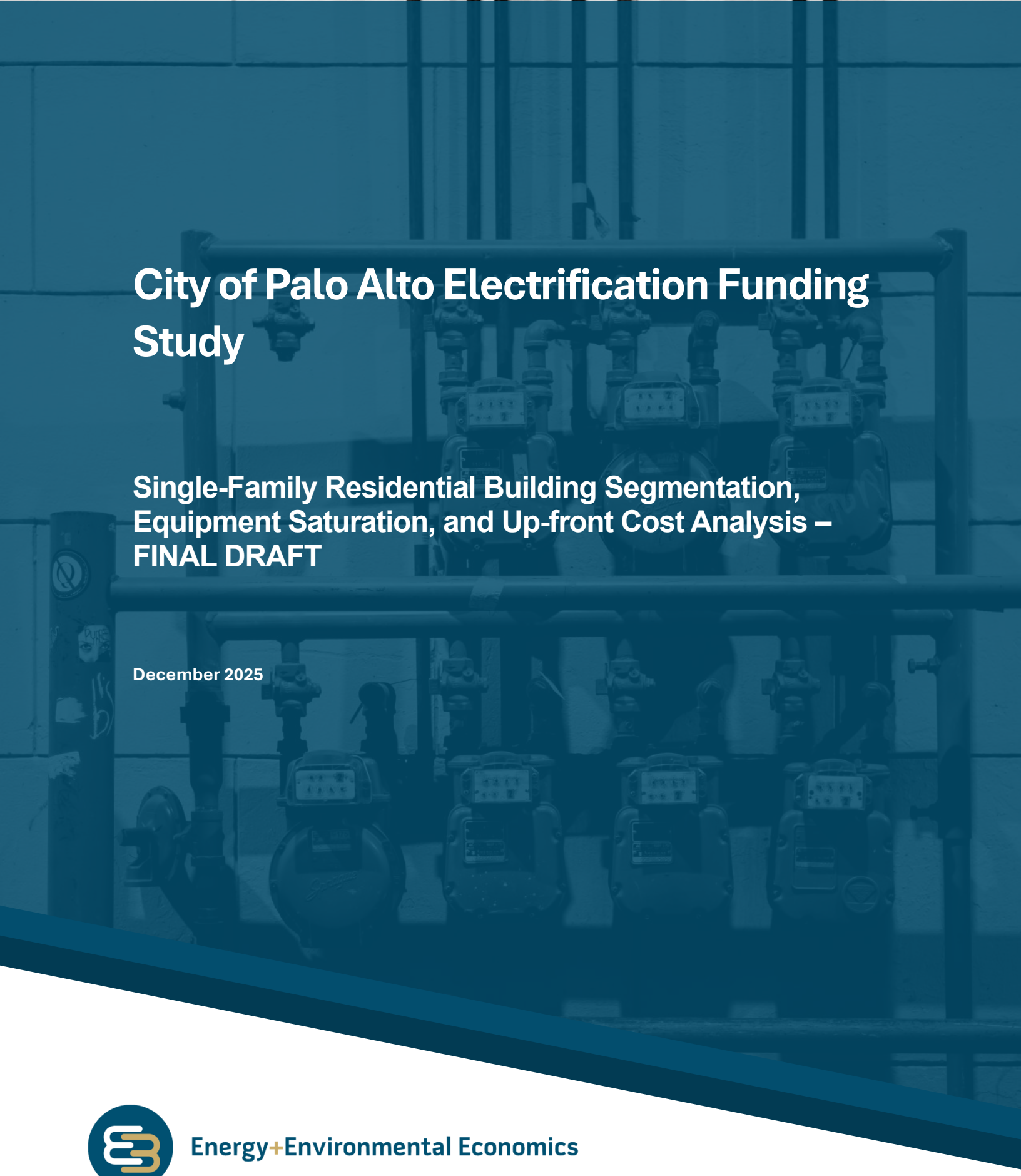

City of Palo Alto Electrification Funding Study

Single-Family Residential Building Segmentation, Equipment Saturation, and Up-front Cost Analysis – FINAL DRAFT

December 2025

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Table of Contents

Table of Figures

Table of Tables

Introduction

The City of Palo Alto is interested in understanding the cost to electrify the existing building stock and has engaged E3 to develop a building electrification funding model. In support of the S/CAP electrification funding model being developed by E3, Rincon Consultants Inc., has conducted a study of single-family homes in Palo Alto to inform the electrification model. This study includes:

- Building segmentation analysis by vintage, income level, and air conditioning status
- Up-front cost analysis

Data in this report was summarized from existing sources, some of which are not specific to the city of Palo Alto. However, the findings are of sufficient scale and accuracy to help guide this process but not intended as an accurate interpretation of the final cost of electrification for any specific building in Palo Alto due to the variability which can exist within the building stock. Data from this report will be incorporated into the S/CAP electrification funding model that will estimate the cost of electrifying all single-family homes in Palo Alto. The S/CAP electrification funding model includes an assessment of other cost considerations such as ongoing operational costs and incentives that are not addressed within this subsector study.

Single Family Homes Customer and Building Segmentation Analysis

This analysis focuses on the technologies and costs associated with electrification of single-family homes. This assessment also includes two-family homes (duplexes) as they generally utilize similar equipment and see similar costs for electrification.

Building Characterization

The purpose of the single-family sector study is to inform the S/CAP Funding model on the cost to electrify all single-family homes in Palo Alto. The cost to electrify a single-family home is largely dependent on the building's existing conditions, such as the technologies currently being used, the panel capacity and the size of the existing electrical service. Homes requiring panel or service upgrades increase the cost of electrification. Building vintage and the presence of central air conditioning or heat pumps correlate to whether the building's panel and service may need an upgrade. As such, as described in the following sub sections, a building segmentation analysis was conducted by building vintage and air conditioner status to determine the number of single-family buildings in Palo Alto likely requiring panel and/or service upgrades.

