DOCKETED	
Docket Number:	18-IEPR-09
Project Title:	Decarbonizing Buildings
TN #:	224761
Document Title:	California Building Industry Association Comments - Impacts of Residential Appliance Electrification
Description:	N/A
Filer:	System
Organization:	California Building Industry Association/Robert Raymer
Submitter Role:	Public
Submission Date:	9/20/2018 11:19:56 AM
Docketed Date:	9/20/2018

Comment Received From: Robert Raymer
Submitted On: 9/20/2018
Docket Number: 18-IEPR-09

Impacts of Residential Appliance Electrification

Additional submitted attachment is included below.

California Building Industry Association

1215 K Street, Suite 1200 • Sacramento, CA 95814 • (916) 443-7933 • fax (916) 443-1960

Date: September 20, 2018

RE: Navigant Study: Impacts of Residential Appliance Electrification

The California Building Industry Association (CBIA) commissioned Navigant to summarize the potential cost impact of residential appliance electrification in new and existing homes throughout the state. This initial study intends to support future stakeholder discussion on the issue of appliance electrification. This analysis relies on several general assumptions about the composition of California's housing stock and may not reflect the electrification costs for individual properties.

One thing is clear: **There is still a great deal of additional research needed.** The following list highlights some factors that should be explored further in future research:

Electricity Grid Impacts – Future research should examine the impacts that appliance electrification initiatives could have on local and statewide electrical grids, residential electric rates, and utility line-extension and development costs for builders and the resulting impact on consumers. Also, there is the interactive effect of:

- Mandatory installation of solar PV in new residential construction (starting 1/1/20),
- A considerable increase in EV-charging stations in both new and existing neighborhoods, and
- The emerging electrification efforts in both the new and existing building stock

It should be noted that, because of the passage of AB 3232 (Friedman), the CEC and others will be studying the interactive effect of these three issues during the next few years.

Utility Rates – Additional research is necessary to understand the impacts appliance electrification could have in future years for natural gas and electricity rates, including rate structures, stranded assets, and other issues. For example, this study did not include an analysis of the Time-of-Use (TOU) electricity rate impact on consumer utility bills and the resulting impact on consumer behavior.

Solar + Storage - The combined impact of solar PV and energy storage on a home's annual electric utility bill (which is anticipated to be substantial) and the unclear impact this will have on future electrical utility rates for those with (and without) solar + storage.

Gas Infrastructure Costs – This analysis did not consider the possible cost savings in new construction from not installing gas lines, meters, and running gas pipes throughout the dwelling. Future research should evaluate the possible gas infrastructure cost savings for new construction.

Electric Utility Line-Extension Allowance – This analysis does not consider how electrification, rooftop solar PV systems, or other trends would affect the payback of electric utility line-extension allowances to builders. Stakeholders should study how decreased grid-supplied electricity consumption in new homes could negatively affect utility payback of electric utility line-extension allowances to builders.

Electric HPWH Installed Costs – Available electric HPWH purchase and installation cost estimates vary widely based on underlying assumptions, and this analysis illustrates the sensitivity of the results to the HPWH cost assumptions. Stakeholders should conduct further research to develop a common set of assumptions for HPWH purchase and installation costs for new and existing homes in California.

Homeowner Preferences – Stakeholders should study the impacts that appliance electrification initiatives would have on homeowner preferences, satisfaction, resale values, and other attributes for the California housing market.

Electrical Upgrade Costs for Existing Homes – Limited information exists on the average electrical upgrade costs for existing homes, and anecdotal estimates range widely based on the type of electrical appliance being considered (e.g., electric HPWH, solar PV system, electric vehicle charger), the age of the building, contractor prices, etc. Stakeholders should conduct additional research to quantify the cost to upgrade electrical infrastructure in existing California homes, and the proportion of homes requiring different levels of upgrades.

Renewable Gas – Appliances using natural gas could have lower GHG emissions in future years if the California gas supply included a percentage of renewable gas. Additional research is necessary to analyze the impacts on the residential sector.

NAVIGANT

Impacts of Residential Appliance Electrification

Final Report

Prepared for:
California Building Industry Association

Submitted by:
Navigant Consulting, Inc.
1375 Walnut Street
Suite 100
Boulder, CO 80302

213.670.2724
navigant.com

Reference No.: 202878
August 31, 2018

TABLE OF CONTENTS

Disclaimer ii
List of Acronymns iii
Executive Summary iv
1. Project Description 1
1.1 Home Designs 2
1.2 Natural Gas and Electric Technologies 4
2. Summary of Results 9
2.1 GHG Emissions Savings 9
2.2 Cost for Electric Appliances and Upgrades 11
2.3 Annual Energy Bill Impact 13
2.4 Homeowner Cost Comparison 16
2.5 Additional Factors for Appliance Electrification Discussion 18
3. Conclusions 20
Appendix A. Home Designs and Parameters 22
A.1 Model Building Configurations 22
A.2 Appliance Assumptions 23
A.3 Energy Cost Assumptions 28
A.4 Emissions Factor Assumptions 29
Appendix B. Detailed Modeling Results with Base HPWH Cost Estimate 32
B.1 GHG Emissions Savings 33
B.2 Costs for Electric Appliances and Upgrades (Assuming Electrical Infrastructure Costs are Required for Existing Homes) 35
B.3 Costs for Electric Appliances and Upgrades (Assuming Electrical Infrastructure Costs are Not Required for Existing Homes) 37
B.4 Annual Energy Bill Impact 39
B.5 Homeowner Cost Comparison (Assuming Electrical Infrastructure Costs are Required) 42
B.6 Homeowner Cost Comparison (Assuming Electrical Infrastructure Costs are Not Required) 45
Appendix C. Detailed Modeling Results with Low HPWH Cost Estimate 48
C.1 GHG Emissions Savings 49
C.2 Costs for Electric Appliances and Upgrades (Assuming Electrical Infrastructure Costs are Required for Existing Homes) 51
C.3 Costs for Electric Appliances and Upgrades (Assuming Electrical Infrastructure Costs are Not Required for Existing Homes) 53
C.4 Annual Energy Bill Impact 55
C.5 Homeowner Cost Comparison (Assuming Electrical Infrastructure Costs are Required) 58
C.6 Homeowner Cost Comparison (Assuming Electrical Infrastructure Costs are Not Required) 61

DISCLAIMER

Copyright

Disclaimer

This report ("report") was prepared for CBIA on terms specifically limiting the liability of Navigant Consulting, Inc. (Navigant), and is not to be distributed without Navigant's prior written consent. Navigant's conclusions are the results of the exercise of its reasonable professional judgment. By the reader's acceptance of this report, you hereby agree and acknowledge you are bound by the disclaimers and/or limitations on liability otherwise set forth in the report. Navigant does not make any representations or warranties of any kind with respect to (i) the accuracy or completeness of the information contained in the report, (ii) the presence or absence of any errors or omissions contained in the report, (iii) any work performed by Navigant in connection with or using the report, or (iv) any conclusions reached by Navigant as a result of the report. Any use of or reliance on the report, or decisions to be made based on it, are the reader's responsibility. Navigant accepts no duty of care or liability of any kind whatsoever to you, and all parties waive and release Navigant from all claims, liabilities and damages, if any, suffered as a result of decisions made, or not made, or actions taken, or not taken, based on this report.

LIST OF ACRONYMNS

AC	Air Conditioning
ACH	Air Changes per Hour
ASHP	Air Source Heat Pump
Btu	British Thermal Unit
CBECC-Res	Residential California Building Energy Code Compliance Modeling Software
CBIA	California Building Industry Association
CEC	California Energy Commission
CPUC	California Public Utilities Commission
CO_2	Carbon Dioxide
CZ	Climate Zone
EF	Energy Factor
eGRID	Emissions & Generation Resource Integrated Database
EIA	U.S. Energy Information Administration
EPA	U.S. Environmental Protection Agency
GHG	Greenhouse Gas
HPWH	Heat Pump Water Heater
HSPF	Heating Seasonal Performance Factor
IEPR	Integrated Energy Policy Report
IOU	Investor-owned Utility
IRP	Integrated Resource Plan
kW	Kilowatt
kWh	Kilowatt-hour
LADWP	Los Angeles Department of Water and Power
LAO	Legislative Analyst's Office
mtCO2e	Metric Tons of Carbon Dioxide Equivalent
MWh	Megawatt-hour
NREL	National Renewable Energy Laboratory
O.C.	On Center
Pa	Pascals
PG&E	Pacific Gas and Electric
PV	Photovoltaic
RASS	Residential Appliance Saturation Study
RPS	Renewable Portfolio Standard
SCE	Southern California Edison
SEER	Seasonal Energy Efficiency Ratio
SF	Square Foot
SoCalGas	Southern California Gas Company
UC	University of California

EXECUTIVE SUMMARY

The California Building Industry Association (CBIA) commissioned Navigant to summarize the potential impact of residential appliance electrification for homeowners[1] throughout the state to support discussions with California stakeholders. This project analyzes representative existing and new construction homes across several California regions and estimates the greenhouse gas (GHG) emissions reductions, electrification cost, and annual energy bills. Navigant estimated gas and electricity consumption using the compiled data from residential building models within the Residential California Building Energy Code Compliance (CBECC-Res) 2019 modeling software, and estimated electricity GHG emissions factors, utility rates, appliance purchase and installation costs, and electricity infrastructure upgrade costs from available resources.

The following section summarizes the results of this investigation into the impacts associated with electrification of water heating, space heating, cooking, and clothes drying in homes in several California locations. This analysis includes single-family new homes, single-family and multi-family existing homes, six home locations, and appliance and energy costs for 2020 and 2030. This analysis analyzes incremental costs for gas and electric appliances assuming complete appliance replacement at end of life (e.g., normal replacement for existing homes) or initial installation (e.g., new homes). The GHG emissions and cost results are presented at a whole-home level, accounting for all end-uses within the home, including those that do not use natural gas (e.g., space cooling, lighting, plug loads, etc.). The results are highly sensitive to underlying assumptions on equipment efficiency and costs, infrastructure needs and costs, electricity rates, natural gas rates, electric utility rebates, and other factors.

Navigant's scope of work was to conduct an energy bill analysis that reflects annual average electricity rates. Navigant did not analyze time-of-use nor multi-tiered utility rate structures that have higher prices during peak periods. This analysis also does not evaluate cost impacts for natural gas and electricity line extensions and metering, grid infrastructure upgrades, builder development costs, nor payback of line allowances to builders. Appliance rebates are not factored into this analysis due to the variability in incentive levels by region and uncertainty of incentive availability in future years. Large incentives for electric appliances can significantly shift the cost comparison of natural gas and electric appliances from the perspectives of the customer, homebuilder, and building owner.[2]

Key Findings

- **Cost for Electric Appliances and Upgrades** – Most electric appliances have similar or lower costs than natural gas appliances, but current electric HPWHs have a cost premium over a baseline gas water heater.[3] The estimated total installed cost increase in 2020 for electric appliances (water heating, space heating, cooking, and clothes drying) is $243 to $2,674 for an existing home and $185 to $418 for a new single-family home, assuming a range of HPWH cost estimates. Existing homes may require electrical infrastructure upgrades (e.g., panel, branch circuit, utility service upgrade fees) to accommodate an electric HPWH. If comprehensive

[1] This report discusses impacts for homeowners, meaning owner-occupied homes, but leased single- and multi-family homes would encounter similar decisions. They key difference is that costs would be split between landlord and tenant, with the landlord responsible for appliance purchase and any applicable infrastructure upgrade, and the tenant responsible for energy bills.

[2] Currently, California electric utilities offer an energy efficiency rebate for HPWHs of $200 to $3,000, which decreases the appliance purchase cost where applicable.

[3] For this analysis, Navigant selected an electric heat pump water heater (HPWH) the baseline electric option rather than an electric resistance model. The electrification discussions among stakeholder in the state generally assume that the HPWH would be used.

electrical infrastructure upgrades are required, the analysis estimates that an existing home converting from natural gas to electric appliances may experience total cost increases of approximately $4,642 to $7,345 in 2020 and $5,044 to $8,339 in 2030, including incremental appliance and infrastructure upgrade costs. However, some existing homes may have sufficient electrical infrastructure and would require minimal electrical upgrade costs and in this situation the electrification cost increases are estimated to be approximately $243 to $2,674 in 2020 and -$319 to $2,645 in 2030. The incremental combined costs for an all-electric new home are estimated to be approximately $235 to $468 in 2020 or -$290 to -$6 in 2030, mostly due to electric HPWH cost.

- **Annual Energy Bill Impact** – Based on the current electric technologies (e.g., heat pumps for space and water heating) and January 2017 IEPR rate projections[4], the analysis estimates that appliance electrification in 2020 may increase a homeowner's annual energy bill by approximately $50 to $387 per year across all home types in Bakersfield, Riverside, Compton, Oakland, and San Diego. In 2030, appliance electrification may increase a homeowner's annual energy bill by approximately $32 to $338 per year using IEPR 2030 rates and $143 to $746 per year using higher electricity rates[5] across all home types in Bakersfield, Riverside, Compton, Oakland, and San Diego. Homeowners in Sacramento across all home types would experience bill savings of approximately $14 to $91 per year in 2020 due to lower electricity rates than in other regions.

- **Homeowner Cost Comparison** – If the appliance and upgrade costs are spread over the 15-year life of many appliances, California's existing single-family homeowners would experience a combined annual cost increase of $236 to $1,302 if infrastructure upgrades are required, and -$119 to $922 if infrastructure upgrades are not required for existing homes (range includes 2020 and 2030 scenarios and HPWH cost estimates). The estimated range of -$119 to $1,302 annual cost increase represents up to 1-2% of median household income for California customers.

- **GHG Emissions Savings** – Replacing major natural gas appliances with electric space and water heating, cooking, and laundry appliances can reduce an existing home's total GHG emissions by 35-66% in 2020 and 42-72% in 2030, and 55-60% in 2020 and 63-67% for new homes. In 2015, the residential sector accounted for approximately 6% of California's total GHG emissions of 440.4 million metric tons of CO2e.[6] The existing home savings would account for approximately 2% of California's statewide GHG emissions in 2020. GHG emissions savings from appliance electrification will increase in future years as the electric Renewable Portfolio Standard (RPS) hits 50% and beyond.

---

[4] California Energy Commission. 2017. "Mid Case Final Baseline Demand Forecast - 2016 California Energy Demand Electricity Forecast Update." January 2017. Available at: http://www.energy.ca.gov/2016_energypolicy/documents/2016-12-08_workshop/mid_demand_case.php

[5] To understand the impacts that increased grid infrastructure requirements could have on electricity rates, the team analyzed a higher electricity rate scenario to bookend the IEPR rate scenario. This high uncertainty projection is meant to capture an upper case scenario for future electricity rates based on other rate projections in the region, including Los Angeles Department of Water and Power's (LADWP's) 2016 Final Integrated Resource Plan (IRP), Southern California Edison (SCE) General Rate Case for 2018, and University of California (UC) Berkeley/Lawrence Berkeley National Laboratory (Berkeley Lab) analysis on residential water heating electrification. There is high uncertainty in projecting future electricity rates, and the higher annual growth rate provides sensitivity over the IEPR values of an approximately 1% annual growth rate. Appendix A.3 contains assumptions for energy costs.

[6] California Air Resources Board. 2017. "California Greenhouse Gas Emission Inventory - 2017 Edition." June 2017. Available at: https://www.arb.ca.gov/cc/inventory/data/data.htm

1. PROJECT DESCRIPTION

To support discussions with California stakeholders, the California Building Industry Association (CBIA) commissioned Navigant to provide an objective analysis of the potential impact of residential appliance electrification for homeowners[7] throughout the state. This project analyzed representative existing and new construction homes within several California regions[8] and estimated the greenhouse gas (GHG) emissions, appliance cost, electrical infrastructure upgrade cost, and annual energy cost. Table 1-1 highlights the key parameters in the project. Navigant leveraged the prototypical residential building models within the Residential California Building Energy Code Compliance (CBECC-Res) 2019 modeling software[9] and adjusted key parameters for existing and new construction building characteristics (e.g., baseline appliance selection, window U-factor, attic and wall insulation R-values). The energy consumption results were compared to utility and climate zone averages from the Residential Appliance Saturation Study (RASS) for existing homes to verify the simulated consumption values represent existing home characteristics.[10]

Table 1-1. Key Parameters of Analysis

Parameter	Scenarios
Location (Climate Zone, Utility)	• Bakersfield (CZ 13) • Riverside (CZ 10) • Compton (CZ 8) • Oakland (CZ 3) • Sacramento (CZ 12) • San Diego (CZ 7)
Home Design	• Single-family existing homes o 2,100 SF, 1 story o 2,700 SF, 2 story with and without 3 kW solar PV system • Single-family new homes • Multi-family existing home
Timeframe	• Near-term appliance costs and utility rates (2020) • 2030 appliance costs and utility rates

Source: Navigant analysis.

[7] This report discusses impacts for homeowners, meaning owner-occupied homes, but leased single- and multi-family homes would encounter similar decisions. They key difference is that costs would be split between landlord and tenant, with the landlord responsible for appliance purchase and any applicable infrastructure upgrade, and the tenant responsible for energy bills.

[8] The selection of climate zones / location is intended to provide a range of heating and cooling loads, as well as gas and electric utility rates. The analysis results reflect the climate zone and the listed city is meant to locate the general region within the state.

[9] CBECC-Res 2019. CBECC-Res Compliance Software Project. Managed by Bruce Wilcox for the California Energy Commission. Available at: http://www.bwilcox.com/BEES/BEES.html.

[10] DNV-GL. 2010 "2009 California Statewide Residential Appliance Saturation Study." Saturation Tables. Available at: https://webtools.dnvgl.com/RASS2009/Default.aspx (accessed March 2018).

Assumptions for building parameters, appliance costs, electrical infrastructure upgrade costs, GHG emissions factors, and utility rates are detailed in Appendix A. Based on the timeline and goals for the project, Navigant made several simplifying assumptions to focus the analysis, particularly regarding utility rate structures. Navigant used the CBECC-Res modeling software, which provides annual energy consumption data, but cannot directly analyze the time-of-use or multi-tiered utility rate structures. In addition, homes with solar PV systems may experience monthly fees or minimum charges in future years as part of utility tariffs. With these limitations, this analysis assumes average annual electricity and natural gas rates from the 2017 California Energy Commission Integrated Energy Policy Report[11] (CEC IEPR) for 2020 and 2030.

Navigant recognizes that these rates may represent a lower end of possible electricity prices, as the IEPR forecasted rates may not reflect possible distribution, transmission, and generation needs in alternative scenarios. Navigant analyzed a higher electricity rate scenario to bookend the IEPR rate scenario. The team applied an annual growth rate of 3.25% to the 2020 IEPR rates based on projections within LADWP's 2016 Final Integrated Resource Plan (IRP)[12] that represent the stacked impacts of increased renewable portfolio standard (RPS), energy storage, local solar, system reliability, electrification impacts, as well as other factors which may be unique to LADWP. The SCE General Rate Case for 2018[13] projects increased rates of 2.7% in 2018, 4.2% in 2019, and 5.2% in 2020 as part of the distribution infrastructure upgrade planning.[14] A recent UC Berkeley/Berkeley Lab analysis on residential water heating electrification uses electricity growth rates of 2%-5% for future projections (2% in base and 5% as upper bound).[15] There is high uncertainty in projecting future electricity rates, and the higher annual growth rate provides sensitivity over the IEPR values of an approximately 1% annual growth rate. These higher electricity rate projections may or may not capture the full costs of distribution system upgrades that may be incurred with full electrification.

Section 2.5 discusses additional factors affecting appliance electrification and areas for future research.

1.1 Home Designs

Navigant analyzed the GHG emissions reductions, and energy cost, and appliance cost impacts for 4 primary home designs. Table 1-2 provides a high-level overview of differentiating factors, and Appendix A provides the full details used in the CBECC-Res models.

[11] California Energy Commission. "Mid Case Final Baseline Demand Forecast - 2016 California Energy Demand Electricity Forecast Update." January 2017. Available at: http://www.energy.ca.gov/2016_energypolicy/documents/2016-12-08_workshop/mid_demand_case.php

[12] LADWP. 2016. "2016 Final Power Integrated Resource Plan." Available at https://www.ladwp.com/ladwp/faces/wcnav_externalId/a-p-doc?_adf.ctrl-state=iirytk0lc_4&_afrLoop=35208544433395

[13] Edison International. 2016. "2018 SCE General Rate Case Overview." September 1, 2016. Available at: https://www.edison.com/content/dam/eix/documents/investors/sec-filings-financials/2018-SCE-general-rate-case-overview.pdf

[14] The SCE General Rate Case only covers the years 2018-2020 and does not project across the full 2018-2030 range. Historically, there are instances of large increases in several years, followed by several years of low or zero annual rate increases.

