

Total Electrification of Existing Multifamily Buildings: A Case Study

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ABSTRACT

This paper explores the challenge of electrifying gas end uses in multifamily buildings, specifically focusing on the Sacramento region. In Sacramento County, 60% of multifamily units have gas space heating and 88% have gas water heating. An analysis of all multifamily building loads finds that 9% of distribution transformers, 20% of main service building panels, and 8% of unit panels are currently loaded above their nameplate ratings and will need to be upsized during electrification. The study finds that even in the most expensive electrification scenarios, average incremental costs of electrification compared to like-for-like gas equipment replacement are more than covered by utility incentives. The study also projects that 92% of customers that electrify will see a decrease in total annual energy bills, and that average total energy bills will decrease by 11%. The study finds that the biggest barrier to multifamily electrification is not financial but rather the time and expertise required to perform electrification projects.

Introduction

Research Motivation

Building electrification technologies, specifically heat pumps and induction stoves, are available and affordable for many homes and businesses today, providing relatively easy access to the greenhouse gas (GHG) reduction and indoor air quality benefits they provide. However, there are segments of the building stock, and thus resident and worker population, that have many barriers to accessing these technologies. This study focuses on existing multifamily buildings, which pose specific challenges for decarbonization. These buildings have proportionally less space for rooftop PV and EV charging than single-family homes, more technical challenges for installing all-electric retrofitted appliances, and split incentives between owners trying to minimize costs and occupants trying to minimize rent, bills, and negative health impacts. To ensure that occupants of these buildings experience the same benefits of electrification as the rest of the population, it is crucial to identify the biggest barriers to electrification and develop strategies and policies that make electrification the path of least resistance for multifamily buildings.

The goal for this research is to provide a granular analysis of what total multifamily electrification would look like on a local scale, in this case the territory of the Sacramento Municipal Utility District (SMUD). SMUD, a publicly owned electric utility serving most of Sacramento County and parts of Placer and Yolo Counties, offers a good case study for statewide electrification with a mid-sized urban center and suburban and exurban surrounding areas and a climate with just slightly more heating and cooling requirements than the population-weighted average for the state of California. Sacramento is in the International Energy Conservation Code's climate zone 3B, meaning it has slightly more cooling needs and fewer heating needs than the United States on average, but it is not an extreme climate (ICC 2021). This research can be used as a model for studying the potential for multifamily electrification in other localities, as each region will face similar challenges but may have different priorities, infrastructure, demographics, and building stock.

Health and Welfare Impacts

Leaving existing multifamily buildings out of electrification policy makes centering an equitable electrification transition challenging – most multifamily residents are renters, and if the capital cost of electrifying a building requires increasing rent, the lower income tenants may be priced out of the building. If efficient all-electric buildings become unattainable for low-income renters, they will also see their gas bills increase as fewer Californians share the cost of the gas transmission system. In many cases, these low income residents may live in disadvantaged communities, which are defined by CalEnviroScreen, a tool developed by the California Environmental Protection Agency, as “census tract[s] that are disproportionately burdened by, and vulnerable to, multiple sources of pollution” (*CalEnviroScreen 3.0* 2018). Leaving these residents to pay higher utility bills while increasing the disproportion of impacts from gas-related pollution would be a devastating scenario for the building energy transition.

Gas appliances, especially gas cooktops, have also been shown to significantly increase air pollutant concentrations in homes, occasionally above the standards for outdoor air. In a study conducted by researchers at Lawrence Berkeley National Laboratory (LBNL), of the 155 California homes that were sampled, 10% had 6-day NO₂ levels above outdoor limits set by the California Ambient Air Quality Standards (CAAQS), and although exhaust fans should have reduced the impacts from stoves, there was no statistically significant difference between the air quality in homes with exhaust hoods and without (Mullen, Li, and Singer 2012). If a multifamily building owner has made envelope efficiency upgrades in the building to improve performance, it could actually lead to worse air quality and health outcomes for occupants in units with gas appliances. A study by researchers at Boston University modeled multifamily buildings with natural gas appliances before and after adding building insulation and sealing measures and found that air quality-related healthcare costs from trapping pollutants indoors far outweighed any energy-saving cost benefits from the measures (Underhill et al. 2020). If California hopes to see an equitable transition to all-electric buildings that centers environmental justice, it must focus on reducing the barriers to electrifying existing multifamily buildings.

