

Electrofit cost effectiveness, policymaking, and financing considerations for local governments

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ABSTRACT

Many forward-thinking jurisdictions in California that adopted local energy code amendments, also known as “reach codes”, requiring all-electric new construction are now seeking pathways to decarbonize their existing building stock. This paper discusses the considerations of existing building electrification retrofit (abridged as *electrofit* in this paper for brevity) technologies, cost effectiveness, and financing to inform local government policymaking considerations.

The paper begins with a description of estimated cost effectiveness with electrification of existing residential and nonresidential building stock, performed by the California Statewide Utility Codes & Standards program. On-bill utility cost impacts to consumers are discussed and contextualized with existing incentive programs. In many cases the results do not yield on-bill cost effectiveness, leaving questions for how to bridge the remaining cost gap. Major cost-effectiveness gaps exist for replacing a gas furnace with a heat pump space heater in a building that doesn’t already have air-conditioning.

The paper summarizes financing design and to support electrification, such as utility-provider on-bill financing and incentive programs, and program design to insulate vulnerable residents from onerous costs, both upfront and operational. Several jurisdictions have designed financing programs, including Ithaca and Denver, to mitigate the high costs of electrofits, and statewide programs like TECH Clean California may support smaller cities from having to develop custom program designs. The paper concludes with a discussion of the workplan considerations toward existing building electrification.

Electrification as a Means of Building Decarbonization

Building electrification has emerged as a primary strategy to achieve building decarbonization. In California electrification retrofits (abridged as *electrofits* in this paper for brevity) have been shown to be a lower-risk and lower-cost pathway compared to multiple other pathways, such as biofuels displacing fossil gas, given a growing amount of renewable electricity generation (CEC 2021, E3 2018). California’s draft Integrated Energy Policy Report characterizes renewable gas produced from waste streams as a key state strategy to reduce methane emissions from landfills, wastewater, dairies, and other agricultural waste. But building electrification is still the most promising decarbonization strategy to reduce residential and commercial building gas demand (CEC 2022).

In many ways, local jurisdictions (i.e., cities and counties) in California can respond more rapidly than state policymaking bodies to explore building decarbonization policies. Local jurisdictions have smaller constituencies and shorter policymaking cycles which allows them to cater policy to local and immediate conditions. Accordingly, dozens of California cities have adopted standards restricting the use of fossil fuel in new construction (CEC 2020a). Adopting these types of standards is more complicated across the United States. Some states have no statewide code (home rule) which can make it easier for cities to adopt local decarbonization

measures, while others set a minimum code which cannot be exceeded by municipalities. Nonetheless, due to the success in California, jurisdictions have embraced local policies restricting the use of fossil fuel and are beginning to focus on existing buildings, which are far more numerous and thus represent a greater source of emissions than new construction.¹

More state-level studies highlight electrofits as the path forward (New York 2020, Washington 2021). Local governments must process the research to develop customized and detailed workplans identifying the following factors most appropriate for their existing building stock and corresponding systems:

- technology selection,
- cost-effective opportunities,
- policy design, and
- financing mechanisms.

Each of these elements are dependent on multiple factors, such as manufacturer and workforce capacity, climate, geography, and stakeholder support. However, jurisdictions are beginning to successfully navigate these complexities, as exemplified by policy frameworks adopted by the City of Denver, City of Seattle, and the City of Berkeley (Seattle 2020, Denver 2021, Berkeley 2022).

Technology Selection

Heat pumps are available for both water heating and space heating applications from a variety of manufacturers, and supply chains are well-established in California. Heat pumps extract heat from ambient air (like an air-conditioner operating in reverse) while operating at a Coefficient of Performance (COP) of over 3.5 under typical conditions and remaining at a COP of 1.75 even when outside air temperatures are as cold as 5°F (NEEA 2020). In comparison, conventional natural gas water heaters or furnaces which only reach a maximum of 0.95 COP, well below that of a typical heat pump. Electric resistance technology is also available for space and water heating, though should only be used in certain applications where heat pump water heater (HPWHs) may be ineffective, such as point of use water heaters in office building restrooms, due to a maximum potential COP of 1.²

Electric ranges are most often associated with electric resistance technology. Electric resistance ranges have long held had the majority market share in the United States, and provide a familiar cooking experience and even heat, while producing less airborne toxins than gas ranges (RMI 2020). In recent years, high-end consumers have preferred gas ranges due to enhanced controllability and delayed response times. The market is slowly gaining awareness of electric induction ranges, which are cost comparable with natural gas ranges, suitable for luxury applications due to high controllability and responsiveness, and safer because the surface of the stove does not get hot (BDC 2019, NBI 2021). Induction ranges have demonstrated to be more efficient in transferring heat to the cookware (85 percent) than both natural gas (30 percent) and electric resistance (75 percent) technology (Frontier 2019a).

¹ According to the U.S. Census Bureau there were about 1.6 million housing starts in 2021, compared to over 142 million dwellings existing statewide.

² Heat pump water heaters with integrated tanks can lead to high tank losses in applications with low hot water demand. Instantaneous heat pump water heating is a current market gap.

Electric clothes dryers are available in both resistance and heat pump technology, although heat pumps have been shown to reduce energy consumption by 35-50 percent (PNNL 2016). While electric resistance dryers are widely available in the United States, heat pump dryers could potentially save costs compared to resistance.