[15] Raghavan et al. 2017. "Scenarios to Decarbonize Residential Water Heating in California." *Energy Policy, 109*. 441-451. Available at: https://rael.berkeley.edu/publication/scenarios-to-decarbonize-residential-water-heating-in-california/

Table 1-2. Home Designs

Home Design	Vintage	Single-family or Multi-family	Size	Solar
Home A	Existing	Single-family	One-story 2,100 SF	-
Home B w/o Solar PV	Existing	Single-family	Two-story 2,700 SF	-
Home B w/ Solar PV	Existing	Single-family	Two-story 2,700 SF	3 kW
Home C (solar)	New	Single-family	Two-story 2,700 SF	Sized to Title 24-2019 requirements
Home D	Existing	Multi-family (8 units)	Two-story 6,960 SF	-

Navigant analyzed two variations of Home B – with and without a 3 kilowatt (kW) solar photovoltaic (PV) system. Solar PV systems connect to the home's electrical panel and require dedicated breakers sized to the specifications of the solar PV system's inverter. For this analysis, Navigant assumed that an existing home's 100 Amp electrical panel has sufficient capacity to accommodate a 3 kW solar PV, or requires minimal electrical upgrades such as a subpanel. Larger solar PV systems (5-7 kW and greater) and other large electrical appliances such as pool pumps, pool/spa heaters, and electric vehicle chargers would also affect whether an electrical panel upgrade is necessary for existing homes with natural gas appliances. Discussed further in this section, limited information exists on electrical upgrade requirements and costs for existing buildings across California. Additional research is necessary to quantify the cost to upgrade electrical infrastructure in existing California homes, and the proportion of homes requiring different levels of upgrades.

CBECC-Res sizes the solar PV systems for new homes to offset the site electricity consumption for a home with natural gas appliances per 2019 Title 24 code.[16] This strategy promotes the consumption of on-site solar PV generation, reduces the solar PV system sizing for all-electric homes, and reduces the impacts of net overgeneration on the larger electricity grid (e.g., "duck curve" issues).

This analysis also does not evaluate cost impacts for natural gas and electricity line extensions and metering, grid infrastructure upgrades, builder development costs, nor payback of line allowances to builders. For new construction, there may be costs and time savings because gas line extensions and gas meters would not be required that were not analyzed as part of this effort. Limited information exists on average gas infrastructure costs within California and estimates vary widely. Recent research by TRC estimated a total installed cost of $6,412 per home ($848 plan review, $4,343 connection charge, $850 meter, $371 indoor plumbing),[17] and RMI compiled available data showing a range of $1,000 to $24,000 with a median value of $8,800 per home.[18] Navigant understands that builders pay a line extension

[16] Shirak et al. 2017. "2019 Building Energy Efficiency Standards ZNE Strategy." April 20, 2017 CEC Staff Workshop. Available at: http://docketpublic.energy.ca.gov/PublicDocuments/17-BSTD-01/TN217286_20170424T162107_4202017_Staff_Workshop_Zero_Net_Energy_Strategy_Presentation.pdf

[17] TRC. "Palo Alto Electrification Final Report." City of Palo Alto. 2016. Available at: https://www.cityofpaloalto.org/civicax/filebank/documents/55069

[18] Billimoria et al. 2018. "The Economics of Electrifying Buildings: How Electric Space and Water Heating Supports Decarbonization of Residential Buildings." Rocky Mountain Institute. June 14, 2018. Available at: https://rmi.org/insight/the-economics-of-electrifying-buildings/

allowance to gas utilities, and this allowance is returned to the builder over time after the occupants move into the home and establish their utility accounts. This process ensures that ratepayers are not burdened if a builder defaults on the development before home sale and occupancy. In addition, this analysis does not consider how building electrification, solar PV systems, or other trends would affect the payback of line allowances from gas and electric utilities to builders due to decreased natural gas and grid-supplied electricity consumption.

The multi-family home assumes eight units within the building, with each unit served by a separate set of appliances. The analysis results are provided as per unit values.

1.2 Natural Gas and Electric Technologies

California homes have a choice of appliance fuel type for major end uses within the home. Many existing California homes use natural gas for water heating, space heating, cooking, and clothes drying, Appliances using electricity are readily available in California with different energy efficiencies and features.

Table 1-3 highlights the natural gas and electric appliances selected for this analysis. Appendix A specifies the key attributes for the natural gas and electric appliances. This analysis analyzes incremental costs for gas and electric appliances assuming complete appliance replacement at end of life (e.g., normal replacement for existing homes) or initial installation (e.g., new homes). Natural gas appliances are baseline efficiency options per Title 20, Title 24, and DOE appliance standards, with the exception for single-family new homes, where a tankless non-condensing water heater is used per Title 24 code. For this analysis, Navigant selected an electric heat pump water heater (HPWH) as the baseline electric option rather than an electric resistance model. The electrification discussions among stakeholders in the state generally assume that the HPWH would be used.[19]

Table 1-3. Natural Gas and Electric Appliances Selected for Analysis

Appliance Type	Natural Gas Option	Electric Option
Water Heating	• Existing homes: Baseline gas storage water heater (0.62 EF 50 gal) • New homes: Baseline gas tankless noncondensing water heater (0.82 EF)	Baseline electric HPWH (50 gal, AOSmith HPTU 50, model selected in CBECC-Res)
Space Heating	Baseline gas furnace (14 SEER A/C,3 ton; 80% gas furnace)	Baseline electric air source heat pump (ASHP) (14 SEER, 8.2 HSPF heat pump, 3 ton)
Cooking	Baseline gas range/oven	Baseline electric range/oven
Clothes Dryer	Baseline gas dryer	Baseline electric dryer

Note: Appendix A provides the key attributes for the natural gas and electric appliances.

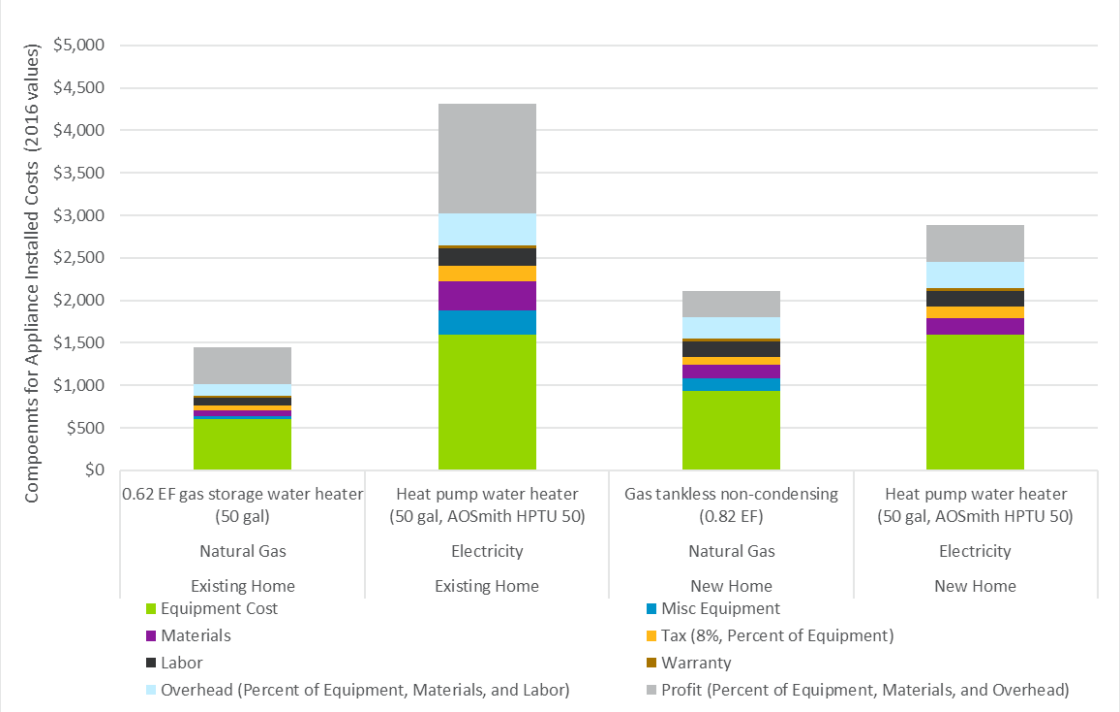
Source: Navigant analysis.

[19] Evaluating high efficiency appliances are outside the scope of this analysis. Generally, high efficiency appliances carry increased purchase cost and offer reduced energy cost, with a net cost reduction to the homeowner over the lifetime of the appliance.

Navigant estimated energy consumption for each appliance using the CBECC-Res building simulation software. Appliance cost estimates are based on 2016 data compiled by KPF Group based on construction invoice and budget estimates from Southern California builders and contractors.[20] The estimated costs assume the combined purchase, installation, and upgrade costs including contractor overhead, profit, permit fees, and other factors that homeowners would experience with professional installation.[21, 22] HVAC equipment cost estimate includes material and labor cost for necessary ducting.

Figure 1-1 summarizes the buildup of appliance purchase cost to installed water heater costs for this analysis, including factors that are calculated as a percentage of material costs, such as profit, tax, and overhead. The line-item labor and materials estimates include 30% gross margin for existing homes and 15% for new homes, and installation labor hour estimates of 7 hours for electric HPWH and 3 hours for baseline gas water heater. Discussed below, Navigant conducted an analysis with a Low HPWH Cost Estimate to illustrate the sensitivity of results to this assumption. Key results are discussed in the following sections, with full details in Appendix C.

Figure 1-1. Representative Buildup of Appliance Cost in Analysis (2016 values, unadjusted for future years)



Source: Appliance costs from Gilbert Kitching of KPF Group in 2016. SoCalGas provided KPF Group research to Navigant for use in this report.

[20] Appliance costs from Gilbert Kitching of KPF Group in 2016. SoCalGas provided KPF Group research to Navigant for use in this report.

[21] Navigant reviewed the cost estimates from KPF Group relative to other data sources, and the equipment costs appear higher for, each type of equipment relative to what was observed from other sources, particularly for water heating. The other sources do not detail contractor mark-up for overhead and profits. For consistency across all appliance categories and home types, Navigant uses the KPF Group cost estimates for new and existing homes throughout the analysis, and conducted a sensitivity analysis with the Low HPWH Cost Estimate.

[22] Electrician subcontractor cost for HPWH was removed to avoid double counting upgrade cost.

Table 1-4 summarizes available water heater cost estimates and incremental cost comparison between gas and electric models. Navigant reviewed the cost estimates from KPF Group relative to other data sources, and the equipment costs appear higher for each type of equipment relative to what was observed from other sources, particularly for water heating. Lower installed cost estimates for electric HPWHs would reduce the incremental cost for all-electric homes. Nevertheless, these other sources may not reflect fully installed costs with local conditions, like the construction invoice and budget estimates compiled by KPF Group. For consistency across all appliance categories and home types, Navigant uses the KPF Group cost estimates for new and existing homes throughout the analysis and conducted a sensitivity analysis with the Low HPWH Cost Estimate. In this scenario, the lowest incremental cost ($550 from UC Berkeley / Berkeley Lab) is applied to the gas water heater cost estimates from the KPF Group data. The results are presented both with Base HPWH Cost Estimate (2016 incremental cost of $2,867) and Low HPWH Cost Estimate (2016 incremental cost of $550). Key results are discussed in the following sections, with full details using Base HPWH Cost Estimate in Appendix B and Low HPWH Cost Estimate in Appendix C.

Table 1-4. Comparison of Residential Water Heater Cost Estimates (Existing Home)

Estimate	Gas Storage Water Heater Cost	Electric HPWH Cost	Incremental Cost (Total Installed Cost)	Notes
KPF Group (2016)[23]	• Equipment Cost: $598 • Total Installed Cost: $1,447	• Equipment Cost: $1,600 • Total Installed Cost: $4,314	$2,867	Figure 1-1 summarizes the buildup of appliance purchase costs to installed costs from KPF Group data.
UC Berkeley / Berkeley Lab (2017)[24] citing EIA Measure Cost Study (2016)[25]	• Equipment Cost: $850 • Total Installed Cost: $1,350	• Equipment Cost: $1,400 • Total Installed Cost: $1,900	$550	The study cites "ENERGY STAR" level for gas water heater in the EIA resource reflecting updated Federal standard. If using "0.62 EF" or "2020" values in EIA resource, gas water heater shows $525 appliance cost and installed cost of $990-$1,020. The study cites "Typical" level for HPWH in 2020 (range of $1,400-$1,700 appliance cost and installed cost of $1,510-$2,230).
Potential and Goals Study (2017)	• Equipment Cost: $921 • Total Installed Cost: $1,274	• Equipment Cost: $1,565 • Total Installed Cost: $2,033	$759	This study uses appliance and installation cost estimates from Itron Measure Cost Study (2016)[26]
SMUD Analysis (2018)[27]	• Equipment Cost: $800 • Total Installed Cost: $1,400	• Equipment Cost: $1,300 • Total Installed Cost: $2,800	$1,400	Prices based on analysis of customer invoices and survey of plumbers. In an article discussing the analysis, SMUD also notes that installation costs ranged widely in their dataset, with observed costs up to $4,500.[28]

Note: Costs represent water heater replacement for existing home, assuming like-for-like replacement rather than conversion from natural gas to electric option.

Sources referenced in table.

Navigant estimated electrical infrastructure upgrade costs from a report for the City of Palo Alto, which used estimates from RS Means and discussions with contractors, distributors, city officials, and other

[23] Appliance costs from Gilbert Kitching of KPF Group in 2016. SoCalGas provided KPF Group research to Navigant for use in this report.

[24] Raghavan et al. 2017. "Scenarios to Decarbonize Residential Water Heating in California." Energy Policy, 109. 441-451. Available at: https://rael.berkeley.edu/publication/scenarios-to-decarbonize-residential-water-heating-in-california/

[25] EIA. 2016. "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies – Appendix A." Latest version dated November 9, 2016. Available at: https://www.eia.gov/analysis/studies/buildings/equipcosts/

[26] Itron. 2014. "2010-2012 WO017 Ex Ante Measure Cost Study Final Report." Prepared for CPUC. May 27, 2014. Available at: http://www.calmac.org/publications/2010-2012_WO017_Ex_Ante_Measure_Cost_Study_-_Final_Report.pdf

[27] Howlett, Owen. 2018. "Electrification Cost-Effectiveness and Current Programs at SMUD." Presentation at the June 14, 2018 IEPR Workshop on Achieving Zero Emission Buildings. Docket Number: 18-IEPR-09, TN #: 223760. Available at: https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=18-IEPR-09

[28] Gerdes, Justin. 2018. "Sacramento Utility Pushes All-Electric Homes: 'California Is Wasting Money to Build Homes With Gas'." Greentech Media. June 27, 2018. Available at: https://www.greentechmedia.com/articles/read/sacramento-utility-pushes-all-electric-homes#gs.zYUQKf8

industry stakeholders.[29] It should be noted that some existing homes may already have sufficient electrical infrastructure to accommodate the additional electrical loads and would thus require minimal electrical upgrade costs. As such, the team presents the appliance purchase, installation, and upgrade costs as a range. The appliance and upgrade costs were estimated for 2016 and increased by 5% to reflect 2020 values. Navigant assumed an annual inflation value of 2% for the years from 2020 to 2030 to adjust for the projected increases in appliance and upgrade costs. The 2% inflation compounded annually resulted in a 22% cost increase from 2020 to 2030. To account for the increasing market adoption of the HPWHs and air-source heat pumps, Navigant used a projection from the National Renewable Energy Laboratory (NREL)[30] of a 15% cost reduction for air-source heat pumps and a 20% cost reduction for HPWHs from 2020 to 2030.[31]

[29] TRC. "Palo Alto Electrification Final Report." City of Palo Alto. 2016. Available at: https://www.cityofpaloalto.org/civicax/filebank/documents/55069

[30] NREL. 2017. "Electrification Future Study: End-Use Electric Technology Cost and Performance Projections through 2050." December 2017. Available at: https://www.nrel.gov/docs/fy18osti/70485.pdf

[31] Electric HPWH and air-source heat pump costs are adjusted upward with all appliance costs and adjusted downward due to technology cost reductions.

2. SUMMARY OF RESULTS

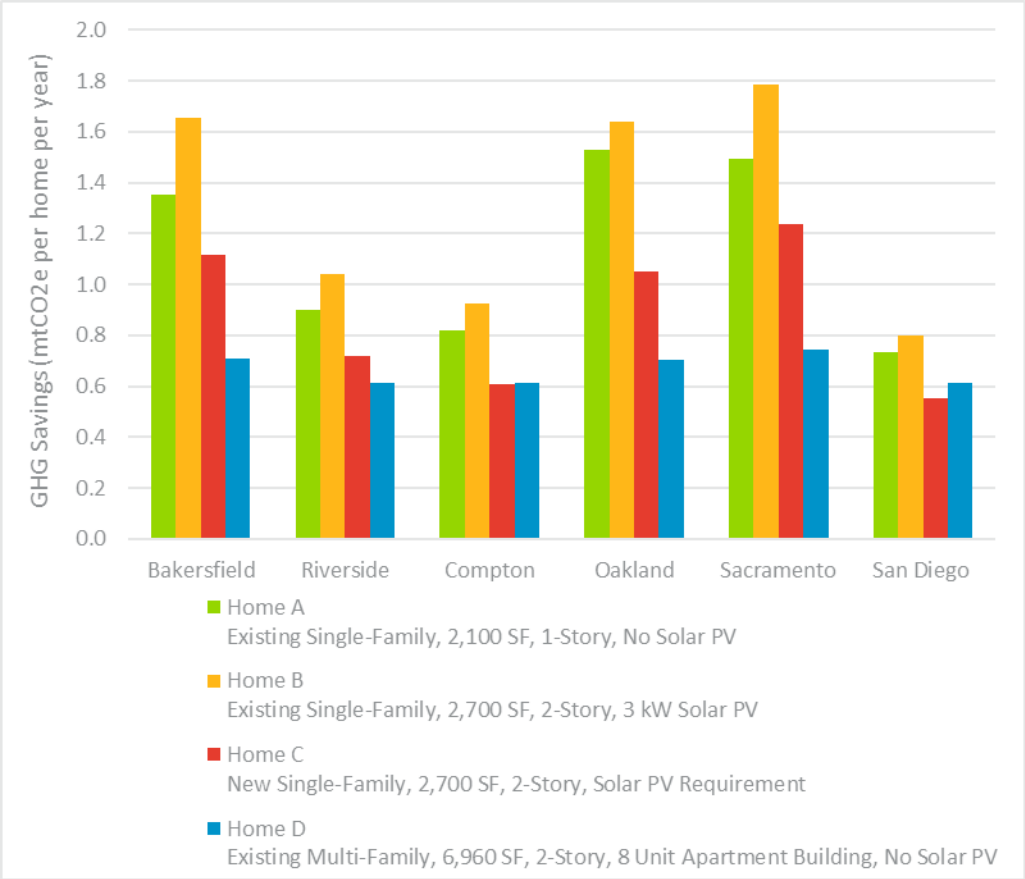
This section summarizes the technical, economic, and GHG results of the analysis on homes across California. Navigant presents the GHG emissions and cost results at a whole-home level, accounting for all end-uses within the home, including those that do not use natural gas (e.g., space cooling, lighting, plug loads, etc.). Multi-family results are presented on a per-unit basis within an 8-unit building, as detailed in Appendix A. Appendix B provides detailed results tables using Base HPWH Cost Estimate and Appendix C provides detailed results tables using Low HPWH Cost Estimate.

2.1 GHG Emissions Savings

Figure 2-1 highlights the GHG emissions savings from switching major natural gas appliances to electric appliances in 2020, categorized by region and home design. Appliance electrification provides estimated GHG emissions savings of 35-48% in 2020 for existing homes without solar PV systems, which grows to 42-56% savings in 2030 because of lower emissions factors for grid electricity. New single-family homes save 55-60% in GHG emissions in 2020 and 63-67% in 2030. Multi-family homes save 37-43% in 2020 and 45-50% in 2030. In 2015, the residential sector accounted for approximately 6% of California's total GHG emissions of 440.4 million metric tons of CO2e.[32] In 2020, the savings for existing homes would account for approximately 2% of California's statewide GHG emissions. Results for 2030 results follow similar trends, but generally show higher savings due to the lower emissions factor for electricity. Appendix B and Appendix C contains detailed tables, including results for 2030.