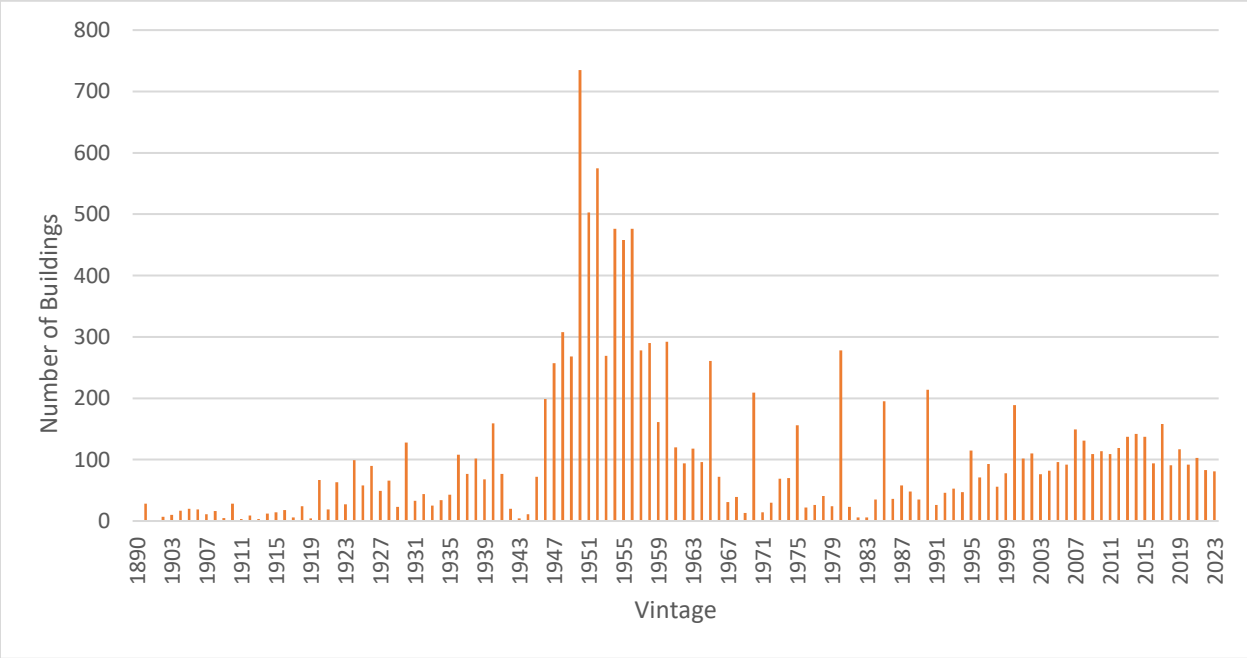
Segmentation by Building Vintage

Countywide assessor data obtained from Santa Clara County was utilized to characterize the building stock in Palo Alto by vintage. According to the Countywide assessor data, there are approximately 12,980 single-family homes and 130 duplexes. The County assessor data provides records of the year the building was constructed as well as the building effective year.[1] Effective year refers to the relative age of the home based on its assessed condition and accounts for significant improvements or remodeling that occurred since build year. For example, if a home was built in the 1950s but has an effective year in the 1970s, the home has been upgraded to a condition similar to a home built in the 1970s. Based on building assessor data, approximately 25% of single-family homes in Palo Alto underwent significant improvements or remodels and have a newer effective date than build date. To account for the impact of such remodels on building stock characteristics, the effective year of homes built in Palo Alto was utilized to characterize building stock by vintage as this is more representative of the homes current condition. Figure 1 provides a visualization of the building vintage for single-family homes in Palo Alto based on the building's effective year.

[1] Tax assessor data as of February 2024. Additional data sources including electric meter data from CPAU point to there being over 15,000 single family residential buildings. However, this data source does not provide information like building vintage that was used for this analysis. Future studies should look to scale up the number of single family buildings to address the missing data associated with the countywide parcel data. This information is particularly important for understanding a total cost to decarbonize every building in the city.

Building vintage can be used to generate assumptions about the technologies employed in a particular building. While vintage does not indicate whether updates have been made, it does provide some idea of potential barriers to electrifying that home. Based on a recent study by UCLA Center for Sustainable Communities buildings under 2,000 sq. ft. and constructed before the 1950s generally had electric panels of 60 amps or smaller, whereas homes over 2,000 sq. ft. constructed in the 1950s through the 1970s are more likely to have electric panels of 100 amps or more. [2] According to the study, larger buildings were tied to larger panel sizes in earlier vintages, with homes over 4,000 square feet assumed to have a 150 amp panel as early as 1978. Homes with lower amp panels or old fuse boxes are more likely to require electrical upgrades and these upgrades can significantly increase the cost and timeline for building electrification. A substantial number (~54%) of Palo Alto's single-family homes have an effective year before 1960 and had an average home size of 1,800 square feet meaning they could potentially need panel upgrades or other electrical work prior to full electrification. However, many of these buildings could have already completed panel upgrades without triggering a new "effective year" designation. The same UCLA Center for Sustainable Communities study found that statewide only 3% of single-family homes currently have panels smaller than 100amps. Cost implications associated with panel and service upgrades associated with electrification are discussed further in the section *Single-Family Building Electrification Up-Front Cost Analysis* below. Other research from the New Buildings Institute shows similar results with many buildings seeing at least a 100 amp panel by the 1960's. [3]

Figure 1 Building Vintage for Single-Family Buildings in Palo Alto



[2] https://www.ioes.ucla.edu/wp-content/uploads/2024/06/2024-Quantifying-the-electric-service-panel-capacities-of-Californias-residential-properties.pdf

[3] https://newbuildings.org/we-can-power-the-homes-of-the-future-with-electric-panels-of-the-past/#:~:text=Back%20in%201962%20the%20%E2%80%9CLive,and%20it's%20enough%20power%20now.

For the purpose of further building segmentation analysis, buildings were assumed to have the following panel capacities based on building effective date. building vintage is more generally characterized as:

- ≤1950s: homes built with electric panels less 60amps or less
- 1960s-1970s: home built with electric panels at least 100 amps
- ≥1980s; homes built with electric panels of at least 150 amps

This is a conservative estimate based on the building codes and construction methods assumed in the electric service panel capacity study completed by the California Center for Sustainable Communities.

