City of Palo Alto Electrification Funding Study

Nonresidential Sector Study Report (FINAL DRAFT)

December 2025

Energy+Environmental Economics

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Executive Summary

In 2020, the City of Palo Alto (City) announced an update to the Sustainability and Climate Action Plan (S/CAP) to develop the strategies needed to meet its sustainability goals, including the goal of reducing greenhouse gas (GHG) emissions 80% below 1990 levels by 2030 (the 80 x 30 goal). In January 2024 the City Council approved a contract with E3 and Willdan to complete an S/CAP Funding Study to determine the costs of achieving these goals. They also approved three parallel Building Sector Studies covering the single-family residential, multifamily residential, and non-residential sectors. These studies are meant to provide building data for the S/CAP Funding Study and to help City staff identify opportunities to electrify equipment in the multi-family and non-residential building sectors. This report and its attachments document the process and results of the Nonresidential Building Sector Study.

Willdan analyzed public data for 997 nonresidential parcels (after screening for data outliers), representing 1,166 individual nonresidential customers. In addition, Willdan performed detailed field-based site assessments of a sample of nine nonresidential sites. Willdan estimates that this sector in total consumes approximately 77% of the community's electricity and 52% of the community's gas[1]. The category of equipment in this sector that uses the most gas is space heating, which is estimated to account for approximately 60% of nonresidential gas use. These systems represent the largest opportunities for electrification. They overwhelmingly serve office and retail, representing over 80% of customers.

Space heating electrification efforts should focus on conversion of packaged HVAC units and gas-fired furnaces, as these can be straightforwardly replaced with heat pump alternatives. Conversion of space heating boilers is more complicated and expensive, because compatibility issues with existing, interconnected HVAC systems need to be addressed.

Within this category of equipment, however, implementation cost of electrification ranges greatly. Space heating (i.e., HVAC) electrification costs can range from approximately $26,000 [2] to $3,000,000 per customer. Costs are lower for small[3] nonresidential buildings with simple HVAC systems like packaged rooftop units or gas-fired furnaces, and when existing electrical infrastructure is robust enough to support the new electric loads. Costs are higher at larger buildings with complex HVAC requirements, and when major building electrical upgrades are needed. Buildings with complex HVAC requirements include those with space heating boilers (noted above), or multizone systems with reheat (often the same systems). Electrification of these systems require fully engineered solutions rather than "out of the box" retrofit options.

Other opportunities include electrification of water heating systems and kitchen equipment (both kitchenettes and commercial kitchens). Commercial heat pump water heaters with integrated

[1] This accounts for all CPAU customers with account classes 30, 40, 50, and 60.

[2] Equivalent to approximately $4,000 to $5,500 per ton for a packaged heat pump unit retrofit.

[3] For the purposes of this study "small" nonresidential buildings are thought of as Offices < 3,500 square feet, Retail < 2,800 square feet, Schools < 25,000 square feet, and Assembly < 3,200 square feet.

storage are a common retrofit technology that is gaining traction in the market. Distributors of kitchen equipment readily offer electric induction ranges and electric ovens in the mid- to upper-tier quality ranges.

Heat pumps represent an electric energy efficiency improvement opportunity for customers that already have older electric resistance-style equipment (it is estimated that approximately 40% of nonresidential customers utilize inefficient electric resistance systems for water heating).

Using data from the Nonresidential Building Sector Study as a foundation, the S/CAP Funding and Financing Study has ultimately projected that the total community cost to reduce the gas use shown above to zero would be between **$991 and $1,240 million** in nominal dollars. This would be offset by between **$573 and $1,354 million** in avoided costs for like equipment replacement and Federal, State, and/or Regional incentives. Operational savings from switching from gas to electricity would provide additional benefits not included here and are incorporated into the S/CAP Funding and Financing Study results.

Summary of Analysis Inputs

Public Data

In pursuit of the characterization of Nonresidential buildings in Palo Alto, Willdan has identified available public data sources. This analysis is documented in detail in a standalone report, *Nonresidential Building Inventory and Equipment Saturation Analysis-Public Data*, which is included here as Attachment A. To summarize, Attachment A describes the following activities:

+ Our collection and processing of multiple City and public data sets
    - City Utility Account Data
    - County of Santa Clara Tax Assessor Records
    - National Renewable Energy Laboratories (NREL) ComStock Modeling Data
+ Our analysis of the customer sector data
    - Total number of customers and square footage
    - Building age distribution
    - Total energy consumption across the sector
+ Segmentation of the buildings for modeling purposes across multiple categories
    - Building type segmentation
    - Building vintage segmentation
    - Building square footage segmentation
+ Estimation of technology type impacts. Here, technology types refer to primary energy consuming appliances and systems for things like space cooling and heating, cooking, and pools and spas. The two main impact results evaluated are:
    - Applicability by segment – percentage of customers in the segment using the technology types
    - Electricity and natural gas use impacts of specific technology types

Refer to Attachment A for detailed documentation of the public data evaluation process, findings, and key takeaways. Some key takeaways discussed in Attachment A are as follows:

+ The largest portion of nonresidential utility customers fall under the office segment (55% of common nonresidential types), with the next largest portion under the retail segment (36% of common nonresidential types). Other nonresidential customer groups are significantly smaller.
    - Office and retail spaces are commonly served by packaged rooftop HVAC systems, which lend themselves to straightforward electrification solutions (i.e., packaged rooftop heat pumps)

+ For nonresidential buildings with air conditioning, the primary cooling equipment type found in the NREL models is packaged DX systems (including packaged-terminal air conditioning, PTAC). Both public data review and customer site visits show that nearly all non-residential buildings have air conditioning. The primary cooling type estimated in Palo Alto based on the NREL models (in 84% of customers buildings) is packaged direct expansion (DX), where a refrigerant is used to transfer heat.
    - Buildings using DX cooling typically use direct fired gas systems for heating (integrated into the packaged unit). These systems are readily upgraded to all-electric packaged heat pump systems, where the refrigerant cycle can be reversed to provide either heating or cooling. This is in contrast to HVAC systems that use hot water for heating (i.e., systems with HVAC boilers). These heating hot water systems require higher temperature water than simple heat pumps can achieve, and therefore require more engineered solutions and/or extensive total HVAC system changeouts (including air and water distribution, etc.)
+ The NREL models show most of the space heating at nonresidential customer sites is provided by natural gas sources, via either gas-fired packaged rooftop units, boilers, or furnaces. However, there is a significant amount of electric heating identified in the models, particularly in smaller buildings. This was validated against data collected from field evaluations of nonresidential sites conducted under this study.
    - Field validation demonstrated that three of nine sites visited had only gas-fired sources of heating. The remaining sites all had a combination of gas-fired and electric heating systems in service.
+ Space heating via air-source heat pump systems appears in the models (6% of customers), most prevalently in smaller schools. This likely may be due the prevalence of “portable” structures at these types of schools, which are frequently equipped with packaged terminal heat pump type equipment.
    - Note that based on the field validation noted above, this percentage may be undercounted, however, there may be selection bias contributing via those customers that chose to participate in the field studies being more inclined to have incorporated some electric heat pumps at their sites in the past
+ There is also a significant amount of electric-resistance storage water heating systems identified in the NREL models (50% of customers). Ranges depend on building type and size. During the on-site surveys we observed a mix of technologies in alignment with these estimates.
    - While electric-resistance storage water heating systems do not represent an electrification opportunity, they may represent energy efficiency opportunities. For storage water heaters above 30-gallons capacity, heat pump water heaters can offer opportunities to reduce electricity consumption by 50% to 75%. For smaller units, electric resistance offers a satisfactory all-electric solution, especially where

point-of-use service may be required (like remote bathrooms or service sinks). Generally heat pump water heaters are not offered in these small sizes.

+ The primary focus of the Nonresidential Building Sector Study has been on more common commercial gas users, such as offices, retail, assembly, and schools. The reason for this approach is as follows:
  - Meaningful energy, carbon, and cost impact estimates can be generally developed for the common systems serving these types of buildings
  - Future potential programs serving these types of buildings will serve the largest number of customers, leading to large carbon impacts, at a high number of buildings and systems
  - The public data available for analysis focuses on these types of buildings
+ Alternatively, if we are thinking about the uncommon, high gas-using customers such as industrial, research and development, and inpatient hospitals (estimated to be approximately 11% of CPAU nonresidential customers, using 24% of nonresidential gas), we find the following:
  - Generalized commercial decarbonization solutions don't impact their footprints significantly because of their highly specialized and unique building systems. The custom developed measures applicable to one site do not generally apply to other sites without significant adaptation
  - Decarbonization measures need to be custom developed based on the specifics of the site
  - Willdan's recommendation for helping these high-gas-using, specialized sites would be to explore offering a robust, customized decarbonization support program to help the customers develop and pay for large projects designed for their systems.

Site Surveys

As part of this comprehensive study, site surveys were conducted for nine nonresidential buildings that were picked based on the segmentations above. These visits served as a critical step in gathering detailed and site-specific information necessary for subsequent analysis and reporting. During the surveys, we documented the inventory of HVAC equipment, water heating systems, laundry equipment, and other types of systems installed in buildings and/or individual suites using a customized tool based on the ArcGIS platform, which is described further in this section. This information provided valuable insights into the current electrical infrastructure and mechanical equipment across the buildings. Using the data collected during these visits, Willdan formed the foundation for developing customized customer reports, which will be detailed in a later section. With these reports, Willdan aims to provide actionable recommendations tailored to the unique characteristics of each property, supporting informed decision-making for energy efficiency upgrades and electrification opportunities.

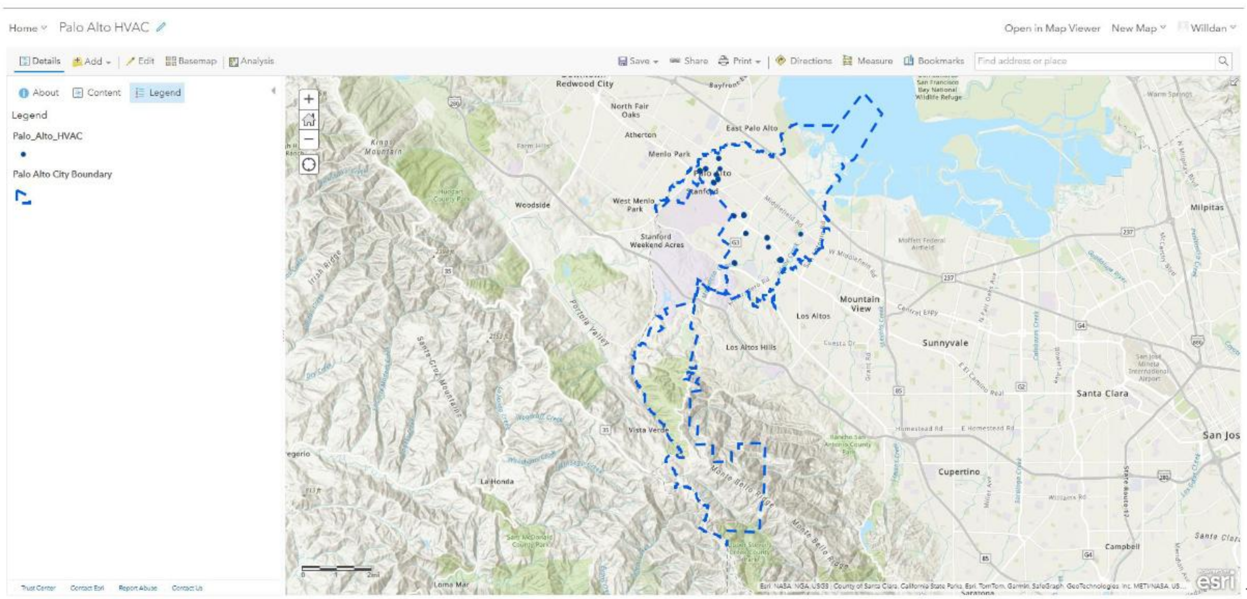
ArcGIS Tool Development and Execution

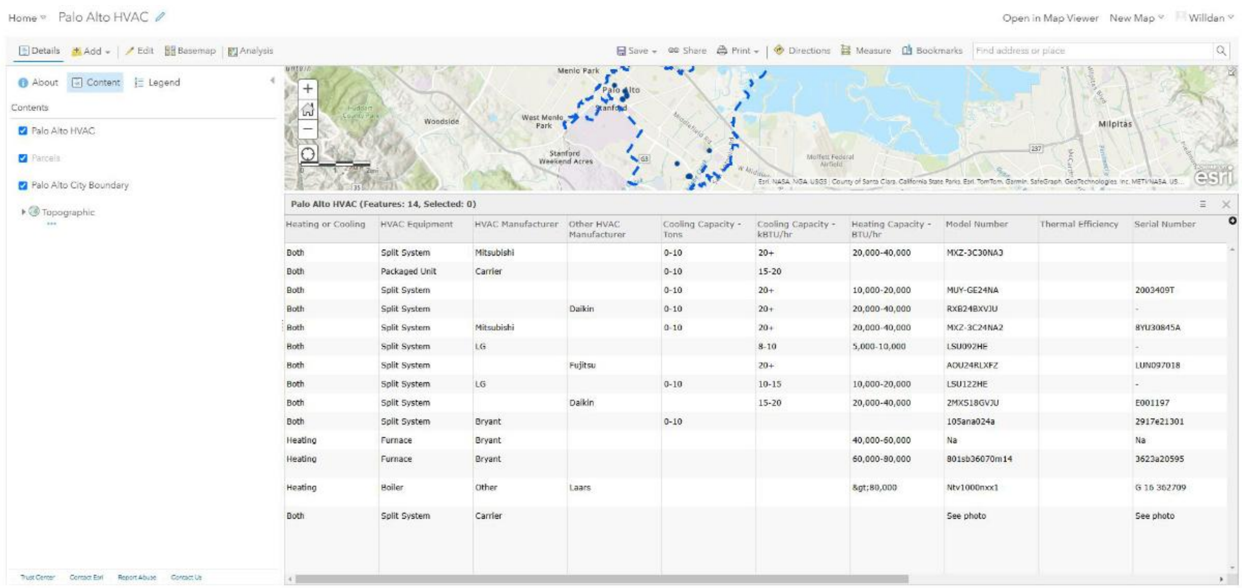
To most accurately and efficiently collect data during these site surveys, Willdan used the ArcGIS platform. This tool is a data collecting app that lets the user collect photos, notes, and data in the field while automatically tracking that data geospatially using the geographic information system (GIS). Willdan created seven different modules to capture the data. The different modules covered:

- HVAC
- Water Heating
- Kitchen Equipment
- Laundry Equipment
- Pools
- Electrical Infrastructure and General Site
- Plug Loads and Others

Exhibit 1 shows an example of the data visualization and collection functionality of the ArcGIS tool used for this Study. A comprehensive collection of information from the tool can be found in Attachments C.2 and C.3.

Exhibit 1. – Example ArcGIS Tool Data Visualization and Collection Screens





Palo Alto HVAC (Features: 14, Selected: 0)

Heating or Cooling	HVAC Equipment	HVAC Manufacturer	Other HVAC Manufacturer	Cooling Capacity - Tons	Cooling Capacity - kBTU/hr	Heating Capacity - BTU/hr	Model Number	Thermal Efficiency	Serial Number
Both	Split System	Mitsubishi		0-10	20+	20,000-40,000	MXZ-3C30NA3		
Both	Packaged Unit	Carrier		0-10	15-20				
Both	Split System			0-10	20+	10,000-20,000	MUY-GE24NA		2003409T
Both	Split System		Daikin	0-10	20+	20,000-40,000	RXB24BXVJU		-
Both	Split System	Mitsubishi		0-10	20+	20,000-40,000	MXZ-3C24NA2		8YU30845A
Both	Split System	LG			8-10	5,000-10,000	LSU092HE		-
Both	Split System		Fujitsu		20+		AOU24RLXFZ		LUN097018
Both	Split System	LG		0-10	10-15	10,000-20,000	LSU122HE		-
Both	Split System		Daikin		15-20	20,000-40,000	2MXS18GVJU		E001197
Both	Split System	Bryant		0-10			105ana024a		2917e21301
Heating	Furnace	Bryant				40,000-60,000	Na		Na
Heating	Furnace	Bryant				60,000-80,000	801sb36070m14		3623a20595
Heating	Boiler	Other	Laars			>80,000	Ntv1000nxx1		G 16 362709
Both	Split System	Carrier					See photo		See photo

Customer Selection and Outreach

Willdan performed initial customer screening based on a data set consisting of information from County Assessor Records and City utility customer usage data. During this screening process, Willdan segregated the customers based on the segmentation described above (e.g., building types, building vintages, etc.), and filtered out energy-consumption outliers, such as customers with no gas use, or abnormally high- or low-electricity use per square foot.

After each site visit and data collection, customers received a brief Electrification Assessment Report for each individual property. The assessment reports included an identification of the primary technology systems in use at the site, conceptual electrification alternatives where applicable and associated rough-order-of-magnitude (ROM) budgeting ranges, identification of electric infrastructure, upgrades needed to support electrification projects and associated ROM budget range and estimates of the annual GHG emissions avoidance that would result from these projects. The individual customer Electrification Assessment Reports are included here under Attachment B.

Comparison of Site Survey Data and Public Data

This section focuses on comparing public data with the Willdan-collected detailed survey data from the eight sample sites collected by Willdan engineers, to verify whether the public data accurately reflects field observations.

The comprehensive data shown in Exhibits 2, 3, and 4 were derived from NREL's ComStock modeling data and represent the percentages of customers in each segment that are estimated to use the various technology types. See Attachment A for information on the development of this data in detail.

The call-out boxes overlaid on the exhibits point to the technologies we observed in use at the eight sites Willdan engineers visited in the field, and which segments they belong to.

Exhibit 2. – HVAC Technologies in Nonresidential Buildings: Categorization Based on Publicly Available Data.[4]

Initial Building-Technology Mapping/Shares and Full Palo Alto Stock [X% of customers have Y technology; there are Z # of customers]											
	Space Cooling						Space Heating				
Customer Type Segments	Electric-Cooling-Split System	Electric-Cooling-PTAC/Packaged DX	Electric-Cooling-PTHP/Packaged HP	Electric-Cooling-WC Chiller	Electric-Cooling-AC Chiller	Electric-Cooling-VRF	Electric-Space Heating-Packaged Unit-Electric Resistance	Electric-Space Heating-ASHP	Gas-Space Heating-Packaged Unit	Gas-Space Heating-Boiler	Gas-Space Heating-Furnace
	0-100%	*0-100%*	*0-100%*	*0-100%*	*0-100%*	*0-100%*	*0-100%*	*0-100%*	*0-100%*	*0-100%*	*0-100%*
Comm-Office-0-3499-AC-Not Applicable	4.03%	83.56%	9.55%	2.86%	0.00%	0.00%	43.21%	9.55%	37.56%	5.07%	4.61%
Comm-Retail-0-2799-AC-Not Applicable	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	17.86%	0.00%	82.14%	0.00%	0.00%
Comm-K-12-0-24999-AC-Not Applicable	0.00%	0.00%	30.77%	38.46%	30.77%	0.00%	0.00%	30.77%	0.00%	69.23%	0.00%
Comm-Assembly-0-3199-AC-Not Applicable	6.08%	93.92%	0.00%	0.00%	0.00%	0.00%	39.86%	0.00%	54.05%	0.00%	6.08%
Comm-Office-3500-10999-AC-Not Applicable	3.95%	81.69%	11.91%	2.45%	0.00%	0.00%	36.89%	11.63%	40.96%	6.07%	4.45%
Comm-Retail-2800-5999-AC-Not Applicable	6.33%	88.61%	1.90%	3.16%	0.00%	0.00%	3.80%	1.90%	67.09%	20.89%	6.33%
Comm-K-12-25000-49999-AC-Not Applicable	0.00%	62.50%	0.00%	37.50%	0.00%	0.00%	0.00%	0.00%	41.67%	58.33%	0.00%
Comm-Assembly-3200-7499-AC-Not Applicable	0.00%	97.29%	1.43%	0.00%	1.27%	0.00%	36.79%	1.42%	56.45%	5.35%	0.00%
Comm-Office->=11000-AC-Not Applicable	2.52%	78.88%	8.71%	8.55%	0.86%	0.19%	25.30%	6.54%	39.31%	26.04%	2.81%
Comm-Retail->=6000-AC-Not Applicable	2.15%	95.11%	0.86%	1.88%	0.00%	0.00%	9.17%	0.86%	65.02%	22.64%	2.31%
Comm-K-12->=50000-AC-Not Applicable	0.00%	68.51%	4.98%	19.57%	6.94%	0.00%	6.76%	4.98%	42.88%	45.37%	0.00%
Comm-Assembly->=7500-AC-Not Applicable	7.71%	76.21%	12.40%	3.69%	0.00%	0.00%	26.47%	12.40%	41.71%	6.03%	13.40%

Site A and Site B both fall under the office segmentation with a building square footage under 3,499. Each are served by gas-fired furnaces.
Site A is served by a split system cooling unit.

Site C and Site D both fall under the office segmentation with a building square footage between 3,500 and 10,999.

Site C is served by packaged cooling units with gas heat. **Site D** is served by packaged and split system heat pumps, plus a gas

Site G and Site I both fall under the retail segmentation with a building square footage between 2,800 and 5,999.

Site I is served by gas furnaces and split system heat pumps. **Site G** is served by packaged units with gas heat.

Sites E, F, and H fall under the office segmentation with a building footage equal or higher to 11,000.

Site H is served by split system and packaged heat pumps, packaged units with gas heat, and a VRF system. **Site F** is served by electric air cooled chillers, split system heat pumps, and a gas fired boiler. **Site E** is served by large packaged DX units and large furnaces.

[4] See Attachment C.6 for photographs and brief descriptions of the various technologies discussed here and elsewhere in this Report.

Exhibit 3. – Cooking Technologies in Nonresidential Buildings: Categorization Based on Publicly Available Data.

Initial Building-Technology Mapping/Shares and Full Palo Alto Stock [X% of customers have Y technology; there are Z # of customers]

	Cooking				
Customer Type Segments	**Electric-Cooking Range-Resistance Stove**	**Electric-Cooking Range-Induction Stove**	**Electric-Cooking Range-Oven**	**Gas-Cooking Range-Stove**	**Gas-Cooking Range-Oven**
	0-100%	*0-100%*	*0-100%*	*0-100%*	*0-100%*
Comm-Office-0-3499-AC-Not Applicable	0.00%	0.00%	0.00%	0.00%	0.00%
Comm-Retail-0-2799-AC-Not Applicable	0.00%	0.00%	0.00%	0.00%	0.00%
Comm-K-12-0-24999-AC-Not Applicable	0.00%	0.00%	0.00%	50.00%	50.00%
Comm-Assembly-0-3199-AC-Not Applicable	0.00%	0.00%	31.68%	43.56%	24.75%
Comm-Office-3500-10999-AC-Not Applicable	0.00%	0.00%	0.00%	0.00%	0.00%
Comm-Retail-2800-5999-AC-Not Applicable	0.00%	0.00%	22.22%	7.41%	70.37%
Comm-K-12-25000-49999-AC-Not Applicable	0.00%	0.00%	17.86%	50.00%	32.14%
Comm-Assembly-3200-7499-AC-Not Applicable	3.58%	0.37%	25.89%	40.69%	29.47%
Comm-Office->=11000-AC-Not Applicable	0.00%	0.00%	0.00%	0.00%	0.00%
Comm-Retail->=6000-AC-Not Applicable	0.96%	0.14%	31.59%	22.53%	44.78%
Comm-K-12->=50000-AC-Not Applicable	3.73%	0.53%	31.47%	45.87%	18.40%
Comm-Assembly->=7500-AC-Not Applicable	2.49%	0.24%	23.96%	47.21%	26.10%

Site D was served by an all electric kitchen

Site I was served by both an electric resistance range and a gas range

Exhibit 4. – Water Heating Technologies in Nonresidential Buildings: Categorization Based on Publicly Available Data.

Initial Building-Technology Mapping/Shares and Full Palo Alto Stock [X% of customers have Y technology; there are Z # of customers]						
	Service Water Heating					
Customer Type Segments	Electric-Water Heating-Electric Resistance Water Heater	Electric-Water Heating-Heat Pump Water Heater	Electric-Water Heating-Tankless	Gas-Water Heating-Storgae Water Heater	Gas-Water Heating-Boiler	Gas-Water Heating-Tankless
	0-100%	0-100%	0-100%	0-100%	0-100%	0-100%
Comm-Office-0-3499-AC-Not Applicable	58.82%	3.49%	6.91%	27.70%	0.00%	3.09%
Comm-Retail-0-2799-AC-Not Applicable	57.14%	3.57%	7.14%	28.57%	0.00%	3.57%
Comm-K-12-0-24999-AC-Not Applicable	50.00%	3.85%	7.69%	34.62%	0.00%	3.85%
Comm-Assembly-0-3199-AC-Not Applicable	28.86%	2.01%	3.36%	59.06%	0.00%	6.71%
Comm-Office-3500-10999-AC-Not Applicable	59.82%	3.51%	7.07%	26.66%	0.00%	2.95%
Comm-Retail-2800-5999-AC-Not Applicable	36.71%	1.90%	4.43%	51.27%	0.00%	5.70%
Comm-K-12-25000-49999-AC-Not Applicable	14.29%	0.00%	2.04%	75.51%	0.00%	8.16%
Comm-Assembly-3200-7499-AC-Not Applicable	23.11%	1.42%	2.67%	65.57%	0.00%	7.23%
Comm-Office->=11000-AC-Not Applicable	50.08%	2.96%	5.89%	36.95%	0.00%	4.12%
Comm-Retail->=6000-AC-Not Applicable	40.59%	2.41%	4.77%	47.02%	0.00%	5.20%
Comm-K-12->=50000-AC-Not Applicable	23.65%	1.44%	2.71%	64.98%	0.00%	7.22%
Comm-Assembly->=7500-AC-Not Applicable	17.83%	1.82%	2.04%	71.14%	0.00%	7.98%

Site A is served by a small electric resistance storage water heater.

Site B is served by a gas storage water heater.

Site C is served by a gas tankless water heater.

Site D is served by an electric storage water heater.

Site I is served by multiple gas storage water heaters

Site G is served by a small electric resistance storage water

Site H is served by electric storage water heaters.
Site E and Site F are served by gas storage water heaters.

Using assessor data and cross-referencing it with CPAU customer account data, Willdan estimated that the total number of active nonresidential customers is 1,116. Out of these customers, a total of eight nonresidential facilities were visited. While the number of sites visited is not a large enough sample to verify the weighted counts for each customer segment and technology type, the information collected during the field surveys confirms the presence of the different technology types identified in the public data.

Characterization of Sector Gas Consumption

Public Data

Willdan has estimated the natural gas consumption of various types of nonresidential sites in Palo Alto. These types are characterized by primary nonresidential activity on the parcel, which is informed by the County Assessor's assigned land use codes. County assessor data was matched to CPAU utility consumption data based on customer addresses, which led to the breakdown shown in the table below. Note that the nonresidential customer base which is focused on by this Study is estimated to consume approximately 37% of all CPAU supplied electricity, and 28% of all CPAU supplied gas.

As noted in the *Summary of Analysis Inputs* Section, The primary focus of the Nonresidential Building Sector Study has been the subset of more common commercial gas users, such as offices, retail, assembly, and schools. However, the nonresidential sector also includes uncommon, high gas-using customers such as industrial, research and development, and inpatient hospitals (this uncommon subset is estimated to be approximately 11% of CPAU nonresidential customers, using 24% of nonresidential gas). The top of Exhibit 5 shows the energy consumption of the total nonresidential sector, of this Study's focused subset, and of all CPAU's customers across all sectors for comparison purposes. The bottom of Exhibit 5 shows a more detailed breakdown by building type for the focused subset.

Exhibit 5. – Sector Energy Consumption Information

Total NR Sector Energy Use and Focused Subset Compared to Total CPAU All Sectors	Estimated Annual Electricity Consumption, kWh	Percentage of Electricity	Estimated Annual Natural Gas Consumption, therms	Percentage of Natural Gas
Total NR Sector Energy Use	632,000,000	77%	14,300,000	52%
NR Subsector Energy Use (Focused)	305,000,000	37%	7,800,000	28%
Total CPAU Energy Use	822,000,000	100%	27,400,000	100%

Focused Subset: Nonresidential Building Types - Land Use Codes	Estimated Annual Electricity Consumption, kWh	Percentage of Electricity	Estimated Annual Natural Gas Consumption, therms	Percentage of Natural Gas
Office Uses	171,180,000	56%	4,070,000	52%
Retail Uses	65,060,000	21%	2,260,000	29%
Neighborhood (Supermarket)	29,060,000	10%	330,000	4%
Regional (Department Store)	22,740,000	8%	230,000	3%
Public Schools	9,818,000	3%	583,000	8%
Other Schools	2,022,000	1%	28,000	<1%
Churches	2,530,000	1%	70,000	1%
Recreational Facilities	2,530,000	1%	240,000	3%
Total	**304,940,000**	**100%**	**7,811,000**	**100%**

Based on publicly available NREL ComStock data, we can estimate the typical gas consumption of specific technologies for nonresidential customers that have these appliances/systems in their facilities. These are shown in the following table on a “per customer” basis. Note that not every customer will be using every technology.

For detailed documentation of how public data was evaluated to reach these findings along with similar data for electricity use per technology type, refer to Attachment A.