Methodology

Building Attribute & Load Data

This paper defines multifamily housing as either a parcel with four or more units or a condominium parcel in a building with four or more units, not including mobile home parks. According to Sacramento County’s open parcel data, units in parcels meeting these criteria can be matched to 110,898 SMUD meters (Sacramento County, 2021). Each meter can be matched to a SMUD distribution transformer. This study used hourly electricity consumption data at the meter level for all of 2019 instead of 2020, meaning there are no impacts due to COVID-19 in the data.

This study only considers the impact of electrifying space heating, water heating, and cooking in multifamily buildings. This is not comprehensive, as pool heating and laundry are two other end uses that often use fossil fuels on-site, but according to the 2019 California Residential Appliance Saturation Survey (RASS) organized by the CEC, space heating accounts for 32% of residential gas consumption, water heating accounts for 59%, cooking accounts for 5%, dryers account for 2%, and pools, spas, and miscellaneous uses account for the final 2% (Palmgren et al. 2021). Specifically for California multifamily homes, the RASS projects that 63% of units

have gas space heating, 69% have gas water heating, 71% have gas cooking, 28% have gas dryers, and 1% have gas pool heating. Additionally, it is much harder to determine which buildings have gas laundry and pool heating from the resources available. Given the minimal adoption of heat pumps and induction stoves in multifamily buildings at this point in time, if a building has electric water heating, space heating, or cooking, it is assumed to use electric resistance elements for heating (Palmgren et al. 2021). For the sake of simplicity, this study organizes each water heating system as either individual, multi-central, or central to each building, where multi-central means a storage water heater that serves two to ten units but does not recirculate the hot water. Space heating can be done with a variety of technologies, such as wall furnaces, packaged A/C and heating units, central forced air heating and cooling, or central hydronic radiators. The specific technology type is too granular of a level to predict using the methodology laid out in this section, so this study simply assigns a space heating system type of either individual or central to each building.

One issue caused by the way that parcels are divided is that one parcel does not necessarily equal one building. There may be one building per parcel, there may be multiple buildings per parcel, or, in the case of condos, there may be multiple parcels per building. For this study, if a parcel had meters attached to more than one transformer, the meters on each transformer were deemed to be in one building within a parcel of multiple buildings. If a transformer had multiple parcels with single meters attached to it, as would be the case in a condo, those meters were deemed to be in a single building with multiple parcels. Otherwise, the meters in a single parcel were deemed to be part of one building. Each building was assigned a unique identifier similar to the parcel or transformer identifiers. There are 6,232 multifamily parcels in SMUD territory and 5,315 transformers that have multifamily meters attached, which led to 6,722 unique buildings.

The data for fuel and system types were pulled from three sources: Sacramento County building permit data, which is available for every year starting in 2007, the California Tax Credit Allocation Committee's (TCAC) low-income housing capital needs assessments, and a former contractor of SMUD's multifamily energy efficiency program ("Permits" 2021; "Project Mapping" 2021). By matching these records to individual parcels, space heating fuel type could be specifically determined for 17% of meters, water heating fuel type could be determined for 21% of meters, and cooking fuel type could be determined for 2% meters.

Building Attribute Prediction & Imputation

To predict the fuel and system types of the remaining multifamily building stock, the primary strategy used is to create average normalized annual electric load shapes of the buildings with known fuel and system types and then match the unknown buildings to these load shapes. This method is not effective for predicting stove fuel type, as stove fuel type has a minimal impact on overall load shape. Additionally, the difference between central and individual space heating load profiles at the building and transformer level is not significantly different, so they were treated the same. This leaves three variables to determine for each building using the load profile matching method: space heating fuel, water heating fuel, and water heating system type.

To create normalized load shapes at the building level, hourly energy consumption for each meter is aggregated to the building level so that any central or master meter consumption is included as well. The aggregated building load for each of the 8,760 hours in 2019 is then divided by the aggregated annual building electricity consumption to get the normalized load

shape for each building, where the value for each hour represents the percent of annual electricity consumption consumed in that hour.

The load shapes for buildings with known values for each of the three variables mentioned above are averaged to create distinct load shapes for each variable combination. Table 1 below shows the number of buildings and units with a given space heating fuel, water heating type, and water heating fuel. The three buildings with both gas space heating and electric central water heating are not included as an option when matching unknown attributes to buildings due to the low sample size and outlier consumption levels. This means that buildings that actually have these specific characteristics are matched incorrectly but, based on the known data, this should not affect a significant amount of the building predictions.