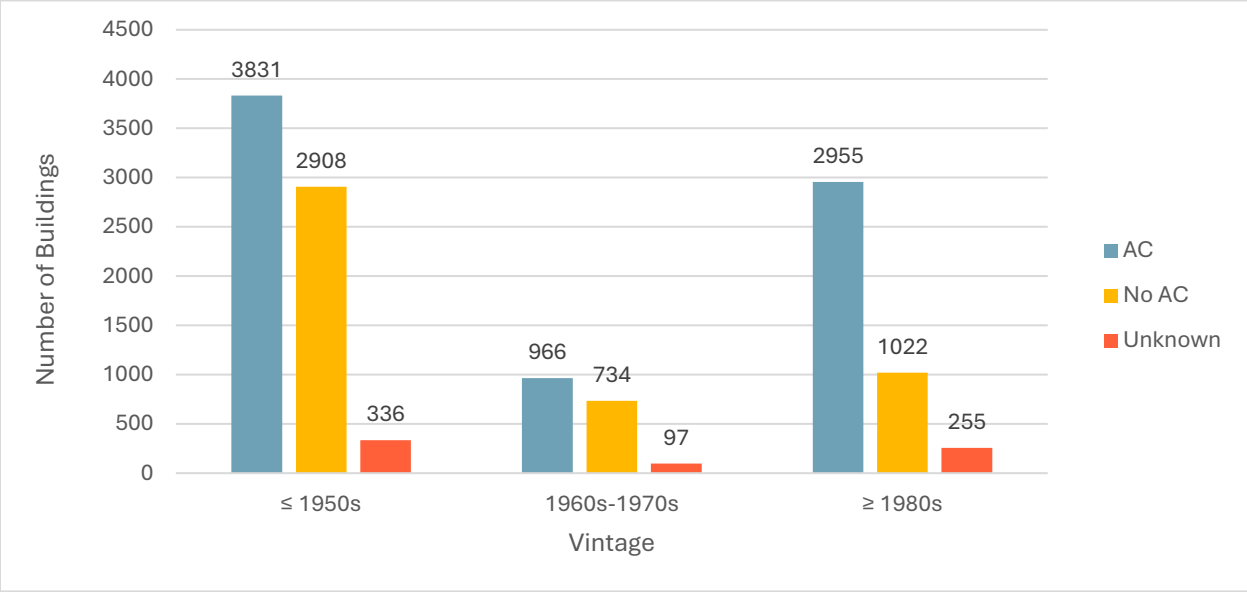
Segmentation by Air Conditioning Status

The building stock was further segmented based on the technology used for cooling the home as buildings with central air conditioning (AC) or heat pumps regardless of age, are likely to have undergone panel and/or service upgrades to accommodate the additional electricity needs of these appliances. National Renewable Energy Laboratories (NREL) ResStock Modeling Data[4] was used to determine the prevalence of different air-cooling technologies within Palo Alto by building vintage. To ensure a large enough sample size representative of Palo Alto, data from ResStock for Palo Alto and other comparable nearby cities (e.g., Campbell, Cupertino, Mountain View, San Mateo, Santa Clara, and Sunnyvale) were utilized to estimate the prevalence of different air-cooling technologies in single-family homes. ReStock data included the following five categories of cooling technology for single family homes: central AC, room AC, non-ducted heat pump, ducted heat pump, and none. For the purposes of this analysis, it was assumed that if a building had either central AC or a heat pump (ducted or non-ducted) that the building had undergone panel and service upgrades. Figure 2 shows the number of buildings by vintage with and without AC (i.e., no central AC or heat pump present). As shown, approximately 60% of homes in Palo Alto have either central AC or heat-pumps and therefore, likely already have the panel size and electrical service necessary to accommodate further electrification.[5]

[4] ResStock Modeling data is a tool for large-scale residential analysis combining public and private data sources, statistical sampling, building simulations, and high-performance computing. ReStock uses surveys which include the U.S. Census, the Public Use Microdata Sample (a microdata version of the American Community Survey [ACS]), the American Housing Survey (AHS), and the EIA's Residential Energy Consumption Survey (RECS). These surveys provided weighted survey samples with different building characteristics (for example: heating fuel, vintage, number of occupants, floor area, etc.) that ResStock leverages. https://docs.nrel.gov/docs/fy25osti/91621.pdf

[5] The presence of air conditioners is a key cost effectiveness consideration for building electrification since heat pumps provide both heating and cooling and one unit replaces both an AC and furnace. However, various sources provide different estimates for the number of central AC units in Palo Alto. The Palo Alto 2018 DER survey found 31% of respondents had a central AC. The 2019 California Residential Appliance Saturation Study (RASS) found 38% central AC saturation. The ResStock dataset also uses surveys from the region to come to a 58% saturation level. In addition, AC installation is increasing over time in the Bay Area due to a higher number of extreme heat days. The City should consider the impacts of various AC saturation rates in future studies.

Figure 2 Estimated Prevalence of AC by Building Vintage for Single-Family Buildings in Palo Alto (ResStock)



Overview

Table 1 summarizes the number of single-family Palo Alto buildings by vintage and presence of AC or heat pump. The table also includes information on whether panel and/or service upgrades are potentially needed for that building classification. Buildings built before the 1980s, when panel size was smaller, without a central AC or heat pump already installed may need panel and service upgrades for future electrification work. Buildings built in or post 1980s without a central AC or heat pump already installed likely already have a panel of adequate size, though may need service upgrades for future electrification work. As such, it is conservatively estimated that up to approximately 4,074 or 31% of single-family buildings in Palo Alto may need panel and service upgrades. This estimate is conservative, as many of these homes may already have completed panel upgrades or have intermediate size panels sufficient for electrification when paired with smart circuits or other load sharing technologies. For example, using the 3% panel upgrade estimate generated by the UCLA paper, less than 400 homes would have a panel smaller than 100amps and would need to upgrade.

Table 1 Building Segmentation Analysis for Single-Family Buildings in Palo Alto

Vintage	AC	No AC	AC Status Unknown
≤ 1950s	3,831	2,908	336
Upgrades Needed:	*None*	*Panel and service*	*Panel and service*
1960s-1970s	966	734	97
Upgrades Needed:	*None*	*Panel and service*	*Panel and service*
≥ 1980s	2,955	1,022	255
Upgrades Needed:	*None*	*None*	*None*
Total Number of Homes Potentially needing Panel and Service Upgrades: 4,075			