Exhibit 6. – Typical Annual Energy Impacts of Technology Types by Segment – Natural Gas Technologies

Customer Type Segments	Gas-Space Heating-Packaged Unit-Gas Heat	Gas-Space Heating-Boiler	Gas-Space Heating-Furnace	Gas-Water Heating-Storage Water Heater	Gas-Water Heating-Boiler	Gas-Water Heating-Tankless	Gas-Clothes Dryer-Gas Dryer	Gas-Cooking Range-Stove	Gas-Cooking Range-Oven	Gas-Other[5]
	therm / cust.	*therm / cust*	*therm / cust*	*therm / cust*	*therm / cust*	*therm / cust*	*therm / cust*	*therm / cust*	*therm / cust*	*therm / cust*
Comm-Office-0-3499	191	260	110	22	0	20		- -	- -	0
Comm-Retail-0-2799	196	- -	- -	57	- -	52		- -	- -	0
Comm-K-12-0-24999	- -	3,823	- -	177	- -	163		13	23	164
Comm-Assembly-0-3199	505	- -	3	563	- -	518		32	62	15,181
Comm-Office-3500-10999	587	665	143	83	- -	76		- -	- -	0
Comm-Retail-2800-5999	629	2,735	151	148	- -	136		11	16	681
Comm-K-12-25000-49999	1,722	23,094	- -	1,957	- -	1,801		21	36	2,017
Comm-Assembly-3200-7499	1,417	2,365	- -	1,318	- -	1,212		32	56	15,462
Comm-Office->=11000	3,205	8,249	934	812	0	747		- -	- -	0
Comm-Retail->=6000	3,923	24,330	273	1,134	- -	1,044		35	66	6,340
Comm-K-12->=50000	5,548	46,941	- -	7,528	0	6,925		44	112	1,911
Comm-Assembly->=7500	4,954	1,589	315	3,627	- -	3,337		58	66	20,807

[5] "Gas-Other" includes the following use types from the ComStock Models: any natural gas-powered equipment that is not used for space heating or water heating, primarily specialty gas kitchen equipment (e.g., fryers) and pool and spa heating systems.

Site Surveys

The table below shows the potential reduction in GHG emissions in metric tons of CO_2 for the sites surveyed as well as reductions in annual therms usage by each site.

Exhibit 7. – CO_2 Reduction Potential

Facility	Annual GHG Emissions Avoided (Metric Tons CO_2e[6])	Potential Annual Therms Saved / Therms Used by End-Use[7]				
		Space Heating	Water Heating	Kitchen	Laundry	Total
Site A	3	300	0	0	0	300
Site B	4	100	200	0	100	400
Site C	6	200	400	0	0	600
Site D	7	700	0	0	0	700
Site E	219	19,100	1,600	0	0	20,700
Site F	137	7,700	5,200	0	0	12,900
Site G	34	3,200	0	0	0	3,200
Site H	15	1,400	0	0	0	1,400
Site I	36	600	2,600	100	100	3,400

[6] CO_2 and CO_2 equivalents are calculated here as, 0.0053 metric ton / therm from CO_2, 0.0024ton / therm from CH_4, and 0.0029 metric ton / therm from N_2O.

[7] For the purposes of our detailed customer site evaluations for seven customers, we attempted to find electrification solutions for every gas burning system found. Therefore, the total potential savings also equals the total annual use.

Estimated Costs of Electrification Measures & Infrastructure Upgrades

Cost Estimating Approach

Willdan developed cost estimates for the electrification projects and associated infrastructure upgrades described in this Report from a variety of sources. The primary foundation of the approach is based on Willdan's current role running large retrofit and new-construction incentive programs across California, as well as Willdan's experience as a turn-key performance contractor developing these electrification conceptual designs and costs.

Willdan used in-house estimating tools that draw base-level material and installation cost data from industry standard databases like RSMeans and ProEst, plus Willdan's independent research and experience with equipment distributors and contractors, then added appropriate soft costs (e.g., design and development, permitting, contractor overhead, and profit, etc.), and localization factors to reasonably estimate ranges for total cost to complete these types of projects in Palo Alto. The costs generated by Willdan's in-house estimating tools are then calibrated against recent project cost data we have received from licensed contractors (mechanical, electrical, and plumbing) that work with Willdan in California both locally and state-wide. For some technologies, Willdan saw it necessary to apply a discount factor for economies of scale where specific customer segment types were more likely to install multiple quantities simultaneously.

Willdan estimated the costs for electrical infrastructure upgrades separately from the technologies being evaluated, as the electrical infrastructure upgrades would be applicable to multiple technologies and customer types.

HVAC

Space heating in small and medium non-residential buildings (i.e., small-medium businesses, or SMBs) in Palo Alto is estimated to be 12% driven by electricity and 88% by gas, on an equivalent Btu basis. The majority of gas space heating units in SMBs (72% of all gas heated buildings) are mixed-fuel packaged systems, which could be replaced by all-electric packaged heat pump systems. These units are responsible for 30% of the gas heating load in SMB. Other types of gas equipment estimated to be in Palo Alto include:

- Boilers (23% of all gas heating buildings), responsible for 70% of the gas heating load in SMBs, used for space heating, are assumed to be central systems and are expected to be replaced by electric heat pumps. ComStock data predicts that these larger central systems are found in larger offices, retail, and schools. The large city-wide heating load impact, compared to the prevalence of these systems in SMBs, is likely due to the larger square footage being served and the fact that these systems typically being operated round the clock, and associated losses with the distribution systems.

- Furnaces generally dominate gas heating in commercial buildings. Furnaces (5% of all gas heated buildings), responsible for less than 1% of the gas heating load in SMBs, are expected to be replaced by heat pumps or high-efficiency electric heating systems.

All of the above types of equipment were observed in Willdan's site surveys.

The basis for determining the HVAC cost estimates is the cost estimating platform database that Willdan has compiled for use within Willdan's Net Energy Optimizer (NEO) tool. The database uses RSMeans construction cost estimating data as the foundation and contains cost estimates for various system types at varying system capacities and varying components. Because the base RSMeans cost data is obtained roughly one year before its release date, is more applicable to new construction direct contractor costs, and is generalized to be used for varying applications throughout the U.S., various factors were applied to tailor the cost data for this study. The factors applied included: RSMeans cost factor for the applicable region, prevailing wage, permit/plan check fees, consulting fees, taxes, contingency, and inflation factors to adjust for present day costs.

These totals for the tailored cost estimates were then averaged and categorized into the electric and gas technology options that would be used in the analysis. To make these costs scalable, the cost estimates were converted into dollar per square foot ($\$/ft^2$) values using common metrics such as: dollars per ton of cooling ($/ton) and square feet per ton of cooling (ft^2/ton). The resulting $\$/ft^2$ values were then applied to their respective electric and gas technologies for the varying customer type segments. Where opportunities for economies of scale seemed likely, a reduction factor was applied.

Once the initial HVAC cost estimates were generated, they were reviewed and adjusted by the larger stakeholder team[8] to match the group's wider experience with these types of projects. These adjustments were based on the following factors:

- Soft costs (e.g., engineering, plan check/permit fees, etc.) and some ancillary hard costs (e.g., gas connections) were increased for gas-electric hybrid systems, compared to all-electric systems that only require an electrical connection.
- Costs were added to the air source heat pump (ASHP) retrofit, associated with removing baseline equipment in one location (e.g., in-wall furnaces) when replacing them with all-electric solutions that would be located elsewhere (e.g., on the roof.)
- Costs were added to the ASHP retrofit, associated with adapting these systems in a retrofit scenario such as curb adapters and other duct rerouting, and final electrical connections.

[8] CPAU staff, E3 staff, and Willdan.

Exhibit 8a. – Range of HVAC Electrification Cost Estimates (per Customer)

Customer Type	Electric-Cooling-PTHP/Packaged HP	Electric-Space Heating-Packaged Unit-Electric Resistance	Electric-Space Heating-ASHP
Office, < 3,500 sf	$33,379[9]	$36,403	$48,351
Retail, < 2,800 sf	$25,613[9]	$28,049	$25,613
K-12, < 25,000 sf	$90,628[9]	$90,628	$101,072
Assembly, < 3,200 sf	$48,684[9]	$48,684	$48,684
Office, 3,500 to 11,000 sf	$128,516	$140,158	$186,158
Retail, 2,800 to 6,000 sf	$77,508	$84,878	$77,508
K-12, 25,000 to 50,000 sf	$939,577	$939,577	$1,047,845
Assembly, 3,200 to 7,500 sf	$116,468	$116,468	$116,468
Office, > 11,000 sf	$1,104,163	$1,204,187	$1,599,402
Retail, > 6,000 sf	$640,440	$701,335	$640,440
K-12, > 50,000 sf	$2,597,295	$2,597,295	$2,896,583
Assembly, > 7,500 sf	$518,617	$518,617	$518,617

Exhibit 8b. – Range of HVAC Like-for-Like Gas System Cost Estimates (per Customer)

Customer Type	Gas-Space Heating-Packaged Unit	Gas-Space Heating-Boiler	Gas-Space Heating-Furnace
Office, < 3,500 sf	$29,205[10]	$46,669	$29,589
Retail, < 2,800 sf	$22,251[10]	$38,372	$22,572
K-12, < 25,000 sf	$75,857[10]	$130,676	$88,721
Assembly, < 3,200 sf	$48,869[10]	$74,108	$38,477
Office, 3,500 to 11,000 sf	$112,444	$179,684	$113,921
Retail, 2,800 to 6,000 sf	$67,334	$116,119	$68,305
K-12, 25,000 to 50,000 sf	$786,433	$1,354,761	$919,806
Assembly, 3,200 to 7,500 sf	$116,912	$177,292	$92,050
Office, > 11,000 sf	$966,082	$1,543,779	$978,768
Retail, > 6,000 sf	$556,375	$959,472	$564,395
K-12, > 50,000 sf	$2,173,955	$3,744,998	$2,542,643
Assembly, > 7,500 sf	$520,594	$789,458	$409,886

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[9] Equivalent to approximately $4,000 to $5,500 per ton for small, packaged heat pump unit retrofits.
[10] Equivalent to approximately $3,500 to $4,800 per ton for small, packaged hybrid gas-electric unit retrofits.

Water Heating

Water heating in SMBs in Palo Alto is estimated to be 38% driven by electricity and 62% by gas on an equivalent Btu basis. The following types of gas water heating equipment are estimated to be in Palo Alto:

- Storage gas water heaters, estimated to represent 90% of all buildings with gas water heating, and 91% of all gas water heating gas consumption. Gas storage water heaters are expected to be replaced by electric heat pump water heaters.
- Boilers are not typically used at SMBs, but can sometimes be found at large non-residential facilities. Service water heating boilers were not found in the ComStock data and were not observed during the field site surveys conducted for this Report. Service water heating boilers may be replaced by large engineered heat pump water heating systems.
- Tankless gas water heaters estimated to represent 10% of all buildings with gas water heating and 9% of all gas water heating gas consumption. These units are expected to be replaced by heat pump water heaters if space allows, and electric resistance tankless units if space is not available.

Note that heat pump water heaters are the primary recommendation for replacement of all the technologies above, given their high efficiency versus electric resistance systems. A primary consideration for system retrofits is that heat pump water heaters, of a given storage size, may heat water more slowly than their equivalently sized gas storage counterparts. This is particularly true for gas-storage units with oversized/high-heat option burners. There are several approaches to handle this particularity of heat pump water heater technology:

- Perform a system sizing analysis to determine of the baseline system is appropriately sized. This typically entails counting hot water using fixtures and estimating peak load durations.
- Increase the storage capacity of the retrofit system to counterbalance the lower heat input rate. This solution is dependent on the available physical space for the additional units or supplemental storage. The new heat pump system may need to be moved to a different location, or new structures may be constructed to house them
- Supplemental electric resistance backup can be added to the system. This can be in the form of electric resistance tankless units, or additional resistive elements located in supplemental storage tanks.

All of the above types of equipment were observed in Willdan's site surveys with the exception of service water heating boilers as noted.

The primary basis for determining the cost of water heating systems is derived from the Southern California Edison (SCE) Commercial Energy Efficiency Program (CEEP) and Pacific Gas & Electric (PG&E) Government and K-12 Program (GK12) project cost records for 2021 to 2023. The project cost records include data from installations in hotels, grocery stores, retail buildings, and assembly building types.

After analyzing the pricing records in detail, Willdan found that costs for electrification options can vary greatly depending on existing conditions and infrastructure upgrades needed. As such, Willdan elected to use projects with typical field conditions and an average project cost to represent the basic minimum level for a water heating electrification project. These typical projects include installations where there is sufficient space, adequate ventilation, and no additional infrastructure work is needed. Minimal electrical costs were captured, such as installing an electrical conduit run or relocating units within existing structures. To estimate the total costs for Palo Alto customers in this sector, Willdan added these types of additional infrastructure costs as a separate line-item applied to different portions of the overall cohort as expected, based on experience with the sector. Willdan's cost estimates for the non-infrastructure-related costs include the following key assumptions for water heating cost estimates:

- Each building is served by central water heating systems
- Adequate space is available to accommodate additional water storage if necessary
- No significant costs would be needed to existing structures or utility infrastructures to accommodate electric water heating options. Costs for infrastructure upgrades were estimated separately.

Willdan used the following methodology to estimate the costs for the various water heating technologies:

- Determine a baseline water heating system for each customer type segment
    - CEEP project cost records for projects with similar water heating capacities were referred to and the costs were used as the base cost component
    - The applicable CEEP project costs then had adjustment factors added such as regional cost indexing, prevailing wage adders, permit/plan check fees, consulting fees, taxes, contingency
- Determine appropriately sized electric water heating system options or alternative gas systems for each customer type segment, based on the baseline water heating systems
    - Wherever sufficient cost data was not available, RSMeans was referred to for determining the base cost

The outlined methodology combines baseline determination, cost analysis, and system sizing to deliver actionable insights for suitable replacements. By tailoring the CEEP data with regional adjustments and project-specific considerations, average costs have been derived for the varying technologies. However, it is important to note that when implementing energy-efficient solutions such as heat pump water heaters (HPWHs), it is necessary to consider the details of individual projects to ensure that new HPWH systems are properly sized to serve the needs of the facilities.

Exhibit 9a. – Range of Water Heating Electrification Cost Estimates (per Customer)

Customer Type	Electric-Water Heating-Electric Resistance Water Heater	Electric-Water Heating-Heat Pump Water Heater	Electric-Water Heating-Tankless
Office, < 3,500 sf	$10,866	$11,329	$9,253
Retail, < 2,800 sf	$10,866	$11,329	$9,253

Customer Type	Electric-Water Heating-Electric Resistance Water Heater	Electric-Water Heating-Heat Pump Water Heater	Electric-Water Heating-Tankless
K-12, < 25,000 sf	$13,370	$11,642	$18,507
Assembly, < 3,200 sf	$13,370	$11,642	$9,253
Office, 3,500 to 11,000 sf	$13,370	$11,642	$27,760
Retail, 2,800 to 6,000 sf	$13,370	$11,642	$27,760
K-12, 25,000 to 50,000 sf	$42,728	$90,501	$37,014
Assembly, 3,200 to 7,500 sf	$26,741	$23,285	$27,760
Office, > 11,000 sf	$21,364	$45,251	$55,521
Retail, > 6,000 sf	$21,364	$45,251	$55,521
K-12, > 50,000 sf	$64,092	$135,752	$74,028
Assembly, > 7,500 sf	$42,728	$90,501	$55,521

Exhibit 9b. – Range of Water Heating Like-for-Like Gas System Cost Estimates (per Customer)

Customer Type	Gas-Water Heating-Storage Water Heater	Gas-Water Heating-Tankless
Office, < 3,500 sf	$11,038	$10,584
Retail, < 2,800 sf	$11,684	$10,584
K-12, < 25,000 sf	$27,633	$21,168
Assembly, < 3,200 sf	$11,038	$10,584
Office, 3,500 to 11,000 sf	$27,633	$31,752
Retail, 2,800 to 6,000 sf	$11,684	$31,752
K-12, 25,000 to 50,000 sf	$55,266	$42,336
Assembly, 3,200 to 7,500 sf	$23,367	$31,752
Office, > 11,000 sf	$27,633	$63,504
Retail, > 6,000 sf	$27,633	$63,504
K-12, > 50,000 sf	$82,899	$84,672
Assembly, > 7,500 sf	$55,266	$63,504

Appliances (Kitchen and Laundry)

Cost-estimating data for commercial grade kitchen equipment was composed through a combination of RSMeans and independent research of material costs and labor costs for installation. Where available, Energy Star-certified products were selected. The material and labor costs served as the basis for the cost estimates and the same approach to the HVAC cost estimates was taken in which various factors were applied to tailor the cost estimates for the study.

Comstock does not model data for laundry at commercial facilities. As such a cost estimating exercise for laundry technology types was not performed for the nonresidential sector.

Exhibit 10. – Range of Appliance Electrification Cost Estimates (per Customer)

Customer Type	Electric-Cooking Range-Resistance Stove	Electric-Cooking Range-Induction Stove
Office, < 3,500 sf	$691	$1,084
Retail, < 2,800 sf	$2,712	$4,160
K-12, < 25,000 sf	$4,202	$6,416
Assembly, < 3,200 sf	$4,708	$7,221
Office, 3,500 to 11,000 sf	$2,659	$4,173
Retail, 2,800 to 6,000 sf	$8,208	$12,589
K-12, 25,000 to 50,000 sf	$43,566	$66,515
Assembly, 3,200 to 7,500 sf	$11,263	$17,275
Office, > 11,000 sf	$22,848	$35,857
Retail, > 6,000 sf	$67,820	$104,025
K-12, > 50,000 sf	$120,429	$183,869
Assembly, > 7,500 sf	$50,151	$76,924

Electrical Infrastructure

Costs for electrical infrastructure upgrades were derived separately between electrical panel upgrade costs and main service upgrade costs. This provides a degree of transparency when substantial electrical infrastructure upgrades are expected.

Costs for electrical infrastructure upgrades were derived primarily from historical project cost data from Willdan-evaluated or developed projects. More specifically, historical contractor cost data for these projects that have been implemented within California over the past four years, served as the majority data source. RSMeans construction cost data, as well as vendor pricing, was then used to complement the contractor cost data to account for variances, especially when larger service upgrades may be required. The total costs that were derived were then increased to account for prevailing wage, permit/plan check fees, consulting fees, taxes, contingency, and inflation for approximately two years.

Willdan compared the cost estimates for upgrading an electrical panel with the electrical panel upgrade cost range stated on the City of Palo Alto's website for residential customers, to ensure consistency.

As each customer meter results in a separate electrical panel per customer, the cost estimates for electrical panel upgrades were applied directly as a price per customer ($/customer) cost. Electrical infrastructure upgrades to the main service however, are performed at the facility or parcel level. As such, the average quantity of customers per parcel was used to estimate the potential upgrades needed, and the resulting cost estimates were then divided by the average quantity of customers per parcel to obtain a $/customer cost, which could be allocated to the per-customer electrification costs.

Key assumptions made for electrical infrastructure upgrades include:

- Base cost for an electrical panel installation: $12,000[11]
- Retail is assumed to require the largest panel and switchboard capacities of the different building types
- Maximum switchboard capacity that would need to be installed assumes one new 4,000 Amp switchboard and the costs associated with its installation.
- Existing switchboards may remain with new switchboards being installed if additional capacity is needed.

Exhibit 11. – Range of Electrification Infrastructure Cost Estimates

Range	Electrical Infrastructure Upgrades
Low Range	$12,000 per customer
High Range	$170,000 per customer

[11] Typically, a 100 to 200 Amp panel will be installed for a basic electrification project where existing panel capacity is not sufficient. New panels may be oversized to add available capacity for future needs.

Cost Scenarios for Typical Customer/Building Prototypes

Willdan developed Electrification Assessment Reports for a sample of nonresidential customers using the information collected during the detailed field surveys. Each report provides valuable insights and identifies specific potential electrification measures along with associated implementation costs. The table below summarizes the types of customers visited:

Exhibit 12. – Details of Nonresidential Buildings Surveyed

Building Type	Customers Visited	Building Sqft Range	AC
Commercial Office	2	0 – 3,499	Yes
Commercial Office	2	3,500 – 10,999	Yes
Commercial Office	3	>= 11,000	Yes
Commercial Retail	2	2,800 – 5,999	Yes

The following table represents a list of potential electrification measures and their estimated implementation costs for one of the sites. The costs provided are presented as a range for preliminary budgeting purposes, as more detailed analysis and gathering of contractor bids is required to accurately determine implementation costs. Similar summary tables were created for all eight sites visited and can be accessed in Appendix C.4.

The installation price range was developed using the cost methodology discussed in previous sections as the foundation, with adjustments made based on the specific conditions and requirements of each site.

An example of the assessment findings is shown in the table below. See Appendix C.4 for a compiled table of the opportunities found across the full sample of all customers visited.

Note that the final row in the table characterizes “Electrical Infrastructure” and the estimated improvements that will be needed to support the other electrification projects identified. These upgrades do not reduce emissions on their own but support the emissions avoidance of the associated opportunities. Typical upgrades in this category include things like new high-voltage outlets, upgraded subpanels, and upgraded main electrical service as applicable to each site. The example site below is estimated at this time to not require these types of upgrades, but this was not true of all nonresidential sites visited.

Exhibit 13. – Example of Customer Electrification Assessment results showing identified opportunities and budgetary price ranges: Site H.

Equipment Type	List of Equipment	Electrification Opportunity	Installation Price Range	Annual GHG Emissions Avoided*
Water Heating	(1) 30-gallon Electric Resistance Storage Water Heater (1) 80-gallon Electric Resistance Storage Water Heater	System is already electric, but savings could be gained by converting to a heat pump water heater system which can be up to 4x as efficient	$40k to $55k for combined system	N/A
HVAC	(2) Package units with Gas Heating	Packaged Heat Pump System	$80k to $95K	15 metric tons CO2e
HVAC	(1) Package unit cooling only, no heating	System is already electric	N/A	N/A
HVAC	(5) Ducted split system heat pumps	System is already electric	N/A	N/A
HVAC	(1) Split System Heat Pumps	System is already electric	N/A	N/A
HVAC	(1) Variable Refrigerant Flow (VRF) Heat Pump with Heat Recovery System	System is already electric	N/A	N/A
Electrical Infrastructure	Main service is 1,200 Amps. Multiple spare circuits are available at the main panel.	This site will likely not require any enhancements to the electrical infrastructure to support addition of the electrified ducted heat pump split system load, especially if electrical load is reduced by switching from the electric resistance water heater to a more efficient heat pump unit	N/A	Supports emissions avoidance shown above
Total Annual Emissions Reduction Potential Identified				**15 metric tons CO2e**

Total Costs to Electrify All City Buildings in Sector

Willdan has taken the findings of this Nonresidential Sector Study and delivered customer building characterization, technology saturation, and energy consumption data to E3 for detailed modeling of costs to fully electrify all customers in this sector. E3's model projects these costs 35 years into the future, which represents an estimated time frame to accomplish this goal completely. These total rough-order-of-magnitude (ROM) costs are shown below (in nominal dollars), along with likely available incentives from Federal, State, and regional entities. The second-to-bottom row of the table shows the costs to replace the systems in question with like-for-like, non-electrified, gas-burning alternatives. The incremental cost to electrify is the electrification capital expenditures (capex), minus the like-for-like replacement capex. This incremental cost is negative, representing an overall savings versus business as usual, as shown by E3's model.

Exhibit 14. – Total Cost to Electrify All Buildings in Sector – Small and Medium Nonresidential Customers

Sector	Metric	2025-2060 Total ROM Cost (Nominal $)		
		Low Local Action	Medium Local Action	High Local Action
Non-residential	Total Cost of Electrification Capex	$724,000,000	$865,000,000	$979,000,000
	Potential Federal / State / Regional Incentives	$5,000,000	$6,000,000	$5,000,000
	Like-for-Like Replacement Capex	$970,000,000	$1,103,000,000	$1,214,000,000
	Incremental Replacement Capex (Savings Shown from Electrification)	($246,000,000)	($238,000,000)	($235,000,000)

In the above table, three scenarios are presented: low-, medium-, and high-local action. In the low local action scenario building electrification is assumed to take place at a much slower pace than the high local action scenario, leading to greater cost escalation. The medium-local action scenario lies between these two. Due to cost escalation, and the fact that costs are denominated in nominal rather than real dollars, this estimate is higher than would be calculated by multiplying the costs shown in previous sections by the number of units served, leading to a conservatively high estimate.

For detailed documentation of this cost modeling and projection, refer to E3's, *Palo Alto Electrification Funding & Financing Study Final Report*. This report also includes the operational savings from electrifying gas equipment due to the energy efficiency of heat pumps, which is not included in the above estimate.

Key Findings

Several key findings have been identified through this study and have been summarized below, grouped by focus area.

+ **Existing and proposed technologies observed in Public and Site Survey data:**
  - There already exists some marginal level of adoption of heat pumps for space heating in office buildings (~10% of offices), and K-12 schools (~12% of schools), but there is still substantial opportunity to electrify space heating using heat pumps.
  - Adoption of heat pumps for water heating amongst nonresidential customers is less prevalent than for space heating uses (average ~2% across all sector customer segments), presenting an even larger opportunity.
  - An additional large number of nonresidential buildings utilize electric but inefficient resistance heating sources (e.g., in wall heaters, baseboard heating) - (average ~21% across all sector customer segments). This provides potential electric energy efficiency opportunities by installing heat pumps, even if this would not reduce gas use.
  - A significant number of MF buildings utilize electric but inefficient resistance water heaters (average ~38% across all sector customer segments). As above, this is an energy efficiency opportunity.
+ **Existing natural gas consumption:**
  - Offices and retail uses consume over 52% and 29%, respectively, of the natural gas across the nonresidential sector, making them the most common types of small and medium nonresidential buildings.
    - These customer types typically have smaller hot water systems for bathroom sinks and kitchenettes only (with the exception of food related retail), which present straightforward applications for electric heat pumps or small point of use electric resistance tankless retrofits.
    - Most gas used by these customers is for space heating, and most of these customers' HVAC consists of packaged rooftop air conditioners with gas heating. These types of HVAC systems are straightforward to replace with packaged air source heat pump HVAC systems.
    - Food related retail presents some barriers to electrification associated with gas cooking appliances. Appliances in commercial kitchens typically have long service lives and these businesses may be reluctant to replace gas systems that are still functioning. In addition, kitchen staff may be averse to new all-electric technologies. Both education programs and incentives are likely to be important in moving this particular market.
    - Boilers in larger office buildings are responsible for a lot of gas use and may be an opportunity to make significant progress through a single project, though these projects will be more complex than rooftop HVAC replacements.

- Small and medium non-residential customers consume 29% of all gas consumed in Palo Alto, and with office and retail uses representing over 80% of that gas consumption, office and retail electrification would go a long way toward reducing emissions in Palo Alto.
- An additional 14% of all gas use in Palo Alto is consumed by large industrial, medical, and other major facilities. This report did not address these in detail due to the uniqueness of each facility, but customized partnerships or studies with owners of these facilities may yield additional opportunities for cost-effective emissions reduction.

+ The cost to electrify:

- When combined, permit fees, plan check fees, engineering, and contingency can increase the prevailing wage materials and labor-only construction costs by 10 – 30%.
  - K-12 customer types experience the greatest increase from soft costs due to the more rigorous Division of the State Architect (DSA) requirements.
- When considering the total cost to electrify, high local action may require greater funding support by City and/or CPAU, as discussed in a separate report, the S/CAP Funding and Financing Study, especially in the near term, but may reduce overall nominal costs to all City stakeholders in the long term. Contributing factors to the lower overall cost are more rapid adoptions which reduce inflationary cost increases, plus greater availability of non-local incentives which will likely expire if projects aren't implemented until later periods.

Attachments

Attachment A - Public Data / Saturation Study

Attachment B - Customer Reports

Attachment C - Primary Data Files

Attachment C.1 - Cost Data to E3

Attachment C.2 - ArcGIS Map Images

Attachment C.3 - ArcGIS Field Data Collected

Attachment C.4 - Compiled Customer Report Table Data

Attachment C.5 - Preliminary Online Surveys and Results

Attachment C.6 – Basic HVAC and Water Heating Technology Descriptions

City of Palo Alto Electrification Funding Study

Task 5.2 – Nonresidential Building Inventory and Equipment Saturation Analysis-Public Data

November 2024

Energy+Environmental Economics

Introduction

E3 and Willdan Energy Solutions are performing a study of the nonresidential building sector in the City of Palo Alto that will accomplish the following tasks:

- Characterize gas usage in nonresidential buildings by end-use (e.g., space heating, water heating, cooking, clothes drying)
- Estimate the cost of electrification for various gas end-uses and behind-the-meter electrical upgrades
- Identify cost effective efficiency opportunities in nonresidential buildings
- Estimate the cost of electrifying all nonresidential buildings in the City of Palo Alto

In pursuit of this larger Study, we have identified available public data sources that can be used to characterize nonresidential building stock in the City of Palo Alto. The following document summarizes the results of our analysis of these data sources.

In a later stage of the project, we will be conducting interviews and on-site evaluations of a sample set of these customer sites, to determine if this public data review accurately reflects field observations.

Data Sources

City of Palo Alto nonresidential building stock has been generally characterized using the data sources described in the following sections.

This base-level building stock characterization based on these available data sources will be followed up with assessments of specific sample nonresidential sites and will include on-premises inspections and interviews with site owners, managers, and occupants to align the base-level characterizations with facts from the field. This evaluation of sample sites will occur at a later stage.

For the purposes of this public data review, we are focused on the following nonresidential sectors: office, retail, assembly, and K-12 schools. Customers in other sectors such as medical, industrial, and research & development tend to have significant site-by-site variability and will thus be dealt with using different approaches at a later stage.

