30 through Table 113, by climate zone and building vintage. Site energy savings, cost savings, measure cost, and cost effectiveness including lifecycle B/C ratio and NPV of savings are provided. For climate zones that are served by multiple utilities, where cost effectiveness may differ based on applicable utility rates, cost-effectiveness results are reported for both applicable utility territories.

Where measures are dependent on climate zone and building vintage (envelope efficiency measures), cost effectiveness is reported for each vintage and climate zone. Some measure results do not differ between the vintages such as LED lamp replacement and water heating upgrades. The water heating and LED lighting measures are cost-effective in all cases. A summary of these results is provided below.

Cost effectiveness by metric for each climates zone and building vintage is represented in the tables as summarized in Table 10:

Table 10: Results Table Legend

Cost Effectiveness	Label
Cost-effective both On-Bill and TDV	Both
Cost-effective TDV only, not On-Bill	TDV
Cost-effective On-Bill only, not TDV	On-Bill
Not cost-effective On-Bill or TDV	N/A

Unless called out specifically, TDV cost effectiveness is based on the 2019 TDV, using the 2019 version of CBECC-Res software. On-Bill cost effectiveness assumes savings based on 2022 weather files.

4.1 Building Envelope/Non-Preempted Measures

A summary of the cost effectiveness of individual efficiency measures is summarized in Table 11 based on both the On-Bill and 2019 TDV metrics.

R-49 Attic Insulation: R-49 attic insulation is cost-effective both On-Bill and TDV in older vintage homes except some coastal climates (Climate Zones 1, 3, and 5), and less cost-effective in newer vintage homes because of reduced energy savings.

Air Sealing: Reducing building leakage by 30 percent alone is only cost-effective in a handful of climates.

Duct Sealing: Duct sealing to ten percent of nominal airflow has the best economics of the envelope/duct measures in most climates and vintages and is cost-effective. It is not cost-effective in Climate Zones 3 and 5 through 7 in the 1992-2010 vintage homes.

New Ducts: Replacing old ductwork with new R-8 ducts sealed to five percent of nominal airflow has similar economics as the duct sealing measure and is cost-effective in many cases. It is not cost-effective in Climate Zones 3, 5, and 7 in any vintage and is only cost-effective in a handful of climate zones in 1992-2010 vintage homes.

Cool Roof: Cool roof is cost-effective for all vintages of single family homes in Climate Zones 8 through 15. It is also cost-effective for homes built before 1992 for homes in Climate Zone 2, 4, 6, and 7.

Wall Insulation: Blowing in wall insulation into exterior walls is only practical in pre-1978 homes with no insulation installed in the wall cavities. It is cost-effective On-Bill in Climate Zones 1 and 11 through 16, and it is cost-effective based on TDV in Climate Zones 1, 2, and 9 through 16.

Window Replacement: Window replacements are only cost-effective in homes built before 1978 in Climate Zones 10 through 15, and in Climate Zones 11 through 15; in addition, window replacements are also cost-effective in Climate Zone 10 for 1978 through 1991 vintage homes in SDG&E territory.

Table 11: Summary of Single Family Efficiency Measures – On-Bill & 2019 TDV (Climate Zone 2)

Measure	Pre-1978	1978-1991	1992-2010
R-49 Attic Insulation	Both	TDV	N/A
Air Sealing	N/A	N/A	N/A
Duct Sealing	Both	Both	TDV
New Ducts	Both	TDV	N/A
Cool Roof	Both	TDV	N/A
Insulate Walls	Both	N/A	N/A
Windows	N/A	N/A	N/A

[a] Duct Sealing requires sealing all ductwork to 10% of nominal airflow (as proposed in 2022 Title 24).

[b] Air Sealing requires sealing all accessible cracks, holes, and gaps in the building envelope at walls, floors, and ceilings.

4.2 Envelope and Duct Packages

Cost effectiveness of the various envelope and duct packages are summarized in Table 12 based on both the On-Bill and 2019 TDV metrics. Cost effectiveness tends to be better in older vintage homes where potential for heating and cooling savings are higher.

1. **R-49 Attic Insulation and Air Sealing:** Increasing attic insulation to R-49 and air sealing the building is cost-effective based on either On-Bill or TDV in all climates except Climate Zones 3 and 5 in pre-1978 homes, and 1 and 3 through 8 in 1978 to 1991 vintage homes. Air sealing and attic insulation are less cost-effective in newer vintages and in mild climates where heating and cooling energy use is lower.
2. **R-49 Attic Insulation and Duct Sealing:** Increasing attic insulation to R-49 and duct sealing is cost-effective both On-Bill and TDV in all climates except Climate Zones 3 and 5 in pre-1978 homes, and 3 and 5 through 7 in 1978 to 1991 vintage homes. In newer vintage homes (1992-2010) this package is cost-effective On-Bill in Climate Zones 11, 13, 15, and in SDG&E territory in Climate Zones 10 and 14. The newer vintage is cost-effective based on TDV in Climate Zones 9 through 15.
3. **R-49 Attic Insulation, Air Sealing, and Duct Sealing:** Duct sealing is more cost-effective than air sealing and attic insulation measures. Packaging these measures provides improved cost effectiveness relative to these additional measures on their own. All three of these measures are cost-effective for the following vintages and climates:
   - Pre-1978: Climate Zones 1, 2, 4, and 7 through 16 (On-Bill), and 6 (TDV only).
   - 1978-1991: Climate Zones 1, 8 through 16 (On-Bill), and 2 and 4 (TDV only).
   - 1992-2010: Climate Zones 13 and 15 (On-Bill), and 11, and 13 through 15 (TDV only).
4. **R-49 Attic Insulation, Air Sealing, and New Ducts:** Results for this package are not presented in Table 12 but cost effectiveness is similar to Package 3.
5. **Advanced Envelope Package - R-49 Attic Insulation, Air Sealing, and Duct Sealing, plus Wall Insulation and New Windows:** This package only applies to pre-1978 homes without wall insulation. It is cost-effective in the following climates:
   - On-Bill: Climate Zones 10 through 16, except SMUD.
   - TDV: Climate Zones 2, 4, and 9 through 16.

4.3 Water Heating and Lighting Measures/Packages

Cost effectiveness of water heating and lighting measures are also summarized in Table 12. Cost effectiveness was evaluated based on customer On-Bill basis only. TDV cost effectiveness was not evaluated because the evaluation periods for these measures was less than the 30-year evaluation period used for TDV in some cases.

Water Heating Package – Water Heater Blanket, Hot Water Pipe Insulation, and Low-Flow Fixtures: The package including these three water heating measures is cost-effective On-Bill in all climate zones and vintages.

Lighting Measures – LED Lamps and Exterior Photocell Control: Replacing either an existing CFL or incandescent lamp with an LED lamp is cost-effective in all climate zones and vintages. The lighting results in Appendix D report cost effectiveness for replacement of CFLs with LED lamps. Replacement of incandescent with LED lamps results in better cost effectiveness. Savings for exterior photocell controls assume LED luminaires. Exterior photocell controls are cost-effective in all cases except in Climate Zone 4 with CPAU rates and Climate Zone 12 with SMUD rates.

Table 12: Summary of Single Family Efficiency Packages – On-Bill & 2019 TDV (Climate Zone 2)

Measure Package	Pre-1978	1978-1991	1992-2010
R-49 Attic & Air Sealing	Both	TDV	N/A
R-49 Attic & Duct Sealing Package	Both	Both	N/A
R-49, Air Sealing & Duct Sealing Package	Both	TDV	N/A
Advanced Envelope Package	TDV	N/A	N/A
Water Heating Package	On-Bill	On-Bill	On-Bill
LED Lamps	On-Bill	On-Bill	On-Bill
Exterior Photosensor	On-Bill	On-Bill	On-Bill

[a] Duct Sealing requires sealing all ductwork to 10% of nominal airflow (as proposed in 2022 Title 24).
[b] Air Sealing requires sealing all accessible cracks, holes, and gaps in the building envelope at walls, floors, and ceilings.
[c] Water heating package includes water heater blanket, hot water pipe insulation, and low-flow fixtures.
[d] Lighting package includes replacement of screw-in CFL and incandescent lamps with LED luminaires and installation of photocell control on exterior lighting luminaires.

4.4 PV and Batteries

On-Bill and 2019 TDV cost effectiveness for PV and PV with batteries are summarized in Table 13. Cost effectiveness for PV is not sensitive to building vintage but when paired with batteries results differ by vintage and the package is not as cost-effective with newer vintage homes.

PV: For this analysis, a PV system sized to offset the electricity use per the 2019 new construction standards by climate zone was assumed. PV systems are cost-effective in all climate zones and vintages based on both an On-Bill and TDV basis. 30-year On-Bill net benefits exceed $5,000 across all the IOU scenarios, but cost effectiveness is marginal under both CPAU and SMUD municipal utility rates. Figure 1 summarizes both customer On-Bill and TDV lifecycle net benefits. PV cost effectiveness is not very sensitive to system size until the PV system size approaches net zero on an annual basis, or with very small systems which are more costly per kilowatt.

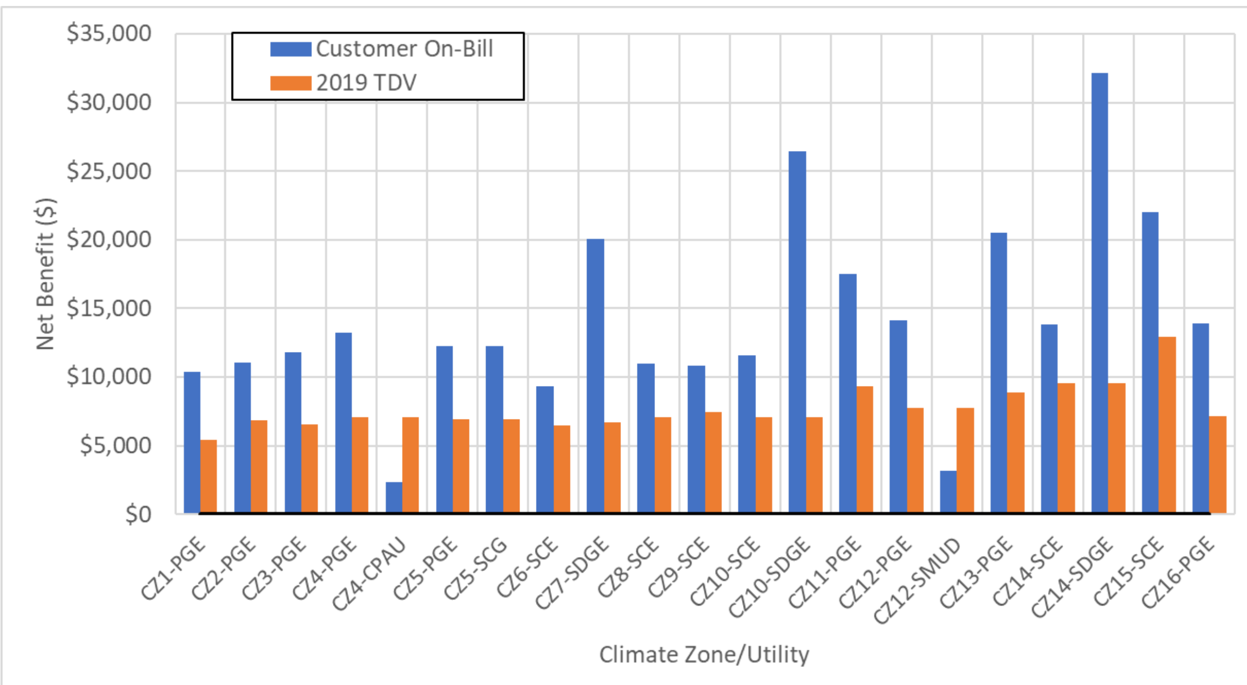

Figure 1: Net Benefit–Rooftop PV system sized to new construction standards (2-4 kW): 1992-2010.

PV and Batteries: Pairing a ten kWh battery storage system with a PV system sized to the 2019 new construction sizing criteria is cost-effective for the following vintages and climates:

- Pre-1978: Climate Zones 3 through 16 based on TDV; On-Bill everywhere except Climate Zones 4 under CPAU and 12 under SMUD municipal utility rates.
- 1978-1991: Climate Zones 3 through 16 based on TDV; On-Bill everywhere except Climate Zones 1; 4 under CPAU and 12 under SMUD municipal utility rates.
- 1992-2010: Climate Zones 3 through 16 based on TDV; On-Bill everywhere except Climate Zones 1, 2, 6; 4 under CPAU and 12 under SMUD municipal utility rates..

Figure 2 and Figure 3 summarize customer On-Bill and TDV lifecycle net benefits for PV and Battery for the pre-1978 vintage and the 1992-2010 vintage, respectively.

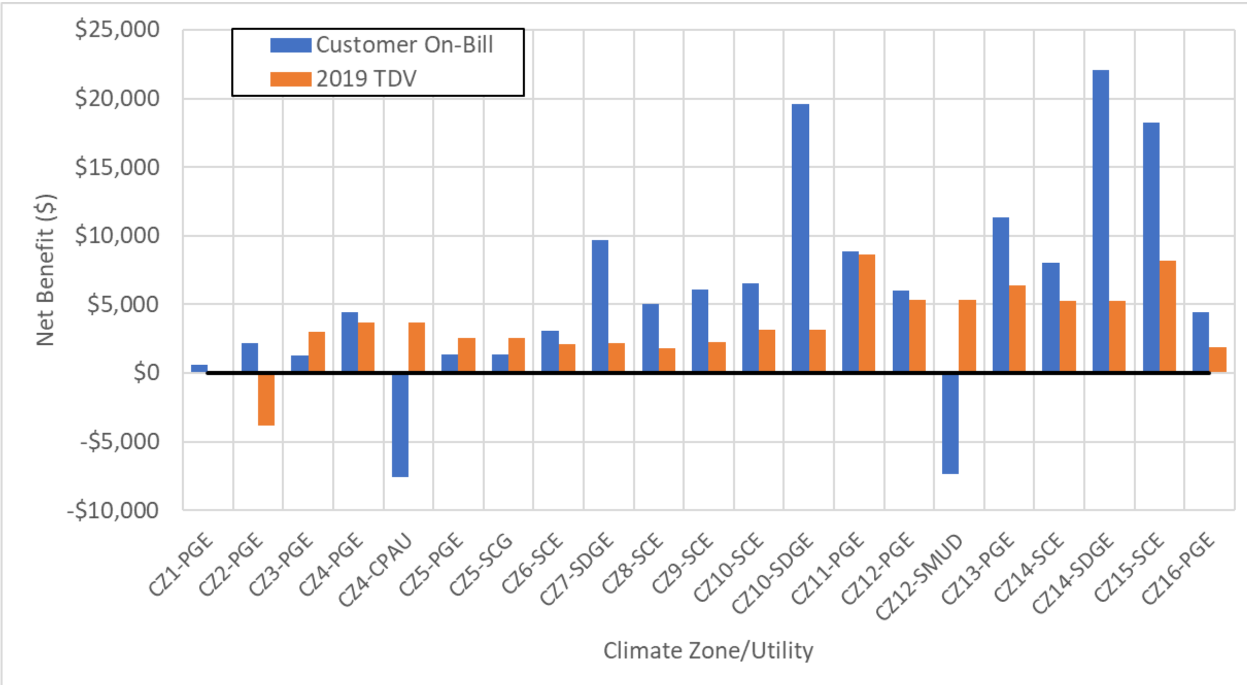

Figure 2: Net benefit - rooftop PV + 10 kWh battery, TOU control: pre-1978.

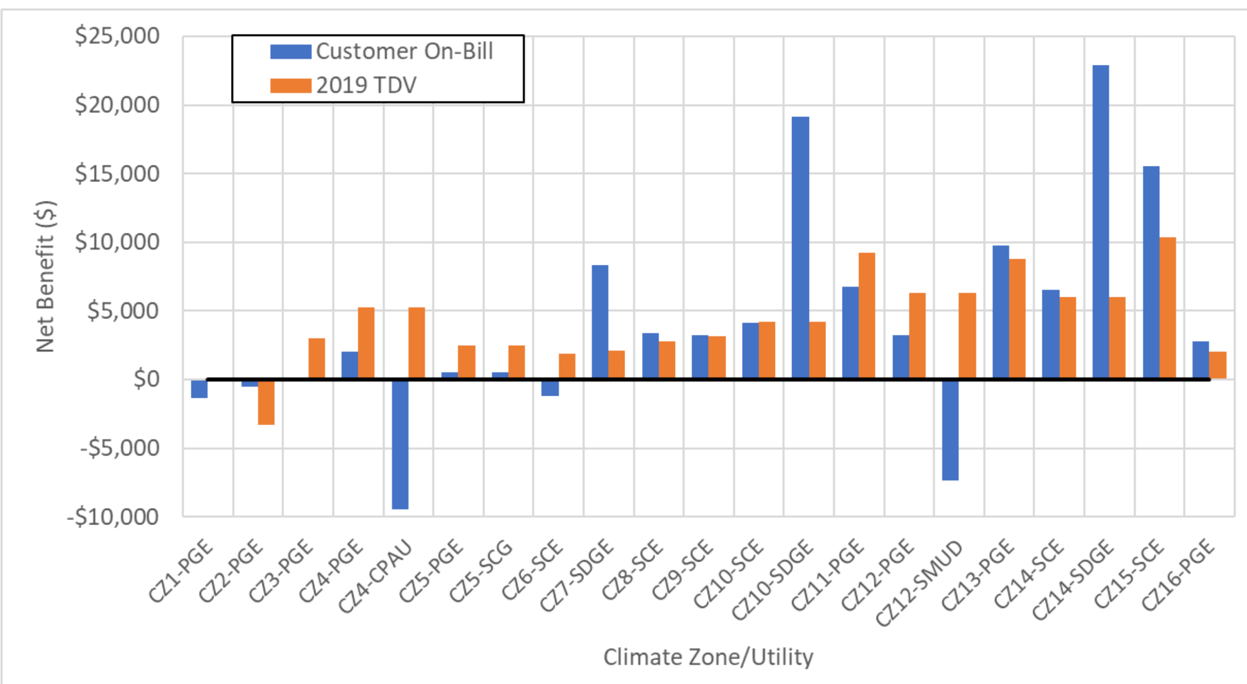

Figure 3: Net benefit - rooftop PV + 10 kWh battery, TOU control: 1992-2010.

