Challenging Use Cases and Emerging Solutions for Zero-NOx Appliances

Bay Area Air Quality Management District

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July 2024

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Introduction

This whitepaper provides a summary of challenging use cases associated with the installation of zero-nitrogen-oxide (NOx) appliances in compliance with Bay Area Air Quality Management District (BAAQMD) Rule 9-6 (water heating) and Rule 9-4 (space heating and cooling). While challenges and solutions for both Rule 9-6 and Rule 9-4 are included in this summary, Rule 9-6 (small water heaters (75,000 British Thermal Unit [BTU]/hour) is the primary focus due to the earlier implementation date. While understanding the current challenges associated with Rule 9-4 is important, these challenges will change over the next several years and will be re-evaluated closer to the 2029 implementation date.

Rule 9-6 will prohibit the sale of NOx-emitting water heaters and boilers with a rated heat capacity of 75,000 BTU/hour or less starting in 2027. NOx-emitting water heaters affected by Rule-9-6 primarily refer to water heaters sized up to 74 gallons, serving approximately five people. This size of water heaters generally reflects single-family, low-rise, multifamily, and small-commercial uses.[1] NOx-emitting water heaters manufactured after January 1, 2027, up to this 75,000 BTU/hour threshold, will not be able to be sold or installed in the Bay Area. Sale and installation of equipment manufactured before that date is permissible for older units that meet the current ultra-low NOx requirements.[2]

Rule 9-4 will affect the future sale of NOx-emitting furnaces designed to be a source of interior space heating with a heat input rate of 175,000 BTU/hour or less, and combination heating/cooling units with an electric cooling rate less than 65,000 BTU/hour. NOx-emitting furnaces and central furnaces manufactured after January 1, 2029, cannot be sold in the Bay Area. However, like water heaters under Rule 9-6, sale and installation of older units manufactured before the compliance date will be unaffected. NOx-emitting appliances regulated under Rule 9-4 generally include natural gas-fired wall furnaces, unit heaters, and package units used in single-family to small-commercial settings. Current zero-NOx heat pump (HP) Heating, Ventilation, and Air Conditioning (HVAC) appliances available include HP rooftop package units for small-commercial and low-rise, multifamily uses and ducted or ductless mini-split HP HVAC for single-family uses.

The only zero-NOx appliance options currently available on the market are electric (e.g., heat pump water heaters (HPWH)), electric resistance storage water heaters, on-demand tankless water heaters). Fuel switching (from gas to electric) can present a set of challenges, both real and perceived, due to the different sizes, power sources, and operational needs of the equipment. This analysis of technical challenges will focus on HPWHs and space heaters (HVACs) as they are the most cost-effective (i.e., available rebates, bill savings) and energy efficient option of the available zero-NOx appliances.

Implementing these rules will likely require replacement of NOx-emitting appliances with heat pumps throughout a wide-range of building applications when the original appliance fails or "burns out." While replacement of NOx-emitting appliances with zero-NOx HPs is well understood for most buildings, some existing policies and building configurations can lead to challenging "edge-cases"

[1] "Installation Costs for Zero-NOx Space and Water Heating Appliances." Rincon Consultants and E3. January 2024. See Table 2 "Water Heating Common Appliance Sizes and Corresponding BAAQMD BTU/Hr threshold." Rule 9-6 also regulates natural gas fired boilers and water heaters with a rated heat input capacity of 75,001-2 million BTU/hour starting on January 1, 2031. These larger-sized appliances are not included in this memo at direction of BAAQMD due to the later start date of this regulation.

[2] Older NOx-emitting units manufactured prior to the 2027 date will still be available for sale/install.

which can increase costs or extend timelines for replacement. The technical challenges summarized in this whitepaper reference installation hurdles experienced by contractors, building owners, and program staff (e.g., BayREN). These technical challenges reflect direct challenges such as physical space constraints and electrical infrastructure, as well as indirect challenges, including operational timeline increases and service upgrades. Along with these challenges are emerging and established solutions that may help alleviate some of the challenges associated with HPs in these unique cases.

The insights related to challenges and solutions for zero-NOx appliances in this summary are based on interviews with contractors, manufacturers, and policy makers. These interviews are supplemented by desktop research from building efficiency think tanks, program reports (e.g., BayREN, TECH Clean California [TECH]), government reporting, pilot results, and other sources which were available in December-January of 2023/2024.

Overview of Challenging Use Cases and Solutions for Zero-NOx Appliances

When switching from a NOx-emitting appliance to a zero-NOx appliance, there are several new requirements that may lead to technical challenges during a retrofit. Many of these challenges were identified through feedback to BAAQMD during the adoption of zero-NOx amendments to Rule 9-6 and Rule 9-4, or during incentive-driven HP installations supported by programs like BayREN and TECH.

Key use case challenges for HP installation

- Water heater relocation due to tank upsizing, condensate draining, or airflow/venting requirements
- HPWH installation in small spaces
- Location restrictions for outside condensing units for HP HVAC; physical barriers to accessing perimeter walls to install refrigerant lines for HP HVAC mini-multi-split appliances
    - Local policy barriers to appliance relocation (e.g., garage install restrictions, noise limits)
    - Negative perceptions of HP noise by HOAs and residents
- Difference in circuitry and voltage requirements (most HPWH require 240 volts while natural gas water heaters require 120 volts).
- Need to upsize electrical panels or upgrade electrical service (both HPWH and HP HVAC) coupled with lengthy timelines in Pacific Gas & Electric Company (PG&E) territory
    - Primarily affects buildings with 100 amp and less panels
    - Common misperceptions that HP installation will always require panel upsizing for buildings with 100-amp panels
- Due to the challenges listed above leading to comparatively longer install timelines, and since most water heater and HVAC replacements only happen when the original appliance fails, gaps in water and space heating service can occur.

While technological and policy-driven challenges have been identified, as HP installations have become more common, so have solutions. New technologies, approaches, and policy decisions are being developed to streamline these installations.

Key solutions for HP installation include;

- Emergent 120-volt HPWH technologies
- Emergent quiet HP technologies and low noise certifications
- Permitting updates to remove unintentional zoning barriers hindering HP installation in addition to permit streamlining
- New programming (e.g., BayREN technical support program)/financial incentives for contractors and building owners incentivizing low-voltage equipment and "watt-diet" approaches (e.g., smart panels)
- New programming/financial incentives to support use of temporary portable appliances during longer install projects
- Contractor education to increase passive airflow and normalize HPWH install in smaller spaces
- Contractor education and outreach to normalize watt-diet or panel-optimization approaches
- Emergent research on actual needs for HPWH airflow and space requirements, as well as HP HVAC noise

These challenges and solutions will be further described throughout this whitepaper. They are summarized for HPWH in Table 1 and for HP HVAC in Table 2.

Summary of Challenging Use Cases and Technical Solutions for HPWH and HP HVAC Appliances

Heat Pump Hot Water Heaters (HPWH) - Rule 9-6

A literature review of challenges and potential solutions associated with replacement of NOx-emitting water heaters with zero-NOx water heaters was supported by interviews with BayREN contractors Carbon Zero Buildings and GLD Green Buildings. Both interviewees emphasized that currently both single and multifamily HPWH replacements are driven by the incentive market.

For multifamily buildings, most owners were looking for full-coverage of HPWH upfront install costs via incentives before seriously pursuing a project.[3] Interviewees also noted that retrofits for central HPHWs could be completed without significant technical hurdles. This is because relatively uniform multifamily central HPWH retrofits were less complex than single-family retrofits.

Single-family gas and electric water heater heaters come in a larger variety of shapes and sizes. Additionally, structures to house the original gas or electric water heater (i.e., closet) were often built around the shape of the appliance. This makes it difficult to match the wide range of enclosures of the original water heater to the relatively narrow range of form factors available for single-family tanked HPWH.

The research and contractor interviews that inform this whitepaper indicate that many HPWH installations have minimal additional challenges in comparison to a "like-for-like" swap-out with a new natural gas water heater. However, in some edge cases, when switching from natural gas to an HPWH, new technical challenges emerge. As detailed in the interviews, most challenges can be solved through contractor troubleshooting (e.g., appliance relocation, condensate drain installation)

[3] These interview insights also indicate that as many BayREN/TECH incentivized multifamily projects are currently driven by technologically feasible, cost neutral retrofits recommended to contractors by BayREN program staff, this data may not represent the full scope of technical challenges found within HPWH multifamily installs. Difficult, or costly projects may have been self-selected out of these first mover projects by nature of the current landscape for cost motivation and incentives by multifamily property owners.

without additional intervention besides a slightly longer timeline for installation and associated additional costs.

The technical issues detailed below in Table 1 should be considered edge cases (uncommon installation situations), and most likely will not halt installation of a project completely. However, these hurdles can be minimized by potential solutions from technology, policy, or programming innovation detailed in the rightmost column. It is important to note that the challenges outlined in Table 1 specifically pertain to the installation of HPWH and do not always encompass the requirements for electric resistance tanked or tankless (on-demand) zero-NOx water heating options. **Bold text** indicates the summary for each technical issue.

Table 1 Technical Issue and Solution Summary

White Paper Challenge #	Technical Issue	Potential Solutions
Challenge 1: Replacement Timelines	**Longer replacement timelines due to troubleshooting installation/permit differences between gas and HPs.** Contractor time needed for technical fixes like appliance relocation, condensate drain installation, electric infrastructure upgrades leads to an extended gap in service. This technical challenge encompasses the compounding results from infrastructure and policy challenges	Emergency replacement programs (gas or 120-volt HPWH) Emergent technology: low-voltage; small-space HPWH technology Local ordinance updates and permit streamlining
Challenge 2: Small Spaces & Appliance Relocation	**Larger tank space and airflow needs than NOx-emitting water heaters** Tank upsizing recommended from gas to HPWHs due to longer recovery time makes appliance relocation to larger space necessary in some edge cases. Most HPWHs can be replaced on same footprint as gas appliances. However, there are limited shapes and sizes of HPWHs in comparison to the diversity of gas water heaters on market. HPWHs require larger airflow and venting requirements in comparison to gas appliances. Airflow requirements require at least 700 cubic feet of space according to manufacturers.[1] HPWHs also require installation of condensate drains which not all natural gas water heaters need. Note that this requirement is also shared by some high-efficiency natural gas units.	Workforce education – small-space location and methods to increase airflow in small spaces Outdoor appliance relocation/enclosure building Emergent technology: low-voltage; small-space HPWH technology Emergent research on actual HPWH space and ventilation needs (significantly smaller than manufacturer estimates)
Challenge 3: Noise from HPs and Outdoor Space Constraints	Some edge case HPWH installed close to areas that require quiet spaces (e.g., bedroom) may require appliance relocation based on consumer preference. BAAQMD legal authority supersedes HOA covenants, conditions, and restrictions ; meaning that HOA rules restricting HP install should not be considered a technical challenge to implementation of BAAQMD rules.	Emergent technologies: quiet certifications and quieter HP models

White Paper Challenge #	Technical Issue	Potential Solutions
Challenge 4: Access to Perimeter Walls and Missing Ductwork (Ductless Mini-Multi-Splits – HP HVAC)	N/A – pertains only to HP HVAC	N/A – pertains only to HP HVAC
Challenge 5: Electrical Infrastructure and Distribution Grid Challenges	**Electrical panel upsizing may be required for buildings with a panel sized less than 200 amps**, leading to a potential electrical service upgrade with a long timeline.	Emergent low-voltage 120-volt HPWH technologies Watt-diet approaches (e.g., smart panels, load splitters) Updated program and funding that incentivize watt-diet, low-voltage, and energy-efficient technologies Workforce education on watt-diet approaches If upgrade unavoidable: emergency replacement programs Utilities-led solutions to streamline processes and expedite service upgrades (PG&E/California Public Utilities Commission)

[1] Note that venting and space requirements also apply to natural gas appliances. Standard atmospheric vents are required for natural-gas HPWH, and California building codes also require a minimum of 50 cubic feet of space per 1000 BTU/hour: https://www.hotwater.com/info-center/water-heater-venting.html; https://www.buildingincalifornia.com/pdf/WaterHeaterChecklist1.pdf

Heating, Ventilation, and Air Conditioning (HVAC) - Rule 9-4

Rule 9-4 requires furnaces to be zero-NOx beginning in 2029. Rule 9-4 primarily addresses NOx-emitting furnaces, but the discussion extends to cooling as HP HVAC units provide both heating and cooling with one unit. Rule 9-4 covers furnaces with a heat input rate less than 175,000 BTU/hour, which could be found in residential, multifamily, and small commercial applications.

