The Utility Bill Speedbump on the Road to a Carbon Free Future

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ABSTRACT

California has established many forward-looking energy efficiency and carbon reduction goals including doubling energy efficiency savings by 2030 and transitioning to 100% renewable and zero-carbon electricity by 2045. To achieve these bold goals, it will be necessary for all Californians to participate in the transition. State agencies, utilities, and regulators are working to address barriers encountered by the State's various constituents, including low-income and disadvantaged communities. This transition, however, is threatened by an affordability crisis. California's three largest IOUs have increased residential electricity rates by 75 to 125 percent over the last 10 years. Twenty-one percent of the three largest IOUs' residential customers are in arrears, potentially limiting their ability to participate in this important transition.

To achieve California's energy efficiency and zero-carbon goals, it will be necessary to realize dramatic increases in the number of households investing in distributed generation (DG), energy efficiency (EE), and electrification. Achieving the necessary growth in DG, EE, and electrification will be highly dependent on the impact of these technologies on energy burden. The long-running and substantial increase in electric rates, however, may decrease the likelihood and affordability of electrification. This paper assesses and compares utility bill impacts associated with installing solar and batteries, undertaking a deep retrofit of the home (i.e., insulation, infiltration control, and gas and electric appliances without fuel substitution), and electrification of HVAC and water heating end uses.

Introduction

California is committed to the goal of carbon neutrality, with Senate Bill 100 requiring 60 percent of California's electricity to be generated from renewable resources by 2030 and 100 percent by 2045. California's Air Resource Board has approved a ban on the sale of new residential gas appliances starting in 2030, and many cities have proactively implemented bans on gas appliances in new construction, while stricter energy efficiency standards for new buildings make installing gas appliances challenging. The carbon neutrality goals and bans on gas appliances are driven by concerns about climate change, indoor air quality, and human health. The goal of reducing residential use of gas appliances relies on customers replacing their gas furnaces, water heaters, and other appliances with high efficiency electric alternatives. To address residential use of gas appliances, the California Legislature passed Senate Bill 1477 which calls on the California Public Utility Commission (CPUC) to develop the Technology and Equipment for Clean Heating (TECH) Initiative. The TECH initiative was launched in December of 2021 and between 2021 and July 2023 over 10,000 TECH participants completed heat pump projects (Opinion Dynamics 2024). In alignment with the goal of replacing gas appliances, Governor Newsom has set a goal of installing 6 million heat pumps by 2030. As of the end of 2024, 1.9 million heat pumps had been installed. At the current rate of adoption, California is projected to reach 4 million heat pumps by 2030, falling 2 million short of the Governor's goal (California Heat Pump Partnership 2025). One of the major barriers to heat pump adoption is the perception that California's electricity rates are high and getting higher and that electrification will increase customers' total (gas + electricity) utility bills.

California's investor-owned utility (IOU) electricity rates have traditionally been higher than most other electric IOUs in the United States. California's higher rates, however, didn't always imply higher electric utility bills as the average California home is dual fuel and uses less electricity than the national

average.[1] Beginning in 2010, however, California electricity rates began to rise substantially faster than inflation or the national average increase in electricity rates (see Figure 1). The California Public Advocate's Office Q4 2024 Electric Rates Report states that Pacific Gas & Electric's (PG&E) average residential electric rates increased 41% from January 2022 to February 2025. Over this same time period, Southern California Edison's (SCE) rates increased 26% and San Diego Gas & Electric's (SDG&E) rates increased 5%. The 10-year change in the average residential electricity rate is 101% for PG&E, 85% for SCE, and 71% for SDG&E. While there is ongoing debate about the underlying causes of California's rate increases, contributing factors include increasing wildfire mitigation efforts, transmission and distribution investments, and cost shifts associated with other programs. California's energy programs benefit the state and residential customers, however, they may come at the expense of higher rates for the average customer.