Table 13: Summary of Single Family PV & Batteries – On-Bill & 2019 TDV

Measure	Pre-1978	1978-1991	1992-2010
PV	Both	Both	Both
PV + Battery	On-Bill	On-Bill	N/A

4.5 Equipment Fuel Substitution Measures

On-Bill and TDV (both 2019 and 2022) cost effectiveness for electric fuel substitution measures are summarized in Table 14 and Table 15. Cost-effectiveness for these measures is not as sensitive to building vintage as the building envelope and duct measures but HVAC heat pump installations in newer vintage homes tend to be more cost-effective than in older vintage homes.

<u>Heat Pump at HVAC Replacement:</u> Cost-effectiveness of replacing a ducted furnace and air conditioner with a minimum efficiency ducted air-source heat pump is limited. It is cost-effective On-Bill in SMUD territory with SMUDS's favorable electricity utility rates relative to natural gas rates. In all other climates, shifting from natural gas to electricity for space heating with a minimum efficiency heat pump results in both an increase in incremental lifecycle installed cost and utility costs. Incremental first costs are similar between a heat pump and gas furnace/AC, but because the assumed average equipment lifetime is 15 years for a heat pump compared to 17.5 years for the gas furnace/AC, lifetime incremental costs are slightly higher than first costs for heat pumps. TDV cost effectiveness is very different under the 2019 and 2022 metrics, and results are more favorable under the 2022 TDV where it is cost-effective in the newer vintage homes in Climate Zones 2 through 4 and 11 through 13, and cost-effective in older vintage homes in Climate Zones 1 through 4, 9, and 11 through 13. Figure 4 compares lifecycle net benefit of the heat pump installation based on customer On-Bill, 2019 TDV, and 2022 TDV for newer vintage homes.

Cost effectiveness for the no AC scenario is not shown. In mild climates without AC, the higher incremental costs do not justify heat pump replacement unless the project is planning on installing AC at replacement.

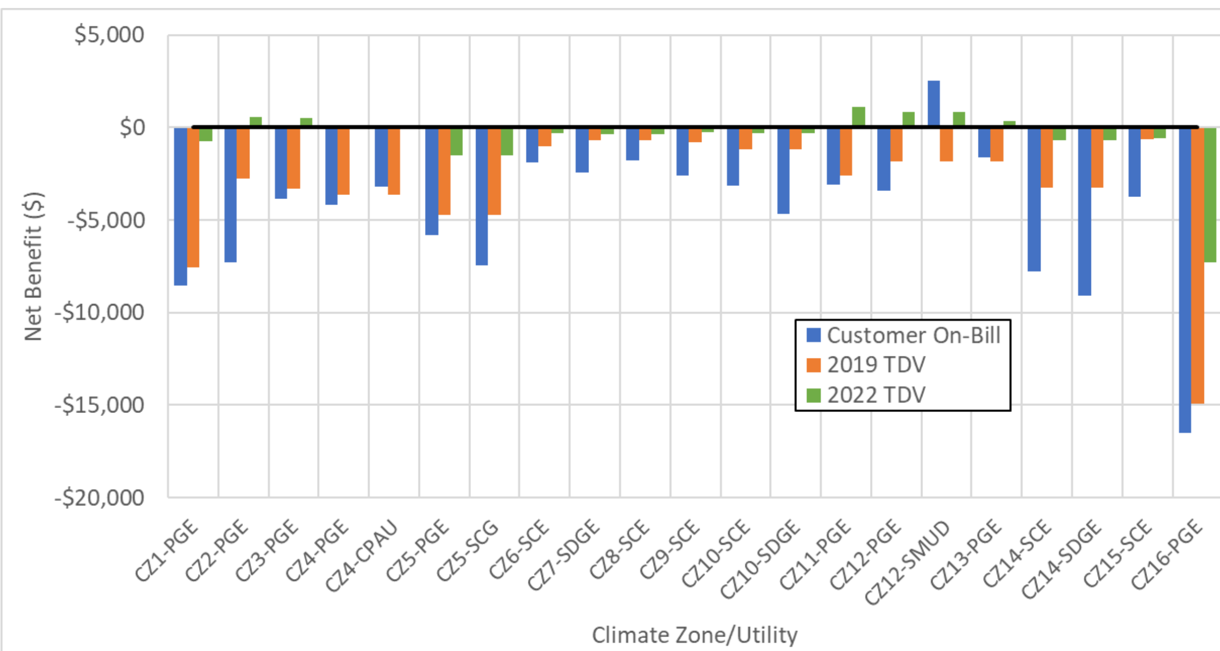

Figure 4: Net benefit – minimum efficiency heat pump at HVAC replacement: 1992-2010.

<u>High-Efficiency Heat Pump at HVAC Replacement:</u> Cost-effectiveness of replacing a ducted furnace and air conditioner with a high-efficiency, 21 SEER, 11 HSPF ducted air-source heat pump is also limited. Higher efficiency provides operating cost savings in most cases, but incremental costs are also higher. In 1992-2010 vintage homes it is cost-effective On-Bill in Climate Zones 13, and 15, and in 12 with SMUD rates.

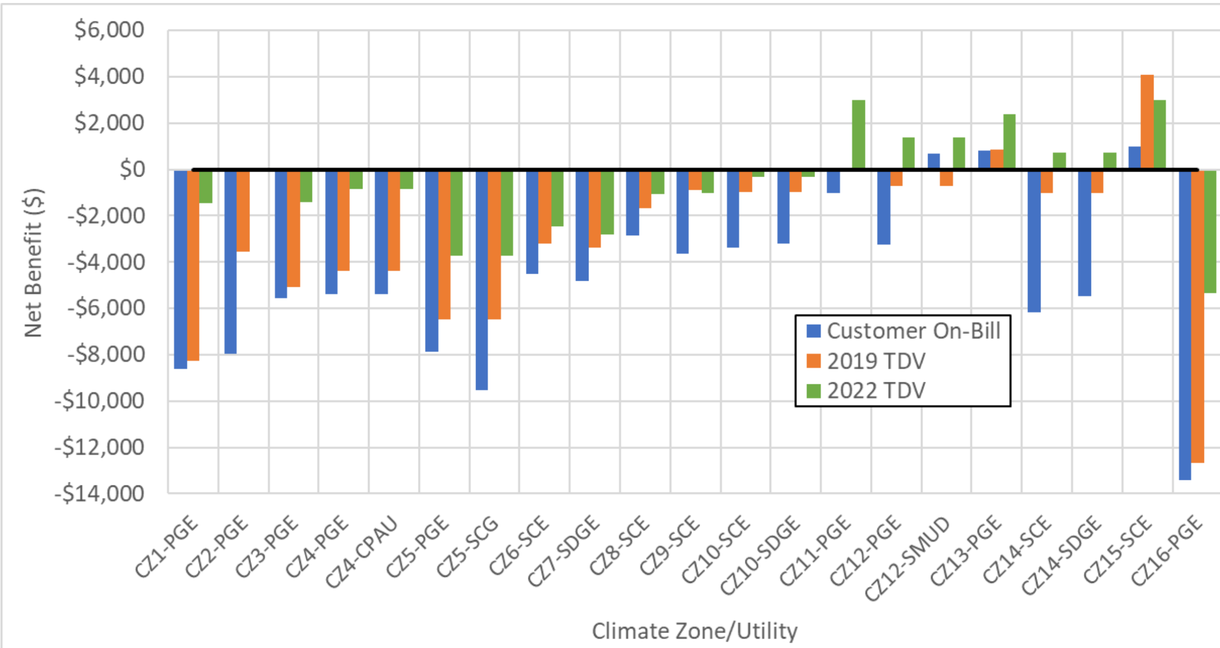

Figure 5: Net benefit – high-efficiency heat pump at HVAC replacement: 1992-2010.

<u>HVAC Heat Pump + PV:</u> Combining heat pump installation with a new PV system when replacing a natural gas furnace/AC increases first costs but improves cost effectiveness (see Figure 6 and Table 15). PV offsets additional electricity used by the heat pump, resulting in net energy cost savings and On-Bill cost effectiveness in all cases except homes in Climate Zone 1 (older vintage homes only), 16 and 4 in CPAU territory. Adding the $3,181 cost to upgrade the main service panel, the combination of these measures is still cost-effective in most cases (see Figure 7).

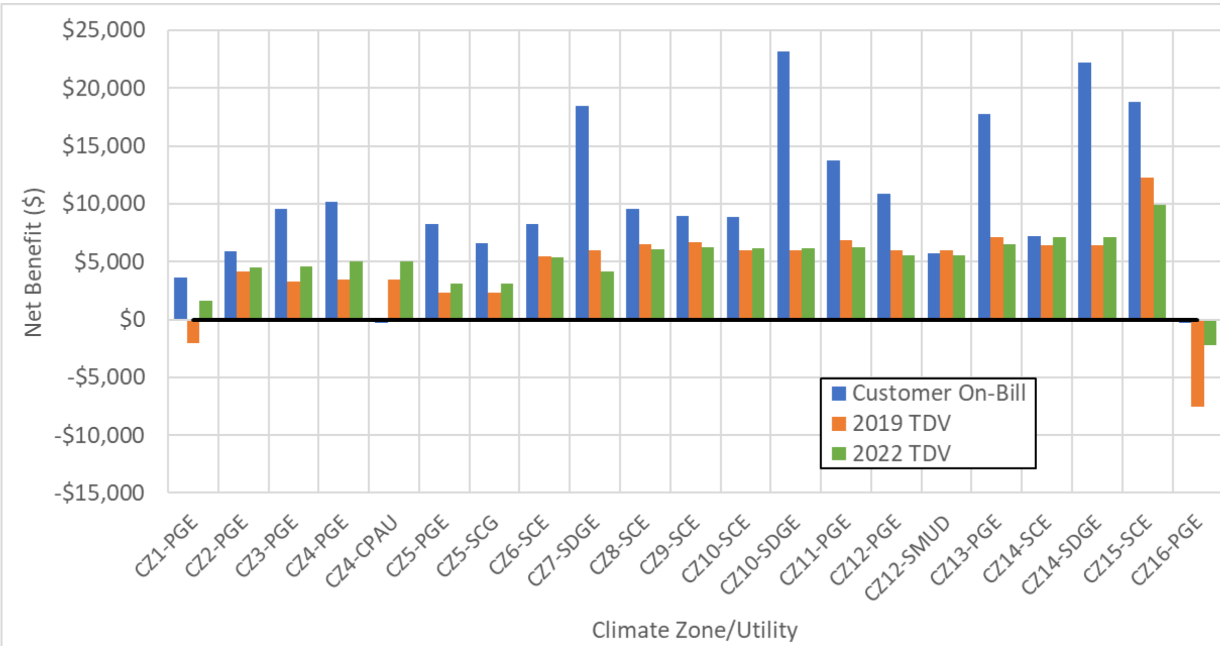

Figure 6: Net benefit – min efficiency heat pump at HVAC replacement + PV: 1992-2010.

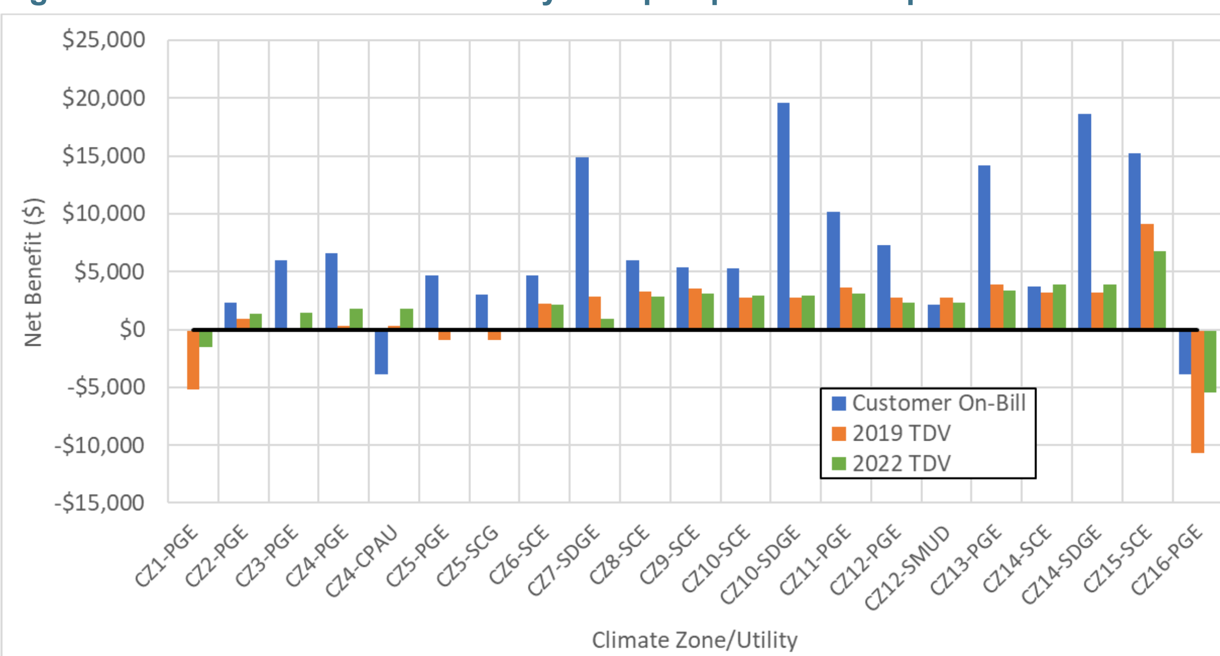

Figure 7: Net benefit – min efficiency heat pump at HVAC replacement + PV + panel upgrade: 1992-2010.

<u>Heat Pump at DHW Replacement:</u> Cost effectiveness of replacing a natural gas storage water heater with a minimum efficiency HPWH is limited under customer On-Bill and 2019 TDV metrics. Due to higher incremental costs and operating costs relative to natural gas storage water heaters, it is only cost-effective On-Bill in SMUD territory due to the favorable electricity utility rates relative to natural gas rates. A HPWH is cost-effective in all climate zones except 1 and 16 based on 2022 TDV economics. Figure 8 compares lifecycle net benefit of the HPWH installation for customer On-Bill, 2019 TDV, and 2022 TDV, showing how cost effectiveness is positive for most climates based on 2022 TDV.

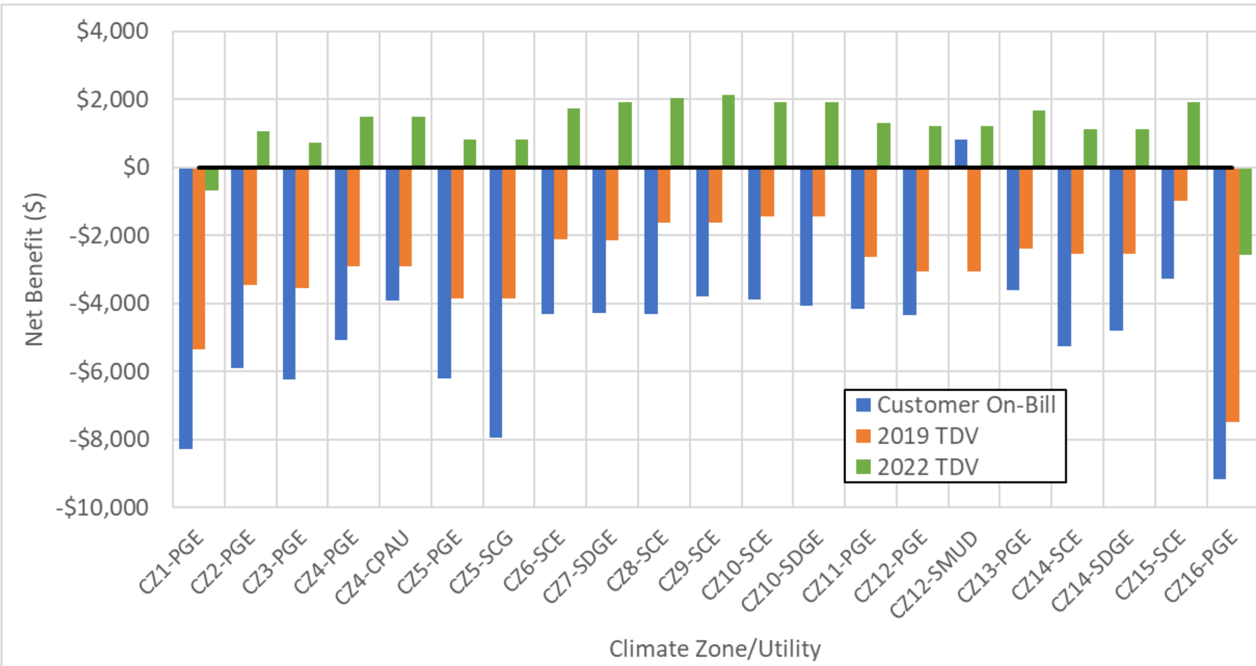

Figure 8: Net benefit – minimum efficiency HPWH at DHW replacement: 1992-2010.