Common HP HVAC types for single-family homes are ductless and ducted mini-split systems. Ductless mini-splits offer targeted heating and cooling for individual rooms, providing flexibility and energy efficiency without the cost and technical challenge of ductwork retrofits. On the other hand, ducted mini-splits use a central unit with ductwork to distribute air throughout the entire home, offering a more traditional HVAC approach with zoning capabilities for personalized comfort.

Most commercial and high-rise, multifamily buildings utilize packaged unit single zone (rooftop units), split systems, unit ventilators, or unit heaters. Rule 9-4 would cover any of these units up to 175,000 BTU/hour and therefore, could apply to a wide range of building types. Replacements for zero-NOx appliances in this commercial/multifamily category encompass a central HP system with refrigerant distribution, a packaged HP, or a packaged rooftop unit system. Any system larger than this size will not be subject to regulation under the 2029 Rule 9-4 requirement.

HP HVAC technical challenges stem from installation differences between base case natural gas furnaces and HP HVAC installation needs. HVAC replacements are generally more complicated and are currently less supported by existing programming and financial support than HPWH retrofits. However, many HP HVAC technical challenges can be solved through contractor troubleshooting (e.g., interior linework installed with covers, enclosures added to the exterior of the building) without additional intervention besides longer installation timelines and associated labor costs.

Installation needs will be essentially identical for buildings replacing both a central AC unit and a gas furnace with an HP HVAC. This fact uniquely positions these buildings with existing heating and cooling capabilities to seamlessly transition to an HP HVAC without the technical challenges associated with installing an HP HVAC if it is replacing only a gas furnace. More challenging install cases for HP HVAC are expected in retrofits with complex ductwork, limited outdoor space with closely situated neighbors, and buildings with limited or no access to perimeter walls for installation of new refrigerant lines. A summary of existing technical issues, and potential solutions for HP HVAC installation is detailed in Table 2. **Bold text** indicates the summary for each technical issue cause and description.

Table 2 HP HVAC Technical Challenges and Solutions Summary

White Paper Challenge #	Technical Issue Cause and Description	Potential Solutions
Challenge 1: Replacement Timelines	**Longer replacement timelines due to the need to troubleshoot installation differences between gas and HP HVAC.** Contractor time needed for technical fixes like appliance relocation, condensate drain installation, lengthy permit processes, electric infrastructure upgrades lead to a gap in space heating service.	Temporary heating and cooling solutions (portable units) Programming for emergency replacement programs (plug-in appliances) Local ordinance updates & permit streamlining
Challenge 2: Small Spaces and Appliance Relocation	N/A- Pertains mainly to HPWH	N/A- Pertains mainly to HPWH
Challenge 3: Noise from Heat Pumps and Outdoor Space Constraints	**Local setback requirements and noise ordinances may unintentionally restrict HP HVAC installation (in particular-outdoor condensing units).** BAAQMD legal authority BAAQMD legal authority supersedes HOA covenants, conditions, and restrictions; meaning that HOA rules restricting HP installation should not be considered a technical challenge to implementation of BAAQMD rules.	Emergent technologies: quiet certifications and quieter HP models Local ordinance updates and permit streamlining. Ductless mini multi-split HP HVAC. Local ordinance updates and permit streamlining
Challenge 4: Access to Perimeter Walls and Missing Ductwork	Fixing old ductwork and installing return air systems for air conditioning when switching from a gas furnace to a ducted HP HVAC can increase project costs and timelines. Ductless mini-multi-split HP HVAC can overcome this challenge by removing the need for any renovation of ductwork, as heat is instead moved through refrigerant-liquid filled line sets which are typically located on exterior walls. However, not all buildings have easy access to exterior walls, due to building design and other factors. **When exterior wall access is restricted, installation of mini/multi-split HP HVAC can be more challenging and result in longer timelines and increased costs.**	Contractor education and innovative install techniques (e.g., covers for interior line installation)

White Paper Challenge #	Technical Issue Cause and Description	Potential Solutions
Challenge 5: Electrical Infrastructure and Distribution Grid Challenges	**Electrical panel upsizing may be required for buildings with a panel sized less than 200 amps**, leading to a potential electrical service upgrade with a long timeline as well.	Watt-diet approaches (e.g., smart panels, load splitters) Program and funding updates that incentivize watt-diet, low-voltage, and energy-efficient technologies Workforce education on watt-diet approaches If upgrade unavoidable: emergency replacement programs Utilities solutions and customer programs

Challenge 1: Replacement Timelines

Due to the potential challenges outlined in this report, longer replacement timelines can become a challenge for both HPWH and HP HVAC installation. Longer replacement timelines are a reflection of the time spent by the contractor on troubleshooting technical challenges like appliance relocation due to space constraints, more complex permitting processes, and electrical infrastructure upgrades. These longer timelines are considered a technical challenge as in many cases, water and space heating appliances are only replaced when the original appliance fails or "burns out." This can lead to a gap in critical water or space heating service that can negatively impact building occupant wellbeing.

The majority of this section details the approaches to overcoming gaps in service for water heating during HPWH installation, however a high-level overview of emergent challenges and solutions for HP HVAC is also provided at the end.

Challenge Overview: HPWH Replacement Timelines

Eighty-five to 90 percent of replacements for hot water heating appliances occur when the original appliance failed.[4] As most building owners will not pre-plan for water heater replacement, they may encounter longer timelines to install HPWH depending on the building conditions and local permit requirements. This lag time can result in a gap in hot water service which underscores the need for interim measures, such as installing temporary appliances or avoiding electric infrastructure upgrades, to ensure a turnaround time in line with like-for-like replacement.

Factors that may lead to a longer HPWH installation timeline than a like-for-like replacement include new installation considerations like condensate draining needs, appliance relocation due to tank upsizing, and venting needs. According to contractor interviews, permitting burdens for HPWH replacement also vary significantly by location and can be significantly longer than like-for-like replacements; for example, some Bay Area Cities (Santa Rosa) require only one permit for HPWH installation, while others require multiple permits for a single appliance.[5] In cases where HPWH requires electrical work, including higher voltage sockets for standard 240 volt HPWH, and a subsequent circuit or panel upgrade, relocation of an appliance, finding an electrician and pulling all relevant permits could take weeks. In cases where a subsequent electric service upgrade is required through coordination with PG&E projects could potentially take months to complete. Each of these hurdles is covered in more detail in subsequent portions of this report.

[4] According to BayREN contractors Barnett Plumbers, consistent with national research: https://techcleanca.com/quick-start-grants/2021-quick-start-grant-recipients/barnett-plumbing/; New Buildings Institute: https://newbuildings.org/scaling-up-market-transformation-for-heat-pump-water-heaters/

[5] These considerations are further explored in an upcoming BAAQMD whitepaper written by Rincon on the existing permitting landscape in the Bay Area. See BayREN presentation for summary: https://www.bayren.org/sites/default/files/documents/2023/BayREN-Q4-2023-Forum-HPWH-Permitting-Pilot_Kristiansson.pdf

Potential Solutions: HPWH Replacement Timelines

Addressing the key challenges that can lead to longer HPWH replacement timelines involves several solutions involving new programming and workforce training (e.g., same-day replacement gas pilots), permit streamlining, and emergent "retrofit-ready" technologies like 120-volt HPWH.

120-Volt HPWH Technologies

When timelines are extended because of the need for electrical infrastructure upgrades (including a new circuit, panel, or service), using 120-volt HPWH technologies can be both a short-term and long-term solution. Low-voltage HPWH systems can be conveniently plugged into the standard wall outlet, which was required for the previous NOx-emitting appliance without additional electric work. This approach aligns with an energy-efficient, watt-diet strategy, where the need for panel upsizing is avoided through selection of efficient/low-voltage appliances. While these technologies may not be suitable as a permanent solution for water heating in large buildings with higher hot water demands, it can be a low-cost way to support smaller units with one or two people, or as a short-term solution in larger buildings (see interim replacement programs). One-hundred-and-twenty-volt technologies will be further addressed later in this whitepaper under *Challenge 5: Electrical Infrastructure and Distribution Grid Challenges.*

Permit Streamlining

Based on research conducted by Rincon Consultants, Inc (Rincon), permit requirements for HP installation in the nine county Bay Area can vary significantly between jurisdictions. While some cities have made efforts to streamline installation by offering pathways for HPs that require a single permit and same day turnaround, other jurisdictions require multiple permits and multiple inspectors (for plumbing, electrical, mechanical, and building). These requirements add cost and time to the installation through increased permit fees and contractor hours. Cities can rework their permit requirements to allow for a more streamlined single permit approach to cut installation timelines and potentially increase the amount of permitted work completed.

BayREN and TECH have started to dedicate regional policy resources towards streamlining and standardizing HPWH permitting across the Bay Area through the HPWH Permitting Pilot. The pilot will provide local governments with a Building Code Assistance Sheet, Permit Supplement Template, and Electrical Load Estimator.[6] These policy resources are currently beta versions that are being tested and are thus not further described here though they should continue to be monitored for future updates.[7] A full discussion of permit processes in relation to zero-NOx appliances is provided in a separate report conducted by Rincon and BAAQMD in support of the zero-NOx appliance standards.

Emergency Replacement Interim Programs

While leveraging retrofit ready or 120-volt HPWH technologies can reduce the need for electrical upgrades, another approach is to provide interim hot water heating technologies, while additional required work (electrical or otherwise) is completed. Emergency replacement programs can be implemented, utilizing short term installations of 120-volt, plug-in HPs or gas heaters that can be

[6] https://www.bayren.org/sites/default/files/documents/2023/BayREN-Q4-2023-Forum-HPWH-Permitting-Pilot_Kristiansson.pdf

[7] https://www.bayren.org/building-dept-tools-guides/heat-pump-water-heaters

used while the building owner waits for the associated contracting/electrical work to be completed for an HPWH install.[8] These programs are still in their exploratory stage with recent successful pilots funded by TECH.