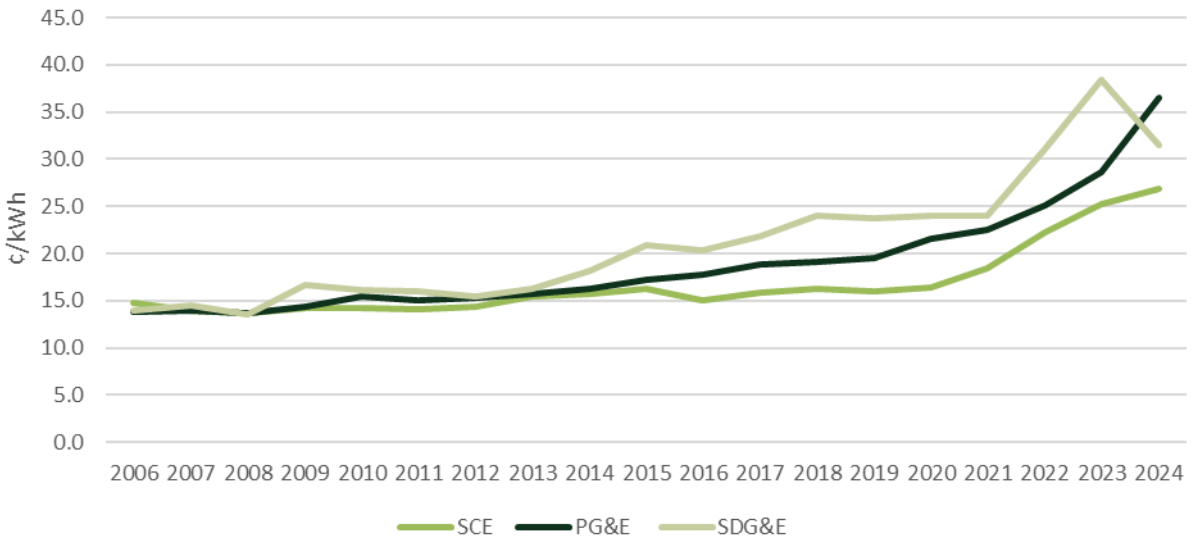

Figure 1. California IOUs' Bundled System Average Residential Electric Rate (January 1) (California Public Utilities Commission, 2024a)

As reflected in the U.S. Energy Information Agency (EIA) data on average bundled residential electric rates across 200 IOUs in the United States (California Public Utilities Commission, 2024b), recent California IOU rate increases caused PG&E's average residential rate ranking to move from 176th highest rates in 2019 to 193rd highest rates in 2022 (i.e., in 2022, only 7 IOUs had higher average residential electricity rates than PG&E, see Figure 2). SDG&E's average residential rate increased from 183rd highest in 2019 to 195th highest in 2022 while SCE's average residential rate rose from 158th to 183rd (California Public Utilities Commission, 2024b).[2] More important for affordability and California's decarbonization goals, over this same period the ranking of the California IOUs' average residential bill ranking rose faster than their rate rankings – indicating increasing electricity bills relative to other utilities. PG&E's residential electric bills rose from 130th to 182nd highest across the 200 largest IOUs, SCE's rose from 58th to 135th, and SDG&E's rose from 78th to 157th.

[1] Information on the average electricity and gas usage for California households can be found in the 2019 California Residential Appliance Saturation Survey https://www.energy.ca.gov/sites/default/files/2021-08/CEC-200-2021-005-PO.pdf

[2] See tables 1 and 2 in the cited report.

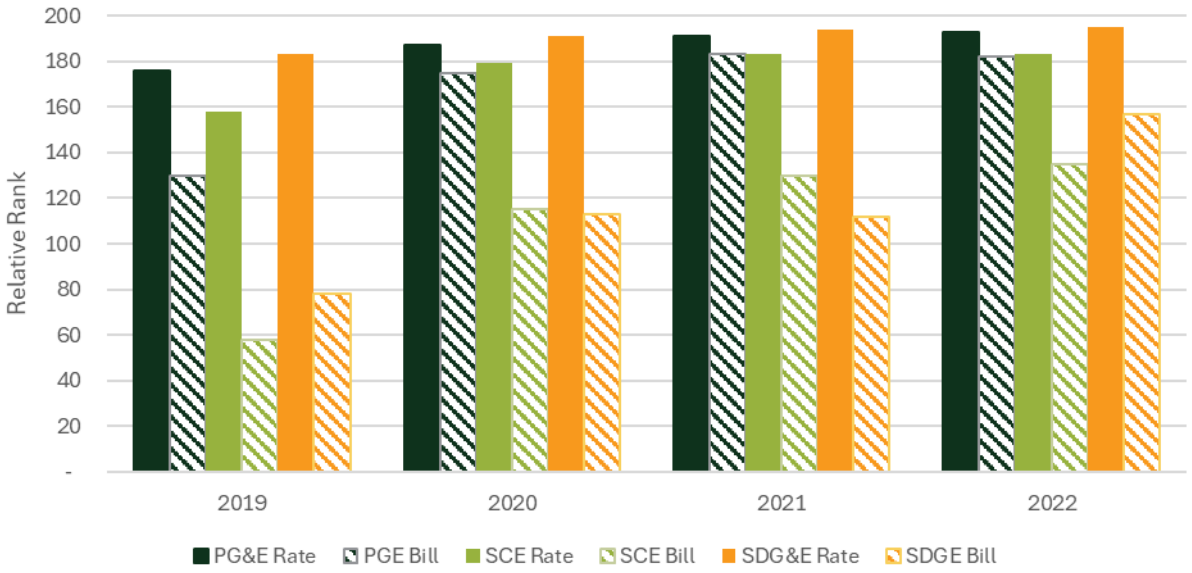

Figure 2. California IOUs' Relative Average Residential Electric Rate and Bill (Relative to 200 U.S. IOUs)

High levels of electric rate inflation, combined with substantial electric bill increases, jeopardize California's electrification goals. Residential customers undertaking electrification of existing equipment must be convinced to switch from gas-fueled systems to electric systems. Rising electricity rates discourage customers from the fuel substitution that is needed to reach California's clean energy goals.

Although considerable research has examined energy and bill impacts of electrification measures (such as (Miller, Satchwell, and Kahn-Lang, 2024), and key considerations for program and policy design (such as Levin, Schaaf, & Nedwick, 2022), there is limited research utilizing metered or observed data that assess how various energy efficiency and customer-sited generation interventions impact customer bills, particularly when accounting for pre- and post-tariff changes. This paper leverages publicly available datasets and modeling tools, along with Verdant's cost-effectiveness and bill-calculator models, to estimate customer bill and utility avoided cost impacts of these interventions. We will focus on bill impacts as a likely barrier to adoption and discuss which combinations of measures maximize grid benefits while providing the greatest benefits to customers.