Table 1. Percent of meters served by given fuel and system types for different end uses

Space Heating Fuel	Water Heating Type	Water Heating Fuel	Number of Buildings	Number of Units	Average Electricity Use per Unit (kWh/yr)	Used for Matching?
Electric	Central	Electric	10	132	4,983	Yes
Gas	Central	Electric	3	74	2,643	No
Electric	Central	Gas	89	2,248	4,935	Yes
Gas	Central	Gas	131	3,081	4,123	Yes
Electric	Individual	Electric	41	1,107	7,552	Yes
Gas	Individual	Electric	39	785	5,611	Yes
Electric	Individual	Gas	68	1,871	5,365	Yes
Gas	Individual	Gas	124	1,754	4,626	Yes

To match the normalized load shapes of the buildings with unknown attributes, the sum of squared errors for each hour between each building and each known load shape is calculated. The minimum sum of squared errors across all seven potential load shapes determines which combination of attributes is assigned to each building. The predicted attributes for buildings that have some but not all attributes already known can be compared to the known values, resulting in the match success rate shown in Table 2, and suggests that the matching methodology is over-predicting the number of buildings with electric space heating as well as buildings with individual and electric water heating.

Table 2. Successful match rate of buildings with known attributes

	Space Heating Fuel	Water Heating Type	Water Heating Fuel
Buildings Correct	701	762	960
Buildings Incorrect	259	473	171
Successful Match Rate	73%	62%	85%

To strengthen confidence in the matching results as well as predict the stove fuel for all buildings, a secondary method is used called multivariate imputation by chained equations (MICE), which is a method of imputing, or predicting, missing values in a dataset based on other variables. It is an alternative to regression analysis when too much data is missing to create a

meaningful model. This study used classification and regression trees (CART) for the MICE model, which is a form of machine learning that splits outcomes into different partitions based on combinations of the predictor variables with the goal of creating similar outcomes for similar combinations of variables (Burgette and Reiter 2010). The variables used in the models to impute the missing fuel and system type data are Year Built, Number of Units, and Parcel Area. The model is iterated five times for each fuel and system type variable.

Stove fuel is simply determined by the fuel type that is selected in three or more of the five iterations. For space and water heating variables, if 1) all five iterations produce the same value, 2) the value is different than the predicted value from the matching process, and 3) the minimum sum of squared errors from the matching process is in the top 20% of sum of squared errors – in this case, greater than $8.4e-7$ – then the value of the variable is changed to what was predicted by the MICE methodology. In sum, this led to the values in Table 3. There are sure to be incorrect variable predictions from this methodology combination, but without better initial data from physical inspections of the buildings, this should be sufficient for the territory-wide analysis. These data align well with the statewide data in the RASS study mentioned previously, which estimated that in multifamily units, 63% of space heating is gas, 69% of water heating is gas, and 71% of cooking is gas.

Table 3. Percent of meters served by given fuel and system types for different end uses

End Use	System Type	Fuel Type		
		Gas	Electric	Total
Space Heating	Central	5%	5%	10%
	Individual	55%	35%	90%
	Total	60%	40%	100%
Water Heating	Central	29%	1%	29%
	Individual	59%	12%	71%
	Total	88%	12%	100%
Stove		1%	58%	42%

Electrification Load Shapes

The next step in understanding the impacts of electrification is adding on the load shapes of the gas-to-electric measures to the existing load profiles for each unit. Figure 1 shows a summary of the electrification load shapes to be added. The individual heat pump water heater (HPWH) load shape is aggregated from unpublished simulations of individual storage HPWH energy use in SMUD's climate zone for different household sizes and HPWH brands obtained from the Natural Resource Defense Council (Delforge 2020). The central HPWH load shape per unit served is aggregated from simulations run in California's building compliance software, CBECC Res (Wilcox 2019). As discussed earlier, individual and central space heating are treated as having the same impact in this study, so only one load shape is used for both. Because the HVAC heat pump (HP) can operate in both directions and is replacing not only the existing gas space heating system but also the existing A/C cooling system, there are typically efficiency gains as a new high performance, better-sized cooling system replaces an older and potentially larger system. Every unit is assumed to already have air conditioning, as 95% of dwellings in

SMUD territory are estimated to have air conditioning according to the RASS (Palmgren et al. 2021). This reduction from the baseline is represented in the negative load in the warmer months. The HVAC HP load shape is developed through internal SMUD measurements and models based on typical heating and cooling degree days in SMUD territory. The induction cooktop load shape is developed through internal SMUD estimates. Note that the magnitude of the induction cooktop load shape is much smaller than the heat pump load shapes.