Note that while building electrification is related to a wide set of complicating issues, such as grid capacity and contractor training, as well complimentary measures such as battery storage and load shifting, this paper focuses only on appliance electrification with brief references to solar PV.

Existing Buildings Cost Effectiveness Study Findings

The California Statewide Reach Codes Team, composed of a set of California utilities and technical consultants, completed cost effectiveness of electrification measures for existing residential and nonresidential buildings across all sixteen California climate zones.^{3,4} The analysis considered replacement at the end of equipment life and evaluated the energy and cost impacts of installing an electric appliance instead of a traditional gas appliance. Cost effectiveness was assessed using a customer-based lifecycle cost approach that valued savings based on utility bill costs using electricity and natural gas utility rate schedules and accounting for discount rate and energy cost inflation. The analysis period was a 30-year duration for single family and multifamily buildings and a 15-year duration for nonresidential buildings (Frontier 2021, Frontier 2022, TRC 2022).

Residential Buildings

The Statewide Reach Codes Team evaluated three residential prototypes. A 1,665 ft² single family home, an 8-unit 2-story garden-style multifamily building, and a 117-unit 10-story high-rise multifamily building. Three vintages were considered. These were pre-1978, 1978-1991, and 1992-2010 construction for the single family and low-rise multifamily prototypes. The high-rise multifamily building was evaluated for 1980s, 1990s, and 2000s vintage construction. Building characteristics for each vintage were determined based on either prescriptive requirements from the historical California Building Energy Efficiency Standards that were in effect or standard construction practice during that time period and accounted for building upgrades over time in some cases.

Measure and costs

Table 1 summarizes the evaluated residential electrofit measures and associated lifetime incremental costs. Equipment was evaluated with minimum federal efficiencies for both the base gas appliance retrofit and the electrofit. Costs were obtained from engineering cost estimators, distributors, contractors, literature review, and online sources such as Home Depot and RS Means. Contractor markups and taxes were added where appropriate. Where equipment lifetimes were shorter than the 30-year analysis period replacement costs were included. This study attempted to quantify average statewide costs, recognizing that cost variations exist regionally and based on existing building conditions and building type. Single family and low-rise

³ Information on the Statewide Reach Codes Program available here: <https://localenergycodes.com/>

⁴ Information on California Climate Zones available here: <https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/climate-zone-tool-maps-and>

multifamily were grouped together because the analysis assumed the same existing and upgrade system types.

Table 1. Summary of measures and costs for residential electrofit cases

Building Type	Appliance	Gas Baseline	Electrofit	Incremental Lifecycle Cost per Unit
Single Family & Low-Rise Multifamily	HVAC	Ducted gas furnace and split air conditioner (14 SEER, 80% AFUE)	Ducted split heat pump (14 SEER, 8.2 HSPF)	\$501
			Ducted split heat pump (21 SEER, 11 HSPF)	\$3,749
	DHW	Gas storage water heater (0.63 UEF)	Heat pump water heater (2.0 UEF)	\$2,594
			Heat pump water heater (NEEA Tier 3)	\$2,775
High-Rise Multifamily	HVAC	PTACs (EER: 9.3 – 11.7, based on capacity) and gas Boilers (80% AFUE). Existing baseboards remain.	PTHPs (EER: 9.5 – 11.9, based on capacity, COP: 2.9 – 3.3, based on capacity). Decommission baseboards.	-\$52
	DHW	Central gas water heater with storage (Thermal efficiency: 80%)	Central heat pump water heater with storage (3.3 UEF)	\$1,883

Sources: (Frontier 2021, Frontier 2022, TRC 2022).

Results

The Statewide Reach Codes Team evaluated annual utility bill impacts for California’s Investor Owned Utilities (IOUs) and selected municipal utilities. Figure 1 presents calculated first year utility cost impacts in single family homes for installing a ducted heat pump in place of a ducted gas furnace with air conditioning. This retrofit scenario results in an increase in annual utility costs except in California Climate Zone 12 in Sacramento Municipal Utility District (SMUD) territory. Rate tariff structures significantly influence the benefit of electrification to consumers. At the time of this analysis residential rates across the IOU service territories averaged \$0.25 to \$0.40 per kWh and \$1.30 to over \$1.80 per therm. SMUD customers receive gas service from PG&E but electricity from SMUD at almost half what a customer with PG&E electric service would experience; therefore, offsetting gas use at this lower electric rate results in a net benefit to the customer.