High-Efficiency Heat Pump at DHW Replacement: Cost effectiveness improves when replacing a natural gas storage water heater with a NEEA Tier 3 HPWH but still is limited under customer On-Bill and 2019 TDV metrics. Higher efficiency equipment results in operating cost savings in many climate zones, but due to higher incremental costs it is still only cost-effective On-Bill in SMUD territory. Similar to the minimum efficiency HPWH case, the high-efficiency HPWH is cost-effective based on 2022 TDV in all climate zones except 16. Figure 9 compares lifecycle net benefit of the HPWH installation for customer On-Bill, 2019 TDV, and 2022 TDV, showing how cost effectiveness is positive for most climates based on 2022 TDV.

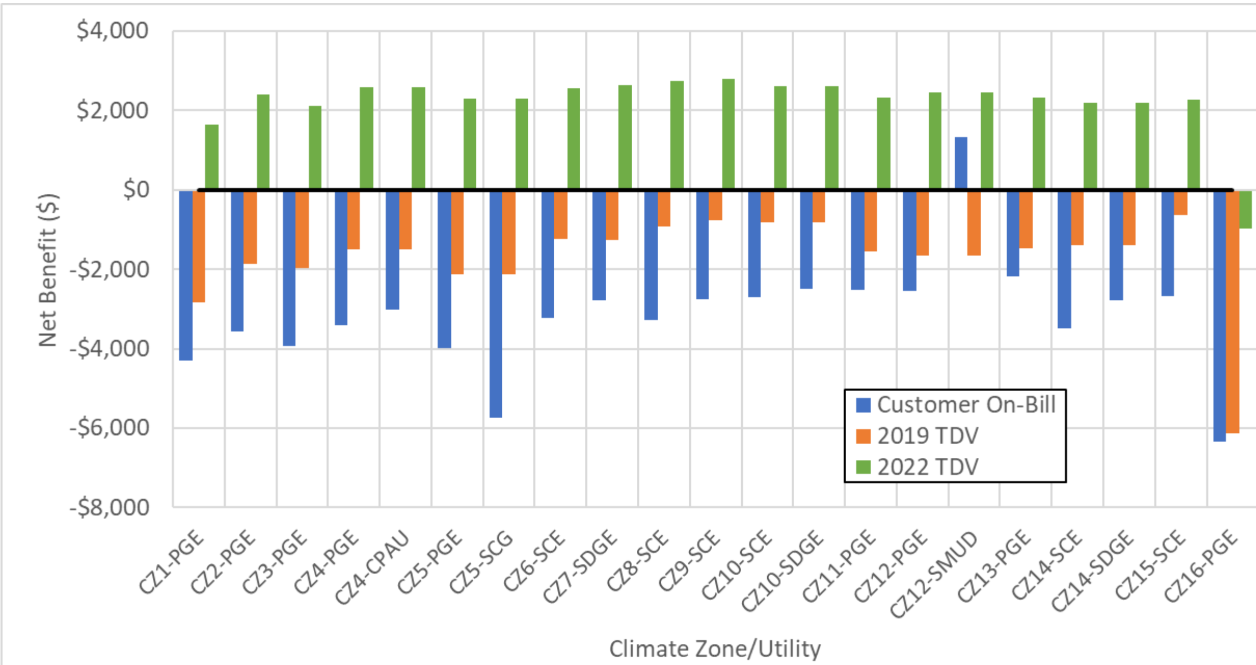

Figure 9: Net benefit – high-efficiency HPWH at DHW replacement: 1992-2010.

<u>HPWH + PV:</u> Combining installation of PV with a HPWH at the time of water heater replacement increases first costs but improves On-Bill cost effectiveness (see Figure 10 and Table 15). PV offsets additional electricity used by the HPWH, resulting in net energy cost savings and positive customer On-Bill cost effectiveness in all cases except Climate Zone 4 with CPAU rates. If the $3,181 cost to upgrade the main service panel is included in the first cost, the combination of these measures is still cost-effective in most cases (see Figure 11).

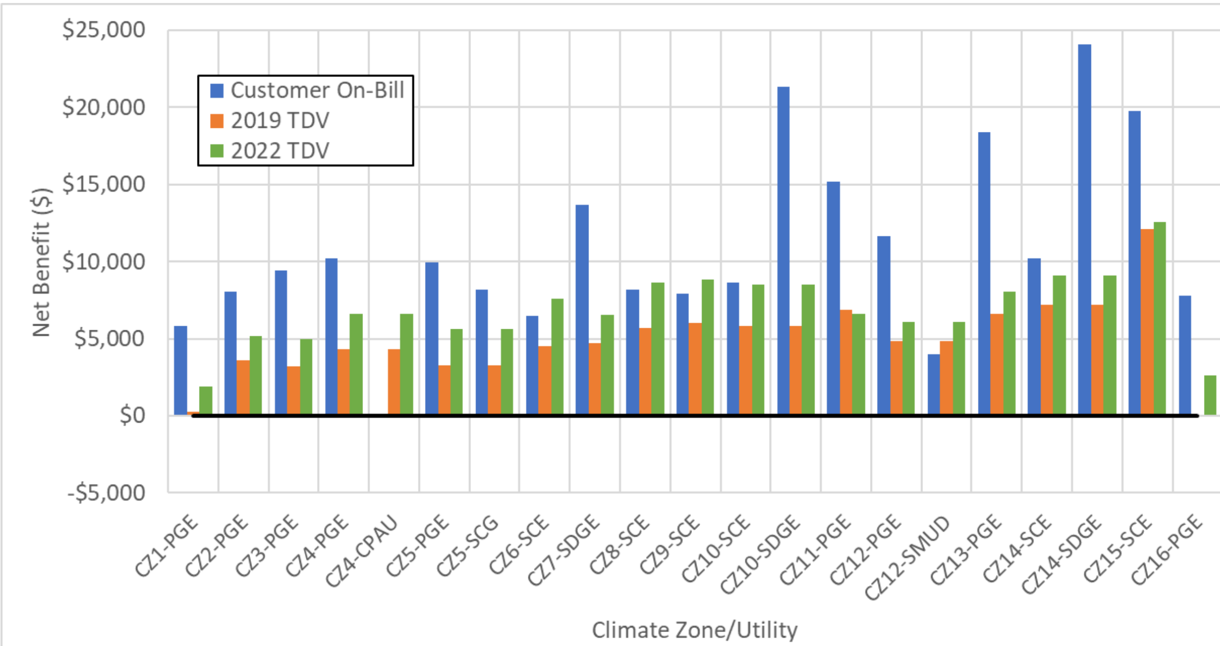

Figure 10: Net benefit – min efficiency HPWH at DHW replacement + PV: 1992-2010.

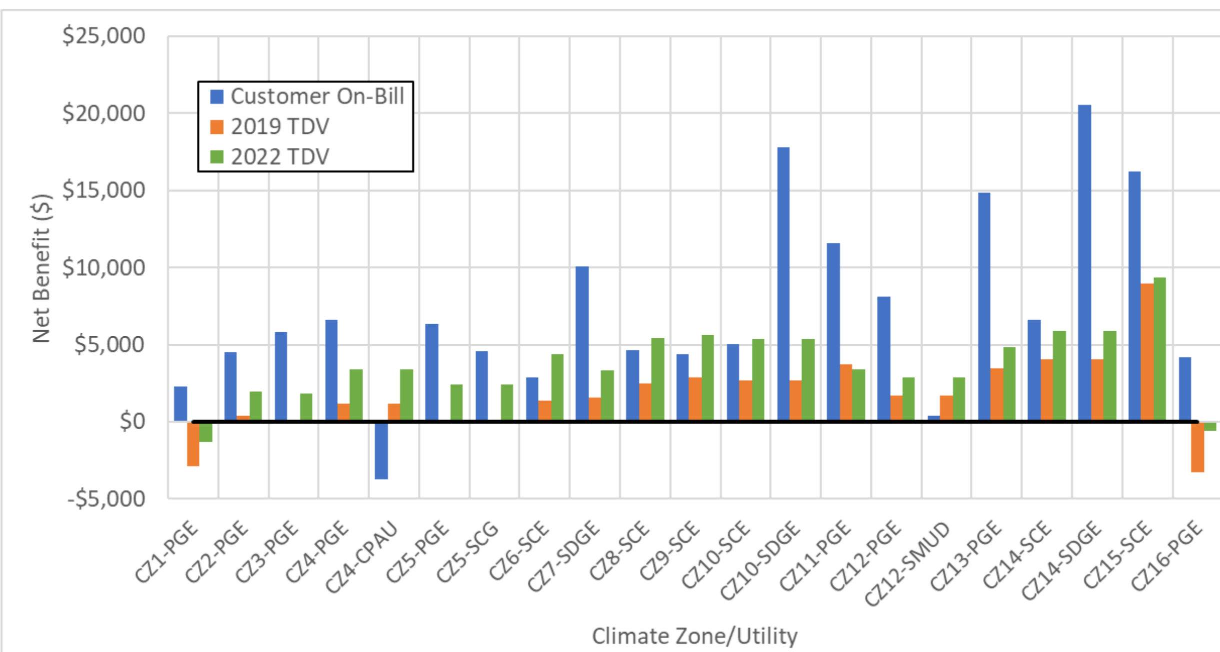

Figure 11: Net benefit – min efficiency HPWH at DHW replacement + PV + Panel Upgrade: 1992-2010.

Table 14: Summary of Single Family Equipment Fuel Substitution– On-Bill & TDV – Federal Minimum Efficiency, (Climate Zone 2)

14A – Heat Pump at HVAC Replacement

Heat Pump at HVAC Replacement	Pre-1978	1978-1991	1992-2010
2019 TDV	N/A	N/A	N/A
2022 TDV	TDV	TDV	TDV

14B – HPWH at DHW Replacement

HPWH at DHW Replacement	Pre-1978	1978-1991	1992-2010
2019 TDV	N/A	N/A	N/A
2022 TDV	TDV	TDV	TDV

Table 15: Summary of Single Family Equipment Fuel Substitution + PV – On-Bill & TDV – Federal Minimum Efficiency, (Climate Zone 2)

15A – Heat Pump plus PV at HVAC Replacement

Heat Pump + PV at HVAC Replacement	Pre-1978	1978-1991	1992-2010
2019 TDV	Both	Both	Both
2022 TDV	Both	Both	Both

15B – HPWH plus PV at DHW Replacement

HPWH + PV at DHW Replacement	Pre-1978	1978-1991	1992-2010
2019 TDV	Both	Both	Both
2022 TDV	Both	Both	Both

PV and Electric Readiness Measures: Electric ready measures do not result in any energy savings, but combining electric ready measures with installation of PV provides a path to finance needed prewiring and service panel upgrades and reduce fuel substitution costs when appliances are replaced at end of useful life (see Figure 12 and Table 16). Upgrading the main service panel and pre-wiring for future space and water heating heat pumps with installation of a PV system is cost-effective On-Bill in all cases except in Climate Zone 4 with CPAU rates and Climate Zone 12 with SMUD rates due to reduced cost effectiveness of PV with those municipal rates. It is cost-effective based on TDV in all climate zones.

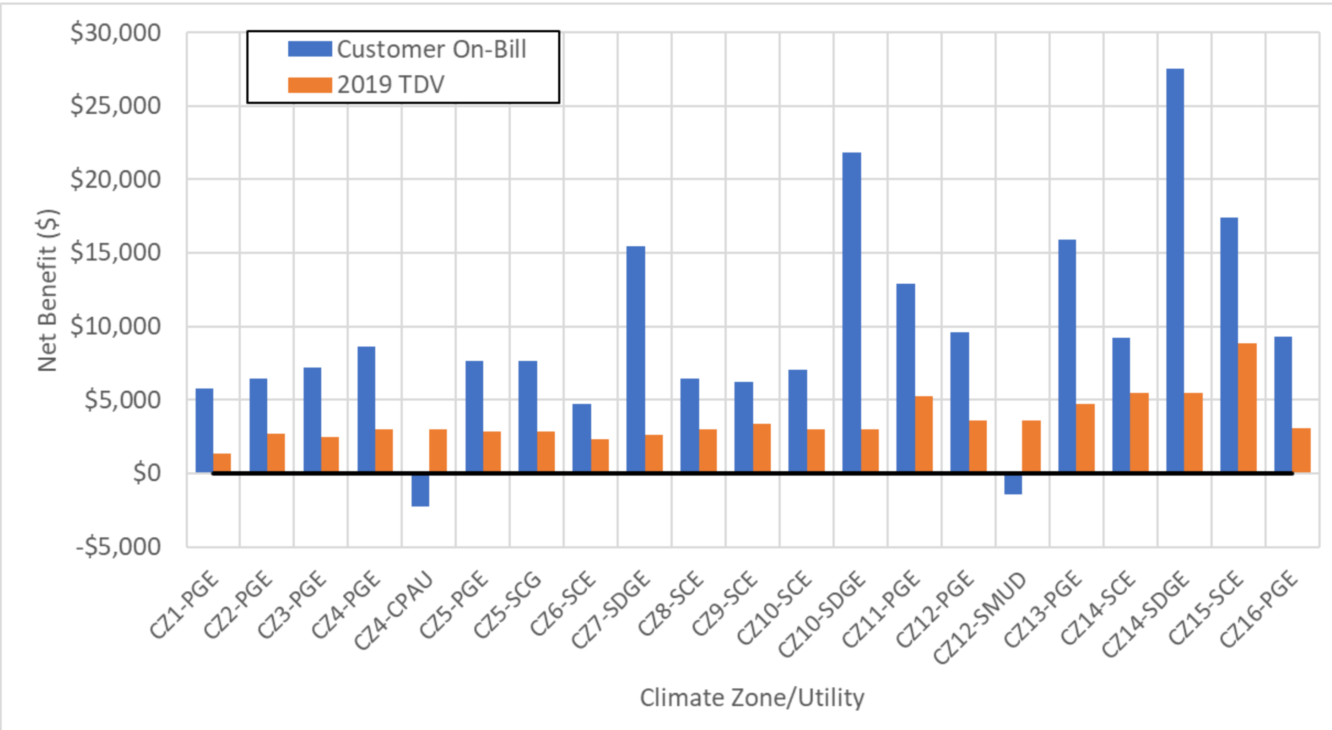

Figure 12: Net benefit – PV and Electric Readiness: 1992-2010.

Table 16: Summary of Single Family Electric Ready Measures at PV Install – On-Bill & 2019 TDV

CZ2	Pre-1978	1978-1991	1992-2010
2019 TDV	Both	Both	Both

5 Energy Performance Equivalency

For jurisdictions looking to provide flexibility in their reach codes for existing buildings, an approach to energy performance equivalency for retrofit measures and packages was completed. The metric for evaluating equivalency is based on the 2022 Title 24 source energy metric (EDR1). A summary of the results and how this can be applied is described below. Appendix E – Details on Energy Performance Equivalency provides additional background and the point score for all retrofit measures and packages by climate zone.

The results of this analysis presented in Section 4 demonstrate different sets of cost-effective measures based on home vintage. The energy performance equivalency defines value for the building characteristics that are applied in each of the three vintage prototypes and evaluated as upgrades. The values are relative to a typical worst-case scenario (i.e., uninsulated or minimally insulated assemblies, very leaky ducts, old mechanical equipment).

Table 17 presents the energy performance equivalency for the three vintage homes. The pre-1978 vintage generally represents the worst-case scenario and therefore has zero points. These values reflect the assumptions presented in Table 2.

Table 17: Energy Performance Equivalency for Each Vintage by Climate Zone

Climate Zone	Pre-1978	1978-1991	1992-2010
1	0	8.8	25.5
2	0	5.3	9.3
3	0	4.1	6.1
4	0	3.7	6.9
5	0	3.9	5.5
6	0	2.1	3.4
7	0	1.6	2.7
8	0	1.8	3.8
9	0	2.3	4.8
10	0	3.0	6.2
11	0	6.0	13.1
12	0	5.1	10.5
13	0	4.3	10.3
14	0	5.8	11.3
15	0	2.3	8.3
16	0	9.9	29.9

If a jurisdiction adopts an ordinance with different sets of requirements based on home vintage, an applicant could either conform with the requirements based on their home's year of construction or value existing upgrades to the home according to a points menu. A sample points menu for Climate Zone 12 is presented in Table 18. Measures are valued differently according to each of the three prototype vintages evaluated.

