City of Palo Alto Utilities February 2022

Multifamily Gas Furnace to Heat Pump Retrofit Pilot Report

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1. PROJECT OVERVIEW

Acknowledgements

We thank the following organizations and individuals for their contributions to this report:

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CPAU Multifamily Gas Furnace to Heat Pump Retrofit Pilot

Through a 2018 Climate Protection Grant funded by the Bay Area Air Quality Management District, the City of Palo Alto Utilities (CPAU) launched a limited-time pilot to implement a Multifamily Gas Furnace to Heat Pump Retrofit Pilot. The pilot intended to retrofit existing in-unit gas wall furnaces with energy-efficient electric heat pumps at one or more affordable multifamily properties within Palo Alto. CPAU issued an RFP to implement this pilot in December 2018 and contracted with the Association for Energy Affordability (AEA) in May 2019 as the vendor to help with Pilot implementation and provide technical support for the selected demonstration site. The pilot aimed to identify viable retrofit options, costs, energy savings, and greenhouse gas reductions from replacing gas wall furnaces with efficient heat pump alternatives. Additionally, the pilot sought to compile lessons learned to inform the development of future program offerings.

This report outlines the results (to date) from the pilot and offers recommendations to inform future programs and decarbonization efforts in multifamily buildings within and outside of Palo Alto. The following is a timeline that captures major scope development, construction, and permitting efforts for the project. The project was delayed numerous times due to Covid-19. As of the publication of this report, the selected demonstration pilot building has completed construction on all (24) heat pump HVAC systems.

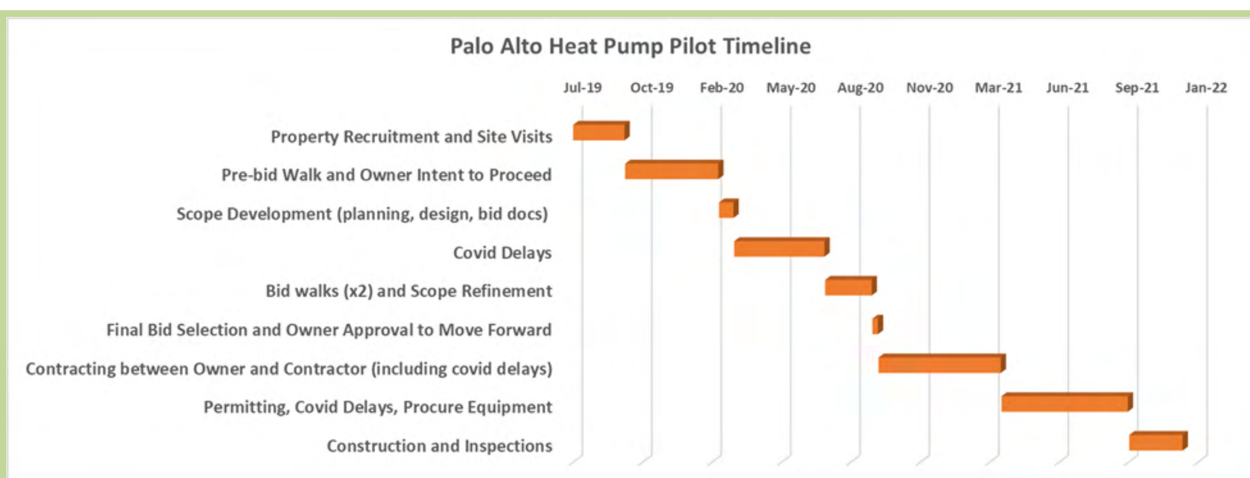


Figure 1: Palo Alto Heat Pump Pilot Timeline

2. Recruitment & Site Selection

Approach to Recruitment

AEA worked with CPAU, a local HUD representative, and existing contacts to identify and recruit affordable housing candidates that would be eligible for grant funds. Recruitment of identified sites included sharing a flyer summarizing the grant opportunity (**see Appendix A**), scoping phone calls, and walkthrough site visits. Ten affordable multifamily properties consisting of 345 apartments received walkthrough feasibility audits from AEA to help verify existing conditions, electrical infrastructure, related energy conservation measures, etc.

- One building owner had multiple eligible sites with opportunities both for wall furnace to heat pump upgrades as well as other upgrades. However, decision-makers had insufficient organizational commitment to move the projects beyond this initial scoping phase.

- A second building owner was interested and engaged, having undertaken a similar retrofit in a prior rehabilitation project at a sister property. However, the retrofit in the selected property presented a technically challenging installation that would not have been feasible with the grant budget and owner funds. Since then, AEA has provided pro-bono advice to a design team working with the owner to perform renovation work funded through a larger refinance, which may allow these upgrades to be performed.

- A third owner had two potential demonstration sites, and while both were good candidates, the larger of the two (157 units) would only have been able to receive a partial upgrade. In addition, the project was beginning to recapitalize the property and wanted to defer construction activities. The final site consisting of 24 apartments was selected as the best candidate to pursue, as it did not have any conflicting finance events, was large enough to meet grant requirements and was small enough to allow the entire property to be upgraded. Additionally, the building owner provided a dedicated and enthusiastic project manager to the team at no cost. Their participation was crucial in helping drive the project forward through all scoping and decision-making phases.

3. Existing Conditions

Summary

The selected pilot site is a 24-unit apartment complex built in 1998 by a local affordable housing developer. There are two buildings on site; Building A has 10 apartment units, and Building B has 14. Except for a manager unit, all apartments are reserved for adults with developmental disabilities. There are (16) one-bedroom apartments and (8) two-bedroom apartments at the site. Apartments are served by central gas water heating and have electric cooking. The only gas use in apartments is for space heating. Each apartment is separately metered for gas and electricity consumption.

Figure 2: Project Site

Envelope

The building envelope is moderately efficient, with dual pane metal windows, attics insulated with ~11" of blown fiberglass (R30), walls insulated to R13, and uninsulated slab on grade foundation.

Heating and Cooling

One-bedroom apartments, which range from 830-900 sq ft, are heated by a single ~70% efficient 32,000 btu input wall furnace located in the living room and controlled by a programmable thermostat. A vent on the rear of the wall furnace is open to the adjacent bedroom to allow some heat transfer with the door closed. Two-bedroom apartments, which are ~1,100 sq ft, are heated by an ~80% efficient 44,000 btu input forced air gas furnace controlled by a programmable thermostat. Ductwork on bottom floor units runs in soffits within each unit; ductwork on upper floor units is assumed to run through the attic cavity. Bedrooms are provided with ceiling fans and many windows have fixed exterior shading devices, however multiple units had visible window fans or portable AC units present, indicating additional comfort cooling is needed for some residents.

All apartments except for one second-floor unit have either a lower fenced in porch or an upstairs balcony. Per planning department conversations most balconies on site were approved to be built exceeding setback requirements.

Electrical Infrastructure

Each apartment is served by a 70 amp disconnect with a sub panel located in the bedroom or hallway of each apartment. Subpanels have space for additional breakers. Main feeder cables are run in aluminum romex. There are two electric service entrances to the property (one per building), and a 400 amp disconnect serves each bank of apartment meters.

Interviews with an initial bidding electrician indicated that the apartment service size (70 amps) would be sufficient to add the proposed heat pump HVAC load. However, they suggested monitoring the 400 amp apartment main breakers to confirm if the existing main breaker feeding each bank of apartment meters would accommodate the newly added load. Both 400-amp mains were monitored for 30 days at

1 min intervals, and the results (reviewed by bidding electricians) indicated that there was sufficient capacity for adding the new heat pump load.

The table below compares the results of the 30-day monitoring period (“actual” column) against the calculated max amp draw against the National Electric Code (NEC) deemed method. This calculated method allows engineers to size new electric services and added loads using a calculation (vs actual monitored data) but as seen below it often overstates the actual peak load that will be seen at the project. For example, peak demand for the A building was calculated to be 243 amps, but the actual peak draw was 41 amps during the monitoring period. This is often the case because the calculation methodology does not account for occupancy details (families vs seniors), and in some cases actual connected loads (as an example, lighting power density is set to the default value of 3 watt per sqft, which is based on incandescent lighting).

Using the NEC deemed calculation method, the existing electric main panel for both buildings can accommodate the additional heat pump load (see table below). However, had the calculated method shown a max amp draw greater than the existing service size (400 amps), the contractor or engineer could elect to follow the NEC load monitoring method which uses the actual 30-day monitoring period as the baseline load, and then adds the new calculated load to the baseline to confirm the existing service size is sufficient.

The table below also shows the results of a 28-day monitoring period post retrofit. The total electric load with the added heat pump load remains well below the electric main panel size in both buildings.

Electric Load Monitoring Summary	Baseline		Post Retrofit	
	NEC Deemed Calculation	Actual Amp Readings	NEC Deemed Calculation	Actual Amp Readings*
Maximum 3 Phase amp Draw from Service A Building	243	41	281	44.5
Maximum 3 Phase amp Draw from Service B Building	315	30	363	46.1

** Appendix F shows a post-retrofit plot of the daily electrical draw of Building A and B against the daily max and minimum temperature.*

Diagnostic Testing

Diagnostic testing was performed on a vacant unit (A201) heated with a wall furnace. The apartment passed minimum BPI Building Analyst criteria. Still, results indicate that apartments with wall furnaces at this site would be unable to undergo future ventilation or envelope upgrades without causing flue gas spillage from the heating system.

- No gas leaks were identified at the furnace (most gas lines were not accessible for testing)
- 1 ppm carbon monoxide was produced in the ambient air during wall furnace operation indicating some flue gas spillage

- Carbon monoxide flue gas level (as measured) was 5ppm. The combustion analyzer used for the project did not measure NOx levels; this information can be collected as part of a future project if necessary to characterize real world NOx levels of wall furnaces.
- The only exhaust fan present is the bath fan (hood over stove is recirculation type). Operating this fan depressurized the apartment by 2.0 pascals. The furnace experienced weak draft under depressurization and some flue gas spillage occured.
- While the nominal (rated) thermal efficiency is 70%, the tested thermal efficiency was 75%

Pre-retrofit Tenant Interviews

Pre-retrofit tenant interviews were performed prior to the retrofit to understand resident perspectives on their existing heating system, comfort, and utility cost, with selected results compiled below (**see Appendix B for a sample interview form used**). With 13 of 24 total respondents, the interview had a response rate of 54%, of which nine had wall furnaces, and four had ducted gas furnaces.

All ducted furnace users reported regularly using their furnace. In contrast, only a third of wall furnace users reported frequent use. The other two-thirds either never use the wall furnace or only use it infrequently, which is consistent with anecdotal conversations with multifamily tenants who have wall furnaces. Of the six residents who reported not using their wall furnace, only one reported using an electric space heater. Overall, 85% of respondents said they were comfortable when it is cold outside in the winter.

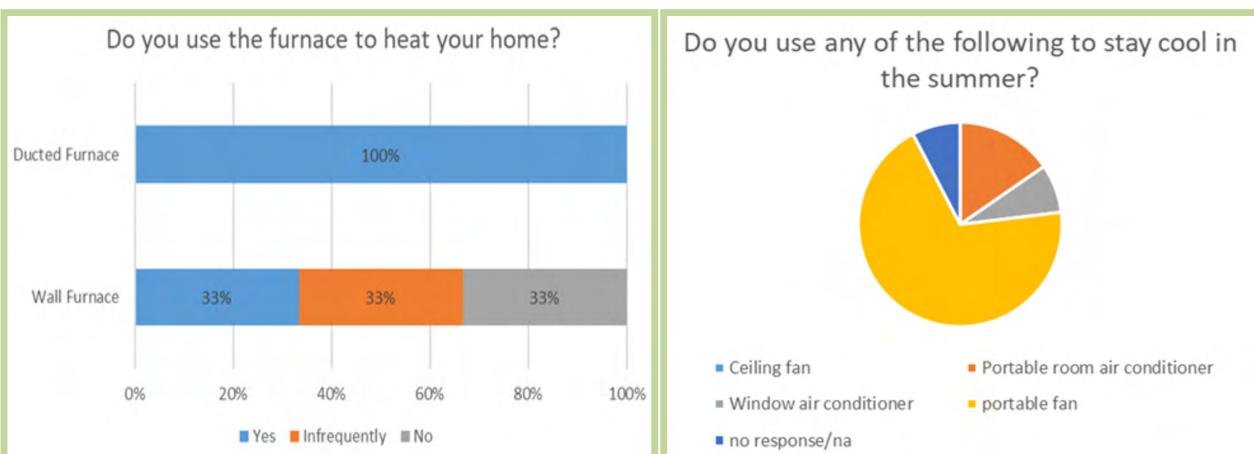


Figure 3: Pre-retrofit interview tenant responses

However, almost half of respondents (46%) indicated they were not comfortable in the summer, with 100% reporting the use of some form of supplemental cooling during the summer. It should be noted that no correlation was found between uncomfortable residents and their location in the building, such as upstairs or south-facing units.