Approach

Our modeling is anchored around prototypical load shapes obtained from National Renewable Energy Laboratory's (NREL) Building Energy Optimization Tool (BEopt) and OpenStudio-HPXML. BEopt software provides capabilities to evaluate residential building designs and identify cost-optimal efficiency packages at various levels of whole-house energy savings along the path to zero net energy. OpenStudio-HPXML allows running residential EnergyPlus simulations and can accommodate a wide range of different building technologies and geometries. EnergyPlus is a whole building energy simulation program that engineers, architects, and researchers use to model both energy consumption—for heating, cooling, ventilation, lighting and plug and process loads—and water use in buildings.

The modeling included the following scenarios:

- A **baseline home** with a gas furnace, gas tank hot water heating and average insulation, as a reference case.
- **Deep Dual-Fuel Retrofit:** A deep dual-fuel retrofit with updated attic insulation (going from R13 to R22), air sealing (reduce leakage from 13 ACH to 10 ACH), high efficiency gas furnace (going from AFUE .78 to .96), improving the AC efficiency (to SEER2 16.2).
- **Gas WH Retrofit:** Installation of a tankless instantaneous gas water heater (WH).
- **Electrification of HVAC:** Installation of a heat pump HVAC (HP HVAC).
- **Electrification of water heating:** Installation of a heat pump water heater (HPWH).

Simulations were run for each of the three large California electric IOUs using the most appropriate retail rates for income-qualified customers (i.e., California Alternative Rates for Energy, or CARE). Simulations were run separately for customers without solar or storage (labeled as DG = None in Table 1), for customers with solar (PV), and for customers with solar and storage (PV + Storage). Our simulations assume the customer maintains their distributed energy generation (DG) resource status (None, PV, or PV + Storage) during the pre- and post-retrofit periods. The subsequent analysis focuses on the utility bill impacts of the retrofits and does not account for the upfront costs of the measures. Given this paper's focus on income-qualified customers, it is likely that the potential customers are eligible for zero/low-cost/direct-install deep, deep dual-fuel retrofits through California's Energy Savings Assistance program and pilots.

For most scenarios, the customer rates in the baseline and retrofit case were held unchanged. For all scenarios where the customers have PV or PV + Storage, the electricity rate is the low-income, time of use (LI TOU) electrification rate with the Net Billing Tariff (NBT; PG&E's E-ELEC CARE, SCE's TOU-D-Prime-CARE, and SDG&E's EV_TOU_5_CARE) and the gas rate is the residential CARE rate. For customers without PV or PV + Storage, the deep dual-fuel retrofits and the instantaneous gas water heater scenarios assume customers maintain their LI TOU rates in both the pre- and post-retrofit period. For the electrification of heating and water heating, however, the customers transition from a standard LI TOU rate in the baseline period to a high-differential electrification LI TOU rate in the post-retrofit period (these rates are listed above, these customers are not on the NBT tariff during the "no DG" scenario). See Table 1 for rates by scenario.

Table 1. Rates by Scenario (All Rates are CARE rates)

Dist. Gen. Type	Scenario	PG&E		SCE		SDG&E	
		Pre-Rate	Post-Rate	Pre-Rate	Post-Rate	Pre-Rate	Post-Rate
None	Deep Dual-Fuel Retrofit	E-TOU-C		TOU-D-4-9		TOU-DR2LI	
	Gas WH Retrofit	E-TOU-C		TOU-D-4-9		TOU-DR2LI	
	HVAC Electrification	E-TOU-C	E-ELEC	TOU-D-4-9	TOU-D-PRIME	TOU-DR2LI	EV-TOU-5
	WH Electrification	E-TOU-C	E-ELEC	TOU-D-4-9	TOU-D-PRIME	TOU-DR2LI	EV-TOU-5
PV & PV + Storage	Deep Dual-Fuel Retrofit	E-ELEC		TOU-D-PRIME		EV-TOU-5	
	Gas WH Retrofit	E-ELEC		TOU-D-PRIME		EV-TOU-5	
	HVAC Electrification	E-ELEC		TOU-D-PRIME		EV-TOU-5	
	WH Electrification	E-ELEC		TOU-D-PRIME		EV-TOU-5	

Two climate zones (CZ) are simulated for each of the three large electric California IOUs. For PG&E, simulations were run for CZ 16 (mountains) and 3a (coastal), SCE's simulations included CZ 14 (high desert) and CZ 6 (coastal), and SDG&E's included CZ 15 (desert) and CZ 7 (coastal). The different CZs allow the analysis to show how the energy and bill savings differ by a home's seasonal climate.