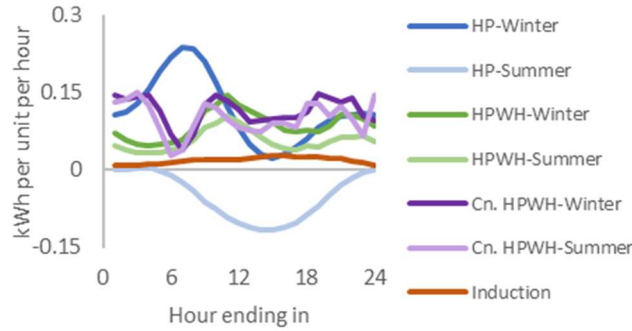


Figure 1: Electrification Average Daily Load Shapes

Shape Adjustment Based on Current Consumption

These load shapes are suitable as base or average impacts per multifamily unit. However, each building has a different envelope and use profile. To account for this, a simple temperature dependent model was created for each aggregated normalized building load shape. The models are initially based on three-parameter cooling and heating models commonly used in evaluating or predicting energy performance but simplified due to the extreme computing power required (Kissock et al. 1998). The only variables used are heating degree days (HDD) and cooling degree days (CDD). The dependent variable in the models is hourly percent of annual electricity consumption, and the model produced a slope for HDD and CDD and an intercept for when HDD and CDD are zero (i.e., at 65 degrees). Each building is assigned a percentile for their variable slopes and intercepts compared to all of the buildings with the same space and water heating characteristics – e.g., a building with gas space heating and central gas water heating is given a percentile for its HDD and CDD slopes and intercept compared to all other buildings with those attributes.

For buildings with gas space heating, the base heat pump electrification load shape detailed previously is scaled by assuming that the current CDD slope will similarly reflect the HDD slope after electrification, as the electricity used for space cooling is likely to be similar to the electricity used for space heating for the same degree day value. The potential range of the scaled load shape is from 0.5 times to 1.5 times the original load shape magnitude, with the CDD slope percentile from 0% to 100% dictating the scaled annual heat pump load within that range, as shown in Equation 1.

$$\begin{aligned} \text{Scaled Annual HP Load } \left(\frac{kWh}{yr} \right) = \\ \text{Base HP Load } \left(\frac{kWh}{yr} \right) \times (50\% + \text{CDD Slope Percentile}) \end{aligned} \quad (1)$$

For buildings with gas water heating, the base HPWH load shape is scaled by assuming that the model's intercept represents the baseline consumption for the building. Of the three

variables available for each building – CDD, HDD, and intercept – the intercept represents the best estimate for scaling the HPWH consumption magnitude, as hot water is consumed year-round, regardless of temperature, although HPWHs tend to use more electricity per unit of water in the colder months. A similar method is used to scale the HPWH load as the HP load but using the model intercept percentile instead of the CDD slope percentile.

After being scaled, these load shapes are added to each unit and result in two electric load shape scenarios for each unit: before electrification (current) and after electrification. These load shapes are then aggregated to different levels to predict the loading on electrical infrastructure, as detailed in the following section.

Transformer & Panel Loading Analysis

This study considers loading scenarios on three different types of electrical infrastructure: distribution transformers, building panels, and unit panels. These are the levels that building owners are responsible for upgrading if needed; anything farther upstream on the grid is the responsibility of SMUD and not in the scope of this study. Distribution transformers may service multiple buildings, including non-multifamily buildings. They also may be connected to a building using a method called “direct bury”. This is an older practice that involves burying the wires from the transformer to the building underground and requires additional trenching to replace the wire if a transformer needs to be upsized. The building panel serves all units in a building; central HPWH impacts will be analyzed on this panel, not unit panels. The unit panel serves all end uses in a single unit and is assumed to have the same load that is seen by the unit’s meter.

Transformer sizes are available from SMUD, but panel sizes are much more difficult to determine. SMUD planners use a table for designing transformer sizes based on building panel sizes; when used in reverse, the table helps predict the building panel sizes based on known transformer sizes. For unit panels, there is much more uncertainty; based only on informal interviews with multifamily electrification project managers at the Association of Energy Affordability (AEA) and the aforementioned TCAC data, Table 4 was used to predict unit panel sizes.