Post-retrofit interview results are located in **section 8, Project Results.**

Recommended Energy Conservation Measures (ECMs)

Recommended Energy Conservation Measures (ECMs) In addition to developing multiple heat pump HVAC solutions for the project the following ECMs were identified and are recommended for the site:

Low Cost Recommendations	**Capital Expenditure Recommendations**
Replace existing apartment and site fluorescent lighting with LED	Replace gas furnaces with heat pumps - provides cooling benefit and increased heating efficiency and eliminates gas hazards in apartments
Install exhaust fan time delay/humidistat to extend bath fan run time after showering.	Install ducted range exhaust and replace bath fans with energy star (constant low speed boost to high speed on occupancy). Only do this after upgrading wall furnaces to avoid significant flue back drafting issues.
Replace old refrigerators (model seen rated at 691 kWh/year) with Energy Star models that use ~350 kwh/year	Replace electric coil stoves with induction – significantly improved safety (eliminate fire danger, major burn risk)
Replace 1.6 GPF toilets with 0.8 GPF flapperless (Niagara or equal)	Install solar PV
Insulate attics to R50, Insulate and weatherstrip attic hatches	Upgrade metal framed windows to thermally broken T-24 compliant models. Only do this after upgrading wall furnaces to avoid significant flue back drafting issues.
DHW distribution • Test for cold/hot water crossover • Replace recirculation pump with variable speed w/ thermostatic balancing valves or demand control • Install low flow handheld showerheads	Replace central gas water heaters with heat pump water heaters Replace gas furnace in common room with air source heat pump

Photos of Existing Conditions

The following images provide a visual representation of existing conditions documented during pre-retrofit visits the site of the pilot project:

Figure 4: Typical one bedroom apartment showing wall furnace (covered removed) in living room (left), and rear vent in bedroom (right)

Figure 5: Typical gas forced furnace seen in two-bedroom apartments

Figure 6: Fans and room AC units seen throughout the site to provide comfort cooling

Figure 7: Existing electrical room (left), 70-amp apartment main breaker (center), typical apartment sub panel (right)

Figure 8: (from left to right) Diagnostic testing results showing -2.0 pa depressurization, 1ppm ambient CO, 5ppm CO in flue gas, and image of wall furnace testing

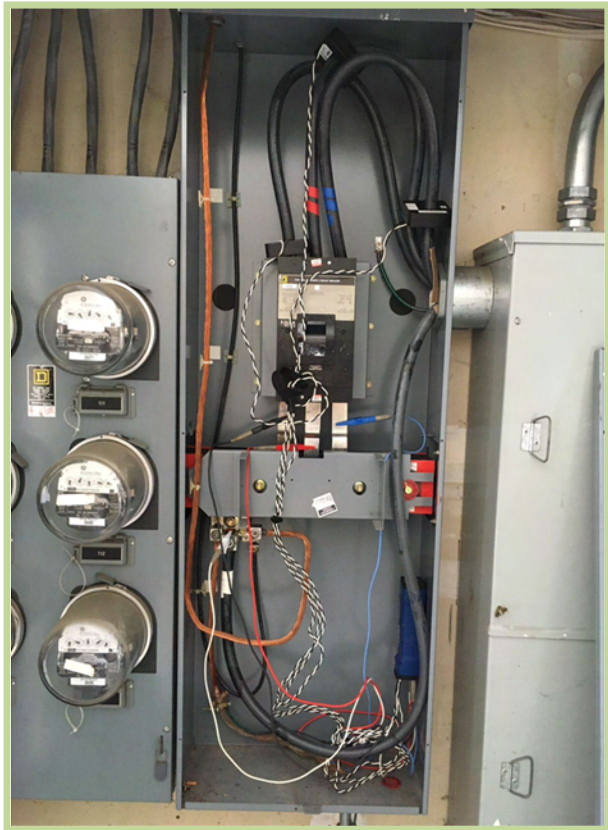


Figure 9: Electric load monitoring installation at main disconnect feeding apartment meters

4. BENCHMARKING

Overview

CPAU provided utility consumption data for the project site covering the period from 2017 to 2019, which AEA reviewed for three primary purposes:

1. Confirm baseline performance and utility cost
2. True-up energy model to more accurately model savings
3. Review potential bill impacts from electrification

Baseline Performance

AEA's review of baseline benchmarking data found that baseline energy use was in line with "typical" peer properties, as shown by a comparison against 58 completed properties from other incentive programs (BayREN and LIWP).

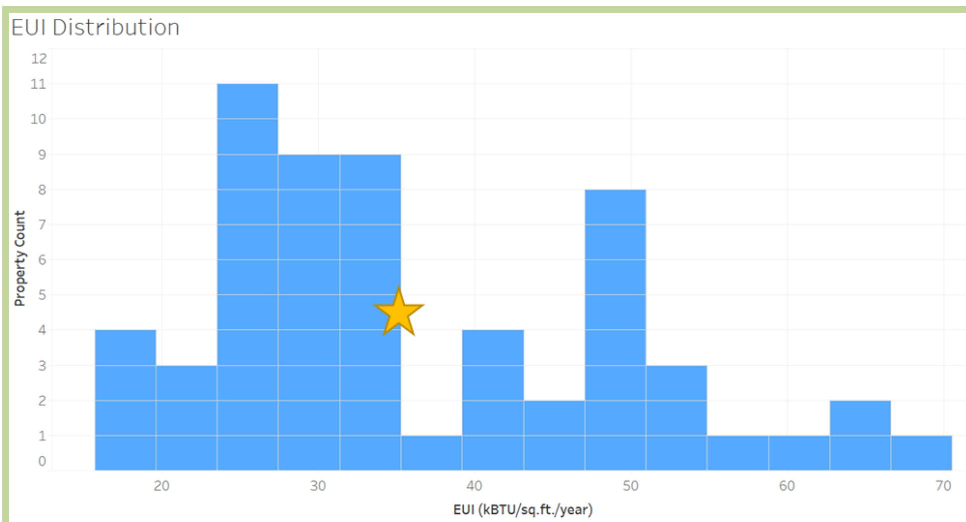


Figure 10: Project's EUI is 36 kBTU/sq ft

AEA's review of baseline data showed a winter-time seasonal peak for residential gas use in aggregate, but the overall gas use was lower than expected, and a closer review of apartment-level data revealed that some residents did not use their furnaces very extensively during the baseline period (this data was available before surveys were received). The apartment-level energy use also showed a significant variance between high and low electricity users on a monthly basis, particularly among one-bedroom apartments with wall furnaces. This wide range of electricity use may be driven (at least in part) by the handful of apartments that use portable electric space heaters in the winter and portable AC units during the summer.

		Apartment Type					
		Min. Elec Kwh		Avg. Elec Kwh		Max. Elec Kwh	
		1 bedroom	2 bedrooms	1 bedroom	2 bedrooms	1 bedroom	2 bedrooms
2019	January	37.0	16.0	188.8	150.9	593.0	372.0
	February	68.0	31.0	201.8	182.1	607.0	332.0
	March	71.0	36.0	187.4	193.0	625.0	381.0
	April	61.0	31.0	169.9	168.3	507.0	301.0
	May	61.0	35.0	180.9	169.0	391.0	294.0
	June	69.0	40.0	204.8	169.1	438.0	264.0
	July	95.0	44.0	215.9	151.5	407.0	249.0
	August	105.0	19.0	225.4	160.4	548.0	236.0
	September	102.0	20.0	210.0	144.5	551.0	236.0
	October	105.0	41.0	209.1	149.3	414.0	228.0
	November	84.0	32.0	165.7	153.0	329.0	240.0
	December	79.0	91.0	181.6	173.3	444.0	263.0

Figure 11: Monthly min, avg, and max electricity use, by apartment type

Given the results of AEA's review, the energy savings potential may be slightly lower at this site than at a property with more "typical" operation of existing heating systems. Assuming that this is an indicator that residents don't use their heating system but would benefit from added heating, the baseline data presents an opportunity to improve resident comfort potentially without increasing monthly bills through the provision of high-efficiency heat pumps.

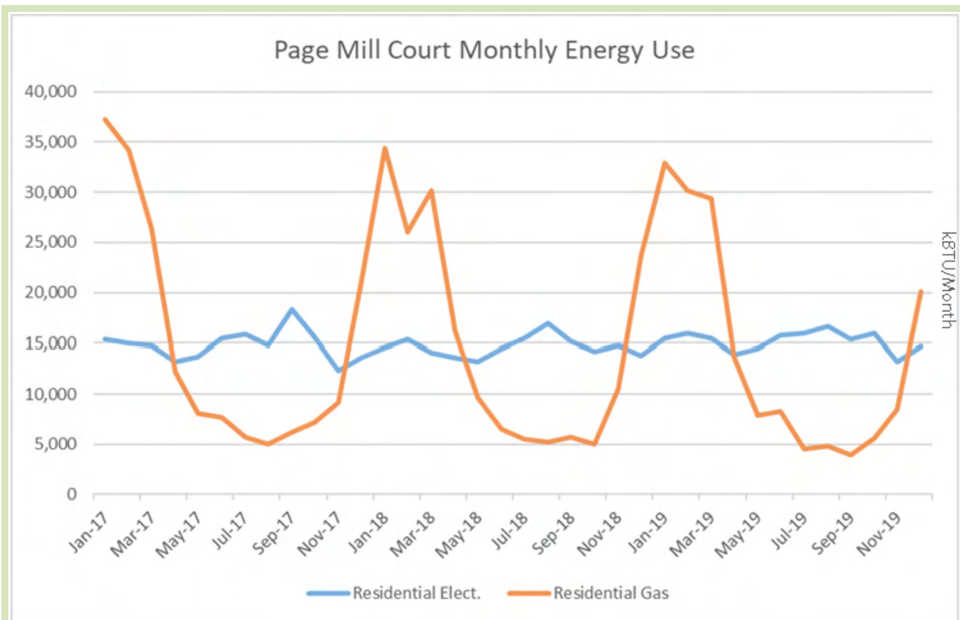


Figure 12: Project Site Monthly Residential Gas and Electricity Use

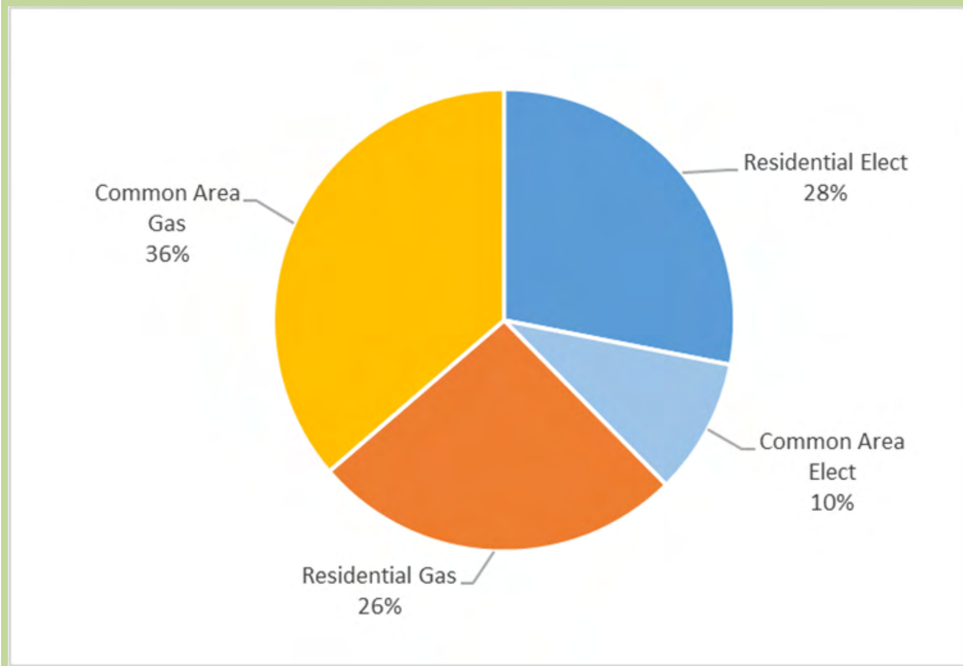


Figure 13: Comparison of common area vs. tenant energy use (2019 annual data)

Analysis of Energy Savings Potential & Bill Impacts

Having access to meter-level electricity and gas use also allowed AEA to true-up energy model predictions, to see how the property performs on average compared to the model, as well as potential impacts for apartments that are above or below typical energy use ranges. We found that the energy model's predicted gas consumption was close to the average, with the exception of summer months where actual bills revealed that many apartments with wall furnaces have year-round gas consumption (due to pilot lights, which maintenance staff only turn off when requested). We focused on three scenarios when reviewing potential energy savings: low, average, and high consumers. We found that apartments with the highest baseline heating use will likely see the most extensive energy use reduction. However, the energy savings should still be significant even for low consumers.