+ **City of Palo Alto Utilities Utility Account Data**
    - 12-months of natural gas and electric billing data for calendar year 2023
    - Approximately 1,170 active Utility accounts for nonresidential customers in the sectors listed above
+ **County of Santa Clara Tax Assessor Records**
    - Cross referenced with CPAU Utility account addresses
    - Contains detailed information not captured by account data
        - Land use codes indicate the primary nonresidential activity being conducted on each parcel
        - Includes building square footage per parcel
        - Includes building year-built, and effective-year-built for major renovations
+ **National Renewable Energy Laboratories (NREL) ComStock Modeling Data**[1]
    - A tool for large-scale residential energy analysis combining public and private data sources, statistical sampling, building simulations, and high-performance computing.
        - *"The commercial building sector stock model, or ComStock™, is a highly granular, bottom-up model that uses multiple data sources, statistical sampling methods, and advanced building energy simulations to estimate the annual subhourly energy consumption of the commercial building stock across the United States.*

[1] https://www.nrel.gov/buildings/comstock.html

> *ComStock asks and answers two questions: (1) How is energy used in the U.S. building stock? and (2) What are the impacts of energy saving technologies?"*[2]

- Comstock draws from multiple data sources including CoStar – a commercial building real estate intelligence broker, county assessor's databases, Homeland Infrastructure Foundation-Level Data (HIFLD), the U.S. Department of Education's National Center for Educational Statistics, and a U.S. Department of Homeland Security database that provides information on critical infrastructure assets. More details regarding these specific data sets can be found in Section 3.1.1 of ComStock's reference documentation, which can be found on the Github Page[2].
- ComStock modeling data was gathered at the County level for both Santa Clara and San Mateo counties as representative of nonresidential City of Palo Alto Utility customers
- The following ComStock data was mapped to CPAU nonresidential customer accounts according to various customer segments:
    - Building technology type saturation
    - Technology type typical system ages for average customer
    - Technology type electricity and natural gas energy impacts for average customer

Sector Footprint, Construction Year, and Energy Consumption

Number of Customers and Building Square Footage

The County Assessor data indicates the following total building footprint and parcel count for various nonresidential building types in Palo Alto.

Exhibit 1. – Assessor Footprint and Parcel Count Information

Nonresidential Building Types - Land Use Codes	Total Building Square Footage	Number of Parcels
Office Uses	13,706,000	632
Retail Uses	3,791,000	398
Research & Development	3,338,000	35
Electrical Machinery and Electronics	1,601,000	17
Major Hospitals, Other Hospital Owned Buildings	1,266,000	71

[2] Quoted from ComStock's Github page: https://nrel.github.io/ComStock.github.io/

Public Schools	1,226,000	3
Convalescent Hospitals; Skilled Nursing Facilities	339,000	7
General Industrial	1,323,000	62
Other Schools	343,000	20
Major Universities	135,000	6
Neighborhood (Supermarket)	548,000	28
Recreational Facilities	133,000	14
Regional (Department Store)	1,653,000	6
Others	3,446,000	691
Total	**32,848,000**	**1,990**

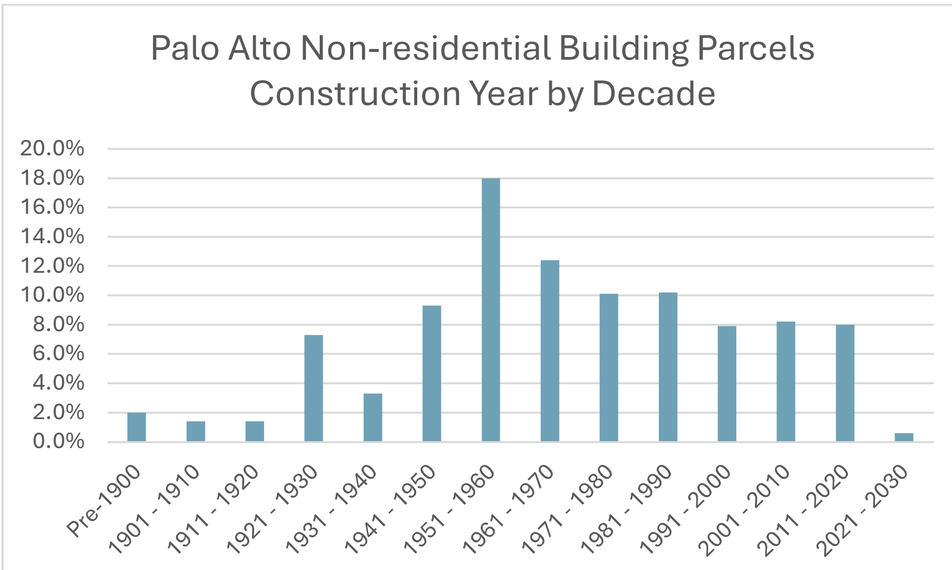
Note that the total number of individual nonresidential customer accounts doesn't necessarily align with the number of Parcels. A single commercial property may span multiple parcels, a single parcel may have multiple nonresidential businesses, or a parcel may be undeveloped or currently not operating as a nonresidential customer.

According to our current evaluation, there are approximately 1,170 individual nonresidential customers, with currently active CPAU accounts, in the primary focus sectors of office, retail, K-12 schools, and assembly.

Construction Year Distribution

The County Assessor data provides records of the year in which each non-residential building was constructed. The distribution of these construction years is shown below (data here is limited to offices, retail, K-12 schools, and assembly buildings). The data shows that after approximately 1940, the pace of construction of these buildings was relatively consistent, with the exception of a construction boom in the 1950s, somewhat carrying over into the 1960s.

Exhibit 2.1 – Year-Built Distribution Curve for Commercial Buildings in Palo Alto



Building Size Distribution

For the purposes of this study, we have also segmented the primary focus sectors according to individual building sizes. That segmentation is shown below. Segments were designated for each focus sector individually to maintain approximately equal segment populations.

Exhibit 2.2. – Sector Specific Building Size Segmentation

Customer Sector	Building Size Segment, Square Footage	Approximate Number of CPAU Customers
Office	0 to 3,499	181
Office	3,500 to 10,999	229
Office	Over 11,000	234
Retail	0 to 2,799	133
Retail	2,800 to 5,999	144
Retail	Over 6,000	145
K-12 Schools	0 to 24,999	31
K-12 Schools	25,000 to 49,999	15
K-12 Schools	Over 50,000	18
Assembly	0 to 3,199	12
Assembly	3,200 to 7,499	11
Assembly	Over 7,500	13
Total		**1,166**

Total Energy Consumption Across the Sector

An analysis of the County Assessor data and CPAU customer account usage data together indicates the following estimates for annual energy consumption for various non-residential building types in Palo Alto.

Exhibit 3. – Sector Energy Consumption Information

Nonresidential Building Types - Land Use Codes	Estimated Annual Electricity Consumption, kWh	Percentage of Electricity	Estimated Annual Natural Gas Consumption, therms	Percentage of Natural Gas
Office Uses	171,180,000	56%	4,070,000	52%
Retail Uses	65,060,000	21%	2,260,000	29%
Neighborhood (Supermarket)	29,060,000	10%	330,000	4%
Regional (Department Store)	22,740,000	8%	230,000	3%
Public Schools	9,818,000	3%	583,000	8%
Other Schools	2,022,000	1%	28,000	<1%
Churches	2,530,000	1%	70,000	1%
Recreational Facilities	2,530,000	1%	240,000	3%
Total	**304,940,000**	**100%**	**7,811,000**	**100%**

Electrification Funding Study Customer Segmentation

For the purposes of the funding study model, CPAU customers have been segmented into representative groups. The segmentation of nonresidential sector customers follows the distinctions of Building Type and Building Size (square footage).

For model segmentation purposes, an individual customer account in the fundamental unit. These account types correspond to CPAU account types “30”, “40”, “50”, and “60”.

Segmentation by Building Type

In the nonresidential building sector, building types have been segmented by the type of nonresidential activity occurring at the customer site. Segments are as follows:

- Office
- Retail
- K-12 Schools
- Assembly

Segmentation by Building Size

Each building type was segmented into three building size categories, based on the total building square footage. This is total occupiable square footage, meaning multiple floors contribute to additional square footage, as opposed to the building footprint only.

Segments were designated for each building type individually to maintain approximately equal segment populations. See Exhibit 2.2 above for the square footage segmentation values for each building type focused on for this Study.

Electrification Funding Study Technology Types

Under this funding study, we are evaluating what common building technology types are present for each customer segment, to what extent they are present, and their estimated energy impacts.

End Use and Fuel Type

The technologies being investigated have been categories by end-use, and fuel type

- End-uses
    - Space Cooling
    - Space Heating
    - Water Heating
    - Clothes Drying
    - Cooking
    - Pool and Spa Heating
- Fuel types
    - Electricity
    - Natural gas

For the purposes of modeling, we have also evaluated "other" loads as an end-use type for both electricity and natural gas. Other loads are defined as any end-uses not specified above. Since this is a generalized category, there are no technology types associated with this category of end-use.

Technology Types

The list of technology types being evaluated is shown below:

Exhibit 4. – Funding Study Technology Types

Fuel	End-Use Type	Technology
Electric	Cooling	Split Systems
Electric	Cooling	Packaged Terminal Air Conditioners (PTACs) / Packaged Unit Air Conditioners
Electric	Cooling	Packaged Terminal Heat Pumps (PTHPs) / Packaged Unit Heat Pumps
Electric	Cooling	Water-cooled Chiller Systems
Electric	Cooling	Air-cooled Chiller Systems
Electric	Cooling	Variable Refrigerant Flow (VRF) Systems
Gas	Space Heating	Packaged HVAC Units-Gas Heat
Electric	Space Heating	Packaged HVAC Units-Electric Resistance Heat
Electric	Space Heating	Air-source Heat Pumps (ASHPs)
Gas	Space Heating	Boiler Systems
Gas	Space Heating	Furnaces
Gas	Water Heating	Gas Storage Water Heaters
Gas	Water Heating	Service Water Boilers
Electric	Water Heating	Electric Storage Water Heaters
Electric	Water Heating	Heat Pump Water Heaters
Gas	Water Heating	Tankless Gas Water Heaters
Electric	Water Heating	Tankless Electric Water Heaters
Electric	Clothes Dryer	Electric Dryers
Gas	Clothes Dryer	Gas Dryers
Gas	Cooking Range	Gas Stoves
Gas	Cooking Range	Gas Ovens
Electric	Cooking Range	Electric Resistance Stoves
Electric	Cooking Range	Electric Induction Stoves
Electric	Cooking Range	Electric Ovens
Electric	Pool Heater	Electric Pool Heaters
Gas	Pool Heater	Gas Pool Heaters
Electric	Spa Heater	Electric Spa Heaters
Gas	Spa Heater	Gas Spa Heaters

Public Data Results

The review of public data leads us to the following information about CPAUs multi-family residential customers. In a later stage of the project, we will be conducting interviews and on-site evaluations of a sample set of these customer sites, to determine if this public data review accurately reflects field observations.

The data shown in Exhibit 5 derives from the County Assessor data, which includes information regarding the type of nonresidential activity occurring on each parcel, and the year of construction. For the purposes of this study, we are using the Assessor field "Effective Year Built" which accounts for major building renovations that would result in upgraded base systems, as opposed to the "Year Built" field which reflects initial year of construction.

The Assessor data was cross-referenced with CPAU customer account data to estimate the number of active multifamily customers in each segment. The Active Customers shown include CPAU Account Class 30 (Commercial), Account Class 50 (Public Facilities), and Account Class 60 (City of Palo Alto).

Exhibit 5. – Number of Customers in Each Segment and Average Building Ages

Customer Type Segments	**Full Palo Alto Stock**	**Average Building Age in 2025**
	Estimated # of Active Customers	*Years*
Comm-Office-0-3499	181	61
Comm-Retail-0-2799	133	64
Comm-K-12-0-24999	31	47
Comm-Assembly-0-3199	12	59
Comm-Office-3500-10999	229	60
Comm-Retail-2800-5999	144	64
Comm-K-12-25000-49999	15	45
Comm-Assembly-3200-7499	11	54
Comm-Office->=11000	234	52
Comm-Retail->=6000	145	63
Comm-K-12->=50000	18	44
Comm-Assembly->=7500	13	51
TOTAL	**1,166**	

Exhibits 6 and 7 show data derived from NREL's ComStock modeling data. We've evaluated the weighted counts of ComStock models that are mapped to our specific Customer Type Segments for San Mateo and Santa Clara Counties and counted the weighted customer models that incorporate each type of technology. We've then represented those weighted counts as a percentage of the total population.

Exhibit 6. - Applicability of Technology Types by Segment – Electric Technologies

Customer Type Segments	**Electric-Cooling-Split System**	**Electric-Cooling-PTAC/Packaged DX**	**Electric-Cooling-PTHP/Packaged HP**	**Electric-Cooling-WC Chiller**	**Electric-Cooling-AC Chiller**	**Electric-Cooling-VRF**	**Electric-Space Heating-Packaged Unit-Electric Resistance**	**Electric-Space Heating-ASHP**	**Electric-Water Heating-Electric Resistance Water Heater**	**Electric-Water Heating-Heat Pump Water Heater**	**Electric-Water Heating-Tankless**	**Electric-Clothes Dryer-Electric Dryer***	**Electric-Cooking Range-Resistance Stove**	**Electric-Cooking Range-Induction Stove**	**Electric-Cooking Range-Oven**	**Electric-Other**
	0-100%	*0-100%*	*0-100%*	*0-100%*	*0-100%*	*0-100%*	*0-100%*	*0-100%*	*0-100%*	*0-100%*	*0-100%*	*0-100%*	*0-100%*	*0-100%*	*0-100%*	*0-100%*
Comm-Office-0-3499	4.0%	89.1%	4.0%	2.9%	0.0%	0.0%	43.2%	9.6%	58.8%	3.5%	6.9%		0.0%	0.0%	0.0%	100.0%
Comm-Retail-0-2799	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	17.9%	0.0%	57.1%	3.6%	7.1%		0.0%	0.0%	0.0%	100.0%
Comm-K-12-0-24999	0.0%	0.0%	30.8%	38.5%	30.8%	0.0%	0.0%	30.8%	50.0%	3.9%	7.7%		0.0%	0.0%	0.0%	100.0%
Comm-Assembly-0-3199	6.1%	93.9%	0.0%	0.0%	0.0%	0.0%	39.9%	0.0%	28.9%	2.0%	3.4%		0.0%	0.0%	31.7%	100.0%
Comm-Office-3500-10999	4.0%	88.9%	4.7%	2.5%	0.0%	0.0%	36.9%	11.6%	59.8%	3.5%	7.1%		0.0%	0.0%	0.0%	100.0%
Comm-Retail-2800-5999	6.3%	90.5%	0.0%	3.2%	0.0%	0.0%	3.8%	1.9%	36.7%	1.9%	4.4%		0.0%	0.0%	22.2%	100.0%
Comm-K-12-25000-49999	0.0%	62.5%	0.0%	37.5%	0.0%	0.0%	0.0%	0.0%	14.3%	0.0%	2.0%		0.0%	0.0%	17.9%	100.0%
Comm-Assembly-3200-7499	0.0%	98.7%	0.0%	0.0%	1.3%	0.0%	36.8%	1.4%	23.1%	1.4%	2.7%		3.6%	0.4%	25.9%	100.0%
Comm-Office->=11000	2.5%	84.1%	3.5%	8.6%	0.9%	0.2%	25.3%	6.5%	50.1%	3.0%	5.9%		0.0%	0.0%	0.0%	100.0%
Comm-Retail->=6000	2.2%	96.0%	0.0%	1.9%	0.0%	0.0%	9.2%	0.9%	40.6%	2.4%	4.8%		1.0%	0.1%	31.6%	100.0%
Comm-K-12->=50000	0.0%	73.5%	0.0%	19.6%	6.9%	0.0%	6.8%	5.0%	23.7%	1.4%	2.7%		3.7%	0.5%	31.5%	100.0%
Comm-Assembly->=7500	7.7%	81.2%	7.4%	3.7%	0.0%	0.0%	26.5%	12.4%	17.8%	1.0%	2.0%		2.5%	0.2%	24.0%	100.0%
Total Estimated Quantity of Customer with This System Type	36	975	81	60	13	0	278	75	579	34	69	0	3	0	96	1,166

*NREL ComStock does not model data for laundry at commercial buildings

Exhibit 7. - Applicability of Technology Types by Segment – Natural Gas Technologies

Customer Type Segments	Gas-Space Heating-Packaged Unit-Gas Heat	Gas-Space Heating-Boiler	Gas-Space Heating-Furnace	Gas-Water Heating-Storage Water Heater	Gas-Water Heating-Boiler	Gas-Water Heating-Tankless	Gas-Clothers Dryer-Gas Dryer*	Gas-Cooking Range-Stove	Gas-Cooking Range-Oven	Gas-Other
	0-100%	*0-100%*	*0-100%*	*0-100%*	*0-100%*	*0-100%*	*0-100%*	*0-100%*	*0-100%*	*0-100%*
Comm-Office-0-3499	37.6%	5.1%	4.6%	27.7%	0.0%	3.1%		0.0%	0.0%	100.0%
Comm-Retail-0-2799	82.1%	0.0%	0.0%	28.6%	0.0%	3.6%		0.0%	0.0%	100.0%
Comm-K-12-0-24999	0.0%	69.2%	0.0%	34.6%	0.0%	3.9%		50.0%	50.0%	100.0%
Comm-Assembly-0-3199	54.1%	0.0%	6.1%	59.1%	0.0%	6.7%		43.6%	24.8%	100.0%
Comm-Office-3500-10999	41.0%	6.1%	4.5%	26.7%	0.0%	3.0%		0.0%	0.0%	100.0%
Comm-Retail-2800-5999	67.1%	20.9%	6.3%	51.3%	0.0%	5.7%		7.4%	70.4%	100.0%
Comm-K-12-25000-49999	41.7%	58.3%	0.0%	75.5%	0.0%	8.2%		50.0%	32.1%	100.0%
Comm-Assembly-3200-7499	56.5%	5.4%	0.0%	65.6%	0.0%	7.2%		40.7%	29.5%	100.0%
Comm-Office->=11000	39.3%	26.0%	2.8%	37.0%	0.0%	4.1%		0.0%	0.0%	100.0%
Comm-Retail->=6000	65.0%	22.6%	2.3%	47.0%	0.0%	5.2%		22.5%	44.8%	100.0%
Comm-K-12->=50000	42.9%	45.4%	0.0%	65.0%	0.0%	7.2%		45.9%	18.4%	100.0%
Comm-Assembly->=7500	41.7%	6.0%	13.4%	71.1%	0.0%	8.0%		47.2%	26.1%	100.0%
Total Estimated Quantity of Customer with This System Type	586	187	40	435	0	49	0	90	200	1,166

*NREL ComStock does not model data for laundry at commercial buildings

Exhibits 8 and 9 show data derived from NREL's ComStock modeling data. We've evaluated the energy impacts in the ComStock models for each type of technology for both electricity and natural gas. The values below represent the energy impacts of these technologies for the average customer using that technology in each segment. Note that the averages do not include the customers that do not utilize a given technology, which would give an impact of zero for that given technology and show lower values for each technology.

Exhibit 8. - Typical Annual Energy Impacts of Technology Types by Segment – Electric Technologies

Customer Type Segments	Electric-Cooling-Split System	Electric-Cooling-PTAC/Packaged DX	Electric-Cooling-PTHP/Packaged HP	Electric-Cooling-WC Chiller	Electric-Cooling-AC Chiller	Electric-Cooling-VRF	Electric-Space Heating-Packaged Unit-Electric Resistance*	Electric-Space Heating-ASHP	Electric-Water Heating-Electric Resistance Water Heater	Electric-Water Heating-Heat Pump Water Heater	Electric-Water Heating-Tankless	Electric-Clothers Dryer-Electric Dryer	Electric-Cooking Range-Resistance Stove	Electric-Cooking Range-Induction Stove	Electric-Cooking Range-Oven	Electric-Other[3]
	kWh / Cust.	*kWh / Cust.*	*kWh / Cust.*	*kWh / Cust.*	*kWh / Cust.*	*kWh / Cust.*	*kWh / Cust.*	*kWh / Cust.*	*kWh / Cust.*	*kWh / Cust.*	*kWh / Cust.*	*kWh / Cust.*	*kWh / Cust.*	*kWh / Cust.*	*kWh / Cust.*	*kWh / Cust.*
Comm-Office-0-3499	1,717	7,706	1,933	3,649	- -	- -	6,205	776	682	170	538		- -	- -	- -	8,031
Comm-Retail-0-2799	- -	10,463	- -	- -	- -	- -	7,802	- -	1,507	377	1,191		- -	- -	- -	8,801
Comm-K-12-0-24999	- -	- -	8,936	35,401	38,111	- -	- -	708	14,270	3,567	11,275		- -	- -	- -	35,835
Comm-Assembly-0-3199	194,941	156,588	- -	- -	- -	- -	17,589	- -	13,523	3,382	10,683		- -	- -	679	642,581
Comm-Office-3500-10999	8,060	26,526	7,328	17,195	- -	- -	19,003	2,540	1,959	489	1,549		- -	- -	- -	28,211
Comm-Retail-2800-5999	9,544	35,972	- -	34,009	- -	- -	25,733	2,386	3,041	761	2,404		- -	- -	556	44,780
Comm-K-12-25000-49999	- -	270,391	- -	302,526	- -	- -	- -	- -	123,521	30,880	97,587		- -	- -	532	171,172
Comm-Assembly-3200-7499	- -	120,908	- -	- -	246,995	- -	35,863	3,700	32,726	8,184	25,854		460	414	804	411,205
Comm-Office->=11000	93,927	213,969	112,460	173,955	219,866	192,488	112,881	21,902	18,280	4,591	14,447		- -	- -	- -	262,533
Comm-Retail->=6000	102,722	270,927	- -	292,421	- -	- -	119,468	18,495	22,194	5,549	17,545		340	305	1,037	299,919
Comm-K-12->=50000	- -	770,538	- -	641,665	894,013	- -	486,478	60,051	228,327	57,082	180,354		695	627	904	500,040
Comm-Assembly->=7500	20,428	182,318	26,140	58,210	- -	- -	61,065	9,665	65,393	16,343	51,664		382	345	1,039	448,150

[3] "Electric-Other" includes the following use types from the ComStock Models: plug loads, lighting (interior, garage, exterior), pumps, and refrigeration.

Exhibit 9. - Typical Annual Energy Impacts of Technology Types by Segment – Natural Gas Technologies

Customer Type Segments	Gas-Space Heating-Packaged Unit-Gas Heat	Gas-Space Heating-Boiler	Gas-Space Heating-Furnace	Gas-Water Heating-Storage Water Heater	Gas-Water Heating-Boiler	Gas-Water Heating-Tankless	Gas-Clothers Dryer-Gas Dryer	Gas-Cooking Range-Stove	Gas-Cooking Range-Oven	Gas-Other[4]
	therm / cust.	*therm / cust*	*therm / cust*	*therm / cust*	*therm / cust*	*therm / cust*	*therm / cust*	*therm / cust*	*therm / cust*	*therm / cust*
Comm-Office-0-3499	191	260	110	22	0	20		- -	- -	0
Comm-Retail-0-2799	196	- -	- -	57	- -	52		- -	- -	0
Comm-K-12-0-24999	- -	3,823	- -	177	- -	163		13	23	164
Comm-Assembly-0-3199	505	- -	3	563	- -	518		32	62	15,181
Comm-Office-3500-10999	587	665	143	83	- -	76		- -	- -	0
Comm-Retail-2800-5999	629	2,735	151	148	- -	136		11	16	681
Comm-K-12-25000-49999	1,722	23,094	- -	1,957	- -	1,801		21	36	2,017
Comm-Assembly-3200-7499	1,417	2,365	- -	1,318	- -	1,212		32	56	15,462
Comm-Office->=11000	3,205	8,249	934	812	0	747		- -	- -	0
Comm-Retail->=6000	3,923	24,330	273	1,134	- -	1,044		35	66	6,340
Comm-K-12->=50000	5,548	46,941	- -	7,528	0	6,925		44	112	1,911
Comm-Assembly->=7500	4,954	1,589	315	3,627	- -	3,337		58	66	20,807

[4] Gas-Other" includes the following use types from the ComStock Models: any natural gas-powered equipment that is not used for space heating or water heating, primarily specialty gas kitchen equipment (e.g., fryers) and pool and spa heating systems.

Key Takeaways

Here are some preliminary key takeaways that will inform the broader Electrification Funding Study and strategies with CPAU nonresidential customers.

- The largest portion of nonresidential utility customers fall under the office segment (55% of common nonresidential types), with the next largest portion under the retail segment (36% of common nonresidential types). Other nonresidential customer groups are significantly smaller.
- For nonresidential buildings with air conditioning, the primary cooling equipment type found in the NREL models is packaged DX systems (including packaged-terminal air conditioning, PTAC).
- The NREL models show most of the space heating at nonresidential customer sites is provided by natural gas sources, via either gas-fired packaged rooftop units, boilers, or furnaces. However, there is a significant amount of electric heating identified in the models, particularly in smaller buildings. We intend to validate this later against data collected from field evaluations of nonresidential sites conducted under this study.
- Space heating via air-source heat pump systems appears in the models, most prevalently in smaller schools. This likely may be due the prevalence of "portable" structures at these types of schools, which are frequently equipped with packaged terminal heat pump type equipment.
- There is also a significant amount of electric-resistance storage water heating systems identified in the NREL models. Ranges depend on building type and size. We intend to validate this later against data collected from field evaluations of nonresidential sites conducted under this study.
- The primary focus of the Nonresidential Building Sector Study has been on more common commercial gas users, such as buildings housing offices, retail, assembly, and schools. The reasoning for this approach is as follows:
  - Meaningful energy, carbon, and cost impact estimates can be generally developed for the common systems serving these types of buildings
  - Future potential programs serving these types of buildings will serve the largest number of customers
  - Because of the mass-market nature of these types of customers, carbon impacts will be large by impacting a high number of buildings and systems
  - The public data available for analysis focuses on these types of buildings
- Alternatively, if we are thinking about the uncommon, high gas using customers such as industrial, research and development, and inpatient hospitals, we find the following
  - Generalized commercial decarbonization solutions don't impact their footprints significantly because of their highly specialized and unique building systems.
  - Decarbonization measure need to be custom developed based on the specifics of the site
  - The custom developed measures applicable to one site do not generally apply to other sites without significant adaptation

- Willdan’s recommendation for helping these high-gas-using, specialized sites is to offer a robust, customized decarbonization support program to help the customers develop and pay for large projects designed for their systems.

WILLDAN

City of Palo Alto Utilities
Electrification Survey Report

Presented on behalf of City of Palo Alto Utilities (CPAU)

CITY OF PALO ALTO UTILITIES

Presented to:
Site A

Willdan Primary Contact:
Lance Kincaid
Willdan Energy Solutions
lkincaid@willdan.com

Date:
November 27, 2024

Electrification Opportunity Summary

Equipment Type	List of Equipment	Electrification Opportunity	Installation Price Range	Annual GHG Emissions Avoided*
Water Heating	(1) 20-gallon Storage Electric Water Heaters	System is already electric, but savings could be gained by converting to a heat pump water heater system which can be up to 4x as efficient. However, location in existing space may be too limited to accommodate heat pump devices which tend to be larger.	$8k to $12k	N/A
HVAC	(1) Split Unit Ducted Air Conditioner – Cooling Only	System already electric	N/A	N/A
HVAC	(1) Gas fired furnace	Ducted split system heat pump. Note that this device will replace the gas fired heating capability but can also fulfill the function of the existing air conditioner allowing that device to be removed/taken out of service	$25k to $32k	3 metric tons CO2e
Kitchen	No Kitchen Equipment	N/A	N/A	N/A
Washers	No Washers	N/A	N/A	N/A

Equipment Type	List of Equipment	Electrification Opportunity	Installation Price Range	Annual GHG Emissions Avoided*
Dryers	No Dryers	N/A	N/A	N/A
Electrical Infrastructure	200-AMP Main Circuit	There appears to be adequate space in existing subpanels to accommodate new electrified water heater and ducted split system heat pump, especially if existing air conditioner is removed (redundant to heat pump cooling function)	N/A	N/A
		Total Annual Emissions Reduction Potential Identified		**3 metric tons CO2e**

*For ongoing operational savings assumptions, please see section below on typical utility bill impacts.