Upcoming pilots from Bay Area Community Choice Aggregators and research from the Emerging Technologies Coordinating Council will assess the market for emergency replacement HPWHs. However, these studies will not be available until late 2024 and are not cited here.[9]

TECH Clean California Barnett Plumbing and Water Heater Emergency Replacement Program

> *"Heat pumps are the future, that's the direction California is going. Fuel switching takes time, but we have a solution that works for the customer and the contractor."-BayREN Contractor Ben Foster (Barnett Plumbing)*

In February 2022, Barnett Plumbing initiated the Emergency Replacement Program pilot, aiming to reduce reliance on gas-powered appliances during emergencies. With funding from TECH, the pilot program allowed customers to receive temporary gas water heaters while contractors installed HPWHs. TECH funding was used to cover the cost of the plumbers' installation labor for the temporary gas water heater temporary install, while Barnett Plumbing provided the HPWH. Each gas loaner installed was given a $975 Quick Start Grant payment to cover the installation cost of loaner gas water heater. Since the loaner program reused the water heating equipment for multiple installations, no additional equipment costs needed to be covered.

Barnett Plumbing successfully installed 177 HPWHs, offering customers an electric water heating replacement at a comparable cost to gas water heaters. This program increased the rate of conversion from gas water heaters to heat pump water heaters from less than one percent to over 17 percent among Barnett Plumbing customers.[10] Although the grant has concluded, the company continues to provide gas loaner water heaters as well as adding new 120 volt plug-in heat pump water heaters as another loaner option. Barnett reported an increased rate of conversion from gas to electric water heating of 52 percent after providing short-term loaner heaters (both 120 volt and gas options).

The results of the pilot program were positive among consumers, which is reflected by the significant increase in gas to electric HP conversions. However, scaling a program like this presents several potential challenges. Loaner water heaters must be stored, the added costs (in this case $975 provided by TECH) must be covered, and incentives must continue to cover the cost difference between gas and HP appliances. It is not clear from the report if $975 is the true cost of installing and removing the loaner water heater, but costs in that range are expected. The final report prepared for the pilot identifies partnerships with Community Choice Aggregators, regional energy networks, and utilities as important partners in addressing these potential challenges.

It should be noted that contractors using this approach after 2027 would need to install a gas water heater manufactured before Jan 1, 2027, in order to stay in compliance with Rule 9-6. Other Rule 9--6 compliant approaches could include interim installation of small low-voltage HPWH (120 volt).

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[8] Most existing gas appliances are 120 volt, while most existing HPWH are 240-volt appliances.

[9] https://www.etcc-ca.com/reports/emergency-replacement-heat-pump-water-heater-market-study

[10]

HP HVAC Replacement Timelines Challenges and Solutions Summary

HP HVAC retrofits may also have comparatively longer retrofit timelines than a like-for-like replacement of a gas furnace. This is due to installation differences resulting from the new outdoor condensing unit components and refrigerant lines which would not have previously been installed if the HP HVAC is replacing a gas furnace without an AC. HP HVAC may also require an electrical panel and service upgrade especially if an HPWH retrofit has already taken place on a limited panel size.[11] In the case where an HP HVAC is replacing both a gas furnace and a central AC, it can be located on virtually the same footprint as the existing AC condenser. This replacement case offers an easy win for a near one-for-one replacement of an existing furnace and AC system with an HP HVAC.

Portable low-voltage electric heating and cooling units (e.g., window AC) could provide building owners with a temporary solution for a gap in heating service.[12] However, this approach is not currently financially or technically supported by third party programs like TECH or BayREN. Unlike HPWH, there are no current emergency replacement interim programs, or long-term, low-voltage solutions that are plug-in-ready. It should be noted that a gap in heating service may be considered less urgent than a gap in hot water service due to the mild climate of the Bay Area and the wide availability of space heaters.

[11] https://www.greenbuildingadvisor.com/article/does-your-electrification-project-require-a-service-upgrade

[12] https://www.redwoodenergy.net/research/a-pocket-guide-to-all-electric-retrofits-of-single-family-homes; also supported as a potential solution with BayREN Multifamily Contract GLD Green Energy.

Challenge 2: Small Spaces and Appliance Relocation

Technical challenges associated with space constraints were identified as a technical challenge for some HPWH installations. This is due to both tank upsizing (to offset slower recharge times associated with HPWH) and increased space needs to intake and vent air. Contractor interviews indicate that in some cases, the enclosure for the original water heating appliance (e.g. closet) was built around the original form of the natural gas tanked water heater. In cases where the original enclosure was small, or does not feature vent space, this may make it necessary to relocate the appliance to a new location with more space to store a larger tank and provide sufficient air for the HPWH to operate effectively.

Relocation challenges pertaining to HP HVAC installation are associated with the installation of a new outdoor condensing unit, which is not required for a gas furnace. This also introduces a new source of noise in the same decibel range as a central AC unit. Contractor interviews indicate that this is not a significant barrier for multifamily HP HVAC installation.

Accordingly, the majority of this section details challenges and solutions for small spaces and appliance relocation for HPWH. The final section provides a high-level overview of challenges and solutions for HP HVAC.

Challenge Overview: Small Spaces and Appliance Relocation for HPWH

In most situations, a tanked HPHW can take the place of an existing gas appliance without additional intervention. However, the increased size of HPWH's paired with the need for larger room volume and airflow requirements may require appliance relocation, additional venting, or installation of a smaller zero-NOx water heater suited to confined spaces or small room volumes. These installation requirements may be especially challenging for water heater installations installed in interior closets other confined spaces.

Airflow is critical for HPWH functionality and cost-effectiveness. HPWHs generate hot water by pulling heat from the air. To accomplish this heating effectively, HPWHs need sufficient air volumes. A lack of sufficient air volumes could reduce energy efficiency or even shut down the compressor, reverting the HPWH to more expensive and energy-intensive electric resistance heating.[13] Most manufacturers recommend at least 700 cubic feet of space to pull heat from the air and vent cold air without impacting equipment efficiency. However, emergent research conducted by the Northwest Energy Efficiency Alliance suggests that these manufacturer recommendations are far more conservative than actual space needs.[14] HPWH tank size will also likely need to be upsized compared to their NOx-emitting counterparts, because HPWHs heat significantly more efficiently but more slowly than their gas counterparts. This larger tank size can exacerbate space constraints when installed in tight spaces, such as interior closets.

[13] https://neea.org/img/documents/Confined-Space-Analysis-The-Amazing-Shrinking-Room.pdf

[14] Note that NOx-emitting gas water heaters also have space requirements for installation, with California building codes requiring a minimum of 50 cubic feet of space per thousand BTU/Hr. https://www.buildingincalifornia.com/pdf/WaterHeaterChecklist1.pdf

These installation differences between NOx-emitting and zero-NOx water heating technologies primarily apply to tanked HPWH. In cases where the size differences and air volume/venting needs of HPWH are not consistent with the existing location, contractors will need to either modify the existing space (by moving walls, framing, or other equipment) or find another suitable location. Moving the location of the water heater is technically feasible but does add costs for new piping, could trigger a building permit, or other work which increases costs and timelines. However, several solutions exist to avoid these hurdles.

Solutions Overview: Emergent Small HPWH Technologies and Contractor Innovation

Solutions for installing HPWHs in small spaces primarily involve emergent technologies and equipment types, other existing technologies that may feature efficiency trade-offs (e.g., tankless electric water heaters), and emergent innovations in HPWH installation in small spaces that increase and optimize airflow. At the time of researching this whitepaper, information on the prevalence of these types of technologies or install methods throughout Bay Area building stock was not available. However, some information on these options and their feasibility is included below.

Water Heating Technologies for Small Spaces

Several technology options are available for water heating in buildings where there is no space for a tanked water heater (e.g. closet install) and/or the space needed to flow air for HPWH as described below in Table 3.[15] It should be noted these technologies may have comparatively higher bill impacts to operate and there may be a lack of market-ready appliances due to early stage product development.

Table 3 Zero-NOx Water Heating Technologies for Small Spaces

Appliance	Space Requirement	Building Application	Pros/Cons
SANCO2: Central mini-split HPWH[1]	43-83 Gallon	Multi-family	Currently in-use for multi-family central HPWH retrofits
Steibel Eltron 24 kW 4.68 GPM Residential Tankless Water Heater[2]	1-2 showers; 16.5” by 4.5”	Small spaces/ apartment buildings	Requires minimum of 150 amp total service to residence; considered to be less energy efficient than HPWH
120 volt 41 Gallon HPWH Split System (EmberH20)[3]	41-Gallon	Manufactured Homes/ Utility Closets	Emergent technology still in pilot phase in California; market available in Australia.

Source(s):

[1] https://www.smallplanetsupply.com/sanc02; GLD Green Energy Contractor Interview; https://performancebuildingsupply.com/wp-content/uploads/2016/07/SanCO2_specs_6_16.pdf

[2] https://www.homedepot.com/p/Stiebel-Eltron-Tempra-24-Plus-Adv-Flow-Control-and-Self-Modulating-24-kW-4-68-GPM-Residential-Electric-Tankless-Water-Heater-Tempra-24-Plus/306745520

[3] EmberH20 Interview

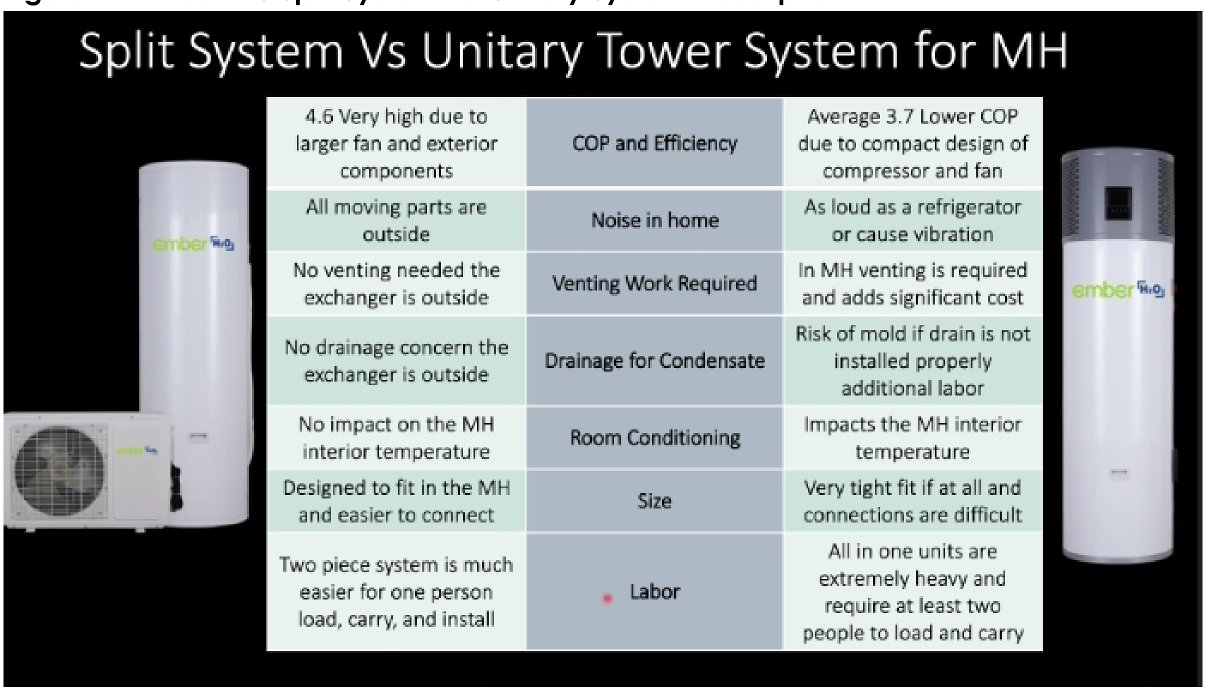
[15] https://drive.google.com/file/d/14nKrbWxfGxEFcO9Yabbk6DJYl8NBg1LG/view; See “Install Challenges from the Field” slide.