AEA reviewed potential utility bill impacts of electrification by layering actual baseline energy use for appliances and lighting with modeled heating/cooling load for new heat pumps, using the same three scenarios of low, average, and high consumers.

	Modeled Annual Operating Costs (elect and gas)				
	Baseline *(Actual historic usage applied to today's rate structure)*		**Heat Pumps** *(Baseline plug loads plus modeled heating & cooling)*		
	Disaggregated Costs	*Total Cost**	*Disaggregated Costs*	*Total Cost**	*w/o Fixed Gas Meter Charges*
Low Users	Plug loads: $129 Heating: $26 + $130 fixed meter charges = $156	**$330**	Plug loads: $129 Heating & Cooling: $83	**$361**	**$231**
Average Users	Plug load: $323 Heating: $91 + $130 fixed meter charges = $221	**$602**	Plug loads: $323 Heating & Cooling: $100	**$582**	**$452**
High Users	Plug load: $917 Heating: $181 + $130 fixed meter charges = $311	**$1,320**	Plug loads: $803 Heating & Cooling: $160	**$1,269**	**$1,139**

*Includes Utility Users Tax

Figure 14: Project Modeled Annual Operating Costs

Primary findings of utility bill analysis:

- The utility bill cost of added cooling load should be relatively insignificant, ranging from approximately $15 - $40 annually (based on energy model projected consumption).
- Fixed meter charges ($10.89 per month) make up about 60% of current annual gas costs for the average apartment.
- Bills for residents who currently have average or high energy use should stay fairly flat if gas meters remain, with the potential for slightly decreased cost. Removing gas meters should result in annual savings.
- Bills for residents who are not currently using their wall furnaces, or who use them infrequently, will likely go up if gas meters remain and they follow more average heating patterns after heat pumps are installed. Removing gas meters should counterbalance this increase and result in overall cost savings for low users.
- Eliminating fixed gas meter charges is a strong pathway to cost neutrality or savings for electrification projects in Palo Alto.
- Future sites with multiple gas end-uses may present challenges to achieve utility bill neutrality/savings if it's not possible to electrify all end-uses and remove gas meters (thereby eliminating monthly fixed charges).
- If customers qualify for financial or medically qualifying rate assistance, they are eligible for a 25% discount on both utility rates and the monthly gas meter charge. The calculations presented above do not include this potential rate discount. It should be noted that 15 out of the 24 tenants in this complex are on rate assistance and property management is actively encouraging all tenants to enroll in rate assistance.

Once post-retrofit utility data is available property performance should be re-analyzed to determine the following:

- Changes in energy use and utility costs, including confirmation of how cost savings is impacted by fixed charges for gas meters
- Overall change in EUI at the property post-electrification
- Identifying any higher than typical users and confirming any O&M or education needs to help drive down utility bills (are any residents still using space heaters and window ACs, for example?)
- Review relative energy use and cost impact of heating versus cooling post-retrofit

5. Scope Development

Equipment Sizing

AEA performed heating and cooling load calculations early in the scope development phase to help with equipment selection (bidding contractors were aware that they would be responsible for final load calcs). Manual J and ASHRAE load calculation methods were used for these calculations; the more conservative results from Manual J were ultimately used for heating, and ASHRAE was used for cooling.

During preliminary bidding, each of the three bidding contractors proposed larger output equipment than was indicated by initial load calculations, citing various estimates or rule of thumb recommendations. The awarded contractor worked with a third-party firm to perform load calculations during the design phase. These calculations also resulted in much larger output equipment than was initially estimated, and through various meetings reviewing existing conditions assumptions, the contractor was able to reduce the equipment sizing. The pros and cons discussed during these meetings included:

- Oversized equipment speeds up recovery times, especially for residents used to oversized furnaces
- Oversized equipment leads to short cycling especially during typical heating days when loads are low. Short cycling decreases comfort and increases equipment wear and tear
- Right sized equipment (in this case) would result in smaller compressors which take up less space on patios and cost less to purchase and operate
- Selecting equipment that did not meet the load for a de minimis number of heating or cooling hours out of the year was acceptable
- Calculated cooling loads did not factor in existing fixed shading elements at the site or significant tree shading and were likely overstated

The contractor and the building owner agreed on the final sizing selection, resulting in a final equipment heating capacity that was 40% smaller than existing wall furnaces and ~60% smaller than the ducted furnaces. However, this final sizing was still 150% to 200% higher than AEA and the contractor's final design loads. The following box plots show the min, median, and max calculated loads for each apartment type at the site.

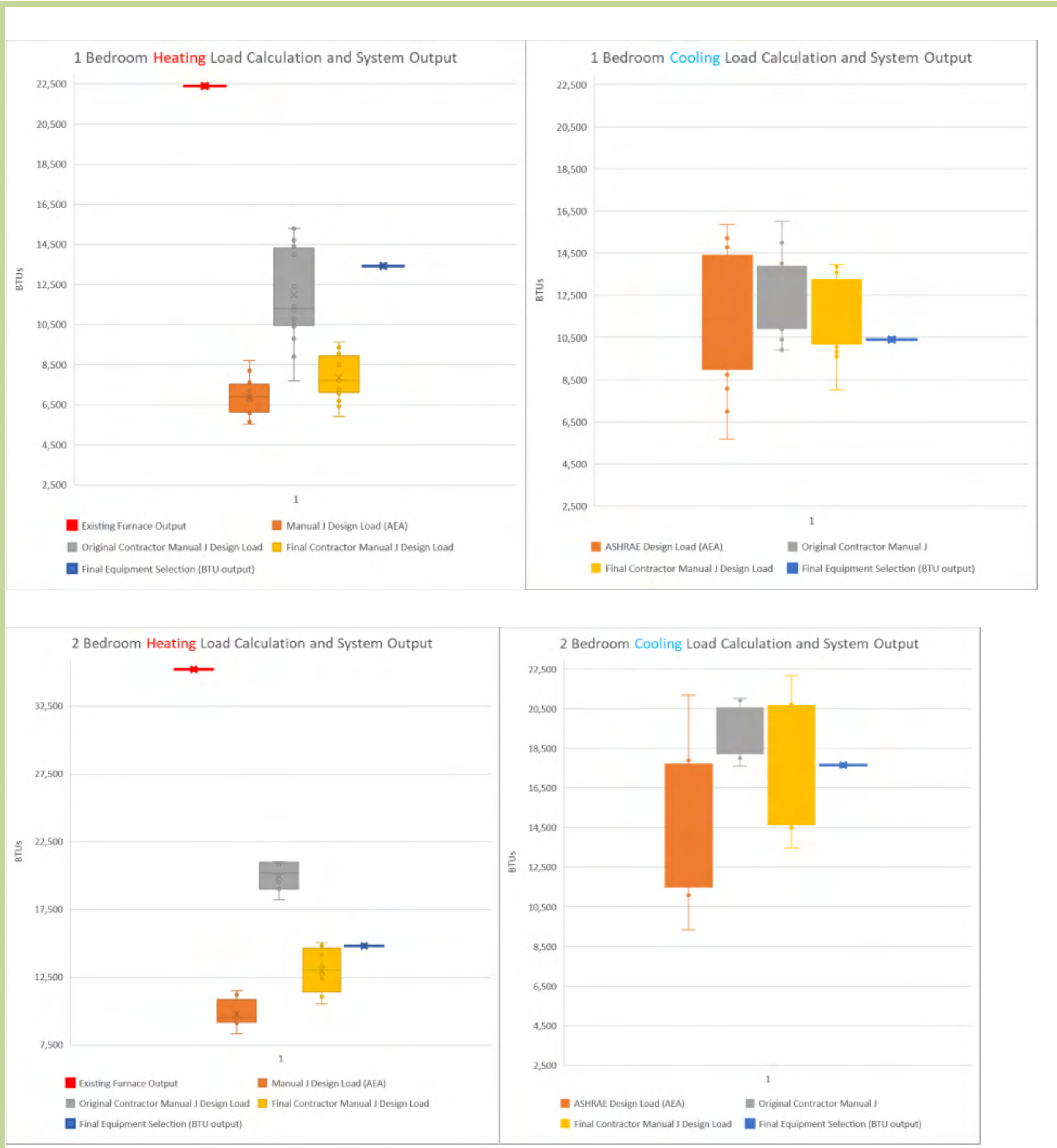


Figure 15: Min, median, and max calculated loads per apartment type at project site

Equipment Selection

AEA initially investigated three potential heat pump HVAC products for the project. They were reviewed with bidding contractors during an initial feasibility site visit. Bidders were asked to price various solutions for the one-bedroom wall furnace installation that included one heat pump in each room and a single heat pump with an air share fan located in the living room. Ultimately the Ephoca system option shown below was slightly too tall to fully fit under existing windowsill heights (and the vertical, narrow version of the system was not yet available for purchase), so it was not pursued beyond initial bidding. Ultimately, the building owner's construction manager eliminated the airshare fan as a bid option, citing success on their other projects where a single ductless fan coil located in a living room was sufficient to maintain comfort in a one-bedroom apartment without using an airshare. The final project performance requirements document reflective of the planned scope of work is located in the **Appendix C** of this report.

Name	Description	Pros/Cons	Image
Ephoca HPAC*	Inverter driven package terminal heat pump (ductless)	No outdoor compressor to locate, low BTU output, must be located on exterior wall	
Mitsubishi Ductless Heat Pump *(selected for 1 bed apts)*	Split heat pump utilizing outdoor compressor and indoor ductless fan coil	Flexible interior location for fan coil, requires outdoor compressor and lineset, electrical, and condensate line to run from fan coil to exterior, able to right size equipment in low load apartments only when using a single fan coil (when multiple are used the minimum size available was much larger than needed).	
Mitsubishi Ducted Heat Pump *(selected for 2 bed apts)*	Split heat pump utilizing outdoor compressor and indoor ducted fan coil	Easiest to retrofit in existing ducted distribution system, requires outdoor compressor	
Tjernlund Aireshare Fan (considered for 1 bedroom apartments)	Small fan meant to exchange air from one room to an adjacent room to promote heating/cooling distribution	Easy to install in existing wall where wall furnace is installed, are not intuitive to control (on/off switch), mixed opinions on efficacy from speaking with building owner and Mitsubishi's performance team	

Figure 16: Potential Equipment Options

Bid Results

The final bid results noted below were based on installing a single ductless mini-split in one-bedroom apartments and the ducted heat pump in two-bedroom apartments. The costs shown include all overhead and markup but did not include city permit fees. While the selected contractor was not the low bidder, the owner felt more comfortable in this contractor's ability to support the project during construction. Itemized costs for this final selected bid are also shown below.