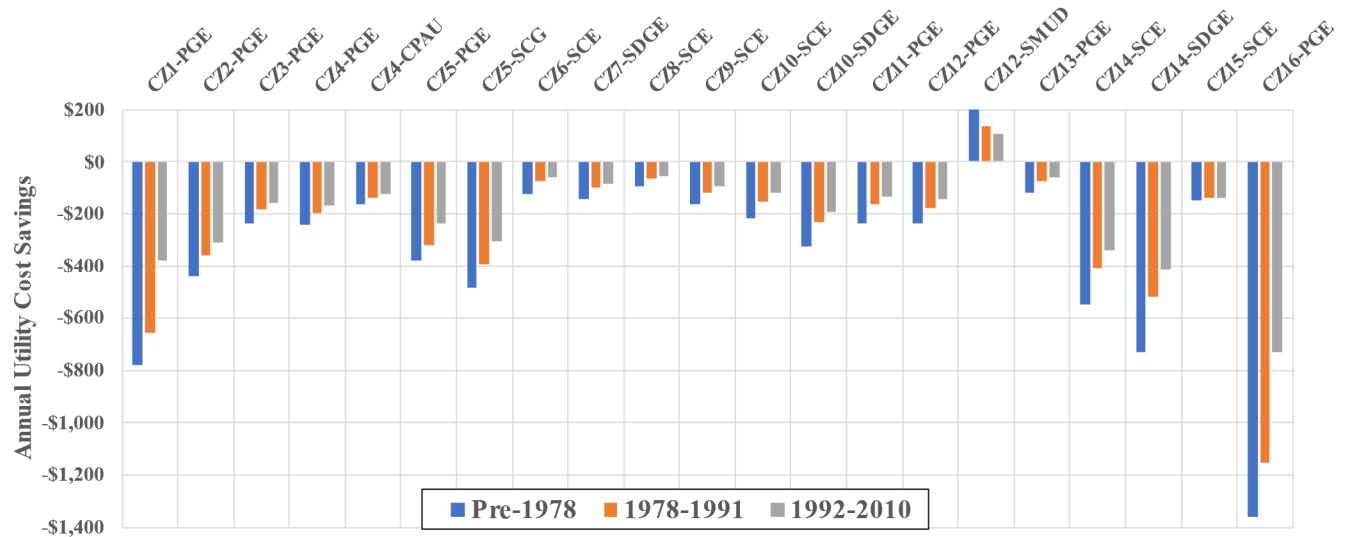


Figure 1. First year utility cost savings for space heating electrofit in single family homes of three vintages across all 16 California climate zones (CZs). Results across x-axis represent various climate zone and utility combinations. PGE = Pacific Gas & Electric, CPAU = City of Palo Alto Utilities, SCG = Southern California Gas, SDGE = San Diego Gas & Electric, SCE = Southern California Edison, SMUD = Sacramento Municipal Utility District. *Source:* Frontier 2021.

Utility costs over the 30-year analysis period vary due to electricity and gas escalation rates. Anticipating future changes in utility tariffs is challenging, especially over long periods of time. The Statewide Reach Code Team evaluated escalation based on two sources and assessed the impacts on lifecycle costs. Table 2 presents the impact on lifetime utility cost savings and net present value (NPV) for a heat pump water heater (HPWH) installation.

- Escalation Rate 1 is based on assumptions in E3’s 2019 study Residential Building Electrification in California (and applies General Rate Case filings, utility estimates and historical data).
- Escalation Rate 2 uses assumptions from the California Public Utilities Commission 2021 En Banc hearings on utility costs through 2030 and applies a higher gas escalation rate over time than Escalation Rate 1 (Energy & Environmental Economics 2019, CPUC 2021).

The results in Table 2 show that even with an increase in utility costs in the first year after installing a HPWH, savings over the lifetime can be positive if natural gas rates are expected to increase at a higher rate than electricity rates. However, because of the \$2,594 incremental cost, the upgrade is not anticipated to save money over the lifetime even with the positive utility cost savings.

Table 2 also demonstrates the impact on lifetime net benefit between PG&E and SMUD rates. Under both escalation rate scenarios in SMUD territory a water heater electrofit results in lifetime savings and is cost effective.

Table 2. 30-year analysis NPV results with sensitivity to escalation rate for a water heating electrofit in a 1978-1991 single family home in California Climate Zone 12 using IOU and municipal utility rates.

	First Year Utility Cost Savings	30-Year Utility Cost Savings	Net Benefit with Electrofit Incremental Cost
PG&E – Escalation Rate 1	-\$85	-\$1,532	-\$4,423
PG&E – Escalation Rate 2	-\$85	\$278	-\$2,613
SMUD – Escalation Rate 1	\$139	\$3,770	\$879
SMUD – Escalation Rate 2	\$139	\$5,469	\$2,578

Figure 2 presents NPV for a water heating electrofit in a 1992-2010 single family home in California Climate Zones 3 (San Francisco Bay Area) and 12 (Sacramento) both in PG&E territory. The upgrade is not cost-effective with either a minimum efficiency or high efficiency (NEEA Tier 3) HPWH, although cost-effectiveness improves with the higher efficiency appliance. If a \$3,000 incentive is provided, similar to what is currently offered in California through the TECH Clean California program, the HPWH upgrade also becomes cost effective.⁵ When the upgrade is completed at the same time as a new PV system is installed and the costs and benefits are combined, even excluding incentives, the package is quite cost effective with a lifetime benefit greater than \$10,000.