Technology Highlight: EmberH20- Low-Voltage HP HVAC Technologies for Manufactured Homes[16]

EmberH20 is an emerging technology currently available in the Australian, United Kingdom, and New Zealand markets, manufactured by Embertec (https://embertec.com/), and which offers an HPWH solution that is specifically tailored to manufactured and mobile home applications. EmberH20 offers a split system HPWH that is designed to fit in manufactured and mobile home utility closets through the installation of an outdoor compressor. This application is critical for successful HPWH installation where there is no room for an in-unit (unitary) system (also a product offering from EmberH20) as shown below in Figure 1.

The EmberH20 is designed to overcome barriers for installation of unitary HPWH systems, mainly, size constraints, interior noise, condensation drainage, room conditioning, and venting. The EmberH20 is currently in the pilot stage in California, with installations expected to be completed in 2024. Although no current specifications sheet was provided by Embertec at the time of writing this report, California pilots should continue to be monitored to assess feasibility of this emergent technology in the context of the Bay Area.

Figure 1 EmberH20 Split System vs. Unitary System Description



4.6 Very high due to larger fan and exterior components	COP and Efficiency	Average 3.7 Lower COP due to compact design of compressor and fan
All moving parts are outside	Noise in home	As loud as a refrigerator or cause vibration
No venting needed the exchanger is outside	Venting Work Required	In MH venting is required and adds significant cost
No drainage concern the exchanger is outside	Drainage for Condensate	Risk of mold if drain is not installed properly additional labor
No impact on the MH interior temperature	Room Conditioning	Impacts the MH interior temperature
Designed to fit in the MH and easier to connect	Size	Very tight fit if at all and connections are difficult
Two piece system is much easier for one person load, carry, and install	Labor	All in one units are extremely heavy and require at least two people to load and carry

Innovative Install Techniques for HPWH in Small Spaces

If installing in an industry-recommended sized room is not possible due to building space constraints, then HPWH installers can increase the supply of warmer make-up air ("thermal resource") through techniques like air openings in confined spaces through air return grilles, louvered doors, exhaust ducts, wall grilles, and structures to create forced convection without a duct. In emergent research on HPWH install in small spaces conducted by Larson Energy Research, it

[16] Source: 1.20.2024 BAAQMD and Rincon Interview with Embertec. Figure 1 cites their presentation deck.

was also found that manufacturer recommendations for room volume were far more conservative than actual room volume needs to deliver operational HPWH cost savings without intervention.

As these findings are still in their research stage, it will likely take additional time, resources, and general training to normalize these installation techniques among contractors and the workforce.

Reduced Air Volume Requirements

The following are key takeaways from a 2022 study funded by the Northwest Energy Efficiency Alliance conducted by Larson Energy Research. Researchers modeled HPWH functionality in spaces smaller than the 700 cubic feet recommended by manufacturers. For modeling room size and air flow interventions for a 55-gallon HPWH in an 84-cubic-foot room, takeaways include:

Volume Requirements

- Installation room volumes as small as 450 cubic feet can deliver lifetime cost savings to HPWH operations with no additional intervention. This is significantly smaller than the 700 cubic feet typically recommended by manufacturers.

Air Flow/Convection Requirements

- For natural convection (free convection), where air flow is caused by natural means, total net free area (e.g., grille space, lattices), and open areas for both high and low spaces in the confined space were critical in maintaining HPWH cost-effective operation.
  - Successful interventions included a full and half-latticed door and both upper and lower wall grilles.
- For forced convection, where air is forced to move via external means like a pump or a fan, flowrate is more important than total space volume.
  - Successful interventions included increasing forced air flow by building a shelf to divide the room into two compartments.[17]

Multifamily Heat Pump Installation Key Challenges

At first glance, installation of HPWH in apartment buildings may appear to pose similar technical challenges to installing HPWH in small spaces like closets and manufactured homes. However, interviews with BayREN multifamily contractors Carbon Zero Buildings and GLD Green Buildings indicated that in many cases HPWH central retrofits in multifamily buildings are actually easier than their single-family counterparts due to uniformity of form factors for central water heating units. From the contractor perspective, HPWH installation jobs in multifamily buildings also provide better margins than single-family retrofits.

GLD Green Buildings has found success in utilizing SANCO2 mini-split technologies (https://www.smallplanetsupply.com/sanc02) for multifamily HPWH installation (under 50 units). GLD Green buildings noted that centralized retrofits were easier than in-unit retrofits, since many apartment-level HPWH installations would require a wiring/circuit upgrade from the original gas appliance. While both contractors discussed the benefits of installing centralized HPWH’s in larger multifamily buildings, the first 2027 compliance dates for Rule 9-6 will cover NOx-emitting hot water heaters up to 75,000 BTU/hour, which is not likely large enough to cover most centralized hot water

[17] https://hotwatersolutionsnw.org/partners/news/new-opportunities-to-install-electric-hybrid-water-heaters-in-small-spaces

systems for multifamily buildings. In instances where multifamily buildings do have systems covered by the first compliance dates, the same hurdles/solutions identified for single-family buildings are likely to be relevant.

HP HVAC Small Spaces Challenges and Solutions Overview

Space constraints and appliance relocation is primarily a challenge for HPWH retrofits and less common for HP HVAC installation cases. The main difference in replacing a gas furnace with an HP HVAC for small spaces is the location of the new outdoor compressor units. Contractor interviews indicated that most multifamily units feature a gas wall furnace, which can be swapped out relatively easily with an HP HVAC mini-split system. The prevalence of existing AC baseline cases vary across the Bay Area, with less/virtually no observed instances in San Francisco and the Peninsula, some in Oakland, and virtually all observed buildings in Antioch or Walnut Creek featuring AC systems.[18] Housing units that already have AC installed prior to HP HVAC installation will likely experience fewer additional technical hurdles to using HP HVAC.

Emergent solutions to this technical challenge will be further discussed under Challenge 3 and 4. Local policy updates are a key strategy to easing technical burdens for installing outdoor components of HP HVACs, and alleviating zoning burdens related to new fan noise from HP HVAC compressors.

[18] Source: GLD Green Buildings Contractor Interviews

Challenge 3: Noise from Heat Pumps and Outdoor Space Constraints

Noise issues which impact installation are primarily related to the installation of HP HVAC units rather than water heaters. The main issue is the noise generated by the condensing unit fans associated with HP technologies. This issue is predominantly related to the operation of HP HVAC units in areas where AC is not already in use, since both AC and HP HVAC units have similar noise impacts. HPWHs also have condensing units, but they are integrated into the water heating unit and therefore, located within a building or enclosure, limiting noise impacts. In edge cases where the original location of the water heater is close to a sound sensitive space (e.g., bedroom), the installer may want to consider appliance relocation or noise dampening measures.

Some jurisdictions require aesthetic review for condensing unit installation for some projects (e.g. San José requires review for multifamily projects, but not single family) which could further limit installation locations for HP condensing units. Anecdotally, Homeowner Associations (HOA) could also have requirements for siting condensing units or other outdoor equipment that could limit installation. It should be noted that a January 2024 scan of these rules did not result in any findings that this was currently a significant issue—potentially because available online resources were limited.

HOAs are nonprofit organizations established to create and enforce bylaws for those living in residential developments. According to California Civil Code 4350, associations can enforce essentially any rule so long as it does not conflict with local, state, or federal law, is in writing, is reasonable, is adopted in good faith, and is board-approved.[19] In addition to BAAQMD Rule 9-4 and Rule 9-6 for zero-NOx appliance installation, the California Energy Commission may also require the replacement of broken AC units with HP HVAC in the upcoming building code cycle beginning in 2026 and which would limit or eliminate the ability of an HOA to disallow condensing units.[20]

Many of the issues associated with noise and outdoor space constraints can be addressed through local policy changes, noise mitigation (such as barriers), and new technologies.

Challenge Overview: Noise from Heat Pumps and Outdoor Space Constraints (HPWH and HP HVAC)

HP technologies use fans to move the air used in heating and cooling; these fans can lead to HP-related noise concerns. HPWHs produce noise similar to other appliances that use HP technologies, for example a window-AC (60 decibels) or a refrigerator (45 decibels).[21] HP HVAC outdoor units are

[19] Cal. Civ. Code section 4350; https://www.sacbee.com/news/california/article278460724.html

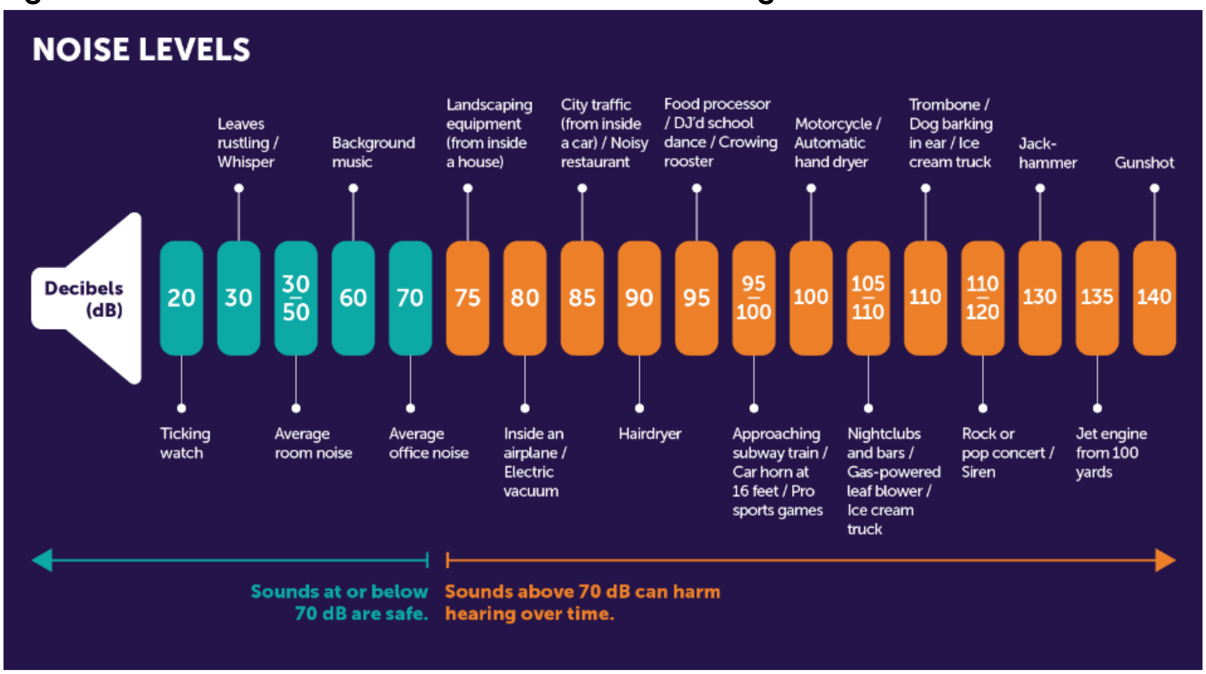
[20] https://www.sacbee.com/news/politics-government/capitol-alert/article282727143.html

[21] https://www.canarymedia.com/articles/heat-pumps/heat-pump-water-heaters-are-a-winner-for-the-climate-and-your-wallet; https://www.energystar.gov/products/ask-the-experts/what-goes-into-the-cost-of-installing-a-heat-pump-water-heater#:~:text=Heat%20pump%20water%20heaters%20have%20become%20quieter%20in%20recent%20years%2C%20with%20most%20new%20models%20generating%20between%2045%20and%2060%20decibels%20(db)%20while%20running%20-%20roughly%20the%20quiet%20hum%20of%20a%20kitchen%20refrigerator%20(45%20dB)%20or%2C%20on%20the%20other%20end%2C%20a%20modern%20window%20AC%20unit%20(60%20dB).

expected to have a similar noise threshold as HPWH.[22] The quietest HPWH currently on market is the AO Smith Voltex, which operates at 45 decibels, falling within the range of normal ambient room noise.[23]

It should be noted that the level of noise generated by HPs is not new. For the many Bay Area buildings that also have AC, noise thresholds will be similar. The Occupational Safety and Health Administration (OSHA) ranks workplace noise at 85 decibels or higher as “hazardous” with HP noise falling significantly below this threshold.[24] As shown by Figure 2, HP noise falls somewhere between “background music” (60 decibels) and “average room noise” (30 to 50 decibels).