As an example, consider a home built in the 1950s in Climate Zone 12 that recently replaced their HVAC system with an 80 AFUE furnace (0.4 points) and 14 SEER air conditioner (1.4 points) and testing confirmed duct leakage of no more than 15 percent (2.1 points). In addition, the home has replaced windows with a U-factor less than or equal to 0.32 (2.5 points). This combination results in a total of 6.4 points which is greater than the 1978-1991 vintage points of 5.1 but less than the 10.5 points for the 1992-2010 vintage. In this instance the project could be subject to the ordinance retrofit requirements for a 1978-1991 vintage home instead of a pre-1978 vintage home. The existing home characteristics should be verified by a HERS Rater, the building department, or another third party.

Table 18: Energy Performance Equivalency by Measure for Climate Zone 12

Component	Pre-1978	1978-1991	1992-2010
Walls	-		
R-11 (<=0.110 U-factor)	2.9	0.4	n/a
R-19 (<=0.074 U-factor)	4.2	1.7	1.1
Attic Ceiling Insulation			
R-19	1.4	n/a	n/a
R-30	2.3	0.9	n/a
R-38	2.6	1.2	0.3
≥ R-49	2.9	1.5	0.6
Roof			
Cool roof (aged solar reflectance >=0.25)	0.1	0.1	0.0
Floors			
≥ R-19 raised floor	3.5	1.3	n/a
Windows			
Double non-metal	1.8	1.4	n/a
U-factor <=0.32	2.5	2.1	1.3
Infiltration			
<=10 ACH50	0.8	n/a	n/a
<=7 ACH50	1.3	0.5	n/a
<=5 ACH50	1.7	0.9	0.3
Duct Leakage			
<=15% leakage	2.1	1.1	n/a
<=10% leakage	2.7	1.6	n/a
New ducts[a]	4.5	3.3	1.1
Heating			
80% AFUE	0.4	0.3	0.3
90% AFUE	2.3	1.7	1.3
Heat Pump: 8.2 HSPF	7.8	5.8	4.9
Heat Pump: 9 HSPF	8.4	6.3	5.5
Cooling			

Component	Pre-1978	1978-1991	1992-2010
13 SEER	0.9	0.8	n/a
14 SEER	1.4	1.2	0.2
16+ SEER	1.7	1.4	0.4
Water Heater			
Gas tankless	3.0	3.0	3.0
Condensing gas water heater	3.8	3.8	3.8
2.0 UEF HPWH	7.1	7.2	7.2
NEEA Tier 3 HPWH	7.6	7.7	7.7
PV+Battery			
Solar PV	1.2	1.2	1.2
10 kWh Battery	3.2	3.3	3.4

[a] ≥R-6+ and <=5% leakage, ducts in conditioned space, or ductless distribution.

The energy performance equivalency approach also provides additional flexibility in allowing applicants the ability to choose upgrades from the points menu that result in equivalent performance to the applicable reach code requirement. Table 19 and Table 20 demonstrate how this could be implemented. As an example, consider a jurisdiction with an ordinance that requires attic insulation, air sealing, and duct sealing package. While not cost-effective in all climate zones and vintages, where cost-effective and if this package was part of an ordinance, there are other measures that provide equal or greater energy performance that could be used as equivalent to the required ordinance. For a pre-1978 home (Table 19), the value for this package is 6.2 in Climate Zone 12. Based on the menu of options (Table 18) there are several alternative individual or packages of measures that provide equal or greater energy performance. For the 1992-2010 home (Table 20) almost all the mechanical packages provide equivalent or greater performance than the package. This is because the impact of those insulation and air sealing measures is reduced in a newer home with a better building envelope. Measures like water heating upgrades have a similar impact across vintages because the loads are primarily occupant driven.

Table 19: Performance Equivalency Options – Pre-1978 Home

Climate Zone	R-49, Air & Duct Sealing Package	80 AFUE/14 SEER	90 AFUE/16 SEER/New Ducts	8.2 HSPF/14 SEER	Condensing Water Heater	NEEA Tier 3 HPWH	NEEA Tier 3 HPWH & PV/Battery	R-13 Wall Insulation & R-49 Attic Insulation
1	9.7	No	No	Yes	No	No	Yes	No
2	5.8	No	No	Yes	No	Yes	Yes	No
3	4.2	No	No	Yes	No	Yes	Yes	Yes
4	4.2	No	No	Yes	No	Yes	Yes	No
5	3.9	No	No	Yes	Yes	Yes	Yes	Yes
6	2.2	No	No	No	Yes	Yes	Yes	Yes
7	1.8	No	No	No	Yes	Yes	Yes	Yes
8	2.1	No	Yes	Yes	Yes	Yes	Yes	Yes
9	2.8	No	Yes	Yes	Yes	Yes	Yes	No
10	3.4	No	Yes	Yes	Yes	Yes	Yes	No
11	7.1	No	Yes	Yes	No	Yes	Yes	No
12	6.2	No	Yes	Yes	No	Yes	Yes	No
13	5.5	No	Yes	Yes	No	Yes	Yes	No
14	6.7	No	Yes	Yes	No	Yes	Yes	No
15	3.5	Yes	Yes	Yes	No	Yes	Yes	No
16	12.8	No	No	Yes	No	No	No	No

Table 20: Performance Equivalency Options – 1992-2010 Home

Climate Zone	R-49, Air & Duct Sealing Package	80 AFUE/14 SEER	90 AFUE/16 SEER/New Ducts	8.2 HSPF/14 SEER	Condensing Water Heater	Minimum Efficiency HPWH	New Construction PV System
1	1.9	No	Yes	Yes	Yes	Yes	No
2	1.2	No	Yes	Yes	Yes	Yes	No
3	0.9	No	Yes	Yes	Yes	Yes	Yes
4	0.9	No	Yes	Yes	Yes	Yes	Yes
5	0.8	No	Yes	Yes	Yes	Yes	Yes
6	0.4	No	Yes	Yes	Yes	Yes	Yes
7	0.3	No	Yes	Yes	Yes	Yes	Yes
8	0.4	No	Yes	Yes	Yes	Yes	Yes
9	0.6	No	Yes	Yes	Yes	Yes	Yes
10	0.7	No	Yes	Yes	Yes	Yes	Yes
11	1.5	No	Yes	Yes	Yes	Yes	No
12	1.3	No	Yes	Yes	Yes	Yes	No
13	1.2	No	Yes	Yes	Yes	Yes	Yes
14	1.4	No	Yes	Yes	Yes	Yes	Yes
15	0.6	Yes	Yes	Yes	Yes	Yes	Yes
16	2.5	No	Yes	Yes	Yes	Yes	No

6 Recommendations and Discussion

This analysis evaluated the feasibility and cost effectiveness of retrofit measures in California existing homes built before 2010. The Statewide Reach Codes Team used both On-Bill- and TDV-based LCC approaches to evaluate cost effectiveness and quantify the energy cost savings associated with energy efficiency measures compared to the incremental costs associated with the measures.

6.1 Recommended Efficiency Measures

Based on the analysis, the following cost-effective measures or packages of measures are recommended where they are found to be cost-effective in Section 4. Descriptions of each measure or package and the relevant requirements are provided below. In most cases, exceptions are defined which would exempt a particular project from a measure under certain conditions. These exceptions are based on existing on-site conditions and cost effectiveness.

Attic Insulation: In vented attics, insulation shall be installed to achieve a weighted U-factor of 0.020 or insulation installed at the ceiling level shall result in an installed thermal resistance of R-49 or greater for the insulation alone. Recessed downlight luminaires in the ceiling shall be covered with insulation to the same depth as the rest of the ceiling. Luminaires not rated for insulation contact must be replaced or fitted with a fire-proof cover that allows for insulation to be installed directly over the cover. This measure applies to homes according to vintage and climate zone as defined in Table 2.

> Exception 1: Buildings with at least R-38 existing insulation installed at the ceiling level. Buildings with at least R-30 existing insulation installed at the ceiling level are exempt from the recessed downlight luminaire requirements.
>
> Exception 2: Buildings where the alteration would directly cause the disturbance of asbestos unless the alteration is made in conjunction with asbestos abatement.
>
> Exception 3: Buildings with knob and tube wiring located in the vented attic.
>
> Exception 4: Where the accessible space in the attic is not large enough to accommodate the required R-value, the entire accessible space shall be filled with insulation provided such installation does not violate roof ventilation clearance requirements in Section 806.3 of Title 24, Part 2.5.
>
> Exception 5: Where the attic space above the altered dwelling unit is shared with other dwelling units and the attic insulation requirement is not triggered for the other dwelling units.

Air Sealing: Seal all accessible cracks, holes, and gaps in the building envelope at walls, floors, and ceilings. Pay special attention to penetrations including plumbing, electrical, and mechanical vents, recessed can light luminaires, and windows. Weather-strip doors if not already present. Verification shall be conducted following a prescriptive checklist (to be developed) that outlines which building aspects need to be addressed by the permit applicant and verified by an inspector. Compliance can also be demonstrated with blower door testing showing at least a 30 percent reduction from pre-retrofit conditions. This measure applies to homes according to vintage, building type and climate zone as defined in Table 11.

> Exception 1: Buildings that can demonstrate blower door test results showing five ACH50 or lower or can otherwise demonstrate that air sealing meeting the requirements of this ordinance was conducted within the last 12 months.

Duct Sealing: Air seal all space conditioning ductwork to meet the requirements of the 2019 Title 24 Section 150.2(b)1E, with the exception that the duct sealing requirements be reduced from the current code requirement of 15 percent to ten percent in alignment with the 2022 Title 24 code change proposal. The duct system must be tested to confirm that the requirements have been met. Cost effectiveness included costs for a third-party HERS Rater to verify the duct sealing. See Appendix C – Standards Sections for additional details on the requirements per Title 24. This measure applies to homes according to vintage, building type and climate zone as defined in Table 11.

> Exception 1: All exceptions as stated in the 2019 Title 24 Section 150.2(b)1E are allowed.

Exception 2: Buildings without ductwork or where the ducts are in conditioned space.

New Ducts: Replace existing space conditioning ductwork with new R-8 ducts that meet the requirements of 2019 Title 24 Section 150.0(m)11.

Exception 1: Buildings without ductwork or where the ducts are in conditioned space.

Windows: Replace existing windows with high performance windows with an area weighted average U-factor no greater than 0.32.

Exception 1: All exceptions as stated in the 2019 Title 24 Section 150.1(c)3A are allowed.

Exception 2: Buildings where it is not feasible to meet the performance requirements as a result of historic preservation design guidelines or other reasons as determined by the jurisdiction.

Window upgrades were only found to be cost-effective in Climate Zones 10-15 for the pre-1992 vintage homes and as part of the Advanced Envelope Package in pre-1978 vintage homes. Because the cost requirement for window replacement is significant and the margin for cost effectiveness is lower than many other measures, it is recommended that jurisdictions consider whether a window replacement requirement is appropriate and only require it for large projects where the additional cost is small relative to total cost.

Wall Insulation: Older vintage homes with no insulation in exterior walls shall be insulated to achieve a weighted U-factor of 0.102 or insulation installed in the exterior wall cavity shall result in an installed thermal resistance of R-13 or greater for the insulation alone.

Cool Roof: When replacing a roof, install a roofing product rated by the Cool Roof Rating Council to have an aged solar reflectance equal to or greater than 0.25, and a thermal emittance equal to or greater than 0.75, regardless of the compliance approach (prescriptive or performance). This measure only applies to steep slope roofs (ratio of rise to run greater than 2:12) and to buildings that are installing a new roof as part of the scope of the remodel and where more than 50 percent of the roof is being replaced. This applies only to certain homes according to vintage, building type, and climate zone as defined in Table 11. Low slope roofs (ratio of rise to run of 2:12 or less) shall meet the requirements of Section 150.2(b)1Iii of 2019 Title 24, Part 6. See Appendix C – Standards Sections for additional details on the requirements per Title 24.

Exception 1: Projects that are not installing a new roof as part of the scope. Only areas of roof that are to be re-roofed are subject to the cool roof upgrade.

Exception 2: All exceptions as stated in the 2019 Title 24 Section 150.2(b)1Ii for steep slope roofs and 150.2(b)1Iii for low slope roofs are allowed.

Envelope and Duct Packages: From a performance perspective, air sealing of the boundary between the attic and living space should be addressed any time there is significant work in the attic, such as adding attic insulation and sealing or replacing ductwork. When the building shell is being improved, air sealing is an important component to be addressed. The boundary between the living space and vented attics is where a significant amount of building air leakage can occur and sealing these areas prior to covering the attic floor with insulation is both practical and effective. For this reason, several envelope and duct packages were evaluated and are recommended where cost-effective. Detailed requirements and relevant exceptions are listed above for the individual measures.

Attic Insulation, Air Sealing, and Duct Packages: These requirements can be triggered when an entirely new or complete replacement duct system is installed in a vented attic space in alignment with the 2022 Title 24 code change proposal. Addressing air sealing and attic insulation when attic ductwork is being replaced avoids lost opportunities to improve the building shell. While replacing ductwork the contractor accesses most areas of the ceiling and there are efficiencies to be gained with performing air sealing at the same time. Other benefits to addressing air sealing and ceiling insulation when HVAC systems and ductwork are being replaced is the potential ability to downsize equipment by reducing heating and cooling loads.

Advanced Envelope Package: This package only applies to older vintage homes with single-pane windows and no exterior wall insulation where cost-effective as defined in Table 12. Because the incremental cost of this package is significantly higher than other packages, jurisdictions may wish to consider placing a limit on the incremental cost relative to the total project cost, limiting the requirement to large projects.

Water Heating Package: Add exterior insulation meeting a minimum of R-6 to storage water heaters. Insulate all accessible hot water pipes with pipe insulation a minimum of ¾ inch thick. This includes insulating the supply pipe leaving the water heater, piping to faucets underneath sinks, and accessible pipes in attic spaces or crawlspaces. Upgrade fittings in sinks and showers to meet current CALGreen (Title 24, Part 11) requirements.

Exception 1: Water heater blanket is not required on water heaters less than 20 gallons.

Exception 2: Water heater blanket not required if application of a water heater blanket voids the warranty on the water heater.

Exception 3: Fixtures with rated or measured flow rates no more than ten percent greater than current CALGreen requirements.

Lighting Measures – LED Lamps and Exterior Photocell Sensors: Replace all interior and exterior screw-in incandescent, halogen, and compact fluorescent lamps with screw-in LED lamps. Install photocell controls on all exterior lighting luminaires.

Installation of PV: Install a PV system that meets the requirements of 2019 Title 24 Section 150.1(c)14. Alternatively, a smaller PV system can be required as analysis found that cost-effectiveness results do not change appreciably with a PV system as small as one kW_{DC}.

Exception 1: All exceptions as stated in the 2019 Title 24 Section 150.1(c)14 are allowed.

Exception 2: A smaller PV system may be installed if the proposed system capacity is larger than the maximum size allowed by the electric utility based on NEM requirements.

Installation of PV and Battery: Install a PV system that meets the requirements of 2019 Title 24 Section 150.1(c)14 and a battery system that meets the requirements of 2019 Title 24 Joint Appendix 12. Combining PV with a battery system is cost-effective both On-Bill and TDV as shown in Table 13; however, battery systems are not cost-effective on their own without the energy savings from the PV system.

Alternatively, instead of requiring a battery system battery-ready measures could be required with a PV installation including locating and reserving a zone for installation of a battery storage system, running conduit for a future battery storage system, and possibly panel upgrades if the main service panel is replaced as part of the scope of work.

Exception 1: All exceptions as stated in the 2019 Title 24 Section 150.1(c)14 are allowed.

6.2 Fuel Substitution Measures

HVAC Heat Pump: Replace an existing ducted natural gas furnace/AC with a ducted heat pump at time of equipment replacement. This measure applies to homes according to climate zone as defined in Table 14, and summarized in Figure 4, Figure 5, and Figure 6. While it is cost-effective based on 2022 TDV in some conditions, replacement of the HVAC equipment with a minimum efficiency heat pump results in higher utility costs in most cases, resulting in negative impact on customer's ability to recover costs. Operating costs are sensitive to utility rate structures and changes in natural gas and electricity rates. As shown in Climate Zone 12 with SMUD rates, installing a heat pump can result in lower utility costs. Installing high-efficiency heat pumps can improve cost-effectiveness and lower operating costs but cannot be used for the basis of a reach code.

Installation of PV in addition to replacing a gas furnace/AC with a heat pump increases first cost but results in reduced utility costs and positive On-Bill cost effectiveness in most cases.

Exception 1: Non-ducted space conditioning systems and systems without central air conditioning.

Exception 2: Ducted space conditioning systems where only the gas furnace is replaced.

Exception 3: The main service panel does not have the capacity or space to accommodate an additional 240 V, 30 A circuit, and the cost to upgrade the main service panel and run required electrical service to the heat pump air handler is prohibitive as determined by the jurisdiction.

HPWH: Replace an existing natural gas storage water heater with a heat pump at time of equipment replacement. This measure applies to homes according to climate zone as defined in Table 15, and summarized in Figure 8, Figure 9, and Figure 10. This measure is cost-effective based on 2022 TDV in all climate zones except 1 and 16, but installation of a HPWH to replace an existing storage tank water heater can result in higher utility costs. Like the space conditioning heat pump, operating costs are sensitive to utility rate structures and future changes in natural gas and electricity rates. Installing a HPWH in Climate Zone 12 with SMUD rates results in lower utility costs. Like space conditioning heat pumps, installing higher efficiency equipment lowers operating costs but cannot be used for the basis of a reach code.

Installation of PV in addition to replacing an existing water heater with a HPWH significantly increases first cost but results in reduced utility costs and positive On-Bill cost effectiveness in all cases except the newest vintage case in Climate Zone 4 and CPAU territory.