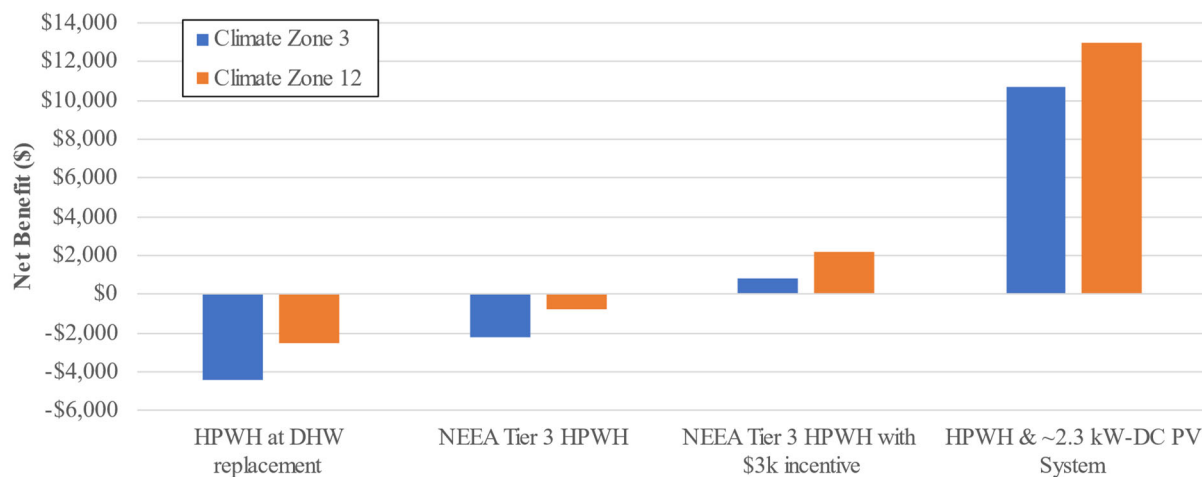


Figure 2. Net lifetime benefit for water heating electrofit in a 1992-2010 single family home in California Climate Zones 3 and 12).

The reach code studies found that electrofits using minimum efficiency equipment result in higher utility costs and are not cost effective in most cases. Results are sensitive to utility rate structures and changes in natural gas and electricity rates. Under some municipal rates, such as SMUD, City of Palo Alto, and Los Angeles Department of Water and Power, the measures result in utility cost savings and are cost effective. Upgrading to high efficiency equipment was found to be cost effective for some climate zones. Leveraging the benefits of PV during an electrofit

⁵ More information on the TECH Clean California program available at: <https://energy-solution.com/tech-incentives/>

increases first cost but substantially lowers utility costs and provides a net benefit over the lifetime in almost all cases for single family and low-rise multifamily buildings, and in limited cases for high-rise multifamily.

Nonresidential Buildings

The Statewide Reach Code Team analyzed developed three vintages of nonresidential building prototypes by leveraging data and methodologies from IOU studies, Senate Bill 350 (SB350) analysis, and Commercial Building Energy Consumption Survey to identify appropriate characteristics (ITRON 2014, CEC 2017). These datasets include estimates of retrofits/upgrades to older buildings as well as field data on existing conditions. Real building existing conditions are often a variety of old and new components, and equipment performance degrades over time. The analysis assumes some equipment replacement over time, varying by building system and envelope component, based primarily on the SB350 analysis.

Measure and costs

Of the six nonresidential prototypes analyzed in the full study, results are described below for the 53,628 ft² medium office and 24,563 ft² standalone retail prototypes. The medium office HVAC configuration is a common multizone system type consisting of a central hot water plant and variable air volume terminal units with hydronic reheat. The standalone retail has single zone packaged rooftop units, an HVAC system that is highly common across many nonresidential building types.

Table 3 and 4 summarize the average measure costs for these two prototypes, using costs obtained from engineering cost estimators and online sources. The Statewide Reach Code Team assumed that all HVAC and service hot water (SHW) equipment has a 15-year useful life and, therefore, did not consider replacements in either the mixed-fuel or the all-electric scenario for all nonresidential building types.

Table 3. Summary of measures and costs for medium office electrofit

Gas Measure	Gas Cost	Electrofit Measure	Electrofit Cost	Electrofit Incremental Cost
Central boiler space heating plant	\$45,508	Central heat pump water heater with electric resistance booster	\$157,070	\$111,562
Gas storage service water heater	\$73,479	Central heat pump water heater	\$88,762	\$15,283
Electrical upgrades	\$0	Wiring, distribution boards, and transformers to serve central HVAC and SHW systems	\$31,233	\$31,233
Total	\$118,987		\$277,065	\$158,078 (\$2.95/ft ²)

Table 4. Summary of measures and costs for standalone retail electrofit

Gas Measure	Gas Cost	Electrofit Measure	Electrofit Cost	Electrofit Incremental Cost
Packaged SZ AC + gas furnace space heating	\$176,229	Packaged SZ heat pump	\$173,617	-\$2,612
Gas storage service water heater	\$1,255	Point of use electric resistance	\$1,723	\$468
Electrical upgrades	\$0	Wiring for SHW	\$2,007	\$2,007
Total	\$177,484		\$177,347	-\$137 (~\$0/ft ²)

Results

The Statewide Reach Code Team simulated prototypes in California Building Energy Code Compliance Calculator for Commercial buildings (CBECC-Com) energy code compliance software, except for the medium office central heat pump space heating plant, which required an outside calculation.⁶ Results are shown for Climate Zone 3 (San Francisco Bay Area) and Climate Zone 12 (Sacramento) in Table 5. Results again indicate the selected rate is highly impactful to long-term bill savings. The energy profile of the medium office requires that it be in a different PG&E rate category (B-10) than the medium retail (B-1). Although there are positive on-bill impacts for the medium office in both PG&E and SMUD territories, the high incremental cost of the electrofit package is greater over the 15-year analysis period, making the package not cost-effective.