Figure 2 HPWH and HP HVAC are in a Safe Decibel Range [25]



These noise considerations may apply to the location of HPWHs, limiting some locations such as bedrooms. Appliance relocation of HPWH because of this technical challenge can be considered an edge case to reflect consumer preference.

However, installation of an HP HVAC requires the noise-producing condensing units be located outside, which may be impacted by local regulations for appliance location and noise impacts on sensitive receptors (noise sensitive locations such as a backyard) and neighbors. It should also be noted that some analyses suggest that manufacturer estimates of air source HP noise are underestimated when compared to actual operating levels. However, this same analysis also noted that only a minority of consumers noted neighboring property HP noise to be a concern, even if actual HP operation level noise was higher than manufacturer estimates.[26]

[22] https://vancouver.ca/files/cov/heat-pump-noise-guide.pdf

[23] https://www.aosmith.com/News/2022-News/2022-09-27-Voltex/

[24] https://www.cdc.gov/niosh/topics/noise/preventoccunoise/understand.html

[25] https://hearinghealthfoundation.org/decibel-levels

[26] https://assets.publishing.service.gov.uk/media/659bc3f2614fa2000df3a992/ashp-planning-regulations-review-main-report.pdf

Solutions Overview: Manufacturer and Policy Innovation (HPWH and HP HVAC)

Solutions for HP noise include technology and manufacturer innovations, like the Quiet Mark certification, and policy and local regulation updates to accommodate new sources of HP noise and location requirements.

Manufacturer Innovation on Quieter Heat Pumps

Modern HPs have become progressively quieter over time with manufacturers widely noting the market value of quieter HPs.[27] A recent example of a manufacturer using low-noise levels as a selling point is the Quiet Mark certified Ideal Logic Monobloc HP. Although these certifications are more widespread in the United Kingdom, the movement to test and certify low-noise products could be a compelling development for the U.S./California market as well.[28] This reflects the current information available in January 2024 but should be continued to be monitored for similar developments for U.S. HP manufacturers.

Policy Innovations to Remove Barriers for Heat Pump Installation

As HP installations have become more widespread across the Bay Area (HP sales across the U.S. surpassed gas furnaces in 2022)[29], local policymakers and government staff have started to identify and remove local zoning/policy barriers to HP installation by providing additional guidance on appliance location and noise impacts.

There have been a number of local government innovators in the Bay Area paving the way for HPs enabling zoning and noise policy updates. In October 2023, the City of Palo Alto approved a series of policy changes that aimed to remove barriers to HP installation. This involved increasing clearance requirements to maintain property access to 3 feet (both property rear and side), ability to encroach into required parking spaces, and an updated decibel level raised to 50 decibels at the property line.[30]

The City of Menlo Park also approved zoning ordinance amendments in December 2023 to remove barriers for HPWH installation and which is further described in the case study below. City of Menlo Park zoning updates are primarily aimed at addressing HPWH installations in garages, as there is no overnight street parking allowed within the city. This necessitates garage/driveway parking requirements for the city, limiting space for water heating and HVAC equipment. These local zoning and policy updates can serve as a blueprint for other Bay Area cities to ease policy challenges for HP installation.

[27] Ibid.

[28] https://assets.publishing.service.gov.uk/media/659bc3f2614fa2000df3a992/ashp-planning-regulations-review-main-report.pdf; https://www.quietmark.com/products/ideal-logic-air-10kw-heat-pump

[29] https://www.utilitydive.com/news/heat-pump-sales-topped-gas-furnaces-United-States/652277/

[30] https://www.paloaltoonline.com/news/2023/10/04/code-changes-aim-to-spark-conversions-to-electric-appliances

Case Study: Menlo Park Zoning Ordinance Update Addresses HPWH Installation Challenges

The City of Menlo Park's December 2023 Zoning Ordinance Amendment addressed two key challenges for HP installation. First, space constraints for HPWH installation that required appliance relocation due to tank gallon size upsizing. Second, limits to protective enclosures built within setback limits. This second scenario would mostly apply where an HPWH could not be physically located in a garage. The zoning changes allowed for location of HPWH in garages and protective closures for HPs in the side or rear setback, as shown in Figure 3.[31] Equipment must meet local noise requirements of a 50 decibel nighttime property line noise limit and 60 decibels in the day.

In a January 2024 interview with city staff, staff members noted that the goal of these zoning changes was to incorporate challenges shared by first-movers in the community who had voluntarily retrofitted their properties with HPWHs and had encountered this obstacle. An additional policy goal was to not create a more onerous permitting process for HPWHs than a like-for-like replacement, while simultaneously updating zoning requirements. City staff noted that inter-department coordination between Permitting and Sustainability staff was key for successful passage of this zoning update.

Other Bay Area cities with restrictions on garage usage due to street parking policies may also want to consider if existing policy rules may hinder HP installation and may require updates.

Case Study: Palo Alto Policy Changes to Facilitate HP Installation

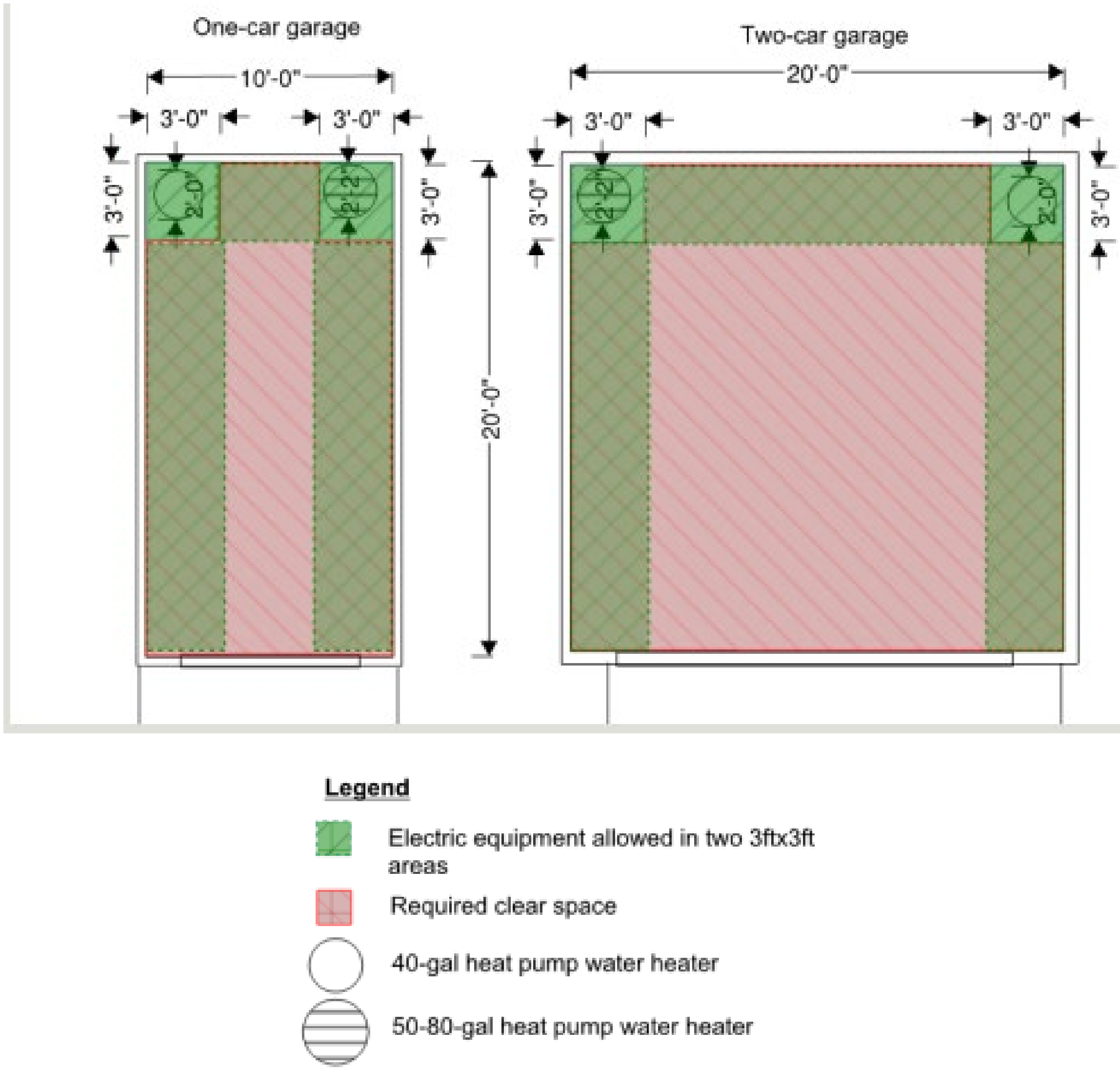
The City of Palo Alto identified challenges associated with noise generating HP equipment (namely HP HVAC condensing units) meeting the requirements of their existing noise ordinance as well as potential space constraints relating to HPWH, EV chargers, and battery storage. To help solve these challenges the city developed an ordinance to loosen restrictions on placement of non-gas fueled electric equipment within residential home setbacks and in some cases, residential parking spaces.[32] The current noise ordinance allows equipment to exceed local ambient noise levels by 6 decibels (dB) but equipment must be placed beyond established setbacks. The ordinance update allows equipment to encroach on these setbacks so long as they meet noise requirements either with or without mitigation. The code also allows HPWH, EV chargers, and energy storage devices to be placed within the parking area of one- and two-family garage and carport spaces. Specifically, the ordinance update (which was adopted by City Council in October 2023) modified the following items:

- enabling the placement of such equipment for new construction to meet the new green building requirements in residential zones, as well as replacement of existing equipment, within the minimum side (including street side) and rear property setbacks in residential zones (PAMC 18.10, 18.12, 18.13, 18.40) enabling electrification equipment to encroach 18 inches into required one- and two-family garage and carport parking stalls, with specified clearances (18.40, 18.54)

[31] https://www.bayren.org/sites/default/files/documents/2023/BayREN-Q4-2023-Forum-Zoning-Changes-Help-Electrify-Existing-Homes_Paz.pdf

[32] Agenda - Wednesday, December 14, 2022 (cityofpaloalto.org)

Figure 3 Approved Menlo Park Zoning Changes allow for HPWH Relocation in Garages



- modifying requirements for equipment housing/noise suppression measures
- modifying 18.40.070 (to allow storage structures – specifically, sound attenuating enclosures for electrification equipment – when required to meet the noise ordinance - to encroach further into setbacks than currently allowed)
- modifying 18.40.260 to enable residentially used electric vehicle charging stations and energy storage system equipment, together with safety bollards, to encroach up to two feet into a required front yard or up to six feet into a required street side yard, with vegetative screening as feasible
- modifying 18.40.070 item (c) that allows storage structures six feet or less in height to encroach up to two feet into a side yard and up to four feet into a front or rear yard to add “Storage structures housing electrification equipment may encroach into required interior side yards and required rear yards and may encroach six feet into a required street side yard.”