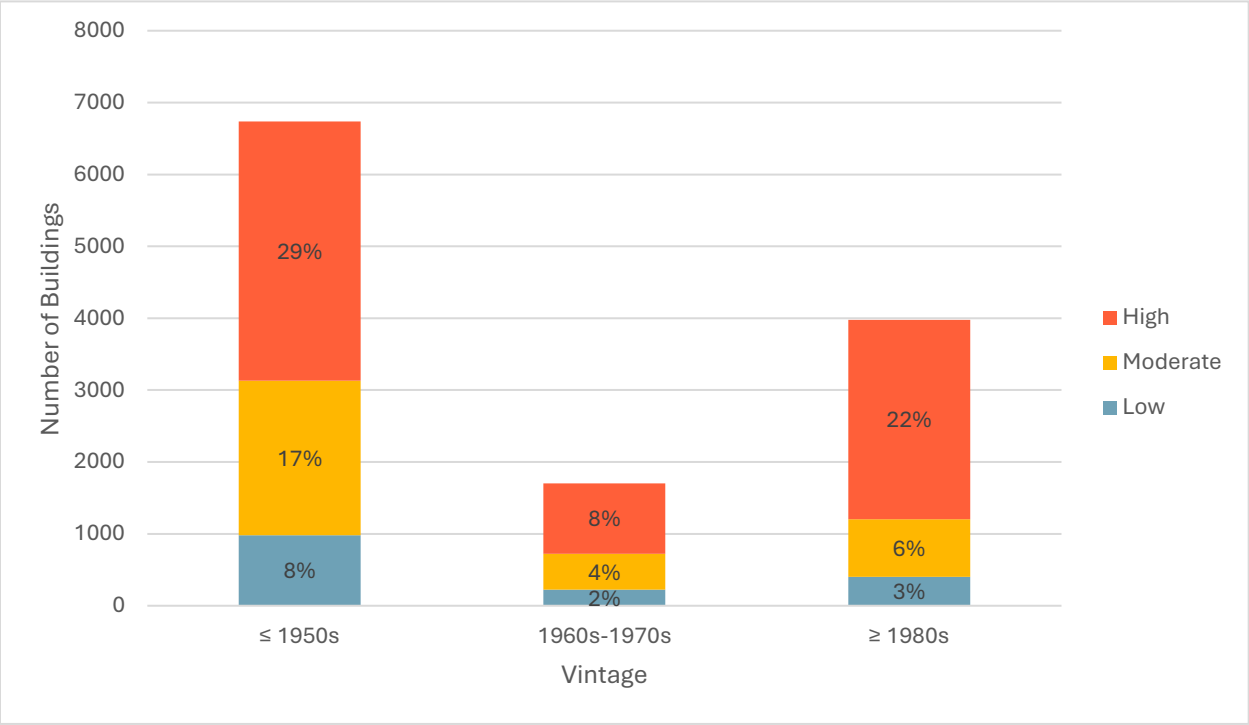
Customer Income Classification

Distinction of income level provides information in terms of the potential financial barriers the residents may face related to electrification as well as the potential available incentives based on household income level. Therefore, building stock was further segmented based on the income status of the building occupants. NREL ResStock Modeling Data provides estimates on household income level and building characteristics for buildings across Santa Clara and San Mateo Counties. To ensure a large enough sample size representative of Palo Alto in terms of income levels by building characteristic data from ResStock for Palo Alto and other comparable nearby cities (e.g., Campbell, Cupertino, Mountain View, San Mateo, Santa Clara, and Sunnyvale) were utilized to estimate the customer class by vintage and air-conditioning status. Customer class was defined as follows:

- Low Income: the household income is less than 80% of the local area median income
- Moderate Income: the household income is between 80% and 120% of the local area median income
- High Income: the household income is greater than 120% of the local area median income

Figure 3 presents the breakdown of customer income level by vintage. As shown, approximately 59% of customers are considered high income, 28% considered moderate income, and 13% considered low income.

Figure 3 Customer Income for Single-Family Buildings in Palo Alto



Single Family Homes Building Energy Profile

Energy Consumption

An analysis of City of Palo Alto Utilities (CPAU) customer account usage data was utilized to determine the annual energy consumption in terms of electricity and natural gas consumption from single family building types in Palo Alto. The total annual energy consumption for the Single Family Account Class and the average energy consumption per single-family building obtained from CPAU are presented in Table 2.[6]

Table 2 Energy Consumption Analysis for Single-Family Buildings Palo Alto

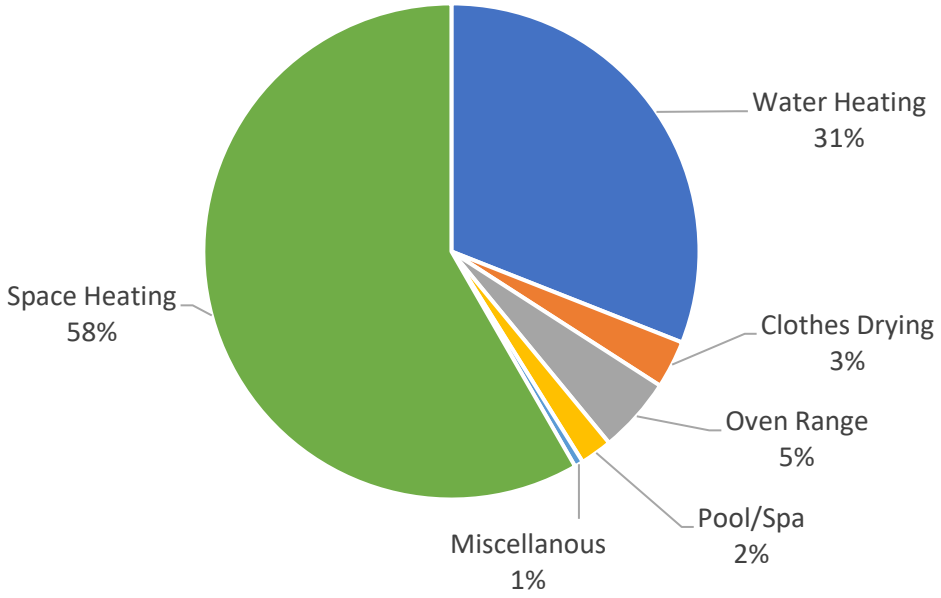
	Estimated Annual Electricity Consumption, kWh	Estimated Annual Natural Gas Consumption, Therms
All Single-Family Buildings	120,429,600	9,173,187
Per Single-family Building	7,758	601

Appliance and Fuel Source Analysis

To better understand where natural gas is being used Palo Alto single-family buildings, an appliance fuel source analysis was completed using data obtained from NREL ResStock. To ensure a large enough sample size representative of Palo Alto in terms of income levels by building characteristic data from ResStock for Palo Alto and other comparable nearby cities (e.g., Campbell, Cupertino, Mountain View, San Mateo, Santa Clara, and Sunnyvale) were utilized to estimate the prevalence of different appliance technology and fuel type and to estimate total annual energy consumption by technology type. As shown in Figure 4, a majority of natural gas consumption in single-family homes is estimated to be for space heating (58%) and water heating (31%).

[6] As noted above, based on this analysis of meters, the number of single family homes in Palo Alto could be higher than the ~13,000 identified in the countywide parcel data. Based on meter data provided by the City, approximately 15,500 meters were active during any given month. The per single-family building consumption data was calculated by summing the monthly average usage for all active meters.

Figure 4 Customer End-use Gas Consumption in Single-Family Buildings in Palo Alto (ResStock)



Funding Study Technology Types

For the purposes of this funding study, the technologies in single-family homes consuming energy were evaluated using data obtained from NREL ResStock. The natural gas end-use categories evaluated include: space heating, water heating, cooking, clothes drying, pool/spa, and miscellaneous energy consumption. The following section summarizes the prevalence of the technologies and fuel type in single-family homes by building vintage in Palo Alto.

Space Heating Technology Types

Space heating is the largest gas consumption end-use in single-family buildings in Palo Alto. Uniquely, Palo Alto is home to approximately 2,200 Eichler homes currently, which are characterized by radiant heating systems that are heated with natural gas boilers. A majority of Eichler homes were built through the 1950s, with a few tracts built in the 1960s and 1970s.[7] ResStock data for space heating in the region was modified to account for the significant number of Eichler homes in Palo Alto. As shown in Figure 5, a majority of single-family homes in Palo Alto are fueled with natural gas with natural gas central furnaces being the most common space heating system making up 57% of all space heating units in the city followed by natural gas boilers making up 17% of single-family space heating units in the city. Of the 15% of single-family homes that use electricity fueled space heating units, 36% are estimated to be electric baseboards, 23% air-source heat pumps and 23%

[7] https://atriare.com/palo-alto-eichler-homes

electric furnaces. Different types of furnaces will have different space and cost impacts on operations. This detail will likely be building specific. However, central gas furnaces are most common and can be replaced by central air source heat pumps in most scenarios. These heat pumps also provide air conditioning. The most cost-effective approach for buildings without existing ductwork (those with wall furnaces for example) would be ductless split systems. Gas boilers could be replaced with ductless mini-splits or with heat pump water heaters which connect to the existing boiler system.