For the retail building, the bill impact is negative, leading to a slightly negative NPV. The full study depicts how the retail building 15-year utility cost savings can become positive with a small set of efficiency measures performed at time of retrofit. The nonresidential analysis did not perform sensitivity analysis on escalation rates, and use the escalations used to develop 2022 California Energy Code time dependent valuation (CEC 2020b).

⁶ CBECC is based on the EnergyPlus engine with certain limitations to ensure the software can be used for compliance with the California Building Energy Efficiency Standards. One of these limitations is an inability to model a central heat pump boiler space heating plant. However, a central heat pump boiler is an ideal electrofit for an existing gas boiler. Thus, the Statewide Reach Code Team needed to create an engineering approximation of the heat pump space heating plant energy usage using CBECC-Com loads and manufacturer-provided performance curves in an Excel workbook. These load estimates were then combined with the standard CBECC-Com results to create a set of whole-building results.

Table 5. Summary of measures and costs for standalone retail electrofit

	IOU Territory	Electric Rate / Gas Rate	Elec Savings (kWh)	Gas Savings (therms)	15-year Utility Cost Savings	NPV (On-bill)
Medium Office	PG&E	B-10 / G-NR-1	(87,716)	14,697	\$74,758	-\$83,320
	SMUD	GSS / G-NR-1	(96,643)	15,300	\$128,173	-\$29,905
Medium Retail	PG&E	B-1 / G-NR-1	(39,706)	3,832	-\$43,786	-\$43,415
	SMUD	GSS / G-NR-1	(51,517)	4,704	-\$3,587	-\$3,216

Financing Options

Design

While it is less expensive to build an all-electric home than a mixed-fuel home during new construction, converting existing gas appliances to electric often increases costs versus replacing the gas equipment in-kind. The increased costs that occur by end-use are depicted in Table 6. In addition, there may be costs associated with residential panel upgrades, which can range from \$1,000 to \$5,000, though these costs can be avoided in most situations by using power efficient appliances and circuit splitters (Pecan Street 2021, Redwood Energy 2021).

Table 6. Summary of existing building upgrade costs

End Use	Make-Ready	Equipment	Installation
Water Heater	New circuit	Increased equipment cost	Increased cost
Space Heater (No existing A/C)	New circuit	Increased equipment cost	Increased cost
Space Heater (Existing A/C)	N/A	Increased equipment cost	Same cost
Cooking	New circuit	Same cost	Same cost
Clothes Drying	New circuit	Same cost	Same cost

Nonetheless, the incremental increase in costs associated with work listed above are extremely low in comparison to home prices. The cost for whole-home electrification listed in Table 1, plus the addition of cooking and clothes branch circuits at \$600 each and a panel upgrade of \$3,000, would total to represent less than 1% of California's \$834,000 median home price (Title Track 2022). However, any increase in cost can cause significant strain on lower and

middle-class homeowners who would be unable to sustainably finance an electrofit. Privately owned utilities, Community Choice Aggregators, municipal utilities, and the State must and are providing rebates, loan programs, and other financing options to help cover the cost of electrification.

Incentive Programs

Due to a 1990s era rule which disallowed incentives related to fuel switching, California is behind on the development of decarbonization programs. In 2019, modifications to the Public Utilities Commission's three-prong test allowed incentivization of fuel-switching as a decarbonization measure (Walton 2019). Programs are being rapidly developed throughout the state to help offset the costs related to electrification of existing buildings. Incentive approaches currently include:

- Midstream incentives for heat pump water heaters and heat pump space heaters (including TECH Clean California, described further below)
- Rebates for both induction cooktops and heat pump dryers (BayREN 2022a)
- Incentives for panel upgrades are offered by many entities (BayREN 2022b)

These programs are fundamental to adoption of existing building electrification, and a pre-requisite for the adoption of existing building electrification ordinances. Incentives support existing building electrification at scale while mitigating harm to constituents in-need through the transition.

The need for access to financing for electrification varies widely among homeowners. Some homeowners can afford the upgrades without any financing, others will find traditional financing methods like a Home Equity Line of Credit to be most cost-effective. Some homeowners need utility assistance to access to financing offerings, and lower-income homeowners may require increased incentives rather than financing. In recognition that the cost of electrofits may be high, California has recently rolled out several programs designed that incentivize residential electrification. Most notably, TECH Clean California is a \$120 million initiative that provides up to \$3,100 for heat pump water heaters replacing gas water heaters and \$3,000 for heat pump space heaters replacing gas space heaters, and \$2,800 for panel upgrades (Energy Solutions 2022).

Figure 3 depicts how the TECH program can cover the conversion of existing gas equipment residential buildings using the incremental cost data above. The total investment costs are provided for context, and do not include panel upgrades. As an example, a single family building in California that is replacing a gas water heater with a heat pump water heater could receive \$3,100, covering more than half the total investment cost, and more than cover the incremental cost compared to replacing a like-for-like gas water heater. These costs will of course vary widely depending on the existing building conditions, as well as the proposed system type, and figures below represent averages for common system selections (E3 2019).