The city also developed a screening table to establish setbacks for each equipment noise level and neighborhood noise level (40dBA or 50dBA) to streamline applications. Equipment that meets the table requirements are considered to be consistent with the noise ordinance as shown in Figure 4.[33]

Figure 4 Example Setback Requirements Screening Table – City of Palo Alto

Equipment Sound Level (dBA) in 40 dBA Area	Equipment Sound Level (dBA) in 50 dBA Area	Minimum Setback from Receiving Property Line (ft.)
43	53	4
44	54	5
46	56	6
47	57	7
49	59	8
50	60	9
51	61	10
52	62	12
53	63	13
54	64	15
55	65	17
56	66	19
57	67	22
58	68	24
59	69	27
60	70	30

[33] City of Palo Alto Municipal Code- Table 1- Setback Requirements: https://www.cityofpaloalto.org/files/assets/public/v/1/agendas-minutes-reports/agendas-minutes/planning-and-transportation-commission/2023/ptc-8.09-muni-code-electrification.pdf

Challenge 4: Access to Perimeter Walls and Missing Ductwork

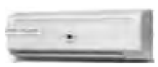
This section focuses specifically on HP HVAC installation. As illustrated by Rincon's January 2024 BAAQMD Whitepaper *Installation Costs for Zero-NOx Space and Water Heating Appliances*, ducted HP HVAC systems are significantly more costly to install than their ductless counterparts. This increased cost is directly tied to the need to reconfigure and replace unsuitable or old ductwork which can cause inefficient operation and comfort issues. Furthermore, if a home was only designed for heating (which is common in the Bay Area) then a return air duct would be needed for AC associated with a ducted HP. This can add costs and time to a project if no AC was present.

Ductless mini-multi-splits are a promising solution to avoid the challenge of ducting, especially in buildings with no ducting (wall furnaces) or old/broken ducting. However, installing mini-multi-split HP HVAC systems may also pose technical challenges related to the need for new refrigerant lines when heating/cooling multiple rooms. Choosing ductless mini-multi-split systems can lower installation costs and simplify retrofits compared to ducted HP HVAC systems in some building types. Ductless mini-splits also have energy efficiency advantages by eliminating energy losses associated with leaking ductwork.[34] Examples of low-voltage, 120-volt, ductless mini-multi-splits consistent with a watt-diet approach are described in Figure 5.

[34] https://assets-global.website-files.com/62b110a14473cb7777a50d28/6396be1051f34460e7dd5f26_A%20Pocket%20Guide%20to%20All%20Electric%20Retrofits%20of%20Single%20Family%20Homes.pdf

Figure 5 Ductless Mini-Split Heat Pump System Descriptions (Redwood Energy)[35]

Ductless Mini-Split Heat Pumps (120V)

Interior Wall-Mounted Fan Coil 	**GE** Caliber Series AS12CRA 	**Mitsubishi** MZ-JP12WA 	**Gree** LIV (09,12) HP115V1B 	**Carrier** 38MAR 	**Haier** 
Description	1 Indoor Fan Coil	1 Indoor Fan Coil	1 Indoor Fan Coil	1 Indoor Fan Coil	1 Indoor Fan Coil
Dimension (in) (HxWxD)	21 x 31 x 10	22 x 32 x 11	33 x 21 x 13	32 x 21 x 13	28 x 35 x 14
Ref. Type	R410a	R410a	R410a	R410a	R410a
Ambient Temp. Range (H/C) (F)	**-4 - 115**	**-4 - 115**	**0 - 115**	**-13 - 122**	**-4 – 115**
Crankcase Heater	Not Indicated		Not Indicated	Not Indicated	Not Indicated
Power (W)		800 – 1,300	1,955	1,725	2,100
Max Amps (A)		11.8	17	15	18
Heating Cap. (BTU/h)	12,000	12,200	9,600; 12,500	12,000	16,000
Cooling Cap. (BTU/h)	12,000	12,000	9,000; 12,000	12,000	12,000
Heating (COP)	2.92	2.9	3.3	2.03 - 3.80	3.2
Cooling (COP)	2.92	2.9	4.67	3.8	3.75
Price ($)	$860	$1200	$790	$1800	

Challenge Overview: Old and Outdated Ductwork (Ducted)

Because gas furnaces produce a lot of heat quickly (though inefficiently) they can often mask issues of poorly designed, leaky, or otherwise inefficient ductwork. However, because HPs work more slowly (and maintain temperatures more efficiently) ductwork inefficiencies can create comfort issues if they are not addressed. Replacing or repairing old ductwork and installing new sections as needed can increase costs and timelines associated with replacing a central ducted NOx-emitting furnace with an HP HVAC unit. Furthermore, central ducted furnaces without a central AC could lack a return air system required for efficient AC. This return air brings already chilled air from the buildings conditioned spaces back to the AC unit instead of bringing in hotter outside air. Multistory buildings without a return already installed could face additional hurdles. While not technically challenging, these issues can increase installation costs and timelines.

Solution: Install New Ducting or Move to Ductless

To provide the benefits of efficient heating and cooling, old and inefficient ducts will need to be fixed or replaced. Buildings without return vents will need to add them to gain the benefits of AC. This will require additional work from the contractor which will add costs and days to the overall project timeline but should not be a technological issue. The other option is to move to a ductless

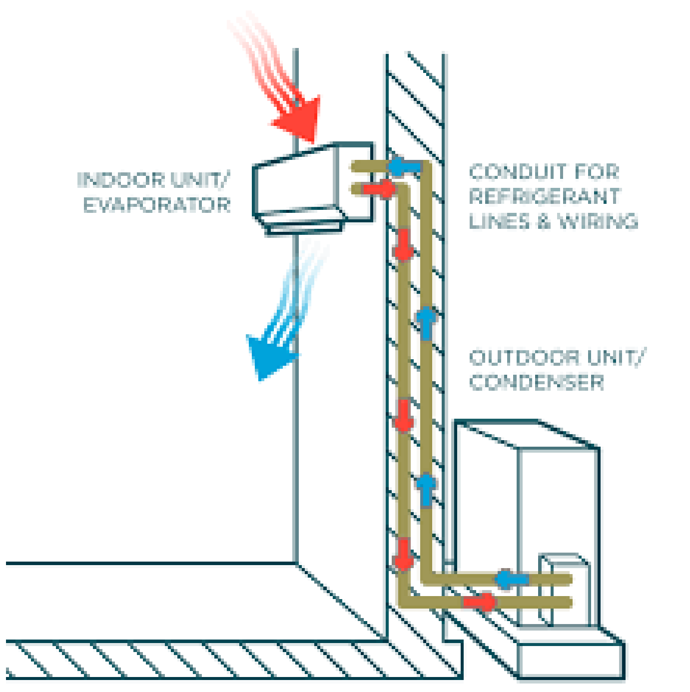
[35] https://assets-global.website-files.com/62b110a14473cb7777a50d28/6396be1051f34460e7dd5f26_A%20Pocket%20Guide%20to%20All%20Electric%20Retrofits%20of%20Single%20Family%20Homes.pdf

system which bypasses the need for any ductwork at all. It also removes the need for a return air vent since each mini-split heat unit provides both conditioned and return air.

Challenge Overview: Lack of Access to Perimeter Walls (Ductless)

Ductless HPs do not require ductwork, and instead move heat around with thin "line sets" filled with a refrigerant that move between the interior head unit and exterior condensing unit. These mini-splits are perfect for buildings without existing ductwork like those that utilize a wall heater but could also be used when dealing with old or extremely outdated ducting. While ductless HP HVAC units remove the need for fixing or installing new ductwork throughout a building, installing them in larger buildings with multiple rooms can add challenges since each room could potentially need its own indoor unit or air handler. A typical multi-unit mini-split pairs two to four indoor units per one condenser. This system for a single room is illustrated in Figure 6.[36]

Figure 6 Ductless Mini-Split System Diagram[36]



As refrigerant lines run through holes made through perimeter walls, if perimeter wall access is restricted, installation could prove technically challenging or costly because of modifications needed to run refrigerant lines to multiple separate zones in the building on interior walls (e.g., requiring routing of refrigerant lines through attic space if lacking outdoor duct, running lines on interior walls with line covers). Ductless mini-multi split line sets are typically mounted and run on the exterior wall.[37]

[36] Image source : https://www.armstrongair.com/products/mini-split-systems

[37] https://inabadenko-america.com/2022/07/installing-mini-split-systems-on-interior-walls/; https://inabadenko-america.com/2022/07/installing-mini-split-systems-on-interior-walls/

Solution: Innovative Installation for HP HVAC

Various line-set concealing solutions for interior wall installations are offered by manufacturers such as Inaba Denko.[38] Generally, opting for interior wall line set installation may result in higher installation costs and necessitate on-the-ground troubleshooting. This is supported by GLD Green Energy's descriptions of multi-split HP HVAC installation, where they detailed case studies involving line set installations in interior walls using plastic covers or soffits.

According to contractor interviews, concerns on running lines in interior walls instead of exterior are primarily related to increased installation costs, and concerns that the interior line set installation will be unsightly. This indicates that this is primarily a consumer preference challenge, rather than a technical challenge that could impact overall project feasibility.

[38] https://inabadenko-america.com/2022/07/installing-mini-split-systems-on-interior-walls/

Challenge 5: Electrical Infrastructure and Distribution Grid Challenges

This section characterizes technical challenges (lag time, challenging contracting situations, cost impacts) based on potential need for electric infrastructure upgrades including panels, services, and associated distribution grid components including transformers. These impacts could occur during zero-NOx appliance installation if the added electrical demand from the new appliance exceeds the capacity of the existing panel and service line. Costs to the building owner due to panel and service upgrades are a major variable addressed in the memorandum *Installation Costs for Zero-NOx Space and Water Heating Appliances*[39]. These cost burdens are not addressed as part of this analysis, which instead focuses on the technical challenges associated with service upgrade undergrounding and distribution grid capacity issues due to location.

The analysis below under 5.1 and 5.2 pertains to both HPWH and HP HVAC appliances. If a building requires panel upsizing, it could also potentially trigger a service line upgrade. Electric panel sizing is closely connected to building age (vintage). Generally, older single-family homes have 60-to-100-amp panels, while newer homes have 200-amp panels. Homes built before the mid-1960s or early 1970s are likely to have main panels of 60 amps while homes built before the 1980s are likely to have 100-amp panels.[40] Depending on the size of the home and the number of electric appliances, installation of zero-NOx appliances could necessitate a larger panel (and associated service line). Single-family homes with 100-150-amp panels are likely able to accommodate zero-NOx HPWH and HP HVAC with additional planning and efficiency measures (watt diet), while single-family homes with 200-amp panels (generally, single-family homes) are predicted to have ample space to install zero-NOx appliances in addition to other electric upgrades like electric vehicle charging.