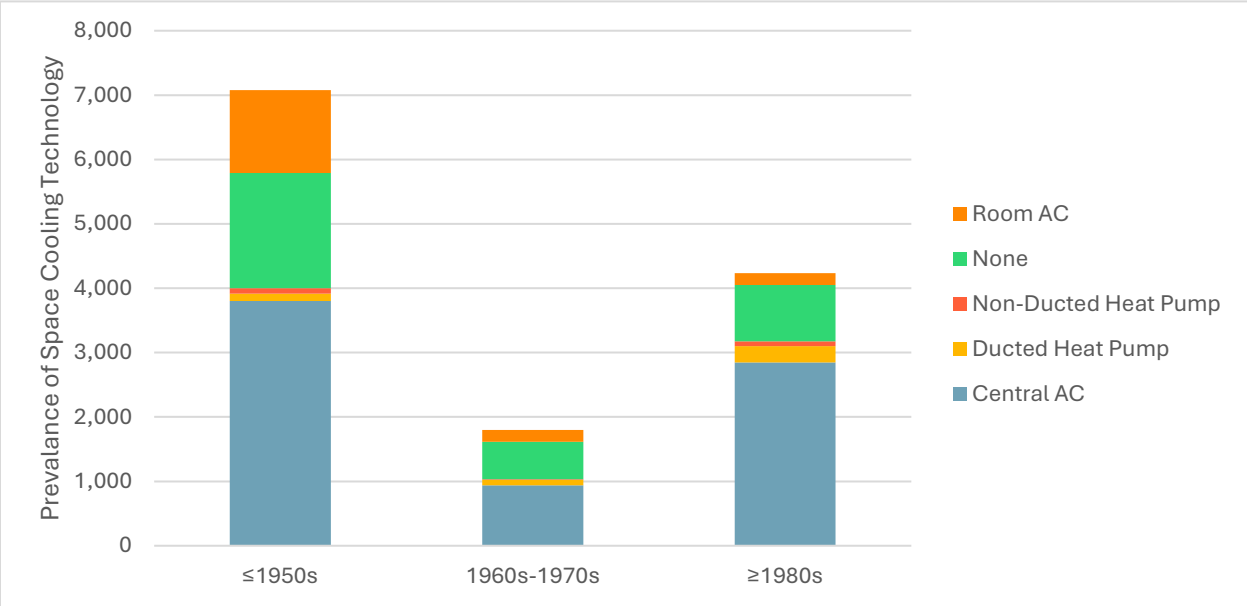
Figure 5 Space Heating Technology by Building Vintage in Palo Alto

Space Cooling Technology Types

As shown in Figure 6, according to ResStock modeling, approximately 75% of single-family buildings in Palo Alto have a space cooling unit with the most prevalent technology being central air conditioning at 58% followed by non-ducted room air conditioning units at 13%.[8] Currently, only 3% of single-family homes have ducted heat pumps and 1% have non-ducted heat pumps. As previously discussed, buildings with central air conditioning or heat pumps likely already have the panel size and electrical service necessary to accommodate further electrification. This is due to the ability of a heat pump HVAC unit to provide both heating and cooling using the same electrical load as the existing central AC unit. Further, it is anticipated that AC adoption will increase over time as projected temperatures increase due to climate change. This represents an important opportunity for buildings to use a "two-way" air conditioning system, or heat pump. When considering the cost of both a furnace and air conditioner, a heat pump is significantly less expensive (see cost analysis below).

[8] The presence of air conditioners is a key cost effectiveness consideration for building electrification since heat pumps provide both heating and cooling and one unit replaces both an AC and furnace. However, various sources provide different estimates for the number of central AC units in Palo Alto. The Palo Alto 2018 DER survey found 31% of respondents had a central AC. The 2019 California Residential Appliance Saturation Study (RASS) found 38% central AC saturation. The ResStock dataset also uses surveys from the region to come to a 58% saturation level. In addition, AC installation is increasing over time in the Bay Area due to a higher number of extreme heat days. The City should consider the impacts of various AC saturation rates in future studies.

Figure 6 Space Cooling Technology by Building Vintage in Palo Alto



Water Heater Technology Types

In Palo Alto, an estimated 84% of water heaters in single-family homes run on natural gas (with a small amount of electricity used for the spark igniter) with only 13% of water heaters fueled by electricity. ResStock data differentiates water heater types as Standard, Premium, Tankless or Heat Pump where Standard and Premium are both tanked water heaters but Premium indicates high-energy efficiency models compared with Standard tanked water heater models.

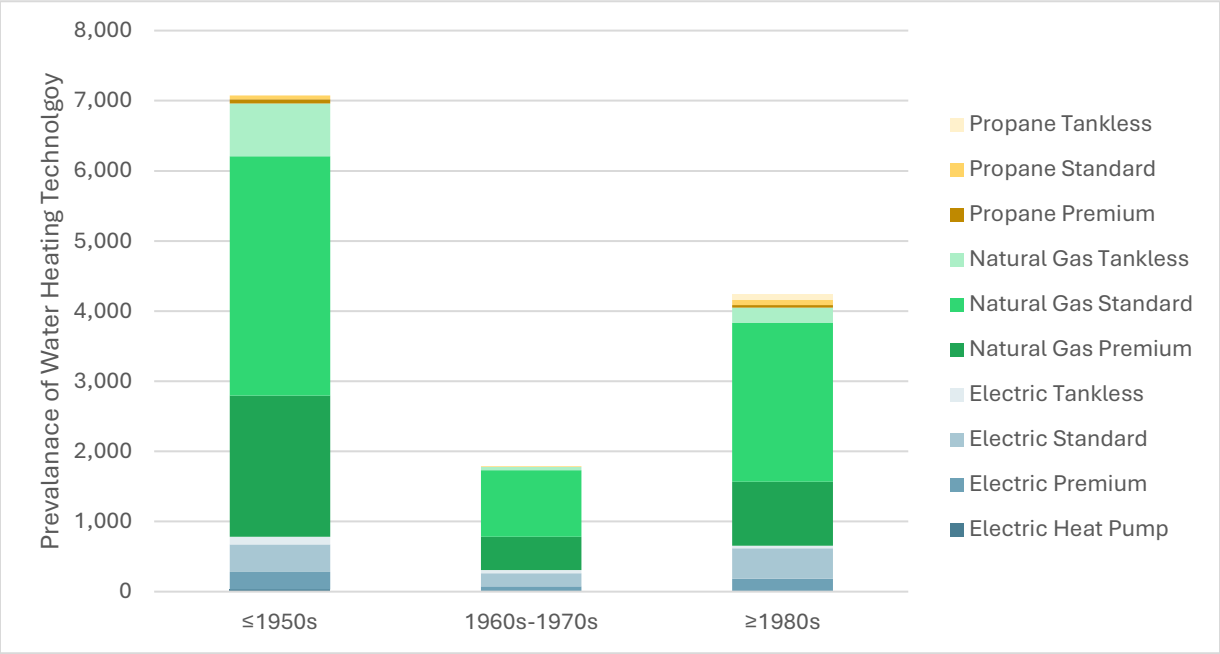
As shown in Figure 7, most of the water heaters in single-family homes are either standard or premium gas fired tanked water heaters. Tankless gas water heaters are the next most common followed by standard electric resistance tanked water heaters, premium electric tanked water heaters, tankless electric water heaters and propane water heater varieties. Electric heat pumps represent less than 1% of water heating technology. However, this data does not reflect the recent programs implemented by the City of Palo Alto to increase the adoption of heat pump hot water heaters. These programs have added an estimated 655 heat pump water heaters to the city which would increase the rate of heat pump water heater adoption to approximately 5%.[9]