This requirement could apply when replacing an existing water heater under the following conditions:

1. Electric resistance water heater located in a garage or vented closet with adequate space and ventilation,
2. Natural gas or propane water heater located in a garage or vented closet with adequate space and ventilation, and
    a. there is adequate space in the main service panel for a 240 V, 30 A dedicated breaker.

Exception 1: The proposed location of the new water heater is located within conditioned space.

Exception 2: The proposed location of the replacement water heater is not large enough to accommodate a HPWH equivalent in size and one-hour capacity rating to the existing water heater or the next nominal size available.

Exception 3: The main service panel does not have the capacity or space to accommodate an additional 240 V, 30 A circuit, or the cost to upgrade the main service panel and run required electrical service to the water heater is prohibitive as determined by the jurisdiction.

Exception 4: A solar water heating system is installed meeting the installation criteria specified in Reference Residential Appendix RA4.20 and with a minimum solar savings fraction of 60 percent.

PV and Electric Readiness Measures: Install a PV system and wiring for 240 V power to the furnace location and the water heater location and upgrade the main service panel to allow for installation of electric appliances at a future date. The requirements include the following:

1. Install a dedicated 240 V, 50 A or greater electrical circuit that terminates within three feet of the existing furnace or designated future location of an electric replacement heater with no obstructions into a listed cabinet, box, enclosure, or receptacle labelled “For Future Heat Pump Space Heater”.

    Exception 1: The building does not have existing central ducted heating or cooling system.

    Exception 2: The building already has a heat pump for space heating.

2. Install a dedicated 240 V, 30 A or greater electrical circuit that terminates within three feet of the existing water heater or designated future location of an electric replacement water heater with no obstructions into a listed cabinet, box, enclosure, or receptacle labelled “For Future Heat Pump Water Heater”.

    Exception 1: The proposed location of the new water heater is located within conditioned space.

    Exception 2: The proposed location of the replacement water heater is not large enough to accommodate a HPWH equivalent in size and one-hour capacity rating to the existing water heater or the next nominal size available.

    Exception 3: The building already has a HPWH.

3. Upgrade existing main service panel to a minimum 200 A panel to accommodate future connection of electric appliances.

Exception 1: The existing main service panel can be documented by an electrician or engineer to have sufficient capacity for the following electrical appliances: space heating, water heating, cooking, clothes drying, and Level 2 electric vehicle service equipment.

Exception 2: The building already uses electric appliances for space heating, water heating, cooking, and clothes drying.

6.3 Other Considerations

Measure Tradeoffs for Energy Performance Equivalency: Jurisdictions looking to provide flexibility in their reach codes for existing buildings can use the energy performance equivalency results to allow projects to select alternative measures or packages to meet the energy performance of the ordinance. This approach also allows an applicant to value previous upgrades made to the building in determining which ordinance requirements should apply. If tradeoffs are adopted by a jurisdiction, it can also provide flexibility to applicants to choose upgrades from the points menu that result in equivalent performance to the applicable reach code requirement or allow a jurisdiction to encourage installation of fuel substitution measures, such as space conditioning heat pumps or HPWHs as an equivalent alternative path to the adopted reach code measure or package.

HERS Rater Field Verification: HERS Rater field verification applies to duct sealing and new duct measures. It also may be required for other measures depending on the project work scope.

Combustion Appliance Safety and Indoor Air Quality: Implementation of some of the recommended measures will affect the pressure balance of the home which can subsequently impact the safe operation of existing combustion appliances as well as indoor air quality. Buildings with older gas appliances can present serious health and safety problems which may not be addressed in a remodel if the appliances are not being replaced. It is recommended that the building department require inspection and testing of all combustion appliances after completion of the retrofit work. It is also recommended that jurisdictions require combustion safety testing by a certified professional whenever air sealing and insulation measures are applied, and existing combustion appliances are located within the pressure boundary of the building.

Jurisdictions may also want to consider requiring mechanical ventilation in homes where air sealing has been conducted. In older buildings, outdoor air is typically introduced through leaks in the building envelope. After air sealing a building, it may be necessary to forcefully bring in fresh outdoor air using supply and/or exhaust fans to minimize potential issues associated with indoor air quality.

Required Measures Included in Title 24 Performance Simulation: If any of the measures above are included in a performance Title 24 compliance report, it's suggested that trade-offs be allowed as long as all minimum code requirements are met. For example, if a project is installing new windows, a new roof, and insulating the attic and is demonstrating Title 24 compliance with a performance simulation run, it would be acceptable if the installed roof did not meet the requirements listed above as long as this was traded off with either an increase in attic insulation or better performing windows. This would also allow trade-offs for projects that are installing high impact measures, such as solar water heating or whole house fans. This would require two simulation runs; however, it's not expected this approach would be utilized often. Run number one would evaluate the proposed building upgrades. This would also be the report submitted to the building department for the permit application demonstrating compliance with Title 24. Run number two would also be completed with the minimum ordinance requirements modeled for each of the affected building components. To show compliance with the ordinance the applicant would need to demonstrate that the proposed upgrades in run one would result in annual TDV energy use equal to or less than the annual TDV energy use of the case based on the ordinance requirements in run two.

7 References

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8 Appendices

8.1 Appendix A: Map of California Climate Zones

Climate zone geographical boundaries are depicted in Figure 13. The map in Figure 13 along with a zip-code search directory is available at: https://ww2.energy.ca.gov/maps/renewable/building_climate_zones.html

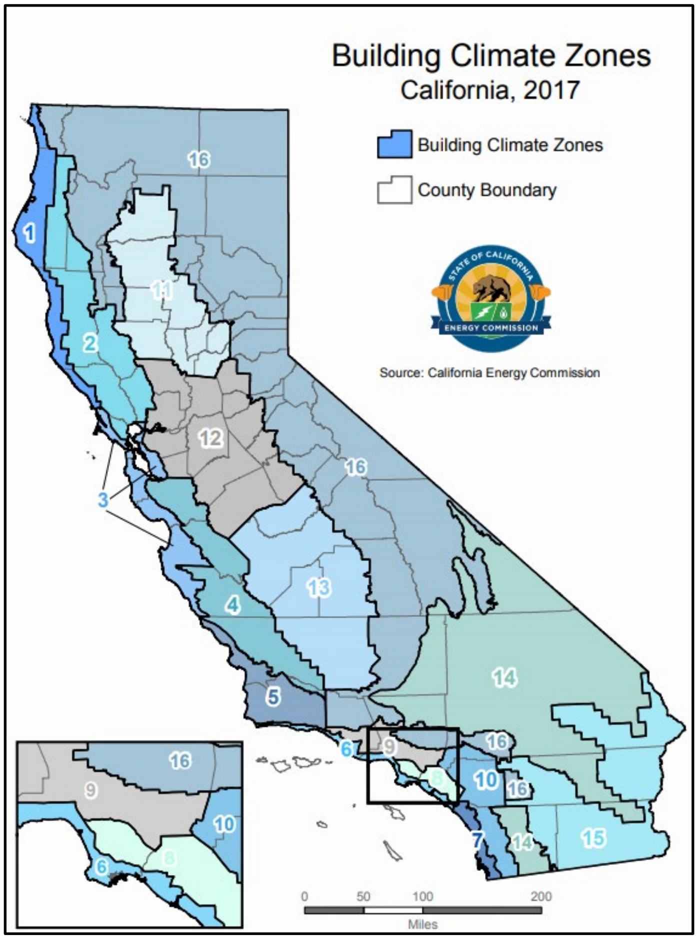

Figure 13: Map of California Climate Zones.
Source: California Energy Commission

8.2 Appendix B: Utility Rate Schedules

PG&E

The following pages provide details on the PG&E electricity and natural gas tariffs applied in this study. Table 21 describes the baseline territories that were assumed for each climate zone.

Table 21: PG&E Baseline Territory by Climate Zone

	Baseline Territory
CZ01	V
CZ02	X
CZ03	T
CZ04	X
CZ05	T
CZ11	R
CZ12	S
CZ13	R
CZ16	Y

The PG&E monthly gas rate in $/therm was applied on a monthly basis for the 12-month period ending March 2021 according to the rates shown in Table 22.

Table 22: PG&E Monthly Gas Rate ($/therm)

Month	Procurement Charge	Transportation Baseline Charge	Transportation Excess Charge	Total Baseline Charge	Total Excess Charge
Jan 2021	$0.49332	$1.09586	$1.53752	$1.58918	$2.03084
Feb 2021	$0.49073	$1.09586	$1.53752	$1.58659	$2.02825
Mar 2021	$0.42316	$1.19868	$1.68034	$1.62184	$2.1035
Apr 2020	$0.23856	$1.13126	$1.64861	$1.36982	$1.88717
May 2020	$0.23187	$1.13126	$1.64861	$1.36313	$1.88048
June 2020	$0.24614	$1.13126	$1.64861	$1.3774	$1.89475
July 2020	$0.23892	$1.13126	$1.64861	$1.37018	$1.88753
Aug 2020	$0.28328	$1.13126	$1.64861	$1.41454	$1.93189
Sept 2020	$0.41891	$1.13126	$1.64861	$1.55017	$2.06752
Oct 2020	$0.38068	$1.13416	$1.65280	$1.51484	$2.03348
Nov 2020	$0.46046	$1.13416	$1.65280	$1.59462	$2.11326
Dec 2020	$0.48474	$1.13416	$1.65280	$1.6189	$2.13754

Pacific Gas and Electric Company		Revised	Cal. P.U.C. Sheet No. 35436-G
U 39 San Francisco, California	Cancelling	Revised	Cal. P.U.C. Sheet No. 34288-G

GAS SCHEDULE G-1
RESIDENTIAL SERVICE

Sheet 2

BASELINE QUANTITIES: The delivered quantities of gas shown below are billed at the rates for baseline use.

BASELINE QUANTITIES (Therms Per Day Per Dwelling Unit)

Baseline Territories ***	Summer (April-October) Effective Apr. 1, 2020		Winter Off-Peak (Nov,Feb,Mar) Effective Nov. 1, 2019		Winter On-Peak (Dec, Jan) Effective Dec. 1, 2019		(T) | (T)
P	0.39	(R)	1.88	(R)	2.16	(I)	
Q	0.59	(R)	1.55	(R)	2.16	(I)	
R	0.36	(R)	1.28	(R)	1.97	(I)	
S	0.39	(R)	1.38	(R)	2.06	(I)	
T	0.59	(R)	1.38	(R)	1.81	(I)	
V	0.62	(R)	1.51	(R)	1.84	(I)	
W	0.39	(R)	1.18	(R)	1.84	(I)	
X	0.49	(R)	1.55	(R)	2.16	(I)	
Y	0.69	(R)	2.15	(R)	2.65	(I)	

SEASONAL CHANGES: The summer season is April-October, the winter off-peak season is November, February and March, and the winter on-peak season is December and January. Baseline quantities for bills that include the April 1, November 1 and December 1 seasonal changeover dates will be calculated by multiplying the applicable daily baseline quantity for each season by the number of days in each season for the billing period.

Pacific Gas and Electric Company		Revised	Cal. P.U.C. Sheet No.	49113-E
U 39 San Francisco, California	Cancelling	Revised	Cal. P.U.C. Sheet No.	48199-E

ELECTRIC SCHEDULE E-TOU-C Sheet 2
RESIDENTIAL TIME-OF-USE (PEAK PRICING 4 - 9 p.m. EVERY DAY)

RATES:
(Cont'd.)

E-TOU-C TOTAL RATES

Total Energy Rates ($ per kWh)	PEAK		OFF-PEAK	
Summer				
Total Usage	$0.41813	(I)	$0.35469	(I)
Baseline Credit (Applied to Baseline Usage Only)	($0.07584)	(R)	($0.07584)	(R)
Winter				
Total Usage	$0.32104	(I)	$0.30372	(I)
Baseline Credit (Applied to Baseline Usage Only)	($0.07584)	(R)	($0.07584)	(R)
Delivery Minimum Bill Amount ($ per meter per day)	$0.32854			
California Climate Credit (per household, per semi-annual payment occurring in the April and October bill cycles)	($17.20)			

Total bundled service charges shown on customer's bills are unbundled according to the component rates shown below. Where the delivery minimum bill amount applies, the customer's bill will equal the sum of (1) the delivery minimum bill amount plus (2) for bundled service, the generation rate times the number of kWh used. For revenue accounting purposes, the revenues from the delivery minimum bill amount will be assigned to the Transmission, Transmission Rate Adjustments, Reliability Services, Public Purpose Programs, Nuclear Decommissioning, Competition Transition Charges, Energy Cost Recovery Amount, Wildfire Fund Charge, and New System Generation Charges based on kWh usage times the corresponding unbundled rate component per kWh, with any residual revenue assigned to Distribution.

(Continued)

Advice	6090-E-A	*Issued by*	*Submitted*	February 26, 2021
Decision		***Robert S. Kenney***	*Effective*	March 1, 2021
		Vice President, Regulatory Affairs	*Resolution*	

Pacific Gas and Electric Company		Revised	*Cal. P.U.C. Sheet No.*	46190-E
U 39 *San Francisco, California*	*Cancelling*	Revised	*Cal. P.U.C. Sheet No.*	43414-E

ELECTRIC SCHEDULE E-TOU-C Sheet 4 (T)

RESIDENTIAL TIME-OF-USE (PEAK PRICING 4 - 9 p.m. EVERY DAY)

SPECIAL CONDITIONS:

1. BASELINE (TIER 1) QUANTITIES: The following quantities of electricity are to be used to define usage eligible for the baseline credit (also see Rule 19 for additional allowances for medical needs):

BASELINE QUANTITIES (kWh PER DAY)

	Code B - Basic Quantities		Code H - All-Electric Quantities	
	Summer	Winter	Summer	Winter
Baseline Territory*	Tier I	Tier I	Tier I	Tier I
P	14.2	12.0	16.0	27.4
Q	10.3	12.0	8.9	27.4
R	18.6	11.3	20.9	28.1
S	15.8	11.1	18.7	24.9
T	6.8	8.2	7.5	13.6
V	7.5	8.8	10.9	16.9
W	20.2	10.7	23.6	20.0
X	10.3	10.5	8.9	15.4
Y	11.0	12.1	12.6	25.3
Z	6.2	8.1	7.0	16.5

2. TIME PERIODS FOR **E-TOU-C**: Times of the year and times of the day are defined as follows: (T)

Summer (service from June 1 through September 30):

Peak:	4:00 p.m. to 9:00 p.m.	All days
Off-Peak:	All other times	

Winter (service from October 1 through May 31):

Peak:	4:00 p.m. to 9:00 p.m.	All days
Off-Peak:	All other times	

* The applicable baseline territory is described in Part A of the Preliminary Statement

(Continued)

Advice	5759-E	*Issued by*	*Submitted*	February 14, 2020
Decision	D.19-07-004	***Robert S. Kenney***	*Effective*	March 1, 2020
		Vice President, Regulatory Affairs	*Resolution*	

SCE

The following pages provide details on are the SCE electricity tariffs applied in this study. Table 23 describes the baseline territories that were assumed for each climate zone.