Table 4. Prediction of Unit Panel Sizes

If Year Built Known	If Not: Main Service Size per Unit	Unit Panel Size
<1950	<20 Amps	40 Amps
<1975	<40 Amps	60 Amps
<2010	<70 Amps	90 Amps
2010+	70+ Amps	150 Amps
+20 Amps for in-unit electric water heater		

According to SMUD transmission and distribution planning staff, transformers are deemed to be overloaded if the cumulative load for any hour on the transformer is above the rated size in kVA. This assumes that average hourly demand is a good enough proxy for actual demand and that the transformer load has a power factor of 100%, meaning that kVA is equal to kW. Panels are deemed to be overloaded in a similar manner, assuming that building panels use the same voltage that is used for the transformer and that unit panels use 120V for all in-unit appliances. As required by the National Electric Code (NEC) Section 220.87 for calculating

existing panel loads, the peak demand seen by the panel over one year is multiplied by 125% as a safety factor before adding on the new potential load (NFPA 2020). The NEC requires the new loads to be added to the existing demand as its nameplate demand rating with certain demand factors, but this study uses the electrification load shapes determined previously as a more accurate, less conservative method of determining panel loading.

Estimating Total Project Costs

The cost of replacing transformers that are overloaded is known by utilities – the SMUD transmission and distribution planning staff has detailed information on upgrade costs that include materials, labor, and overhead depending on the type, location, and size of the transformer. For projects that require unearthing direct bury lines, an extra \$6,000 per project is added plus \$100 per kVA of transformer size, an estimate based on interviews with project managers. Panel cost estimates are harder to determine, but after interviewing project managers and utility experts at SMUD and AEA, main building panel costs are assumed to be \$8,000 per project plus \$50 per amp of panel size and unit panel costs are assumed to be \$2,000 per project plus \$25 per amp of panel size.

The bulk of project costs will be allocated to the actual equipment and installation of the equipment for electrification. Table 5 shows the base cost per unit for each piece of equipment that may be needed for an electrification project and the corresponding gas equipment replacement cost as well. For space heating, the cost of both the gas furnace and the cost of the air conditioner are included in the gas equipment cost, as the heat pump would replace both and should be compared as such. The individual HPWH project costs are collected from a SMUD report compiled in 2020; the gas storage water heater, induction stove, and gas range costs are collected from a study on building electrification (Mahone et al. 2019); the central water heating and space heating costs are collected from the 2022 Title 24 CASE report on multifamily buildings (Pande et al. 2021).

Table 5. Base Equipment Costs

	Garden (<9 Units)	Low-rise (9-36 Units)	Mid-rise (37-88 units)	High-rise (89+ units)
Individual Gas Storage WH	\$2,300			
Central HPWH	\$4,500	\$2,412	\$2,908	\$2,952
Central Boiler	\$4,488	\$1,453	\$947	\$709
Single Zone HP	\$4,608	\$4,854	\$5,070	\$5,057
Furnace & Split DX AC	\$5,955	\$6,214	\$6,349	\$6,360
Induction Stove	\$2,100			
Gas Range	\$1,800			

These base costs are scaled using a similar method as the scaled electrification loads, but with a slightly smaller range of potential values – 0.75 times the base cost to 1.25 times the base cost. These costs are added to any predicted electrical infrastructure costs to get total project costs per unit.

Bill Impacts

Current SMUD time-of-day rates and Pacific Gas & Electric's (PG&E) monthly gas rates from 2019 are used to estimate bill impacts due to electrification (Residential Time-of-Day Service Rate Schedule R-TOD 2019; "Gas Rates" 2021). Pre-electrification bills are calculated for each customer for each month based on the SMUD rates to get their annual costs, and they are also calculated for the second loading scenario, post-electrification. If a customer is on the EAPR rate, \$32 was subtracted from their monthly bill, which is the median SMUD EAPR bill deduction across different low-income classes (Residential and Commercial Industrial Energy Assistance Program Rate Schedule EAPR 2018). To get the estimated current gas bill – household PG&E gas bills were not available for this study – the base annual therm consumption for gas end uses is based on internal SMUD estimates. The same method of scaling electric consumption for water and space heating is applied to these values for each building.

2019 PG&E gas rates are used to calculate the monthly gas bills before electrification. If a customer is on the EAPR rate, it was assumed that they were also on the California Alternate Rates for Energy (CARE) rate, an analogous low-income rate for other California utilities. The study assumes gas lines would be disconnected from an electrified building and thus there would be no outstanding gas bill costs; the study also assumes that central water heating would be paid by the building owner, not split across individual units.