[32] California Air Resources Board. 2017. "California Greenhouse Gas Emission Inventory - 2017 Edition." June 2017. Avalable at : https://www.arb.ca.gov/cc/inventory/data/data.htm

Figure 2-1. Total Home GHG Emissions Savings for Complete Electrification in 2020



Note: Results represent energy consumption for all major appliances.

Source: Navigant analysis.

GHG emissions vary for several reasons. Regional differences arise due to space heating load variations by climate. New homes save less GHG emissions upon electrification due to higher home efficiencies and a different baseline natural gas water heating technology, as noted in Table 1-3.

For existing homes with a 3 kW solar PV system, the same amount of GHG emissions savings accounts for a higher proportion of annual emissions due to the lower baseline values compared to existing homes without solar. Existing homes with solar PV systems achieve an estimated GHG emissions savings of 49-66% in 2020 and 56-72% in 2030 due to the lower baseline values.

Navigant calculated GHG emissions by multiplying the simulated energy consumption for each of these scenarios by an emissions factor to obtain the GHG emissions. Navigant estimated a GHG emissions factor for delivered electricity of 0.20 metric tons of carbon dioxide equivalent (mtCO2e) per MWh in 2020 and 0.16 mtCO2e/MWh in 2030. Navigant assumed a natural gas emissions factor of 0.0053 mtCO2e per therm (11.71 lbs CO2e per therm) from EIA estimates.[33] Appendix A provides additional details on the emissions factor assumptions.

[33] EIA. 2016. "Carbon Dioxide Emissions Coefficients." February 2016. Available at: https://www.eia.gov/environment/emissions/co2_vol_mass.php

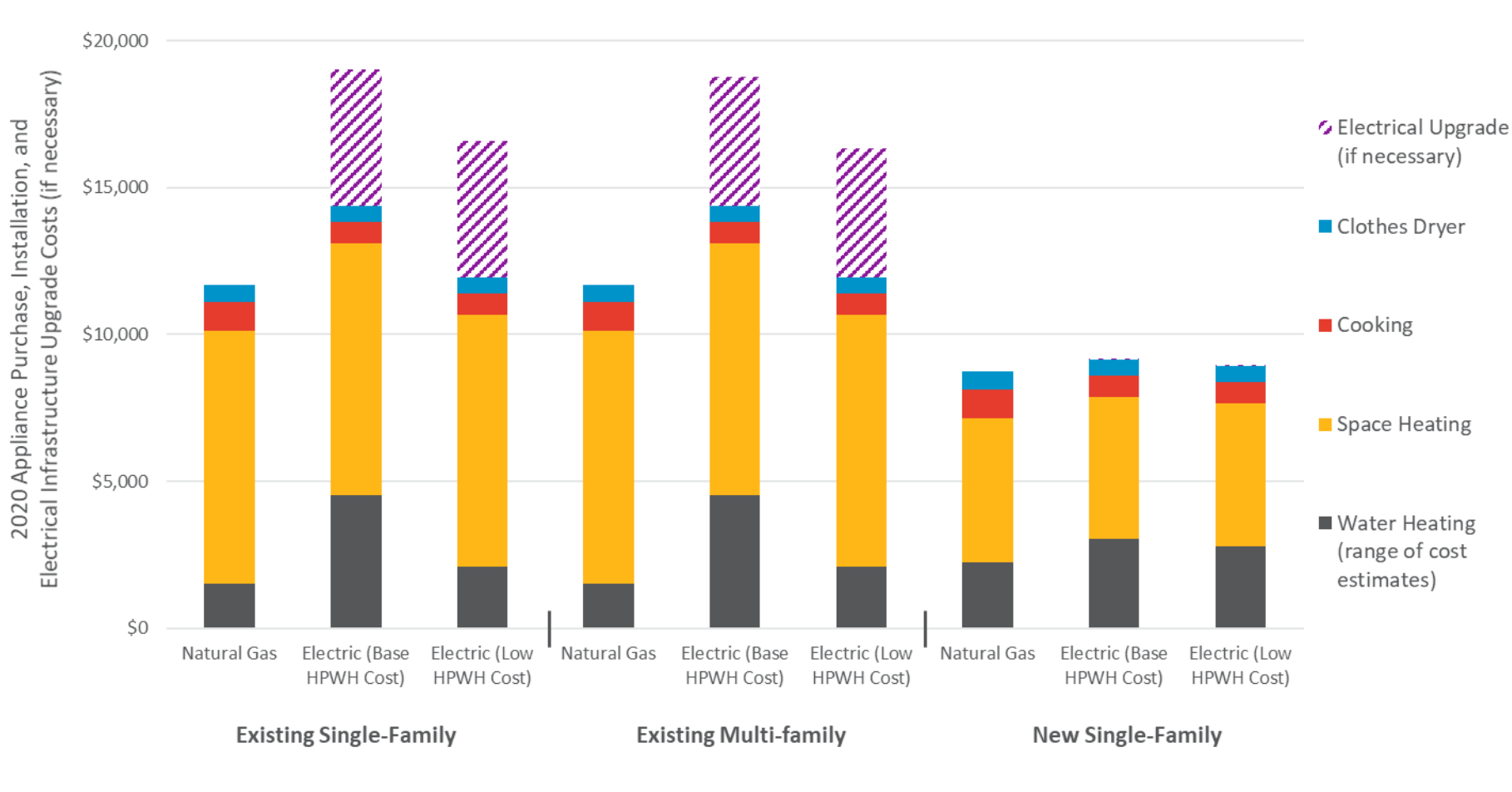
2.2 Cost for Electric Appliances and Upgrades

Figure 2-2 provides a comparison of the installed cost of natural gas and electric appliances for the major end uses, including electrical infrastructure upgrade costs, if necessary, and a range of HPWH cost estimates. The estimated costs assume the combined purchase, installation, and upgrade costs (if applicable), including contractor overhead, profit, and permit fees with professional installation (Figure 1-1). Electric appliances for space heating, cooking, and clothes drying have lower costs than natural gas options, while the electric HPWH has higher costs than a baseline gas storage water heater. In total, the estimated total installed cost increase for electric appliances in 2020 is $243 to $2,674 in an existing home and $185 to $418 in a new home for the range of HPWH cost estimates, without considering possible electrical infrastructure upgrades. In 2030, these cost premiums for electric appliances drop to -$319 to $2,645 for existing homes and -$351 to -$67 for new homes, without considering possible electrical infrastructure upgrades. Appendix B contains additional details.

Currently, California electric utilities offer an energy efficiency rebate for HPWHs of $200 to $3,000, which decreases the appliance purchase cost where applicable.[34] Large incentives for electric appliances can significantly shift the cost comparison of natural gas and electric appliances from the perspectives of the customer, homebuilder, and building owner. Appliance rebates are not factored into this analysis due to the variability in incentive levels by region and uncertainty of incentive availability in future years.

[34] SMUD Residential Appliance Rebate Program. $3,000 HPWH rebate for gas to electric conversion. Accessed August 2018. Available at: https://www.smud.org/en/Rebates-and-Savings-Tips/Rebates-for-My-Home/Home-Appliances-and-Electronics-Rebates

Figure 2-2. 2020 Total Appliance Purchase, Installation, and Electrical Infrastructure Upgrade Costs (if necessary), including Range of Water Heater Cost Estimates



Notes: The estimated costs assume the combined purchase, installation, and upgrade costs, including contractor overhead, profit, permit fees, and other factors that homeowners would experience with professional installation. Electrician subcontractor cost for HPWH removed to avoid double counting upgrade cost.

Source: Appliance costs estimated from KPF Group data for 2016 and increased by 5% to reflect 2020 values. Base HPWH Cost Estimate uses KPF Group data, and Low HPWH Cost Estimate assumes incremental cost of $550 over gas water heater in 2016. Electrical upgrade costs from TRC, Palo Alto Electrification Final Report*, City of Palo Alto, 2016. https://www.cityofpaloalto.org/civicax/filebank/documents/55069*

This analysis assumes that an existing home has natural gas appliances, and therefore homeowners may need to upgrade their electrical infrastructure to accommodate electric appliances. In addition, the analysis assumes that baseline homes have air conditioning, so the electrical infrastructure for an electric heat pump for space heating is available.

In 2020, an existing home may require an electrical infrastructure upgrade to accommodate an electric HPWH at an estimated cost of up to $4,671 for single-family and $4,399 for multi-family. By 2030, Navigant estimates these costs would be $5,694 for single-family and $5,362 for multi-family in 2030. The $4,671 upgrade cost for a single-family existing home includes a higher capacity electrical panel (100 Amp to 200 Amp, $3,181), upgraded branch circuit to the HPWH (15 Amp to 30 Amp branch circuit, $640), and utility service upgrade fee ($850).[35] Some existing homes (particularly newer homes and those with a swimming pool, EV charger or solar PV) may have sufficient electrical infrastructure and require minimal electrical upgrade costs. Thus, the team presents the appliance purchase, installation, and upgrade costs as a range.

For existing homes that require electrical infrastructure upgrades, homeowners converting from natural gas to electric appliances would experience total 2020 cost increases of $4,914 to $7,345 for single-family and $4,642 to $7,073 for multi-family and 2030 cost increases of $5,375 to $8,339 for single-family and $5,044 to $8,007 for multi-family. For existing homes that do not require electrical infrastructure upgrades, homeowners would experience total 2020 cost increases of $243 to $2,674 for single-family and multi-family and 2030 cost increases of -$319 to $2,645 for single-family and multi-family. The full range of incremental cost for existing homes is $243 to $7,345 for 2020 and -$319 to $8,339 for 2030. This incremental cost is used rather than the full replacement cost because this analysis assumes that electrification would occur upon burnout of the natural gas appliances.

As shown in Figure 2-2, installed costs are lower for new homes due to decreased labor costs to the homeowner. Similarly, the electrical infrastructure costs are much lower for new homes, as the only incremental cost is the higher capacity branch circuit to accommodate the HPWH ($50 in 2020 and $61 in 2030). When including these electrical infrastructure costs, new homes would experience total 2020 cost increases of $235 to $468 and 2030 cost increases of -$290 to -$6. For new homes with electric appliances, there may be some cost savings from the elimination of gas line to the home and the gas meter. This analysis does not include gas infrastructure costs, and this is a suggested area for future research (Section 2.5).

As discussed in Section 1.1, Navigant assumed that the 2,700 square foot (SF) existing home with 3 kW solar PV system did not previously require an electrical panel upgrade. If the electric panel was previously upgraded to 200 Amp service, appliance electrification would require less extensive upgrades. The total electrification requirements would be for a branch circuit upgrade for the HPWH (15 Amp to 30 Amp branch circuit).

2.3 Annual Energy Bill Impact

Figure 2-3 provides the estimated annual energy bill change for homes that choose to move from natural gas to electric appliances. As detailed in Section 1, this analysis assumes average annual electricity and natural gas rates from IEPR for 2020 and 2030 to represent the lower end of possible electricity prices,

[35] TRC. “Palo Alto Electrification Final Report.” City of Palo Alto. 2016. Available at: https://www.cityofpaloalto.org/civicax/filebank/documents/55069

and a higher electricity rate scenario for 2030 in which the IEPR rates were escalated per LADWP's 2016 IRP.[36] This high uncertainty projection is meant to capture an upper case scenario for future electricity rates based on other rate projections in the region. Appendix B and Appendix C contain detailed results tables.

The analysis indicates that appliance electrification has the potential to increase a homeowner's annual energy bill in 2020 and 2030 in Bakersfield, Riverside, Compton, Oakland, and San Diego using baseline electric and gas equipment. In 2020, existing single-family homes without solar PV systems may pay 8-19% more in energy costs. For existing single-family homes with 3 kW solar PV systems, appliance electrification carries the same energy bill impacts, but accounts for a higher percentage increase due to lower baseline energy costs (24-39%). Existing multi-family homes may pay 6-16% more and new single-family homes may pay 38-86% more in annual energy costs in 2020. In 2030, existing homes without solar pay 3-25% more, existing multi-family homes pay 3-22% more, and new single-family homes pay 26-128% more in annual energy costs. Note the 2030 ranges include both energy cost projections.

In Sacramento, homeowners across all home types would experience energy cost savings upon electrification due to lower electricity rates. In 2020, existing homes without solar PV systems save 5% on their annual energy bills, existing single-family homes with a 3 kW solar PV system save 8%, multi-family homes save 5%, and new single-family homes save 2%. In 2030, using IEPR electricity rates, existing homes without solar PV systems save 5% on their annual energy bills, existing single-family homes with a 3 kW solar PV system save 8%, multi-family homes save 4%, and new single-family homes save 1%. The high electricity rates forecast for 2030 indicate that existing single-family homes pay 7-12% more on their annual energy bills, multi-family homes pay 6% more, and new single-family homes pay 28% more.

Annual energy bills vary by region due to space heating loads varying by climate and electricity and natural gas rates for each utility. The 2030 scenarios provide a range for electricity rates. Navigant calculated annual energy bills by multiplying the simulated energy consumption for each of these scenarios by an annual average natural gas and electric rate for each region. Navigant's scope of work was to conduct an energy bill analysis that reflects annual average electricity rates. Navigant did not analyze time-of-use nor multi-tiered utility rate structures that have higher prices during peak periods. Appendix A provides additional details on the energy cost assumptions. For new construction, there may be costs or time savings because gas line extensions and gas meters would not be required that were not analyzed as part of this effort.

[36] LADWP. "2016 Power Integrated Resource Plan." December 2016. Available at: https://www.ladwp.com/ladwp/faces/wcnav_externalId/a-p-doc?_adf.ctrl-state=iirytk0lc_4&_afrLoop=35208544433395

Figure 2-3. Annual Energy Bill Changes for Electrification of Homes Relative to Homes Using Gas in 2020 and 2030 Scenarios

Note: Annual energy bill for natural gas home represents combined natural gas and electric energy bill for all end-uses within the home.

Source: Navigant analysis.

2.4 Homeowner Cost Comparison

Homeowners currently using or planning to use gas would experience annual energy bill impacts in each year after appliance electrification. There would also be a one-time up-front cost for appliance acquisition (primarily the HPWH) and possible electric infrastructure in existing construction. Note the following values reflect the range of electrification costs, including the with and without infrastructure upgrades for existing homes, and projections for utility and appliance costs in 2020 and 2030.

If spread over the 15-year life of many electric appliances, the incremental appliance and electrical infrastructure costs (where necessary) would be in the range of $16 to $490 per year for existing single-family homes, $16 to $472 for existing multi-family, and $16 to $31 for new single-family homes in 2020.[37] In 2030, the incremental appliance and electrical infrastructure costs (where necessary) would be in the range of -$21 to $556 per year for existing single-family homes, -$21 to $534 for existing multi-family, and -$19 to $0 for new single-family homes.

Homeowner total cost includes both up-front HPWH incremental cost, infrastructure cost (where necessary) and annual energy bill impacts. If the appliance and upgrade costs are spread over the 15-year life of many appliances, California's existing single-family homeowners would experience a combined annual cost increase of $236 to $1,302 if infrastructure upgrades are required, and -$119 to $922 if infrastructure upgrades are not required for existing homes (range includes 2020 and 2030 scenarios and HPWH cost estimates).

Across the entire range for 2020 and 2030, California's existing single-family homeowners would experience a combined -$119 to $1,302 annual cost increase due to annualized appliance electrification costs across the range of scenarios for 2020 and 2030. This increase represents up to 1-2% of median household income for California customers.[38]

If the upgrade costs are spread over 15-year life of many appliances, California's existing multi-family homeowners would experience a $271 to $840 combined annual cost increase if infrastructure upgrades are required, and -$63 to $482 if infrastructure upgrades are not required for existing homes (range includes 2020 and 2030 scenarios and HPWH cost estimates). New single-family homes would experience a -$30 to $635 combined annual cost increase due to annualized appliance electrification cost (range includes 2020 and 2030 scenarios and HPWH cost estimates). Appendix B contains the detailed results across all home designs.

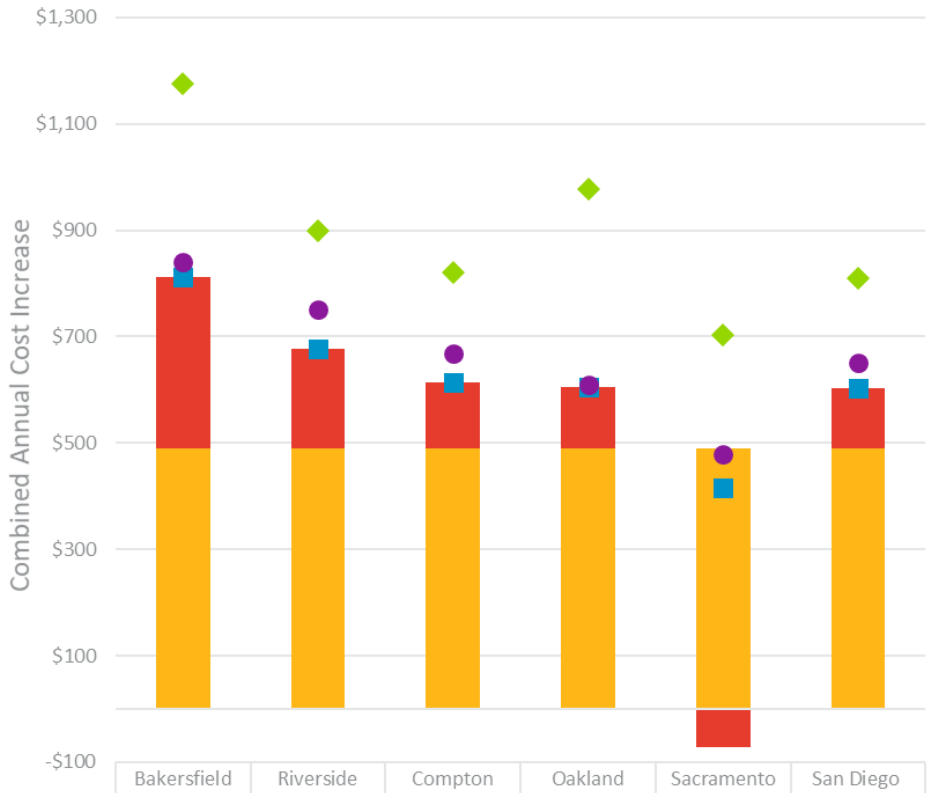
Figure 2-4 provides the costs of electrifying an existing one-story single-family home (Home A) across the six locations used in this analysis, assuming electrical infrastructure upgrade costs and Base HPWH Cost Estimate. The columns illustrate the annual energy bill increase (or savings in the case of Sacramento) and the annualized upfront electrification cost, assuming electrical infrastructure costs are required. The lines show the three temporal scenarios – 2020, 2030 using IEPR rates, and 2030 using the higher electricity rates. If using Low HPWH Cost Estimate, the orange column ($490) for "Electrification Cost Annualized Over 15 Years" would decrease by $162 to $328.

[37] This assumes incremental appliance cost and electric infrastructure costs are divided equally across the 15 year lifetime of many appliances, without considering adjustments for finance, NPV, and other factors.

[38] Median Household Income from U.S. Census Bureau 2012-2016 American Community Survey 5-Year Estimates. https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk
Housing unit approximation from 2009 RASS and other estimates. DNV-GL. 2010. "2009 California Statewide Residential Appliance Saturation Study." Saturation Tables. Available at: https://webtools.dnvgl.com/RASS2009/Default.aspx (accessed March 2018).

Figure 2-4. Electrification Cost Increases for Home Design A in 2020 and 2030 Scenarios (Assumes Electrical Infrastructure Costs are Required)

Note. this figure shows electrification costs assuming that electrical infrastructure costs are required.