Table 23: SCE Baseline Territory by Climate Zone

Climate Zone	Baseline Territory
CZ06	6
CZ08	8
CZ09	9
CZ10	10
CZ14	14
CZ15	15

Summer Daily Allocations (June through September)

Baseline Region Number	Daily kWh Allocation	All-Electric Allocation
5	17.2	17.9
6	11.4	8.8
8	12.6	9.8
9	16.5	12.4
10	18.9	15.8
13	22.0	24.6
14	18.7	18.3
15	46.4	24.1
16	14.4	13.5

Winter Daily Allocations (October through May)

Baseline Region Number	Daily kWh Allocation	All-Electric Allocation
5	18.7	29.1
6	11.3	13.0
8	10.6	12.7
9	12.3	14.3
10	12.5	17.0
13	12.6	24.3
14	12.0	21.3
15	9.9	18.2
16	12.6	23.1

Schedule TOU-D
TIME-OF-USE
DOMESTIC
(Continued)

Sheet 12 (T)

SPECIAL CONDITIONS

1. Applicable rate time periods are defined as follows:

Option 4-9 PM, Option 4-9 PM-CPP, Option PRIME, Option PRIME-CPP : (T)

TOU Period	Weekdays		Weekends and Holidays	
	Summer	Winter	Summer	Winter
On-Peak	4 p.m. - 9 p.m.	N/A	N/A	N/A
Mid-Peak	N/A	4 p.m. - 9 p.m.	4 p.m. - 9 p.m.	4 p.m. - 9 p.m.
Off-Peak	All other hours	9 p.m. - 8 a.m.	All other hours	9 p.m. - 8 a.m.
Super-Off-Peak	N/A	8 a.m. - 4 p.m.	N/A	8 a.m. - 4 p.m.
CPP Event Period	4 p.m. - 9 p.m.	4 p.m. - 9 p.m.	N/A	N/A

SOUTHERN CALIFORNIA EDISON
An EDISON INTERNATIONAL Company

Southern California Edison
Rosemead, California (U 338-E)

Revised Cal. PUC Sheet No. 70277-E
Cancelling Revised Cal. PUC Sheet No. 69597-E

Schedule TOU-D
TIME-OF-USE
DOMESTIC
(Continued)

Sheet 2

RATES

Customers receiving service under this Schedule will be charged the applicable rates under Option 4-9 PM, Option 4-9 PM-CPP, Option 5-8 PM, Option 5-8 PM-CPP, Option PRIME, Option PRIME-CPP Option A, Option A-CPP, Option B, or Option B-CPP, as listed below. CPP Event Charges will apply to all energy usage during CPP Event Energy Charge periods and CPP Non-Event Energy Credits will apply as a reduction on CPP Non-Event Energy Credit Periods during Summer Season weekdays, 4:00 p.m. to 9:00 p.m., as described in Special Conditions 1 and 3, below:

	Delivery Service	Generation[2]	
Option 4-9 PM / Option 4-9 PM-CPP	Total[1]	UG***	DWREC[3]
Energy Charge - $/kWh			
Summer Season - On-Peak	0.24845 (I)	0.18143 (R)	0.00000 (I)
Mid-Peak	0.24845 (I)	0.10036 (R)	0.00000 (I)
Off-Peak	0.19495 (I)	0.07403 (R)	0.00000 (I)
Winter Season - Mid-Peak	0.24845 (I)	0.12593 (R)	0.00000 (I)
Off-Peak	0.19495 (I)	0.08893 (R)	0.00000 (I)
Super-Off-Peak	0.18859 (I)	0.06926 (R)	0.00000 (I)
Baseline Credit**** - $/kWh	(0.07228) (R)	0.00000	
Basic Charge - $/day			
Single-Family Residence	0.031		
Multi-Family Residence	0.024		
Minimum Charge** - $/day			
Single Family Residence	0.346		
Multi-Family Residence	0.346		
Minimum Charge (Medical Baseline)** - $/day			
Single Family Residence	0.173		
Multi-Family Residence	0.173		
California Climate Credit[4]	(29.00) (R)		
California Alternate Rates for			
Energy Discount - %	100.00*		
Family Electric Rate Assistance Discount - %	100.00		
Option 4-9 PM-CPP			
CPP Event Energy Charge - $/kWh		0.80000	
Summer CPP Non-Event Credit			
On-Peak Energy Credit - $/kWh		(0.15170)	
Maximum Available Credit - $/kWh*****			
Summer Season		(0.58115) (I)	

* Represents 100% of the discount percentage as shown in the applicable Special Condition of this Schedule.
** The Minimum Charge is applicable when the Delivery Service Energy Charge, plus the applicable Basic Charge is less than the Minimum Charge.
*** The ongoing Competition Transition Charge CTC of ($0.00002) per kWh is recovered in the UG component of Generation. (R)
**** The Baseline Credit applies up to 100% of the Baseline Allocation, regardless of Time of Use. The Baseline Allocation is set forth in Preliminary Statement, Part H.
***** The Maximum Available Credit is the capped credit amount for CPP Customers dual participating in other demand response programs.
1 Total = Total Delivery Service rates are applicable to Bundled Service, Direct Access (DA) and Community Choice Aggregation Service (CCA Service) Customers, except DA and CCA Service Customers are not subject to the DWRBC rate component of this Schedule but instead pay the DWRBC as provided by Schedule DA-CRS or Schedule CCA-CRS.
2 Generation = The Gen rates are applicable only to Bundled Service Customers.
3 DWREC = Department of Water Resources (DWR) Energy Credit – For more information on the DWR Energy Credit, see the Billing Calculation Special Condition of this Schedule.
4 Applied on an equal basis, per household, semi-annually. See the Special Conditions of this Schedule for more information.

(Continued)

(To be inserted by utility)
Advice 4377-E-A
Decision
2C11

Issued by
Carla Peterman
Senior Vice President

(To be inserted by Cal. PUC)
Date Submitted Jan 11, 2021
Effective Feb 1, 2021
Resolution

SoCalGas

Following are the SoCalGas natural gas tariffs applied in this study. Table 24 describes the baseline territories that were assumed for each climate zone.

Table 24: SoCalGas Baseline Territory by Climate Zone

	Baseline Territory
CZ05	2
CZ06	1
CZ08	1
CZ09	1
CZ10	1
CZ14	2
CZ15	1

The SoCalGas monthly gas rate in $/therm was applied on a monthly basis for the 12-month period ending March 2021 according to the rates shown in Table 25. Historical natural gas rate data was only available for SoCalGas' procurement charges.[5] To estimate total costs by month, the baseline and excess transmission charges were assumed to be relatively consistence and applied for the entire year based on January 2021 costs.

Table 25: SoCalGas Monthly Gas Rate ($/therm)

Month	Procurement Charge	Transportation Baseline Charge	Transportation Excess Charge	Total Baseline Charge	Total Excess Charge
Jan 2021	$0.39764	$0.82358	$1.21382	$1.22122	$1.61146
Feb 2021	$0.36766	$0.82358	$1.21382	$1.19124	$1.58148
Mar 2021	$0.36982	$0.82358	$1.21382	$1.19340	$1.58364
Apr 2020	$0.20307	$0.82358	$1.21382	$1.02665	$1.41689
May 2020	$0.25654	$0.82358	$1.21382	$1.08012	$1.47036
June 2020	$0.2758	$0.82358	$1.21382	$1.09938	$1.48962
July 2020	$0.26816	$0.82358	$1.21382	$1.09174	$1.48198
Aug 2020	$0.26239	$0.82358	$1.21382	$1.08597	$1.47621
Sept 2020	$0.25498	$0.82358	$1.21382	$1.07856	$1.4688
Oct 2020	$0.25268	$0.82358	$1.21382	$1.07626	$1.4665
Nov 2020	$0.3432	$0.82358	$1.21382	$1.16678	$1.55702
Dec 2020	$0.36159	$0.82358	$1.21382	$1.18517	$1.57541

[5] The SoCalGas procurement and transmission charges were obtained from the following site: https://www.socalgas.com/for-your-business/energy-market-services/gas-prices

SOUTHERN CALIFORNIA GAS COMPANY	Revised	CAL. P.U.C. SHEET NO.	57456-G
LOS ANGELES, CALIFORNIA CANCELING	Revised	CAL. P.U.C. SHEET NO.	57430-G

Schedule No. GR

Sheet 1

RESIDENTIAL SERVICE

(Includes GR, GR-C and GT-R Rates)

APPLICABILITY

The GR rate is applicable to natural gas procurement service to individually metered residential customers.

The GR-C, cross-over rate, is a core procurement option for individually metered residential core transportation customers with annual consumption over 50,000 therms, as set forth in Special Condition 10.

The GT-R rate is applicable to Core Aggregation Transportation (CAT) service to individually metered residential customers, as set forth in Special Condition 11.

The California Alternate Rates for Energy (CARE) discount of 20%, reflected as a separate line item on the bill, is applicable to income-qualified households that meet the requirements for the CARE program as set forth in Schedule No. G-CARE.

TERRITORY

Applicable throughout the service territory.

RATES	GR	GR-C	GT-R
Customer Charge, per meter per day:	16.438¢	16.438¢	16.438¢
For "Space Heating Only" customers, a daily Customer Charge applies during the winter period from November 1 through April 30[1/]:	33.149¢	33.149¢	33.149¢

SDG&E

Following are the SDG&E electricity and natural gas tariffs applied in this study. Table 26 describes the baseline territories that were assumed for each climate zone.

Table 26: SDG&E Baseline Territory by Climate Zone

	Baseline Territory
CZ07	Coastal
CZ10	Inland
CZ14	Mountain

The SDG&E monthly gas rate in $/therm was applied on a monthly basis for the 12-month period ending March 2021 according to the rates shown in Table 27. Historical natural gas rate data from SDG&E was reviewed to identify the procurement and transmission charges[6] used to calculate the monthly total gas rate.

Table 27: SDG&E Monthly Gas Rate ($/therm)

Month	Procurement Charge	Transportation Baseline Charge	Transportation Excess Charge	Total Baseline Charge	Total Excess Charge
Jan 2021	$0.39803	$1.44464	$1.70732	$1.84267	$2.10535
Feb 2021	$0.28035	$1.36166	$1.59166	$1.64201	$1.87201
Mar 2021	$0.22130	$1.36166	$1.59166	$1.58296	$1.81296
Apr 2020	$0.20327	$1.35946	$1.59125	$1.56273	$1.79452
May 2020	$0.25676	$1.39202	$1.62888	$1.64878	$1.88564
June 2020	$0.27605	$1.39202	$1.62888	$1.66807	$1.90493
July 2020	$0.2684	$1.39202	$1.62888	$1.66042	$1.89728
Aug 2020	$0.26263	$1.39202	$1.62888	$1.65465	$1.89151
Sept 2020	$0.25521	$1.39202	$1.62888	$1.64723	$1.88409
Oct 2020	$0.2529	$1.42577	$1.67181	$1.67867	$1.92471
Nov 2020	$0.34351	$1.42577	$1.67181	$1.76928	$2.01532
Dec 2020	$0.36192	$1.42577	$1.67181	$1.78769	$2.03373

[6] The SDG&E procurement and transmission charges were obtained from the following sets of documents:

http://regarchive.sdge.com/tm2/pdf/GAS_GAS-SCHEDS_GM_2020.pdf

http://regarchive.sdge.com/tm2/pdf/GAS_GAS-SCHEDS_GM_2019.pdf

RATES	GR	GR-C	GTC/GTCA[1/]
Minimum Bill, per day: [3/]			
Non-CARE customers:	$0.13151	$0.13151	$0.13151
CARE customers:	$0.10521	$0.10521	$0.10521

Baseline Usage: The following quantities of gas used in individually metered residences are to be billed at the baseline rates:

All Customers:	Daily Therm Allowance
Summer (May 1 to October 31, inclusive)	0.493
Winter (November 1 to April 30, inclusive)	1.546

SDGE
San Diego Gas & Electric Company
San Diego, California

Revised Cal. P.U.C. Sheet No. 33144-E
Canceling Revised Cal. P.U.C. Sheet No. 32930-E

Sheet 2

SCHEDULE TOU-DR1

RESIDENTIAL TIME-OF-USE

RATES

Total Rates:

Description – TOU DR1	UDC Total Rate		DWR-BC Rate	EECC Rate + DWR Credit		Total Rate	
Summer:							
On-Peak	0.22374	I	0.00580	0.29042	R	0.51996	R
Off-Peak	0.22374	I	0.00580	0.09305	R	0.32259	R
Super Off-Peak	0.22374	I	0.00580	0.04743	R	0.27697	R
Winter:							
On-Peak	0.25734	R	0.00580	0.07844	R	0.34158	R
Off-Peak	0.25734	R	0.00580	0.06961	R	0.33275	R
Super Off-Peak	0.25734	R	0.00580	0.05981	R	0.32295	R
Summer Baseline Adjustment Credit up to 130% of Baseline	(0.07506)	I				(0.07506)	I
Winter Baseline Adjustment Credit up to 130% of Baseline	(0.06833)	I				(0.06833)	I
Minimum Bill ($/day)	0.338					0.338	

Note:
(1) Total Rates consist of UDC, Schedule DWR-BC (Department of Water Resources Bond Charge), and Schedule EECC (Electric Energy Commodity Cost) rates, with the EECC rates reflecting a DWR Credit.
(2) Total Rates presented are for customers that receive commodity supply and delivery service from Utility.
(3) DWR-BC charges do not apply to CARE customers.
(4) As identified in the rates tables, customer bills will also include line-item summer and winter credits for usage up to 130% of baseline to provide the rate capping benefits adopted by Assembly Bill 1X and Senate Bill 695.

(Continued)

2C8

Advice Ltr. No. 3514-E

Decision No. D.20-01-021

Issued by
Dan Skopec
Vice President
Regulatory Affairs

Submitted Mar 26, 2020
Effective Apr 1, 2020
Resolution No.

Time Periods

All time periods listed are applicable to local time. The definition of time will be based upon the date service is rendered.

TOU Periods – Weekdays	Summer	Winter
On-Peak	4:00 p.m. – 9:00 p.m.	4:00 p.m. – 9:00 p.m.
Off-Peak	6:00 a.m. – 4:00 p.m.; 9:00 p.m. - midnight	6:00 a.m. – 4:00 p.m. Excluding 10:00 a.m. – 2:00 p.m. in March and April; 9:00 p.m. - midnight
Super Off-Peak	Midnight – 6:00 a.m.	Midnight – 6:00 a.m. 10:00 a.m. – 2:00 p.m. in March and April
TOU Period – Weekends and Holidays	Summer	Winter
On-Peak	4:00 p.m. – 9:00 p.m.	4:00 p.m. – 9:00 p.m.
Off-Peak	2:00 p.m. – 4:00 p.m.; 9:00 p.m. - midnight	2:00 p.m. – 4:00 p.m.; 9:00 p.m. - midnight
Super Off-Peak	Midnight – 2:00 p.m.	Midnight – 2:00 p.m.

Seasons:	Summer	June 1 – October 31
	Winter	November 1 – May 31

15. Baseline Usage: The following quantities of electricity are used to calculate the baseline adjustment credit.

	Baseline Allowance For Climatic Zones*			
	Coastal	Inland	Mountain	Desert
Basic Allowance				
Summer (June 1 to October 31)	9.0	10.4	13.6	15.9
Winter (November 1 to May 31)	9.2	9.6	12.9	10.9
All Electric**				
Summer (June 1 to October 31)	6.0	8.7	15,2	17.0
Winter (November 1 to May 31)	8.8	12.2	22.1	17.1

* Climatic Zones are shown on the Territory Served, Map No. 1.

** All Electric allowances are available upon application to those customers who have permanently installed space heating or who have electric water heating and receive no energy from another source.

SMUD

Following are the SMUD electricity tariffs applied in this study.

II. Firm Service Rates

A. Time-of-Day (5-8 p.m.) Rate **Rate Category RT02**

Effective January 1, 2021	
Non-Summer Prices*	
System Infrastructure Fixed Charge per month	$22.25
Electricity Usage Charge	
Peak $/kWh	$0.1465
Off-Peak $/kWh	$0.1061
Summer Prices	
System Infrastructure Fixed Charge per month	$22.25
Electricity Usage Charge	
Peak $/kWh	$0.3105
Mid-Peak $/kWh	$0.1765
Off-Peak $/kWh	$0.1277
Effective October 1, 2021	
Non-Summer Prices*	
System Infrastructure Fixed Charge per month	$22.70
Electricity Usage Charge	
Peak $/kWh	$0.1494
Off-Peak $/kWh	$0.1082
Summer Prices	
System Infrastructure Fixed Charge per month	$22.70
Electricity Usage Charge	
Peak $/kWh	$0.3167
Mid-Peak $/kWh	$0.1800
Off-Peak $/kWh	$0.1303

* Non-Summer Season includes Fall (Oct 1 – Nov 30), Winter (Dec 1 – Mar 31) and Spring (Apr 1 – May 31) periods.

Summer (Jun 1 - Sept 30)	Peak	Weekdays between 5:00 p.m. and 8:00 p.m.
	Mid-Peak	Weekdays between noon and midnight except during the Peak hours.
	Off-Peak	All other hours, including weekends and holidays[1].
Non-Summer (Oct 1 - May 31)	Peak	Weekdays between 5:00 p.m. and 8:00 p.m.
	Off-Peak	All other hours, including weekends and holidays[1].

CPAU

Following are the CPAU electricity and natural gas tariffs applied in this study.

The CPAU monthly gas rate in $/therm was applied on a monthly basis for the 12-month period ending February 2021 according to the rates shown in Table 28. The distribution charge was $0.4835/therm for Tier 1 and $1.0426/therm for Tier 2. The monthly service charge applied was $10.94 per month per the G-1 tariff in effect at the time of the analysis.

Table 28: CPAU Monthly Gas Rate ($/therm)

Effective Date	Commodity Rate	Cap and Trade Compliance Charge	Transportation Charge	Carbon Offset Charge	G1 Tier 1 Volumetric Totals	G1 Tier 2 Volumetric Totals
Jan 2021	$0.3436	$0.0486	$0.11104	$0.040	$1.04704	$1.83144
Feb 2021	$0.3309	$0.0486	$0.11104	$0.040	$1.03434	$1.81874
Mar 2020	$0.2416	$0.033	$0.09891	$0.040	$0.89701	$1.45611
Apr 2020	$0.2066	$0.033	$0.09891	$0.040	$0.86201	$1.42111
May 2020	$0.2258	$0.033	$0.09891	$0.040	$0.88121	$1.44031
June 2020	$0.2279	$0.033	$0.09891	$0.040	$0.88331	$1.44241
July 2020	$0.2186	$0.033	$0.09862	$0.040	$0.89402	$1.67842
Aug 2020	$0.2257	$0.033	$0.09862	$0.040	$0.90112	$1.68552
Sept 2020	$0.3203	$0.033	$0.09862	$0.040	$0.99572	$1.78012
Oct 2020	$0.3724	$0.033	$0.09862	$0.040	$1.04782	$1.83222
Nov 2020	$0.3749	$0.033	$0.09862	$0.040	$1.05032	$1.83472
Dec 2020	$0.3446	$0.033	$0.09862	$0.040	$1.02002	$1.80442

RESIDENTIAL ELECTRIC SERVICE

UTILITY RATE SCHEDULE E-1

A. APPLICABILITY:

This Rate Schedule applies to separately metered single-family residential dwellings receiving Electric Service from the City of Palo Alto Utilities.