Results

Transformer Loading

For both loading scenarios – baseline and post-electrification – the peak load as a percent of rated size is determined for each transformer. Figure 2 shows the distribution of peak loads on transformers as a percentage of the rated size. Most transformers see peak loads in June, July, and August, the hottest months of the year in SMUD territory, and the lowest peak loads in October and December, two of the mildest months in 2019 in SMUD territory.

After electrification, overall electric consumption will likely be higher, but the peak impacts are dependent on the timing of added load as well as gained efficiency from the air conditioning of the heat pumps. As seen in Figure 2, the shift in transformer loading from pre-electrification to post-electrification mostly impacts transformers loaded in the 20%-40% range. The summer peaks remain about the same in the electrification scenario but the winter peaks, especially December, increase significantly, although not enough to get close to surpassing the summer peaks.

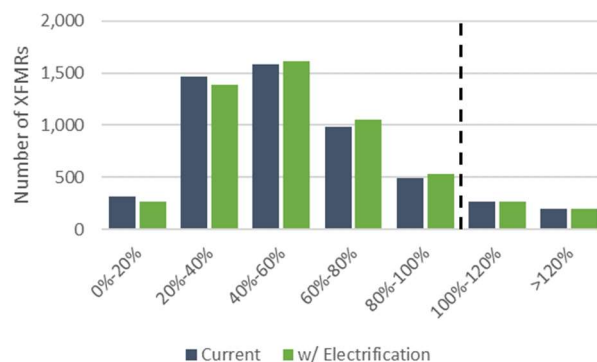


Figure 2. Histogram of Peak Transformer Loads as a Percent of Nameplate Rating

Table 6 summarizes the results from the transformer loading study by describing the range of transformers with peak loading at both 95% or more of the rated size and 105% or more of the rated size to show the sensitivity of the study. Meters on overloaded transformers are relatively evenly distributed – overloaded transformers are not significantly more likely to have more meters than non-overloaded transformers – and less than 10% of meters are likely to be on overloaded transformers. Efficiency gains from heat pump air conditioning have very small impacts on avoiding overloading.

Table 6. Number of Transformers Over 95% & 105% Loaded

	Number of XFMRs				% of All XFMRs	% of All Meters
	Current	Electrification Caused	Heat Pump Avoided	Total		
>95% Loaded	555	34	17	589	11.1%	10.3%
>105% Loaded	368	20	13	388	7.3%	6.9%

Main Service Panel Loading

The results for the panels are more uncertain than the transformer results because the panel sizes are unverified and the exact meters on each panel are not confirmed. As mentioned previously, the NEC requires a safety factor of 125% be applied to the existing peak demand, so panels loaded above 80% are considered overloaded. Figure 3 shows the distribution of peak loads on the panels as a percentage of the rated size. Compared to the transformer overloading distribution profile, the main service panels tend to either be very far over the rated capacity or around 10% to 40% loaded at peak load. With electrification, some building panels move into the 80% loaded region, and are thus overloaded, but more of the panels in those regions are currently overloaded than incrementally overloaded from electrification.

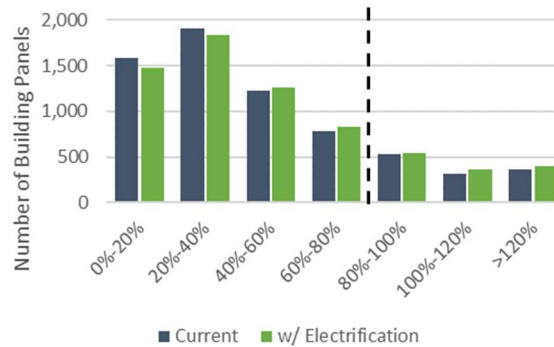


Figure 3. Histogram of Peak Building Panel Loads as a Percent of Nameplate Rating

Table 7 summarizes the building panel overloading. While the proportion of main service panels that are potentially facing overloading is somewhat more than the transformers – around 20% – the proportion of meters on main service panels facing overloading is much higher, around 42%.

Table 7. Number of Building Panels Over 75% & 85% Loaded

	Number of Building Panels				% of All Panels	% of All Meters
	Current	Electrification Caused	Heat Pump Avoided	Total		
>75% Loaded	1,378	134	18	1,512	22.5%	45.6%
>85% Loaded	1,067	100	16	1,167	17.4%	37.5%

Unit Panel Loading

Figure 4 shows the distribution of peak loading as a percent of the predicted rated size of the panel. Most panels are far from overloading, with the majority clustered around 20% to 60% loaded. As previously discussed, this level of electrical loading is most uncertain – the predicted panel size is an estimate often based on the estimate of main service panel size, if Year Built is not available. Because of this, the loading distributions for the electrification scenario is not shown, as the level of granularity in the changes would be misleading compared to the overall uncertainty. However, Table 8 summarizes the potential impacts of the scenarios. Around 0.2% of all unit panels are impacted by the electrification scenario, and only around 8% of panels would be overloaded in the worst-case scenario. This study does not suggest that an electrician would come to the conclusion that most of these panels do not need to be upsized, but instead that most panels are likely to physically be able to handle the increased loads of electrification because of the relatively small impact to the peak load and current predicted loading profiles of the panels.