Available Electrification Project Support

- Your participation in this CPAU survey will assist the development of new, future electrification support programs. Keep an eye on the CPAU electrification landing page for existing and future programs: https://www.cityofpaloalto.org/Departments/Utilities/Sustainability/Electrification
- Food Service Technology Center - https://frontierfstc.com/resources/
- California Energy Wise Foodservice - Instant Rebates https://caenergywise.com/instant-rebates/
- High-Efficiency Electric Home Rebate Act (HEEHRA) Federal Rebates for income-qualifying multifamily electrification, provided through TECH Clean California: https://techcleanca.com/incentives/heehrarebates/. Please note that participation in this program requires compliance with CA Department of Industrial Relations Prevailing Wage and Public Works Requirements. Using prevailing wages may add 15% to 25% to representative project costs shown above.
- California Department of Community Services and Development Low-Income Weatherization Program (LIWP): https://www.csd.ca.gov/Pages/Low-Income-Weatherization-Program.aspx

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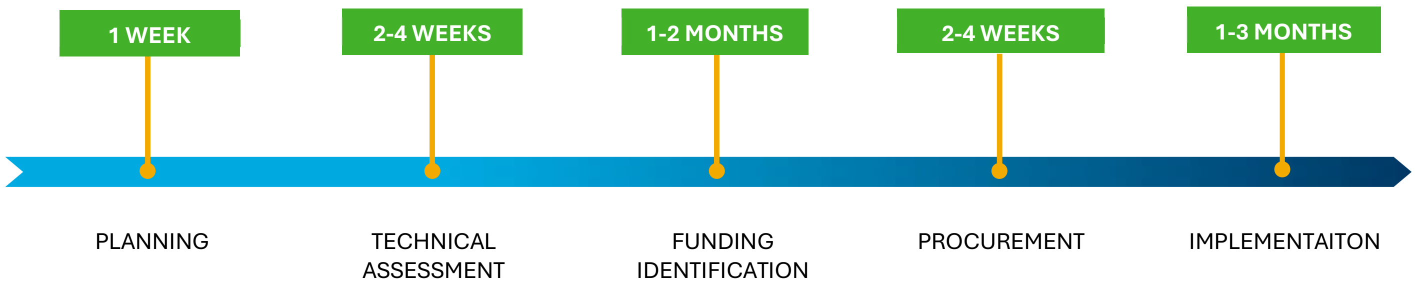
Typical Project Milestones



- PLANNING – Decide what opportunities will be pursued, and in what order of prioritization
- TECHNICAL ASSESSMENT- Engage contractors and engineers (for more complicated projects such as large HVAC systems or complex water heating systems) to determine the technical parameters of the electrification solutions
- FUNDING IDENTIFICATION – Secure funding for the projects and apply for any available rebates
- PROCUREMENT- Identify a qualified contractor and purchase materials. For larger projects you may want to compare multiple bids.
- IMPLEMENTATION – Obtain applicable permits and manage the construction of the projects. For larger projects, some customers may wish to hire a dedicated construction manager.

Next Steps

- REVIEW THIS OPPORTUNITY SUMMARY – Discuss the electrification opportunities with key decision-makers and other relevant stakeholders, such as your local utility representatives.
- START THE PLANNING PROCESS – see typical project milestones above.

Typical Utility Bill Impacts

- The following examples provide comparisons of the utility bill impacts customers would see with typical gas-fired equipment and their electrified equivalents. For these typical scenarios, customers would be close to break-even or even see savings on their utility bills after upgrading to the electrified systems.

- Typical CPAU Energy Rates: Natural Gas = $2.50 per therm; Electricity = $0.22 per kWh[1]

- Typical Service Water Heating Example: Average Daily Hot Water Usage = 240 gallons, at 70˚F Rise[2]

Standard Gas Fired Water Heater	Electrified Heat Pump Water Heater
Typical Gas Water Heater Thermal Efficiency = 81% Estimated Monthly Gas Use = 240 gallons per day x 70˚F x 8.34 lbs per gallon x 1 Btu per˚F-lb ÷ 81% x 30 days per month x 1 therm per 100,000 Btu = **52 therms per month** Typical Monthly Charge for Gas-Fired Water Heating = 52 therms per month x $2.50 per therm = **$130 per month**	Typical Heat Pump Water Heater Uniform Energy Factor (UEF) = 3.0 Estimated Monthly Gas Use = 240 gallons per day x 70˚F x 8.34 lbs per gallon x 1 Btu per˚F-lb ÷ 3.0 x 30 days per month x 0.00293 kWh per Btu = **411 kWh per month** Typical Monthly Charge for Heat Pump Water Heating = 411 kWh per month x $0.22 per kWh = **$90 per month**

- Typical HVAC Space Heating Example: Average Monthly Heating Load = 18,000,000 Btu[3]

Standard Rooftop Unit (RTU) or Furnace with Gas-Fired Heating	Electrified Heat Pump RTU or Furnace
Typical Gas-Fired HVAC Unit Thermal Efficiency = 82% Estimated Monthly Gas Use = 18,000,000 Btu per month ÷ 82% x 1 therm per 100,000 Btu = **220 therms per month** Typical Monthly Charge for Gas-Fired Space Heating = 220 therms per month x $2.50 per therm = **$550 per month**	Typical Heat Pump HVAC Unit Heating Seasonal Performance Factor (HSPF) = 8.0 Btu/W-hr Estimated Monthly Gas Use = 18,000,000 Btu ÷ 8.0 Btu/W-hr x 1 kWh/1,000 W-hr = **2,250 kWh per month** Typical Monthly Charge for Heat Pump Water Heating = 2,250 kWh per month x $0.22 per kWh = **$495 per month**

[1] https://www.cityofpaloalto.org/Departments/Utilities/Customer-Service/Utilities-Rates/Business-Rates
[2] Typical medium-sized business customer water heating load, 75-gallon storage water heater example
[3] Typical small to medium-sized business customer, single HVAC unit load, 60,000 Btu capacity heating unit example

WILLDAN

City of Palo Alto Utilities
Electrification Survey Report

Presented on behalf of City of Palo Alto Utilities (CPAU)

CITY OF PALO ALTO UTILITIES

Presented to:
Site C

Willdan Primary Contact:
Lance Kincaid
Willdan Energy Solutions
lkincaid@willdan.com

Date:
November 22, 2024
(revised)

Electrification Opportunity Summary

Equipment Type	List of Equipment	Electrification Opportunity	Installation Price Range	Annual GHG Emissions Avoided*
Water Heating	Tankless Gas Water Heater	Heat Pump Water Heater System The system appears to be oversized for existing loads in the building based on a preliminary water use analysis. Estimated price range shown represents a "right-sized" system	$20k to $35k for "right-sized" system	4 metric tons CO2e
HVAC	(3) Package Units with Natural Gas Heating North Unit (74,000 Btuh heating) has failed Center and South Units (125,000 Btuh, and 100,000 Btuh heating) are operational	Package heat pump system The Center and South Units will likely require electric resistance backup heating to match the existing units' heating capacity	$100k to $120k for all three units	2 metric tons CO2e
Kitchen	No kitchen on site.	N/A	N/A	N/A

Equipment Type	List of Equipment	Electrification Opportunity	Installation Price Range	Annual GHG Emissions Avoided*
Laundry	Washing Machine, Electric Dryer	The system is already electric. Hot water used by washing machine will be electrified indirectly from the water heating opportunity shown above	N/A	N/A
Electrical Infrastructure	Main service is estimated to be 400 Amps. Multiple spare circuits are available at the main panel.	This site will likely require the installation of new electrical subpanels to feed electrified water heating system. Rooftop heat pump package HVAC units may be able to connect to existing HVAC subpanel(s). However, if new HVAC heat pump units are optioned with resistance heat backup, additional Amp capacity may be needed. Specific electrical design parameters will need to be determined by engineers. Preliminary estimate of total combined subpanel capacity needed is 100 to 200 Amps.	$7k to $20K	Supports emissions avoidance shown above
			Total Annual Emissions Reduction Potential Identified	**6 metric tons CO2e**

*For ongoing operational savings assumptions, please see section below on typical utility bill impacts.

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Available Electrification Project Support

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- High-Efficiency Electric Home Rebate Act (HEEHRA) Federal Rebates for income-qualifying multifamily electrification, provided through TECH Clean California: https://techcleanca.com/incentives/heehrarebates/. Please note that participation in this program requires compliance with CA Department of Industrial Relations Prevailing Wage and Public Works Requirements. Using prevailing wages may add 15% to 25% to representative project costs shown above.
- California Department of Community Services and Development Low-Income Weatherization Program (LIWP): https://www.csd.ca.gov/Pages/Low-Income-Weatherization-Program.aspx

Typical Project Milestones

- PLANNING – Decide what opportunities will be pursued, and in what order of prioritization
- TECHNICAL ASSESSMENT- Engage contractors and engineers (for more complicated projects such as large HVAC systems or complex water heating systems) to determine the technical parameters of the electrification solutions
- FUNDING IDENTIFICATION – Secure funding for the projects and apply for any available rebates
- PROCUREMENT- Identify a qualified contractor and purchase materials. For larger projects you may want to compare multiple bids.
- IMPLEMENTATION – Obtain applicable permits and manage the construction of the projects. For larger projects, some customers may wish to hire a dedicated construction manager.

Next Steps

- REVIEW THIS OPPORTUNITY SUMMARY – Discuss the electrification opportunities with key decision-makers and other relevant stakeholders, such as your local utility representatives.
- START THE PLANNING PROCESS – see typical project milestones above.

Typical Utility Bill Impacts

- The following examples provide comparisons of the utility bill impacts customers would see with typical gas-fired equipment and their electrified equivalents. For these typical scenarios, customers would be close to break-even or even see savings on their utility bills after upgrading to the electrified systems.

- Typical CPAU Energy Rates: Natural Gas = $2.50 per therm; Electricity = $0.22 per kWh[1]

- Typical Service Water Heating Example: Average Daily Hot Water Usage = 240 gallons, at 70˚F Rise[2]

Standard Gas Fired Water Heater	Electrified Heat Pump Water Heater
Typical Gas Water Heater Thermal Efficiency = 81% Estimated Monthly Gas Use = 240 gallons per day x 70˚F x 8.34 lbs per gallon x 1 Btu per˚F-lb ÷ 81% x 30 days per month x 1 therm per 100,000 Btu = **52 therms per month** Typical Monthly Charge for Gas-Fired Water Heating = 52 therms per month x $2.50 per therm = **$130 per month**	Typical Heat Pump Water Heater Uniform Energy Factor (UEF) = 3.0 Estimated Monthly Gas Use = 240 gallons per day x 70˚F x 8.34 lbs per gallon x 1 Btu per˚F-lb ÷ 3.0 x 30 days per month x 0.00293 kWh per Btu = **411 kWh per month** Typical Monthly Charge for Heat Pump Water Heating = 411 kWh per month x $0.22 per kWh = **$90 per month**

- Typical HVAC Space Heating Example: Average Monthly Heating Load = 18,000,000 Btu[3]

Standard Rooftop Unit (RTU) or Furnace with Gas-Fired Heating	Electrified Heat Pump RTU or Furnace
Typical Gas-Fired HVAC Unit Thermal Efficiency = 82% Estimated Monthly Gas Use = 18,000,000 Btu per month ÷ 82% x 1 therm per 100,000 Btu = **220 therms per month** Typical Monthly Charge for Gas-Fired Space Heating = 220 therms per month x $2.50 per therm = **$550 per month**	Typical Heat Pump HVAC Unit Heating Seasonal Performance Factor (HSPF) = 8.0 Btu/W-hr Estimated Monthly Gas Use = 18,000,000 Btu ÷ 8.0 Btu/W-hr x 1 kWh/1,000 W-hr = **2,250 kWh per month** Typical Monthly Charge for Heat Pump Water Heating = 2,250 kWh per month x $0.22 per kWh = **$495 per month**

[1] https://www.cityofpaloalto.org/Departments/Utilities/Customer-Service/Utilities-Rates/Business-Rates
[2] Typical medium-sized business customer water heating load, 75-gallon storage water heater example
[3] Typical small to medium-sized business customer, single HVAC unit load, 60,000 Btu capacity heating unit example

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City of Palo Alto Utilities
Electrification Survey Report

Presented on behalf of City of Palo Alto Utilities (CPAU)

CITY OF PALO ALTO UTILITIES

Presented to:
Site B

Willdan Primary Contact:
Lance Kincaid
Willdan Energy Solutions
lkincaid@willdan.com

Date:
November 27, 2024

Electrification Opportunity Summary

Equipment Type	List of Equipment	Electrification Opportunity	Installation Price Range	Annual GHG Emissions Avoided*
Water Heating	(1) 75-gallon Storage Water Heaters	Heat Pump Water Heater System	\$20k to \$35k	2 metric tons CO2e
HVAC	(2) Split Heat Pumps	System already electric	N/A	N/A
HVAC	(1) Condenser Cooling Unit	System already electric	N/A	N/A
HVAC	(1) Gas Furnace Unit	Ducted heat pump split system	\$26K to \$30K	1 metric tons CO2e
Kitchen	No Stoves	N/A	N/A	N/A
Washers	(1) Electric washers	Washers consume hot water. Opportunities come from replacing gas water heaters with electric heat pumps as shown above	N/A	N/A
Dryers	(1) Gas Dryer	New Electric Heat Pump Dryer	\$1.5 K to \$2K	1 metric tons CO2e

Equipment Type	List of Equipment	Electrification Opportunity	Installation Price Range	Annual GHG Emissions Avoided*
Electrical Infrastructure	Medical Area service panel is 125 Amps (though main breaker is rated for 100 Amps). All existing circuits are being used Each upstairs residential unit has a 100 Amp service panel	This site will likely require enhancements to the medical area electrical infrastructure to support the addition of the electrified ducted heat pump split system load and the new heat pump water heater system (both circuit spaces and capacity is likely required) Specific electrical design parameters will need to be determined by engineers. Preliminary estimate of total combined subpanel capacity needed is 100 to 200 Amps, and approximately 4 circuit breaker spaces.	$3k to $7k	Supports emissions avoidance shown above
			Total Annual Emissions Reduction Potential Identified	**4 metric tons CO2e**

*For ongoing operational savings assumptions, please see section below on typical utility bill impacts.

Available Electrification Project Support

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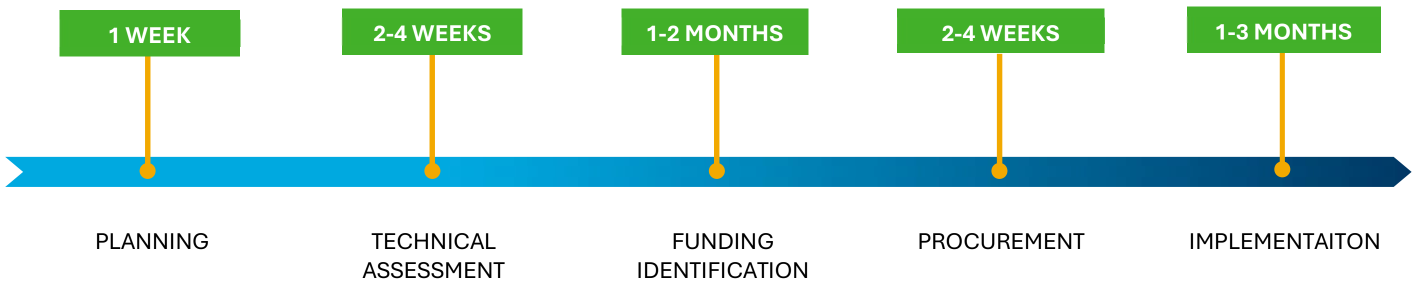
- California Department of Community Services and Development Low-Income Weatherization Program (LIWP): https://www.csd.ca.gov/Pages/Low-Income-Weatherization-Program.aspx

Typical Project Milestones



- PLANNING – Decide what opportunities will be pursued, and in what order of prioritization
- TECHNICAL ASSESSMENT- Engage contractors and engineers (for more complicated projects such as large HVAC systems or complex water heating systems) to determine the technical parameters of the electrification solutions
- FUNDING IDENTIFICATION – Secure funding for the projects and apply for any available rebates
- PROCUREMENT- Identify a qualified contractor and purchase materials. For larger projects you may want to compare multiple bids.
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Next Steps

- REVIEW THIS OPPORTUNITY SUMMARY – Discuss the electrification opportunities with key decision-makers and other relevant stakeholders, such as your local utility representatives.
- START THE PLANNING PROCESS – see typical project milestones above.

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Typical Utility Bill Impacts

- The following examples provide comparisons of the utility bill impacts customers would see with typical gas-fired equipment and their electrified equivalents. For these typical scenarios, customers would be close to break-even or even see savings on their utility bills after upgrading to the electrified systems.

- Typical CPAU Energy Rates: Natural Gas = $2.50 per therm; Electricity = $0.22 per kWh[1]

- Typical Service Water Heating Example: Average Daily Hot Water Usage = 240 gallons, at 70˚F Rise[2]

Standard Gas Fired Water Heater	Electrified Heat Pump Water Heater
Typical Gas Water Heater Thermal Efficiency = 81% Estimated Monthly Gas Use = 240 gallons per day x 70˚F x 8.34 lbs per gallon x 1 Btu per˚F-lb ÷ 81% x 30 days per month x 1 therm per 100,000 Btu = **52 therms per month** Typical Monthly Charge for Gas-Fired Water Heating = 52 therms per month x $2.50 per therm = **$130 per month**	Typical Heat Pump Water Heater Uniform Energy Factor (UEF) = 3.0 Estimated Monthly Gas Use = 240 gallons per day x 70˚F x 8.34 lbs per gallon x 1 Btu per˚F-lb ÷ 3.0 x 30 days per month x 0.00293 kWh per Btu = **411 kWh per month** Typical Monthly Charge for Heat Pump Water Heating = 411 kWh per month x $0.22 per kWh = **$90 per month**

- Typical HVAC Space Heating Example: Average Monthly Heating Load = 18,000,000 Btu[3]

Standard Rooftop Unit (RTU) or Furnace with Gas-Fired Heating	Electrified Heat Pump RTU or Furnace
Typical Gas-Fired HVAC Unit Thermal Efficiency = 82% Estimated Monthly Gas Use = 18,000,000 Btu per month ÷ 82% x 1 therm per 100,000 Btu = **220 therms per month** Typical Monthly Charge for Gas-Fired Space Heating = 220 therms per month x $2.50 per therm = **$550 per month**	Typical Heat Pump HVAC Unit Heating Seasonal Performance Factor (HSPF) = 8.0 Btu/W-hr Estimated Monthly Gas Use = 18,000,000 Btu ÷ 8.0 Btu/W-hr x 1 kWh/1,000 W-hr = **2,250 kWh per month** Typical Monthly Charge for Heat Pump Water Heating = 2,250 kWh per month x $0.22 per kWh = **$495 per month**

[1] https://www.cityofpaloalto.org/Departments/Utilities/Customer-Service/Utilities-Rates/Business-Rates
[2] Typical medium-sized business customer water heating load, 75-gallon storage water heater example
[3] Typical small to medium-sized business customer, single HVAC unit load, 60,000 Btu capacity heating unit example

City of Palo Alto Utilities
Electrification Survey Report

Presented on behalf of City of Palo Alto Utilities (CPAU)

CITY OF PALO ALTO UTILITIES

Presented to:
Site E

Willdan Primary Contact:
Lance Kincaid
Willdan Energy Solutions
lkincaid@willdan.com

Date:
November 22, 2024

Electrification Opportunity Summary

Equipment Type	List of Equipment	Electrification Opportunity	Installation Price Range	Annual GHG Emissions Avoided*
Water Heating	80-gallon Gas Storage Water Heater	Heat Pump Water Heater System	$30k to $40k	17 metric tons CO2e
HVAC	(2) Large Packaged Cooling Units	System is already electrified	N/A	N/A
HVAC	(3) Split System Heat Pumps	System is already electrified	N/A	N/A
HVAC	(2) Large Natural Gas-Fired Furnaces	Large, packaged unit heat pumps, or retrofit furnaces with heating hot water (HHW) coils and install heat pump HHW heater	$300k to $450k	202 metric tons CO2e
Electrical Infrastructure	Main service is estimated to be 1200 Amps. Multiple spare circuits are available at the main panel.	New electrical conduit and local disconnects will be required at the water heating and HVAC heat pump locations. HVAC heat pumps may require a new 480V subpanel	$5k to $20K	Supports emissions avoidance shown above
			Total Annual Emissions Reduction Potential Identified	**219 metric tons CO2e**

*For ongoing operational savings assumptions, please see section below on typical utility bill impacts.

Available Electrification Project Support

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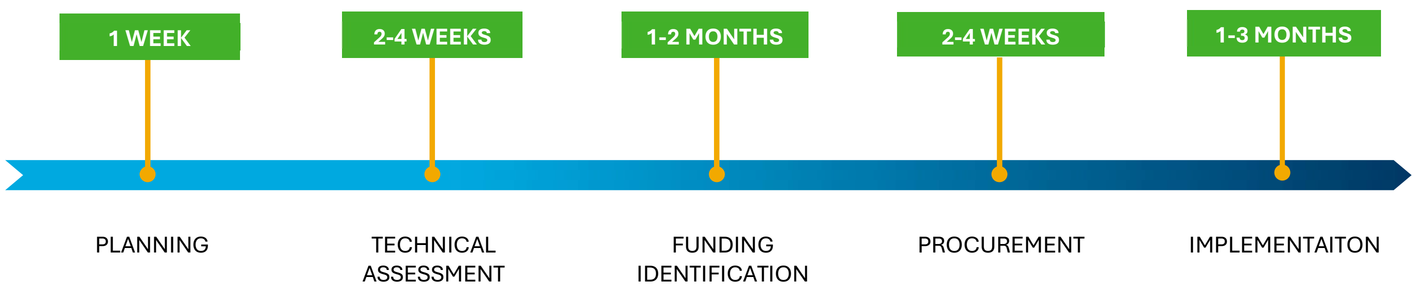
Typical Project Milestones



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Next Steps

- REVIEW THIS OPPORTUNITY SUMMARY – Discuss the electrification opportunities with key decision-makers and other relevant stakeholders, such as your local utility representatives.
- START THE PLANNING PROCESS – see typical project milestones above.

Typical Utility Bill Impacts

- The following examples provide comparisons of the utility bill impacts customers would see with typical gas-fired equipment and their electrified equivalents. For these typical scenarios, customers would be close to break-even or even see savings on their utility bills after upgrading to the electrified systems.

- Typical CPAU Energy Rates: Natural Gas = $2.50 per therm; Electricity = $0.22 per kWh[1]

- Typical Service Water Heating Example: Average Daily Hot Water Usage = 240 gallons, at 70˚F Rise[2]

Standard Gas Fired Water Heater	Electrified Heat Pump Water Heater
Typical Gas Water Heater Thermal Efficiency = 81% Estimated Monthly Gas Use = 240 gallons per day x 70˚F x 8.34 lbs per gallon x 1 Btu per˚F-lb ÷ 81% x 30 days per month x 1 therm per 100,000 Btu = **52 therms per month** Typical Monthly Charge for Gas-Fired Water Heating = 52 therms per month x $2.50 per therm = **$130 per month**	Typical Heat Pump Water Heater Uniform Energy Factor (UEF) = 3.0 Estimated Monthly Gas Use = 240 gallons per day x 70˚F x 8.34 lbs per gallon x 1 Btu per˚F-lb ÷ 3.0 x 30 days per month x 0.00293 kWh per Btu = **411 kWh per month** Typical Monthly Charge for Heat Pump Water Heating = 411 kWh per month x $0.22 per kWh = **$90 per month**

- Typical HVAC Space Heating Example: Average Monthly Heating Load = 18,000,000 Btu[3]

Standard Rooftop Unit (RTU) or Furnace with Gas-Fired Heating	Electrified Heat Pump RTU or Furnace
Typical Gas-Fired HVAC Unit Thermal Efficiency = 82% Estimated Monthly Gas Use = 18,000,000 Btu per month ÷ 82% x 1 therm per 100,000 Btu = **220 therms per month** Typical Monthly Charge for Gas-Fired Space Heating = 220 therms per month x $2.50 per therm = **$550 per month**	Typical Heat Pump HVAC Unit Heating Seasonal Performance Factor (HSPF) = 8.0 Btu/W-hr Estimated Monthly Gas Use = 18,000,000 Btu ÷ 8.0 Btu/W-hr x 1 kWh/1,000 W-hr = **2,250 kWh per month** Typical Monthly Charge for Heat Pump Water Heating = 2,250 kWh per month x $0.22 per kWh = **$495 per month**

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[2] Typical medium-sized business customer water heating load, 75-gallon storage water heater example
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City of Palo Alto Utilities
Electrification Survey Report

Presented on behalf of City of Palo Alto Utilities (CPAU)

Presented to:
Site H

Willdan Primary Contact:
Lance Kincaid
Willdan Energy Solutions
lkincaid@willdan.com

Date:
November 18, 2024

Electrification Opportunity Summary

Equipment Type	List of Equipment	Electrification Opportunity	Installation Price Range	Annual GHG Emissions Avoided*
Water Heating	(1) 30-gallon Electric Resistance Storage Water Heater (1) 80-gallon Electric Resistance Storage Water Heater	System is already electric, but savings could be gained by converting to a heat pump water heater system which can be up to 4x as efficient	$40k to $55k for combined system	N/A
HVAC	(2) Package units with Gas Heating	Packaged Heat Pump System	$80k to $95K	15 metric tons CO2e
HVAC	(1) Package unit cooling only, no heating	System is already electric	N/A	N/A
HVAC	(5) Ducted split system heat pumps	System already electric	N/A	N/A
HVAC	(1) Split System Heat Pumps	System already electric	N/A	N/A
HVAC	(1) Variable Refrigerant Flow (VRF) Heat Pump with Heat Recovery System	System already electric	N/A	N/A
Electrical Infrastructure	Main service is 1,200 Amps. Multiple spare circuits are available at the main panel.	This site will likely not require any enhancements to the electrical infrastructure to support addition of the electrified ducted heat pump split system load, especially if	N/A	Supports emissions avoidance shown above

Equipment Type	List of Equipment	Electrification Opportunity	Installation Price Range	Annual GHG Emissions Avoided*
		electrical load is reduced by switching from the electric resistance water heater to a more efficient heat pump unit		
		Total Annual Emissions Reduction Potential Identified		**15 metric tons CO2e**

*For ongoing operational savings assumptions, please see section below on typical utility bill impacts.

Available Electrification Project Support

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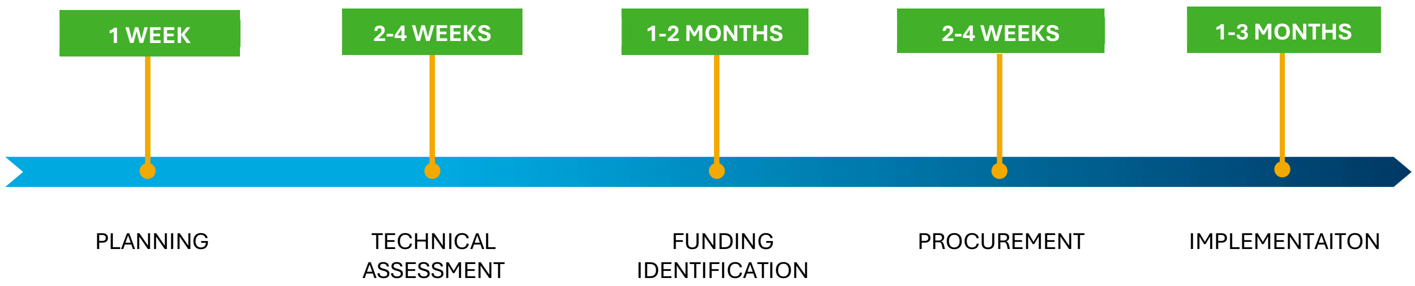
- California Department of Community Services and Development Low-Income Weatherization Program (LIWP): https://www.csd.ca.gov/Pages/Low-Income-Weatherization-Program.aspx

Typical Project Milestones



- PLANNING – Decide what opportunities will be pursued, and in what order of prioritization
- TECHNICAL ASSESSMENT- Engage contractors and engineers (for more complicated projects such as large HVAC systems or complex water heating systems) to determine the technical parameters of the electrification solutions
- FUNDING IDENTIFICATION – Secure funding for the projects and apply for any available rebates
- PROCUREMENT- Identify a qualified contractor and purchase materials. For larger projects you may want to compare multiple bids.
- IMPLEMENTATION – Obtain applicable permits and manage the construction of the projects. For larger projects, some customers may wish to hire a dedicated construction manager.

Next Steps

- REVIEW THIS OPPORTUNITY SUMMARY – Discuss the electrification opportunities with key decision-makers and other relevant stakeholders, such as your local utility representatives.
- START THE PLANNING PROCESS – see typical project milestones above.