	Bakersfield	Riverside	Compton	Oakland	Sacramento	San Diego
2020 Annual Energy Bill Increase	$323	$187	$124	$116	($73)	$113
2020 Electrification Cost Annualized Over 15 Years	$490	$490	$490	$490	$490	$490
2020 Combined Annual Cost Increase	$813	$677	$614	$606	$417	$603
2030 IEPR Combined Annual Cost Increase	$839	$751	$668	$609	$478	$650
2030 High Elec. Rates Combined Annual Cost Increase	$1,176	$899	$820	$977	$703	$811

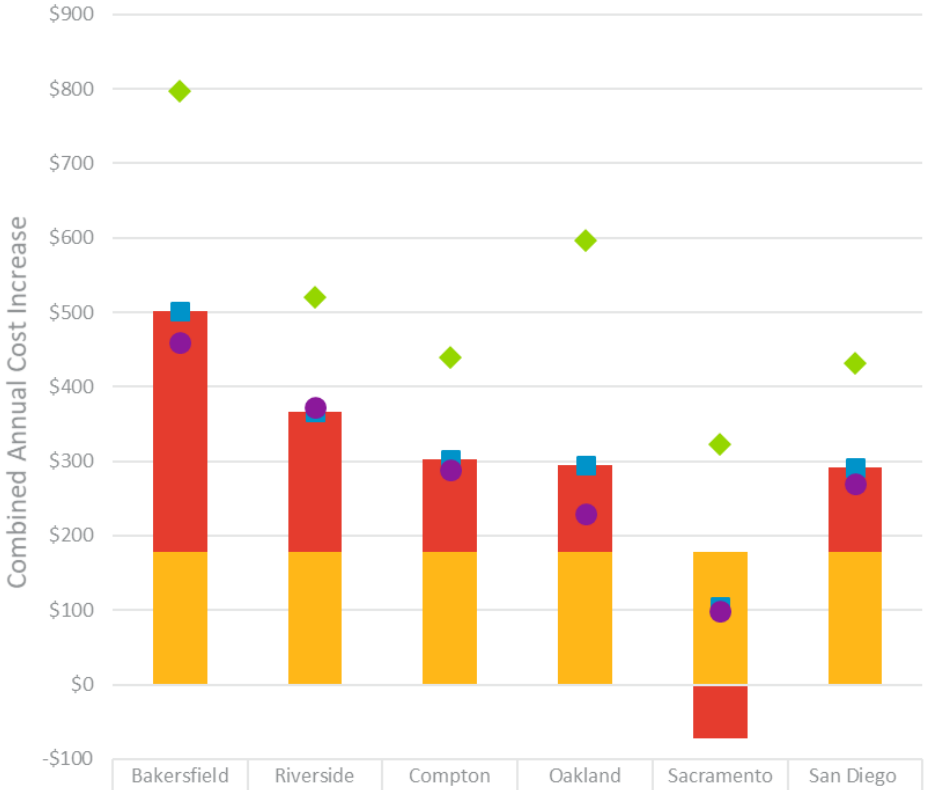
Note: Annualized electrification cost assumes the net electrification cost is spread over a 15-year period, without considering adjustments for finance, NPV, and other factors.

Source: Navigant analysis.

Figure 2-5 provides the costs of electrifying an existing one-story single-family home (Home A) across the six locations used in this analysis, assuming electrical infrastructure upgrades are not required and Base HPWH Cost Estimate. The columns illustrate the annual energy bill increase (or savings in the case of Sacramento) and the annualized upfront electrification cost, assuming electrical infrastructure costs are not required. The lines show the three temporal scenarios – 2020, 2030 using IEPR rates, and 2030 using the higher electricity rates. If using Low HPWH Cost Estimate, the orange column ($178) for "Electrification Cost Annualized Over 15 Years" would decrease by $162 to $16.

Figure 2-5. Electrification Cost Increases for Home Design A in 2020 and 2030 Scenarios (Assumes Electrical Infrastructure Upgrades are Not Required)

Note. this figure shows electrification costs assuming that electrical infrastructure costs are not required.



	Bakersfield	Riverside	Compton	Oakland	Sacramento	San Diego
2020 Annual Energy Bill Increase	$323	$187	$124	$116	($73)	$113
2020 Electrification Cost Annualized Over 15 Years	$178	$178	$178	$178	$178	$178
2020 Combined Annual Cost Increase	$502	$366	$302	$294	$105	$291
2030 IEPR Combined Annual Cost Increase	$460	$372	$288	$229	$98	$270
2030 High Elec. Rates Combined Annual Cost Increase	$797	$520	$440	$597	$323	$431

Note: Annualized electrification cost assumes the net electrification cost is spread over a 15-year period, without considering adjustments for finance, NPV, and other factors.

Source: Navigant analysis.

2.5 Additional Factors for Appliance Electrification Discussion

Navigant conducted this analysis to summarize the potential impacts of residential appliance electrification for California homeowners to support stakeholder discussion around appliance electrification initiatives. This analysis relies on a number of assumptions about the composition of California housing stock, and may not reflect the electrification costs for individual properties. The following list highlights some factors that may be explored further in future research:

- **Electrical Upgrade Costs** – This analysis leverages research performed by TRC for the City of Palo Alto[39] on electrical upgrade costs in California. Limited information exists on the average electrical upgrade costs for existing homes, and anecdotal estimates range widely based on the type of electrical appliance (e.g., electric HPWH, solar PV system, electric vehicle charger), age of building, contractor prices, etc. Stakeholders should conduct additional research to quantify the cost to upgrade electrical infrastructure in existing California homes, and the proportion of homes requiring different levels of upgrades.
- **Electric HPWH Installed Costs** – Available electric HPWH purchase and installation cost estimates vary widely based on underlying assumptions, and this analysis illustrates the sensitivity of the results to the HPWH cost assumptions. Stakeholders should conduct further research to develop a common set of assumptions for HPWH purchase and installation costs for new and existing homes in California.
- **Homeowner Preferences** – Stakeholders should study the impacts that appliance electrification initiatives would have on homeowner preferences, satisfaction, resale values, and other attributes for the California housing market.
- **Electricity Grid Impacts** – Future research should examine the impacts that appliance electrification initiatives could have on local and statewide electricity grid, residential electric rates, and utility line extension and development costs for builders.
- **Gas Infrastructure Costs –** This analysis did not consider the possible cost savings in new construction from not putting in gas lines, meters, and running gas pipes within the house. Future research should evaluate the possible gas infrastructure cost savings for new construction.
- **Line Allowance Payback** – This analysis does not consider how building electrification, solar PV systems, or other trends would affect the payback of line allowances to builders. Stakeholders should study how decreased natural gas and grid-supplied electricity consumption in new and existing homes would affect utility payback of line allowances to builders.
- **Increased Space Cooling in Existing Homes** –Stakeholders should study the potential impacts that electric heat pump adoption could have on increasing space cooling consumption in homes that did not previously use air conditioners.
- **Utility Rates** – Additional research is necessary to understand the impacts that appliance electrification could have in future years for natural gas and electricity rates, including rate structures, stranded assets, and other issues.
- **Installation, Operation, and Maintenance Requirements** – Additional research is necessary to analyze the differences in installation, operation, and maintenance requirements between gas and electric appliances.
- **Renewable Gas** – Appliances using natural gas could have lower GHG emissions in future years if the California gas supply included a percentage of renewable gas. Additional research is necessary to analyze the impacts for the residential sector.

[39] TRC. "Palo Alto Electrification Final Report." City of Palo Alto. 2016. Available at: https://www.cityofpaloalto.org/civicax/filebank/documents/55069

3. CONCLUSIONS

Navigant analyzed the potential impact of residential appliance electrification of water heating, space heating, cooking, and clothes drying for existing and new homes in several California regions. Navigant leveraged the prototypical residential building models within the CBECC-Res 2019 modeling software and estimated on electricity GHG emissions factors, energy cost, appliance purchase and installation cost, and possible electricity upgrade costs from available resources. This section summarizes the key findings from the analysis. Note the results are highly sensitive to underlying assumptions on equipment efficiency and costs, infrastructure needs and costs, electricity rates, natural gas rates, electric utility rebates, and other factors.

- **Cost for Electric Appliances and Upgrades**
    - Most electric appliances have similar or lower costs than natural gas appliances, but current electric HPWHs have a cost premium over a baseline gas water heater. In total, the estimated total installed cost increase in 2020 for electric appliances (water heating, space heating, cooking, and clothes drying) is $243 to $2,674 for an existing home and $185 to $418 for a new single-family home, assuming a range of HPWH cost estimates.
    - Existing homes may require electrical infrastructure upgrades to accommodate an electric HPWH, with an estimated cost of $4,671 for single-family home and $4,399 for a multi-family home for higher capacity panel, branch circuit, and utility service upgrade fee.[40]
    - For existing homes that require electrical infrastructure upgrades, homeowners converting from natural gas to electric appliances may experience total cost increases of approximately $4,642 to $7,345 in 2020 and $5,044 to $8,339 in 2030, including incremental appliance and infrastructure upgrade costs. However, some existing homes may have sufficient electrical infrastructure and require minimal electrical upgrade costs and, in this situation, the electrification cost increases are estimated to be approximately $243 to $2,674 in 2020 and -$319 to $2,645 in 2030. The full range for existing homes is $243 to $7,345 for 2020.
    - New homes have minimal incremental costs to upgrade electrical infrastructure, with an estimated cost of $50 in 2020 and $61 in 2030. Combined with total appliance costs, a new home choosing electric appliances over natural gas would experience total incremental costs of $235 to $468 in 2020 and -$290 to -$6 in 2030.[41]
- **Annual Energy Bill Impact**
    - Appliance electrification in 2020 may increase a homeowner's annual energy bill by an estimated $50 to $387 per year across all home types in Bakersfield, Riverside, Compton, Oakland, and San Diego. In Sacramento, homeowners would experience bill savings of $14 to $91 per year due to lower electricity rates than other regions.
    - Appliance electrification using IEPR 2030 rates increases a homeowner's annual energy bill by $32 to $338 per year across all home types in Bakersfield, Riverside, Compton,

[40] TRC. "Palo Alto Electrification Final Report." City of Palo Alto. 2016. Available at: https://www.cityofpaloalto.org/civicax/filebank/documents/55069

[41] For new construction, there may be costs savings because gas line extensions and gas meters would not be required that were not analyzed as part of this effort.

Oakland, and San Diego. In Sacramento, homeowners would experience energy bill savings of $11 to $98 per year.

  - Appliance electrification using high electricity rates for 2030 increases a homeowner's annual energy bill by $69 to $746 per year across all locations.

- **Homeowner Cost Comparison**
  - Homeowners, in most cities analyzed, would experience annual energy bill increases in each year after appliance electrification as well as experience a one-time incremental appliance and electrical upgrade cost from the electric HPWH, where necessary. If the appliance and upgrade costs are spread over the 15-year life of many appliances, California's existing single-family homeowners would experience a combined annual cost increase of $236 to $1,302 if infrastructure upgrades are required, and -$119 to $922 if infrastructure upgrades are not required for existing homes (range includes 2020 and 2030 scenarios and HPWH cost estimates).
  - The estimated range of -$119 to $1,302 annual cost increase represents up to 1-2% of median household income for California customers.
  - If the upgrade costs are spread over 15-year life of many appliances, California's existing multi-family homeowners would experience a $271 to $840 combined annual cost increase if infrastructure upgrades are required, and -$63 to $482 if infrastructure upgrades are not required for existing homes (range includes 2020 and 2030 scenarios and HPWH cost estimates).
  - New single-family homes would experience a -$30 to $635 combined annual cost increase due to annualized appliance electrification cost (range includes 2020 and 2030 scenarios and HPWH cost estimates).
- **Impact of Solar PV System**
  - The GHG emissions, upgrade costs, and energy bill impacts for appliance electrification are similar for an existing home with or without a solar PV system.
  - If the electrical panel for the existing home with natural gas appliances was previously upgraded for solar PV or other large electrical device (e.g., pool pump, pool/spa heater, electric vehicle charger), the infrastructure upgrades could be very small.
- **GHG Emissions Savings**
  - Replacing major natural gas appliances for water heating, space heating, cooking, and clothes drying with electric appliances reduces total home GHG emissions by 35-66% in 2020 and 42-72% in 2030 for existing homes and 55-60% in 2020 and 63-67% for new homes. The savings for existing homes would account for approximately 2% of California's statewide GHG emissions in 2020. GHG emissions savings from appliance electrification will increase in future years as the electric RPS reaches 50% and higher.

APPENDIX A. HOME DESIGNS AND PARAMETERS

Appendix A provides a summary of the key data sources and assumptions for calculating baseline energy consumption and market sizing for natural gas and electric appliances:

- Section A.1. Model Building Configurations
- Section A.2. Appliance Assumptions
- Section A.3. Energy Cost Assumptions
- Section A.4. Emissions Factor Assumptions

A.1 Model Building Configurations

Table A-1 details the building parameters Navigant used to model the four home designs. The values of the parameters are intended to roughly match the conditions of existing homes in cities analyzed. Navigant used the historical data from Title 24 – 2016 Residential Compliance Manual[42] for the default insulation and infiltration values for home from 1978 to 2014. Navigant used the 2009 Residential Appliance Saturation Survey[43] to determine the distribution of the year built of the homes in each utility area. Multiplying the values per year built by the distribution, Navigant calculated the average insulation and infiltration for each climate zone.

Table A-1. Building Configurations for Home A and B

Parameter	Home A 2,100 SF	Home B 2,700 SF Existing	Home C 2,700 SF New	Home D MF
Dwelling Units	1	1	1	8
Area (sq.)	2,100	2,700	2,700	6,960
Number of Floors	1	2	2	2
HVAC System	Central AC and gas furnace (3 ton)	Central AC and gas furnace (3 ton)	Central AC and gas furnace (3 ton)	Central AC and gas furnace (3 ton)
Water Heating System	50 gal gas storage, 0.62 EF	50 gal gas storage, 0.62 EF	Gas tankless non-condensing (0.82 EF)	50 gal gas storage, 0.62 EF

[42] "Performance Method" in *2016 Residential Compliance Manual.* (January 2017), 8-12. Table 8-1. http://www.energy.ca.gov/2015publications/CEC-400-2015-032/chapters/chapter_8-Performance_Method.pdf

[43] DNV-GL. 2010 "2009 California Statewide Residential Appliance Saturation Study."

For LADWP: https://webtools.dnvgl.com/rass2009/Uploads/LADWP%20Banners%201_2_3.pdf

For PG&E: https://webtools.dnvgl.com/rass2009/Uploads/PG&E%20Banners%201_2_3.pdf

For SCE: https://webtools.dnvgl.com/rass2009/Uploads/SCE%20Banners%201_2_3.pdf

Parameter	Home A 2,100 SF	Home B 2,700 SF Existing	Home C 2,700 SF New	Home D MF
Framing / Insulation	Framing: 2x6 @ 16 in O.C. CZ 13: R-value 5.6 CZ 10: R-value 5.5 CZ 8: R-value 3.6 CZ 7: R-value 5.7 CZ 3: R-value 5.6	Framing: 2x6 @ 16 in O.C. CZ 13: R-value 5.6 CZ 10: R-value 5.5 CZ 8: R-value 3.6 CZ 7: R-value 5.7 CZ 3: R-value 5.6	Title 24 2019 baseline for each CZ	Framing: 2x6 @ 16 in O.C. CZ 13: R-value 5.6 CZ 10: R-value 5.5 CZ 8: R-value 3.6 CZ 7: R-value 5.7 CZ 3: R-value 5.6
Attic Type / Insulation	CZ 13: R-value 18 CZ 10: R-value 17 CZ 8: R-value 14 CZ 7: R-value 18 CZ 3: R-value 18	CZ 13: R-value 18 CZ 10: R-value 17 CZ 8: R-value 14 CZ 7: R-value 18 CZ 3: R-value 18	Title 24 2019 baseline for each CZ	CZ 13: R-value 18 CZ 10: R-value 17 CZ 8: R-value 14 CZ 7: R-value 18 CZ 3: R-value 18
Internal Insulation	CZ 13: R-value 5.6 CZ 10: R-value 5.5 CZ 8: R-value 3.6 CZ 7: R-value 5.7 CZ 3: R-value 5.6	CZ 13: R-value 5.6 CZ 10: R-value 5.5 CZ 8: R-value 3.6 CZ 7: R-value 5.7 CZ 3: R-value 5.6	Title 24 2019 baseline for each CZ	CZ 13: R-value 5.6 CZ 10: R-value 5.5 CZ 8: R-value 3.6 CZ 7: R-value 5.7 CZ 3: R-value 5.6
Infiltration	7.7 ACH @ 50Pa	7.7 ACH @ 50Pa	5.0 ACH @ 50Pa	7.7 ACH @ 50Pa
Windows	NFRC U-factor: 1.19 Btuh/ft2-F, Solar Heat Gain Coef: 0.83	NFRC U-factor: 1.19 Btuh/ft2-F, Solar Heat Gain Coef: 0.83	NFRC U-factor: 0.3 Btuh/ft2-F, Solar Heat Gain Coef: 0.23	NFRC U-factor: 1.19 Btuh/ft2-F, Solar Heat Gain Coef: 0.83
Duct Leakage*	5%, sealed and tested	5%, sealed and tested	5%, sealed and tested	5%, sealed and tested
Kitchen, Laundry Appliances	Title 24	Title 24	Title 24	Title 24
Lighting	Title 24	Title 24	Title 24	Title 24

**Note: The historical data from the Title 24 - 2016 Residential Compliance Manual indicate the duct leakage to be 15%, but CBECC-Res software did not allow any changes to their default setting of 5%, sealed and tested ducts.*

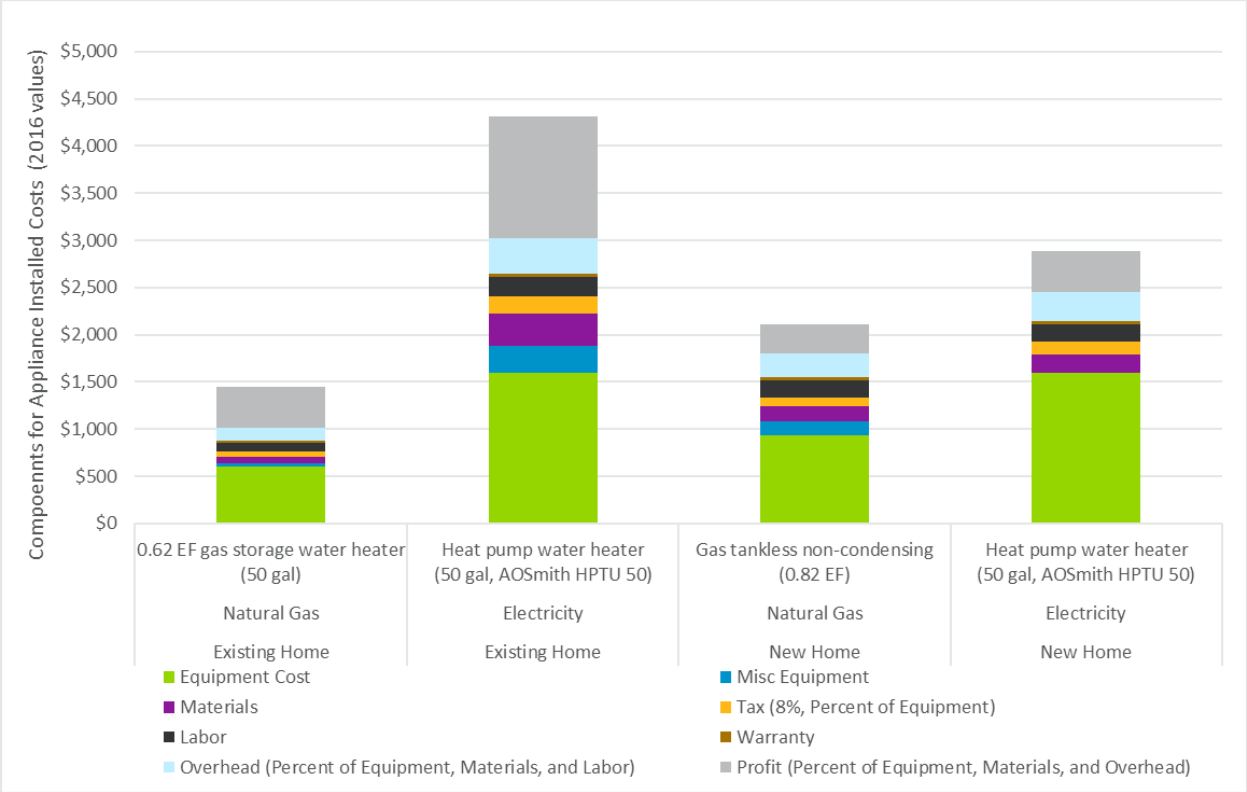
Source: Navigant analysis

A.2 Appliance Assumptions

There are four major appliances involved in electrification. Table A-2 details the technologies used in this analysis for existing homes, and Table A-3 details the technologies used in this analysis for new homes. Appliance costs below were estimated from KPF Group data for 2016 and increased by 5% to reflect 2020 values. The estimated costs assume the combined purchase, installation, and upgrade costs, including contractor overhead, profit, permit fees, and other factors that homeowners would experience

with professional installation. [44] Figure A-1 highlights the buildup of appliance purchase cost to installed costs for this analysis, including factors that are calculated as a percentage of material costs, such as profit, tax, and overhead. The electrical upgrade cost was extracted from a 2016 report for the City of Palo Alto.[45] Electrician subcontractor cost for HPWH was removed to avoid double counting upgrade cost.