Standard gas tank water heaters are most common and can be replaced by electric water heaters or heat pump tank water heaters in most scenarios. However, different types of water heaters will have different space and cost implications. For example, tank style water heaters range in size based on the holding tank and require an appropriate space to be located (i.e., concrete pad in the garage, laundry room, or utility closet) whereas tankless water heaters are much smaller and can usually be mounted on the wall though are more expensive.

[9] Data provided by City of Palo Alto as October 2025.

Installation cost can also vary depending on the existing housing characteristics. Depending on the housing electrical service, switching from one fuel source (i.e., natural gas or propane) to an electric water heater may require additional electrical wiring or a service upgrade to accommodate the electrical needs of the water heater. For example, 240 volt heat pump water heaters may require new circuits and/or panel upsizing as standard circuits are 120-volt. This can be avoided with 120-volt heat pump water heaters, assuming they meet the customers' needs. Electric tankless water heaters, which are low cost and simple to install if neglecting the cost of the electric service, use 120 to 160 amps, so homes with panel sizes less than that would need to upgrade electrical service to 200 amps or more, which can make the installations costly. In addition, operating costs for electric tankless water heaters are very high.

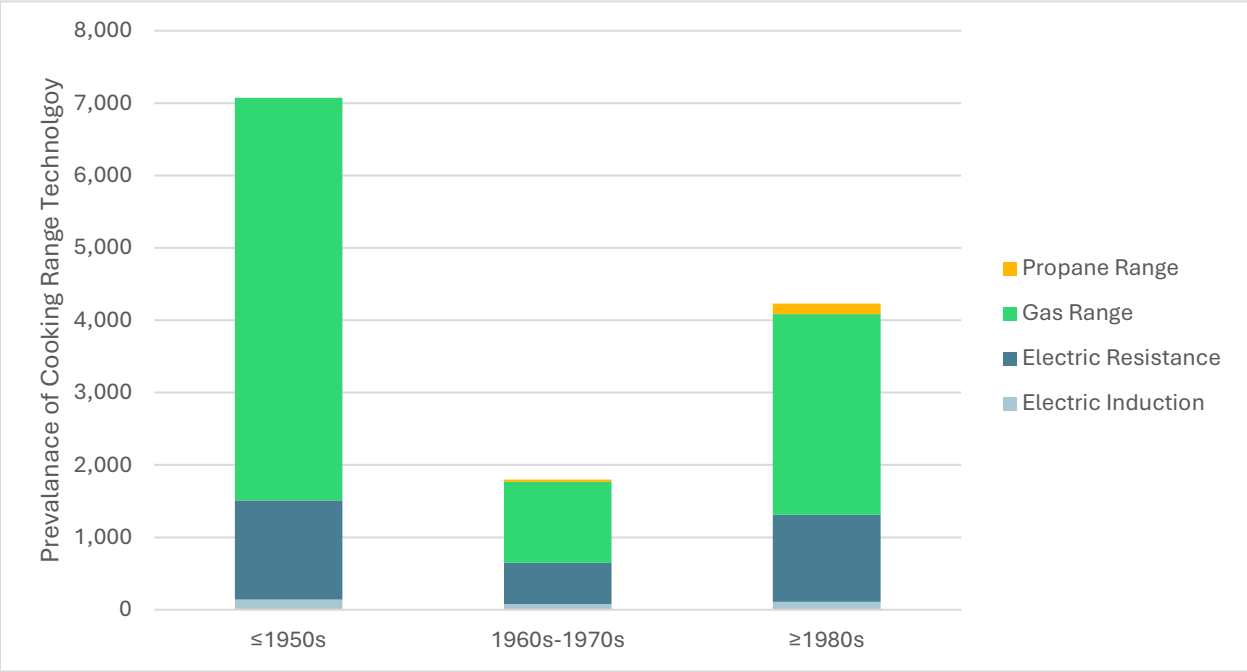
Figure 7 Water Heating Technology by Building Vintage in Palo Alto



Cooking Technology Types

Within Palo Alto, approximately 72% of single-family buildings use natural gas fueled units and 24% use electric resistance units according to the ResStock model results. The remaining 3% of single-family buildings use electric induction and propane fueled cooking ranges. Figure 8 shows the total number of cooking ranges in Palo Alto by technology and building vintage. Gas stoves can be replaced by either traditional electric resistance units or newer induction technologies. Induction stovetops are preferred for their greater efficiency and temperature control.

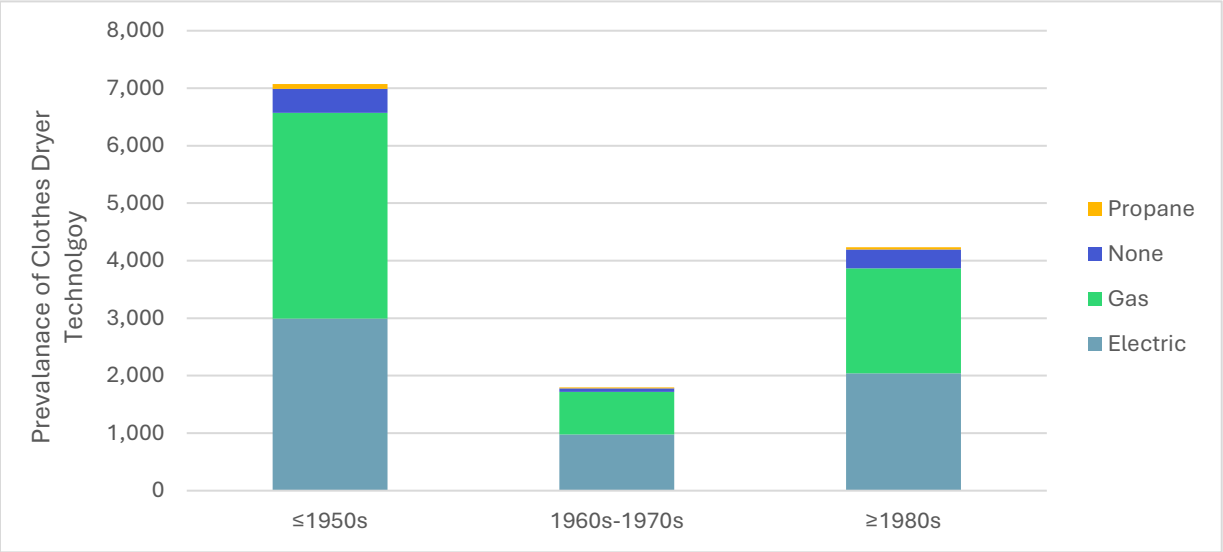
Figure 8 Cooking Range Technology by Building Vintage in Palo Alto