The deep dual-fuel retrofit scenario represents a traditional whole house retrofit, where both electricity and gas saving measures are updated and the customer experiences both reductions in gas and electric usage and bills. The second scenario is a gas only retrofit, replacing a home's standard tank gas water heater with an instantaneous gas water heater leading primarily to reductions in gas usage and bill savings. The HP HVAC electrification retrofit is the most complicated of the various scenarios to predict anticipated changes in usage and bills. The HP HVAC will lead to reductions in gas usage and a change in electricity usage that is dependent on the efficiency of the new HP and the old, replaced air conditioner and the climate zone and usage patterns of the home. The HPWH electrification will lead to a decrease in gas usage and bills and an increase in electric usage and bills where the change in total utility bill will depend on the usage change and utility rates.

Results

The baseline homes' electricity and gas usage are presented in Figure 3 by climate zone. The energy consumption of the homes without and with DG technologies is the same prior to the retrofit – the usage represented is total electricity and gas consumption, not net consumption. This graphic shows the importance of California's climate zones in determining the electricity and gas usage of homes. The PG&E mountain home (CZ 16) has relatively low electricity usage and the highest gas usage. The SDG&E desert home (CZ 15) has high electricity usage and relatively low gas usage.

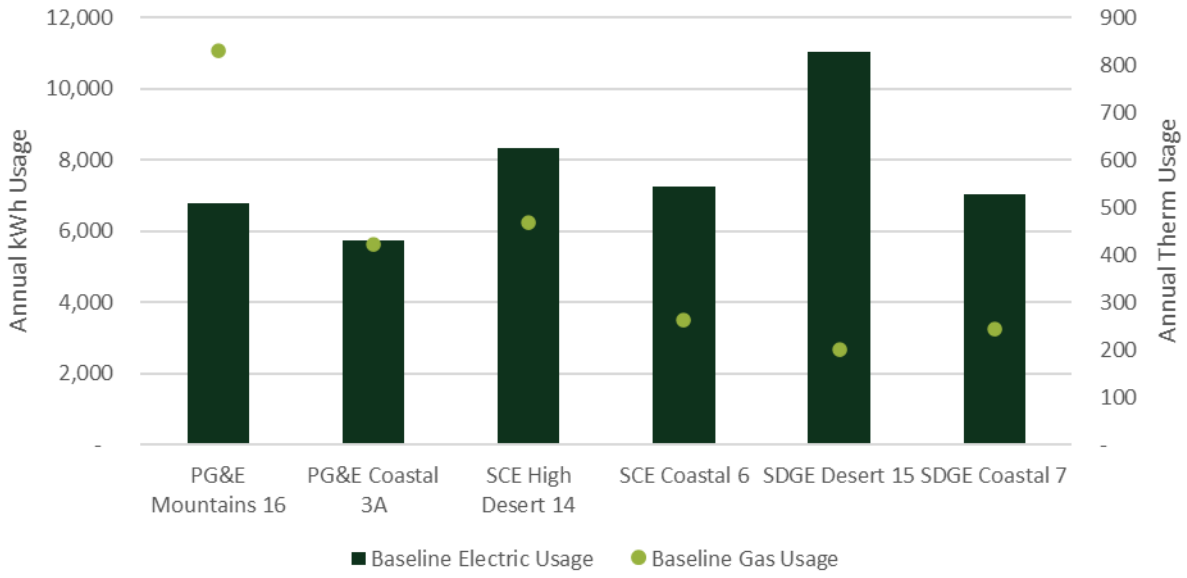

Figure 3. Baseline Home Annual Electricity and Gas Usage

The baseline homes' electric and gas bills are presented in Figure 4. The electric bills are presented for homes without PV, with PV, and for homes with PV + Storage (the gas bill is not dependent on solar or storage). This figure highlights the high gas bills for homes in PG&E's CZ 16 and the high electric bills for non-solar customers in SDG&E's territory relative to the other utilities. The high PG&E CZ 16 gas bills are largely due to the higher gas consumption of homes in CZ 16 (depicted above in Figure 3). SDG&E's CZ 15 bills also reflect the higher electric usage of homes in San Diego's desert climate zone but the relatively high electric bills for non-solar customers in CZ 7 illustrate the impact of SDG&E's high rates relative to the other CA utilities (as noted in Figure 1). The pre-retrofit electric usage for customers is estimated to

be 212 kWh less in SDG&E CZ 7 than in SCE's CZ 6, while the non-solar annual electricity bill in SDG&E's territory is $1,093 higher than in SCE's territory.[3]

The pre-retrofit electric bills are substantially lower for customers with PV or PV + Storage (**light green colors**) compared to customers without either DG technology (**dark green**). For the bill calculations represented in this paper, the non-PV customers' pre-retrofit bills are estimated using the utility's most popular residential TOU rate that does not require the home to have electrification technologies or an EV (PG&E E-TOU-C, SCE TOU-D 4-9, SDG&E TOU-DR2). For the PV and PV + Storage customers, the customers are on the utility electrification rate (PG&E E-ELEC, SCE TOU-D-Prime, SDG&E EV-TOU-5) and the California net billing tariff (NBT or NEM3). **The NBT provides compensation for solar customer exports at a rate much lower than the customer's retail rate during periods with high levels of solar exports and at a higher rate when electricity is in higher demand.** Prior to the NBT, most PV or PV + Storage customers were able to zero out their electric bills. The NBT provides substantial bill savings for PV customers while providing additional bill reductions for PV + Storage customers who can shift their excess PV production to higher value periods.[4]

Electrification rates generally have a higher differential between the on and off-peak period than the standard rate and include a higher monthly fixed charge.