For heat pump space heating, the TECH program far exceeds the incremental cost of \$500 if the existing installation or planned retrofit includes air-conditioning. However, as shown in Figure 3, if air-conditioning is not being installed, costs associated with siting the exterior unit, electrical wiring, and refrigerant piping can be substantial in a heat pump space heating electrofit.

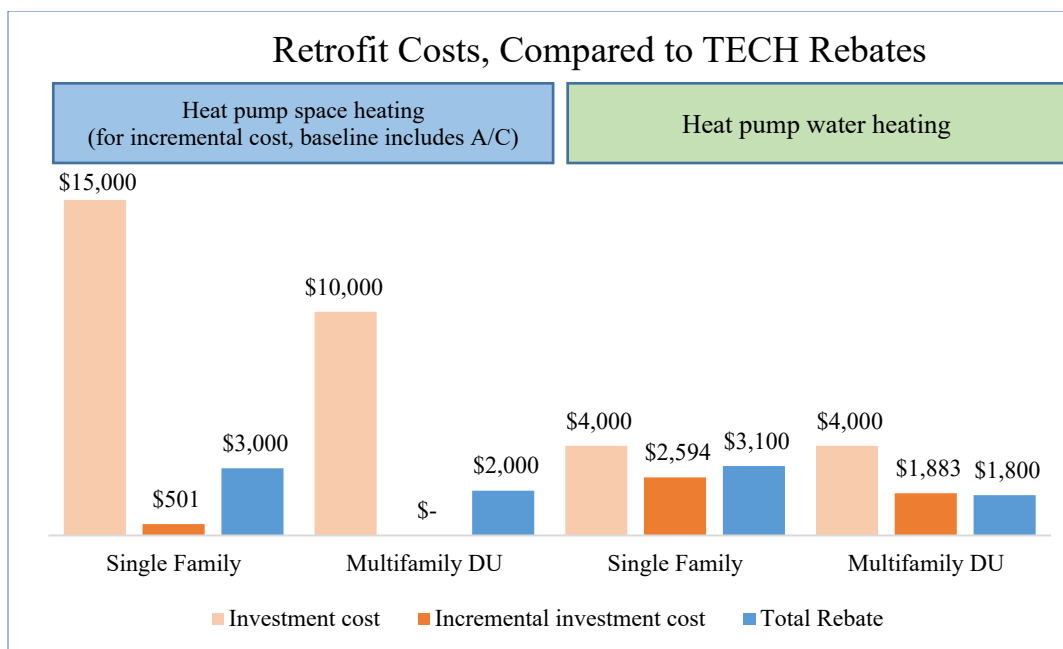


Figure 3. Average retrofit costs, compared to rebates.

The TECH program may be effective in incentivizing heat pumps for many California buildings that will be undergoing replacements of space and water heating equipment, though a significant gap remains for the large proportion of California homes that do not have air-conditioning. For the other clothes dryer and cooking single family measures, programs simply need to cover the cost of the electrical wiring to reach the appliance. The California Energy Smart Homes Program, for example, provides \$500 to install a heat pump dryer in an alteration scenario (PG&E 2022).

To begin addressing higher-cost scenarios, Peninsula Clean Energy, Sonoma Clean Power, and others are offering on-bill financing programs to enable electrification investment to be paid on the electricity bill (SCP 2022). While Sonoma Clean Power's program has been in effect for over a year, Peninsula Clean Energy is just kicking off the program. In both instances, the loans are at 0% interest, can include other energy efficiency measures, but must include at least one electrification measure. Offering repayment on-bill reduces administrative burden, and the 0% interest rate is attractive to customers who have the appetite to increase monthly payments in exchange for a smaller carbon footprint. California's TECH Clean California program is currently piloting Tariffed On-Bill Financing, a solution that enables the incentive to track with the residence, rather than the customer.

Nonetheless, there are at two broad areas where current financing is inadequate. First, the investment for heat pump space heating as a replacement for a gas furnace can be very high in a building that doesn't already have air-conditioning. Current incentives are not large enough to support the transition away from gas heaters. Second, nonresidential buildings are eligible for far fewer decarbonization incentive programs than residential. This may be due to the higher turnover rate of nonresidential spaces and equipment, as well as the higher financing needs and access of the nonresidential market. Given the challenges with nonresidential electrofit cost-effectiveness, targeted incentives, policies, and other programs are needed to capture nonresidential alteration scopes.

Local Government Program Considerations

Given the pace and scale of efforts necessary to achieve carbon neutrality, municipalities must address all areas of the market by invoking as many effective policy and financing options as resources allow. Local jurisdictions must assess the following factors when adopting local electrification policies or programs:

- Availability – How widely available is the policy, program, or financing option currently, particularly in your state? Several examples would indicate readiness for replication.
- Ease of Implementation – How easily would this policy, program, or financing option be administered from the perspective of the agency, and/or participate in from the perspective of the applicant? Reduced administrative burden suggests quicker processing, a high application rate, and stretching resources for a longer program period.
- Scalability – If given enough resources, can the policy or financing option be scaled to capture all of targeted population?

Policy design should be derived using an equitable process. Early and regular communications with marginalized community members can avoid inadvertently harmful policies, and ensure electrification works to reverse compounding historical injustices. The Department of Energy Low-Income Energy Affordability Data (LEAD) Tool can be leveraged by local jurisdictions to identify the number of housing units that are renters and their energy burden (LEAD 2022).