Challenge Overview: Underground Service Line Upgrades

Electric service upgrade costs vary depending on whether a service line is above ground or below ground and the distance between the transformer and the building. As part of California Energy Commission research conducted by E3, PG&E provided estimates that electric service upgrade costs would range from $10,000 to $60,000 per customer based on their evaluation of three communities in the East Bay. More generally PG&E reports that service upgrade projects could cost between $1,000 to $40,000+.[41]

The low end of this range would apply when overhead electric services are short in distance with minimal connections, and the high end would describe circumstances where significant underground trenching is required. Key variables impacting the cost and complexity of trenching included a right of way or easement requirements, upgrades to infrastructure, and length of trench as shown in Figure 7.[42] Wait times for service upgrades/new service connections can range from

[39] https://www.baaqmd.gov/~/media/files/community-health/building-appliance-implementation/task1_electrificationcosts_final_clean-mar2024_baaqmd-exec-review-pdf.pdf?rev=7dfac61088394a74aa90d835d46b1e69&sc_lang=en

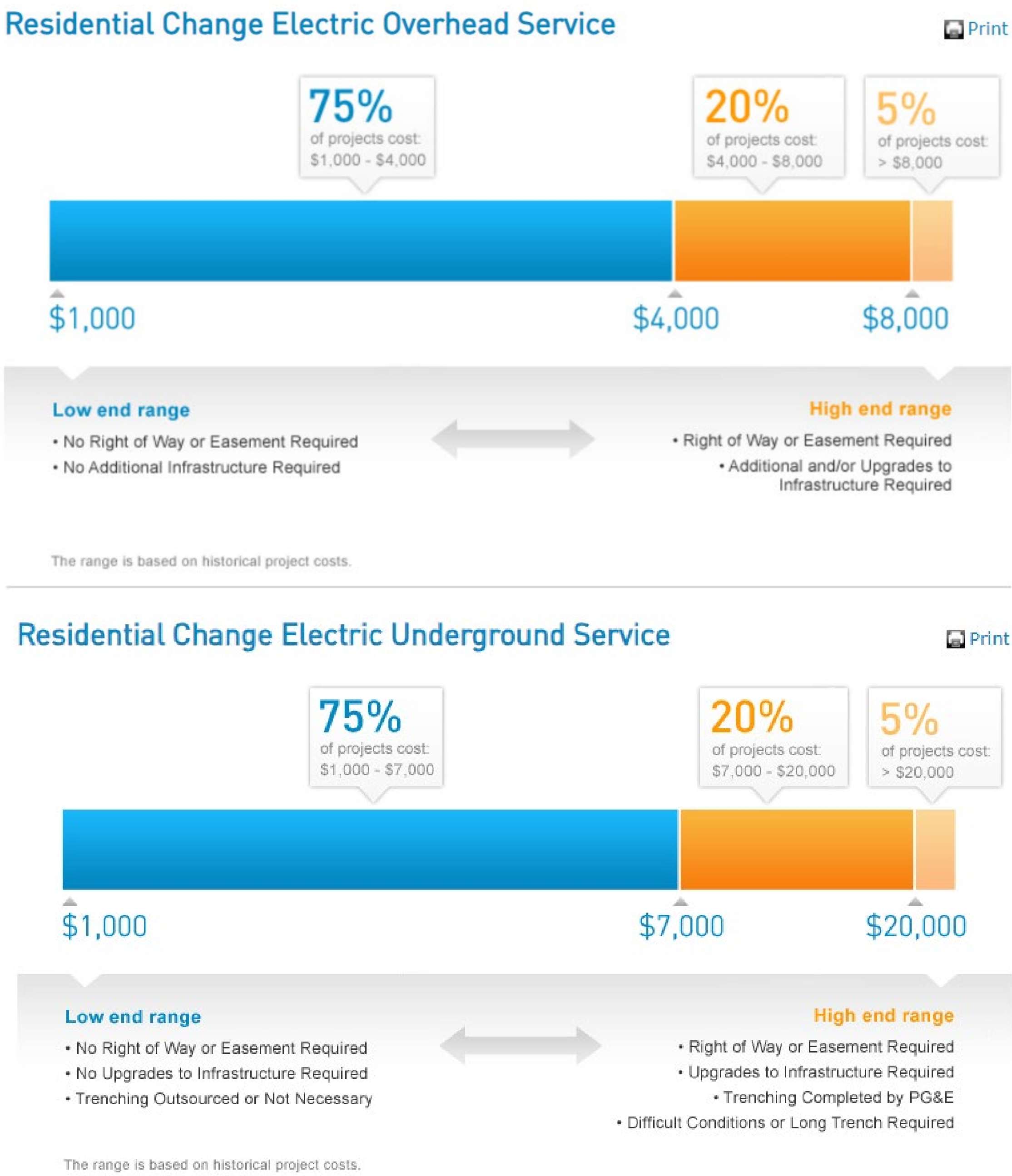
[40] https://newbuildings.org/we-can-power-the-homes-of-the-future-with-electric-panels-of-the-past/#:~:text=Back%20in%201962%20the%20%E2%80%9CLive,and%20it's%20enough%20power%20now.

[41] https://www.pge.com/en/myhome/customerservice/other/newconstruction/projectcosts/results.page?serviceType=electric_over&gasType=&electricOverType=elec_over_change&electricUnderType=elec_under_change&pevType=&proj=elec_over_change

[42] https://www.pge.com/en/myhome/customerservice/other/newconstruction/projectcosts

weeks to months, based on reporting from KQED and Politico.[43] This extended service timeline would necessitate the innovations in programming and technology described under Challenge 1 to fill the gap in hot water or heat service needed in the interim.

Figure 7 Trenching Significantly Increases Complexity, Costs, and Timeline for PG&E Service Upgrades[44]



[43] https://www.politico.com/news/2023/04/21/california-energy-electricity-power-00093187

[44] https://www.pge.com/en/myhome/customerservice/other/newconstruction/projectcosts/results.page?serviceType=electric_over&gasType=&electricOverType=elec_over_change&electricUnderType=elec_under_change&pevType=&proj=elec_over_change

Residential customers receive a ratepayer-funded allowance of $3,255 paid by electric ratepayers, with the customer responsible for paying the remainder, thereby significantly easing the cost burden of service upgrades for the 75 percent of projects that fall between $1,000 to $7,000.[45]

In addition to these potential cost impacts, electrical infrastructure upgrades could add weeks (panel) to months (service) to a project schedule. While PG&E does not provide these timeframes, anecdotal evidence points to significant delays when service upgrades are required.

Besides undertaking strategies to avoid panel upsizing altogether, there is little a building owner or local policy maker can do to ease this transition as it is predominately the responsibility of the utility. Most recommended strategies in a recent PG&E report *Service Upgrades for Electrification Retrofits Study Final Report* recommend internal PG&E reform and strategies to ease customer wait times and streamline internal processes.[46]

Senate Bill (SB) 410 is a recent policy development aimed at easing the lag times and technical challenges associated with customer energization projects and is further described below. Incentive providers can also start to integrate watt-diet approaches into existing programs and financial incentives to increase uptake of smart-panels, low-voltage appliances, and other load-sharing devices that can effectively avoid electric service upgrades.

Policy Highlight: SB 410 Powering Up Californians Act (2023)

SB 410 directs the California Public Utilities Commission to set average and target time periods for customer interconnections and upgrades by September 30, 2024. Regulators are also directed to set annual utility reporting requirements to track and improve electrical corporation performance. SB 410 aims to provide a policy solution to increase speed of project completion for new interconnections, which is considered a significant barrier to electric and zero-NOx appliance adoption.[47]

Challenge Overview: Distribution Grid Capacity Issues Due to Location

The largest infrastructure impact projected from the implementation of Rule 9-6 and Rule 9-4 is expected to be the associated need for electricity to meet new loads from HPWH and HP HVAC. According to recent E3 analysis on the grid impacts of Rule 9-6 and Rule 9-4, 6.2 terawatt-hours would be needed per year of additional electric load by 2050, representing 2.2 percent of statewide electric loads.[48] At the distribution grid level, the Rules are expected to lead to a 420 megawatt impact by 2050 to support new peak loads from zero-NOx water heating and space heating appliances. This translates to an expected $380 million in cumulative costs by 2050.

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[45] https://pda.energydataweb.com/api/view/2635/Service%20Upgrades%20for%20Electrification%20Retrofits%20Study%20FINAL.pdf

[46] Ibid.

[47] https://legiscan.com/CA/text/SB410/id/2813946

[48] This number could be seen as a conservative estimate as it is relative to the “low policy reference,” which assumes little-to-no additional state action to install zero-NOx appliances or otherwise electrify. Source: E3 April RICAPS presentation: https://docs.google.com/presentation/d/1q91JE5Xn1SuapToncW9qBFJDN1jmY6JC/edit?usp=sharing&ouid=105799344088771997660&rtpof=true&sd=true

Distribution infrastructure projects needed to accommodate new loads may range from upgrades or replacements of equipment which occur in existing rights of way, greenfield construction of new line sections, distribution feeder, and substation upgrades as described in Figure 8.[49]

Figure 8 E3 Assessment of Rule 9-4 and Rule 9-6 Potential Distribution Capacity Impacts

	2050 impact relative to Low Policy Reference	2050 impact relative to High Policy Reference
Distribution Capacity (MW)	420 MW	< 10 MW impact by 2050 *Accelerated impact in 2030s, 2040s*
Cumulative Cost (Real $2021 Million)	$380	$100 *Due to accelerated build*
Estimated Banks (New, by 2050)	6 New Banks	Negligible impact by 2050 *Accelerated impact in 2030s, 2040s*
Estimated Feeders (New, by 2050)	45 New Feeders	Negligible impact by 2050 *Accelerated impact in 2030s, 2040s*
Estimated Line Sections (New, by 2050)	10 New Line Section	Negligible impact by 2050 *Accelerated impact in 2030s, 2040s*
Estimated Banks (Upgrades, by 2050)	31 Bank Upgrades	Negligible impact by 2050 *Accelerated impact in 2030s, 2040s*
Estimated Feeders (Upgrades, by 2050)	42 Feeder Upgrades	Negligible impact by 2050 *Accelerated impact in 2030s, 2040s*
Estimated Line Sections (Upgrades, by 2050)	35 Line Section Upgrades	Negligible impact by 2050 *Accelerated impact in 2030s, 2040s*

According to PG&E estimates, these distribution capacity improvements can take 1 to 10 years as shown in Figure 9.[50] Though it is unclear to what extent distribution capacity can constrain consumer adoption of zero-NOx technologies, these long timelines to upgrade distribution infrastructure should continue to be monitored as a technical hurdle to be overcome by future legislation and local policy advocacy.

Figure 9 PG&E Timeline Estimates for Distribution Capacity Improvements

Scope of Distribution Capacity Improvement	Typical Timeline
Distribution line work to increase capacity or reconfigure circuits	12-36 months
Add a new circuit from an existing substation	24-36 months
Add or replace a substation transformer at an existing substation	36-48 months
Build a new substation	5-10 years depending on agency with CEQA oversight responsibility

[49] https://www.baaqmd.gov/~/media/dotgov/files/rules/reg-9-rule-4-nitrogen-oxides-from-fan-type-residential-central-furnaces/2021-amendments/documents/20221220_sr_appd_rg09040906-pdf.pdf?la=en

[50] PG&E Presentation, April 2023 RICAPS Webinar (County of San Mateo): https://docs.google.com/presentation/d/10ATvDA6jULdbEiAnGVSscp9WWP_k6dBp/edit#slide=id.p25

Solutions Summary: Avoiding Panel and Service Upgrades

Zero-NOx Appliance Installation on a 100-Amp Panel

The root cause of an electrical service upgrade is electrical panel upsizing. According to recent analysis conducted on behalf of BAAQMD, the majority of zero-NOx upgrade projects in single-family homes and all projects in multifamily homes were completed without panel upsizing. When panel upsizing did occur, it is not clear if this was required for the project, or if it was completed preemptively to allow for future electrification projects or EV charging. Additionally, 19 to 22 percent of HPWH projects were successfully completed on a 100 amp or less electric panel across single and multifamily projects. About 24 to 29 percent of all HP HVAC projects were successfully completed on a 100 amp or smaller panel across single-family and multifamily projects respectively. This analysis does not include zero-NOx upgrade projects that may have not been completed due to the potentially prohibitive costs of panel upsizing.[51]

These findings are supported by a growing body of research that suggests HP installation, in addition to other new electric loads (e.g., induction stove, electric vehicle), can be accommodated on a 100-amp panel through the selection of energy efficient appliances, and if needed, load-sharing devices (e.g. circuit splitter). Especially when paired with energy efficient retrofits, this approach is called the watt diet, which allows increases in home electrical use without a potentially technically difficult and costly electric panel and service upgrade.