Typical Utility Bill Impacts

- The following examples provide comparisons of the utility bill impacts customers would see with typical gas-fired equipment and their electrified equivalents. For these typical scenarios, customers would be close to break-even or even see savings on their utility bills after upgrading to the electrified systems.
- Typical CPAU Energy Rates: Natural Gas = $2.50 per therm; Electricity = $0.22 per kWh[1]
- Typical Service Water Heating Example: Average Daily Hot Water Usage = 240 gallons, at 70˚F Rise[2]

Standard Gas Fired Water Heater	Electrified Heat Pump Water Heater
Typical Gas Water Heater Thermal Efficiency = 81% Estimated Monthly Gas Use = 240 gallons per day x 70˚F x 8.34 lbs per gallon x 1 Btu per˚F-lb ÷ 81% x 30 days per month x 1 therm per 100,000 Btu = **52 therms per month** Typical Monthly Charge for Gas-Fired Water Heating = 52 therms per month x $2.50 per therm = **$130 per month**	Typical Heat Pump Water Heater Uniform Energy Factor (UEF) = 3.0 Estimated Monthly Gas Use = 240 gallons per day x 70˚F x 8.34 lbs per gallon x 1 Btu per˚F-lb ÷ 3.0 x 30 days per month x 0.00293 kWh per Btu = **411 kWh per month** Typical Monthly Charge for Heat Pump Water Heating = 411 kWh per month x $0.22 per kWh = **$90 per month**

- Typical HVAC Space Heating Example: Average Monthly Heating Load = 18,000,000 Btu[3]

Standard Rooftop Unit (RTU) or Furnace with Gas-Fired Heating	Electrified Heat Pump RTU or Furnace
Typical Gas-Fired HVAC Unit Thermal Efficiency = 82% Estimated Monthly Gas Use = 18,000,000 Btu per month ÷ 82% x 1 therm per 100,000 Btu = **220 therms per month** Typical Monthly Charge for Gas-Fired Space Heating = 220 therms per month x $2.50 per therm = **$550 per month**	Typical Heat Pump HVAC Unit Heating Seasonal Performance Factor (HSPF) = 8.0 Btu/W-hr Estimated Monthly Gas Use = 18,000,000 Btu ÷ 8.0 Btu/W-hr x 1 kWh/1,000 W-hr = **2,250 kWh per month** Typical Monthly Charge for Heat Pump Water Heating = 2,250 kWh per month x $0.22 per kWh = **$495 per month**

[1] https://www.cityofpaloalto.org/Departments/Utilities/Customer-Service/Utilities-Rates/Business-Rates
[2] Typical medium-sized business customer water heating load, 75-gallon storage water heater example
[3] Typical small to medium-sized business customer, single HVAC unit load, 60,000 Btu capacity heating unit example

City of Palo Alto Utilities
Electrification Survey Report
Presented on behalf of City of Palo Alto Utilities (CPAU)

Presented to:
Site D

Willdan Primary Contact:
Lance Kincaid
Willdan Energy Solutions
lkincaid@willdan.com

Date:
November 14, 2024

Electrification Opportunity Summary

Equipment Type	List of Equipment	Electrification Opportunity	Installation Price Range	Annual GHG Emissions Avoided*
Water Heating	(1) 30-gallon Electric Resistance Storage Water Heater	System is already electric, but savings could be gained by converting to a heat pump water heater system which can be up to 4x as efficient	\$10k to \$13k	N/A
HVAC	(1) Gas Furnace	Ducted heat pump split system	\$18k to \$22k	7 metric tons CO2e
HVAC	(2) Split System Heat Pumps	System already electric	N/A	N/A
HVAC	(4) Roof Top Package Units with Electric Heating	System already electric	N/A	N/A
Kitchen	(2) Dishwashers, refrigerator, (2) beverage coolers, (2) microwaves, toaster oven, coffee maker	Kitchen is already all electric	N/A	N/A
Electrical Infrastructure	Main service is 400 Amps. Multiple spare circuits are available at the main panel.	This site will likely not require any enhancements to the electrical infrastructure to support addition of the electrified ducted heat pump split system load, especially if	N/A	Supports emissions avoidance shown above

Equipment Type	List of Equipment	Electrification Opportunity	Installation Price Range	Annual GHG Emissions Avoided*
		electrical load is reduced by switching from the electric resistance water heater to a more efficient heat pump unit		
Total Annual Emissions Reduction Potential Identified				**7 metric tons CO2e**

*For ongoing operational savings assumptions, please see section below on typical utility bill impacts.

Available Electrification Project Support

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- California Energy Wise Foodservice - Instant Rebates https://caenergywise.com/instant-rebates/
- High-Efficiency Electric Home Rebate Act (HEEHRA) Federal Rebates for income-qualifying multifamily electrification, provided through TECH Clean California: https://techcleanca.com/incentives/heehrarebates/. Please note that participation in this program requires compliance with CA Department of Industrial Relations Prevailing Wage and Public Works Requirements. Using prevailing wages may add 15% to 25% to representative project costs shown above.
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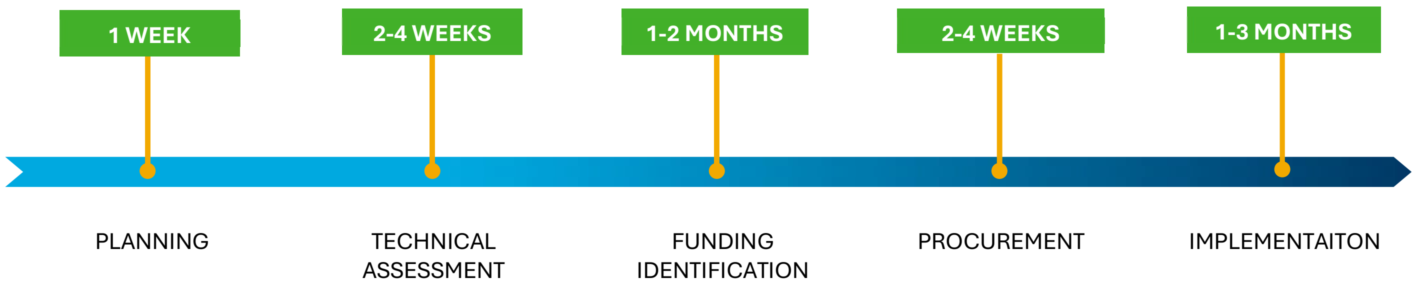
Typical Project Milestones



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Next Steps

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- START THE PLANNING PROCESS – see typical project milestones above.

Typical Utility Bill Impacts

- The following examples provide comparisons of the utility bill impacts customers would see with typical gas-fired equipment and their electrified equivalents. For these typical scenarios, customers would be close to break-even or even see savings on their utility bills after upgrading to the electrified systems.

- Typical CPAU Energy Rates: Natural Gas = $2.50 per therm; Electricity = $0.22 per kWh[1]

- Typical Service Water Heating Example: Average Daily Hot Water Usage = 240 gallons, at 70˚F Rise[2]

Standard Gas Fired Water Heater	Electrified Heat Pump Water Heater
Typical Gas Water Heater Thermal Efficiency = 81% Estimated Monthly Gas Use = 240 gallons per day x 70˚F x 8.34 lbs per gallon x 1 Btu per˚F-lb ÷ 81% x 30 days per month x 1 therm per 100,000 Btu = **52 therms per month** Typical Monthly Charge for Gas-Fired Water Heating = 52 therms per month x $2.50 per therm = **$130 per month**	Typical Heat Pump Water Heater Uniform Energy Factor (UEF) = 3.0 Estimated Monthly Gas Use = 240 gallons per day x 70˚F x 8.34 lbs per gallon x 1 Btu per˚F-lb ÷ 3.0 x 30 days per month x 0.00293 kWh per Btu = **411 kWh per month** Typical Monthly Charge for Heat Pump Water Heating = 411 kWh per month x $0.22 per kWh = **$90 per month**

- Typical HVAC Space Heating Example: Average Monthly Heating Load = 18,000,000 Btu[3]

Standard Rooftop Unit (RTU) or Furnace with Gas-Fired Heating	Electrified Heat Pump RTU or Furnace
Typical Gas-Fired HVAC Unit Thermal Efficiency = 82% Estimated Monthly Gas Use = 18,000,000 Btu per month ÷ 82% x 1 therm per 100,000 Btu = **220 therms per month** Typical Monthly Charge for Gas-Fired Space Heating = 220 therms per month x $2.50 per therm = **$550 per month**	Typical Heat Pump HVAC Unit Heating Seasonal Performance Factor (HSPF) = 8.0 Btu/W-hr Estimated Monthly Gas Use = 18,000,000 Btu ÷ 8.0 Btu/W-hr x 1 kWh/1,000 W-hr = **2,250 kWh per month** Typical Monthly Charge for Heat Pump Water Heating = 2,250 kWh per month x $0.22 per kWh = **$495 per month**

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City of Palo Alto Utilities
Electrification Survey Report
Presented on behalf of City of Palo Alto Utilities (CPAU)

Presented to:
Site G

Willdan Primary Contact:
Lance Kincaid
Willdan Energy Solutions
lkincaid@willdan.com

Date:
November 18, 2024

Electrification Opportunity Summary

Equipment Type	List of Equipment	Electrification Opportunity	Installation Price Range	Annual GHG Emissions Avoided*
Water Heating	(1) 10-gallon Electric Storage Water Heaters	The system is already electric. Another water heater of similar size is decommissioned in place. Very low hot water usage. Heat pump water heaters are not typically available in this small size range, however, electric instantaneous point of use water heaters that can be located under sinks may offer small efficiency gains	N/A	N/A
HVAC	(3) Roof Top Units with Natural Gas Heating	Packages Heat Pump System	$90k to $115k	34 metric tons CO2e
Electrical Infrastructure	Main service is 200 Amps.	Rooftop heat pump package HVAC units may be able to connect to existing HVAC subpanel(s). However, if new HVAC heat pump units are optioned with resistance heat backup, additional	$3k to $7k	Supports emissions avoidance shown above

Equipment Type	List of Equipment	Electrification Opportunity	Installation Price Range	Annual GHG Emissions Avoided*
		Amp capacity may be needed. Specific electrical design parameters will need to be determined by engineers. Preliminary estimate of total combined subpanel capacity needed is 100 to 200 Amps.		
			Total Annual Emissions Reduction Potential Identified	**34 metric tons CO2e**

*For ongoing operational savings assumptions, please see section below on typical utility bill impacts.

Available Electrification Project Support

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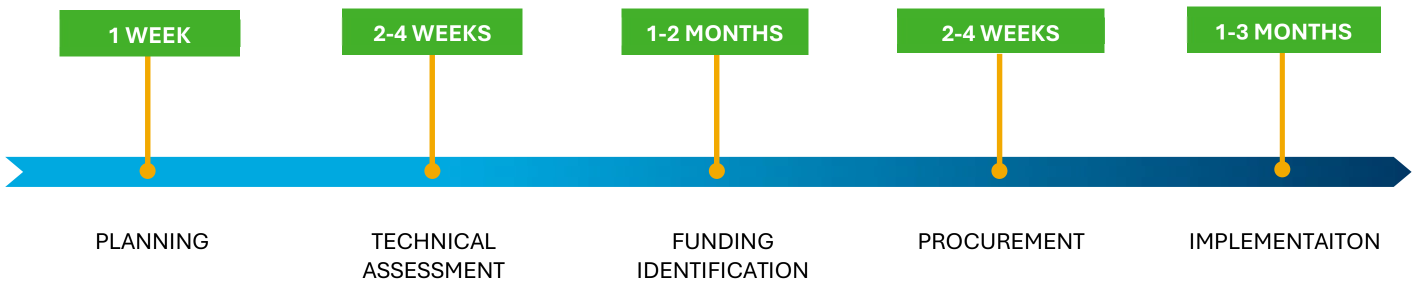
Typical Project Milestones



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Next Steps

- REVIEW THIS OPPORTUNITY SUMMARY – Discuss the electrification opportunities with key decision-makers and other relevant stakeholders, such as your local utility representatives.
- START THE PLANNING PROCESS – see typical project milestones above.

Typical Utility Bill Impacts

- The following examples provide comparisons of the utility bill impacts customers would see with typical gas-fired equipment and their electrified equivalents. For these typical scenarios, customers would be close to break-even or even see savings on their utility bills after upgrading to the electrified systems.
- Typical CPAU Energy Rates: Natural Gas = $2.50 per therm; Electricity = $0.22 per kWh[1]
- Typical Service Water Heating Example: Average Daily Hot Water Usage = 240 gallons, at 70˚F Rise[2]

Standard Gas Fired Water Heater	Electrified Heat Pump Water Heater
Typical Gas Water Heater Thermal Efficiency = 81% Estimated Monthly Gas Use = 240 gallons per day x 70˚F x 8.34 lbs per gallon x 1 Btu per˚F-lb ÷ 81% x 30 days per month x 1 therm per 100,000 Btu = **52 therms per month** Typical Monthly Charge for Gas-Fired Water Heating = 52 therms per month x $2.50 per therm = **$130 per month**	Typical Heat Pump Water Heater Uniform Energy Factor (UEF) = 3.0 Estimated Monthly Gas Use = 240 gallons per day x 70˚F x 8.34 lbs per gallon x 1 Btu per˚F-lb ÷ 3.0 x 30 days per month x 0.00293 kWh per Btu = **411 kWh per month** Typical Monthly Charge for Heat Pump Water Heating = 411 kWh per month x $0.22 per kWh = **$90 per month**

- Typical HVAC Space Heating Example: Average Monthly Heating Load = 18,000,000 Btu[3]

Standard Rooftop Unit (RTU) or Furnace with Gas-Fired Heating	Electrified Heat Pump RTU or Furnace
Typical Gas-Fired HVAC Unit Thermal Efficiency = 82% Estimated Monthly Gas Use = 18,000,000 Btu per month ÷ 82% x 1 therm per 100,000 Btu = **220 therms per month** Typical Monthly Charge for Gas-Fired Space Heating = 220 therms per month x $2.50 per therm = **$550 per month**	Typical Heat Pump HVAC Unit Heating Seasonal Performance Factor (HSPF) = 8.0 Btu/W-hr Estimated Monthly Gas Use = 18,000,000 Btu ÷ 8.0 Btu/W-hr x 1 kWh/1,000 W-hr = **2,250 kWh per month** Typical Monthly Charge for Heat Pump Water Heating = 2,250 kWh per month x $0.22 per kWh = **$495 per month**

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City of Palo Alto Utilities
Electrification Survey Report

Presented on behalf of City of Palo Alto Utilities (CPAU)

Presented to:
Site F

Willdan Primary Contact:
Lance Kincaid
Willdan Energy Solutions
lkincaid@willdan.com

Date:
November 22, 2024

Electrification Opportunity Summary

Equipment Type	List of Equipment	Electrification Opportunity	Installation Price Range	Annual GHG Emissions Avoided**
Water Heating	(2) 100-gallon Gas Storage Water Heater (275 kBtu/h each)	Heat Pump Water Heater System System may be downsized if a water use study is conducted. Estimated price shown is to match existing capacity	$120k to $160k	55 metric tons CO2e
HVAC	(2) Air Cooled Chillers	System is already electrified	N/A	N/A
HVAC	(1) Split System Heat Pump and (1) Evaporative Cooling Unit	System is already electrified	N/A	N/A
HVAC	(1) Natural Gas-Fired Heating Water Boiler	Heat Pump Water Heater. Alternatively, a Heat Recovery Chiller could support both chilled water and heating water loads simultaneously. Electric resistance backup option may be needed to meet peak heating water loads.	$125k to $250k	82 metric tons CO2e

Equipment Type	List of Equipment	Electrification Opportunity	Installation Price Range	Annual GHG Emissions Avoided**
Electrical Infrastructure	Main service is estimated to be 3000 Amps. Multiple spare circuits are available at the main panel.	New electrical conduit and local disconnects will be required at the HVAC heat pump locations. HVAC heat pump may require a new 480V subpanel	$5k to $10K	Supports emissions avoidance shown above
			Total Annual Emissions Reduction Potential Identified	**137 metric tons CO2e**

*Buildings A and C were not inspected but may have similar opportunities.

**For ongoing operational savings assumptions, please see section below on typical utility bill impacts.

Available Electrification Project Support

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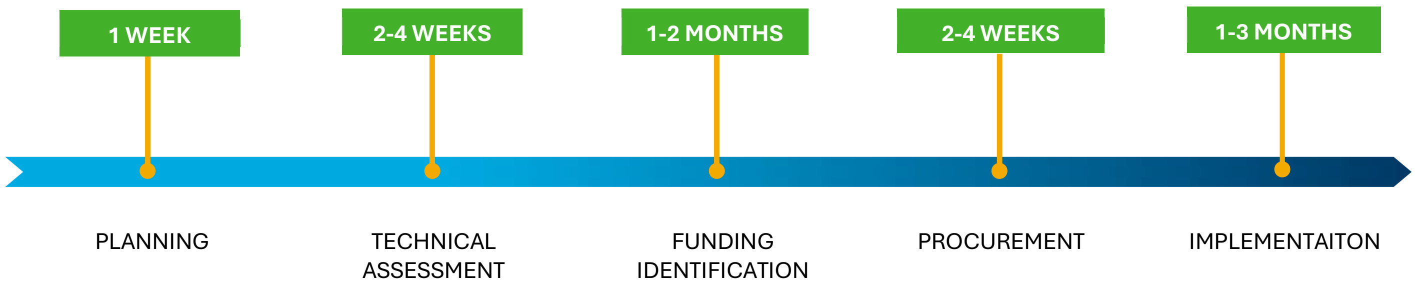
Typical Project Milestones



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Next Steps

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- START THE PLANNING PROCESS – see typical project milestones above.

Typical Utility Bill Impacts

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Standard Gas Fired Water Heater	Electrified Heat Pump Water Heater
Typical Gas Water Heater Thermal Efficiency = 81% Estimated Monthly Gas Use = 240 gallons per day x 70˚F x 8.34 lbs per gallon x 1 Btu per˚F-lb ÷ 81% x 30 days per month x 1 therm per 100,000 Btu = **52 therms per month** Typical Monthly Charge for Gas-Fired Water Heating = 52 therms per month x $2.50 per therm = **$130 per month**	Typical Heat Pump Water Heater Uniform Energy Factor (UEF) = 3.0 Estimated Monthly Gas Use = 240 gallons per day x 70˚F x 8.34 lbs per gallon x 1 Btu per˚F-lb ÷ 3.0 x 30 days per month x 0.00293 kWh per Btu = **411 kWh per month** Typical Monthly Charge for Heat Pump Water Heating = 411 kWh per month x $0.22 per kWh = **$90 per month**

- Typical HVAC Space Heating Example: Average Monthly Heating Load = 18,000,000 Btu[3]

Standard Rooftop Unit (RTU) or Furnace with Gas-Fired Heating	Electrified Heat Pump RTU or Furnace
Typical Gas-Fired HVAC Unit Thermal Efficiency = 82% Estimated Monthly Gas Use = 18,000,000 Btu per month ÷ 82% x 1 therm per 100,000 Btu = **220 therms per month** Typical Monthly Charge for Gas-Fired Space Heating = 220 therms per month x $2.50 per therm = **$550 per month**	Typical Heat Pump HVAC Unit Heating Seasonal Performance Factor (HSPF) = 8.0 Btu/W-hr Estimated Monthly Gas Use = 18,000,000 Btu ÷ 8.0 Btu/W-hr x 1 kWh/1,000 W-hr = **2,250 kWh per month** Typical Monthly Charge for Heat Pump Water Heating = 2,250 kWh per month x $0.22 per kWh = **$495 per month**

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WILLDAN

City of Palo Alto Utilities
Electrification Survey Report

Presented on behalf of City of Palo Alto Utilities (CPAU)

CITY OF PALO ALTO UTILITIES

Presented to:
Site I

Willdan Primary Contact:
Lance Kincaid
Willdan Energy Solutions
lkincaid@willdan.com

Date:
December 5, 2024
Version 2

Electrification Opportunity Summary

Equipment Type	List of Equipment	Electrification Opportunity	Installation Price Range	Annual GHG Emissions Avoided*
Water Heating	(1) 38-gallon Storage Water Heaters	Heat Pump Water Heater System	$8k to $13k	7 metric tons CO2e
Water Heating	(3) 75-gallon Storage Water Heaters	Heat Pump Water Heater System	$90k to $120k	21 metric tons CO2e
HVAC	(1) Natural gas Furnace	Ducted split system heat pump	$20k to $24k	6 metric tons CO2e
HVAC	(5) Split Heat Pumps	System already electric	N/A	N/A
Kitchen	(1) Electric Ranges (Only one unit has this equipment)	System is already electric. Additional energy efficiency savings can be gained through the installation of induction range	$1k to $1.5k each unit	N/A
Kitchen	(1) Gas Range (Only one unit has this equipment	Electric induction range	$1k to $1.5k each unit	1 metric ton CO2e
Washers	(2) Electric washers (1) Commercial Electric Washer	Washers consume hot water. Opportunities come from replacing gas water heaters with electric heat pumps as shown above	N/A	N/A
Dryers	(2) Electric Dryers	System already electrified	N/A	N/A

Equipment Type	List of Equipment	Electrification Opportunity	Installation Price Range	Annual GHG Emissions Avoided*
Dryers	(1) Commercial Gas Dryer	Commercial Electric Dryer	$8k to $10k	1 metric ton CO2e
Electrical Infrastructure	Main service is 400 Amps.	This site will likely require the installation of new electrical subpanels to feed electrified water heating and HVAC furnace. Specific electrical design parameters will need to be determined by engineers. Preliminary estimate of total combined subpanel capacity needed is 200 to 250 Amps. Commercial electric dryer will likely require new 240V outlet If all electrification options are pursued, a main service upgrade may be required. Confirm upstream transformer capacity with CPAU.	$15k to $17k	Supports emissions avoidance shown above
			Total Annual Emissions Reduction Potential Identified	**35 metric tons CO2e**

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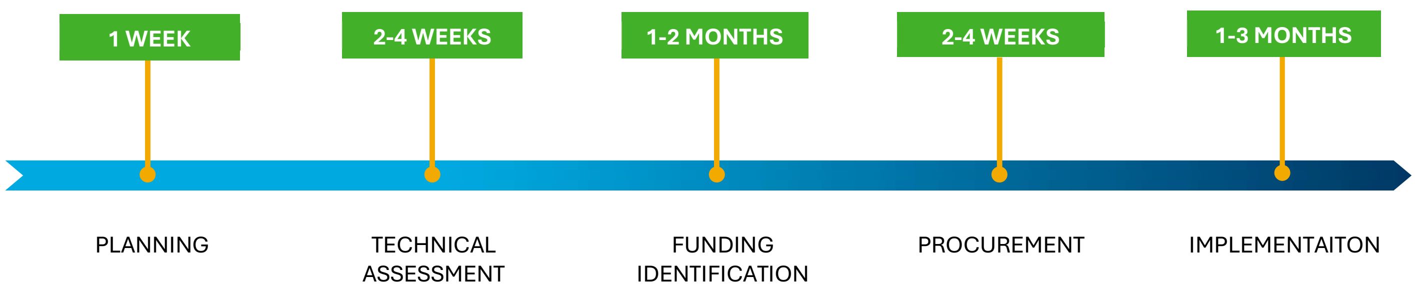

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Standard Rooftop Unit (RTU) or Furnace with Gas-Fired Heating	Electrified Heat Pump RTU or Furnace
Typical Gas-Fired HVAC Unit Thermal Efficiency = 82% Estimated Monthly Gas Use = 18,000,000 Btu per month ÷ 82% x 1 therm per 100,000 Btu = **220 therms per month** Typical Monthly Charge for Gas-Fired Space Heating = 220 therms per month x $2.50 per therm = **$550 per month**	Typical Heat Pump HVAC Unit Heating Seasonal Performance Factor (HSPF) = 8.0 Btu/W-hr Estimated Monthly Gas Use = 18,000,000 Btu ÷ 8.0 Btu/W-hr x 1 kWh/1,000 W-hr = **2,250 kWh per month** Typical Monthly Charge for Heat Pump Water Heating = 2,250 kWh per month x $0.22 per kWh = **$495 per month**

[1] https://www.cityofpaloalto.org/Departments/Utilities/Customer-Service/Utilities-Rates/Business-Rates
[2] Typical medium-sized business customer water heating load, 75-gallon storage water heater example
[3] Typical small to medium-sized business customer, single HVAC unit load, 60,000 Btu capacity heating unit example

Attachment C – Primary Data Files

Attachment C.1 - Cost Data Provided to E3 for S/CAP Funding Model

Exhibit C.1.1. - Cost of Performing Retrofit of Given Technology – Electric Technologies

Customer Type Segments	Electric-Cooling-Split System	Electric-Cooling-PTAC/Packaged DX	Electric-Cooling-PTHP/Packaged HP	Electric-Cooling-WC Chiller	Electric-Cooling-AC Chiller	Electric-Cooling-VRF	Electric-Space Heating-Packaged Unit-Electric Resistance	Electric-Space Heating-ASHP	Electric-Water Heating-Electric Resistance Water Heater	Electric-Water Heating-Heat Pump Water Heater	Electric-Water Heating-Tankless	Electric-Cooking Range-Resistance Stove	Electric-Cooking Range-Induction Stove	Electric-Cooking Range-Oven
	$/unit	*$/unit*	*$/unit*	*$/unit*	*$/unit*	*$/unit*	*$/unit*	*$/unit*	*$/unit*	*$/unit*	*$/unit*	*$/unit*	*$/unit*	*$/unit*
Comm-Office-0-3499-AC-Not Applicable	$29,589	$35,769	$33,379	$50,519	$46,743	$63,337	$36,403	$48,351	$10,866	$11,329	$9,253	$691	$1,084	$635
Comm-Retail-0-2799-AC-Not Applicable	$22,572	$28,251	$25,613	$41,426	$38,396	-	$28,049	$25,613	$10,866	$11,329	$9,253	$2,712	$4,160	$3,436
Comm-K-12-0-24999-AC-Not Applicable	$88,721	$80,791	$90,628	$126,165	$127,921	$121,897	$90,628	$101,072	$13,370	$11,642	$18,507	$4,202	$6,416	$5,309
Comm-Assembly-0-3199-AC-Not Applicable	$38,477	$48,766	$48,684	$74,500	$72,252	-	$48,684	$48,684	$13,370	$11,642	$9,253	$4,708	$7,221	$5,964
Comm-Office-3500-10999-AC-Not Applicable	$113,921	$137,716	$128,516	$194,506	$179,968	$243,856	$140,158	$186,158	$13,370	$11,642	$27,760	$2,659	$4,173	$2,443
Comm-Retail-2800-5999-AC-Not Applicable	$68,305	$85,489	$77,508	$125,358	$116,190	-	$84,878	$77,508	$13,370	$11,642	$27,760	$8,208	$12,589	$10,399
Comm-K-12-25000-49999-AC-Not Applicable	$919,806	$837,586	$939,577	$1,308,002	$1,326,203	$1,263,753	$939,577	$1,047,845	$42,728	$90,501	$37,014	$43,566	$66,515	$55,040
Comm-Assembly-3200-7499-AC-Not Applicable	$92,050	$116,665	$116,468	$178,229	$172,852	-	$116,468	$116,468	$26,741	$23,285	$27,760	$11,263	$17,275	$14,269
Comm-Office->=11000-AC-Not Applicable	$978,768	$1,183,206	$1,104,163	$1,671,126	$1,546,218	$2,095,128	$1,204,187	$1,599,402	$21,364	$45,251	$55,521	$22,848	$35,857	$20,989
Comm-Retail->=6000-AC-Not Applicable	$564,395	$706,385	$640,440	$1,035,813	$960,066	-	$701,335	$640,440	$21,364	$45,251	$55,521	$67,820	$104,025	$85,922
Comm-K-12->=50000-AC-Not Applicable	$2,542,643	$2,315,358	$2,597,295	$3,615,740	$3,666,055	$3,493,423	$2,597,295	$2,896,583	$64,092	$135,752	$74,028	$120,429	$183,869	$152,149
Comm-Assembly->=7500-AC-Not Applicable	$409,886	$519,496	$518,617	$793,632	$769,689	-	$518,617	$518,617	$42,728	$90,501	$55,521	$50,151	$76,924	$63,537

Exhibit C.1.2. - Cost of Performing Retrofit of Given Technology – Gas Technologies

Customer Type Segments	Gas-Space Heating-Packaged Unit	Gas-Space Heating-Boiler	Gas-Space Heating-Furnace	Gas-Water Heating-Storage Water Heater	Gas-Water Heating-Boiler	Gas-Water Heating-Tankless	Gas-Cooking Range-Stove	Gas-Cooking Range-Oven
	$/unit	*$/unit*	*$/unit*	*$/unit*	*$/unit*	*$/unit*	*$/unit*	*$/unit*
Comm-Office-0-3499-AC-Not Applicable	$29,205	$46,669	$29,589	$11,038	-	$10,584	$2,859	$2,626
Comm-Retail-0-2799-AC-Not Applicable	$22,251	$38,372	$22,572	$11,684	-	$10,584	$10,887	$15,563
Comm-K-12-0-24999-AC-Not Applicable	$75,857	$130,676	$88,721	$27,633	-	$21,168	$19,563	$28,748
Comm-Assembly-0-3199-AC-Not Applicable	$48,869	$74,108	$38,477	$11,038	-	$10,584	$7,641	$10,923
Comm-Office-3500-10999-AC-Not Applicable	$112,444	$179,684	$113,921	$27,633	-	$31,752	$8,788	$8,073
Comm-Retail-2800-5999-AC-Not Applicable	$67,334	$116,119	$68,305	$11,684	-	$31,752	$9,482	$13,554
Comm-K-12-25000-49999-AC-Not Applicable	$786,433	$1,354,761	$919,806	$55,266	-	$42,336	$52,212	$76,725
Comm-Assembly-3200-7499-AC-Not Applicable	$116,912	$177,292	$92,050	$23,367	-	$31,752	$9,671	$13,824
Comm-Office->=11000-AC-Not Applicable	$966,082	$1,543,779	$978,768	$27,633	-	$63,504	$16,044	$14,739
Comm-Retail->=6000-AC-Not Applicable	$556,375	$959,472	$564,395	$27,633	-	$63,504	$23,321	$33,337
Comm-K-12->=50000-AC-Not Applicable	$2,173,955	$3,744,998	$2,542,643	$82,899	-	$84,672	$25,083	$36,860
Comm-Assembly->=7500-AC-Not Applicable	$520,594	$789,458	$409,886	$55,266	-	$63,504	$16,613	$23,748

Exhibit C.1.3. - Cost of Performing Retrofit of Given Technology – Electrical Infrastructure

Customer Type Segments	Electrical Panel Upgrade	Electrical Service Upgrade
	$/customer	*$/customer*
Comm-Office-0-3499-AC-Not Applicable	$12,000	$100,000
Comm-Retail-0-2799-AC-Not Applicable	$20,000	$120,000
Comm-K-12-0-24999-AC-Not Applicable	$30,000	$140,000
Comm-Assembly-0-3199-AC-Not Applicable	$12,000	$100,000
Comm-Office-3500-10999-AC-Not Applicable	$20,000	$120,000
Comm-Retail-2800-5999-AC-Not Applicable	$12,000	$100,000
Comm-K-12-25000-49999-AC-Not Applicable	$30,000	$140,000
Comm-Assembly-3200-7499-AC-Not Applicable	$20,000	$120,000
Comm-Office->=11000-AC-Not Applicable	$30,000	$140,000
Comm-Retail->=6000-AC-Not Applicable	$30,000	$140,000
Comm-K-12->=50000-AC-Not Applicable	$30,000	$140,000
Comm-Assembly->=7500-AC-Not Applicable	$20,000	$120,000