A local jurisdiction may simply share information on incentives with project applicants, or – on the other end of the spectrum – lead the development of incentive programs, likely with funding from a partner organization. Some examples of financing approaches that cities can consider are listed below:

- San Jose and Marin County funded electrofit incentives by partnering with the Bay Area Air Quality Management District, or BAAQMD (TRC 2021).
- Supported by \$3 million in incentives annually, Denver has adopted requirements for both electrofits at the time of replacement for space- and water-heaters, as well as Building Performance Standards for larger multifamily and commercial buildings. (Denver 2021)
- Ithaca and Menlo Park engaged BlocPower in public-private partnerships to facilitate electrofits as-a-service (Woody 2022).

Cities, particularly smaller ones, will likely need a programmatic support to design and implement electrofit programs and policies. These local policies and programs will be most adequately buttressed by state and federal support. However, even large state programs can run out of funding, as TECH Clean California did within one year of launching, although it was designed to be a multi-year program. Cities need stable and long-term sources of funding to support their investment of resources into local policies and programs.

Conclusion

Existing building electrification will have incremental upfront cost and will likely reduce on-bill costs in the long-term, depending on electric and gas rate increases. Use of heat pump technology will improve electrofit cost-effectiveness, but capital costs and bill increases are prevalent in the California-specific scenarios examined in this paper. Electrofit on-bill impacts

will be more favorable to occupants in regions with lower electric rates. Improvements to utility rate design, funding and incentives defray capital costs, and financing that mitigates the potential for on-bill increases will all play an important part in protecting vulnerable populations.

Local governments cannot be expected to solve these challenges alone and will need to rely on utility partners and state action to provide financial support to their constituents. The TECH program, Regional Energy Network rebates, and community choice on-bill financing programs begin to provide electrofit pathways that available to vulnerable low-income populations. Local governments need these types of ‘equity guardrails’ before they can adopt policies requiring electrofits during alterations. There is still work left to be done, particularly in the following areas:

- The investment for heat pump space heating as a replacement for a gas furnace can be very high in a building that doesn’t already have air-conditioning, which is prevalent in California. This paper did not identify incentives large enough to support this market to transition.
- Nonresidential buildings are eligible for fewer incentive programs than residential. This may be due to the higher turnover rate of nonresidential spaces and equipment, the higher financing needs and access of the nonresidential market. Nonetheless, high electrofit transition costs associated with central heating plants, as well as complex and varying utility tariffs, pose costly barriers. This issue may be compounded in energy-intensive nonresidential buildings, such as restaurants.
- In early 2022, TECH Clean California ran out of funding. While having a high degree of applications is a mark for program success, California and likely many other states will need to make available substantially higher funding amounts to decarbonize the United States building stock.

References

BayREN (Bay Area Renewable Energy Network). 2022a. “Electrification.”

www.bayren.org/articles-tools-tips/electrification

———. 2022b. “List of Incentive Programs.” www.bayren.org/sites/default/files/2022-05/2022%20BAYREN%20List%20of%20Programs%20for%20Contractors%20v5%2010%20%20%20281%29.pdf

BDC (Building Decarbonization Coalition). 2019. *Stakeholder Assessment of All-Electric Residential New Construction*. www.buildingdecarb.org/uploads/3/0/7/3/30734489/bdc_all-electric_survey_report_final_2019-08-1.pdf

Berkeley, City of. 2022. *Existing Buildings Electrification Strategy*. Berkeley. www.cityofberkeley.info/uploadedFiles/Planning_and_Development/Level_3_-_Energy_and_Sustainable_Development/Berkeley%20Existing%20Bldg%20Elect%20Strategy_Final_102021.pdf

CEC (California Energy Commission). 2022. *Final 2021 Integrated Energy Policy Report, Volume III: Decarbonizing the State’s Gas System*. California Energy Commission.

Publication Number: CEC-100-2021-001-V3.

www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2021-integrated-energy-policy-report

——— 2021. *California Building Decarbonization Assessment*. Publication Number: CEC-400-2021-006-CMF. www.energy.ca.gov/publications/2021/california-building-decarbonization-assessment

——— 2020a. “Local Ordinances Exceeding the 2019 Building Energy Efficiency Standards.” Accessed March. www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2019-building-energy-efficiency-3

——— 2020b. *TDV 2022 Update Model*. www.energy.ca.gov/files/tdv-2022-update-model

——— 2017. *Senate Bill 350 Doubling Energy Efficiency Savings by 2030*. California Energy Commission. Publication Number: CEC-400-2017-010-CMF. www.energy.ca.gov/files/tdv-2022-update-model

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

Denver, City of. 2021. *New Ordinance for Building Electrification*. City of Denver. hwww.denvergov.org/Government/Agencies-Departments-Offices/Agencies-Departments-Offices-Directory/Climate-Action-Sustainability-Resiliency/News-Events/News/2021/New-Ordinance-for-Building-Electrification#:~:text=Denver%20is%20committed%20to%20reducing,30%25%20energy%20savings%20by%202030.