	1 Bed cost (ea)	**2 Bed cost (ea)**
Contractor 1	$ 11,021	$ 16,858
Contractor 2 *selected*	$ 13,385	$ 17,423
Contractor 3	$ 16,081	$ 22,317

Bid Breakdown	**1 bedroom (ea) Ductless heat pump, one head unit)**	**2 Bed (ea) Ducted heat pump**
Heat Pump Install Labor	$4,300	$5,050
Electrical	$2,700	$2,700
Heat Pump Material	$2,364	$4,251
Drywall, patching, painting	$1,200	$1,100
Overhead & Profit	$1,164	$1,514
Demolition	$650	$500
General Conditions	$582	$757
Wall Mount Thermostat	$300	$300
Manual J Load Calcs	$125	$400
Seal Ductwork	$0	$300
HERS testing	$0	$550
Total	**$13,385**	**$17,423**

Figure 17: Itemized costs of the final selected bid

6. PERMITTING

Property Line Setbacks

Early in the project scoping phase, the project team reached out to Palo Alto's Planning department to review potential requirements and barriers to installing the proposed heat pump equipment. Early in project development, assistance from the Planning department was critical in paving the way for approval for the project. Through their assistance, it was eventually discovered, looking through original conditions of approval for the project, that the buildings on site were built right up to property line setbacks. In many cases, each apartment's second-story decks and first-story patios were initially approved to be built over the edge of the property setback line. While the Planning department was clear that in no instance could the heat pump extend over the setback line (to avoid potential future complaints from adjacent neighbors and to stay within planning requirements), they were able to approve locating the equipment within porches. They considered the existing railing and fencing sufficient to meet the aesthetic requirements of shielding mechanical equipment from public view. The image below shows a first-floor location on the site with a 15' setback. Unit A104's patio is shaded blue, the setback line is drawn in red, and potential compressor orientations are shown in dark blue with a red arrow. Based on Planning department guidance, the compressor location shown crossing the setback line would not meet Planning requirements. Fortunately, the building owner and city Planning department were comfortable with a compressor located parallel to the building, which required placement in front of part of the fixed side of each sliding patio door.

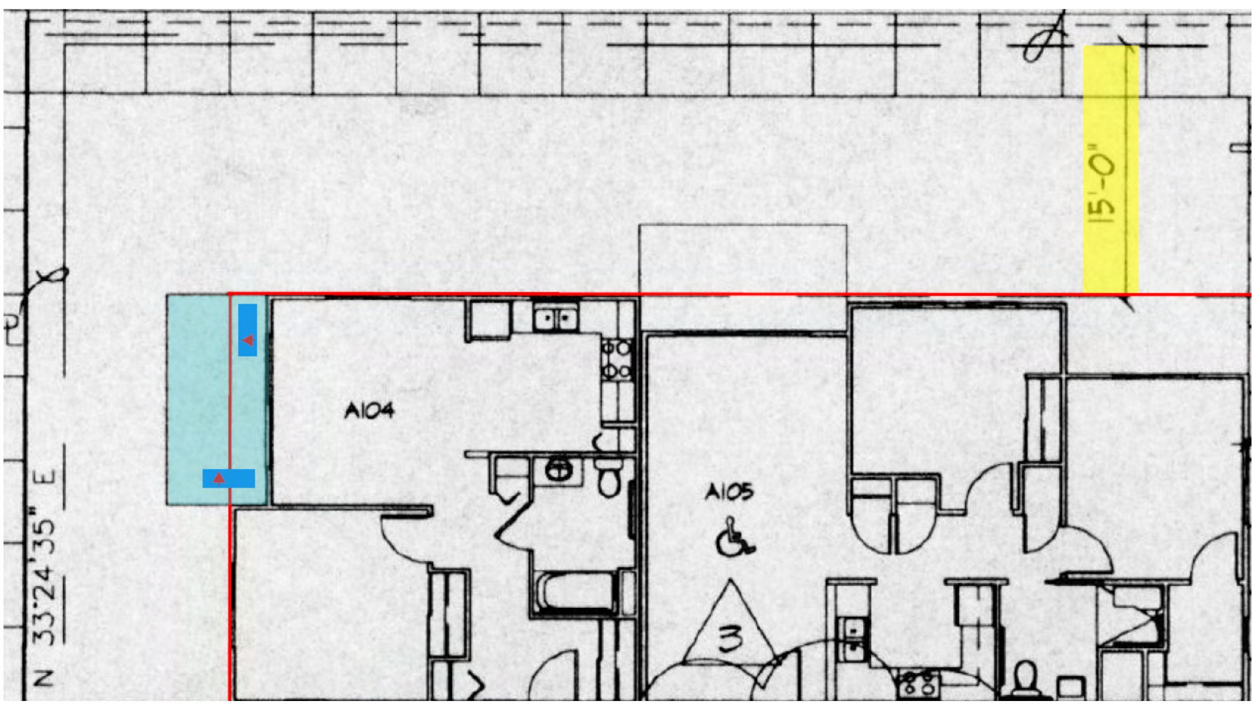


Figure 18: Illustration of site setback (red) and potential compressor orientations (dark blue)

When asked about the packaged terminal heat pump units, the Planning Department confirmed that the Ephoca solution (shown below) would have likely met guidelines, assuming the exterior compressor terminations were painted to match the building.

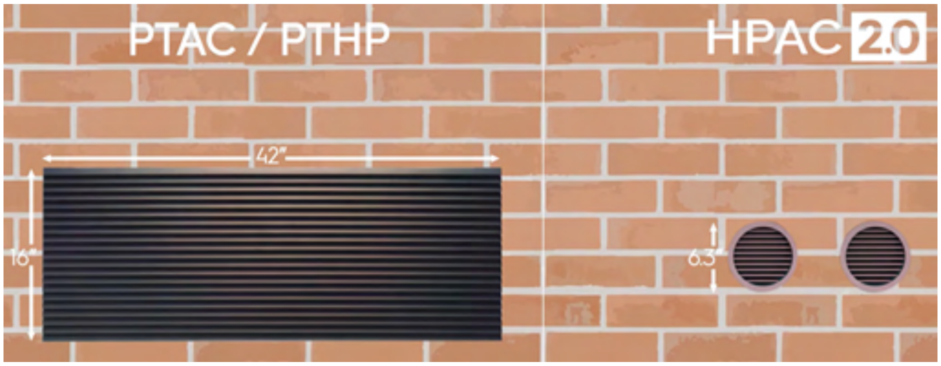


Figure 19:Image Courtesy of Ephoca Website, two holes shown on right represent Ephoca termination, image on left represents a typical package terminal heat pump termination

Architectural Review & General Guidance

The selected contractor was unfamiliar with Palo Alto's planning and building permitting processes. Since this project involved the placement of compressor units outside the building, the project needed to apply for a minor architectural review by the City's Planning Department prior to applying for a building permit. The back-to-back minor architectural review and permitting process took just under three months to complete, with active engagement from MidPen's project manager, CPAU staff, and the City's Building and Planning officials.

Based on the pre-development work with the Planning Department the following outlines general initial guidance for installation of heat pump HVAC in Palo Alto:

1. If the project involves the placement of compressor units outside the building (typical), it is subjected to a Minor Architecture Review prior to applying for a building permit. Compressors must remain behind property setback lines.
2. A copy of the site plan that shows the locations of the compressors for both ground-level and upper floor units needs to be included.
3. Compressors that are located behind a balcony fence do not require additional screening.
4. Compressors located outside the building will require some shielding (e.g. fencing or planting) to screen the equipment if visible from the street.
5. While noise levels for outdoor heat pump equipment must meet the City's noise requirements, variable speed heat pump equipment appears to easily meet these requirements.

Schedule a pre-application meeting with the Planning Department to review proposed compressor locations, shielding, and confirm property setback lines whenever possible to confirm compliance with requirements prior to submitting a complete permit set.

7. Construction

Process and Challenges

Construction overall was a smooth process, aided significantly by the preparation work from the owner's project manager in assisting proactively with resident needs (especially during covid, which required providing support for residents during the day when construction workers occupied their apartments). Additionally, the project benefited from weekly check-in meetings during construction and performing a "first in place" installation of one-bedroom and two-bedroom installations before starting construction on the remaining units. These first in place "mockup" installations allowed AEA, the owner, and contractors to resolve unforeseen issues and set work quality expectations. The scope generally remained per plan, and no change orders were required during the course of work. However, the owner initially wanted the contractor to hide electrical, condensate, and line sets behind drywall wherever possible. During construction on the mockup unit, it was discovered that this routing on downstairs units was not going to be feasible, and the team elected to allow the contractor to move back to surface-mounted line sets hidden behind trim. Additionally, the project team had originally encouraged and requested that ductless head units be installed on the living room wall opposite the bedroom door, allowing direct airflow from the fan coil towards the bedroom door. In practice, it was more challenging to locate equipment in this location given routing back to the compressor, and only a handful of apartments were installed in this manner.

Occupied apartments also presented typical challenges, including moving resident furniture (performed by the building's maintenance supervisor) and requiring multiple entries in a resident's home to perform drywall patch, repair, and painting work, which is disruptive for residents and difficult to schedule and prepare for contractors. The final city building inspections did not present any major punch items, and the contractor sufficiently completed all owner and AEA punch list work.

In Progress & Post-Construction Images

The following images provide a visual representation of in-progress conditions and post construction documented during the pilot project:

Figure 20: Typical one bedroom apartment showing compressor on deck in front of fixed sliding door pane

Figure 21: All combustion air openings and flue pathways were sealed in furnace closets as part of the retrofit (left); Typical gas line capping – all gas shut offs for wall furnace were accessible through access panels located in the bedroom (right)

Figure 22: In progress view showing surface mount line set and hole in drywall to run new electrical (left); In progress photo showing line set hidden under cove trim in two-bedroom apartment (right)

Figure 23: Typical (larger) two-bedroom compressor on patio (left); One bedroom unit with installed ductless fan coil, wall patched, line set cover boxed out (right)

Figure 24: Thermostat used for both ducted and ductless heat pump installs

8. Training

Resident Training

Resident training was an important aspect of the project. During the in-person training provided to residents by AEA in late November after construction was completed, most residents admitted they hadn't tried to use their heating system yet, even though it was cold winter weather. Given this, it's possible to imagine a scenario where another project (without training) could result in residents who continue to use their inefficient portable space heating/cooling appliances or who cannot get the comfort and utility savings benefits of using the new system.

The training included the following:

- **How to operate the thermostat** - AEA worked with Mitsubishi early on in the project to identify the simplest thermostat option available and developed a customized, laminated instruction card posted next to each thermostat as a reference guide. Some functions were turned off to further simplify the thermostat, including 7-day programming, relative humidity readings, and auto switch over between heating and cooling.
- **Prioritize heat pump -** some residents at the site use electric space heaters and portable AC systems and were impressed to learn that their new heating system is 3x more efficient than electric space heaters and more efficient than portable AC. The maintenance supervisor indicated that he would continue to remind residents of this during unit inspections if he saw these appliances being used.
- **Avoid on/off operation -** heat pumps operate most efficiently at slow recovery speeds. Residents were encouraged to leave the thermostat set to a comfortable temperature while home and to turn off the system only if they would be out for the entire day. In making this recommendation, it was necessary to compromise maximum efficiency (avoiding large setpoint increases when people come home) and clear instructions. The expected energy penalty to follow this regimen (given the size of apartments and heating/cooling load) should be small.

Maintenance

The installing mechanical contractor and AEA provided property and regional maintenance staff **maintenance instructions**. Typical long-term maintenance issues seen with heat pump systems are often a result of infrequent filter and condensate pump maintenance, leading to coil soiling and condensate overflow. Compounding this, it is typical to see frequent maintenance staff turnover. Fortunately, this building owner has a more rigorous organizational maintenance plan and video-recorded the training. Otherwise, permanent labels on equipment would have been a minimum recommendation to remind future maintenance staff of necessary tasks.