Figure A-1. Representative Buildup of Appliance Cost in Analysis (2016 values, unadjusted for future years)



Source: Appliance costs from Gilbert Kitching of KPF Group in 2016. SoCalGas provided KPF Group research to Navigant for use in this report.

Navigant reviewed the cost estimates from KPF Group relative to other data sources, and the equipment costs appear higher for each type of equipment relative to what was observed from other sources, particularly for water heating. Lower installed cost estimates for electric HPWHs would reduce the incremental cost for all-electric homes. Nevertheless, these other sources may not reflect fully installed costs with local conditions, like the construction invoice and budget estimates compiled by KPF Group. For consistency across all appliance categories and home types, Navigant uses the KPF Group cost estimates for new and existing homes throughout the analysis and conducted a sensitivity analysis with

[44] Cost data for existing homes are based on 2016 data compiled by KPF Group based on construction invoice and budget estimates from Southern California builders and contractors. The estimated costs assume the combined purchase, installation, and upgrade costs, including contractor overhead, profit, permit fees that homeowners would experience with professional installation.

[45] TRC. "Palo Alto Electrification Final Report." City of Palo Alto. 2016. Available at: https://www.cityofpaloalto.org/civicax/filebank/documents/55069

the Low HPWH Cost Estimate. In this scenario, the lowest incremental cost ($550 from UC Berkeley / Berkeley Lab[46]) is applied to the gas water heater cost estimates from the KPF Group data. The results are presented both with Base HPWH Cost Estimate (2016 incremental cost of $2,867) and Low HPWH Cost Estimate (2016 incremental cost of $550).

Navigant assumed an annual inflation value of 2% for the years from 2020 to 2030 to adjust for the projected appliance and upgrade cost. The 2% inflation compounded annually resulted in a 22% cost increase from 2020 to 2030. To account for the increasing market adoption of the HPWHs and air-source heat pumps, Navigant used the NREL projection[47] of a 15% cost reduction of air-source heat pumps and a 20% cost reduction of HPWHs from 2020 to 2030.

Table A-2. Appliance Type and Projected 2020 Costs for Existing Homes

Appliance Type	Gas Appliances		Electric Appliances	
	Type	Cost	Type	Cost
Water Heating	0.62 EF gas storage water heater (50 gal)	• Equipment Cost: $628 • Total Installed Cost: $1,520	Heat pump water heater (50 gal, AOSmith HPTU 50, model selected in CBECC-Res)	Base HPWH Cost Estimate • Equipment Cost: $1,680 • Total Installed Cost: $4,529 Low HPWH Cost Estimate • Total Installed Cost: $2,097
Space Heating	14 SEER A/C; 80% gas furnace (3 ton)	• Equipment Cost: $1,739 • Total Installed Cost: $8,586	14 SEER, 8.2 HSPF heat pump (3 ton)	• Equipment Cost: $1,855 • Total Installed Cost: $8,560
Cooking	Baseline gas range/oven	• Equipment Cost: $990 • Total Installed Cost: $990	Baseline electric range/oven	• Equipment Cost: $740 • Total Installed Cost: $740
Clothes Dryer	Baseline gas dryer	• Equipment Cost: $593 • Total Installed Cost: $593	Baseline electric dryer	• Equipment Cost: $534 • Total Installed Cost: $534

Source: Cost data for existing homes based on KPF Group Appliance Data for existing home, fully installed cost in 2016. Base HPWH Cost Estimate uses KPF Group data, and Low HPWH Cost Estimate assumes incremental cost of $550 over gas water heater in 2016. HPWH model selected in dropdown menu in CBECC-Res software.

[46] Raghavan et al. 2017. "Scenarios to Decarbonize Residential Water Heating in California." Energy Policy, 109. 441-451. Available at: https://rael.berkeley.edu/publication/scenarios-to-decarbonize-residential-water-heating-in-california/

[47] NREL. 2017. "Electrification Future Study: End-Use Electric Technology Cost and Performance Projections through 2050". December 2017. Available at: https://www.nrel.gov/docs/fy18osti/70485.pdf

Table A-3. Appliance Type and Projected 2030 Costs for Existing Homes

Appliance Type	Gas Appliances		Electric Appliances	
	Type	Cost	Type	Cost
Water Heating	0.62 EF gas storage water heater (50 gal)	• Equipment Cost: $765 • Total Installed Cost: $1,853	Heat pump water heater (50 gal, AOSmith HPTU 50, model selected in CBECC-Res)	Base HPWH Cost Estimate • Equipment Cost: $1,712 • Total Installed Cost: $5,184 Low HPWH Cost Estimate • Total Installed Cost: $2,221
Space Heating	14 SEER A/C; 80% gas furnace (3 ton)	• Equipment Cost: $2,120 • Total Installed Cost: $10,466	14 SEER, 8.2 HSPF heat pump (3 ton)	• Equipment Cost: $1,983 • Total Installed Cost: $10,156
Cooking	Baseline gas range/oven	• Equipment Cost: $1,207 • Total Installed Cost: $1,207	Baseline electric range/oven	• Equipment Cost: $902 • Total Installed Cost: $902
Clothes Dryer	Baseline gas dryer	• Equipment Cost: $723 • Total Installed Cost: $723	Baseline electric dryer	• Equipment Cost: $651 • Total Installed Cost: $651

Source: Cost data for existing homes based on KPF Group Appliance Data for existing home, fully installed cost in 2016. Base HPWH Cost Estimate uses KPF Group data, and Low HPWH Cost Estimate assumes incremental cost of $550 over gas water heater in 2016. HPWH model selected in dropdown menu in CBECC-Res software.

Table A-4. Appliance Type and Projected 2020 Costs for New Homes

Appliance Type	Gas Appliances		Electric Appliances	
	Type	Cost	Type	Cost
Water Heating	Gas tankless non-condensing (0.82 EF)	• Equipment Cost: $986 • Total Installed Cost: $2,221	Heat pump water heater (50 gal, AOSmith HPTU 50, model selected in CBECC-Res)	Base HPWH Cost Estimate • Equipment Cost: $1,680 • Total Installed Cost: $3,031 Low HPWH Cost Estimate • Total Installed Cost: $2,798
Space Heating	14 SEER A/C; 80% gas furnace (3 ton)	• Equipment Cost: $1,580 • Total Installed Cost: $4,923	14 SEER, 8.2 HSPF heat pump (3 ton)	• Equipment Cost: $1,602 • Total Installed Cost: $4,839
Cooking	Baseline gas range/oven	• Equipment Cost: $990 • Total Installed Cost: $990	Baseline electric range/oven	• Equipment Cost: $740 • Total Installed Cost: $740
Clothes Dryer	Baseline gas dryer	• Equipment Cost: $593 • Total Installed Cost: $593	Baseline electric dryer	• Equipment Cost: $534 • Total Installed Cost: $534

Note. Title 24 code specifies tankless non-condensing water heater as basis of design.

Source: Cost data for existing homes based on KPF Group Appliance Data for new home, fully installed cost in 2016. Base HPWH Cost Estimate uses KPF Group data, and Low HPWH Cost Estimate assumes incremental cost of $550 over gas water heater in 2016. HPWH model selected in dropdown menu in CBECC-Res software.

Table A-5. Appliance Type and Projected 2030 Cost for New Homes

Appliance Type	Gas Appliances		Electric Appliances	
	Type	Cost	Type	Cost
Water Heating	Gas tankless non-condensing (0.82 EF)	• Equipment Cost: $1,202 • Total Installed Cost: $2,707	Heat pump water heater (50 gal, AOSmith HPTU 50, model selected in CBECC-Res)	Base HPWH Cost Estimate • Equipment Cost: $1,712 • Total Installed Cost: $3,359 Low HPWH Cost Estimate • Total Installed Cost: $3,075
Space Heating	14 SEER A/C; 80% gas furnace (3 ton)	• Equipment Cost: $1,926 • Total Installed Cost: $6,002	14 SEER, 8.2 HSPF heat pump (3 ton)	• Equipment Cost: $1,713 • Total Installed Cost: $5,659
Cooking	Baseline gas range/oven	• Equipment Cost: $1,207 • Total Installed Cost: $1,207	Baseline electric range/oven	• Equipment Cost: $902 • Total Installed Cost: $902
Clothes Dryer	Baseline gas dryer	• Equipment Cost: $723 • Total Installed Cost: $723	Baseline electric dryer	• Equipment Cost: $651 • Total Installed Cost: $651

Note. Title 24 code specifies tankless non-condensing water heater as basis of design.

Source: Cost data for existing homes based on KPF Group Appliance Data for new home, fully installed cost in 2016. Base HPWH Cost Estimate uses KPF Group data, and Low HPWH Cost Estimate assumes incremental cost of $550 over gas water heater in 2016. HPWH model selected in dropdown menu in CBECC-Res software.

A.3 Energy Cost Assumptions

Navigant extracted the average residential electricity rates in Table A-6 from the January 2017 IEPR Forecast.[48] For natural gas, Navigant used the SoCalGas utility rate from the August 2017 IEPR Forecast.[49] This analysis assumes average annual electricity and natural gas rates from the latest IEPR for 2020 and 2030. Navigant recognize that these rates may represent the lower end of possible electricity prices, as the rates do not reflect possible distribution, transmission, and generation needs to accommodate increased residential electricity loads. To understand the impacts that increased grid infrastructure requirements could have on electricity rates, the team analyzed a higher electricity rate scenario to bookend the IEPR rate scenario. The team applied an annual growth rate of 3.25% to the 2020 IEPR rates based on projections within LADWP's 2016 Final Integrated Resource Plan (IRP)[50] that represent the stacked impacts of increased RPS, energy storage, local solar, system reliability, and

[48] California Energy Commission. 2017. "Mid Case Final Baseline Demand Forecast - 2016 California Energy Demand Electricity Forecast Update." January 2017. Available at: http://www.energy.ca.gov/2016_energypolicy/documents/2016-12-08_workshop/mid_demand_case.php

[49] California Energy Commission. 2017. "California Energy Demand 2018-2028 Preliminary Baseline Forecast - Mid Demand Case." August 2017.Available at: http://www.energy.ca.gov/2017_energypolicy/documents/2017-08-03_workshop/2017-07-06_pre_demand_forecst.php

[50] LADWP. 2016. "2016 Power Integrated Resource Plan." December 2016. Available at: https://www.ladwp.com/ladwp/faces/wcnav_externalId/a-p-doc?_adf.ctrl-state=iirytk0lc_4&_afrLoop=35208544433395

electrification impacts. This high uncertainty projection is meant to capture an upper case scenario for future electricity rates based on other rate projections in the region.

Table A-6. Projected Utility Rates by Location

Location	Title 24 Climate Zone	2020		2030 - IEPR		2030 – Higher Electricity Rates	
		Natural Gas Rate ($/Th)	Electricity Rate ($/kWh)	Natural Gas Rate ($/Th)	Electricity Rate ($/kWh)	Natural Gas Rate ($/Th)	Electricity Rate ($/kWh)
Bakersfield*	13	SCG: $1.09	PG&E: $0.187	SCG: $1.28	PG&E: $0.196	SCG: $1.28	PG&E: $0.279
Riverside	10	SCG: $1.09	SCE: $0.179	SCG: $1.28	SCE: $0.201	SCG: $1.28	SCE: $0.256
Compton	8	SCG: $1.09	LADWP: $0.166	SCG: $1.28	LADWP: $0.181	SCG: $1.28	LADWP: $0.247
Oakland	3	PG&E: $1.59	PG&E: $0.187	PG&E: $1.82	PG&E: $0.196	PG&E: $1.82	PG&E: $0.279
Sacramento	12	PG&E: $1.59	SMUD: $0.143	PG&E: $1.82	SMUD: $0.165	PG&E: $1.82	SMUD: $0.216
San Diego	7	SDG&E: $1.52	SDG&E: $0.213	SDG&E: $1.75	SDG&E: $0.228	SDG&E: $1.75	SDG&E: $0.306

*Note: The selection of climate zones / location is intended to provide a range of heating and cooling loads, as well as gas and electric utility rates. The analysis results reflect the climate zone and the listed city is meant to locate the general region within the state. Bakersfield and the Climate Zone 13 area are by both SCG and PG&E for natural gas. This analysis uses SCG rates and using PG&E rates would result in higher gas energy bills and therefore lower bill increases due to electrification.

Source: Navigant analysis

A.4 Emissions Factor Assumptions

Navigant assumed a natural gas emissions factor of 0.0053 mtCO2e per therm (11.71 lbs CO2e per therm) from EIA estimates.[51] Navigant extracted the annual electricity emissions factor for electric technologies using the E3 Pathways model and "50% RPS Updated Scoping Plan" scenario.[52] The Pathways model is a long-horizon energy model used by California stakeholders to assess the GHG emissions impacts of California's energy demand and supply choices.

The emissions factor (mtCO2e per MWh) for electricity supply varies throughout the day, season, and year depending on the available renewable and non-renewable generation sources in California. This is especially true at higher RPS percentages in 2030 when zero-emissions resources cover the majority of state electricity supply needs at certain hours of the year.

Table A-7 highlights the historic emissions factors for delivered electricity statewide, PG&E territory, and SCE territory. Table A-8 provides the calculated GHG emissions factors for SoCalGas territory for 2016-

[51] EIA. 2016. "Carbon Dioxide Emissions Coefficients." February 2016. Available at: https://www.eia.gov/environment/emissions/co2_vol_mass.php

[52] California Air Resources Board. 2017 "2017 Scoping Plan, Appendix D Pathways." November 2017. Available at: https://www.arb.ca.gov/cc/scopingplan/2030sp_appd_pathways_final.pdf

2030, which are applied across all utility territories for this analysis. Navigant adjusted the hourly emissions factors from the E3 model to align with 2016 annual estimates by SCE and U.S. Environmental Protection Agency (EPA) Emissions & Generation Resource Integrated Database (eGRID) for electricity delivered to customers. The extracted data from the E3 model represents emissions for hourly electricity supply statewide and does not include downstream effects that impact the emissions of delivered electricity (e.g., transmission and distribution losses) or differences in Northern vs. Southern California grid. Navigant scaled the 2018-2030 hourly emissions factors to better reflect the emissions for delivered electricity in SoCalGas territory, while still maintaining the hourly distribution of renewable vs. non-renewable resources and RPS targets. Note that IOU-owned generation has lower GHG emissions than out-of-state sources, but only covers a portion of the electricity delivered to customers.

Table A-7. Historical Electricity Emissions Factors (mtCO2e per MWh)

Electricity Territory	2012	2013	2014	2015	2016	Source
Statewide	0.29	-	-	-	0.24	EPA eGRID
PG&E	-	0.20	0.20	0.19	-	PG&E annual report
SCE	-	0.37	0.26	0.23	0.24	SCE annual reports

Source: Statewide: EPA, Emissions & Generation Resource Integrated Database (eGRID)*. https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid*
PG&E: PG&E Corporation. Corporate Responsibility and Sustainability Report 2017*. 2017. http://www.pgecorp.com/corp_responsibility/reports/2017/en02_climate_change.html (accessed February 2018).*
SCE: SCE. 2016 Corporate Responsibility & Sustainability Report*, October 2017. https://www.edison.com/content/dam/eix/documents/investors/corporate_responsibility/2016-eix-corporate-responsibility-and-sustainability-report.pdf*

Table A-8. California RPS Targets and GHG Emissions Factor

Year	California RPS Targets and GHG Emissions Factor	
	RPS Target (%)	Emissions Factor (mtCO2e per MWh)
2016	25%	0.24
2017	30%	0.22
2018		0.21
2019		0.20
2020	33%	0.20
2021		0.19
2022		0.19
2023		0.19
2024	40%	0.18
2025		0.19
2026		0.18
2027	45%	0.18
2028		0.17
2029		0.17
2030	50%	0.16

Source: RPS Targets from California Energy Commission, California Energy Commission – Tracking Progress*, December 2017. http://www.energy.ca.gov/renewables/tracking_progress/documents/renewable.pdf.*
GHG Emissions factors from Navigant analysis.

APPENDIX B. DETAILED MODELING RESULTS WITH BASE HPWH COST ESTIMATE

Appendix B provides the full detailed results of the following analyses assuming Base HPWH Cost estimate:

- Section B.1. GHG Emissions Savings
- Section B.2. Costs for Electric Appliances and Upgrades (Assuming Electrical Infrastructure Costs are Required for Existing Homes)
- Section B.3. Costs for Electric Appliances and Upgrades (Assuming Electrical Infrastructure Costs are Not Required for Existing Homes)
- Section B.4. Annual Energy Bill Impact
- Section B.5. Homeowner Cost Comparison (Assuming Electrical Infrastructure Costs are Required for Existing Homes)
- Section B.6. Homeowner Cost Comparison (Assuming Electrical Infrastructure Costs are Not Required for Existing Homes)

B.1 GHG Emissions Savings

Table B-1. Total Home GHG Emissions and Savings in 2020

Home Design	Location	Household GHG Emissions (mtCO2e / Year)		GHG Emissions Savings (mtCO2e / Year)	GHG Emissions Savings
		Natural Gas Appliances	Electric Appliances		
Home A Existing Single-Family, 2,100 SF, 1-Story, No Solar PV	Bakersfield	3.5	2.1	1.4	39%
	Riverside	2.5	1.6	0.9	36%
	Compton	2.2	1.4	0.8	37%
	Oakland	3.2	1.6	1.5	48%
	Sacramento	3.4	1.9	1.5	44%
	San Diego	1.9	1.2	0.7	38%
Home B Existing Single-Family, 2,700 SF, 2-Story, No Solar PV	Bakersfield	4.3	2.7	1.7	38%
	Riverside	3.0	2.0	1.0	35%
	Compton	2.6	1.6	0.9	36%
	Oakland	3.6	1.9	1.6	46%
	Sacramento	4.1	2.3	1.8	44%
	San Diego	2.2	1.4	0.8	37%
Home B Existing Single-Family, 2,700 SF, 2-Story, 3 kW Solar PV	Bakersfield	3.4	1.8	1.7	49%
	Riverside	2.0	1.0	1.0	51%
	Compton	1.6	0.7	0.9	57%
	Oakland	2.6	1.0	1.6	63%
	Sacramento	3.2	1.4	1.8	57%
	San Diego	1.2	0.4	0.8	66%
Home C New Single-Family, 2,700 SF, 2-Story, Solar PV Requirement	Bakersfield	1.9	0.8	1.1	59%
	Riverside	1.3	0.6	0.7	56%
	Compton	1.1	0.5	0.6	56%
	Oakland	1.9	0.8	1.1	57%
	Sacramento	2.1	0.8	1.2	60%
	San Diego	1.0	0.4	0.6	55%
Home D Existing Multi-Family, 6,960 SF, 2-Story, 8 Unit Apartment Building, No Solar PV	Bakersfield	1.9	1.2	0.7	37%
	Riverside	1.6	1.0	0.6	38%
	Compton	1.5	0.9	0.6	41%
	Oakland	1.6	0.9	0.7	43%
	Sacramento	1.8	1.1	0.7	41%
	San Diego	1.4	0.8	0.6	42%

Table B-2. Total Home GHG Emissions and Savings in 2030

Home Design	Location	Household GHG Emissions (mtCO2e / Year)		GHG Emissions Savings (mtCO2e / Year)	GHG Emissions Savings
		Natural Gas Appliances	Electric Appliances		
Home A Existing Single-Family, 2,100 SF, 1-Story, No Solar PV	Bakersfield	3.3	1.8	1.5	46%
	Riverside	2.3	1.3	1.0	43%
	Compton	2.0	1.1	0.9	44%
	Oakland	3.0	1.3	1.7	56%
	Sacramento	3.2	1.5	1.7	52%
	San Diego	1.8	1.0	0.8	45%
Home B Existing Single-Family, 2,700 SF, 2-Story, No Solar PV	Bakersfield	4.0	2.2	1.8	46%
	Riverside	2.8	1.6	1.2	42%
	Compton	2.4	1.3	1.0	43%
	Oakland	3.4	1.6	1.8	54%
	Sacramento	3.9	1.9	2.0	51%
	San Diego	2.0	1.1	0.9	44%
Home B Existing Single-Family, 2,700 SF, 2-Story, 3 kW Solar PV	Bakersfield	3.3	1.4	1.8	56%
	Riverside	2.0	0.8	1.2	58%
	Compton	1.6	0.6	1.0	64%
	Oakland	2.6	0.8	1.8	69%
	Sacramento	3.1	1.1	2.0	64%
	San Diego	1.2	0.3	0.9	72%
Home C New Single-Family, 2,700 SF, 2-Story, Solar PV Requirement	Bakersfield	1.9	0.6	1.3	66%
	Riverside	1.3	0.5	0.8	64%
	Compton	1.1	0.4	0.7	64%
	Oakland	1.9	0.7	1.2	65%
	Sacramento	2.1	0.7	1.4	67%
	San Diego	1.0	0.4	0.6	63%
Home D Existing Multi-Family, 6,960 SF, 2-Story, 8 Unit Apartment Building, No Solar PV	Bakersfield	1.8	1.0	0.8	45%
	Riverside	1.5	0.8	0.7	45%
	Compton	1.4	0.7	0.7	47%
	Oakland	1.5	0.8	0.8	50%
	Sacramento	1.7	0.9	0.8	48%
	San Diego	1.3	0.7	0.7	49%