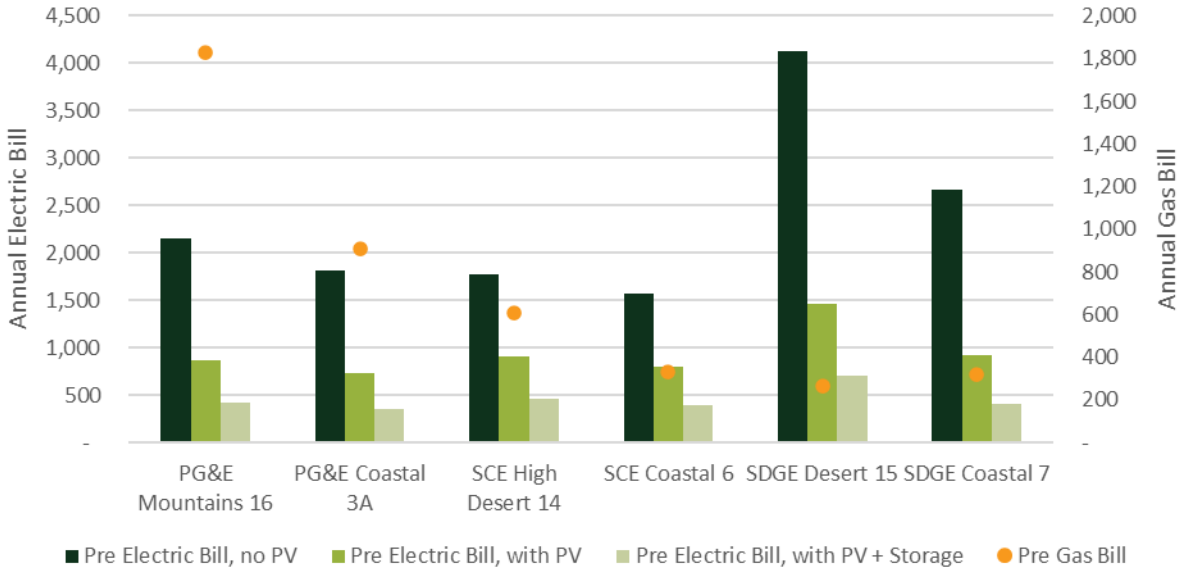

Figure 4. Baseline Home Annual Electric and Gas Bill for homes without PV, with PV and with PV + Storage

Figure 5 shows the first-year total bill impacts (Electric + Gas) for homes without PV or PV + Storage (savings are positive and increases are negative). The deep dual-fuel retrofits and instantaneous gas water heaters provide utility bill savings across all climate zones and utilities. The annual utility bill impacts from the deep dual-fuel retrofits are highest in PG&E CZ 16 ($432) and SDG&E CZ 15 ($332) due

[3] The electric and gas bills are low-income customer bills (the bills were developed using the California Alternative Rates for Energy – CARE reductions), where gas customers have approximately a 20% reduction and electric customers have approximately a 30% reduction relative to market rate customers.

[4] California offers low-income customers the opportunity to install solar systems through the Disadvantaged Communities Single Family Solar Homes program and solar and batteries through the Self Generation Incentive Program.

to the large amount of pre-retrofit heating (CZ 16) and cooling (CZ 15) energy usage in these two climate zones. The deep dual-fuel retrofit leads to substantial gas bill savings for homes in PG&E's CZ 16, substantial electric savings in SDG&E's CZ 15, and significant gas and electric bill savings for SCE's CZ 14. The instantaneous water heaters lead to an annual bill reduction of $197 in PG&E CZ 16, $144 in PG&E CZ 3A, and $107 reduction in SCE CZ 14.

The impact of electrification measures on customer utility bills differs substantially by utility, with customers in PG&E and SDG&E forecast to see utility bill savings (combination of gas and electric bills) and customers of SCE estimated to experience a utility bill increase. Customers in PG&E CZ 16 or CZ 3A that install a HPWH are forecast to see annual bill savings of $263 or $273, respectively. The impact of installing a HP HVAC system also leads to bill savings for customers in these two PG&E CZs, but the savings are substantially higher in CZ 3A ($412) than in CZ 16 ($143). For customers in CZ 16, the first-year electric bill increase ($1,163) and the gas bill decrease ($1,307) are both large while in CZ 3A the electric bill increase ($20) is small and more than compensated by the gas bill decrease ($431). For SCE customers, where a HP HVAC system is forecast to increase bills, the electric bill increases are large ($670) in CZ 14 and not compensated for the gas bill reductions ($342) while customers in coastal CZ 6 experience a small electric bill increase ($101) and a smaller gas bill reduction ($65).

SDG&E customers experience a substantial reduction in their utility bills when they install HP technologies. Focusing on the HP HVAC systems, customers increase their electricity usage while reducing their gas usage but are forecast to see bill reductions for both electricity and gas. Customers in CZ 15 increase their electricity usage by 888 kWh and experience a $578 reduction in their first-year electric bills. The increased electricity usage and the decreased electric bill are driven by the customer changing to an electrification rate when they install the HP systems.