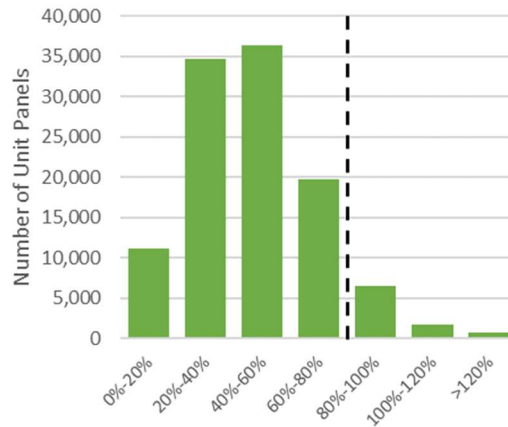


Figure 4. Histogram of Peak Unit Panel Loads as a Percent of Nameplate Rating

Table 8. Number of Unit Panels Over 75% & 85% Loaded

	Number of Unit Panels				% of All Meters
	Current	Electrification Caused	Heat Pump EE Avoided	Total	
>75% Loaded	12,321	269	0	12,590	11.4%
>85% Loaded	6,494	130	0	6,624	6.0%

Project Costs

Figure 5 summarizes the difference in total project costs per unit for electrification compared to the gas replacement baseline, assuming that projects happen upon equipment burnout. The group with the biggest project cost discrepancy is buildings with gas water and space heating that are required to upsize any electrical infrastructure. Even so, the average gap is less than \$2,000 per unit, or around 15% to 20% of the total project cost per unit. At the moment, SMUD offers up to around \$4,000 per unit of incentives for existing multifamily building electrification, depending on the necessary equipment and technical assistance, which would more than cover the difference. While this study was intended to be both comprehensive and conservative in regard to project costs, it is certainly feasible that there would be additional costs associated with the projects not covered in Figure 5. However, it is clear that the magnitude of costs for electrification are in the same range as the gas baseline.

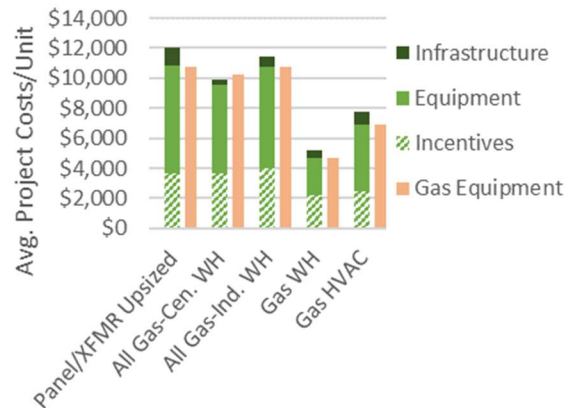


Figure 5. Electrification vs. Gas Project Costs by Category of Project

Bill Impacts

Figure 6 shows the average energy bills before and after electrification for SMUD customers on either the standard Time-of-Use rate or EAPR in buildings with different water and space heating fuels. Because of the markedly better efficiencies of new heat pumps compared to any gas or existing air conditioning equipment, electricity bills decrease for every category. Additionally, for customers who use very little gas, having one energy bill instead of two will decrease bill costs due to the minimum daily costs that exist for natural gas bills from PG&E. Across all multifamily customers, only 8% are projected to see increased energy bills from electrification. Interestingly, the customers in all-electric buildings are currently paying the most for energy of all the subsets of customers, indicating that these buildings may have older, inefficient electric resistance appliances and perhaps poorer insulation or building performance. Although outside the scope of this study, it would be valuable to understand the impacts of newer heat pump technologies in these buildings. The same trends exist for the EAPR customers, but the proportion of savings are even higher for the customers with more gas appliances.