B.2 Costs for Electric Appliances and Upgrades (Assuming Electrical Infrastructure Costs are Required for Existing Homes)

Table B-3. 2020 Appliance Purchase, Installation, and Upgrade Costs for Existing Homes

Appliance Type	Single Family			Multi- Family		
	Appliance Cost		Cost Difference	Appliance Cost		Cost Difference
	Natural Gas	Electric		Natural Gas	Electric	
Water Heating	$1,520	$4,529	$3,009	$1,520	$4,529	$3,009
Space Heating	$8,586	$8,560	($26)	$8,586	$8,560	($26)
Cooking	$990	$740	($250)	$990	$740	($250)
Clothes Dryer	$593	$534	($59)	$593	$534	($59)
All Appliances	**$11,689**	**$14,363**	**$2,674**	**$11,689**	**$14,363**	**$2,674**
Electrical Upgrade	N/A	$4,671	$4,671	N/A	$4,399	$4,399
Total Cost	**$11,689**	**$19,034**	**$7,345**	**$11,689**	**$18,762**	**$7,073**

Table B-4. 2020 Appliance Purchase, Installation, and Upgrade Costs for New Homes

Appliance Type	Single Family		
	Appliance Cost		Cost Difference
	Natural Gas	Electric	
Water Heating	$2,221	$3,031	$811
Space Heating	$4,923	$4,839	($84)
Cooking	$990	$740	($250)
Clothes Dryer	$593	$534	($59)
All Appliances	**$8,728**	**$9,146**	**$418**
Electrical Upgrade	N/A	$50	$50
Total Cost	**$8,728**	**$9,196**	**$468**

Table B-5. 2030 Appliance Purchase, Installation, and Upgrade Costs for Existing Homes

Appliance Type	Single Family			Multi- Family		
	Appliance Cost		Cost Difference	Appliance Cost		Cost Difference
	Natural Gas	Electric		Natural Gas	Electric	
Water Heating	$1,853	$5,184	$3,332	$1,853	$5,184	$3,332
Space Heating	$10,466	$10,156	($310)	$10,466	$10,156	($310)
Cooking	$1,207	$902	($305)	$1,207	$902	($305)
Clothes Dryer	$723	$651	($72)	$723	$651	($72)
All Appliances	**$14,249**	**$16,894**	**$2,645**	**$14,249**	**$16,894**	**$2,645**
Electrical Upgrade	N/A	$5,694	$5,694	N/A	$5,362	$5,362
Total Cost	**$14,249**	**$22,588**	**$8,339**	**$14,249**	**$22,256**	**$8,007**

Table B-6. 2030 Appliance Purchase, Installation, and Upgrade Costs for New Homes

Appliance Type	Single Family		
	Appliance Cost		Cost Difference
	Natural Gas	Electric	
Water Heating	$2,707	$3,359	$652
Space Heating	$6,002	$5,659	($343)
Cooking	$1,207	$902	($305)
Clothes Dryer	$723	$651	($72)
All Appliances	**$10,639**	**$10,572**	**($67)**
Electrical Upgrade	N/A	$61	$61
Total Cost	**$10,639**	**$10,633**	**($6)**

B.3 Costs for Electric Appliances and Upgrades (Assuming Electrical Infrastructure Costs are Not Required for Existing Homes)

Table B-7. 2020 Appliance Purchase, Installation, and Upgrade Costs for Existing Homes

Appliance Type	Single Family			Multi- Family		
	Appliance Cost		Cost Difference	Appliance Cost		Cost Difference
	Natural Gas	Electric		Natural Gas	Electric	
Water Heating	$1,520	$4,529	$3,009	$1,520	$4,529	$3,009
Space Heating	$8,586	$8,560	($26)	$8,586	$8,560	($26)
Cooking	$990	$740	($250)	$990	$740	($250)
Clothes Dryer	$593	$534	($59)	$593	$534	($59)
All Appliances	**$11,689**	**$14,363**	**$2,674**	**$11,689**	**$14,363**	**$2,674**
Electrical Upgrade	$0	$0	$0	N/A	$0	$0
Total Cost	**$11,689**	**$14,363**	**$2,674**	**$11,689**	**$14,363**	**$2,674**

Table B-8. 2020 Appliance Purchase, Installation, and Upgrade Costs for New Homes

Appliance Type	Single Family		
	Appliance Cost		Cost Difference
	Natural Gas	Electric	
Water Heating	$2,221	$3,031	$811
Space Heating	$4,923	$4,839	($84)
Cooking	$990	$740	($250)
Clothes Dryer	$593	$534	($59)
All Appliances	**$8,728**	**$9,146**	**$418**
Electrical Upgrade	N/A	$50	$50
Total Cost	**$8,728**	**$9,196**	**$468**

Table B-9. 2030 Appliance Purchase, Installation, and Upgrade Costs for Existing Homes

Appliance Type	Single Family			Multi- Family		
	Appliance Cost		Cost Difference	Appliance Cost		Cost Difference
	Natural Gas	Electric		Natural Gas	Electric	
Water Heating	$1,853	$5,184	$3,332	$1,853	$5,184	$3,332
Space Heating	$10,466	$10,156	($310)	$10,466	$10,156	($310)
Cooking	$1,207	$902	($305)	$1,207	$902	($305)
Clothes Dryer	$723	$651	($72)	$723	$651	($72)
All Appliances	**$14,249**	**$16,894**	**$2,645**	**$14,249**	**$16,894**	**$2,645**
Electrical Upgrade	N/A	$0	$0	N/A	$0	$0
Total Cost	**$14,249**	**$16,894**	**$2,645**	**$14,249**	**$16,894**	**$2,645**

Table B-10. 2030 Appliance Purchase, Installation, and Upgrade Costs for New Homes

Appliance Type	Single Family		
	Appliance Cost		Cost Difference
	Natural Gas	Electric	
Water Heating	$2,707	$3,359	$652
Space Heating	$6,002	$5,659	($343)
Cooking	$1,207	$902	($305)
Clothes Dryer	$723	$651	($72)
All Appliances	**$10,639**	**$10,572**	**($67)**
Electrical Upgrade	N/A	$61	$61
Total Cost	**$10,639**	**$10,633**	**($6)**

B.4 Annual Energy Bill Impact

Table B-11. Annual Energy Bill Impact Based on 2020 IEPR Rates

Home Design	Location	Annual Energy Bill		Annual Energy Bill Impact	
		Home with Natural Gas Appliances	Home with Electric Appliances		
Home A Existing Single-Family, 2,100 SF, 1-Story, No Solar PV	Bakersfield	$1,728	$2,051	$323	19%
	Riverside	$1,285	$1,472	$187	15%
	Compton	$1,044	$1,168	$124	12%
	Oakland	$1,448	$1,564	$116	8%
	Sacramento	$1,455	$1,382	($73)	-5%
	San Diego	$1,185	$1,298	$113	10%
Home B Existing Single-Family, 2,700 SF, 2-Story, No Solar PV	Bakersfield	$2,159	$2,546	$387	18%
	Riverside	$1,578	$1,795	$217	14%
	Compton	$1,253	$1,394	$141	11%
	Oakland	$1,646	$1,830	$184	11%
	Sacramento	$1,773	$1,681	($91)	-5%
	San Diego	$1,370	$1,496	$126	9%
Home B Existing Single-Family, 2,700 SF, 2-Story, 3 kW Solar PV	Bakersfield	$1,293	$1,680	$387	30%
	Riverside	$706	$923	$217	31%
	Compton	$465	$605	$141	30%
	Oakland	$760	$944	$184	24%
	Sacramento	$1,099	$1,008	($91)	-8%
	San Diego	$324	$450	$126	39%
Home C New Single-Family, 2,700 SF, 2-Story, Solar PV Requirement	Bakersfield	$413	$758	$345	84%
	Riverside	$279	$520	$240	86%
	Compton	$230	$409	$180	78%
	Oakland	$558	$768	$210	38%
	Sacramento	$629	$615	($14)	-2%
	San Diego	$288	$487	$199	69%
Home D Existing Multi-Family, 6,960 SF, 2-Story, 8 Unit Apartment Building, No Solar PV	Bakersfield	$977	$1,134	$157	16%
	Riverside	$815	$908	$93	11%
	Compton	$707	$766	$58	8%
	Oakland	$830	$895	$65	8%
	Sacramento	$830	$792	($38)	-5%
	San Diego	$855	$905	$50	6%

Table B-12. Annual Energy Bill Impact Based on 2030 IEPR Rates

Home Design	Location	Annual Energy Bill		Annual Energy Bill Impact	
		Home with Natural Gas Appliances	Home with Electric Appliances		
Home A Existing Single-Family, 2,100 SF, 1-Story, No Solar PV	Bakersfield	$1,873	$2,156	$283	15%
	Riverside	$1,462	$1,658	$196	13%
	Compton	$1,161	$1,272	$112	10%
	Oakland	$1,591	$1,644	$53	3%
	Sacramento	$1,675	$1,597	($78)	-5%
	San Diego	$1,297	$1,391	$94	7%
Home B Existing Single-Family, 2,700 SF, 2-Story, No Solar PV	Bakersfield	$2,338	$2,676	$338	14%
	Riverside	$1,795	$2,022	$227	13%
	Compton	$1,391	$1,518	$127	9%
	Oakland	$1,807	$1,924	$117	6%
	Sacramento	$2,042	$1,944	($98)	-5%
	San Diego	$1,497	$1,602	$105	7%
Home B Existing Single-Family, 2,700 SF, 2-Story, 3 kW Solar PV	Bakersfield	$1,428	$1,766	$338	24%
	Riverside	$812	$1,039	$227	28%
	Compton	$532	$659	$127	24%
	Oakland	$876	$992	$117	13%
	Sacramento	$1,264	$1,166	($98)	-8%
	San Diego	$376	$482	$105	28%
Home C New Single-Family, 2,700 SF, 2-Story, Solar PV Requirement	Bakersfield	$484	$797	$313	65%
	Riverside	$328	$585	$257	78%
	Compton	$270	$446	$176	65%
	Oakland	$640	$807	$168	26%
	Sacramento	$722	$711	($11)	-1%
	San Diego	$332	$521	$189	57%
Home D Existing Multi-Family, 6,960 SF, 2-Story, 8 Unit Apartment Building, No Solar PV	Bakersfield	$1,056	$1,192	$136	13%
	Riverside	$927	$1,022	$94	10%
	Compton	$787	$834	$47	6%
	Oakland	$904	$940	$36	4%
	Sacramento	$957	$915	($41)	-4%
	San Diego	$937	$969	$32	3%

Table B-13. Annual Energy Bill Impact Based on Higher 2030 Electricity Rates

Home Design	Location	Annual Energy Bill		Annual Energy Bill Impact	
		Home with Natural Gas Appliances	Home with Electric Appliances		
Home A Existing Single-Family, 2,100 SF, 1-Story, No Solar PV	Bakersfield	$2,438	$3,058	$621	25%
	Riverside	$1,769	$2,112	$344	19%
	Compton	$1,469	$1,733	$264	18%
	Oakland	$1,911	$2,332	$421	22%
	Sacramento	$1,939	$2,086	$147	8%
	San Diego	$1,612	$1,867	$255	16%
Home B Existing Single-Family, 2,700 SF, 2-Story, No Solar PV	Bakersfield	$3,051	$3,796	$746	24%
	Riverside	$2,177	$2,575	$399	18%
	Compton	$1,769	$2,068	$299	17%
	Oakland	$2,179	$2,729	$550	25%
	Sacramento	$2,371	$2,539	$169	7%
	San Diego	$1,869	$2,151	$282	15%
Home B Existing Single-Family, 2,700 SF, 2-Story, 3 kW Solar PV	Bakersfield	$1,760	$2,506	$746	42%
	Riverside	$925	$1,324	$399	43%
	Compton	$599	$898	$299	50%
	Oakland	$858	$1,408	$550	64%
	Sacramento	$1,354	$1,523	$169	12%
	San Diego	$365	$646	$282	77%
Home C New Single-Family, 2,700 SF, 2-Story, Solar PV Requirement	Bakersfield	$495	$1,131	$635	128%
	Riverside	$334	$746	$411	123%
	Compton	$273	$607	$334	122%
	Oakland	$641	$1,145	$504	79%
	Sacramento	$726	$929	$203	28%
	San Diego	$333	$699	$366	110%
Home D Existing Multi-Family, 6,960 SF, 2-Story, 8 Unit Apartment Building, No Solar PV	Bakersfield	$1,385	$1,691	$306	22%
	Riverside	$1,121	$1,302	$181	16%
	Compton	$993	$1,136	$143	14%
	Oakland	$1,122	$1,334	$212	19%
	Sacramento	$1,126	$1,196	$69	6%
	San Diego	$1,157	$1,301	$144	12%

B.5 Homeowner Cost Comparison (Assuming Electrical Infrastructure Costs are Required)

Table B-14. 2020 Electrification Cost Increase Based on IEPR Rates vs. Median Household Income (Assuming Electrical Infrastructure Costs are Required for Existing Homes)

Home Design	Location	Net Electrification Cost	Annualized Electrification Cost (15 Years)	Annual Energy Bill Impact	Combined Annual Cost Increase	Median Household Income (2016)
Home A Existing Single-Family, 2,100 SF, 1-Story, No Solar PV	Bakersfield	$7,345	$490	$323	$813	$59,000
	Riverside	$7,345	$490	$187	$677	$59,000
	Compton	$7,345	$490	$124	$614	$45,000
	Oakland	$7,345	$490	$116	$606	$58,000
	Sacramento	$7,345	$490	($73)	$417	$52,000
	San Diego	$7,345	$490	$113	$603	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, No Solar PV	Bakersfield	$7,345	$490	$387	$877	$59,000
	Riverside	$7,345	$490	$217	$707	$59,000
	Compton	$7,345	$490	$141	$630	$45,000
	Oakland	$7,345	$490	$184	$674	$58,000
	Sacramento	$7,345	$490	($91)	$398	$52,000
	San Diego	$7,345	$490	$126	$616	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, 3 kW Solar PV	Bakersfield	$7,345	$490	$387	$877	$59,000
	Riverside	$7,345	$490	$217	$707	$59,000
	Compton	$7,345	$490	$141	$630	$45,000
	Oakland	$7,345	$490	$184	$674	$58,000
	Sacramento	$7,345	$490	($91)	$398	$52,000
	San Diego	$7,345	$490	$126	$616	$68,000
Home C New Single-Family, 2,700 SF, 2-Story, Solar PV Requirement	Bakersfield	$468	$31	$345	$376	$59,000
	Riverside	$468	$31	$240	$271	$59,000
	Compton	$468	$31	$180	$211	$45,000
	Oakland	$468	$31	$210	$241	$58,000
	Sacramento	$468	$31	($14)	$17	$52,000
	San Diego	$468	$31	$199	$230	$68,000
Home D Existing Multi-Family, 6,960 SF, 2-Story, 8 Unit Apartment Building, No Solar PV	Bakersfield	$7,073	$472	$157	$629	$59,000
	Riverside	$7,073	$472	$93	$564	$59,000
	Compton	$7,073	$472	$58	$530	$45,000
	Oakland	$7,073	$472	$65	$536	$58,000
	Sacramento	$7,073	$472	($38)	$433	$52,000
	San Diego	$7,073	$472	$50	$522	$68,000

Table B-15. 2030 Electrification Cost Increase Based on IEPR Rates vs. Median Household Income (Assuming Electrical Infrastructure Costs are Required for Existing Homes)

Home Design	Location	Net Electrification Cost	Annualized Electrification Cost (15 Years)	Annual Energy Bill Impact	Combined Annual Cost Increase	Median Household Income (2016)
Home A Existing Single-Family, 2,100 SF, 1-Story, No Solar PV	Bakersfield	$8,339	$556	$283	$839	$59,000
	Riverside	$8,339	$556	$196	$751	$59,000
	Compton	$8,339	$556	$112	$668	$45,000
	Oakland	$8,339	$556	$53	$609	$58,000
	Sacramento	$8,339	$556	($78)	$478	$52,000
	San Diego	$8,339	$556	$94	$650	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, No Solar PV	Bakersfield	$8,339	$556	$338	$894	$59,000
	Riverside	$8,339	$556	$227	$783	$59,000
	Compton	$8,339	$556	$127	$683	$45,000
	Oakland	$8,339	$556	$117	$673	$58,000
	Sacramento	$8,339	$556	($98)	$458	$52,000
	San Diego	$8,339	$556	$105	$661	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, 3 kW Solar PV	Bakersfield	$8,339	$556	$338	$894	$59,000
	Riverside	$8,339	$556	$227	$783	$59,000
	Compton	$8,339	$556	$127	$683	$45,000
	Oakland	$8,339	$556	$117	$673	$58,000
	Sacramento	$8,339	$556	($98)	$458	$52,000
	San Diego	$8,339	$556	$105	$661	$68,000
Home C New Single-Family, 2,700 SF, 2-Story, Solar PV Requirement	Bakersfield	($6)	($0)	$313	$313	$59,000
	Riverside	($6)	($0)	$257	$256	$59,000
	Compton	($6)	($0)	$176	$175	$45,000
	Oakland	($6)	($0)	$168	$167	$58,000
	Sacramento	($6)	($0)	($11)	($11)	$52,000
	San Diego	($6)	($0)	$189	$189	$68,000
Home D Existing Multi-Family, 6,960 SF, 2-Story, 8 Unit Apartment Building, No Solar PV	Bakersfield	$8,007	$534	$136	$670	$59,000
	Riverside	$8,007	$534	$94	$628	$59,000
	Compton	$8,007	$534	$47	$581	$45,000
	Oakland	$8,007	$534	$36	$570	$58,000
	Sacramento	$8,007	$534	($41)	$493	$52,000
	San Diego	$8,007	$534	$32	$566	$68,000

Table B-16. 2030 Electrification Cost Increase Based on Higher Electricity Rates vs. Median Household Income (Assuming Electrical Infrastructure Costs are Required for Existing Homes)

Home Design	Location	Net Electrification Cost	Annualized Electrification Cost (15 Years)	Annual Energy Bill Impact	Combined Annual Cost Increase	Median Household Income (2016)
Home A Existing Single-Family, 2,100 SF, 1-Story, No Solar PV	Bakersfield	$8,339	$556	$621	$1,176	$59,000
	Riverside	$8,339	$556	$344	$899	$59,000
	Compton	$8,339	$556	$264	$820	$45,000
	Oakland	$8,339	$556	$421	$977	$58,000
	Sacramento	$8,339	$556	$147	$703	$52,000
	San Diego	$8,339	$556	$255	$811	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, No Solar PV	Bakersfield	$8,339	$556	$746	$1,302	$59,000
	Riverside	$8,339	$556	$399	$954	$59,000
	Compton	$8,339	$556	$299	$855	$45,000
	Oakland	$8,339	$556	$550	$1,106	$58,000
	Sacramento	$8,339	$556	$169	$724	$52,000
	San Diego	$8,339	$556	$282	$838	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, 3 kW Solar PV	Bakersfield	$8,339	$556	$746	$1,302	$59,000
	Riverside	$8,339	$556	$399	$954	$59,000
	Compton	$8,339	$556	$299	$855	$45,000
	Oakland	$8,339	$556	$550	$1,106	$58,000
	Sacramento	$8,339	$556	$169	$724	$52,000
	San Diego	$8,339	$556	$282	$838	$68,000
Home C New Single-Family, 2,700 SF, 2-Story, Solar PV Requirement	Bakersfield	($6)	($0)	$635	$635	$59,000
	Riverside	($6)	($0)	$411	$411	$59,000
	Compton	($6)	($0)	$334	$334	$45,000
	Oakland	($6)	($0)	$504	$504	$58,000
	Sacramento	($6)	($0)	$203	$203	$52,000
	San Diego	($6)	($0)	$366	$366	$68,000
Home D Existing Multi-Family, 6,960 SF, 2-Story, 8 Unit Apartment Building, No Solar PV	Bakersfield	$8,007	$534	$306	$840	$59,000
	Riverside	$8,007	$534	$181	$715	$59,000
	Compton	$8,007	$534	$143	$677	$45,000
	Oakland	$8,007	$534	$212	$746	$58,000
	Sacramento	$8,007	$534	$69	$603	$52,000
	San Diego	$8,007	$534	$144	$678	$68,000