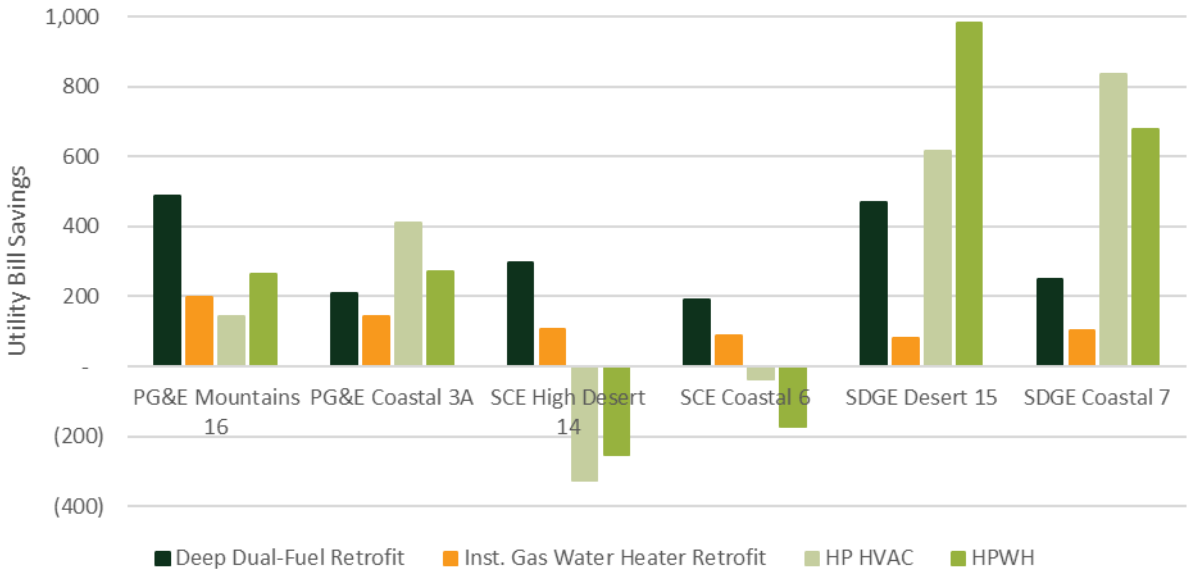

Figure 5. First Year Electric Plus Gas Bill Impacts for Homes without PV or PV + Storage

For this analysis, customers without DG technologies that install HPWH or HP HVAC systems are assumed to transition from a residential TOU rate to the utility's residential TOU electrification rate. As noted above, the electrification rates differ from standard TOU rates in several ways. Electrification rates have a higher rate differential between on- and off-peak periods, they charge a higher fixed fee and generally have lower hourly rates during some of the off-peak TOU periods. The exact combination of

fixed fees and rate differential between the standard and electrification rates, however, differs for each utility.

Figure 6 shows the three electric IOUs' typical low-income residential volumetric TOU rate and their electrification volumetric TOU rate.

- PG&E: the TOU rate is higher than the electrification rate for all periods other than during the summer on-peak period when the electrification rate is slightly higher than the TOU rate. The PG&E electrification rate also leads to an estimated reduction in utility bills for customers electrifying to HPs.
- SCE: The electrification rate is substantially higher than the corresponding TOU rate in the summer and winter peak periods. SCE's higher peak electrification rate during the peak periods contributes to the estimated increase in utility bills for SCE electrification customers.
- SDG&E: the TOU rate is higher than the corresponding electrification rates, across all season and peak periods (on- and off-peak). The reduced rate is likely possible due to the fixed charge and the higher volume of electricity consumed by these customers. The lower volumetric charge with the additional fixed charge allows customers in SDG&E's territory to see bill savings when they electrify their HVAC or WH system with HP technology (see Figure 5 above, note the bill savings estimates include the fixed charge).