Clothes Dryer Technology Types

Most single-family homes in Palo Alto have clothes washer and dryer units, with just 5% not having a clothes washer and 6% not having a clothes dryer. All clothes washers are electricity fueled and therefore are not discussed further in this report as the purpose of the study is to identify fossil fueled appliances for electrification. In Palo Alto, 47% of dryers are natural gas fueled, 46% are electric, and 1% are propane fueled. Figure 9 shows the total number of clothes dryers in Palo Alto by technology and building vintage. Gas clothes dryers can be replaced by either electric resistance dryers or heat pump dryers. Combination heat pump washer and dryers are also available and provide space and energy efficiency benefits.

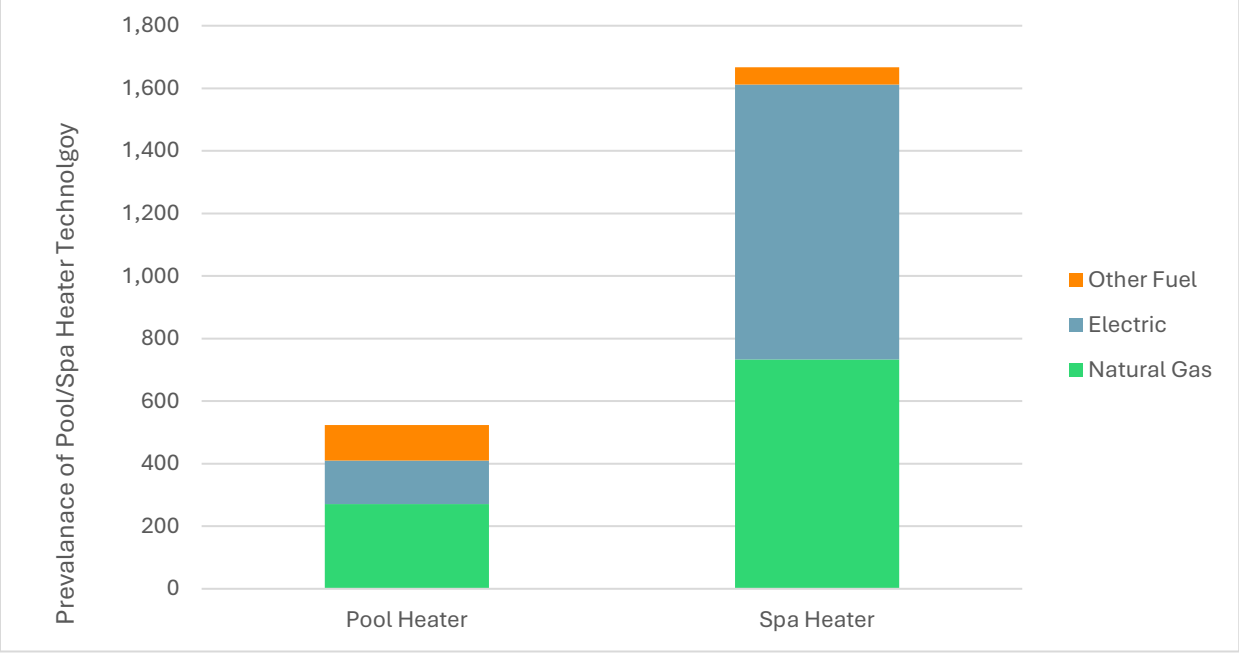
Figure 9 Clothes Dryer Technology by Building Vintage in Palo Alto



Pool and Spa Heater Technology Types

In Palo Alto, according to ResStock modeling, approximately 4% of single-family homes have heated pools and 13% of single-family homes have spas or hot tubs. As shown in Figure 10, a majority of pools in Palo Alto are heated by natural gas (53%), while 44%% of spa heaters in the city are fueled by natural gas and 53% are electric. Gas pool and spa heaters can be swapped to standard electric resistance heaters or more efficient heat pump heaters. Solar water heaters could also be used.

Figure 10 Pool and Spa Heater Fuel Type in Palo Alto



Single-Family Building Electrification Up-Front Cost Analysis

Up-front costs associated with electrification include the costs to purchase an appliance, install it, and make it operational. Up-front costs to electrify were analyzed using the most recent and location specific data available. Location-specific cost estimates were obtained using existing databases and desktop research of local appliance providers and contractors. To be conservative, the 75th percentile cost values were utilized to inform the cost analysis presented below.

Cost by Technology Type

Table 3 provides the upfront cost for installing the appliance technology types identified in the previous section. These costs are used in the S/CAP electrification funding model. This data was obtained from by using regional information from Angi's list, local providers (i.e. Home Depot, Lowes), and local contractor estimates. The table below includes the range of cost values identified for just the equipment (appliance) itself and the range in cost for installation costs. Installation costs include the cost of a building permit, installation labor, and disposal of old units as applicable. As shown, the cost of appliances can vary widely depending on the type of appliance, the quality, and brand that a consumer chooses. For the S/CAP electrification model the 75th percentile of the obtained cost values was utilized for the total-up front cost. Costs associated with panel upsizing, service upgrades, or new circuits are not included in the costs in Table 3.

Table 3 Up-front Cost by Fuel Type for Single-Family Buildings in Palo Alto

Technology	Installation	Appliance	Total Up-front cost (75th Percentile)
Space Heating			
Natural Gas - Boiler	$1,000 - $3,300	$4,000 - $9,000	$10,475
Natural Gas - Central Furnace	$560 - $2,500	$2,000 - $9,000	$9,265
Natural Gas - Wall Furnace[1,2]	$500 - $1,500	$1,000 - $2,500	$3,375
Electric - Boiler	$650 - $1,300	$1,150 - $6,700	$6,450
Electric - Central Furnace	$1,100 - $3,300	$800 - $4,500	$6,325
Electric - Wall Furnace[1,2]	$500 - $1,500	$1,000 - $2,500	$3,375