B.6 Homeowner Cost Comparison (Assuming Electrical Infrastructure Costs are Not Required)

Table B-17. 2020 Electrification Cost Increase Based on IEPR Rates vs. Median Household Income (Assuming Electrical Infrastructure Costs are Not Required for Existing Homes)

Home Design	Location	Net Electrification Cost	Annualized Electrification Cost (15 Years)	Annual Energy Bill Impact	Combined Annual Cost Increase	Median Household Income (2016)
Home A Existing Single-Family, 2,100 SF, 1-Story, No Solar PV	Bakersfield	$2,674	$178	$323	$502	$59,000
	Riverside	$2,674	$178	$187	$366	$59,000
	Compton	$2,674	$178	$124	$302	$45,000
	Oakland	$2,674	$178	$116	$294	$58,000
	Sacramento	$2,674	$178	($73)	$105	$52,000
	San Diego	$2,674	$178	$113	$291	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, No Solar PV	Bakersfield	$2,674	$178	$387	$565	$59,000
	Riverside	$2,674	$178	$217	$396	$59,000
	Compton	$2,674	$178	$141	$319	$45,000
	Oakland	$2,674	$178	$184	$362	$58,000
	Sacramento	$2,674	$178	($91)	$87	$52,000
	San Diego	$2,674	$178	$126	$304	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, 3 kW Solar PV	Bakersfield	$2,674	$178	$387	$565	$59,000
	Riverside	$2,674	$178	$217	$396	$59,000
	Compton	$2,674	$178	$141	$319	$45,000
	Oakland	$2,674	$178	$184	$362	$58,000
	Sacramento	$2,674	$178	($91)	$87	$52,000
	San Diego	$2,674	$178	$126	$304	$68,000
Home C New Single-Family, 2,700 SF, 2-Story, Solar PV Requirement	Bakersfield	$468	$31	$345	$376	$59,000
	Riverside	$468	$31	$240	$271	$59,000
	Compton	$468	$31	$180	$211	$45,000
	Oakland	$468	$31	$210	$241	$58,000
	Sacramento	$468	$31	($14)	$17	$52,000
	San Diego	$468	$31	$199	$230	$68,000
Home D Existing Multi-Family, 6,960 SF, 2-Story, 8 Unit Apartment Building, No Solar PV	Bakersfield	$2,674	$178	$157	$335	$59,000
	Riverside	$2,674	$178	$93	$271	$59,000
	Compton	$2,674	$178	$58	$237	$45,000
	Oakland	$2,674	$178	$65	$243	$58,000
	Sacramento	$2,674	$178	($38)	$140	$52,000
	San Diego	$2,674	$178	$50	$228	$68,000

Table B-18. 2030 Electrification Cost Increase Based on IEPR Rates vs. Median Household Income (Assuming Electrical Infrastructure Costs are Not Required for Existing Homes)

Home Design	Location	Net Electrification Cost	Annualized Electrification Cost (15 Years)	Annual Energy Bill Impact	Combined Annual Cost Increase	Median Household Income (2016)
Home A Existing Single-Family, 2,100 SF, 1-Story, No Solar PV	Bakersfield	$2,645	$176	$283	$460	$59,000
	Riverside	$2,645	$176	$196	$372	$59,000
	Compton	$2,645	$176	$112	$288	$45,000
	Oakland	$2,645	$176	$53	$229	$58,000
	Sacramento	$2,645	$176	($78)	$98	$52,000
	San Diego	$2,645	$176	$94	$270	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, No Solar PV	Bakersfield	$2,645	$176	$338	$514	$59,000
	Riverside	$2,645	$176	$227	$403	$59,000
	Compton	$2,645	$176	$127	$303	$45,000
	Oakland	$2,645	$176	$117	$293	$58,000
	Sacramento	$2,645	$176	($98)	$79	$52,000
	San Diego	$2,645	$176	$105	$282	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, 3 kW Solar PV	Bakersfield	$2,645	$176	$338	$514	$59,000
	Riverside	$2,645	$176	$227	$403	$59,000
	Compton	$2,645	$176	$127	$303	$45,000
	Oakland	$2,645	$176	$117	$293	$58,000
	Sacramento	$2,645	$176	($98)	$79	$52,000
	San Diego	$2,645	$176	$105	$282	$68,000
Home C New Single-Family, 2,700 SF, 2-Story, Solar PV Requirement	Bakersfield	($6)	($0)	$313	$313	$59,000
	Riverside	($6)	($0)	$257	$256	$59,000
	Compton	($6)	($0)	$176	$175	$45,000
	Oakland	($6)	($0)	$168	$167	$58,000
	Sacramento	($6)	($0)	($11)	($11)	$52,000
	San Diego	($6)	($0)	$189	$189	$68,000
Home D Existing Multi-Family, 6,960 SF, 2-Story, 8 Unit Apartment Building, No Solar PV	Bakersfield	$2,645	$176	$136	$312	$59,000
	Riverside	$2,645	$176	$94	$271	$59,000
	Compton	$2,645	$176	$47	$223	$45,000
	Oakland	$2,645	$176	$36	$212	$58,000
	Sacramento	$2,645	$176	($41)	$135	$52,000
	San Diego	$2,645	$176	$32	$209	$68,000

Table B-19. 2030 Electrification Cost Increase Based on Higher Electricity Rates vs. Median Household Income (Assuming Electrical Infrastructure Costs are Not Required for Existing Homes)

Home Design	Location	Net Electrification Cost	Annualized Electrification Cost (15 Years)	Annual Energy Bill Impact	Combined Annual Cost Increase	Median Household Income (2016)
Home A Existing Single-Family, 2,100 SF, 1-Story, No Solar PV	Bakersfield	$2,645	$176	$621	$797	$59,000
	Riverside	$2,645	$176	$344	$520	$59,000
	Compton	$2,645	$176	$264	$440	$45,000
	Oakland	$2,645	$176	$421	$597	$58,000
	Sacramento	$2,645	$176	$147	$323	$52,000
	San Diego	$2,645	$176	$255	$431	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, No Solar PV	Bakersfield	$2,645	$176	$746	$922	$59,000
	Riverside	$2,645	$176	$399	$575	$59,000
	Compton	$2,645	$176	$299	$475	$45,000
	Oakland	$2,645	$176	$550	$726	$58,000
	Sacramento	$2,645	$176	$169	$345	$52,000
	San Diego	$2,645	$176	$282	$458	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, 3 kW Solar PV	Bakersfield	$2,645	$176	$746	$922	$59,000
	Riverside	$2,645	$176	$399	$575	$59,000
	Compton	$2,645	$176	$299	$475	$45,000
	Oakland	$2,645	$176	$550	$726	$58,000
	Sacramento	$2,645	$176	$169	$345	$52,000
	San Diego	$2,645	$176	$282	$458	$68,000
Home C New Single-Family, 2,700 SF, 2-Story, Solar PV Requirement	Bakersfield	($6)	($0)	$635	$635	$59,000
	Riverside	($6)	($0)	$411	$411	$59,000
	Compton	($6)	($0)	$334	$334	$45,000
	Oakland	($6)	($0)	$504	$504	$58,000
	Sacramento	($6)	($0)	$203	$203	$52,000
	San Diego	($6)	($0)	$366	$366	$68,000
Home D Existing Multi-Family, 6,960 SF, 2-Story, 8 Unit Apartment Building, No Solar PV	Bakersfield	$2,645	$176	$306	$482	$59,000
	Riverside	$2,645	$176	$181	$358	$59,000
	Compton	$2,645	$176	$143	$319	$45,000
	Oakland	$2,645	$176	$212	$389	$58,000
	Sacramento	$2,645	$176	$69	$246	$52,000
	San Diego	$2,645	$176	$144	$321	$68,000

APPENDIX C. DETAILED MODELING RESULTS WITH LOW HPWH COST ESTIMATE

Appendix C provides the full detailed results of the following analyses assuming Low HPWH Cost estimate:

- Section C.1. GHG Emissions Savings
- Section C.2. Costs for Electric Appliances and Upgrades (Assuming Electrical Infrastructure Costs are Required for Existing Homes)
- Section C.3. Costs for Electric Appliances and Upgrades (Assuming Electrical Infrastructure Costs are Not Required for Existing Homes)
- Section C.4. Annual Energy Bill Impact
- Section C.5. Homeowner Cost Comparison (Assuming Electrical Infrastructure Costs are Required for Existing Homes)
- Section C.6. Homeowner Cost Comparison (Assuming Electrical Infrastructure Costs are Not Required for Existing Homes)

C.1 GHG Emissions Savings

Table C-1. Total Home GHG Emissions and Savings in 2020

Home Design	Location	Household GHG Emissions (mtCO2e / Year)		GHG Emissions Savings (mtCO2e / Year)	GHG Emissions Savings
		Natural Gas Appliances	Electric Appliances		
Home A Existing Single-Family, 2,100 SF, 1-Story, No Solar PV	Bakersfield	3.5	2.1	1.4	39%
	Riverside	2.5	1.6	0.9	36%
	Compton	2.2	1.4	0.8	37%
	Oakland	3.2	1.6	1.5	48%
	Sacramento	3.4	1.9	1.5	44%
	San Diego	1.9	1.2	0.7	38%
Home B Existing Single-Family, 2,700 SF, 2-Story, No Solar PV	Bakersfield	4.3	2.7	1.7	38%
	Riverside	3.0	2.0	1.0	35%
	Compton	2.6	1.6	0.9	36%
	Oakland	3.6	1.9	1.6	46%
	Sacramento	4.1	2.3	1.8	44%
	San Diego	2.2	1.4	0.8	37%
Home B Existing Single-Family, 2,700 SF, 2-Story, 3 kW Solar PV	Bakersfield	3.4	1.8	1.7	49%
	Riverside	2.0	1.0	1.0	51%
	Compton	1.6	0.7	0.9	57%
	Oakland	2.6	1.0	1.6	63%
	Sacramento	3.2	1.4	1.8	57%
	San Diego	1.2	0.4	0.8	66%
Home C New Single-Family, 2,700 SF, 2-Story, Solar PV Requirement	Bakersfield	1.9	0.8	1.1	59%
	Riverside	1.3	0.6	0.7	56%
	Compton	1.1	0.5	0.6	56%
	Oakland	1.9	0.8	1.1	57%
	Sacramento	2.1	0.8	1.2	60%
	San Diego	1.0	0.4	0.6	55%
Home D Existing Multi-Family, 6,960 SF, 2-Story, 8 Unit Apartment Building, No Solar PV	Bakersfield	1.9	1.2	0.7	37%
	Riverside	1.6	1.0	0.6	38%
	Compton	1.5	0.9	0.6	41%
	Oakland	1.6	0.9	0.7	43%
	Sacramento	1.8	1.1	0.7	41%
	San Diego	1.4	0.8	0.6	42%

Table C-2. Total Home GHG Emissions and Savings in 2030

Home Design	Location	Household GHG Emissions (mtCO2e / Year)		GHG Emissions Savings (mtCO2e / Year)	GHG Emissions Savings
		Natural Gas Appliances	Electric Appliances		
Home A Existing Single-Family, 2,100 SF, 1-Story, No Solar PV	Bakersfield	3.3	1.8	1.5	46%
	Riverside	2.3	1.3	1.0	43%
	Compton	2.0	1.1	0.9	44%
	Oakland	3.0	1.3	1.7	56%
	Sacramento	3.2	1.5	1.7	52%
	San Diego	1.8	1.0	0.8	45%
Home B Existing Single-Family, 2,700 SF, 2-Story, No Solar PV	Bakersfield	4.0	2.2	1.8	46%
	Riverside	2.8	1.6	1.2	42%
	Compton	2.4	1.3	1.0	43%
	Oakland	3.4	1.6	1.8	54%
	Sacramento	3.9	1.9	2.0	51%
	San Diego	2.0	1.1	0.9	44%
Home B Existing Single-Family, 2,700 SF, 2-Story, 3 kW Solar PV	Bakersfield	3.3	1.4	1.8	56%
	Riverside	2.0	0.8	1.2	58%
	Compton	1.6	0.6	1.0	64%
	Oakland	2.6	0.8	1.8	69%
	Sacramento	3.1	1.1	2.0	64%
	San Diego	1.2	0.3	0.9	72%
Home C New Single-Family, 2,700 SF, 2-Story, Solar PV Requirement	Bakersfield	1.9	0.6	1.3	66%
	Riverside	1.3	0.5	0.8	64%
	Compton	1.1	0.4	0.7	64%
	Oakland	1.9	0.7	1.2	65%
	Sacramento	2.1	0.7	1.4	67%
	San Diego	1.0	0.4	0.6	63%
Home D Existing Multi-Family, 6,960 SF, 2-Story, 8 Unit Apartment Building, No Solar PV	Bakersfield	1.8	1.0	0.8	45%
	Riverside	1.5	0.8	0.7	45%
	Compton	1.4	0.7	0.7	47%
	Oakland	1.5	0.8	0.8	50%
	Sacramento	1.7	0.9	0.8	48%
	San Diego	1.3	0.7	0.7	49%

C.2 Costs for Electric Appliances and Upgrades (Assuming Electrical Infrastructure Costs are Required for Existing Homes)

Table C-3. 2020 Appliance Purchase, Installation, and Upgrade Costs for Existing Homes

Appliance Type	Single Family			Multi- Family		
	Appliance Cost		Cost Difference	Appliance Cost		Cost Difference
	Natural Gas	Electric		Natural Gas	Electric	
Water Heating	$1,520	$2,097	$578	$1,520	$2,097	$578
Space Heating	$8,586	$8,560	($26)	$8,586	$8,560	($26)
Cooking	$990	$740	($250)	$990	$740	($250)
Clothes Dryer	$593	$534	($59)	$593	$534	($59)
All Appliances	**$11,689**	**$11,932**	**$243**	**$11,689**	**$11,932**	**$243**
Electrical Upgrade	N/A	$4,671	$4,671	N/A	$4,399	$4,399
Total Cost	**$11,689**	**$16,603**	**$4,914**	**$11,689**	**$16,331**	**$4,642**

Table C-4. 2020 Appliance Purchase, Installation, and Upgrade Costs for New Homes

Appliance Type	Single Family		
	Appliance Cost		Cost Difference
	Natural Gas	Electric	
Water Heating	$2,221	$2,798	$578
Space Heating	$4,923	$4,839	($84)
Cooking	$990	$740	($250)
Clothes Dryer	$593	$534	($59)
All Appliances	**$8,728**	**$8,912**	**$185**
Electrical Upgrade	N/A	$50	$50
Total Cost	**$8,728**	**$8,962**	**$235**

Table C-5. 2030 Appliance Purchase, Installation, and Upgrade Costs for Existing Homes

Appliance Type	Single Family			Multi- Family		
	Appliance Cost		Cost Difference	Appliance Cost		Cost Difference
	Natural Gas	Electric		Natural Gas	Electric	
Water Heating	$1,853	$2,221	$368	$1,853	$2,221	$368
Space Heating	$10,466	$10,156	($310)	$10,466	$10,156	($310)
Cooking	$1,207	$902	($305)	$1,207	$902	($305)
Clothes Dryer	$723	$651	($72)	$723	$651	($72)
All Appliances	**$14,249**	**$13,930**	**($319)**	**$14,249**	**$13,930**	**($319)**
Electrical Upgrade	N/A	$5,694	$5,694	N/A	$5,362	$5,362
Total Cost	**$14,249**	**$19,624**	**$5,375**	**$14,249**	**$19,293**	**$5,044**

Table C-6. 2030 Appliance Purchase, Installation, and Upgrade Costs for New Homes

Appliance Type	Single Family		
	Appliance Cost		Cost Difference
	Natural Gas	Electric	
Water Heating	$2,707	$3,075	$368
Space Heating	$6,002	$5,659	($343)
Cooking	$1,207	$902	($305)
Clothes Dryer	$723	$651	($72)
All Appliances	**$10,639**	**$10,288**	**($351)**
Electrical Upgrade	N/A	$61	$61
Total Cost	**$10,639**	**$10,349**	**($290)**

C.3 Costs for Electric Appliances and Upgrades (Assuming Electrical Infrastructure Costs are Not Required for Existing Homes)

Table C-7. 2020 Appliance Purchase, Installation, and Upgrade Costs for Existing Homes

Appliance Type	Single Family			Multi- Family		
	Appliance Cost		Cost Difference	Appliance Cost		Cost Difference
	Natural Gas	Electric		Natural Gas	Electric	
Water Heating	$1,520	$2,097	$578	$1,520	$2,097	$578
Space Heating	$8,586	$8,560	($26)	$8,586	$8,560	($26)
Cooking	$990	$740	($250)	$990	$740	($250)
Clothes Dryer	$593	$534	($59)	$593	$534	($59)
All Appliances	**$11,689**	**$11,932**	**$243**	**$11,689**	**$11,932**	**$243**
Electrical Upgrade	$0	$0	$0	$0	$0	$0
Total Cost	**$11,689**	**$11,932**	**$243**	**$11,689**	**$11,932**	**$243**

Table C-8. 2020 Appliance Purchase, Installation, and Upgrade Costs for New Homes

Appliance Type	Single Family		
	Appliance Cost		Cost Difference
	Natural Gas	Electric	
Water Heating	$2,221	$2,798	$578
Space Heating	$4,923	$4,839	($84)
Cooking	$990	$740	($250)
Clothes Dryer	$593	$534	($59)
All Appliances	**$8,728**	**$8,912**	**$185**
Electrical Upgrade	N/A	$50	$50
Total Cost	**$8,728**	**$8,962**	**$235**

Table C-9. 2030 Appliance Purchase, Installation, and Upgrade Costs for Existing Homes

Appliance Type	Single Family			Multi- Family		
	Appliance Cost		Cost Difference	Appliance Cost		Cost Difference
	Natural Gas	Electric		Natural Gas	Electric	
Water Heating	$1,853	$2,221	$368	$1,853	$2,221	$368
Space Heating	$10,466	$10,156	($310)	$10,466	$10,156	($310)
Cooking	$1,207	$902	($305)	$1,207	$902	($305)
Clothes Dryer	$723	$651	($72)	$723	$651	($72)
All Appliances	**$14,249**	**$13,930**	**($319)**	**$14,249**	**$13,930**	**($319)**
Electrical Upgrade	N/A	$0	$0	N/A	$0	$0
Total Cost	**$14,249**	**$13,930**	**($319)**	**$14,249**	**$13,930**	**($319)**

Table C-10. 2030 Appliance Purchase, Installation, and Upgrade Costs for New Homes

Appliance Type	Single Family		
	Appliance Cost		Cost Difference
	Natural Gas	Electric	
Water Heating	$2,707	$3,075	$368
Space Heating	$6,002	$5,659	($343)
Cooking	$1,207	$902	($305)
Clothes Dryer	$723	$651	($72)
All Appliances	**$10,639**	**$10,288**	**($351)**
Electrical Upgrade	N/A	$61	$61
Total Cost	**$10,639**	**$10,349**	**($290)**

C.4 Annual Energy Bill Impact

Table C-11. Annual Energy Bill Impact Based on 2020 IEPR Rates

Home Design	Location	Annual Energy Bill		Annual Energy Bill Impact	
		Home with Natural Gas Appliances	Home with Electric Appliances		
Home A Existing Single-Family, 2,100 SF, 1-Story, No Solar PV	Bakersfield	$1,728	$2,051	$323	19%
	Riverside	$1,285	$1,472	$187	15%
	Compton	$1,044	$1,168	$124	12%
	Oakland	$1,448	$1,564	$116	8%
	Sacramento	$1,455	$1,382	($73)	-5%
	San Diego	$1,185	$1,298	$113	10%
Home B Existing Single-Family, 2,700 SF, 2-Story, No Solar PV	Bakersfield	$2,159	$2,546	$387	18%
	Riverside	$1,578	$1,795	$217	14%
	Compton	$1,253	$1,394	$141	11%
	Oakland	$1,646	$1,830	$184	11%
	Sacramento	$1,773	$1,681	($91)	-5%
	San Diego	$1,370	$1,496	$126	9%
Home B Existing Single-Family, 2,700 SF, 2-Story, 3 kW Solar PV	Bakersfield	$1,293	$1,680	$387	30%
	Riverside	$706	$923	$217	31%
	Compton	$465	$605	$141	30%
	Oakland	$760	$944	$184	24%
	Sacramento	$1,099	$1,008	($91)	-8%
	San Diego	$324	$450	$126	39%
Home C New Single-Family, 2,700 SF, 2-Story, Solar PV Requirement	Bakersfield	$413	$758	$345	84%
	Riverside	$279	$520	$240	86%
	Compton	$230	$409	$180	78%
	Oakland	$558	$768	$210	38%
	Sacramento	$629	$615	($14)	-2%
	San Diego	$288	$487	$199	69%
Home D Existing Multi-Family, 6,960 SF, 2-Story, 8 Unit Apartment Building, No Solar PV	Bakersfield	$977	$1,134	$157	16%
	Riverside	$815	$908	$93	11%
	Compton	$707	$766	$58	8%
	Oakland	$830	$895	$65	8%
	Sacramento	$830	$792	($38)	-5%
	San Diego	$855	$905	$50	6%