Maintenance instructions during the training included:

- Demonstration of how to clean filters, discussion of frequency and inspections
- Demonstration how to clean/service/check condensate pumps
- Demonstration how to re-connect wireless thermostats and change batteries
- Discussion of coil cleaning, use of in house staff vs outside vendor

Training & Educational Materials

The following images showcase training sessions provided to residents and maintenance staff, as well as educational materials for the pilot project:

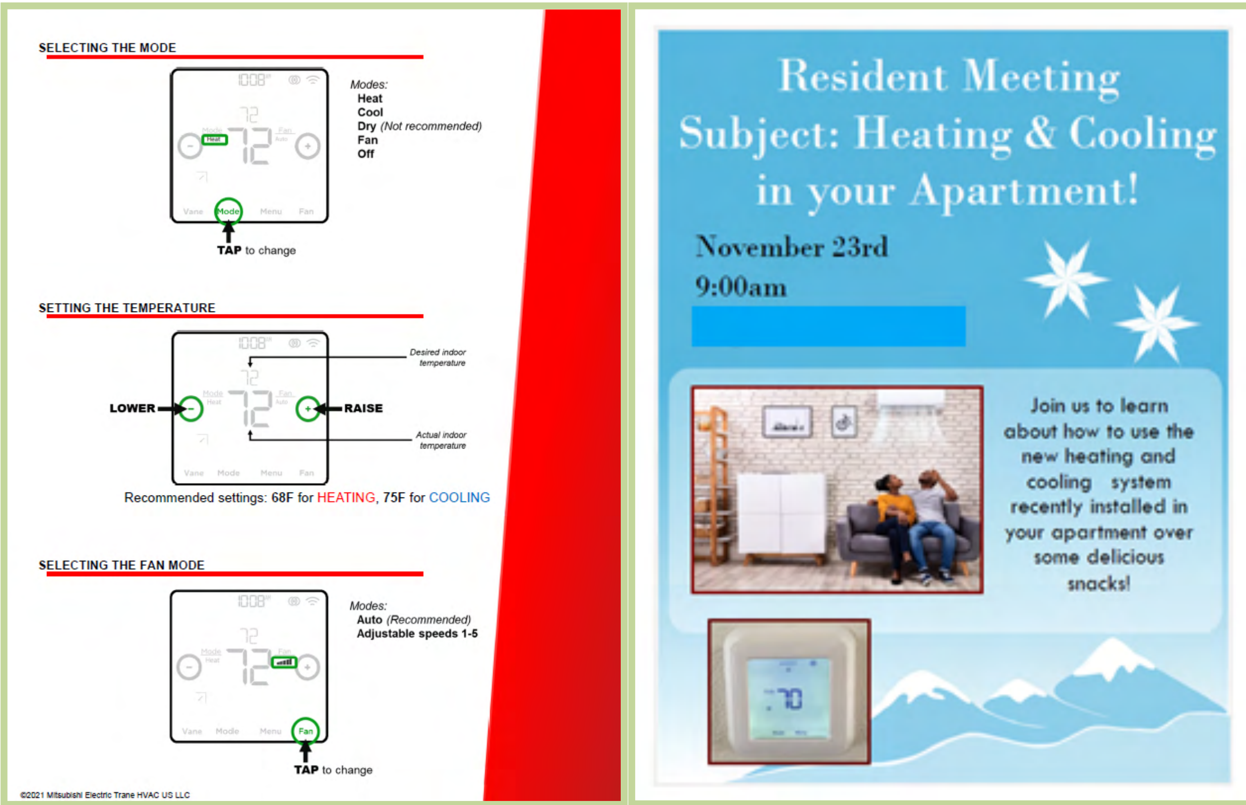


Figure 25: Customized instructions, laminated and posted next to each thermostat (left); Owner notice for tenant training (right)

Figure 26: Resident training (left); Maintenance Staff training (right)

9. Results

Post-retrofit Tenant Interviews

Post-retrofit tenant interviews were performed during the winter heating season, roughly one to two months after the last apartment system was completed, to gauge resident perspectives on their work performed and the new system (**see Appendix D for a sample interview form used**). It should be emphasized that the interview was performed relatively soon after the construction work had been completed and required assistance from the owner's project manager to interpret resident opinions in some instances. That said, with 15 of 24 total respondents, the interview had a response rate of 63%, of which seven had ductless mini splits and eight had ducted heat pumps. All respondents reported using the new heating system, with 73% finding the thermostat and thermostat guide easy to use. 80% of residents indicate that they "are more comfortable than before" (20% indicating they were "about as comfortable as before" or didn't respond to the question). In comparison, 13% indicate that they still plan to use an electric space heater. 73% of respondents also plan to use the new cooling function of the new system, while 13% of residents still plan to also use their room air conditioner. Selected write in comments from residents included:

"The (new) system is quieter."
"I still have to use a space heater for the bedroom."
"I still plan to use my fan during the summer."
"I need help with the thermostat, sometimes cold air comes on."
"I feel the new system is safer."
"I wish they had an air handler in the bedroom."

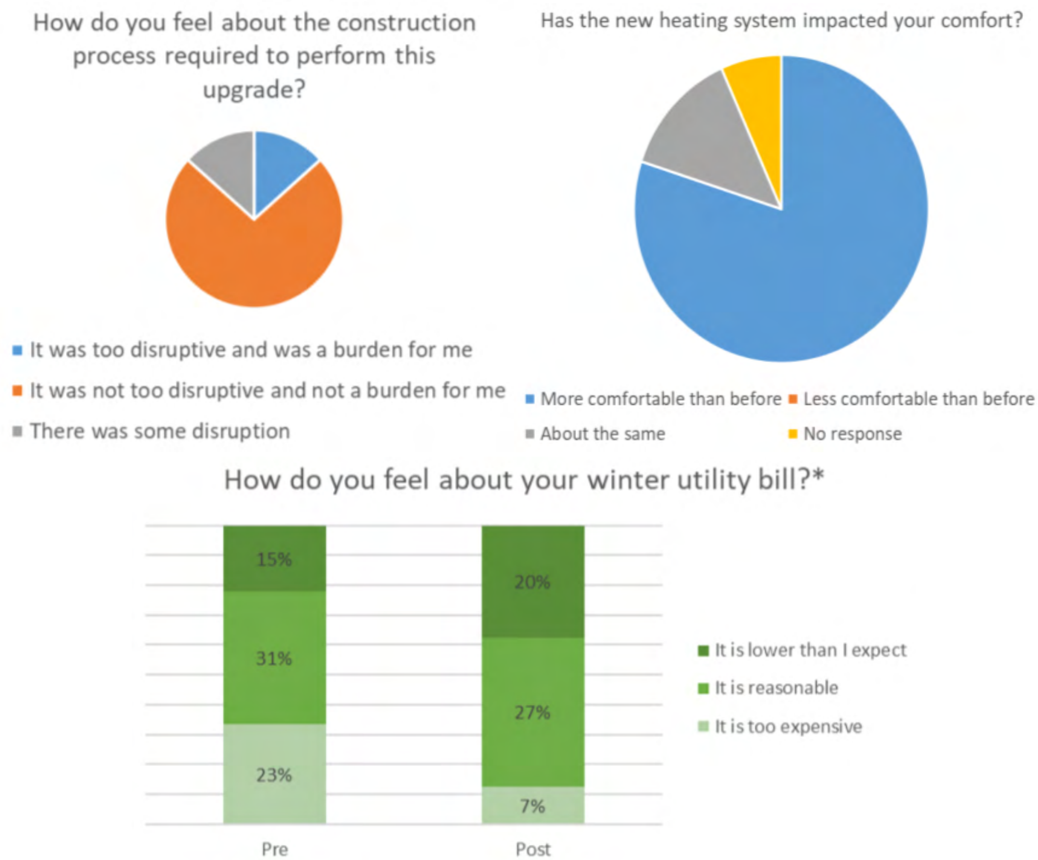


Figure 27: Results of post-retrofit tenant interviews

These comments ring true; while some present a reminder that additional training and support could be beneficial (thermostat issues), some residents are still not as comfortable in their bedroom as they could be, although 80% of residents still reported being more comfortable than they were before. While the owner knew of the potential comfort issue, more emphasis on locating the fan coil to blow towards bedroom doors may have improved this outcome in this property based on the one-bedroom floor plan, as could additional training to assist tenants in using their thermostat and ensuring bedroom doors stay open to allow heat transfer.

Multi-bedroom Apartment Served by a Wall Furnace

It should be noted that the solution of directing a single fan coil towards bedroom doors is much less effective in multi-bedroom apartments, which are often equipped with a single wall furnace located either in a hallway or the living room. This typical floor plan is much more difficult to retrofit with heat pumps. A single ductless fan coil unit may meet the BTU load of the apartment but distributing heat to multiple bedrooms is less likely to occur as the ductless fan coil can't easily be installed in the hallway and is, therefore, farther away from the old wall furnace location. Additionally, the fan coil is (and should be) right-sized, which reduces the amount of instantaneous heat residents were used to before the replacement. Heat pump retrofits for these floor plans are more expensive to perform and often either include: the use of an airshare system (marginal improvement in thermal comfort but opportunity to add improved air filtration), multiple ductless fan coils (which tend to increase the required system size and electrical impact, not to mention the physical impact of locating the fan coils in small bedrooms); or ducted heat pumps which require building soffits or dropping some ceiling locations to accommodate the new ductwork.

Energy & Cost Performance

Energy and cost performance is being tracked for the project. As of the writing of this report the post retrofit utility data is not yet available to review. An addendum to this report will provide the following post-construction results:

- Aggregate reductions in energy-use and GHG-emissions
- Aggregate utility cost impact
- TBD - additional analysis based on above results

Contractor Interviews

Contractor Interviews were performed at the end of construction to understand construction installation time for the retrofit and future considerations for similar projects that may potentially save time or installation cost. During the interview, the contractor acknowledged the initial permitting confusion but indicated that permitting went smoothly thereafter once the desired process was clarified. They did indicate that a single point of contact at the city to facilitate the permitting process could be useful for future projects. When asked if relocating tenants (to a hotel) temporarily would speed up construction, they indicated that as long as access by the maintenance supervisor was provided from 8 am - 5 pm, this wouldn't significantly impact construction efficacy. Lastly, they agree that moving to fully surface mounted linesets and electrical with pre-painted covers has the potential to speed up the project and reduce the budget. The following is a summary of the time spent by trade per typical apartment (excludes GC oversight).

For a typical 1 bed retrofit (ductless)	Mechanical	Electrical	Finish
Person-hours to complete scope	22	16	32
Number of unit entries (# of days)	2	1	3

For a typical 2 bed retrofit (ducted)	Mechanical	Electrical	Finish
Person-hours to complete scope	38	16	32
Number of unit entries (# of days)	2	1	3

Figure 28: Time spent by trade per typical apartment

10. Conclusion and Recommendations for Future Programs

The following are preliminary recommendations based on the results and observations from the Palo Alto Heat Pump pilot project and AEA's experience in managing similar programs across California. Recommendations include those both specific to Palo Alto and those which have the potential to scale retrofits in other jurisdictions.

Technical Assistance

Most building owners won't have an experienced project manager on their staff and a technical consultant to advocate and guide the retrofit process. This will be especially true for smaller multifamily buildings and those held by owners with smaller portfolios ("Mom and Pops") who often lack the resources, scale, or prior experience to approach a larger project like this. The benefits of providing free dedicated technical assistance will often enable projects that would otherwise be technically challenging or facilitate a deeper retrofit. For example, even for this relatively standard project, the electrician that initially visited indicated that a utility service upgrade would be required to accommodate the added load of the heat pumps; this potential cost/concern typically stops project development without intervention from a third party to encourage further investigation. These roadblocks are magnified when undertaking larger retrofits requiring coordination between various trades (and/or engineers) to ensure an integrated approach to the feasibility assessment phase of a project. For additional resources navigating electrical challenges, please see the report conducted by AEA and StopWaste titled "Accelerating Electrification of California's Multifamily Buildings."

Contractor Selection

In addition to providing the owner with third-party technical assistance, encouraging them to work with contractors with appropriate experience and credentials can also help ensure that this critical team member is aligned with the project goals. To this end, "home performance" contractors are practitioners of delivering integrated retrofits (envelope + HVAC) and in right sizing heat pump equipment. Additionally, selecting a contractor with design-build and permitting experience with multifamily electrification retrofits will encounter fewer surprises during project development and installation. Lastly, creating standardized performance and installation requirements will help provide additional consistency when receiving multiple bids. An example performance requirements document (used for this project) is provided in **Appendix E**.