B. TERRITORY:

This rate schedule applies everywhere the City of Palo Alto provides Electric Service.

C. UNBUNDLED RATES:

Per kilowatt-hour (kWh)	Commodity	Distribution	Public Benefits	Total
Tier 1 usage	$0.08339	$0.04971	$0.00447	$0.13757
Tier 2 usage Any usage over Tier 1	0.11569	0.07351	0.00447	0.19367
Minimum Bill ($/day)				0.3283

Escalation Assumptions

The average annual escalation rates in the following table were used in this study and are from E3's 2019 study Residential Building Electrification in California (Energy & Environmental Economics, 2019). These rates are applied to the 2019 rate schedules over a 30-year period beginning in 2020. SDG&E was not covered in the E3 study. The Statewide Reach Code Team reviewed SDG&E's GRC filing and applied the same approach that E3 applied for PG&E and SoCalGas to arrive at average escalation rates between 2020 and 2022.

Table 29: Real Utility Rate Escalation Rate Assumptions

Table 29A: Statewide Electric Residential Average Rate (%/year, real)

	Statewide Electric Residential Average Rate (%/year, real)
2020	2.0%
2021	2.0%
2022	2.0%
2023	2.0%
2024	2.0%
2025	2.0%
2026	1.0%
2027	1.0%
2028	1.0%
2029	1.0%
2030	1.0%
2031	1.0%
2032	1.0%
2033	1.0%
2034	1.0%
2035	1.0%
2036	1.0%
2037	1.0%
2038	1.0%
2039	1.0%
2040	1.0%
2041	1.0%
2042	1.0%
2043	1.0%
2044	1.0%
2045	1.0%
2046	1.0%
2047	1.0%
2048	1.0%
2049	1.0%

Table 29B: Natural Gas Residential Core Rate (%/year escalation, real)

-	PG&E (%/year, real)	SoCalGas (%/year, real)	SDG&E (%/year, real)
2020	1.48%	6.37%	5.00%
2021	5.69%	4.12%	3.14%
2022	1.11%	4.12%	2.94%
2023	4.0%	4.0%	4.0%
2024	4.0%	4.0%	4.0%
2025	4.0%	4.0%	4.0%
2026	1.0%	1.0%	1.0%
2027	1.0%	1.0%	1.0%
2028	1.0%	1.0%	1.0%
2029	1.0%	1.0%	1.0%
2030	1.0%	1.0%	1.0%
2031	1.0%	1.0%	1.0%
2032	1.0%	1.0%	1.0%
2033	1.0%	1.0%	1.0%
2034	1.0%	1.0%	1.0%
2035	1.0%	1.0%	1.0%
2036	1.0%	1.0%	1.0%
2037	1.0%	1.0%	1.0%
2038	1.0%	1.0%	1.0%
2039	1.0%	1.0%	1.0%
2040	1.0%	1.0%	1.0%
2041	1.0%	1.0%	1.0%
2042	1.0%	1.0%	1.0%
2043	1.0%	1.0%	1.0%
2044	1.0%	1.0%	1.0%
2045	1.0%	1.0%	1.0%
2046	1.0%	1.0%	1.0%
2047	1.0%	1.0%	1.0%
2048	1.0%	1.0%	1.0%
2049	1.0%	1.0%	1.0%

8.3 Appendix C – Standards Sections

2019 Building Energy Efficiency Standards Section 150.2(b)1I

Roofs. Replacements of the exterior surface of existing roofs, including adding a new surface layer on top of the existing exterior surface, shall meet the requirements of Section 110.8 and the applicable requirements of Subsections i and ii where more than 50 percent of the roof is being replaced.

i. Low-rise residential buildings with steep-sloped roofs, in Climate Zones 10 through 15 shall have a minimum aged solar reflectance of 0.20 and a minimum thermal emittance of 0.75, or a minimum SRI of 16.

EXCEPTION TO 150.2(b)1Ii: The following shall be considered equivalent to Subsection i:

a. Air-space of 1.0 inch (25 mm) is provided between the top of the roof deck to the bottom of the roofing product; or

b. The installed roofing product has a profile ratio of rise to width of 1 to 5 for 50 percent or greater of the width of the roofing product; or

c. Existing ducts in the attic are insulated and sealed according to Section 150.1(c)9; or

d. Buildings with at least R-38 ceiling insulation; or

e. Buildings with a radiant barrier in the attic meeting the requirements of Section 150.1(c)2; or

f. Buildings that have no ducts in the attic; or

g. In Climate Zones 10-15, R-2or greater insulation above the roof deck.

ii. Low-sloped roofs in Climate Zones 13 and 15 shall have a 3-year aged solar reflectance equal or greater than 0.63 and a thermal emittance equal or greater than 0.75, or a minimum SRI of 75.

EXCEPTION 1 to Section 150.2(b)1Iii: Buildings with no ducts in the attic.

EXCEPTION 2 to Section 150.2(b)1Iii: The aged solar reflectance can be met by using insulation at the roof deck specified in TABLE 150.2-B.

2019 Building Energy Efficiency Standards Section 150.2(b)1E

Altered Space-Conditioning System - Duct Sealing: In all climate zones, when a space-conditioning system serving a single family or multifamily dwelling is altered by the installation or replacement of space-conditioning system equipment, including replacement of the air handler, outdoor condensing unit of a split system air conditioner or heat pump, or cooling or heating coil; the duct system that is connected to the altered space-conditioning system equipment shall be sealed, as confirmed through field verification and diagnostic testing in accordance with the applicable procedures for duct sealing of altered existing duct systems as specified in Reference Residential Appendix RA3.1 and the leakage compliance criteria specified in subsection i, ii, or iii below. Additionally, when altered ducts, air-handling units, cooling or heating coils, or plenums are located in garage spaces, the system shall comply with Section 150.2(b)1Diic regardless of the length of any new or replacement space-conditioning ducts installed in the garage space.

i. The measured duct leakage shall be equal to or less than 15 percent of system air handler airflow as determined utilizing the procedures in Reference Residential Appendix Section RA3.1.4.3.1; or

ii. The measured duct leakage to outside shall be equal to or less than 10 percent of system air handler airflow as determined utilizing the procedures in Reference Residential Appendix Section RA3.1.4.3.4; or

iii. If it is not possible to meet the duct sealing requirements of either Section 150.2(b)1Ei or Section 150.2(b)1Eii, then, all accessible leaks shall be sealed and verified through a visual inspection and a smoke test by a certified HERS Rater utilizing the methods specified in Reference Residential Appendix RA3.1.4.3.5.

EXCEPTION 1 to Section 150.2(b)1E: Duct Sealing. Duct systems that are documented to have been previously sealed as confirmed through field verification and diagnostic testing in accordance with procedures in the Reference Residential Appendix RA3.1.

EXCEPTION 2 to Section 150.2(b)1E: Duct Sealing. Duct systems with less than 40 linear feet as determined by visual inspection.

EXCEPTION 3 to Section 150.2(b)1E: Duct Sealing. Existing duct systems constructed, insulated or sealed with asbestos.

8.4 Appendix D – Measure Cost-Effectiveness Tables

Detailed cost-effectiveness analysis results are summarized by vintage and climate zone in Table 30 through Table 113. Site energy savings, cost savings, measure cost, and cost effectiveness including lifecycle B/C ratio and NPV of savings are provided. For climate zones that are served by multiple utilities, where cost effectiveness may differ based on applicable utility rates, cost-effectiveness results are reported for both applicable utility territories.

Shaded cells in the tables and values in red indicate that the measure is not cost-effective with B/C ratios less than one. Cells with "n/a" reflect lighting and water heating efficiency measures and packages that did not look at TDV cost effectiveness.

Climate Zone 2:

Note: Values in red and grey rows indicate option is not cost-effective with B/C ratio less than 1. Cells with "n/a" reflect lighting and water heating efficiency measures and packages that did not look at TDV cost effectiveness or GHG impacts.

Table 30: CZ 2 - Single Family Efficiency Upgrade Cost-Effectiveness Results

Measure	Vintage	Measure Cost ($)	Electricity Savings (kWh)	Gas Savings (therm)	GHG Savings (lb CO_2e)	Utility Cost Savings		Customer On-Bill		2019 TDV		2022 TDV	
						Year 1	Avg Annual	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV
R-49 Attic Insulation	Pre-1978	$3,332	505	38	484	$269	$217	1.74	$2,758	1.93	$3,093	2.12	$3,743
R-49 Attic Insulation	1978-1991	$2,874	254	19	247	$131	$105	0.98	($69)	1.28	$803	1.39	$1,122
R-49 Attic Insulation	1992-2010	$1,852	34	7	85	$26	$22	0.31	($1,433)	0.61	($720)	0.58	($772)
Reduced Infiltration	Pre-1978	$1,474	21	17	173	$41	$35	0.63	($616)	0.62	($555)	0.91	($135)
Reduced Infiltration	1978-1991	$1,474	12	11	110	$25	$21	0.38	($1,031)	0.41	($866)	0.66	($503)
Reduced Infiltration	1992-2010	$1,474	9	7	73	$16	$14	0.25	($1,246)	0.29	($1,053)	0.36	($938)
Duct Sealing	Pre-1978	$683	184	42	466	$157	$129	5.03	$3,090	6.17	$3,528	8.63	$5,213
Duct Sealing	1978-1991	$683	85	24	269	$80	$66	2.58	$1,209	3.59	$1,768	5.14	$2,825
Duct Sealing	1992-2010	$423	11	7	74	$17	$15	0.92	($38)	1.19	$81	1.83	$352
New Ducts	Pre-1978	$3,986	345	72	806	$280	$230	1.54	$2,410	1.89	$3,529	2.71	$6,801
New Ducts	1978-1991	$3,986	205	51	575	$178	$147	0.98	($78)	1.34	$1,366	2.02	$4,059
New Ducts	1992-2010	$3,986	41	22	232	$56	$46	0.31	($3,084)	0.41	($2,356)	0.64	($1,422)
Cool Roof	Pre-1978	$778	177	-8	-48	$54	$42	1.48	$407	1.76	$593	2.01	$786
Cool Roof	1978-1991	$778	101	-6	-37	$28	$21	0.76	($204)	1.37	$291	1.58	$452
Cool Roof	1992-2010	$778	23	-5	-41	($1)	($1)	0	($878)	0.54	($354)	0.46	($418)
R-13 Wall Insulation	Pre-1978	$3,360	118	56	589	$156	$129	1.03	$109	1.11	$359	1.47	$1,563
Windows	Pre-1978	$9,810	563	21	347	$260	$208	0.57	($4,776)	0.76	($2,309)	0.82	($1,733)
Windows	1978-1991	$9,810	359	16	270	$174	$139	0.38	($6,839)	0.66	($3,369)	0.66	($3,335)
LED lamp vs CFL	All	$2.26	1.2	0	n/a	$0.37	$0.29	3.84	$6.40	n/a	n/a	n/a	n/a
Exterior Photosensor	All	$42.58	12.1	0	n/a	$2.88	$2.27	1.6	$25.62	n/a	n/a	n/a	n/a

Table 31: CZ 2 - Single Family Efficiency Packages Cost-Effectiveness Results

Measure	Vintage	Measure Cost ($)	Electricity Savings (kWh)	Gas Savings (therm)	GHG Savings (lb CO_2e)	Utility Cost Savings		Customer On-Bill		2019 TDV		2022 TDV	
						Year 1	Avg Annual	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV
R49 Attic & Air Sealing Package	Pre-1978	$4,806	533	56	675	$315	$256	1.42	$2,270	1.56	$2,702	1.77	$3,686
	1978-1991	$4,348	270	31	362	$157	$127	0.78	-$1,062	1.00	$15	1.11	$498
	1992-2010	$3,326	42	14	157	$42	$35	0.28	-$2,687	0.48	-$1,739	0.48	-$1,716
R49 Attic & Duct Sealing Package	Pre-1978	$4,015	626	79	931	$398	$323	2.15	$5,196	2.55	$6,239	3.07	$8,291
	1978-1991	$3,557	316	43	499	$199	$162	1.22	$859	1.65	$2,301	1.97	$3,449
	1992-2010	$2,275	44	14	156	$43	$35	0.41	-$1,497	0.70	-$685	0.78	-$501
R49 Attic, Air Sealing & Duct Sealing Package	Pre-1978	$5,489	647	94	1,092	$436	$356	1.73	$4,501	2.04	$5,709	2.47	$8,079
	1978-1991	$5,031	330	53	603	$223	$182	0.96	-$202	1.28	$1,409	1.55	$2,767
	1992-2010	$3,749	52	21	225	$58	$48	0.34	-$2,776	0.54	-$1,727	0.61	-$1,448
R49 Attic, Air Sealing & New Ducts Package	Pre-1978	$8,792	764	123	1,415	$536	$438	1.33	$3,258	1.62	$5,439	2.08	$9,454
	1978-1991	$8,334	422	78	893	$308	$252	0.81	-$1,796	1.09	$773	1.44	$3,675
	1992-2010	$7,312	78	35	377	$92	$76	0.28	-$5,920	0.42	-$4,276	0.55	-$3,294
Advanced Envelope Package	Pre-1978	$18,659	1,000	178	2,048	$730	$596	0.85	-$3,066	1.12	$2,264	1.29	$5,503
Water Heating Package	All Vintages	$208	0	16	n/a	$31	$28	1.82	$192	n/a	n/a	n/a	n/a

Table 32: CZ 2 - Single Family PV & Battery Cost-Effectiveness Results
36A - (Prescriptive PV System)

Vintage	Measure Cost ($)	Electricity Savings (kWh)	Gas Savings (therm)	GHG Savings (lb CO_2e)	Utility Cost Savings		Customer On-Bill		2019 TDV		2022 TDV	
					Year 1	Avg Annual	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV
Pre-1978	$7,167	3,442	0	216	$896	$707	2.68	$13,295	1.95	$6,844	1.55	$3,946
1978-1991	$7,167	3,442	0	216	$863	$681	2.58	$12,505	1.95	$6,829	1.55	$3,932
1992-2010	$7,167	3,442	0	216	$801	$632	2.39	$11,030	1.95	$6,824	1.55	$3,923

36B - (PV + Battery System)

Vintage	Measure Cost ($)	Electricity Savings (kWh)	Gas Savings (therm)	GHG Savings (lb CO_2e)	Utility Cost Savings		Customer On-Bill		2019 TDV		2022 TDV	
					Year 1	Avg Annual	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV
Pre-1978	$18,539	3,252	0	818	$937	$739	1.11	$2,207	0.79	-$3,814	0.83	-$3,071
1978-1991	$18,539	3,265	0	827	$875	$690	1.04	$733	0.81	-$3,607	0.88	-$2,279
1992-2010	$18,539	3,256	0	836	$823	$649	0.97	-$500	0.82	-$3,299	0.96	-$816

Table 33: CZ 2 - Single Family Equipment Fuel Substitution Cost-Effectiveness Results

Measure	Vintage	Measure Cost ($)	Electricity Savings (kWh)	Gas Savings (therm)	GHG Savings (lb CO_2e)	Utility Cost Savings		Customer On-Bill		2019 TDV		2022 TDV	
						Year 1	Avg Annual	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV
Heat Pump at HVAC Replacement	Pre-1978	$501	-3,567	322	1,601	-$443	-$317	0	-$10,046	0	-$3,874	3.90	$1,454
	1978-1991		-2,772	246	1,188	-$357	-$258	0	-$8,279	0	-$3,189	2.42	$711
	1992-2010		-2,400	211	1,035	-$311	-$225	0	-$7,287	0	-$2,757	2.10	$550
High-Effic. Heat Pump at HVAC Replacement	Pre-1978	$3,749	-2,885	322	1,889	-$227	-$146	0	-$8,438	0.34	-$2,473	1.81	$3,046
	1978-1991		-2,263	246	1,410	-$199	-$133	0	-$8,034	0.21	-$2,960	1.32	$1,193
	1992-2010		-2,009	211	1,206	-$192	-$131	0	-$7,981	0.05	-$3,571	0.99	-$54
Heat Pump at HVAC Replacement + PV	Pre-1978	$7,668	-125	322	1,817	$497	$425	1.51	$4,280	1.40	$3,036	1.71	$5,438
	1978-1991		671	246	1,404	$556	$463	1.64	$5,419	1.48	$3,695	1.61	$4,675
	1992-2010		1,042	211	1,251	$581	$479	1.70	$5,901	1.54	$4,136	1.59	$4,513
HVAC HP Replacement w/ Panel Upgrade + PV	Pre-1978	$10,849	-125	322	1,817	$497	$425	1.06	$708	0.99	-$145	1.21	$2,257
	1978-1991		671	246	1,404	$556	$463	1.15	$1,847	1.05	$514	1.14	$1,494
	1992-2010		1,042	211	1,251	$581	$479	1.19	$2,329	1.09	$955	1.12	$1,332
HPWH at Water Heater Replacement	Pre-1978	$2,594	-1,330	164	1,282	-$132	-$88	0	-$5,516	0	-$3,366	1.42	$1,087
	1978-1991		-1,345	165	1,288	-$144	-$97	0	-$5,813	0	-$3,400	1.45	$1,174
	1992-2010		-1,349	165	1,291	-$147	-$101	0	-$5,911	0	-$3,452	1.41	$1,059
NEEA Tier 3 HPWH at Replacement	Pre-1978	$2,775	-983	163	1,391	-$23	-$1	0	-$3,126	0.34	-$1,844	1.89	$2,465
	1978-1991		-1,000	164	1,397	-$35	-$11	0	-$3,430	0.33	-$1,850	1.89	$2,473
	1992-2010		-1,010	165	1,400	-$40	-$16	0	-$3,556	0.32	-$1,876	1.87	$2,416
HPWH at Water Heater Replacement + PV	Pre-1978	$9,761	2,112	164	1,498	$859	$695	1.93	$10,021	1.38	$3,677	1.53	$5,221
	1978-1991		2,098	165	1,504	$814	$659	1.83	$8,942	1.37	$3,628	1.54	$5,295
	1992-2010		2,093	165	1,507	$778	$630	1.75	$8,079	1.37	$3,573	1.53	$5,174
HPWH Replacement w/ Panel Upgrade + PV	Pre-1978	$12,942	2,112	164	1,498	$859	$695	1.45	$6,449	1.04	$496	1.16	$2,040
	1978-1991		2,098	165	1,504	$814	$659	1.37	$5,370	1.03	$447	1.16	$2,114
	1992-2010		2,093	165	1,507	$778	$630	1.31	$4,507	1.03	$392	1.15	$1,993

Measure	Vintage	Measure Cost ($)	Electricity Savings (kWh)	Gas Savings (therm)	GHG Savings (lb CO_2e)	Utility Cost Savings		Customer On-Bill		2019 TDV		2022 TDV	
						Year 1	Avg Annual	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio	NPV
PV + Electric Ready Pre-Wire	Pre-1978	$11,258	3,442	0	216	$896	$707	1.70	$8,701	1.24	$2,753	0.99	-$145
	1978-1991		3,442	0	216	$863	$681	1.63	$7,911	1.24	$2,738	0.99	-$159
	1992-2010		3,442	0	216	$801	$632	1.51	$6,436	1.24	$2,733	0.99	-$168

8.5 Appendix E – Details on Energy Performance Equivalency

Jurisdictions adopting a retrofit reach code that want flexibility in implementation can apply all or portions of the following approach.