Table C-12. Annual Energy Bill Impact Based on 2030 IEPR Rates

Home Design	Location	Annual Energy Bill		Annual Energy Bill Impact	
		Home with Natural Gas Appliances	Home with Electric Appliances		
Home A Existing Single-Family, 2,100 SF, 1-Story, No Solar PV	Bakersfield	$1,873	$2,156	$283	15%
	Riverside	$1,462	$1,658	$196	13%
	Compton	$1,161	$1,272	$112	10%
	Oakland	$1,591	$1,644	$53	3%
	Sacramento	$1,675	$1,597	($78)	-5%
	San Diego	$1,297	$1,391	$94	7%
Home B Existing Single-Family, 2,700 SF, 2-Story, No Solar PV	Bakersfield	$2,338	$2,676	$338	14%
	Riverside	$1,795	$2,022	$227	13%
	Compton	$1,391	$1,518	$127	9%
	Oakland	$1,807	$1,924	$117	6%
	Sacramento	$2,042	$1,944	($98)	-5%
	San Diego	$1,497	$1,602	$105	7%
Home B Existing Single-Family, 2,700 SF, 2-Story, 3 kW Solar PV	Bakersfield	$1,428	$1,766	$338	24%
	Riverside	$812	$1,039	$227	28%
	Compton	$532	$659	$127	24%
	Oakland	$876	$992	$117	13%
	Sacramento	$1,264	$1,166	($98)	-8%
	San Diego	$376	$482	$105	28%
Home C New Single-Family, 2,700 SF, 2-Story, Solar PV Requirement	Bakersfield	$484	$797	$313	65%
	Riverside	$328	$585	$257	78%
	Compton	$270	$446	$176	65%
	Oakland	$640	$807	$168	26%
	Sacramento	$722	$711	($11)	-1%
	San Diego	$332	$521	$189	57%
Home D Existing Multi-Family, 6,960 SF, 2-Story, 8 Unit Apartment Building, No Solar PV	Bakersfield	$1,056	$1,192	$136	13%
	Riverside	$927	$1,022	$94	10%
	Compton	$787	$834	$47	6%
	Oakland	$904	$940	$36	4%
	Sacramento	$957	$915	($41)	-4%
	San Diego	$937	$969	$32	3%

Table C-13. Annual Energy Bill Impact Based on Higher 2030 Electricity Rates

Home Design	Location	Annual Energy Bill		Annual Energy Bill Impact	
		Home with Natural Gas Appliances	Home with Electric Appliances		
Home A Existing Single-Family, 2,100 SF, 1-Story, No Solar PV	Bakersfield	$2,438	$3,058	$621	25%
	Riverside	$1,769	$2,112	$344	19%
	Compton	$1,469	$1,733	$264	18%
	Oakland	$1,911	$2,332	$421	22%
	Sacramento	$1,939	$2,086	$147	8%
	San Diego	$1,612	$1,867	$255	16%
Home B Existing Single-Family, 2,700 SF, 2-Story, No Solar PV	Bakersfield	$3,051	$3,796	$746	24%
	Riverside	$2,177	$2,575	$399	18%
	Compton	$1,769	$2,068	$299	17%
	Oakland	$2,179	$2,729	$550	25%
	Sacramento	$2,371	$2,539	$169	7%
	San Diego	$1,869	$2,151	$282	15%
Home B Existing Single-Family, 2,700 SF, 2-Story, 3 kW Solar PV	Bakersfield	$1,760	$2,506	$746	42%
	Riverside	$925	$1,324	$399	43%
	Compton	$599	$898	$299	50%
	Oakland	$858	$1,408	$550	64%
	Sacramento	$1,354	$1,523	$169	12%
	San Diego	$365	$646	$282	77%
Home C New Single-Family, 2,700 SF, 2-Story, Solar PV Requirement	Bakersfield	$495	$1,131	$635	128%
	Riverside	$334	$746	$411	123%
	Compton	$273	$607	$334	122%
	Oakland	$641	$1,145	$504	79%
	Sacramento	$726	$929	$203	28%
	San Diego	$333	$699	$366	110%
Home D Existing Multi-Family, 6,960 SF, 2-Story, 8 Unit Apartment Building, No Solar PV	Bakersfield	$1,385	$1,691	$306	22%
	Riverside	$1,121	$1,302	$181	16%
	Compton	$993	$1,136	$143	14%
	Oakland	$1,122	$1,334	$212	19%
	Sacramento	$1,126	$1,196	$69	6%
	San Diego	$1,157	$1,301	$144	12%

C.5 Homeowner Cost Comparison (Assuming Electrical Infrastructure Costs are Required)

Table C-14. 2020 Electrification Cost Increase Based on IEPR Rates vs. Median Household Income (Assuming Electrical Infrastructure Costs are Required for Existing Homes)

Home Design	Location	Net Electrification Cost	Annualized Electrification Cost (15 Years)	Annual Energy Bill Impact	Combined Annual Cost Increase	Median Household Income (2016)
Home A Existing Single-Family, 2,100 SF, 1-Story, No Solar PV	Bakersfield	$4,914	$328	$323	$651	$59,000
	Riverside	$4,914	$328	$187	$515	$59,000
	Compton	$4,914	$328	$124	$452	$45,000
	Oakland	$4,914	$328	$116	$443	$58,000
	Sacramento	$4,914	$328	($73)	$255	$52,000
	San Diego	$4,914	$328	$113	$441	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, No Solar PV	Bakersfield	$4,914	$328	$387	$715	$59,000
	Riverside	$4,914	$328	$217	$545	$59,000
	Compton	$4,914	$328	$141	$468	$45,000
	Oakland	$4,914	$328	$184	$512	$58,000
	Sacramento	$4,914	$328	($91)	$236	$52,000
	San Diego	$4,914	$328	$126	$453	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, 3 kW Solar PV	Bakersfield	$4,914	$328	$387	$715	$59,000
	Riverside	$4,914	$328	$217	$545	$59,000
	Compton	$4,914	$328	$141	$468	$45,000
	Oakland	$4,914	$328	$184	$512	$58,000
	Sacramento	$4,914	$328	($91)	$236	$52,000
	San Diego	$4,914	$328	$126	$453	$68,000
Home C New Single-Family, 2,700 SF, 2-Story, Solar PV Requirement	Bakersfield	$235	$16	$345	$361	$59,000
	Riverside	$235	$16	$240	$256	$59,000
	Compton	$235	$16	$180	$195	$45,000
	Oakland	$235	$16	$210	$226	$58,000
	Sacramento	$235	$16	($14)	$2	$52,000
	San Diego	$235	$16	$199	$214	$68,000
Home D Existing Multi-Family, 6,960 SF, 2-Story, 8 Unit Apartment Building, No Solar PV	Bakersfield	$4,642	$309	$157	$467	$59,000
	Riverside	$4,642	$309	$93	$402	$59,000
	Compton	$4,642	$309	$58	$368	$45,000
	Oakland	$4,642	$309	$65	$374	$58,000
	Sacramento	$4,642	$309	($38)	$271	$52,000
	San Diego	$4,642	$309	$50	$359	$68,000

Table C-15. 2030 Electrification Cost Increase Based on IEPR Rates vs. Median Household Income (Assuming Electrical Infrastructure Costs are Required for Existing Homes)

Home Design	Location	Net Electrification Cost	Annualized Electrification Cost (15 Years)	Annual Energy Bill Impact	Combined Annual Cost Increase	Median Household Income (2016)
Home A Existing Single-Family, 2,100 SF, 1-Story, No Solar PV	Bakersfield	$5,375	$358	$283	$642	$59,000
	Riverside	$5,375	$358	$196	$554	$59,000
	Compton	$5,375	$358	$112	$470	$45,000
	Oakland	$5,375	$358	$53	$411	$58,000
	Sacramento	$5,375	$358	($78)	$280	$52,000
	San Diego	$5,375	$358	$94	$452	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, No Solar PV	Bakersfield	$5,375	$358	$338	$696	$59,000
	Riverside	$5,375	$358	$227	$585	$59,000
	Compton	$5,375	$358	$127	$485	$45,000
	Oakland	$5,375	$358	$117	$475	$58,000
	Sacramento	$5,375	$358	($98)	$261	$52,000
	San Diego	$5,375	$358	$105	$464	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, 3 kW Solar PV	Bakersfield	$5,375	$358	$338	$696	$59,000
	Riverside	$5,375	$358	$227	$585	$59,000
	Compton	$5,375	$358	$127	$485	$45,000
	Oakland	$5,375	$358	$117	$475	$58,000
	Sacramento	$5,375	$358	($98)	$261	$52,000
	San Diego	$5,375	$358	$105	$464	$68,000
Home C New Single-Family, 2,700 SF, 2-Story, Solar PV Requirement	Bakersfield	($290)	($19)	$313	$294	$59,000
	Riverside	($290)	($19)	$257	$238	$59,000
	Compton	($290)	($19)	$176	$156	$45,000
	Oakland	($290)	($19)	$168	$148	$58,000
	Sacramento	($290)	($19)	($11)	($30)	$52,000
	San Diego	($290)	($19)	$189	$170	$68,000
Home D Existing Multi-Family, 6,960 SF, 2-Story, 8 Unit Apartment Building, No Solar PV	Bakersfield	$5,044	$336	$136	$472	$59,000
	Riverside	$5,044	$336	$94	$431	$59,000
	Compton	$5,044	$336	$47	$383	$45,000
	Oakland	$5,044	$336	$36	$372	$58,000
	Sacramento	$5,044	$336	($41)	$295	$52,000
	San Diego	$5,044	$336	$32	$369	$68,000

Table C-16. 2030 Electrification Cost Increase Based on Higher Electricity Rates vs. Median Household Income (Assuming Electrical Infrastructure Costs are Required for Existing Homes)

Home Design	Location	Net Electrification Cost	Annualized Electrification Cost (15 Years)	Annual Energy Bill Impact	Combined Annual Cost Increase	Median Household Income (2016)
Home A Existing Single-Family, 2,100 SF, 1-Story, No Solar PV	Bakersfield	$5,375	$358	$621	$979	$59,000
	Riverside	$5,375	$358	$344	$702	$59,000
	Compton	$5,375	$358	$264	$622	$45,000
	Oakland	$5,375	$358	$421	$779	$58,000
	Sacramento	$5,375	$358	$147	$505	$52,000
	San Diego	$5,375	$358	$255	$613	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, No Solar PV	Bakersfield	$5,375	$358	$746	$1,104	$59,000
	Riverside	$5,375	$358	$399	$757	$59,000
	Compton	$5,375	$358	$299	$657	$45,000
	Oakland	$5,375	$358	$550	$908	$58,000
	Sacramento	$5,375	$358	$169	$527	$52,000
	San Diego	$5,375	$358	$282	$640	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, 3 kW Solar PV	Bakersfield	$5,375	$358	$746	$1,104	$59,000
	Riverside	$5,375	$358	$399	$757	$59,000
	Compton	$5,375	$358	$299	$657	$45,000
	Oakland	$5,375	$358	$550	$908	$58,000
	Sacramento	$5,375	$358	$169	$527	$52,000
	San Diego	$5,375	$358	$282	$640	$68,000
Home C New Single-Family, 2,700 SF, 2-Story, Solar PV Requirement	Bakersfield	($290)	($19)	$635	$616	$59,000
	Riverside	($290)	($19)	$411	$392	$59,000
	Compton	($290)	($19)	$334	$315	$45,000
	Oakland	($290)	($19)	$504	$485	$58,000
	Sacramento	($290)	($19)	$203	$184	$52,000
	San Diego	($290)	($19)	$366	$347	$68,000
Home D Existing Multi-Family, 6,960 SF, 2-Story, 8 Unit Apartment Building, No Solar PV	Bakersfield	$5,044	$336	$306	$642	$59,000
	Riverside	$5,044	$336	$181	$518	$59,000
	Compton	$5,044	$336	$143	$479	$45,000
	Oakland	$5,044	$336	$212	$549	$58,000
	Sacramento	$5,044	$336	$69	$406	$52,000
	San Diego	$5,044	$336	$144	$481	$68,000

C.6 Homeowner Cost Comparison (Assuming Electrical Infrastructure Costs are Not Required)

Table C-17. 2020 Electrification Cost Increase Based on IEPR Rates vs. Median Household Income (Assuming Electrical Infrastructure Costs are Not Required for Existing Homes)

Home Design	Location	Net Electrification Cost	Annualized Electrification Cost (15 Years)	Annual Energy Bill Impact	Combined Annual Cost Increase	Median Household Income (2016)
Home A Existing Single-Family, 2,100 SF, 1-Story, No Solar PV	Bakersfield	$243	$16	$323	$340	$59,000
	Riverside	$243	$16	$187	$203	$59,000
	Compton	$243	$16	$124	$140	$45,000
	Oakland	$243	$16	$116	$132	$58,000
	Sacramento	$243	$16	($73)	($57)	$52,000
	San Diego	$243	$16	$113	$129	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, No Solar PV	Bakersfield	$243	$16	$387	$403	$59,000
	Riverside	$243	$16	$217	$233	$59,000
	Compton	$243	$16	$141	$157	$45,000
	Oakland	$243	$16	$184	$200	$58,000
	Sacramento	$243	$16	($91)	($75)	$52,000
	San Diego	$243	$16	$126	$142	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, 3 kW Solar PV	Bakersfield	$243	$16	$387	$403	$59,000
	Riverside	$243	$16	$217	$233	$59,000
	Compton	$243	$16	$141	$157	$45,000
	Oakland	$243	$16	$184	$200	$58,000
	Sacramento	$243	$16	($91)	($75)	$52,000
	San Diego	$243	$16	$126	$142	$68,000
Home C New Single-Family, 2,700 SF, 2-Story, Solar PV Requirement	Bakersfield	$235	$16	$345	$361	$59,000
	Riverside	$235	$16	$240	$256	$59,000
	Compton	$235	$16	$180	$195	$45,000
	Oakland	$235	$16	$210	$226	$58,000
	Sacramento	$235	$16	($14)	$2	$52,000
	San Diego	$235	$16	$199	$214	$68,000
Home D Existing Multi-Family, 6,960 SF, 2-Story, 8 Unit Apartment Building, No Solar PV	Bakersfield	$243	$16	$157	$173	$59,000
	Riverside	$243	$16	$93	$109	$59,000
	Compton	$243	$16	$58	$74	$45,000
	Oakland	$243	$16	$65	$81	$58,000
	Sacramento	$243	$16	($38)	($22)	$52,000
	San Diego	$243	$16	$50	$66	$68,000

Table C-18. 2030 Electrification Cost Increase Based on IEPR Rates vs. Median Household Income (Assuming Electrical Infrastructure Costs are Not Required for Existing Homes)

Home Design	Location	Net Electrification Cost	Annualized Electrification Cost (15 Years)	Annual Energy Bill Impact	Combined Annual Cost Increase	Median Household Income (2016)
Home A Existing Single-Family, 2,100 SF, 1-Story, No Solar PV	Bakersfield	($319)	($21)	$283	$262	$59,000
	Riverside	($319)	($21)	$196	$174	$59,000
	Compton	($319)	($21)	$112	$90	$45,000
	Oakland	($319)	($21)	$53	$32	$58,000
	Sacramento	($319)	($21)	($78)	($99)	$52,000
	San Diego	($319)	($21)	$94	$73	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, No Solar PV	Bakersfield	($319)	($21)	$338	$317	$59,000
	Riverside	($319)	($21)	$227	$206	$59,000
	Compton	($319)	($21)	$127	$106	$45,000
	Oakland	($319)	($21)	$117	$95	$58,000
	Sacramento	($319)	($21)	($98)	($119)	$52,000
	San Diego	($319)	($21)	$105	$84	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, 3 kW Solar PV	Bakersfield	($319)	($21)	$338	$317	$59,000
	Riverside	($319)	($21)	$227	$206	$59,000
	Compton	($319)	($21)	$127	$106	$45,000
	Oakland	($319)	($21)	$117	$95	$58,000
	Sacramento	($319)	($21)	($98)	($119)	$52,000
	San Diego	($319)	($21)	$105	$84	$68,000
Home C New Single-Family, 2,700 SF, 2-Story, Solar PV Requirement	Bakersfield	($290)	($19)	$313	$294	$59,000
	Riverside	($290)	($19)	$257	$238	$59,000
	Compton	($290)	($19)	$176	$156	$45,000
	Oakland	($290)	($19)	$168	$148	$58,000
	Sacramento	($290)	($19)	($11)	($30)	$52,000
	San Diego	($290)	($19)	$189	$170	$68,000
Home D Existing Multi-Family, 6,960 SF, 2-Story, 8 Unit Apartment Building, No Solar PV	Bakersfield	($319)	($21)	$136	$115	$59,000
	Riverside	($319)	($21)	$94	$73	$59,000
	Compton	($319)	($21)	$47	$26	$45,000
	Oakland	($319)	($21)	$36	$15	$58,000
	Sacramento	($319)	($21)	($41)	($63)	$52,000
	San Diego	($319)	($21)	$32	$11	$68,000

Table C-19. 2030 Electrification Cost Increase Based on Higher Electricity Rates vs. Median Household Income (Assuming Electrical Infrastructure Costs are Not Required for Existing Homes)

Home Design	Location	Net Electrification Cost	Annualized Electrification Cost (15 Years)	Annual Energy Bill Impact	Combined Annual Cost Increase	Median Household Income (2016)
Home A Existing Single-Family, 2,100 SF, 1-Story, No Solar PV	Bakersfield	($319)	($21)	$621	$599	$59,000
	Riverside	($319)	($21)	$344	$322	$59,000
	Compton	($319)	($21)	$264	$243	$45,000
	Oakland	($319)	($21)	$421	$399	$58,000
	Sacramento	($319)	($21)	$147	$126	$52,000
	San Diego	($319)	($21)	$255	$234	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, No Solar PV	Bakersfield	($319)	($21)	$746	$724	$59,000
	Riverside	($319)	($21)	$399	$377	$59,000
	Compton	($319)	($21)	$299	$277	$45,000
	Oakland	($319)	($21)	$550	$529	$58,000
	Sacramento	($319)	($21)	$169	$147	$52,000
	San Diego	($319)	($21)	$282	$261	$68,000
Home B Existing Single-Family, 2,700 SF, 2-Story, 3 kW Solar PV	Bakersfield	($319)	($21)	$746	$724	$59,000
	Riverside	($319)	($21)	$399	$377	$59,000
	Compton	($319)	($21)	$299	$277	$45,000
	Oakland	($319)	($21)	$550	$529	$58,000
	Sacramento	($319)	($21)	$169	$147	$52,000
	San Diego	($319)	($21)	$282	$261	$68,000
Home C New Single-Family, 2,700 SF, 2-Story, Solar PV Requirement	Bakersfield	($290)	($19)	$635	$616	$59,000
	Riverside	($290)	($19)	$411	$392	$59,000
	Compton	($290)	($19)	$334	$315	$45,000
	Oakland	($290)	($19)	$504	$485	$58,000
	Sacramento	($290)	($19)	$203	$184	$52,000
	San Diego	($290)	($19)	$366	$347	$68,000
Home D Existing Multi-Family, 6,960 SF, 2-Story, 8 Unit Apartment Building, No Solar PV	Bakersfield	($319)	($21)	$306	$284	$59,000
	Riverside	($319)	($21)	$181	$160	$59,000
	Compton	($319)	($21)	$143	$122	$45,000
	Oakland	($319)	($21)	$212	$191	$58,000
	Sacramento	($319)	($21)	$69	$48	$52,000
	San Diego	($319)	($21)	$144	$123	$68,000