The following is an example of what an owner may need to look for when evaluating a potential bid:

- Bid cost
  - Is cost competitive? Where cost seems too low or high does the scope appear to be omitting necessary scope, or adding unnecessary scope?
  - Are all requested project elements included in bid? If not did the contractor adequately address this?
- Experience
  - Has owner worked with contractor before (with success) or do they have positive multifamily references? Years of experience?
  - Experience with (similar sized) design-build and permitting of multifamily HVAC retrofits (e.g. developing necessary plans and project documentation)?

    - Experience with mini split heat pump installation (is this a standard solution that the contractor installs as part of their day-to-day business?). Do the contractors have any technicians that are certified or trained in mini split installation and diagnostics?
    - Preference to contractors who have experience working in that city or jurisdiction.
- Proposed scope
    - Does it match or exceed minimum requirements?
    - Does it include excessive contingencies or exclusions that increase budget uncertainty?
- Professionalism
    - Does contractor have experience with managing work in occupied units (will they effectively manage their staff and subs related to unit notices/entry/etc)?
    - Will the contractor be easy to work with?

Stacking Incentives

Heat pump retrofit costs have the potential to drop somewhat through the increased scale of retrofits and mass adoption. Further efficiencies can be realized through fast-tracked or "over the counter" permitting processes, and significant cost savings can be achieved once "plug and play" heat pump technology (that utilizes existing electrical circuits) has a consistent code approval pathway. Heat pump equipment is still a more expensive product than incumbent gas technology despite the savings potential. While legislative initiatives can help balance the odds in favor of heat pumps (municipal gas equipment bans, zero-emission equipment standards, etc.), multifamily building owners will still incur a large incremental cost to make these upgrades relative to business-as-usual upgrades. Affordable housing and especially naturally occurring affordable housing (NOAH) properties will need assistance to make these investments. In most cases, a single incentive program alone (even when robustly funded) cannot provide enough incentives to make costly electrification retrofits happen. While owners should be encouraged to capitalize on other eligible funding, the burden of identifying and bundling these disparate funding sources is often out of reach for most owners, and technical assistance is usually needed to guide this process.

Statewide examples of multifamily efficiency and decarbonization funding include (note not all sources below can be "stacked"):

- Community Choice Aggregation (CCA), Regional Energy Network (REN), and Utility incentive funds for efficiency and fuel switching
- Electric Vehicle Service Equipment (EVSE) programs, which may help pay for the cost of infrastructure upgrades at a property when EVSEs are also being added
- The Low Income Weatherization Program (LIWP)
- TECH Clean California
- Solar on Multifamily Affordable Housing (SOMAH)
- Direct install programs for efficiency measures such as the Energy Savings Assistance (ESA) Program
- Demand response and load shifting programs for electric appliances (HVAC, water heating)

Additionally, new cross-cutting pilots are being implemented now that have potential to scale in the future including:

- Air district programs focusing on NOx or other pollutant reduction

- County health departments pilots focusing on interventions to improve health outcomes and reduce costs to the health care system
- (Municipal) utility programs that leverage funding from various internal sources (such as equity and new revenue departments)
- Utility pilots focusing on alleviating constrained infrastructure and improving resiliency are also being tested at the building and community level including microgrid projects, battery programs for at risk homeowners, and solar plus storage partnerships at the property level

Timing

Timing or aligning an upgrade with other related capital events at a project site also provides a critical leveraging opportunity. In the simplest scenario, this could be coordinating with an owner planning to replace existing failing equipment using incentive sources to make up the difference in project cost between their like-for-like budget and the more expensive heat pump budget. This might be feasible at scale if the owner planned to replace all equipment pieces. Still, in many instances, owners may only have the desire or resources to tackle a few apartments at the time of unit turnover, or the project may need to wait to take advantage of larger scale renovations or refinance events. In both cases, incentive program flexibility and longevity are useful to allow owners to make incremental improvements on turnover, while also providing confidence to owners who are planning out rehab work which often takes many years.

Bill Parity

Existing and projected utility costs at the site were evaluated with and without the fixed gas meter charge (see benchmarking, section 2). Based on this evaluation, AEA anticipates that post-electrification utility costs have a strong potential for increases at some sites depending on specific use patterns. While residents at this site are projected to see a reduction in utility costs, much of the savings are attributed to eliminating fixed gas meter charges since the gas furnace is the only gas appliance in each apartment. However, eliminating the fixed gas meter charge should not be relied on as a pathway to bill neutrality because many multifamily apartments (especially older properties) tend to have multiple gas end uses, including stoves which are challenging to electrify from an electrical infrastructure perspective. To avoid creating a disincentive for residential customers who can only electrify some but not all gas appliances, customers at a minimum need to see bill parity as each gas appliance is electrified without requiring an all or nothing approach, and ideally, customers should see utility cost savings as each gas appliance is electrified. This equity issue has an outsized impact on multifamily customers relative to single-family customers; upgrading electrical infrastructure in multifamily housing is disproportionately more challenging to perform. In most situations, multifamily buildings do not have access to receiving solar PV credits.

Over the Counter Permitting

Over the Counter Permitting processes for electrification work across all jurisdictions can eliminate participant confusion and barriers to entry, reduce time spent for all parties, and increase the amount of permitted work. This process could include some or all of the following features, and would have the secondary benefit of allowing projects to self-screen for potential barriers and solutions before submitting for permit:

This pathway would provide permitting and planning approval for *average* projects.

Contractors who opt to follow this pathway would follow a simplified set of submittal, equipment, and installation requirements. If this set of requirements can further be coordinated to apply to multiple jurisdictions in a region it will also help multifamily owners and contractors who work on projects in multiple cities and counties.

Qualified projects could receive heat pump permits “over the counter” (no wait period)

Projects meeting pre-approved planning and building requirements would not be required to submit architectural plans (creating plans is a cost barrier that prevents participation from small multifamily buildings and small contractor shops)

Use of a reduced, flat permit fee for all projects meeting the project criteria will increase program participation, permit rates, and reduce project costs. Permit fees can be expensive and can be unpredictable across AHJs.

As incentive programs increase pressure to electrify and install heat pumps, the program may need to contribute budget to AHJs who may need additional staff support to reduce the staffing burden for an increase in permitting or to supplement for loss of revenue if reduced or flat permit fees are used.

Encourage Adoption of New Technology

Innovative solutions that address electrification’s most difficult constructability barriers have existed for many years but are not yet clearly code-approved, which most building departments rely on when issuing permits. Leadership from building departments to review and accept exceptional pathways for new solutions is needed to prove the use case of these new strategies, which assists other building departments that often look for prior precedent when approving or reviewing a new technology. In parallel, the longer effort of writing and adopting new code pathways that clearly support these new technologies is required.

The following technology have the potential to reduce electrification barriers and scale retrofits:

- Smart electrical panels - are currently approved for avoiding main service upgrades in single family homes when performing EVSE installations but can be used in multifamily projects as a sub panel replacement to avoid costly feeder wire upgrades.
- Plug and play 120v heat pump HVAC and water heating products are available today (and were evaluated for the selected site). While there is code language that can be used to support using this equipment on shared electrical circuits there needs to be more code specificity around when and where this can be allowed.
- Encourage the development of low-amp induction stove products which are another pathway to avoid major electrical upgrades in multifamily buildings (emerging product).

Showcase Benefits in Program Promotional Materials or Events

The benefits of electrification are well supported outside of this report, a summary of results for the site include:

- Public health - During the recent heat waves and Covid pandemic the use of cooling centers was not feasible. Adding cooling to apartments provides resiliency for heat waves, especially for those who have limited access to transportation. Additionally, residents will benefit from improved indoor air quality (elimination of ambient carbon monoxide and other combustion byproducts) and improved air filtration. Lastly, elimination of NOx and other combustion byproducts is a step towards improving local air quality, especially so in disadvantaged communities that tend to be located next to multiple sources of air pollution.

- Comfort - All respondents in the survey of this project reported increased comfort during the winter, and additional summertime comfort will be provided now that residents have access to cooling and don't have to remember to request turning off their pilot lights (which aggravate overheating issues).
- Safety - Electrification of gas appliances reduce the risk from gas leaks, fires, and earthquakes. Where gas stoves are electrified using induction technology open flames and hot surfaces are eliminated, reducing the risk of burns and fire risk.
- Greenhouse gas savings - the project is projected to save 11.1 metric tons of CO2/year (inclusive of added cooling load) based on the heat pump retrofit.
- Predictable, reduced utility costs for low-income customers may be achievable with appropriate rates and discounts.

Forwards-Compatible Flexible Loads

All-electric upgrades being made now will ideally be forward compatible with California's future grid needs. Providing bonus incentives to align new equipment with these anticipated needs will help enable future programs to build capacity quickly, and will aggregate sufficient quantities of devices to allow a third party to start controlling loads. Controllable end uses in single family and multifamily buildings can include:

- Individual heat pump water heaters should ideally be sized enable load shifting (i.e. thermostatic mixing valves, minimum tank size) and which are CTA-2405 compatible)
- Central heat pump water heating systems should be sized to enable load shifting, and include controls that are backwards compatible to enable load shifting
- IOT connectable appliances and thermostats, smart electric panels, dispatchable EV charging and battery storage
- Thermally resilient buildings that can accommodate load shifting

Figure 29: Removal of gas meter at project site

APPENDICES

This appendix contains the following documents:

Appendix A: Multifamily Gas Furnace to Heat Pump Retrofit Pilot Recruitment Flyer
Appendix B: Pre-retrofit Tenant Interviews
Appendix C: Project Performance Requirements in invitation for Bid
Appendix D: Palo Alto Heat Pump Pilot Interview Questions – Post Construction
Appendix E: Minimum Duct Sealing Requirements
Appendix F: Site Post-Retrofit Electrical Load Monitoring Data

Multifamily Gas Furnace to Heat Pump Retrofit Pilot

Upgrade your building with help from the City of Palo Alto Utilities

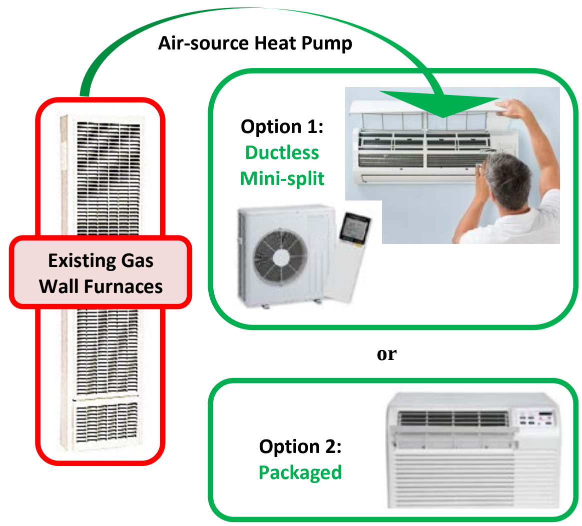
The City of Palo Alto Utilities (CPAU) is launching a limited time pilot through a 2018 Climate Protection Grant funded by the Bay Area Air Quality Management District to implement a Multifamily Gas Furnace to Heat Pump Retrofit Pilot program. This pilot program will help retrofit existing in-unit gas wall furnaces with energy efficient and clean electric space heating alternatives (ductless or packaged terminal heat pumps) for affordable multifamily properties within Palo Alto. Heat pump systems are far more energy efficient than gas furnaces; they eliminate greenhouse gas emissions associated with gas-fired space heaters while improving air quality within the dwelling units. We have determined that at least one of your properties may be eligible for this opportunity. We would like to have further discussion with your team on evaluating potential opportunities with this pilot program and other offerings we may be able collaborate or partner on.

CPAU issued an RFP to implement this pilot in December 2018 and has selected the Association for Energy Affordability (AEA) in February 2019 as the vendor to help with Pilot implementation and provided technical support for the selected site(s). The goal of the pilot is to identify viable retrofit options, costs, and energy savings for replacing gas wall furnaces with efficient heat pump alternatives. Results of this study will inform the development of future program offerings.