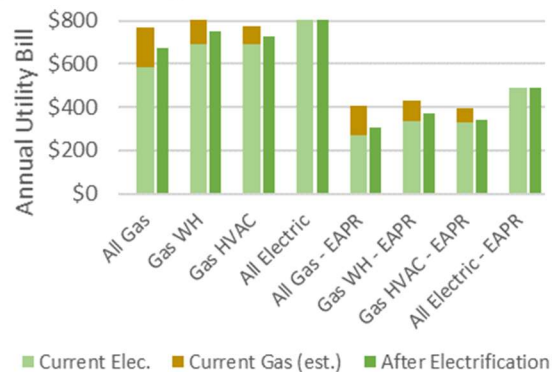


Figure 6. Average Energy Bills Before and After Electrification for Different Building Categories - Time-of-Day Rate

Table 9 shows the average and median change in energy bills for different customer populations. Consistently, low-income customers and those in disadvantaged communities will tend to see larger benefits than the general population. This is likely due in part to the higher rates of gas equipment in those populations.

Table 9. Average and Median Energy Bill Change After Electrification for Different Populations

	% Change of Tenant Utility Bill	
	Average	Median
Average Customer	-11%	-6%
Low-Income Rate Customers	-26%	-13%
Low-Income Housing	-25%	-8%
Disadvantaged Community	-18%	-7%

Discussion

The results from the loading study suggest that multifamily electrification will not lead to widespread overloading of local distribution grids. In fact, multifamily electrification is likely to be cheaper per unit than single-family, as the costs of replacing infrastructure are spread across more households. However, infrastructure upsizing remains a barrier, as the projects that will have to pay for upgrading the distribution transformer not only have to include it as a cost but will have to incur the hassle of potentially digging up any direct bury cables and temporarily shutting off power to units while completing the project. Owners of these buildings may rightfully turn down the opportunity to electrify their gas appliances strictly because of the time and hassle required, regardless of any cost incentives that make electrification more affordable than gas replacement. Additionally, while this study suggests that a minority of main service building panels and very few unit-level panels are or will be technically overloaded, each electrification project will still require an electrician to calculate all of the loads on the panels, which takes additional effort compared to like-for-like replacements of gas equipment. If the load factor calculation method is used instead of the annual maximum demand method used in this study, the panels are more likely to be considered overloaded when they may not need to be upsized.

These results suggest that replacing gas equipment with electric equipment upon burnout is a viable and beneficial strategy. However, because central heat pump water heaters are relatively rare and new compared to boilers, project costs may end up higher than estimated due to additional quality control. SMUD, along with other utilities, should continue efforts contributing to the development of an electrification workforce by providing training and funding for vocational classes.

One clear opportunity offered by electrification, especially in SMUD territory, is the impact on energy costs. This will mostly benefit tenants, but many building owners, especially in larger buildings, pay for central space conditioning and water heating; they will see huge benefits and can count the energy cost savings towards the life cycle value of switching to new efficient electric appliances. More focus should be placed on this benefit when encouraging building owners to electrify.

Conclusion

The goal of this study was to produce a more granular outlook than was previously available on the potential for and impacts from electrification in multifamily buildings in a utility region. In this case, the study was done in SMUD territory. The policy analysis determined that

while California has been focused on cleaning up the electric grid and improving new building performance for decades, they have not yet developed an effective incentive or solution for retrofitting buildings with gas appliances that impact both air quality and GHG emissions, although the state's new TECH program may provide significant assistance. This study focused on the current landscape for retrofitting and electrifying buildings.

The results determined that most buildings would not need to upsize their electrical infrastructure; overall, electrification project costs are relatively similar to gas project costs and electrical infrastructure costs do not represent a significant amount of the total costs that will be spent on electrification in multifamily buildings. Additionally, bills will be lower for nearly every customer and building owner after electrification.

This study is useful for displaying a vision of what electrification will look like at a local scale for a small utility. The results of this study are granular enough that SMUD can develop programs, forecast impacts, and respond to equity concerns around the energy transition, perhaps starting by ranking buildings or areas to reach out to building owners with electrification project funding. Some drawbacks of the study that could be improved in future studies are related to the data that are available: although some of the Sacramento County data such as permits and parcel information was very necessary and useful for determining building attributes, better data on number of stories, year built, and unit sizes would have significantly increased the ability of the models to correctly determine fuel and system types. It may have even been possible to consider more specific system types, such as wall furnaces vs. split DX gas heating, which would be more useful in understanding electrification impacts at the building and unit level. SMUD could work with the county to improve the availability and record-keeping of this data.

Future studies in different regions can hopefully refer to this study and use or adapt some of the methodology to produce results specific to the region.

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