Attachment C – Primary Data Files

Attachment C.2 – ArcGIS Map Images

Exhibit C.2.1.1. – HVAC Equipment: Locations

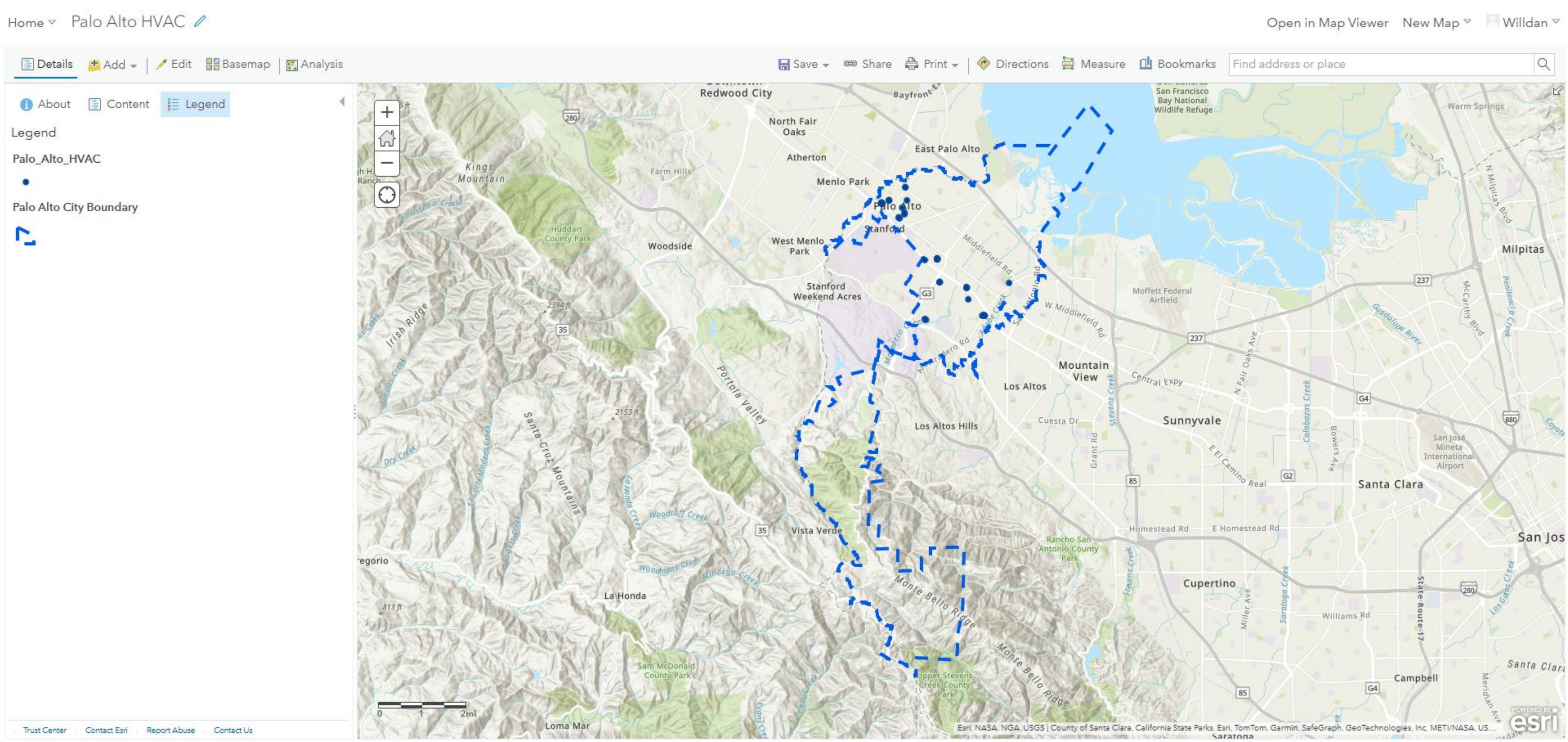
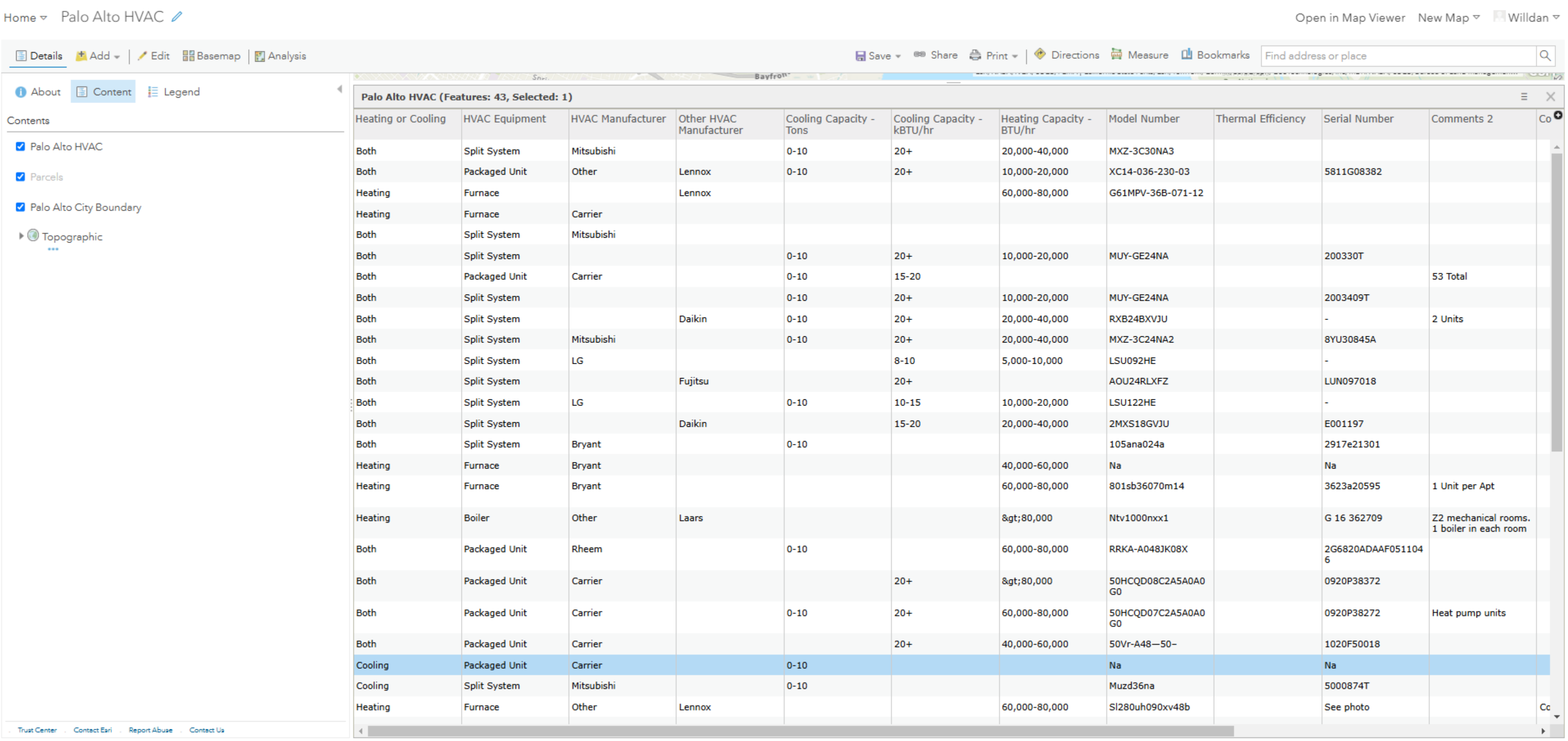


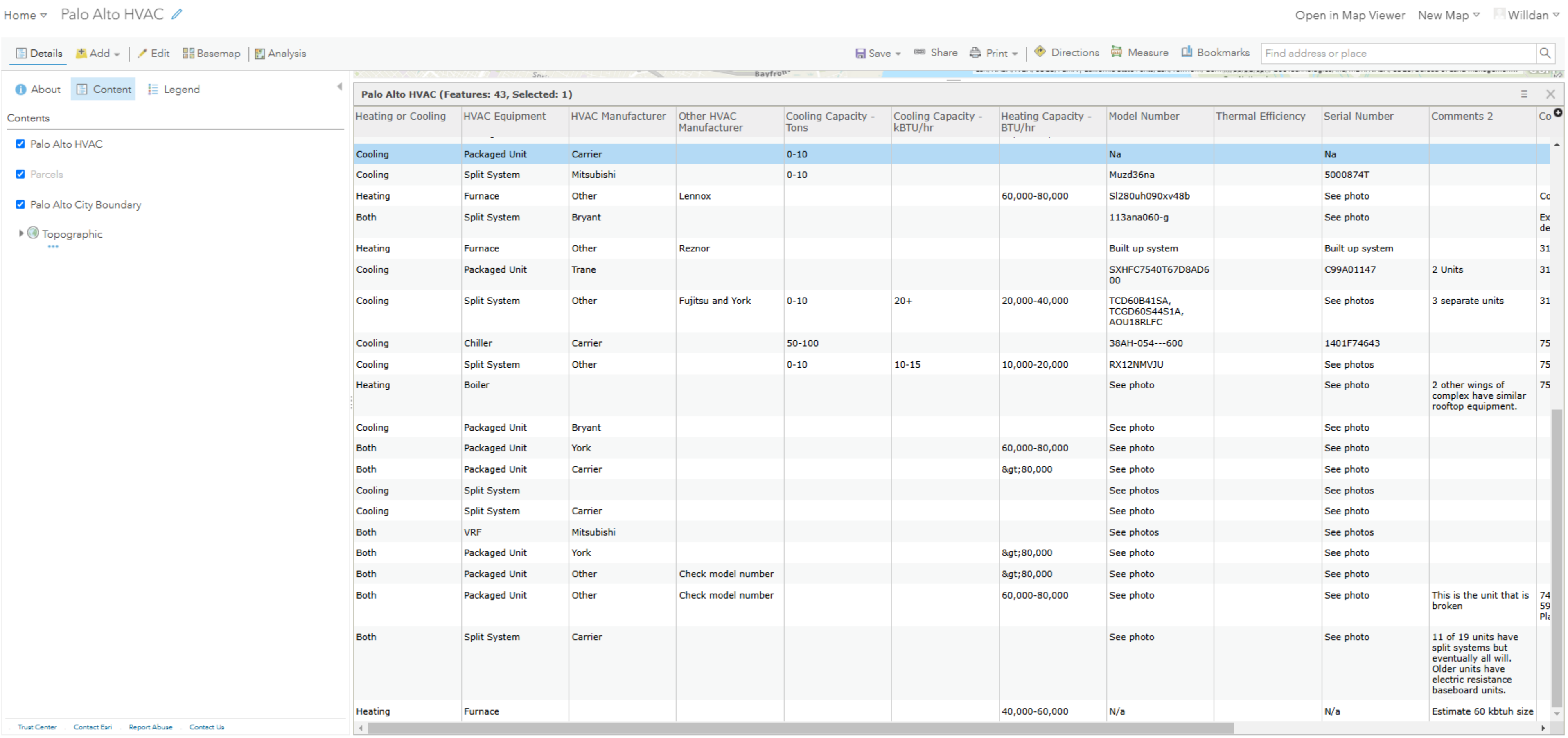
Exhibit C.2.1.2. – HVAC Equipment: Details



Palo Alto HVAC (Features: 43, Selected: 1)

Heating or Cooling	HVAC Equipment	HVAC Manufacturer	Other HVAC Manufacturer	Cooling Capacity - Tons	Cooling Capacity - kBTU/hr	Heating Capacity - BTU/hr	Model Number	Thermal Efficiency	Serial Number	Comments 2	Co
Both	Split System	Mitsubishi		0-10	20+	20,000-40,000	MXZ-3C30NA3				
Both	Packaged Unit	Other	Lennox	0-10	20+	10,000-20,000	XC14-036-230-03		5811G08382		
Heating	Furnace		Lennox			60,000-80,000	G61MPV-36B-071-12				
Heating	Furnace	Carrier									
Both	Split System	Mitsubishi									
Both	Split System			0-10	20+	10,000-20,000	MUY-GE24NA		200330T		
Both	Packaged Unit	Carrier		0-10	15-20					53 Total	
Both	Split System			0-10	20+	10,000-20,000	MUY-GE24NA		2003409T		
Both	Split System		Daikin	0-10	20+	20,000-40,000	RXB24BXVJU		-	2 Units	
Both	Split System	Mitsubishi		0-10	20+	20,000-40,000	MXZ-3C24NA2		8YU30845A		
Both	Split System	LG			8-10	5,000-10,000	LSU092HE		-		
Both	Split System		Fujitsu		20+		AOU24RLXFZ		LUN097018		
Both	Split System	LG		0-10	10-15	10,000-20,000	LSU122HE		-		
Both	Split System		Daikin		15-20	20,000-40,000	2MXS18GVJU		E001197		
Both	Split System	Bryant		0-10			105ana024a		2917e21301		
Heating	Furnace	Bryant				40,000-60,000	Na		Na		
Heating	Furnace	Bryant				60,000-80,000	801sb36070m14		3623a20595	1 Unit per Apt	
Heating	Boiler	Other	Laars			>80,000	Ntv1000nxx1		G 16 362709	Z2 mechanical rooms. 1 boiler in each room	
Both	Packaged Unit	Rheem		0-10		60,000-80,000	RRKA-A048JK08X		2G6820ADAAF051104 6		
Both	Packaged Unit	Carrier			20+	>80,000	50HCQD08C2A5A0A0 G0		0920P38372		
Both	Packaged Unit	Carrier		0-10	20+	60,000-80,000	50HCQD07C2A5A0A0 G0		0920P38272	Heat pump units	
Both	Packaged Unit	Carrier			20+	40,000-60,000	50Vr-A48—50–		1020F50018		
Cooling	Packaged Unit	Carrier		0-10			Na		Na		
Cooling	Split System	Mitsubishi		0-10			Muzd36na		5000874T		
Heating	Furnace	Other	Lennox			60,000-80,000	Sl280uh090xv48b		See photo		Cc

Exhibit C.2.1.3. – HVAC Equipment: Details



Heating or Cooling	HVAC Equipment	HVAC Manufacturer	Other HVAC Manufacturer	Cooling Capacity - Tons	Cooling Capacity - kBTU/hr	Heating Capacity - BTU/hr	Model Number	Thermal Efficiency	Serial Number	Comments 2	Co
Cooling	Packaged Unit	Carrier		0-10			Na		Na		
Cooling	Split System	Mitsubishi		0-10			Muzd36na		5000874T		
Heating	Furnace	Other	Lennox			60,000-80,000	Sl280uh090xv48b		See photo		Cc
Both	Split System	Bryant					113ana060-g		See photo		Ex de
Heating	Furnace	Other	Reznor				Built up system		Built up system		31
Cooling	Packaged Unit	Trane					SXHFC7540T67D8AD6 00		C99A01147	2 Units	31
Cooling	Split System	Other	Fujitsu and York	0-10	20+	20,000-40,000	TCD60B41SA, TCGD60S44S1A, AOU18RLFC		See photos	3 separate units	31
Cooling	Chiller	Carrier		50-100			38AH-054---600		1401F74643		75
Cooling	Split System	Other		0-10	10-15	10,000-20,000	RX12NMVJU		See photos		75
Heating	Boiler						See photo		See photo	2 other wings of complex have similar rooftop equipment.	75
Cooling	Packaged Unit	Bryant					See photo		See photo		
Both	Packaged Unit	York				60,000-80,000	See photo		See photo		
Both	Packaged Unit	Carrier				>80,000	See photo		See photo		
Cooling	Split System						See photos		See photos		
Cooling	Split System	Carrier					See photo		See photo		
Both	VRF	Mitsubishi					See photos		See photos		
Both	Packaged Unit	York				>80,000	See photo		See photo		
Both	Packaged Unit	Other	Check model number			>80,000	See photo		See photo		
Both	Packaged Unit	Other	Check model number			60,000-80,000	See photo		See photo	This is the unit that is broken	74 59 Pl
Both	Split System	Carrier					See photo		See photo	11 of 19 units have split systems but eventually all will. Older units have electric resistance baseboard units.	
Heating	Furnace					40,000-60,000	N/a		N/a	Estimate 60 kbtuh size	

Exhibit C.2.2.1. – Water Heating Equipment: Locations

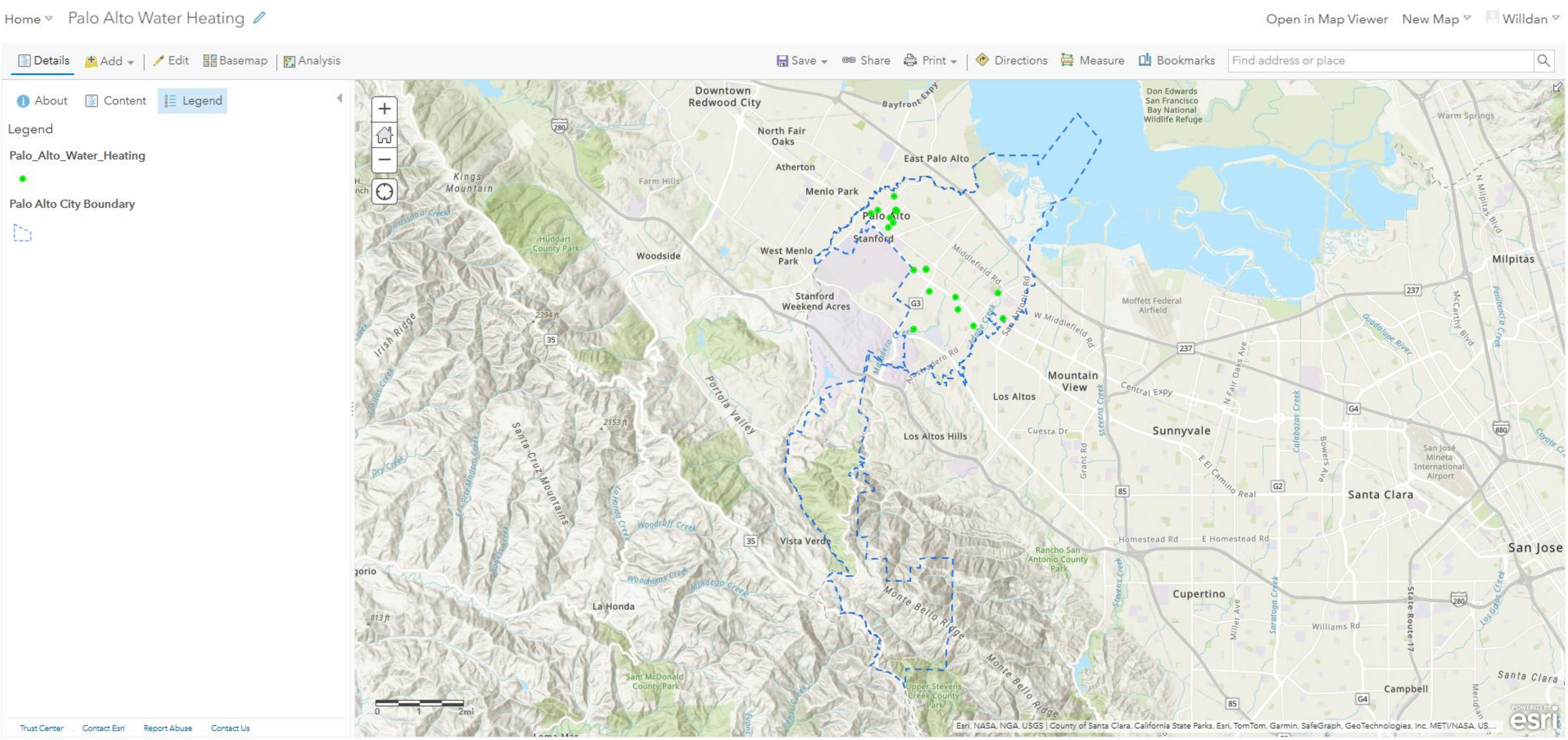


Exhibit C.2.2.2. - Water Heating Equipment: Details

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Palo Alto Water Heating (Features: 21, Selected: 1)

Heater Type	Other Heater Type	Fuel Type	Manufacturer	Other Manufacturer	Capacity - Gallons	Model Number	Gas Input - kBTU per hr	Electric Input: kW	Recovery Rate	Thermal Efficiency	Recirculation Pump Present?	Quantity
Storage Water Heater		Natural Gas	Bradford White		71-80	Urg275h6n	76-90					1
Electric Resistance Water Heater		Electric	AO Smith		0-30	ECT 30 200		3-4				1
Electric Resistance Water Heater		Electric	Bradford White		0-30	M11OU6SS-1NAL		1-2			No	1
Boiler		Natural Gas		Laars	121+	MT2V 300	101-250					1
Boiler		Natural Gas	Bradford White	Laars mark	121+	MT2V	251-500				Yes	2
Storage Water Heater		Natural Gas	Rheem		91-100	Gnu100-200	101-250		200-300 Gal/hr		Yes	4
Storage Water Heater		Natural Gas	Bradford White		71-80	Urg275h6n	76-90				Yes	4
Boiler		Natural Gas	Bradford White	Laars mark	121+	Ntv399nxn3	251-500				Yes	2
Storage Water Heater		Natural Gas	Bradford White		91-100	Ef100t300e3n2	251-500				Yes	2
Storage Water Heater		Natural Gas	Other	General Electric	31-40	Gg38t06axk00	30-40				No	1
Storage Water Heater		Natural Gas	Bradford White		71-80	Ulg27h763n	76-90		0-100 Gal/hr		No	1
Storage Water Heater		Natural Gas	Rheem		71-80	42v75f	61-75				No	1
Storage Water Heater		Natural Gas	Bradford White		71-80	Ulg275h763n	76-90				No	1
Storage Water Heater		Electric	Rheem		0-30	PROE201RH POU		3-4			No	1
Storage Water Heater		Electric	AO Smith		71-80	DRE 80 100		5+			No	1
Storage Water Heater		Natural Gas	AO Smith		91-100	BTL-275 200	251-500		200-300 Gal/hr	80-85%	Yes	2
Other		Natural Gas				Wry						1
Storage Water Heater		Electric	Rheem		31-40	Elds40-ftb		5+				1
Storage Water Heater		Electric	Bradford White		71-80	See photo		4-5			No	1
Tankless Water Heater		Natural Gas	Other	Noritz		See photo	101-250				No	1
Storage Water Heater		Natural Gas	AO Smith	Bradford white	91-100	See photos	101-250				Yes	2

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Exhibit C.2.3.1. - Kitchen Equipment: Locations

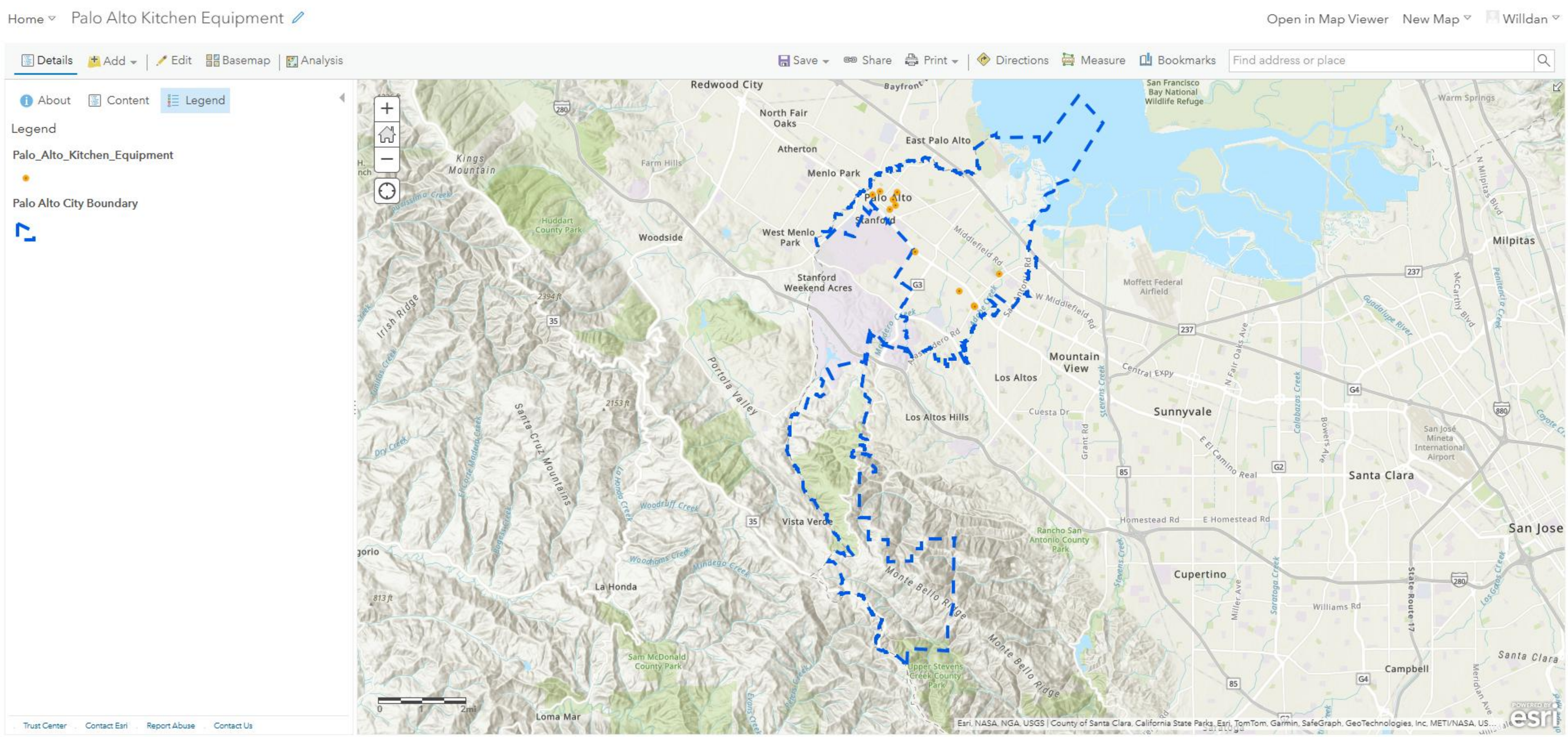
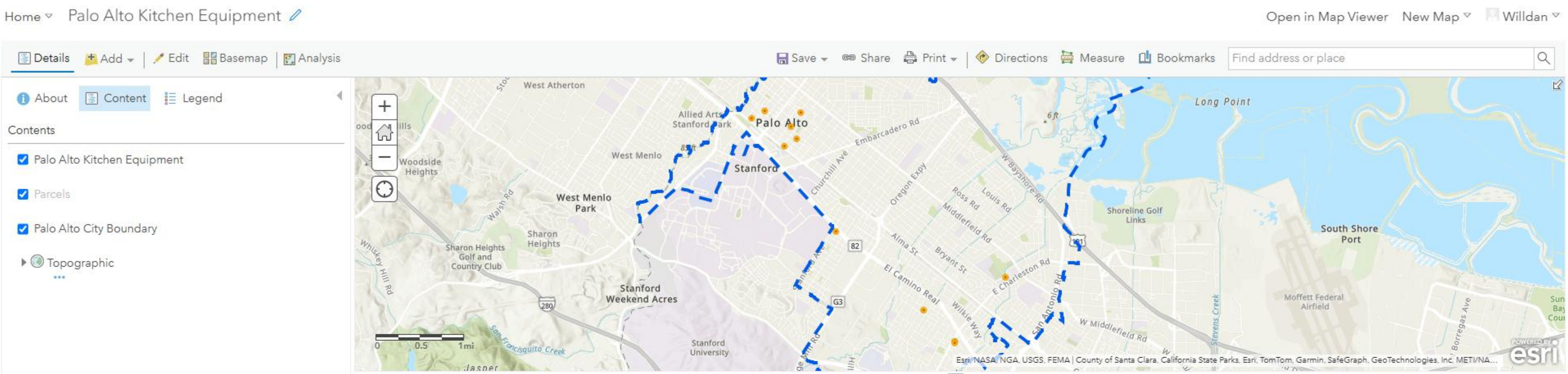


Exhibit C.2.3.2. - Kitchen Equipment: Details



Palo Alto Kitchen Equipment (Features: 11, Selected: 0)

Type	Other Type	Fuel Type	Brand	Other Brand	Model Number	Comments 1	Comments 2	Comments 3	Site Name
									Site B
									Site D
									Site G
Stove		Electric	Other	GE	JB645RK4SS				Site G
Stove		Electric	Other	GE	JB645RK6SS|				Site G
Stove		Gas	Other	Frigidaire	Fcrg3052asc				Site D
Stove		Gas	Other	General Electric	Jgs760sp5ss				Site E
Stove		Electric	Other	General Electric	J bs15 m1ww				Site F
Stove		Electric	Other	Hotpoint					Site C
Stove		Electric	LG		LREL63235			Site I	Site I
Stove		Electric				All units have electric only			Site B