E3 (Energy and Environmental Economics). 2018. *Deep Decarbonization in a High Renewables Future*. California Energy Commission. www.ethree.com/wp-content/uploads/2018/06/Deep_Decarbonization_in_a_High_Renewables_Future_CEC-500-2018-012-1.pdf

——— 2019. “Residential Building Electrification in California.” www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf

Energy Solutions. 2022. *TECH Clean California*. Accessed June 2022. energy-solution.com/tech/

Frontier Energy. 2019a. *Residential Cooktop Performance and Energy Comparison Study*. Sacramento Municipal Utility District. https://peninsulareachcodes.org/wp-content/uploads/2019/11/FrontierEnergy_ResidentialCooktopPerformanceandEnergyComparisonStudy.pdf

- . 2021. “2019 Cost-Effectiveness Study: Existing Single Family Residential Building Upgrades.” California Statewide Utility Reach Codes Program.
https://localenergycodes.com/download/875/file_path/fieldList/2019%20V2-Residential%20Retrofit%20Cost-eff%20Report-2021-08-27.pdf
- . 2022. “2019 Cost-Effectiveness Study: Existing Multifamily Residential Building Upgrades.” California Statewide Utility Reach Codes Program.
https://localenergycodes.com/download/986/file_path/fieldList/Low-rise%20Multifamily%20Retrofits-Cost-eff%20Report.pdf
- ITRON. 2014. *Commercial Saturation Study*. California Public Utilities Commission.
www.calmac.org/publications/California_Commercial_Saturation_Study_Report_Finalv2.pdf
- LEAD (Low-Income Energy Affordability) Tool. Department of Energy. Accessed June 2022.
www.energy.gov/eere/slsc/maps/lead-tool
- NBI (New Buildings Institute). 2021. *Building Electrification Technology Roadmap*. Building Decarbonization Coalition. newbuildings.org/resource/building-electrification-technology-roadmap/
- New York, State of. 2020. *Order Authorizing Utility Energy Efficiency and Building Electrification Portfolios Through 2025*. Albany: State of New York Public Service Commission.
documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B06B0FDEC-62EC-4A97-A7D7-7082F71B68B8%7D
- Pecan Street. 2021. *Addressing an Electrification Roadblock: Residential Electric Panel Capacity*. www.pecanstreet.org/panel-size-paper-update/
- PG&E (Pacific Gas and Electric Company). 2022. *California Energy-Smart Homes All-Electric Residential Program Fact Sheet*. stg.caenergysmarthomes.com/wp-content/uploads/2021/12/CESHP_TRC_Fact-Sheet_All-Electric_2021-12_v1-1.pdf
- PNNL (Pacific Northwest National Laboratory). 2016. *Affordable Hybrid Heat Pump Clothes Dryer*. Department of Energy.
www.pnnl.gov/main/publications/external/technical_reports/PNNL-25510.pdf
- Redwood Energy. 2021. *Watt Diet Calculator*. Accessed March 2022. redwoodenergy.net/watt-diet-calculator/
- RMI. 2020. “Gas Stoves: Health and Air Quality Impacts and Solutions.” Rocky Mountain Institute, Physicians for Social Responsibility, Mothers Out Front, Sierra Club.
rmi.org/insight/gas-stoves-pollution-health/
- Seattle, Office of the Mayor for City of. 2020. *Mayor Durkan Announces Ban on Fossil Fuels for Heating in New Construction to Further Electrify Buildings Using Clean Energy*. City of

Seattle. durkan.seattle.gov/2020/12/mayor-durkan-announces-ban-on-fossil-fuels-for-heating-in-new-construction-to-further-electrify-buildings-using-clean-energy/

SCP (Sonoma Clean Power). 2022. “0% Financing. 100% Easy.” Accessed June 2022. scpadvancedenergycenter.org/financing

Title Track. 2022. *Regional Spotlight: 2022 California Housing Market Could See Decline in Single-Family Home Sales*. RISMedia. ace.rismedia.com/trg/32105/1069382/41743596/119276?utm_source=newsletter&utm_medium=email

TRC. 2022. *Nonresidential Alterations Cost Effectiveness Study*. California Statewide Utility Reach Codes Program. localenergycodes.com/download/960/file_path/fieldList/Nonresidential%20Alterations%20Cost-effectiveness%20Report.pdf

———. 2021. *Existing Building Electrification and Multifamily Electric Vehicle Charging -- Policy and Financing Literature Review and Analysis*. Peninsula Clean Energy. bayareareachcodes.org/wp-content/uploads/2021/06/Policy-and-Financing-Literature-Review-for-Existing-Building-Electrification_20210612.pdf

Walton, R. 2019. *California opens \$1B in efficiency funding to electrification*. Utility Dive. August 2019. www.utilitydive.com/news/california-opens-1b-in-efficiency-funding-to-electrification/560096/

Washington, State of. 2020. *Washington 2021 State Energy Strategy*. Washington State Department of Commerce. www.commerce.wa.gov/wp-content/uploads/2020/12/Washington-2021-State-Energy-Strategy-December-2020.pdf

Woody, T. 2022. “Silicon Valley’s Menlo Park Plans to Electrify 10,000 Buildings.” *Bloomberg Green*. June 17. www.bloomberg.com/news/articles/2022-06-17/silicon-valley-s-menlo-park-plans-to-electrify-10-000-buildings