1. Identify the appropriate home vintage based on one of the following two methods.
    a. Year of construction.
    b. Appraisal of existing conditions of home using the points menu for a pre-1978 home (Table 114) and the relevant climate zone. The sum of the eligible points is compared to the energy performance value for each vintage (Table 17). If the sum is greater than the threshold for any vintage, the requirements for that vintage may be applied in place of those based on the year of construction. Verification should be conducted by a third party such as a HERS Rater or the building department.
2. Identify the relevant reach code requirements per the ordinance.
3. Demonstrate compliance with the reach code in one of the following ways.
    a. Install the prescriptive reach code requirements.
    b. Install individual measures or a package of measures that result in equivalent energy performance as the prescriptive reach code requirement.
        i. Determine the value for the reach code requirement. For individual measures refer to Table 114, Table 115, or Table 116. For packages of measures refer to Table 117. Use the values for the appropriate vintage home determined in Step 1.
        ii. Determine the value for the proposed upgrades using Table 114, Table 115, or Table 116 for the appropriate vintage home determined in Step 1.
        iii. If the sum of the value for the proposed upgrades is greater than or equal to the value of the reach code requirement then the proposed upgrades are an acceptable alternative.

Table 34: Energy Performance Equivalency by Measure for the Pre-1978 Vintage Home

Component	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Walls																
R-11 to R-13	5.4	3.1	2.4	2.1	2.3	1.0	0.7	0.9	1.2	1.6	3.4	2.9	2.4	3.3	1.3	5.9
R-19	7.7	4.5	3.5	3.0	3.4	1.4	1.0	1.4	1.8	2.4	4.9	4.2	3.6	4.7	1.9	8.3
Ceiling																
R-19	1.6	1.3	0.9	1.1	0.8	0.8	0.7	0.6	0.7	0.9	1.6	1.4	1.1	1.5	0.8	2.3
R-30	2.5	2.0	1.5	1.7	1.3	1.2	1.0	1.0	1.2	1.4	2.5	2.3	1.9	2.3	1.2	3.6
R-38	2.8	2.3	1.7	1.9	1.6	1.3	1.1	1.1	1.4	1.5	2.9	2.6	2.1	2.7	1.3	4.2
>R-38	3.2	2.6	1.9	2.2	1.8	1.4	1.2	1.3	1.5	1.7	3.2	2.9	2.4	2.9	1.3	4.6
Roof																
Cool roof	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.3	0.0
Floors																
R-19+ insulation in raised floor	10.9	4.1	4.7	2.8	4.0	1.0	0.5	0.5	1.0	1.7	5.1	3.5	2.8	5.2	1.4	10.0
Windows																
Double non-metal	2.6	1.6	1.0	1.1	0.8	0.4	0.2	0.4	0.6	0.8	2.3	1.8	1.5	1.8	1.0	3.8
<=0.32 U-factor	4.3	1.8	1.6	1.3	1.2	0.4	0.2	0.5	0.7	0.9	3.2	2.5	2.3	1.9	1.8	6.4
Infiltration																
<=10 ACH50	1.8	0.9	0.8	0.6	0.7	0.3	0.1	0.2	0.3	0.5	1.0	0.8	0.7	1.1	0.2	1.8
<=7 ACH50	3.0	1.5	1.2	1.0	1.2	0.4	0.3	0.3	0.5	0.8	1.7	1.3	1.1	1.7	0.4	2.9
<=5 ACH50	3.7	1.9	1.6	1.3	1.6	0.6	0.3	0.4	0.6	0.9	2.1	1.7	1.4	2.1	0.5	3.6
Duct Leakage																
<=15% leakage	3.7	1.9	1.3	1.3	1.2	0.5	0.3	0.6	0.8	1.1	2.5	2.1	1.9	2.2	1.3	5.1
<=10% leakage	4.9	2.5	1.7	1.7	1.5	0.6	0.4	0.8	1.1	1.4	3.2	2.7	2.5	3.0	1.7	6.7
R-6+ & <=5% leakage (or ductless)	7.7	4.1	2.9	2.9	2.6	1.1	0.9	1.4	1.9	2.4	5.3	4.5	4.2	4.8	2.9	10.4
Heating																
80% AFUE	1.0	0.5	0.4	0.3	0.3	0.1	0.1	0.1	0.1	0.2	0.5	0.4	0.3	0.5	0.0	1.3
90% AFUE	5.6	2.6	1.9	1.5	1.7	0.5	0.3	0.4	0.7	1.0	2.6	2.3	1.7	2.4	0.2	6.9
8.2 HSPF	21.9	8.7	6.6	5.0	4.4	1.7	1.1	1.3	2.1	2.7	8.8	7.8	5.4	6.1	0.6	23.7
9 HSPF	23.0	9.3	7.3	5.5	5.6	1.8	1.3	1.4	2.2	2.8	9.2	8.3	5.7	6.8	0.6	25.9

Component	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**	**CZ9**	**CZ10**	**CZ11**	**CZ12**	**CZ13**	**CZ14**	**CZ15**	**CZ16**
Cooling																
13 SEER	0.0	0.3	0.0	0.6	0.0	0.3	0.4	0.8	0.9	1.1	1.5	0.9	1.9	1.2	3.0	0.4
14 SEER	0.0	0.4	0.0	0.8	0.0	0.4	0.4	1.2	1.3	1.6	2.2	1.4	2.9	1.8	4.5	0.5
16+ SEER	0.0	0.5	0.1	1.0	0.0	0.5	0.6	1.5	1.6	2.0	2.8	1.7	3.5	2.2	5.6	0.6
Water Heater																
Tankless	3.1	3.0	3.0	3.0	3.0	2.9	2.9	2.9	2.9	2.9	2.9	3.0	2.9	2.9	2.7	3.1
Condensing water heater	4.1	3.9	3.9	3.8	3.9	3.7	3.7	3.6	3.6	3.6	3.7	3.8	3.7	3.7	3.3	4.0
HPWH	7.4	7.3	7.4	7.2	7.4	7.1	7.1	6.9	7.0	6.9	6.9	7.1	6.9	6.7	6.1	6.9
NEEA HPWH	8.0	7.9	7.9	7.7	8.0	7.5	7.5	7.3	7.4	7.4	7.3	7.6	7.3	7.2	6.4	7.4
PV+Battery																
NC PV	1.1	1.1	1.2	1.2	1.3	1.6	1.5	1.6	1.7	1.7	1.5	1.2	1.6	1.9	3.0	1.3
10kWh Battery	3.0	3.1	3.3	3.0	3.4	3.5	3.0	2.9	3.2	3.1	3.2	3.2	3.1	3.3	2.6	3.4

Table 35: Energy Performance Equivalency by Measure for the 1978-1991 Vintage Home

Component	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Walls																
R-11 to R-13	0.8	0.4	0.3	0.3	0.3	0.1	0.1	0.1	0.2	0.2	0.4	0.4	0.3	0.4	0.2	0.8
R-19	3.0	1.8	1.4	1.2	1.3	0.6	0.4	0.6	0.7	0.9	1.9	1.7	1.5	1.9	0.8	3.2
Ceiling																
R-19	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
R-30	0.9	0.8	0.6	0.7	0.5	0.3	0.3	0.3	0.4	0.5	0.9	0.9	0.7	0.8	0.5	1.4
R-38	1.3	1.1	0.8	0.9	0.7	0.5	0.4	0.5	0.6	0.6	1.2	1.2	1.0	1.2	0.6	1.9
>R-38	1.6	1.3	1.0	1.2	0.9	0.6	0.5	0.6	0.8	0.8	1.5	1.5	1.2	1.4	0.7	2.3
Roof																
Cool roof	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.0	0.1	0.2	0.0	0.3	0.0
Floors																
R-19+ insulation in raised floor	4.0	1.5	1.8	1.1	1.5	0.3	0.2	0.2	0.4	0.6	1.8	1.3	1.0	1.9	0.6	3.7
Windows																
Double non-metal	2.2	1.4	0.9	0.9	0.7	0.3	0.2	0.3	0.5	0.6	1.6	1.4	1.2	1.4	0.7	2.8
<=0.32 U-factor	3.8	1.4	1.5	1.1	1.1	0.4	0.3	0.5	0.7	0.8	2.5	2.1	2.0	1.4	1.5	5.3
Infiltration																
<=10 ACH50	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
<=7 ACH50	1.1	0.6	0.5	0.4	0.5	0.2	0.1	0.1	0.2	0.3	0.6	0.5	0.4	0.6	0.2	1.1
<=5 ACH50	1.8	1.0	0.8	0.7	0.8	0.3	0.2	0.2	0.3	0.4	1.0	0.9	0.8	1.1	0.3	1.8
Duct Leakage																
<=15% leakage	2.0	1.0	0.6	0.6	0.6	0.2	0.1	0.3	0.4	0.5	1.2	1.1	1.1	1.1	0.9	2.9
<=10% leakage	3.0	1.4	0.9	0.9	0.8	0.3	0.2	0.5	0.6	0.8	1.9	1.6	1.6	1.7	1.3	4.2
R-6+ & <=5% leakage (or ductless)	5.5	2.9	2.0	2.1	1.8	0.7	0.5	1.0	1.4	1.7	3.8	3.3	3.3	3.4	2.4	7.6
Heating																
80% AFUE	0.8	0.4	0.3	0.2	0.2	0.1	0.0	0.0	0.1	0.1	0.4	0.3	0.2	0.3	0.0	1.0
90% AFUE	4.3	1.9	1.4	1.1	1.2	0.3	0.2	0.3	0.4	0.7	1.9	1.7	1.2	1.7	0.1	5.4
8.2 HSPF	17.3	6.5	4.7	3.5	2.7	0.9	0.6	0.8	1.3	1.8	6.5	5.8	4.0	4.2	0.3	18.8
9 HSPF	18.6	7.1	5.3	4.0	4.0	1.1	0.7	0.8	1.4	1.9	6.9	6.3	4.3	4.9	0.2	21.2

Component	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Cooling																
13 SEER	0.0	0.2	0.0	0.5	0.0	0.3	0.3	0.7	0.8	0.9	1.3	0.8	1.7	1.1	2.7	0.3
14 SEER	0.0	0.3	0.0	0.6	0.0	0.3	0.3	1.0	1.1	1.3	1.9	1.2	2.4	1.6	4.0	0.4
16+ SEER	0.0	0.3	0.0	0.8	0.0	0.4	0.5	1.3	1.4	1.7	2.3	1.4	3.0	1.9	4.9	0.5
Water Heater																
Tankless	3.1	3.0	3.0	3.0	3.0	2.9	2.9	2.9	2.9	2.9	2.9	3.0	2.9	2.9	2.7	3.1
Condensing water heater	4.1	3.9	3.9	3.8	3.9	3.7	3.7	3.6	3.6	3.6	3.7	3.8	3.7	3.7	3.3	4.0
HPWH	7.4	7.4	7.4	7.3	7.4	7.1	7.1	7.0	7.0	6.9	6.9	7.2	6.9	6.7	6.2	6.9
NEEA HPWH	8.1	7.9	8.0	7.8	8.0	7.5	7.5	7.4	7.4	7.3	7.4	7.7	7.3	7.2	6.4	7.3
PV+Battery																
NC PV	1.1	1.1	1.2	1.2	1.3	1.6	1.5	1.6	1.7	1.7	1.5	1.2	1.6	1.9	3.0	1.3
10kWh Battery	3.0	3.1	3.3	3.1	3.4	3.6	3.1	3.1	3.3	3.2	3.3	3.3	3.3	3.4	2.9	3.5

Table 36: Energy Performance Equivalency by Measure for the 1992-2010 Vintage Home

Component	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Walls																
R-11 to R-13	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
R-19	2.0	1.2	0.9	0.8	0.9	0.4	0.3	0.4	0.5	0.6	1.3	1.1	1.0	1.3	0.4	2.2
Ceiling																
R-19	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
R-30	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
R-38	0.4	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.2	0.3	0.1	0.5
>R-38	0.7	0.4	0.3	0.4	0.3	0.2	0.2	0.2	0.3	0.3	0.6	0.6	0.4	0.6	0.2	1.0
Roof																
Cool roof	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.0
Floors																
R-19+ insulation in raised floor	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Windows																
Double non-metal	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
<=0.32 U-factor	3.6	1.1	1.7	0.8	1.7	0.3	0.2	0.3	0.5	0.6	1.4	1.3	1.1	1.1	0.6	2.5
Infiltration																
<=10 ACH50	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
<=7 ACH50	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
<=5 ACH50	0.7	0.4	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.2	0.4	0.3	0.3	0.4	0.1	0.7
Duct Leakage																
<=15% leakage	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
<=10% leakage	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
R-6+ & <=5% leakage (or ductless)	1.5	1.1	0.7	0.7	0.7	0.2	0.2	0.3	0.5	0.6	1.4	1.1	1.2	1.3	0.8	2.3
Heating																
80% AFUE	0.4	0.3	0.2	0.2	0.2	0.0	0.0	0.0	0.1	0.1	0.3	0.3	0.2	0.3	0.0	0.6
90% AFUE	2.3	1.5	1.1	0.8	1.0	0.2	0.1	0.2	0.3	0.5	1.4	1.3	0.9	1.3	0.1	3.2
8.2 HSPF	9.4	5.7	4.1	3.0	2.9	0.8	0.5	0.6	1.1	1.5	5.4	4.9	3.3	3.8	0.2	11.5
9 HSPF	10.7	6.5	4.9	3.6	3.9	0.9	0.6	0.7	1.3	1.8	5.9	5.5	3.7	4.5	0.2	13.5

Component	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Cooling																
13 SEER	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
14 SEER	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.3	0.3	0.3	0.4	0.2	0.6	0.4	1.1	0.1
16+ SEER	0.0	0.1	0.0	0.2	0.0	0.1	0.1	0.4	0.4	0.6	0.8	0.4	1.1	0.7	1.8	0.2
Water Heater																
Tankless	3.1	3.0	3.0	3.0	3.0	2.9	2.9	2.9	2.9	2.9	2.9	3.0	2.9	2.9	2.7	3.1
Condensing water heater	4.1	3.9	3.9	3.8	3.9	3.7	3.7	3.6	3.6	3.6	3.7	3.8	3.7	3.7	3.3	4.0
HPWH	7.5	7.4	7.4	7.2	7.4	7.1	7.1	7.0	7.0	6.9	6.9	7.2	6.9	6.7	6.1	6.8
NEEA HPWH	8.2	7.9	8.0	7.8	8.0	7.5	7.5	7.4	7.4	7.4	7.4	7.7	7.4	7.2	6.4	7.3
PV+Battery																
NC PV	1.1	1.1	1.2	1.2	1.3	1.6	1.5	1.6	1.7	1.7	1.5	1.2	1.6	1.9	3.0	1.3
5kWh Battery	2.9	3.2	3.3	3.3	3.4	3.9	3.3	3.4	3.7	3.6	3.5	3.4	3.6	3.7	3.5	3.4

Table 37: Energy Performance Equivalency for Packages for all Vintages – Climate Zone 2

Component Package	Pre-1978	1978-1991	1992-2010
R-49 & Air Sealing	3.6	1.9	0.8
R-49 & Duct Sealing	4.9	2.6	0.8
R-49, Air & Duct Sealing	5.8	3.2	1.2
R-49, Air Sealing & New Ducts	7.5	4.7	2
Advanced Envelope	10.8	na	na