Retrofit-Ready 120-Volt HPHW

Emergent field tests for 120-volt HPWH conducted by the New Buildings Institute (NBI) show high customer satisfaction with the performance of existing 120-volt technologies. NBI worked with 120-volt HPWH manufacturers and utilities in California on a statewide field validation program from 2022 to 2023. NBI installed 120-volt HPWH for 32 customers across California climate zones as part of the Advanced Water Heating Initiative. NBI suggests that 120-volt water heaters should be used when replacing an existing gas/propane water heater and when an existing shared circuit is available with enough power (less than 8 to 10 amps of load is expected besides the water heater). The report concluded that 22 to 30 percent of California homes would fit this description.[52] The remaining homes would either be replacing an existing electric water heater (and therefore have access to a 240-volt circuit) or would necessitate additional circuits or panel upgrades at which point a 240-volt water heater should be installed.

This recent report finding highlights the potentially critical role that 120-volt HPs could play in easing technical challenges for HPWH retrofits while avoiding potential panel upsizing and subsequent service upgrades. A table of market available 120-volt HPs is included below in Table 4 for reference.

[51] Rincon and E3. BAAQMD Task 1 Memo: “Installation Costs for Zero-NOx Space and Water Heating Appliances”

[52] https://newbuildings.org/wp-content/uploads/2023/07/PlugInHeatPumpWaterHeaterFieldStudyFindingsAndMarketCommercializationRecommendations_NBI202308.pdf

Table 4 120-Volt HPWH Options

120-Volt Product Description	Appliance Description	Market Available?
Rheem Performance Platinum Plug-In Heat Pump with Hydro Boost	Available 40-, 50-, 65-, and 80-gallon capacities Shared circuit design	Yes
Rheem ProTerra Plug-in Heat Pump	Available in 40- and 50-gallon capacities Dedicated circuit design	Yes
General Electric	-	No; in development
A.O. Smith	-	No; in development
Nyle	-	No; in development

Source(s): https://hotwatersolutionsnw.org/partners/news/120-volt-heat-pump-water-heater-product-overview

Watt-Diet Approach

If a 120-volt option is not suitable for installation (e.g., larger tank demand size necessitates 240-volt technology), a building owner could consider smart panels and other load sharing devices that could be purchased and installed instead of panel upsizing and a potentially costly or complex service upgrade. A table of market available smart panels and load sharing devices is included in Rincon's first whitepaper to BAAQMD *Installation Costs for Zero-NOx Space and Water Heating Appliances* [53] and shown here for reference in Table 5. Installation of most watt-diet appliances will still require dedicated time and costs, which describe labor hours that are unique to the installation of the selected appliance, but will likely be significantly less expensive than the cost of an electric panel upsize project or subsequent electric service upgrade.

Table 5 Watt-Diet Appliance Descriptions and Costs

Watt-Diet Appliance Type	Appliance Description	Total Cost
SPAN Smart Panel	Smart panel allowing for control of circuits based on appliance energy need	$3,500[1]
Leviton Smart Circuit Breaker Box + Whole Home Energy Monitor	Smart panel allowing for turning on and off breakers based on appliance energy need paired with data monitoring app	$358 (whole home energy monitor) $244 (Smart Circuit Breaker)[2]
Eaton Smart Circuit Breaker	Smart energy monitoring and load control	$236[3]
NeoCharge 240-volt Smart Splitter	Smart load shifting tailored to electric vehicle charging uses	$399-476[4]

[1] https://www.span.io/panel Available for additional IRA rebates, bringing cost to $2,900

[2] https://store.leviton.com/search?type=product&q=whole+energy+monitor

[3] https://www.homedepot.com/p/Eaton-Smart-Circuit-Breaker-2-Pole-20-Amp-120-Volt-240-Volt-10-kA-Interrupt-Rating-BREM2020/322052158

[4] https://electrek.co/2020/09/04/neocharge-240v-smart-splitter/

[53] https://www.baaqmd.gov/~/media/files/community-health/building-appliance-implementation/task1_electrificationcosts_final_clean-mar2024_baaqmd-exec-review-pdf.pdf?rev=7dfac61088394a74aa90d835d46b1e69&sc_lang=en

These technology options can be supported by programs like BayREN and TECH in order to train workforces in alternate approaches to panel upsizing and service upgrades. The watt-diet approach could also be bolstered through incentives and education on available low-voltage technologies, and incentives for smart panels and circuit sharing devices instead of a conventional panel upsizing incentive currently offered by most incentive providers.

Highlight: Zero-NOx Appliance Install for Buildings with Solar

Buildings that have installed solar power are uniquely well positioned to install zero-NOx appliances without additional panel or service upgrades. These buildings are more likely to save money on their energy bills after installing heat pumps due to self-generation and will also take advantage of existing electrical work completed to accommodate the solar system. Buildings with solar panels generally require at least a 200-amp rating, which is widely regarded to accommodate both HP HVAC and HPWH retrofits without additional panel upsizing.[54] Buildings with solar thus are uniquely well positioned to overcome technical challenges and bill impacts associated with the installation of zero-NOx appliances. It should be noted that the cost savings resulting from self-generation may be less applicable to larger multifamily buildings. Larger and higher density multifamily buildings don't usually have enough space for a solar array that can offset multiple units worth of electricity demand.

Case Studies: 2023 San Mateo County Zero-NOx Heat Pump Retrofits on a 100-Amp Panel

BayREN and San Mateo County Office of Sustainability published a series of 10 case studies for decarbonizing single-family homes across San Mateo County. Panel load calculations were conducted, as per NEC 220.83 B, to assess costs for whole-home electrification. Whole-home electrification included HP retrofits, but also electric load increase from electric vehicle charging, induction stoves, and electric clothes dryers. The findings from the case studies indicate that even after adding additional electrical loads on top of HPWH and HP HVAC, whole-home electrification is possible without an electric service upgrade or panel upsizing on a 100-amp panel. This is enabled through "panel optimization" using circuit pausing devices, smart-panel installation, and subpanel/wiring upgrades, as shown below in Figure 10.

[54] https://www.bostonsolar.us/solar-blog-resource-center/blog/do-i-need-to-upgrade-my-electrical-panel-when-going-solar/#:~:text=To%20be%20ready%20for%20solar,to%20manage%20with%20less%20amperage

Figure 10 Key Findings: Whole Home Electrification on a 100-Amp Panel (County of San Mateo)

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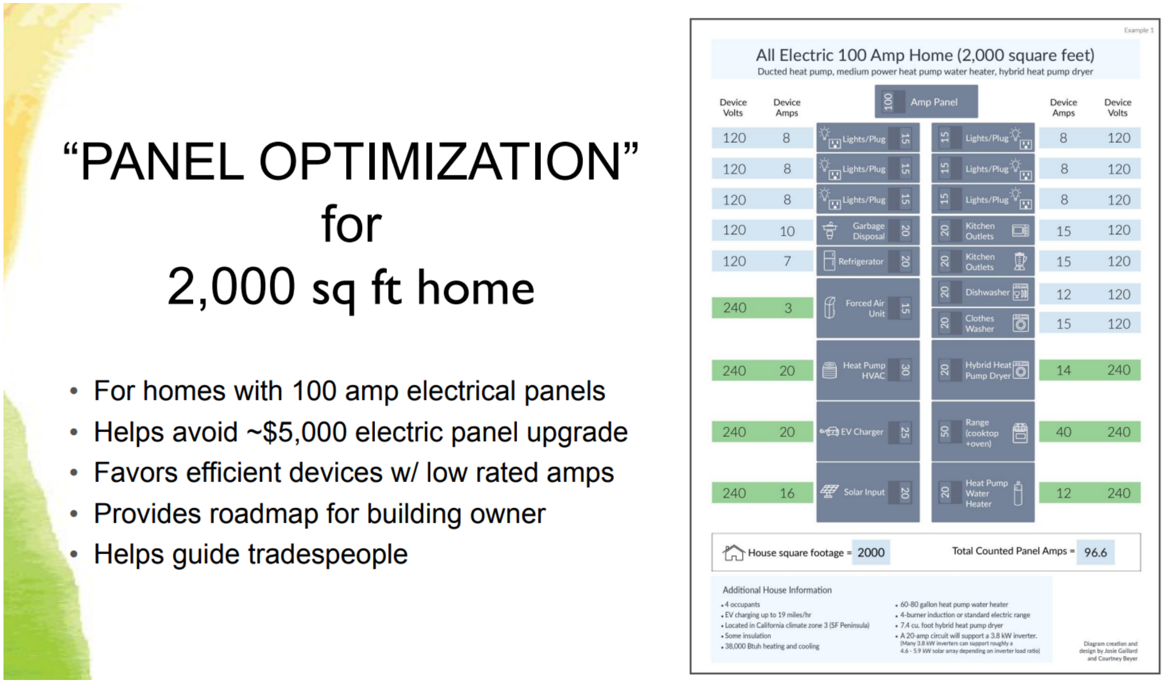

Conclusion

Challenges associated with appliance installation are not new in the construction field. Due to the high variability within the building stock, some challenging edge cases will always exist. In addition, some buildings have seen years of deferred maintenance (like failing ductwork or outdated electrical infrastructure) that will need replacement eventually. Noise and space limitations are not unprecedented for contractors retrofitting buildings with modern appliances like HP HVACs, as these also occur for the installation of conventional central air conditioners. Technical challenges involved in some installation cases, like installing interior wall line set work for mini-multi-split ductless HP HVAC, may be more complex, time intensive and costly but can be supported by stop-gap emergency replacement programs that allow for temporary appliance replacement by gas or low-voltage appliances as a more complex HP install is in process.

Manufacturer innovations in low-voltage, low-noise, small-space-ready HP technologies will likely play an increasingly important role in overcoming technical hurdles. Other solutions, like innovative contractor business models and widespread availability of same-day temporary emergency replacement water and space heaters will need to be championed by contractors and workforce support programs (e.g. trade schools, BayREN, and emergent sustainability/ green building programs supporting transitions from gas to zero-NOx appliances like TECH Clean California Quick Start Grants). These programmatic solutions can also be supported by third-party organizations and programs like TECH direct installation HP pilots (e.g., Barnett Plumbing) and CCA incentive programs facilitating HP installation.

Local policymakers can also ease the burden for HP installation by identifying existing regulatory barriers constraining HP installation locations based on space and noise and altering municipal codes to pave the way, or even make it code-favorable to install zero-NOx appliances.

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