Technology	Installation	Appliance	Total Up-front cost (75th Percentile)
Electric Baseboard[1,3]	$390 - $1,190	$50 - $200	$1,153
Space Heating/Cooling			
Air-source Heat Pump	$4,430 - $12,150	$4,500 - $12,000	$20,345
Mini-Split Heat Pump	$1,630 - $4,750	$3,200 - $18,000	$18,270
Space Cooling			
Electric - Central Air Conditioning	$1,750 - $7,160	$3,900 - $7,900	$12,708
Electric - Room Air Conditioning[1,4]	$60 - $700	$100 - $800	$1,165
Water Heating			
Natural Gas - Premium	$275 - $1,450	$700 - $2,700	$3,356
Natural Gas - Standard	$275 - $1,450	$700 - $1,500	$2,456
Natural Gas - Tankless	$1,125 - $2,300	$500 - $2,200	$3,781
Electric - Premium	$275 - $1,250	$600 - $3,500	$3,781
Electric - Standard	$275 - $1,250	$200 - $1,500	$2,281
Electric - Tankless	$575 - $2,300	$200 - $1,500	$3,044
Electric - Heat Pump Water Heater	$1,400 - $4,650	$800 - $4,500	$7,413
Cooking			
Natural Gas - Range	$105 - $2,000	$300 - $7,000	$6,851
Electric - Induction	$105 - $155	$625 - $9,000	$7,050
Electric - Resistance	$105 - $155	$500 - $6,000	$4,768
Clothes Drying			
Natural Gas - Dryer	$130 - $300	$270 - $1,300	$1,300

Technology	Installation	Appliance	Total Up-front cost (75th Percentile)
Electric - Dryer	$50 - $175	$275 - $2,100	$1,788
Pool and Spa Heating			
Natural Gas – Pool/Spa Heating	$500 - $1,500	$1,500 - $6,000	$6,125
Electric – Pool/Spa Heating	$500 - $1,000	$1,000 - $5,000	$4,875

Notes:

1. Cost range is based on installation cost and appliance cost for one unit. Total cost for home using this technology will vary based on the number of units installed, which is largely driven by number of rooms home and the building configuration (e.g., single story or multi-story)
2. A standard wall furnace is intended to heat a single room in a home. Provided cost is for a single unit, however it is likely homes may have one or more units depending on building size and layout.
3. According to Angi's list, most homes have six electric baseboard heaters.
4. A window AC or portable AC until is intended to cool a single room. Provided cost is for a single unit, however it is likely homes may have one or more units depending on building size and layout.

It is important to note that labor costs and quotes from contractors are likely the most expensive and variable factor in home electrification, not appliance cost. Further, depending on the building characteristics, existing panel size, and electrical service, additional factors may impact cost. For building electrification this commonly includes new circuit installation, panel and/or service upgrades when electrifying the home. While it is difficult to predict when these particular upgrades may be needed for any individual building or project the following provides some conditions under which such upgrades may be needed:

- New Circuit: When switching the fuel type of an appliance from gas to electric or adding electrical appliances, a new dedicated circuit may be required. For example, most homes' standard circuits are 120 v while large electrical appliances like heat pumps or electric water heater may require 240 v. New "retrofit ready" products which use 120v power sources can reduce the need for a new circuit (and downstream panel and service upgrades).
- Panel Upsizing: Homes with less than 150 amp panels may also require panel upsizing to accommodate the addition of new circuits for additional electrical appliances. As discussed in previous sections, it's estimated that approximately 69% of single-family homes in Palo Alto already likely have a 150 amp panel and would not require panel upsizing for their electrification projects. Homes with panels as small as 100 amps may be able to electrify using load sharing or smart circuit devices.

- Service Upgrades: Panel upsizing may also necessitate electrical service upgrades, which require coordination with utilities. In Palo Alto, CPAU owns and is responsible for constructing, maintaining, and upgrading electrical infrastructure up to the meter panel, while the customer is responsible for everything behind the meter. Cost for service upgrades will vary depending on whether lines are run underground or overhead with underground typically costing more.

Table 4 provides the cost range for commonly required electrification upgrades obtained from Angi's list. The provided data is based on desktop review of electrification upgrades in the region and uses the 75th percentile of costs evaluated. These costs would be in addition to the appliance and install costs summarized above. The panel upsizing cost obtained from Angi's list and presented below is comparable to the TRC 2016 Palo Alto Electrification Final Report that used a panel upsize cost of $4,250 per customer for single-family homes.[10] The presented service upgrade cost is based on average cost range for 500 feet of electrical line obtained from Angi's list where the cost for overhead line costs on average between $4,000 and $7,500 and for underground the average cost ranges from $5,000 to $12,500.[11] Service upgrade cost will be dependent on the utility provider and may be offset by credits available to the ratepayer. While panel upgrades can be avoided through a watt diet[12], panel management or a home electrification plan, building owners may want to consider that installing future charging capacity for an electric vehicle may necessitate a panel upgrade anyway.

Table 4 Electrification Additional Cost Single-Family Buildings in Palo Alto

Factor	Cost Range	75th Percentile
New Circuit	$500-$2,000	$1,625
Panel Upgrade	$670 - $4,950	$3,880
Service Upgrade (500 ft)	$4,000 - $12,500	$10,375

Total project cost for electrifying space heating and water heating were compared to TECH Clean California single-family installation project data for the region, summarized in Table 5.[13] Project cost throughout Santa Clara County and San Mateo County were evaluated in addition to Palo Alto as the data set for Palo Alto alone was too small to provide a representative sample.

[10] Palo Alto Electrification Final Report (cityofpaloalto.org)
[11] Cost To Run Electric From Road To House [2024 Data] | Angi
[12] Watt Diet refers to the practice of minimizing the peak electricity demand through smart chargers and other technology to avoid a panel upgrade.
[13] TECH Clean California. "TECH Working Data Set_Single-family". Accessed at https://techcleanca.com/public-data/download-data/. Includes installations in single-family homes and small multifamily homes.

Table 5 Total Project Cost for TECH Projects in Single-Family Homes in Palo Alto

Technology	Number of Projects	Median Project Cost	1st Quartile	3rd Quartile
Heat Pump Water Heater	360	$7,445	$6,000	$7,977
Heat Pump HVAC - Ductless	1069	$19,948	$15,469	$26,195
Heat Pump HVAC - Ducted	202	$20,780	$16,880	$26,195

TECH project data accounts for all costs associated with the project, including installation, appliance, and electrification upgrades (like panels or circuits) needed, as well as other complexities encountered during the project. In general, TECH project costs were slightly higher than the cost estimates shown in Table 3 for heat pump water heaters, but significantly higher for heat pump space heaters. Additionally, to be eligible for the TECH program, the projects must meet certain criteria including:

- Equipment must be installed by a TECH-enrolled contractor
- Project must be a non-heat pump to heat pump installation
- No new construction, retrofits only.
- Equipment must be AHRI matched systems.
- Equipment must meet Title 24 code minimum standards.

These added requirements increase the cost of the project. For the purposes of determining the likely cost of a project, data from the desktop review presented in Table 3 and Table 4 were utilized for the S/CAP funding study as these are found to be more representative of costs that would be incurred outside of the TECH program.