Benefits

- Improved efficiency and reduced greenhouse gas emissions
- Improved indoor air quality
- Modernized HVAC systems
- Installation and hardware costs covered by pilot

NOTE: Tenant move out should not be required for retrofit



Learn More

- Retrofit work is anticipated to start in 2019 (no later than Q2 2020)
- The pilot goal is to retrofit a minimum of 20 to 36 residential units and have existing gas wall furnaces replaced with heat pumps
- Multifamily properties consisting of less than 20 units may be eligible for the pilot, assuming additional eligible units can be identified at other property sites
- The pilot may be able to cover up to 100% of the installation and hardware costs depending on the retrofit complexity and the number of units selected. Additional funds may be available for sites larger than 36 units.
- Final pilot site selection will be based on technical and financial feasibility; owner's demonstrated ability, desire and engagement to complete projects within the timeline specified; and owner availability of additional funding (only) if sites are larger, more complex, or require additional work that cannot be covered by grant funds.

Next Steps

1) Confirm owner/organizational interest with property decision maker
2) Schedule a call with the property's decision maker and technical consultant from AEA to determine if the identified sites should move forward with a preliminary site visits

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PALO ALTO HEAT PUMP PILOT INTERVIEW QUESTIONS

Dear Page Mill Court Resident,

Midpen Housing (Page Mill Court's property owner) has received a grant funded by the Bay Area Air Quality Management District and administered by the City of Palo Alto Utilities to upgrade the gas furnace in your home to a new high efficiency heating and cooling system. In advance of the upgrades **the grant team requests your feedback** regarding your current gas heating system. Thank you in advance for taking time to respond, your answers will help inform future energy efficiency programs!

1. Apartment Number: _______________

2. Do you use the furnace to heat your home?
   - ☐ Yes
   - ☐ Infrequently
   - ☐ No

3. If you answered "no" above please describe why not:

4. Is your furnace thermostat easy to use?
   - ☐ Yes
   - ☐ No

5. Do you use a portable electric space heater?
   - ☐ Yes
   - ☐ No

6. Are you comfortable when it is **cold** outside in the winter?
   - ☐ Yes
   - ☐ No

7. Are you comfortable when it is **hot** outside in the summer?
   - ☐ Yes
   - ☐ No

8. Do you use any of the following to stay cool in the summer? *check all that apply*
   - ☐ Ceiling fan
   - ☐ Portable room air conditioner
   - ☐ Window air conditioner
   - ☐ _______________________ (other, write in)

9. How do you feel about your winter utility bill?
   - ☐ It is too expensive
   - ☐ It is reasonable
   - ☐ It is lower than I expect

10. Do you have any other concerns or issues with the temperature in your home?

Heat Pump Minimum Performance Requirements

Overview and Expectations:

The City of Palo Alto (CPA) is partnering with Association for Energy Affordability (AEA) to implement a Gas Furnace to Heat Pump Retrofit Pilot Program which has been funded through the Bay Area Air Quality Management District's 2018 Climate Protection Grant Program. The purpose of the pilot program is to gain experience and validate the costs and benefits of retrofitting existing in-unit gas furnaces with energy efficient and clean electric space heating alternatives for affordable multifamily properties within Palo Alto.

Design Build Approach:

AEA will provide technical support to selected contractor, but does not perform engineering or design services. Initial scope options included below have been provided to guide bid options, but must be validated through contractor design and load calculations. Alternative scopes/approaches can be presented by the contractor if desired. **It is assumed that contractors will provide a turnkey, design build delivery method**, will be responsible for securing all necessary permits and equipment, will perform or subcontract for any necessary design and sub-contractor work necessary to implement the project.

Required Milestones:

Bid Walk Date *Contractors must attend a site walk to the property*	3/19/2020
Question Due Date *Bidding contractors must submit in writing any clarifications or requested substitutions.*	3/26/2020
Bid Due Date	4/1/2020
Owner Contractor Selection	4/10/2020
Contractor Completes Design, Permit Pulled	5/1/2020
Required Construction 100% Completion *Equipment must be fully installed, final permit signed off, and all required documentation submitted by this date*	7/1/2020

Project Specific Requirements

Scope Summary:

(16) one-bedroom apartments are currently served by a single natural draft wall furnace. (8) multi bedroom apartments are currently served by gas forced air furnaces. The contractor is expected to

provide a bid for the (5) heat pump installation scenarios described below. Initial ASHRAE load calculations have been performed that indicate it is *likely* that the following options will meet design heating requirements for each apartment, but bidding contractors must confirm each option will provide sufficient heating for each apartment.

One-bedroom apts: **Option 1:** Install (1) Innova PTHP located in the living room. Remove wall furnace and replace with air-share fan controlled with on/off switch. *Add alt: install wall-mounted innova smart touch wall controller in accessible location.*

Option 2: Install (2) Innova PTHP, (1) in the living room and (1) in the bedroom. Remove wall furnace and paint patch wall to match. *Add alt: install wall-mounted innova smart touch wall controller in accessible location for each PTHP.*

Option 3: Install (1) ductless mini split head unit in the living room and compressor on rear porch/landscaping. Remove wall furnace and replace with air-share fan controlled with on/off switch. Install wall-mounted thermostat in accessible location.

Option 4: Install (2) ductless mini split head units, (1) in the living room and (1) in the bedroom, with compressor on rear porch/landscaping. Remove wall furnace and paint patch wall to match. Install wall-mounted thermostats in accessible locations.

Multi-bedroom apts: Remove furnace and replace with high static ducted mini split heat pump. Replace thermostat. *Add alt: seal ductwork in attic and behind supply/return registers if leakage testing reveals >15% total duct leakage, and/or if required by T-24.*

Equipment Requirements

Equipment: Ductless minisplit heat pump

- Variable speed inverter driven compressor
- Energy Star Rated
- Heating Seasonal Performance Factor (HSPF): ≥ 10
- Seasonal Energy Efficiency Ratio (SEER): ≥20
- Energy Efficiency Ratio (EER): ≥11.25

Inverter Package Terminal Heat Pump

- Innova 2.0 PTHP or approved equal
- Variable speed inverter driven compressor
- Energy Star Rated
- No electric resistance backup provided

Ducted heat pump minimum efficiency requirements

- For use in multi-bedroom apartments only
- Energy Star Rated
- Variable speed inverter driven compressor
- High static model capable of using existing ductwork
- Heating Seasonal Performance Factor (HSPF): ≥ 10
- Seasonal Energy Efficiency Ratio (SEER): ≥17
- Energy Efficiency Ratio (EER): ≥11.25
- No electric resistance backup provided

Air share fan

- Tjernlund Aireshare AS1 transfer fan or approved equal
- Provide labeled on-off switch at ADA-height adjacent to fan
- Line stud cavity with sheet metal if required by code. Seal stud cavity air tight to prevent air transfer. Vacuum clean stud bay prior to cover.

Thermostat:

- Contractor to provide submittal for ADA approved wall mounted thermostat. Selection should emphasize ease of use and compatibility with proposed high efficiency equipment.

Installation: A neat, professional installation is expected for all aspects of the project. The scope is anticipated to require mechanical, electrical, and drywall repair work. Equipment location, line set and condensate routing, etc. must be approved by the owner's project manager prior to installation.

Load Calculation: Equipment shall be sized based on calculated cooling/heating loads using ACCA Manual J or ASHRAE handbook. Documentation of how equipment was sized must be provided for review and approval prior to ordering equipment.

Line set insulation: Separately insulate both the liquid and suction refrigerant line per thickness required by manufacturer.

For exterior locations insulate and protect piping per T-24 such that "the insulation must be protected from physical damage, UV deterioration, and moisture. Insulation is typically protected by aluminum, sheet metal jacket, painted canvas, or plastic cover." Paint is not allowed as insulation protection.

Line set penetration through the building enclosure should be made rodent-proof (e.g. with PVC sleeve and cap drilled to the size of the refrigerant lines), insulated, and sealed air and water tight.

Condensate line: Drain to approved location. Check condensate line for water leaks and condensate pump for proper operation by adding water to condensate drain. Avoid use of condensate pump when feasible.

Pad: A housekeeping pad or equivalent is required for the outdoor unit.

Refrigerant line: Follow manufacturer's requirements when flushing refrigerant lines and pre-testing for leaks. Charge equipment with refrigerant per manufacturer's requirements. After charging system with refrigerant, but prior to insulating refrigerant lines, installer must check all refrigerant connections with a refrigerant gas leak detector or soapy water, and repair any leaks. If refrigerant is added or removed this should be documented at the outdoor unit for reference by future technicians.

Commissioning: Follow manufacturer's requirements when commissioning system. Provide training to resident and owner's staff per training requirements.

Furnace Removal

All apts: Remove furnace. Cap gas line. Seal airtight the flue pathway above the wall furnace cavity. At forced air units remove the flue back to the ceiling and seal flue opening and any combustion air openings air tight (sheet metal and caulking, or drywall, tape, mud – owner to decide).

Electrical

All apts: Run new electrical circuit(s) as needed to new heat pump equipment from each apartment sub panel. Wall/ceilings should be opened as necessary to conceal wiring within apartment with the exception of locations that are run parallel to heat pump refrigerant lines that will be concealed with line set cover.

Contractors are responsible for confirming during design that the new electric load can be supported by the existing electrical infrastructure. 30 day, 15 minute interval load monitoring data will be provided to all bidding contractors to assist with this assessment.

add alternate Provide electrical to air share fan and control with on off switch at accessible height adjacent to fan. It is assumed that this can be provided from an adjacent general purpose outlet circuit.

Duct sealing

Multi-bed apts: Base bid for equipment replacement should include sealing accessible ductwork with water based low-voc mastic within the furnace closet after furnace removal and prior to heat pump installation.

Add alternate Seal ductwork in attic and behind supply/return registers if leakage testing reveals >15% total duct leakage, and/or if required by T-24. See supplemental duct sealing handout for minimum requirements.

Patching and Painting

All apts: Contractor is responsible for patching, texturing, and painting any holes opened during course of work, and to repair damage caused during course of work. Final color paint coat will be provided by building owner. Paint match of line set hide or condensate line located on interior or exterior of building is not required.

Documentation

At bid:	Provide submittal for each proposed product to be installed showing performance criteria listed above (sizing does not need to be confirmed at bid). Provide thermostat submittal.
Prior to construction:	Provide ACCA Manual J or ASHRAE load calculations that support equipment sizing/selection.

Bid Sheet

Bidding contractors must submit proposal with costs separated in the following *minimum* categories (contractor may break out costs further if desired).

	(16) 1 Bedroom Wall Furnace Units				(8) Multi bedroom FAU
Scope Options	(1) PTHP in living room, (1) airshare fan to bedroom	(2) PTHP (1 in bedroom, 1 in living room)	(1) Ductless Mini Split living room, (1) airshare fan to bedroom	(2) Ductless Mini Split (1 in bedroom, 1 in living room)	Replace Furnace with high static ducted heat pump
Demolition					
Electrical					
Heat Pump Installation Labor					
Heat Pump Material					
Install air share		N/A		N/A	N/A
Seal Ductwork	N/A	N/A	N/A	N/A	
Wall mounted thermostat					
ACCA Manual J Load Calcs					
Drywall patching, painting					
HERS testing (if required)					
Permitting					
Total Cost					

Any scope, material, or tasks not identified above? Please describe:

Any exclusions? Please describe:

General Project Requirements

General

The following describe the minimum performance requirements for the heat pump HVAC measures being considered for the project. The contractor is responsible for reviewing the requirements and for determining any variances that may be required for a complete, functional, code-compliant system.

Requests for variances must be received in writing prior to the installation of equipment and should be directed to the program contact as well as the owner's project manager. Variances that have not been pre-approved may disqualify the installed measure from receiving a rebate.

The contractor shall be responsible of notifying the building owner in writing of any materials or apparatus believed inadequate or unsuitable, in violation of codes, laws, or ordinances, rules or regulations of authorities having jurisdiction, and any necessary equipment, items or work missing in the scope of work which shall prevent the system from operating properly. In absence of such written notice, the contractor and owner mutually agree that the contractor has included, in the submitted bid to the owner, the cost for all the required items to make the specified system work properly.