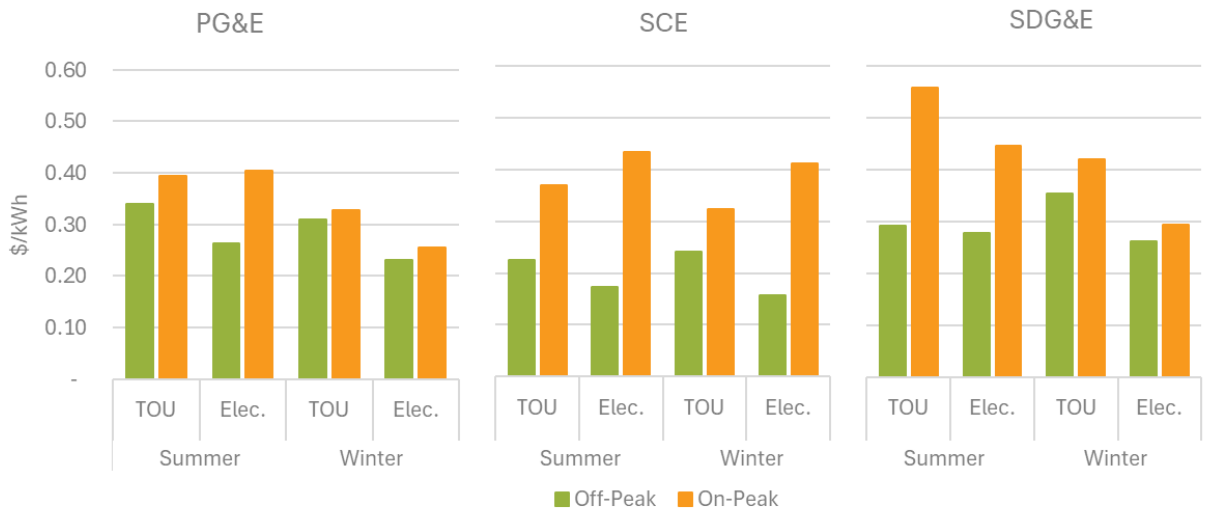

Figure 6. Utility Residential Low-Income TOU and Electrification Rates by Season and On- and Off-Peak Period

Figure 7 presents first-year total bill impacts (Electric + Gas) for homes with PV. Customers with PV in the pre-installation period are assumed to be on the utility's electrification rate in both the pre- and post-installation period. The utility bill impacts presented below are exclusively due to the retrofit. The building simulations indicate that the deep dual-fuel and instantaneous gas water heater retrofits are estimated to reduce customer bills in all simulations. The bill reductions are largest for PG&E CZ 16 and SDG&E CZ 15 due to heating and cooling savings. The simulations and bill calculations also show that HPWHs are estimated to lead to a small reduction in customer bills across all utilities and climate zones, but HP HVAC systems are estimated to increase bills in PG&E CZ 16, SCE CZ 14, and SDG&E CZ 15. The three simulations with increased bills are the climate zones with the highest HVAC needs. In PG&E CZ 3A, SCE CZ 6, and SDG&E CZ 7, the HP HVAC systems are forecast to lead to utility bill savings for customers with PV.

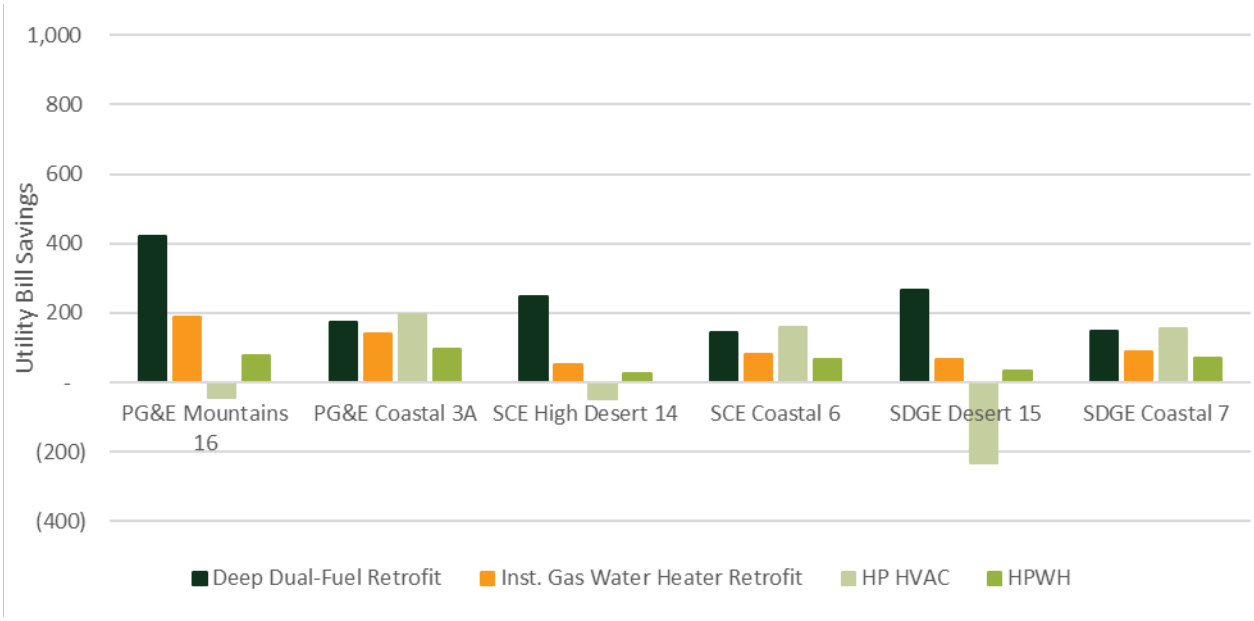

Figure 7. First-Year Electric and Gas Utility Bill Impacts for Homes with PV

Figure 8 shows the first-year total utility bill impacts for customers with PV + Storage. Differences in the forecasted utility bill impacts for homes with PV and homes with PV + Storage are small and due to the change in electricity usage, which impacts the ability of the battery to optimize the discharge of electricity to the grid during high value periods.