Exhibit C.2.4.1. - Laundry Equipment: Locations

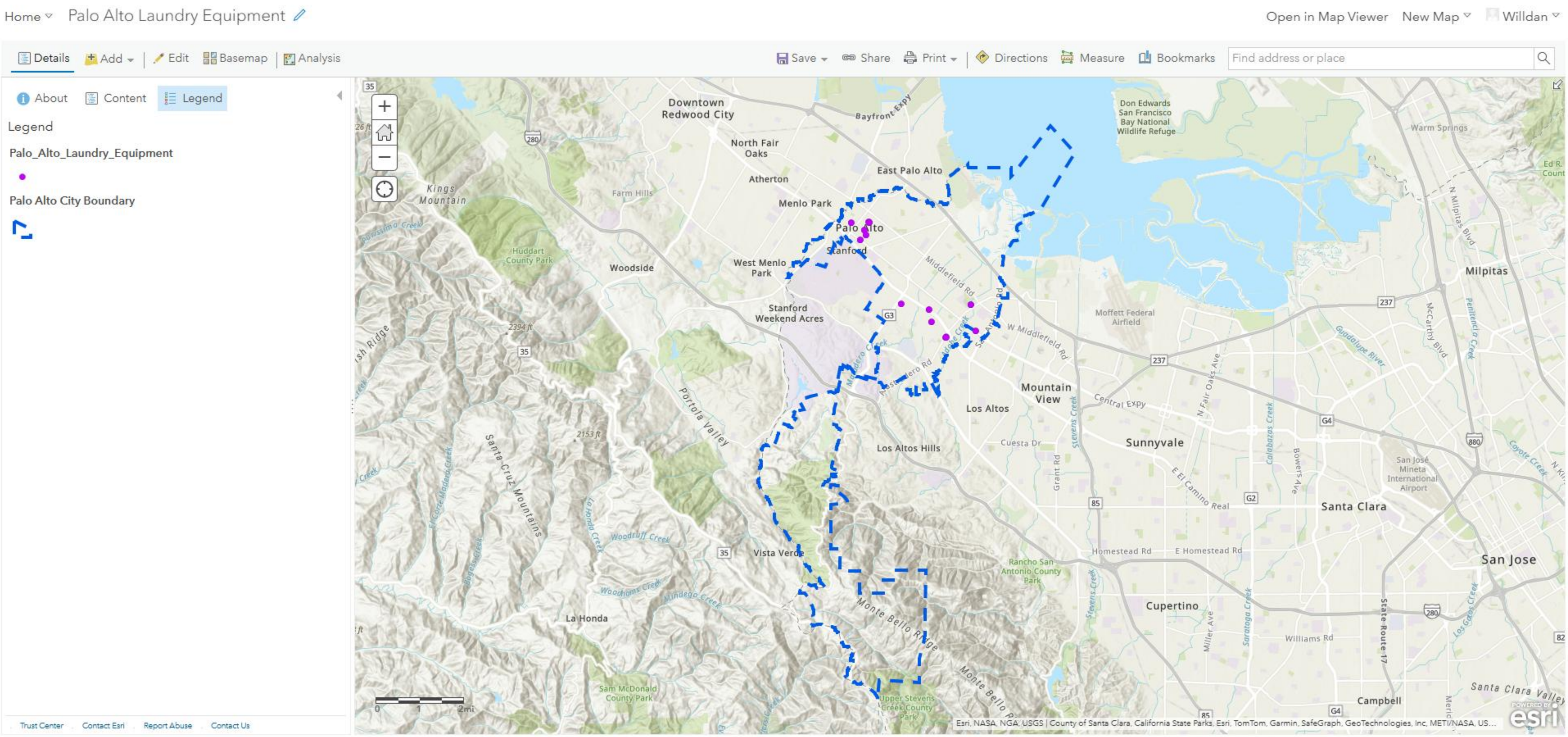
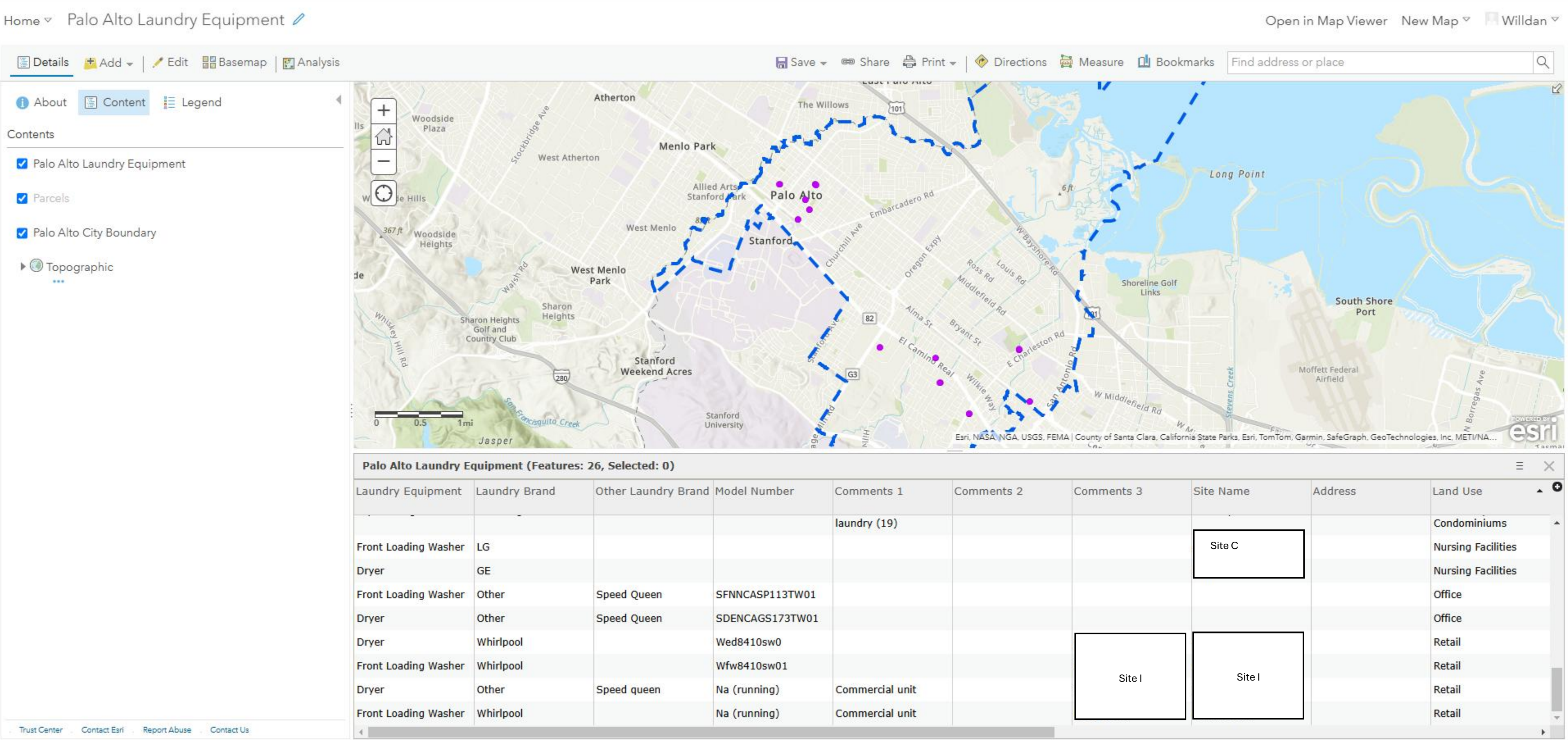


Exhibit C.2.4.2. - Laundry Equipment: Details



Laundry Equipment	Laundry Brand	Other Laundry Brand	Model Number	Comments 1	Comments 2	Comments 3	Site Name	Address	Land Use
				laundry (19)					Condominiums
Front Loading Washer	LG						Site C		Nursing Facilities
Dryer	GE								Nursing Facilities
Front Loading Washer	Other	Speed Queen	SFNNCASP113TW01						Office
Dryer	Other	Speed Queen	SDENCAGS173TW01						Office
Dryer	Whirlpool		Wed8410sw0			Site I	Site I		Retail
Front Loading Washer	Whirlpool		Wfw8410sw01						Retail
Dryer	Other	Speed queen	Na (running)	Commercial unit					Retail
Front Loading Washer	Whirlpool		Na (running)	Commercial unit					Retail

Exhibit C.2.5.1. - Pool Equipment: Locations

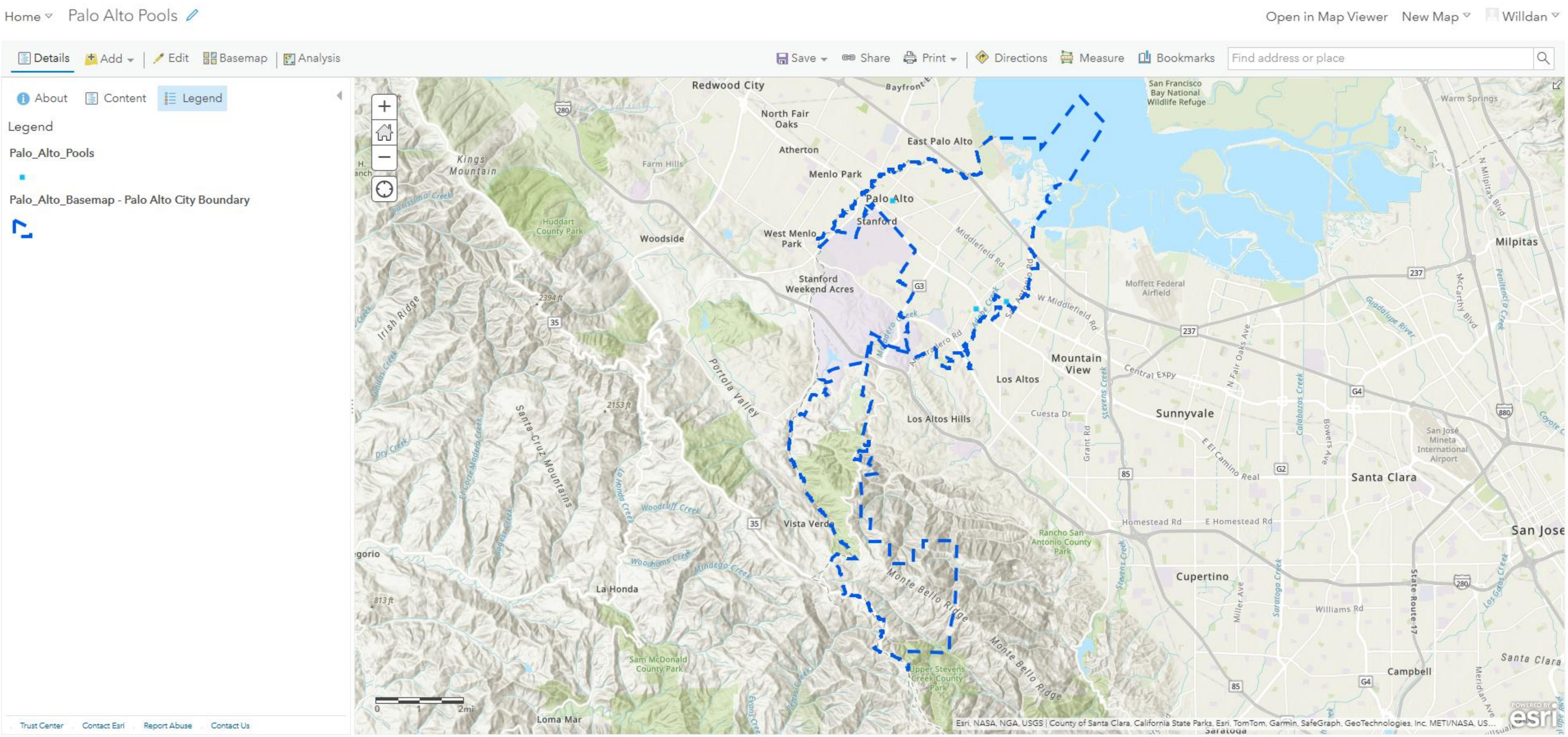
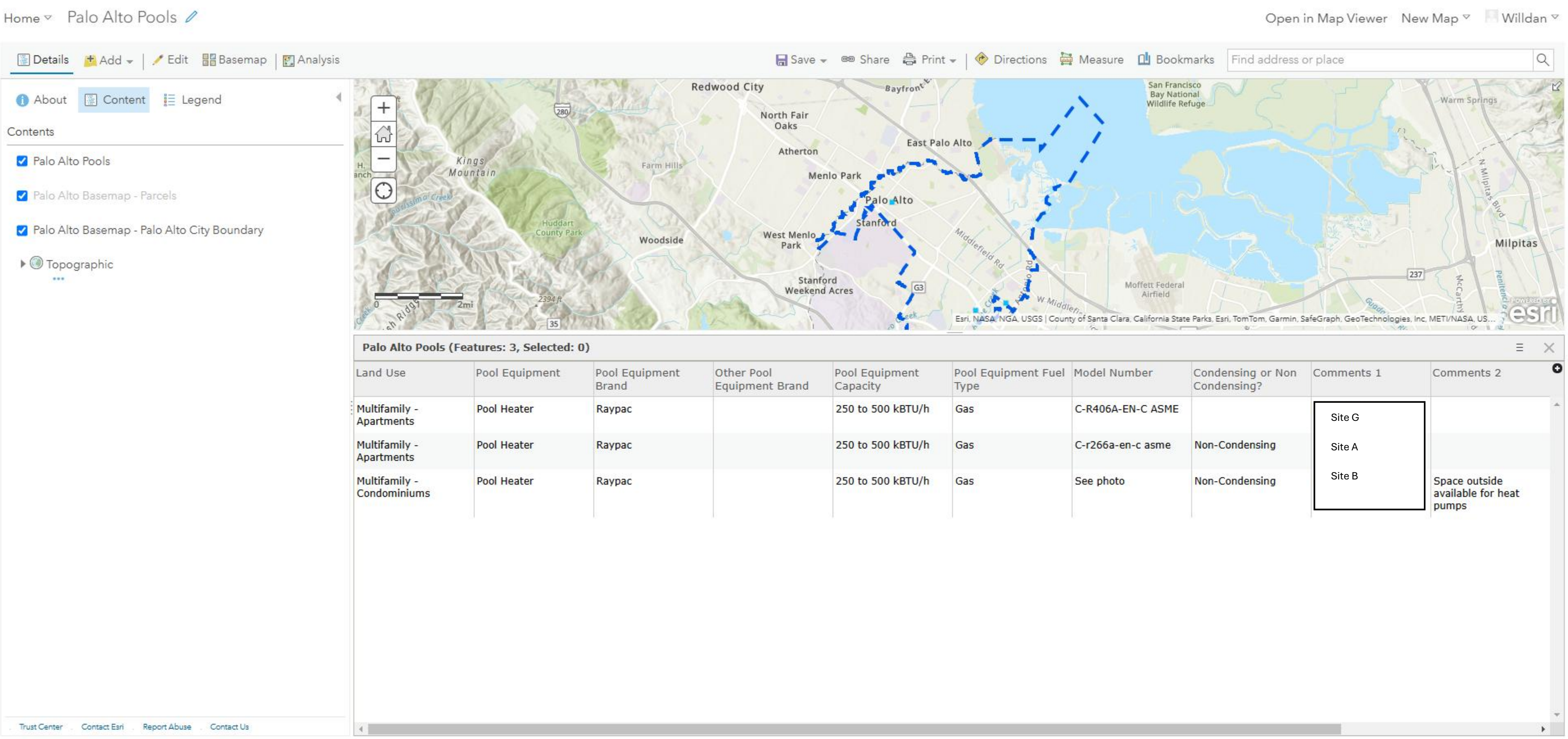


Exhibit C.2.5.2. - Pool Equipment: Details



Land Use	Pool Equipment	Pool Equipment Brand	Other Pool Equipment Brand	Pool Equipment Capacity	Pool Equipment Fuel Type	Model Number	Condensing or Non Condensing?	Comments 1	Comments 2
Multifamily - Apartments	Pool Heater	Raypac		250 to 500 kBTU/h	Gas	C-R406A-EN-C ASME		Site G	
Multifamily - Apartments	Pool Heater	Raypac		250 to 500 kBTU/h	Gas	C-r266a-en-c asme	Non-Condensing	Site A	
Multifamily - Condominiums	Pool Heater	Raypac		250 to 500 kBTU/h	Gas	See photo	Non-Condensing	Site B	Space outside available for heat pumps

Exhibit C.2.6.1. – Electrical Infrastructure and General Site: Locations

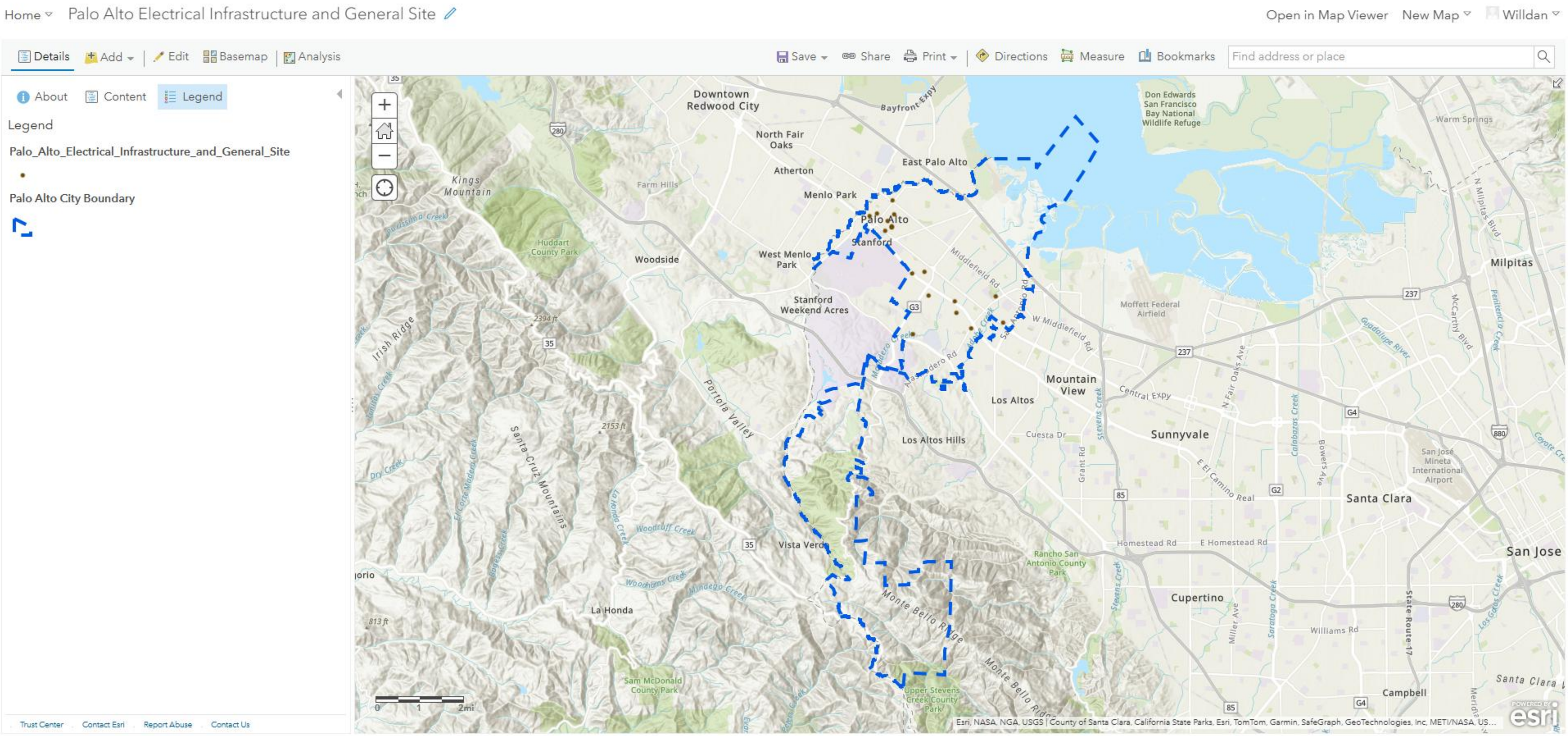


Exhibit C.2.6.2. - Electrical Infrastructure and General Site: Details

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- Palo Alto Electrical Infrastructure and General Site
- Parcels
- Palo Alto City Boundary
- Topographic Base Map

Palo Alto Electrical Infrastructure and General Site (Features: 18, Selected: 0)

Main Switchboard Volts	Main Switchboard Amps	Main Switchboard Breaker Slots Available	Sub Panels Observed	Avg Sub Panel Breaker Slots Available	Comments 1	Comments 2	Comments 3	Land Use	Main Switchboard Brand
		Breakers			limited to 24 v because each unit only has 90 Amps			Condominiums	
208	200 to 400	Full - No Available Breakers	1	10 to 50% Available Breakers	Physical therapy			Nursing Facilities	Zinsco
208	100 to 150	0 to 10% Available Breakers						Office	Challenger
208			1					Office	Other
480	600 or above	10 to 50% Available Breakers	< 4	0 to 10% Available Breakers			Site E	Office	Other
480	600 or above	0 to 10% Available Breakers	< 4	0 to 10% Available Breakers	Upper floor of one wing is residential Mr		Site F	Office	General Electric GE
480	600 or above	10 to 50% Available Breakers	< 4	10 to 50% Available Breakers	Sub panels in basement and on 3rd floor		Site H	Office	Other
208	200 to 400							Retail	Siemens
120	200 to 400	Full - No Available Breakers	2	Full - No Available Breakers	Hotel		Site I	Retail	
208	150 to 200				Could not access breakers		Site A	Retail	Other

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Exhibit C.2.7.1. – Plug Loads and Other Equipment: Locations

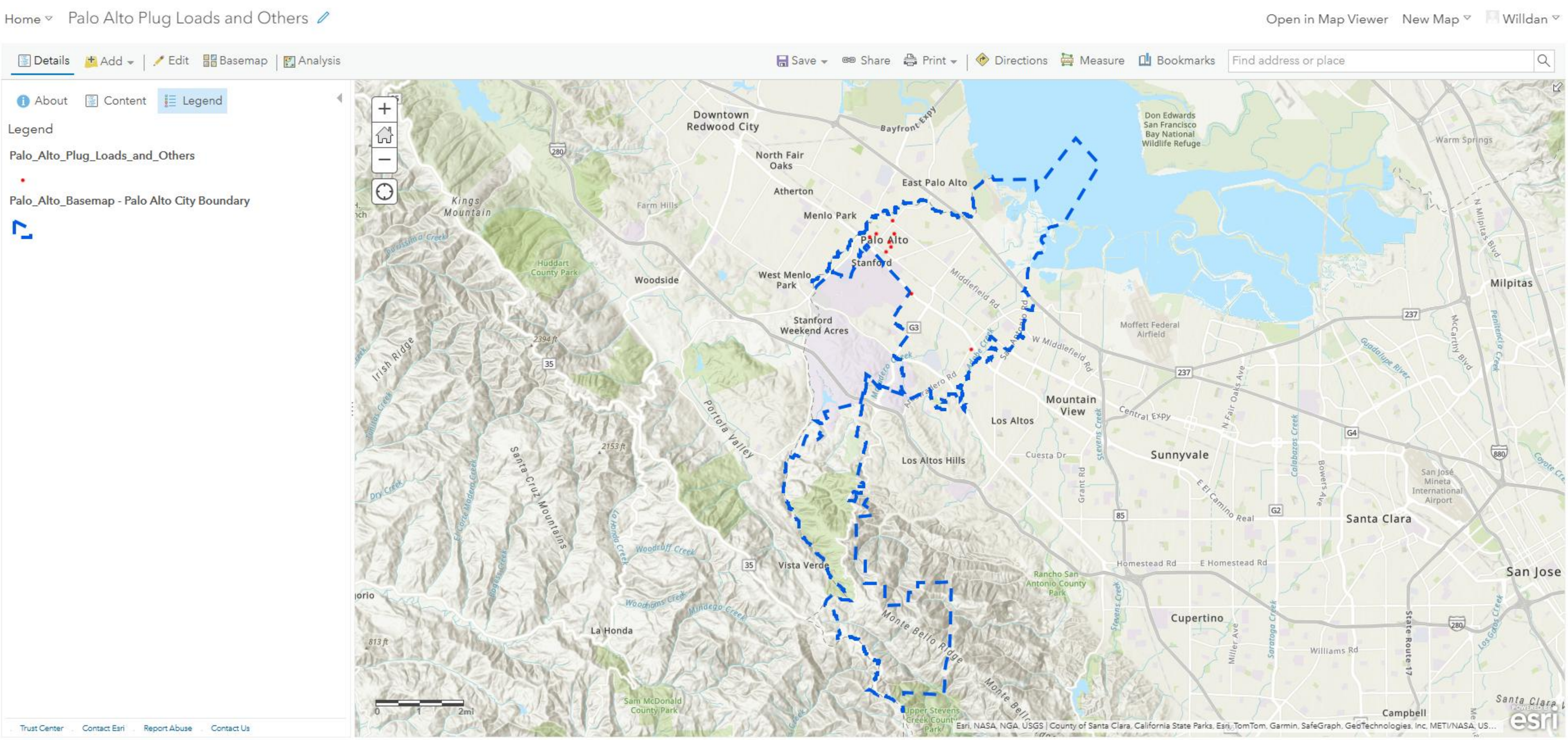

Exhibit C.2.7.2. - Plug Loads and Other Equipment: Details

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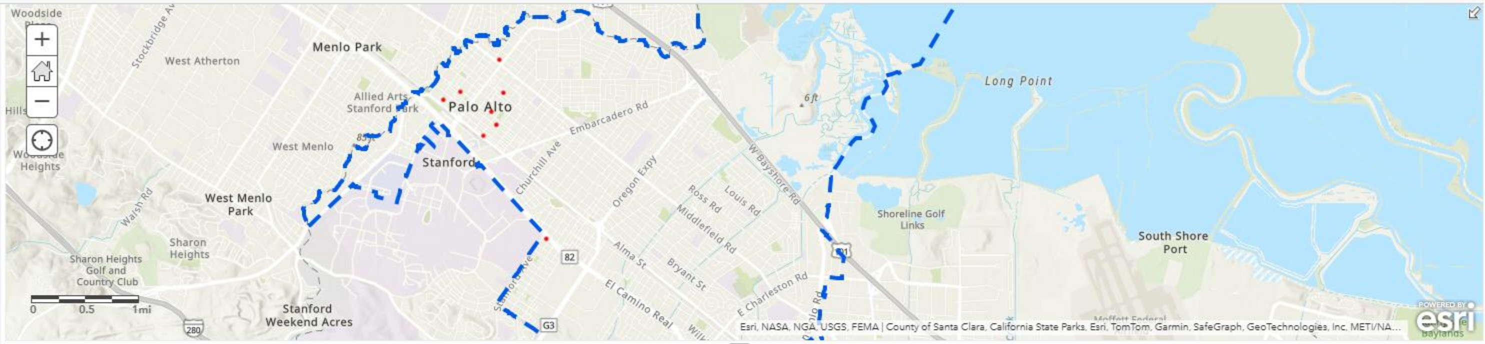

Palo Alto Plug Loads and Others (Features: 9, Selected: 0)

LEDs Percent Coverage	Standard Consumer Appliances?	EV Charger Quantity	EV Charger Level	Solar Panels Existing	Comments 1	Comments 2	Comments 3	Land Use	EV Charging Station Manufacturer
90-100	Average								
60-70								Multifamily - Apartments	
40-50	Average	1-3	Level 2	No	2 EV Chargers			Multifamily - Apartments	ChargePoint
								Multifamily - Apartments	
		15+	Level 2	No				Multifamily - Condominiums	Other
90-100	Average	0		Yes - Rooftop				Office	
90-100	Light							Retail	
	Light	1-3	Level 1				Site I	Retail	Tesla
	Heavy	0		No			Site A	Retail	

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Attachment C.3 ArcGIS Field Data Collected

Water Heater Equipment

Site Name	Land Use	Heater Type	Fuel Type	Manufacturer	Other Manufacturer	Capacity - Gallons
Site B	Office	Storage Water Heater	Natural Gas	Bradford White		71-80
Site D	Office	Electric Resistance Water Heater	Electric	AO Smith		0-30
Site G	Retail	Electric Resistance Water Heater	Electric	Bradford White		0-30
Site I	Retail	Storage Water Heater	Natural Gas	Other	General Electric	31-40
Site I	Retail	Storage Water Heater	Natural Gas	Bradford White		71-80
Site I	Retail	Storage Water Heater	Natural Gas	Rheem		71-80
Site I	Retail	Storage Water Heater	Natural Gas	Bradford White		71-80
Site A	Retail	Storage Water Heater	Electric	Rheem		0-30
Site E	Office	Storage Water Heater	Electric	AO Smith		71-80
Site F	Office	Storage Water Heater	Natural Gas	AO Smith		91-100
	Retail	Other	Natural Gas			
	Office	Storage Water Heater	Electric	Rheem		31-40
	Office	Storage Water Heater	Electric	Bradford White		71-80
	Nursing Facilities	Tankless Water Heater	Natural Gas	Other	Noritz	