Code Compliance, Permits, and Filing

All work shall be in strict accordance with all applicable City, State, and Federal, Codes, rules and regulations. Prior to commencement of any work, Contractor is required to file and obtain all permits as required by agency having jurisdiction and at completion of work shall provide building owner all required signoffs' from all agencies having jurisdiction over the work specified herein. Contractor shall file the work, as applicable with the agencies/departments of the city or county having jurisdiction, under the current codes and regulations of same, and copies shall be provided to Owner upon filing.

Statement of Work Requirements

Contractor's scope shall include all materials, equipment, and services necessary for and reasonably incidental to the performance of the installed measure. All materials used on project shall be new. All labor being provided on this project shall be performed by workmen who regularly perform this specific type of work and they shall be licensed where required. Work shall be of commercial quality, meet all manufacturers' installation requirements, and will be performed in such a manner to ensure installed measure performs for the duration of its expected useful life.

Submittal and Documentation Requirements

Contractor shall provide submittals for review and approval by owner's project manager and AEA. Additionally, contractor shall provide at end of construction an invoice or other evidence showing the total cost for each installed measure.

Demolition and Disposal Requirements

All replaced or abandoned equipment and any and all materials considered waste during the course of the work will be removed from site and disposed of in accordance with all applicable laws.

Hazardous Materials

Lead, asbestos, and other hazardous materials have not been inspected or tested by AEA. It is the Owner and Contractor's responsibility to test for and include in scope of work any necessary abatement, permits, and filing required to complete the scope of work.

Education

Contractor shall furnish two complete sets of neatly bound installation manuals and instruction manuals for all equipment installed as part of the program, including operating instructions, wiring diagrams, and suggested regular maintenance to the building owner. Contractor shall provide in-person training for building operations staff on proper use of equipment and manufacturer's recommended maintenance procedures, controls, and proper operation. Equipment will be labeled sufficiently to assist with basic operations and maintenance procedures as needed.

Warranty

Contractor shall furnish a written guarantee of all equipment with this bid, and shall guarantee all equipment and labor for a minimum of one year, from the date of the final acceptance of the equipment.

PALO ALTO HEAT PUMP PILOT INTERVIEW QUESTIONS – POST CONSTRUCTION

Dear Page Mill Court Resident,

Thank you so much for your patience and enthusiasm during the recent installation of the high efficiency heat pump heating system in your apartment. Now that upgrades are complete **the grant team requests your feedback** regarding your ***new*** **heating** and **cooling** system. Thank you in advance for taking time to respond, your answers will help inform future energy efficiency programs!

1. Apartment Number: ____________

2. Have you started to use your new heating system yet?
   - ☐ Yes
   - ☐ Infrequently
   - ☐ No. If no, please describe why not:

3. Is your new thermostat easy to use?
   - ☐ Yes
   - ☐ No. If no, please describe why not:

4. Is the thermostat guide posted at your thermostat useful?
   - ☐ Yes
   - ☐ No

5. Has the new heating system impacted your comfort?
   - ☐ More comfortable than before
   - ☐ Less comfortable than before
   - ☐ About the same

6. How do you feel about your latest winter utility bill?
   - ☐ It is too expensive
   - ☐ It is reasonable
   - ☐ It is lower than I expected

7. How do you feel about the construction process required to perform this upgrade?
   - ☐ It was too disruptive and was a burden for me
   - ☐ It was not too disruptive and not a burden for me
   - ☐ Other (describe):

8. If you previously used one, do you **still** plan to use a portable electric space heater?
   - ☐ Yes
   - ☐ No
   - ☐ N/A – I don't use a portable space heater

9. Do you plan to use the added cooling function of your new system?
   - ☐ Yes, I plan to use the cooling system
   - ☐ No, I do not plan to use the cooling system

10. If you previously used one, do you **still** plan to use a portable (room) air conditioner?
    - ☐ Yes
    - ☐ No
    - ☐ N/A – I don't use a portable air conditioner

11. Do you have any other comments, concerns, or questions about the new heating system?

Minimum Duct Sealing Requirements

<u>Duct Sealing Minimum Requirements</u>

- The following are for existing duct systems only
- **Required duct sealing locations:** All accessible duct locations including attics, crawlspaces, behind registers, and at air handling equipment. Ductwork enclosed by drywall is considered inaccessible.
- **Target total duct leakage:** T24 requires that ductwork be sealed to leak less than 15% of total **new** air handler fan flow rate.
- **Sealing seams, cracks, joints, holes, and penetrations that are:**
    - Less than ¼" will be sealed using fiberglass mesh and mastic. Mastic alone will be acceptable for holes less than ¼" that are more than 10' from air handler.
    - Between ¼" and ¾" will be sealed in two stages: (1) They will be backed using temporary tape (e.g., foil tape) as a support prior to sealing (2) They will be sealed using fiberglass mesh and mastic. Fiberglass mesh and mastic will overlap temporary tape by at least 1" on all sides. Fiberglass mesh and mastic will become the primary seal.
    - Larger than ¾" will be repaired using rigid duct material. Mastic will overlap repair joint by at least 1" on all sides.
- **Flexible duct connections:** If no tape or mastic is on duct connection or existing tape is brittle and no longer sealing duct: seal inner liner to metal fitting with mastic and reinforce with duct tie tightened with tensioning tool. Apply additional duct tie to secure outer insulation jacket.
- **Behind registers/return grill:** Gaps between duct supply and return gypsum less than a ¼" will be sealed using mastic or appropriate flexible caulking. Gypsum edge will be wetted before applying mastic.
- **At Air Handler:** Joints will be sealed and cracks/holes not needed for proper function of air handler will be sealed using removable sealant (e.g., foil tape)
- **Unlined Return Plenum/Platform:** Debris and dirt will be cleaned out of the return platform. Line interior of plenum with duct board or sheet metal and seal with mastic to create a leak-free assembly. Material will be rated for use in return duct systems.
- **Duct tape <u>cannot</u>** be used to seal duct system. Any tapes used to seal duct work must be UL 181 compliant.
- **Duct insulation:** Replace any duct insulation removed to accommodate sealing ductwork.
- **Return Filter:** after cleaning and sealing air handler filter will be replaced with new properly sized filter of rating/type used by maintenance staff at building.
- **System Operation:** After sealing, proper system operation will be confirmed by contractor to ensure air handler operates within manufacturer's static pressure and temperature rise requirements, and that system noise levels are acceptable.

Photo examples of sealed and unsealed duct systems:

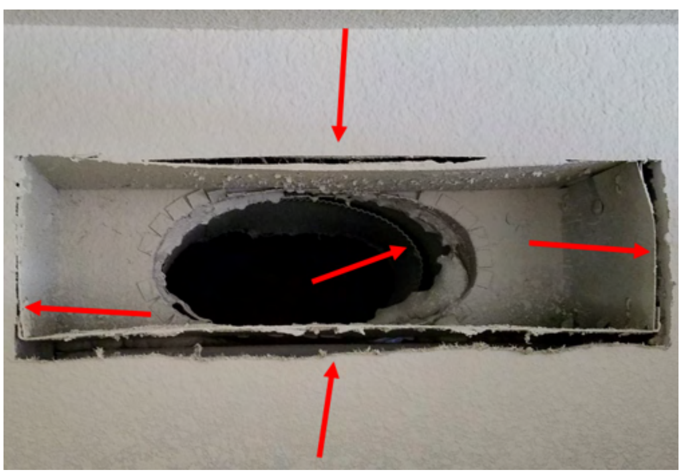
Typical Return – must line the return

Plenum is unlined and unsealed

 [1]

Plenum lined duct board and thoroughly sealed with duct mastic

Typical Boot – must air-seal the boot and connections



Supply boot and connection are unsealed

Supply boot and duct connection are well sealed with mastic; boot sealed to drywall with mastic or caulking

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[1] https://basc.pnnl.gov/resource-guides/air-handler-closet-retrofit#quicktabs-guides=0

Typical Return Can – must air-seal the return can and connections

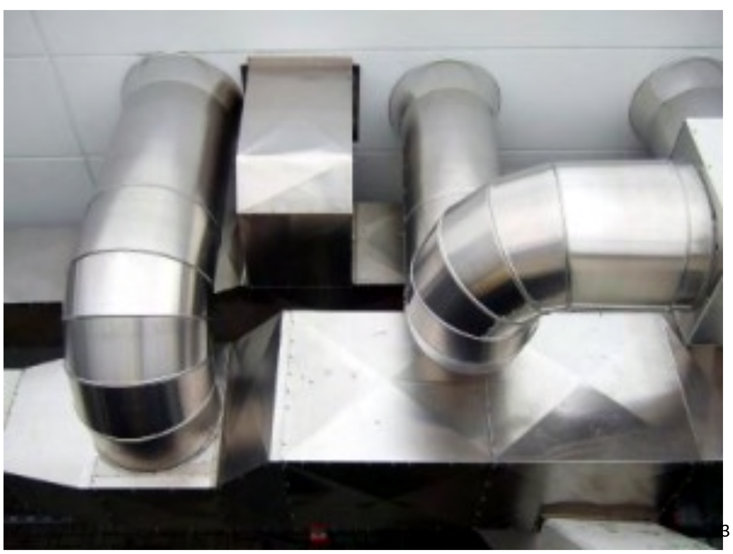

[2]

Unsealed return duct

Well-sealed return with mastic fully covering seams, duct connection, and interior of duct

Typical Duct Connections – must air-seal duct connection points and reinforce as needed, reinsulate over fixed connections

Metal Duct Example


[3]


[4]

Unsealed metal duct

Well-sealed metal duct - all connections and seams are sealed. Insulation has not yet been installed.

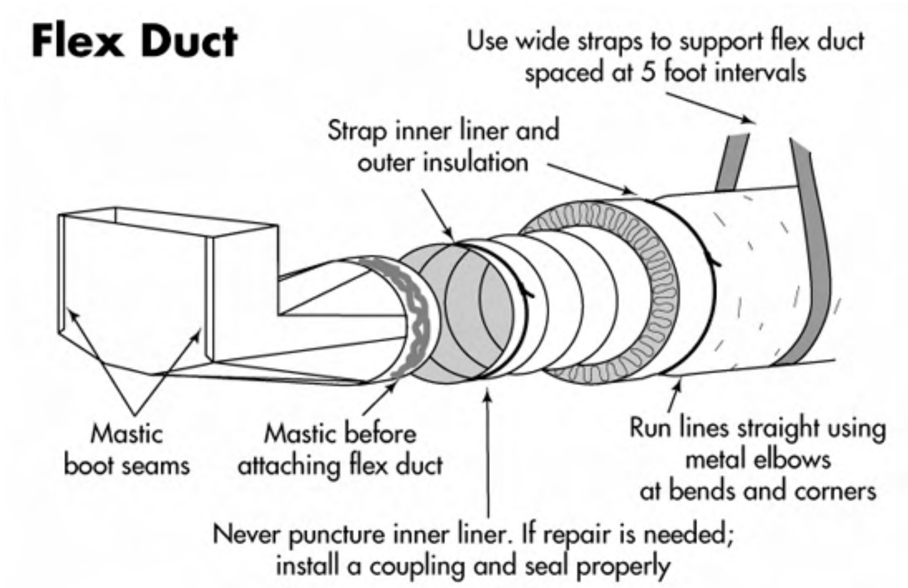
[2]https://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/ENERGY_STAR_V3_HVAC_Quality_Installation_Guidebook.pdf

[3] https://www.jbheatingandair.com/heating-and-cooling-tips/duct-cleaning/keep-home-comfortable-duct-sealing/

[4] https://www.handymanhowto.com/seal-sheet-metal-duct-mastic/

Flex Duct Example

- Seal and reinforce (zip tie) as needed
- Reinsulate over fixed connections



[5]

[5] https://www.rcdmastics.com/duct-sealing/heating-and-cooling-air-duct-repairs.html

Page Mill Court Electrical Load Monitoring Data: 1/21/22 – 2/16/22