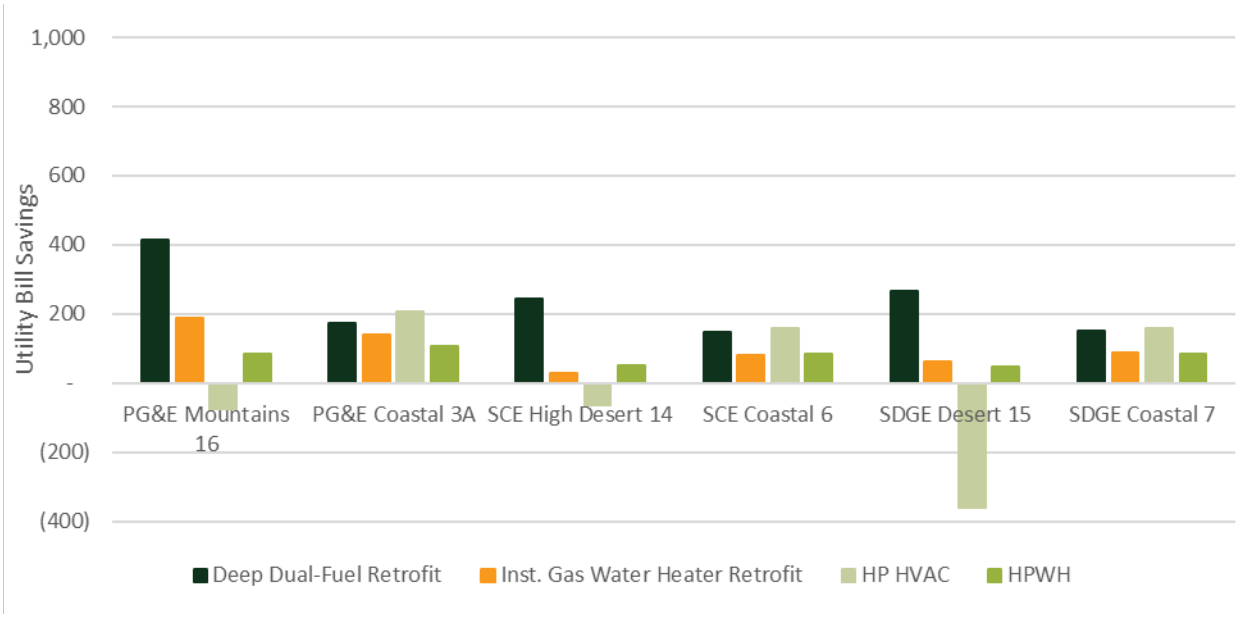

Figure 8. First-Year Electric and Gas Utility Bill Impacts for Homes with PV + Storage

Key Takeaways and Opportunities for Future Research

This paper simulates the energy and bill impacts from traditional deep dual-fuel retrofits, gas energy efficiency, and heat pump electrification projects. The bill impacts are simulated using current California TOU rates, both standard residential TOU rates and high-differential electrification TOU rates. The simulations apply a California low-income customer discount (CARE) to the electric and gas bills to estimate the impact of these retrofits on low-income customer bills. The CARE discount applies approximately a 30% reduction to electric rates and fixed charges relative to a non-low-income customer's costs while the gas discount is approximately 20%. The differential gas versus electric low-income discount should help support California's electrification goals.

Our analysis found that traditional energy efficiency retrofits will consistently lead to customer utility bill reductions while fuel substitution retrofits can lead to reductions or increases in bills. The paper highlighted opportunities where fuel substitution measures can lead to utility bill reductions. The simulations found that, ***for customers without solar, fuel substitution utility bill reductions are common in SDG&E and PG&E territory while bill increases are more likely for SCE customers***. The reduced utility bills for SDG&E and PG&E customers, compared with SCE customers, are largely driven by the assumption that customers installing HP systems will transition to the utilities' electrification rates. The volumetric charges in SDG&E's and PG&E's electrification rates tend to be lower than their standard residential TOU rates, leading to bill savings even with higher fixed charges. The volumetric charges in SCE electrification rates, however, are higher during the summer and winter on-peak periods, contributing to bill increases for these customers.

The forecast HP system bill impacts, and their dependence on the differential between the typical low-income residential TOU rate and the electrification rate, highlights the importance of rate design in achieving California's electrification goals. These findings also show that it is possible to achieve utility bill reductions with an increase in the fixed fee and electricity usage when the volumetric charges are reduced. With thought and analysis, rates can be designed to help the state transition to a clean energy future.

The forecast bill impacts for customers with PV or PV + Storage shows substantially fewer opportunities for bill reduction from fuel substitution measures than for customers without PV or PV + Storage. While this finding may be counter to first impressions, most of the bill reductions found for homes without PV were due to customers transitioning to electrification rates. Customers installing PV or PV + Storage under California's NEM 3 or NBT are required to be on an electrification rate, eliminating the bill impact from transitioning for customers with HP technologies. Note, customers with DG technologies may still be more likely to transition to electrification technologies because their utility bills are lower, but the bill impact of transition is not as favorable as it is for non-DG customers.

The findings from this analysis, combined with the importance of encouraging fuel substitution retrofits, points to the need for additional research on the effect of different rate structures and DG technologies on electrification bill impacts. The findings from analyses of the impacts of electrification rates and electrification technologies on customer bills will help utilities, regulators, and evaluators better understand the real-world impact of these technologies and rates on customer bills. In addition, more research is needed to better understand the likely impacts of future income differentiated fixed charges, and the resulting lower volumetric rates, on bill impacts from electrification.

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