Water Heater Equipment Continuation

Site Name	Model Number	Gas Input - kBTU per hr	Electric Input: kW	Recovery Rate	Thermal Efficiency	Recirculation Pump Present?	Recirculation Pump Controls	Quantity	Serial Number
Site B	Urg275h6n	76-90						1	XC47571488
Site D	ECT 30 200		3-4					1	A07J043009
Site G	M11OU6SS-1NAL		1-2			No	N/A	1	JF16741328
Site I	Gg38t06axk00	30-40				No		1	See photo
Site I	Ulg27h763n	76-90		0-100 Gal/hr		No		1	See photo
Site I	42v75f	61-75				No		1	See photo
Site I	Ulg275h763n	76-90				No		1	See photo
Site A	PROE201RH POU		3-4			No		1	See photo
Site E	DRE 80 100		5+			No		1	1604M000488
Site F	BTL-275 200	251-500		200-300 Gal/hr	80-85%	Yes		2	See photos
	Wry							1	Gff
	Elds40-ftb		5+					1	See photo
	See photo		4-5			No		1	See photo
	See photo	101-250				No		1	See photo

Water Heater Equipment Continuation

Site Name	Panel Location	Distance to Panel (ft)	Location	Age
Site B	N/A			
Site D				
Site G	Same Floor	20	Mechanical Room - First Floor	
Site I		50 ft	Mechanical Room - First Floor	14 years
Site I		30 ft	Mechanical Room - Basement	9 years
Site I		30	Mechanical Room - Basement	12 years
Site I		30		7 years
Site A		20	Mechanical Room - First Floor	
Site E			Mechanical Room - First Floor	
Site F		20 feet	Mechanical Room - Basement	7 years
		30	Mechanical Room - Basement	2 years
		30 feet	Mechanical Room - Basement	
		10 ft		

HVAC Equipment

Site Name	Land Use	Heating or Cooling	HVAC Equipment	HVAC Manufacturer	Other HVAC Manufacturer	Age
Site B	Office	Both	Packaged Unit	Other	Lennox	2013
Site B	Office	Heating	Furnace		Lennox	
Site D	Office	Heating	Furnace	Carrier		2020
Site D	Office	Both	Split System	Mitsubishi		2020
Site F	Office	Both	Split System			
Site G	Retail	Both	Packaged Unit	Rheem		20 years old estimate
Site D	Office	Both	Packaged Unit	Carrier		
Site D	Retail	Both	Packaged Unit	Carrier		
Site D	Office	Both	Packaged Unit	Carrier		
Site D	Retail	Cooling	Packaged Unit	Carrier		
Site D	Office	Cooling	Split System	Mitsubishi		
Site I	Retail	Heating	Furnace	Other	Lennox	
Site A	Retail	Both	Split System	Bryant		14 years
Site E	Office	Heating	Furnace	Other	Reznor	Original to building
Site E	Office	Cooling	Packaged Unit	Trane		Original to building
Site E	Office	Cooling	Split System	Other	Fujitsu and York	
Site F	Office	Cooling	Chiller	Carrier		~20 years
Site F	Office	Cooling	Split System	Other		
Site F	Office	Heating	Boiler			
	Office	Cooling	Packaged Unit	Bryant		
	Office	Both	Packaged Unit	York		
	Office	Both	Packaged Unit	Carrier		
	Office	Cooling	Split System			
	Office	Cooling	Split System	Carrier		
	Office	Both	VRF	Mitsubishi		
	Nursing Facilities	Both	Packaged Unit	York		
	Nursing Facilities	Both	Packaged Unit	Other	Check model number	
	Nursing Facilities	Both	Packaged Unit	Other	Check model number	

HVAC Equipment Continuation

Site Name	Cooling Capacity - Tons	Cooling Capacity - kBTU/hr	Heating Capacity - BTU/hr	Model Number
Site B	0-10	20+	10,000-20,000	XC14-036-230-03
Site B			60,000-80,000	G61MPV-36B-071-12
Site D				
Site D				
Site F	0-10	20+	10,000-20,000	MUY-GE24NA
Site G	0-10		60,000-80,000	RRKA-A048JK08X
Site D		20+	>80,000+	50HCQD08C2A5A0A0G0
Site D	0-10	20+	60,000-80,000	50HCQD07C2A5A0A0G0
Site D		20+	40,000-60,000	50Vr-A48—50–
Site D	0-10			Na
Site D	0-10			Muzd36na
Site I			60,000-80,000	Sl280uh090xv48b
Site A				113ana060-g
Site E				Built up system
Site E				SXHFC7540T67D8AD600
Site E	0-10	20+	20,000-40,000	TCD60B41SA, TCGD60S44S1A, AOU18RLFC
Site F	50-100			38AH-054---600
Site F	0-10	10-15	10,000-20,000	RX12NMVJU
Site F				See photo
				See photo
			60,000-80,000	See photo
			>80,000+	See photo
				See photos
				See photo
				See photos
			>80,000+	See photo
			>80,000+	See photo
			60,000-80,000	See photo

HVAC Equipment Continuation

Site Name	Serial Number	Panel Location	Distance to Panel: ft	Location	System Control
Site B	5811G08382				
Site B					
Site D					
Site D					
Site F	200330T				
Site G	2G6820ADAAF0511046	One Floor Down	80	Rooftop	Smart Thermostat
Site D	0920P38372	One Floor Down	60	Rooftop	
Site D	0920P38272	One Floor Down	80	Rooftop	
Site D	1020F50018	One Floor Down	80	Rooftop	
Site D	Na				
Site D	5000874T				
Site I	See photo	Same Floor	30	In unit	Smart Thermostat
Site A	See photo	Same Floor	20		
Site E	Built up system			Rooftop	BMS
Site E	C99A01147			Rooftop	BMS
Site E	See photos			Rooftop	BMS
Site F	1401F74643	Multiple Floors Down	100 ft	Rooftop	BMS
Site F	See photos	Multiple Floors Down	100 ft		
Site F	See photo	Multiple Floors Down	100 ft		
	See photo		20 ft	Rooftop	Smart Thermostat
	See photo		40 ft	Rooftop	Smart Thermostat
	See photo	Same Floor	40 ft	Rooftop	Smart Thermostat
	See photos	Same Floor	30 ft	Rooftop	Smart Thermostat
	See photo	Same Floor	20 ft	Rooftop	Smart Thermostat
	See photos	Same Floor	20 ft	Rooftop	Smart Thermostat
	See photo	One Floor Down	50 ft	Rooftop	Smart Thermostat
	See photo	One Floor Down	50 ft	Rooftop	Smart Thermostat
	See photo	One Floor Down	50 ft	Rooftop	Smart Thermostat

Electrical Infrastructure

Site Name	Land Use	Main Switchboard Brand	Main Switchboard Volts	Main Switchboard Amps	Main Switchboard Breaker Slots Available
Site B	Office	Challenger	208	100 to 150	0 to 10% Available Breakers
Site D	Office	Other	208		
Site G	Retail	Siemens	208	200 to 400	
Site I	Retail		120	200 to 400	Full - No Available Breakers
Site A	Retail	Other	208	150 to 200	
Site E	Office	Other	480	600 or above	10 to 50% Available Breakers
Site F	Office	General Electric GE	480	600 or above	0 to 10% Available Breakers
	Office	Other	480	600 or above	10 to 50% Available Breakers
	Nursing Facilities	Zinsco	208	200 to 400	Full - No Available Breakers

Electrical Infrastructure Continuation

Site Name	Sub Panels Observed	Avg Sub Panel Breaker Slots Available
Site B		
Site D	1	
Site G		
Site I	2	Full - No Available Breakers
Site A		
Site E	< 4	0 to 10% Available Breakers
Site F	< 4	0 to 10% Available Breakers
	< 4	10 to 50% Available Breakers
	1	10 to 50% Available Breakers

Laundry Equipment

Site Name	Land Use	Laundry Equipment	Laundry Brand	Other Laundry Brand	Laundry Equipment Capacity	Dryer Fuel Type	Model Number	Equipment Quantity
Site I	Retail	Dryer	Whirlpool			Electric	Wed8410sw0	1
Site I	Retail	Front Loading Washer	Whirlpool				Wfw8410sw01	1
Site I	Retail	Dryer	Other	Speed queen		Natural Gas	Na (running)	1
Site I	Retail	Front Loading Washer	Whirlpool			N/A	Na (running)	1
	Nursing Facilities	Front Loading Washer	LG					1
	Nursing Facilities	Dryer	GE			Natural Gas		1

Kitchen Equipment

Site Name	Land Use	Type	Fuel Type	Brand	Other Brand	Model Number
Site B	Office					
Site D						
Site G						
Site I	Retail	Stove	Electric	LG		LREL63235

Plug Loads

Site Name	Land Use	LEDs Percent Coverage	Standard Consumer Appliances?	EV Charger Quantity	EV Charger Level	EV Charging Station Manufacturer
Site B		90-100	Average			
Site D	Office	90-100	Average	0		
Site G	Retail	90-100	Light			
Site I	Retail		Light	1-3	Level 1	Tesla
Site A	Retail		Heavy	0		

Plug Loads Continuation

Site Name	Estimated Parking Count	Private Parking?	Open Parking?	Restricted Charging?	Is Charging Free?	Charger Capacity
Site B	0-20 spaces	Yes	Yes			
Site D	0-20 spaces	Yes				
Site G	0-20 spaces	Yes	Yes			
Site I	0-20 spaces		Yes	Yes, only for residents/employees		
Site A	0-20 spaces		Yes			

Plug Loads Continuation

Site Name	Solar Panels Existing	Battery Energy Storage System Present?
Site B		
Site D	Yes - Rooftop	No
Site G		
Site I		
Site A	No	

Facility Name	Equipment Type	Quantity	List of Equipment	Electrification Opportunity	Installation Lower Ranger	Installation Upper Range	Annual GHG Emissions Avoided * (Metric Tons CO2e)
Site D	Water Heating	1	30-gallon Electric Resistance Storage Water	System is already electric, but savings could be gained by converting to a heat pump water heater system which can be up to 4x as efficient	$10,000	$13,000	N/A
	HVAC	1	Gas Furnace	Ducted heat pump split system	$18,000	$22,000	7
	HVAC	2	Split System Heat Pumps	Ducted heat pump split system	N/A	N/A	N/A
	HVAC	4	Roof Top Package Units with Electric Heating	Ducted heat pump split system	N/A	N/A	N/A
	Kitchen	N/A	2) Dishwashers, (1) refrigerator, (2) beverage coolers, (2) microwaves, (1) toaster oven, (1) coffee maker	Kitchen is already all electric	N/A	N/A	N/A
	Electrical Infrastructure	N/A	Main service is 400 Amps. Multiple spare circuits are available at the main panel.	This site will likely not require any enhancements to the electrical infrastructure to support addition of the electrified ducted heat pump split system load, especially if electrical load is reduced by switching from the electric resistance water heater to a more efficient heat pump unit	N/A	N/A	Supports emission avoidance shown above
						Total Annual Emissions Reduction Petential Identified	**7**

Facility Name	Equipment Type	Quantity	List of Equipment	Electrification Opportunity	Installation Lower Ranger	Installation Upper Range	Annual GHG Emissions Avoided * (Metric Tons CO2e)
Site H	Water Heating	2	(1) 30-gallon Electric Resistance Storage Water Heater (1) 80-gallon Electric Resistance Storage Water Heater	System is already electric, but savings could be gained by converting to a heat pump water heater system which can be up to 4x as efficient	$40,000	$55,000	N/A
	HVAC	2	Package units with Gas Heating	Packaged Heat Pump System	$80,000	$95,000	15
	HVAC	5	Ducted split system heat pumps	System is already electric	N/A	N/A	N/A
	HVAC	1	Roof Top Package Units with Electric Heating	System is already electric	N/A	N/A	N/A
	HVAC	1	Split System Heat Pumps	System is already electric	N/A	N/A	N/A
	HVAC	1	Variable Refrigerant Flow (VRF) Heat Pump with Heat Recovery System	System is already electric	N/A	N/A	N/A
	Electrical Infrastructure	N/A	Main service is 1,200 Amps. Multiple spare circuits are available at the main panel.	This site will likely not require any enhancements to the electrical infrastructure to support addition of the electrified ducted heat pump split system load, especially if electrical load is reduced by switching from the electric resistance water heater to a more efficient heat pump unit	N/A	N/A	Supports emission avoidance shown above
						Total Annual Emissions Reduction Petential Identified	**15**

Facility Name	Equipment Type	Quantity	List of Equipment	Electrification Opportunity	Installation Lower Ranger	Installation Upper Range	Annual GHG Emissions Avoided * (Metric Tons CO2e)
Site C	Water Heating	1	Tankless Gas Water Heater	Heat Pump Water Heater System The system appears to be oversized for existing loads in the building based on a preliminary water use analysis. Estimated price range shown represents a "right-sized" system	$20,000	$35,000	4
	HVAC	3	(3) Package Units with Natural Gas Heating North Unit (74,000 Btuh heating) has failed Center and South Units (125,000 Btuh, and 100,000 Btuh heating) are operational	Package heat pump system The Center and South Units will likely require electric resistance backup heating to match the existing units' heating capacity	$100,000	$120,000	2
	Washers	1	Electric washers	The system is already electric. Hot water used by washing machine will be electrified indirectly from the water heating opportunity shown above	N/A	N/A	N/A
	Dryers	1	Electric Dryer	The system is already electric. Hot water used by washing machine will be electrified indirectly from the water heating opportunity shown above	N/A	N/A	N/A
	Electrical Infrastructure	N/A	Main service is estimated to be 400 Amps. Multiple spare circuits are available at the main panel.	This site will likely require the installation of new electrical subpanels to feed electrified water heating system. Rooftop heat pump package HVAC units may be able to connect to existing HVAC subpanel(s). However, if new HVAC heat pump units are optioned with resistance heat backup, additional Amp capacity may be needed. Specific electrical design parameters will need to be determined by engineers. Preliminary estimate of total combined subpanel capacity needed is 100 to 200 Amps.	$7,000	$20,000	Supports emission avoidance shown above
						Total Annual Emissions Reduction Petential Identified	**6**

Facility Name	Equipment Type	Quantity	List of Equipment	Electrification Opportunity	Installation Lower Ranger	Installation Upper Range	Annual GHG Emissions Avoided * (Metric Tons CO2e)
Site A	Water Heating	1	20-gallon Storage Water Heaters	System is already electric, but savings could be gained by converting to a heat pump water heater system which can be up to 4x as efficient. However, location in existing space may be too limited to accommodate heat pump devices which tend to be larger.	$8,000	$12,000	N/A
	HVAC	1	Split Unit Ducted Air Conditioner – Cooling Only	System already electric	N/A	N/A	N/A
	HVAC	5	Gas fired furnace	Ducted split system heat pump. Note that this device will replace the gas fired heating capability but can also fulfill the function of the existing air conditioner allowing that device to be removed/taken out of service	$25,000	$32,000	3
	Electrical Infrastructure	N/A	200-AMP Main Circuit	There appears to be adequate space in existing subpanels to accommodate new electrified water heater and ducted split system heat pump, especially if existing air conditioner is removed (redundant to heat pump cooling function)	N/A	N/A	Supports emission avoidance shown above
						Total Annual Emissions Reduction Petential Identified	**3**

Facility Name	Equipment Type	Quantity	List of Equipment	Electrification Opportunity	Installation Lower Ranger	Installation Upper Range	Annual GHG Emissions Avoided * (Metric Tons CO2e)
Site B	Water Heating	1	75-gallon Storage Water Heaters	Heat Pump Water Heater System	$20,000	$35,000	2
	HVAC	2	Split Heat Pumps	System is already electrified	N/A	N/A	N/A
	HVAC	1	Condenser Cooling Unit	System is already electrified	N/A	N/A	N/A
	HVAC	1	Gas Furnace Unit	System is already electrified	$26,000	$30,000	1
	Washers	1	Electric washers	Washers consume hot water. Opportunities come from replacing gas water heaters with electric heat pumps as shown above	N/A	N/A	N/A
	Dryers	1	Gas Dryer	New Electric Heat Pump Dryer	$1,500	$2,000	1
	Electrical Infrastructure	N/A	Medical Area service panel is 125 Amps (though main breaker is rated for 100 Amps). All existing circuits are being used Each upstairs residential unit has a 100 Amp service panel	This site will likely require enhancements to the medical area electrical infrastructure to support the addition of the electrified ducted heat pump split system load and the new heat pump water heater system (both circuit spaces and capacity is likely required) Specific electrical design parameters will need to be determined by engineers. Preliminary estimate of total combined subpanel capacity needed is 100 to 200 Amps, and approximately 4 circuit breaker spaces.	$3,000	$7,000	Supports emission avoidance shown above
						Total Annual Emissions Reduction Petential Identified	**4**

Facility Name	Equipment Type	Quantity	List of Equipment	Electrification Opportunity	Installation Lower Ranger	Installation Upper Range	Annual GHG Emissions Avoided * (Metric Tons CO2e)
Site F	Water Heating	2	100-gallon Gas Storage Water Heater (275 kBtu/h each)	Heat Pump Water Heater System System may be downsized if a water use study is conducted. Estimated price shown is to match existing capacity	$120,000	$160,000	55
	HVAC	2	Air Cooled Chillers	System is already electrified	N/A	N/A	N/A
	HVAC	2	(1) Split System Heat Pump and (1) Evaporative Cooling Unit	System is already electrified	N/A	N/A	N/A
	HVAC	1	Natural Gas-Fired Heating Water Boiler	Heat Pump Water Heater. Alternatively, a Heat Recovery Chiller could support both chilled water and heating water loads simultaneously. Electric resistance backup option may be needed to meet peak heating water loads.	$125,000	$250,000	82
	Electrical Infrastructure	N/A	Main service is estimated to be 3000 Amps. Multiple spare circuits are available at the main panel.	New electrical conduit and local disconnects will be required at the HVAC heat pump locations. HVAC heat pump may require a new 480V subpanel	$5,000	$10,000	Supports emission avoidance shown above
						Total Annual Emissions Reduction Petential Identified	**137**

Facility Name	Equipment Type	Quantity	List of Equipment	Electrification Opportunity	Installation Lower Ranger	Installation Upper Range	Annual GHG Emissions Avoided * (Metric Tons CO2e)
Site E	Water Heating	1	80-gallon Gas Storage Water Heater	Heat Pump Water Heater System	$30,000	$40,000	17
	HVAC	2	Large Packaged Cooling Units	System is already electrified	N/A	N/A	N/A
	HVAC	3	Split System Heat Pumps	System is already electrified	N/A	N/A	N/A
	HVAC	2	Large Natural Gas-Fired Furnaces	Large, packaged unit heat pumps, or retrofit furnaces with heating hot water (HHW) coils and install heat pump HHW heater	$300,000	$450,000	202
	Electrical Infrastructure	N/A	Main service is estimated to be 1200 Amps. Multiple spare circuits are available at the main panel.	New electrical conduit and local disconnects will be required at the water heating and HVAC heat pump locations. HVAC heat pumps may require a new 480V subpanel	$5,000	$20,000	Supports emission avoidance shown above
						Total Annual Emissions Reduction Petential Identified	**219**

Facility Name	Equipment Type	Quantity	List of Equipment	Electrification Opportunity	Installation Lower Ranger	Installation Upper Range	Annual GHG Emissions Avoided * (Metric Tons CO2e)
Site G	Water Heating	1	10-gallon Electric Storage Water Heaters	The system is already electric. Another water heater of similar size is decommissioned in place. Very low hot water usage. Heat pump water heaters are not typically available in this small size range, however, electric instantaneous point of use water heaters that can be located under sinks may offer small efficiency gains.	N/A	N/A	N/A
	HVAC	2	Roof Top Units with Natural Gas Heating	Packages Heat Pump System	$90,000	$115,000	34
	Electrical Infrastructure	N/A	Main service is 200 Amps	Rooftop heat pump package HVAC units may be able to connect to existing HVAC subpanel(s). However, if new HVAC heat pump units are optioned with resistance heat backup, additional Amp capacity may be needed. Specific electrical design parameters will need to be determined by engineers. Preliminary estimate of total combined subpanel capacity needed is 100 to 200 Amps.	$3,000	$7,000	Supports emission avoidance shown above
						Total Annual Emissions Reduction Petential Identified	**34**

Free Building Equipment Surveys Form Responses

Date (Manually Enter)	11-Aug	13-Sep	16-Sep	17-Sep	17-Sep	17-Sep	17-Sep	17-Sep	18-Sep	23-Sep		
Your Name	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted
Job Title	Product Manager	Dentist	Operations manager	manager	manager	manager	manager	manager	Owner	Facilities Coordinator		
Email	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted
Phone Number	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted
Organization Name	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted
Building Address	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted
Contact Log	Phone Number is incorrect. Email sent 9/24	Email sent 9/24	Email sent 9/24. Scheduled 10/7	Email sent 9/24. Left vm 9/25. Customer decided to not move forward with survey. She is only interested if rebates are currently available	Email sent 9/24. Left vm 9/25. Customer decided to not move forward with survey. She is only interested if rebates are currently available	Email sent 9/24. Left vm 9/25. Customer decided to not move forward with survey. She is only interested if rebates are currently available	Email sent 9/24. Left vm 9/25. Customer decided to not move forward with survey. She is only interested if rebates are currently available	Email sent 9/24. Left vm 9/25. Customer decided to not move forward with survey. She is only interested if rebates are currently available	Email sent 9/24.	Email sent 9/24	Email sent 9/24	Email delivery failed.
Preferred Site Visit Day		scheduled 10/7							scheduled 10/7	scheduled 10/7		

Energy Survey Screening Form Responses

Date	11-Aug			17-Sep	17-Sep	17-Sep	17-Sep	17-Sep				
What type of building are you requesting to survey? (select one)	Multi-Family Residential Section for Site Owners/Managers/Other Staff:			Offices, Retail, and Assembly Space Section for Owners/Managers/Other Staff:	Offices, Retail, and Assembly Space Section for Owners/Managers/Other Staff:	Offices, Retail, and Assembly Space Section for Owners/Managers/Other Staff:	Offices, Retail, and Assembly Space Section for Owners/Managers/Other Staff:	Offices, Retail, and Assembly Space Section for Owners/Managers/Other Staff:				
Multi-Family Residential Section for Site Owners/Managers/Other Staff:												
Your Name	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted
Phone Number	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted
Your Email	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted
Site Address	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted
How many dwelling units are at your multi-family complex?	4 units											
How are most individual units at the site heated? (Pick the closest option)	Electric wall heaters or radiators											
How are most individual units supplied with service hot water? (Pick the closest option)	Gas water-heaters serving individual units (most common option for smaller complexes)											
Are most individual unit kitchens supplied with gas or are they all-electric?	Individual units' kitchens have gas appliances											
Do individual residential units have air-conditioning?	Yes											
Do common areas have air-conditioning?	Yes											
Are there laundry machines onsite?	Washers and dryers are located in individual units											
Is there a swimming pool on site?	No											
Is the swimming pool covered at night?	N/A											
Are there common areas with kitchen equipment? (e.g., club houses, recreation rooms, etc.)	Yes											
Is there a solar PV system on-site?	Yes											
Are there EV chargers on site?	Yes											
Offices, Retail, and Assembly Space Section for Owners/Managers/Other Staff:												
Your Name	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted
Phone Number	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted
Your Email	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted
Site Address	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted	redacted
What is the primary function of the building?				Offices	Other: restaurant plus plus retail plus office	Other: offices and commercial kitchen	Other: retaurant plus offices	Retail				
What is the square footage of your building? (Pick your closest estimate)				5,000 to 10,000 square feet	5,000 to 10,000 square feet	5,000 to 10,000 square feet	10,000 to 25,000 square feet	2,500 to 5,000 square feet				
How is your individual unit supplied with service hot water? (Pick the closest option) (copy)				Individual electric water-heater serving my unit	Individual gas water-heater in my unit (common in smaller complexes)	Individual gas water-heater in my unit (common in smaller complexes)	Hot water is provided to my unit from a central common water heating system (common in larger complexes)	Individual gas water-heater in my unit (common in smaller complexes)				
What are the hours of operation? (Pick the closest choice)				Typical office hours (e.g, 9 am to 6 pm, Monday through Friday)	Typical retail hours (e.g, 10 am to 8 pm, 7 days per week)	Typical office hours (e.g, 9 am to 6 pm, Monday through Friday)	Extended dining hours (6 to 16 hours per day, 6 or 7 days per week)	Typical retail hours (e.g, 10 am to 8 pm, 7 days per week)				
Which statement best describes your relationship to the building ownership?				I own the building and rent it out to non-residential tenants	I own the building and rent it out to non-residential tenants	I own the building and rent it out to non-residential tenants	I own the building and rent it out to non-residential tenants	I own the building and rent it out to non-residential tenants				
Who is responsible for maintenance of most of the building's lighting, HVAC, and water heating systems?				The tenant(s)	The tenant(s)	The tenant(s)	The tenant(s)	The tenant(s)				
What is the primary source of heating for the building? (Pick the closest option)				Rooftop air conditioning and heating units	Rooftop air conditioning and heating units	Rooftop air conditioning and heating units	Rooftop air conditioning and heating units	Rooftop air conditioning and heating units				
How is service hot water supplied to the building? (Pick the closest option)				Electric storage or instantaneous water-heating	Gas storage or instantaneous water-heating	Gas storage or instantaneous water-heating	Gas storage or instantaneous water-heating	Gas storage or instantaneous water-heating				
Please describe any kitchens that are on site.				No kitchens, or small kitchenettes only with no gas service	Large commercial / institutional scale kitchen(s)	Large commercial / institutional scale kitchen(s)	Large commercial / institutional scale kitchen(s)	Standard residential scale kitchen(s) with gas				
Please describe any other non-food-service, large gas using loads on site that you are aware of (e.g., dry-cleaning /laundry, light-industrial uses, kilns, sterilization, pools, etc.)												
Are there locker rooms or other areas with showers on site?		Yes			No	No	No	No				

Attachment C.6 – Basic HVAC and Water Heating Technology Descriptions

This attachment provides basic descriptions and typical images of common HVAC equipment types described in the Sector Study Report.

Electric-Cooling-Split System

A split system is an HVAC setup with separate indoor and outdoor units. The outdoor unit handles heat exchange, while the indoor unit distributes air. They're connected by refrigerant lines. These units may also be configured to provide heat in the winter (heat pump space heating). The indoor unit may be mounted directly to a wall of a space, or may hidden away inside a furnace/air handler.

Electric-Cooling-Packaged DX / Gas-Space Heating-Packaged Unit

A packaged HVAC unit with gas heat combines all components—cooling and heating—into one outdoor unit. It uses a gas furnace for heating and a standard "direct exchange" (DX) air conditioning compressor for cooling. Direct exchange refers to the refrigerant directly exchanging heat with the airflow, rather than through another medium (typically chilled water, as with central cooling plants). These systems are often installed on rooftops or beside buildings.

Electric-Cooling-Packaged Heat Pump (HP) / Electric-Space Heating-Air Source Heat Pump (ASHP)

A packaged HVAC heat pump is similar to a packaged HVAC DX unit with gas heat, except it forgoes the use of gas and instead uses the heat pump for both cooling and heating. Externally, they look very similar to packaged units with gas heat, except there is no natural gas connection nor is there a flue to vent combustion exhaust.

Image Credit: Carrier Corporation

Electric-Cooling-Variable Refrigerant Flow (VRF)

Variable refrigerant flow (VRF) cooling systems are a type of split-system, but rather than one outdoor unit connecting to one indoor unit, each individual outdoor unit serves multiple indoor units in different cooling zones. Special controls within the VRF system allow the system to provide different levels of cooling based on each cooling zone's need. These systems also may provide space heating (via heat pump heating).

Electric-Cooling-Water Cooled (WC) Chiller and **-Air Cooled (AC) Chiller**

Chillers are devices that consume electricity and generate chilled water. Water-cooled chillers reject heat from the chilled water to a separate condenser water loop that then must in turn reject that heat to the atmosphere (typically through a cooling tower). Air-cooled chillers reject heat from the chilled water to the atmosphere directly. Chilled water produced by these chillers is sent around to building air handling units to cool down ventilation air for the spaces being served.

Electric-Space Heating-Electric Resistance

Electric resistance space heating runs electricity directly through a resistive element which heats up air for space heating purposes. This can be found in electric resistance baseboard units or radiators, but also sometime within electric resistance furnaces.

Gas-Space Heating-Furnace

A gas furnace burns gas to heat up air for space heating purposes. It typically has a fan that pushes the air into the conditioned space, but some very old units rely only on the warm air rising into the space (gravity furnaces). Furnaces may be located in mechanical closets, basements, or on the roof of a building.

Gas-Space Heating-Boiler and **Gas-Water Heating-Boilers**

Similar to how chillers generate chilled water for space cooling, boilers burn gas to create heating hot water for space heating purposes. The heating hot water is typically pumped around the building to radiators or heating coils located in air handers or fan coil units. Sometimes, boilers may be used to generate domestic hot water, but this is rare and normally only found in very large or old buildings.

Gas-Water Heating-Storage Water Heater

A gas storage water heater heats water using natural gas and stores it in an insulated tank, for domestic water uses.

Electric Water Heating-Electric Resistance Water Heater

An electric storage water heater uses electric heating elements to warm water stored in an insulated tank, for domestic water uses.

Electric-Water Heating-Tankless and **Gas-Water Heating-Tankless**

A tankless water heater heats water on demand without storing it in a tank, for domestic water uses.. It provides continuous hot water and is more energy-efficient than storage models. These units are compact and ideal for saving space. Tankless water heaters may use gas to heat the water, or electric resistance elements.

Electric-Water Heating-Heat Pump Water Heater

Electric heat pump water heaters (HPWHs) are storage-type water heaters, that primarily use heat pumps to heat water for domestic purposes. These HPWHs are usually equipped with backup electric resistance elements which are only used when the heat pump can keep up with short periods of high demand, or if the ambient conditions become too cold for the heat pump to operate efficiently and effectively.