Grid Reliability and Interconnection Challenges

Bay Area Air Quality Management District

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Table of Contents

Tables

Figures

1 Introduction

1.1 Power Outages and Interconnection as a Potential Hurdle for Implementation of Rules 9-4 and 9-6

In 2023, the Bay Area Air Quality Management District (BAAQMD) adopted amendments to Rule 9-4: Nitrogen Oxides from Fan Type Residential Central Furnaces and Rule 9-6: Nitrogen Oxides Emissions from Natural Gas-Fired Boilers and Water Heaters. These rules govern point of sale emission standards for natural gas-fired water and space heating systems under stated thresholds. As the updated Rules take effect, nitrogen oxides- (NOx) emitting water heaters under 75,000 British Thermal Units (BTU)/hour manufactured after January 1, 2027 will no longer be available for purchase or installation in the Bay Area.[1] NOx emitting furnaces under 175,000 BTU/hour, and combination heating/cooling units under 65,000 BTU/hour manufactured after January 1, 2029, will no longer be available for purchase or installation in the Bay Area.[2] These thresholds are expected to apply primarily to residential and small-commercial space and water heating appliances.

Rules 9-4 and 9-6 will transform water and space heating appliance installation patterns in the Bay Area. Prior to the amendment of the Rules, NOx- emitting gas water heaters and furnaces were the primary appliances used to heat space and water across the region.[3] After the amendments to the Rules come into effect in 2027 (water heating) and 2029 (space heating), contractors and homeowners will default to installation of zero-NOx appliances for these building functions. Today, the only technologies that meet zero-NOx standards for these end uses are electric devices, although gas-fired technologies that meet zero-NOx standards could be developed in the future. Heat pump hot water heaters (HPWH) and heat pump heating, ventilation and air conditioning (HP HVAC) are cost-effective and energy efficient zero-NOx appliances which are expected to be the primary zero-NO_x [4]

During the passage of the updated Rules, BAAQMD received community feedback on a range of concerns related to the addition of new electrical loads stemming from increased heat pump adoption. As buildings across the Bay Area switch from gas to electric appliances for space and water heating, the demand for electricity is generally expected to increase. Community feedback related to this increase can be characterized as concerns related to the reliability of the electric grid as it manages higher demands and the timelines and costs associated with grid upgrades which could interrupt space and water heating services. This analysis aims to explore these concerns and better understand the extent to which these issues are likely to impact homes and businesses in the Bay Area. To do this, the analysis focused on community electrical grid reliability concerns related to interconnection and service line upgrades, power outages, and appliance-level reliability.

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[1] The Bay Area refers to all BAAQMD governed geographic regions across the Bay Area’s nine counties: San Francisco, San Mateo, Santa Clara, Alameda, Contra Costa, Solano, Napa, Sonoma, and Marin County.

[2] Note that there will be an allowable “sell-through” period of these older units meeting the current requirements for 2024 ultra-low NOx requirements.

[3] https://www.energy.ca.gov/publications/2021/2019-california-residential-appliance-saturation-study-rass

[4] Although there are other zero-NOx appliance options available, such as solar photovoltaic water heaters and electric resistance water heaters, these options are either considered less energy efficient and therefore more costly (electric resistance heaters), or not suitable for the climate conditions of the Bay Area (solar). Accordingly, these zero-NOx technology options are not the focus of this analysis. https://www.energy.gov/energysaver/heat-pump-water-heaters#:~:text=How%20They%20Work&text=Heat%20pump%20water%20heaters%20use,like%20a%20refrigerator%20in%20reverse.

Interconnection is the process by which an individual building is connected to the broader grid. This is done through the service line which generally extends from the local distribution lines to the individual buildings service meter. In some cases when a buildings load increases to the point of needing a panel upgrade, a service line upgrade could also be required which would trigger the interconnection process from PG&E. Not all panel replacements/upsizing will require service upgrades. The need for a service line upgrade will depend on the existing service and the type of panel being installed. A diagram of these components and who owns them is included in Figure 1.

The key concerns relating to grid and appliance reliability and the results of this analysis are summarized below. Full descriptions of each issue along with sources are included in the corresponding sections within the report.

Section 2 Utility Interconnection Lag Times

What is the potential for long wait times for electric hot water or space heating installations due to required electric panel and/or electric service upgrades ("service upgrade") for residences or businesses?

Summary of Findings

- Service upgrades can be triggered by the need for a larger electric panel (when the existing service line is inadequate for the additional load)
- It is unlikely that the installation of only a HPWH will lead to the need for a panel and corresponding service capacity increase. Each additional electric appliance installation increases the chance of needing a panel and/or service upsize in homes without existing air conditioning.
- At least 44 percent of Bay Area households are assumed to have a 200-amp panel based on the year constructed and presence of air conditioning and are therefore, unlikely to need a panel upsize. Many of the remaining 56 percent of households can install zero-NOx HPWH and HP HVAC on panels 100-amps or smaller with some of these households have updated their panels for other reasons such as safety or purchasing an EV.
- If a service upgrade is needed, installation timelines from Pacific Gas and Electric (PG&E) are between 10 days and eight+ months. The length of this process is directly related to the complexity of the service upgrade (e.g., upgrading underground electrical lines will take much longer than above-ground lines).
- Recent legislation and internal reform processes at PG&E are aimed at shortening timelines for service upgrades and new interconnections.
- Panel and service upgrades and corresponding lengthy timelines for interconnection can be avoided by selection of low-voltage appliances like 120-volt HPWH and using a "watt-diet"[5] approach.

[5] "Watt diet" refers to an approach to appliance electrification that integrates inexpensive technology choices/interventions, like choosing power efficient equipment options, adding electrical circuit-sharing/splitters, using EV charging schedules, etc., to enable building electrification without upgrading a home's electric service capacity. See page 13 of this report for more discussion on this topic.

Section 3 New Electric Loads from Zero-NOx Appliances and Grid Reliability

Will adding new electrical appliances cause issues with the grid or result in power outages?

Summary of Findings

- Public perception often associates new electric loads with "rolling" power outages initiated by State grid operators when peak electric demand exceeds the supply of power, leading to widespread blackouts.
- However, most power outages are caused by physical damage to equipment (e.g., vegetation contact, wind, animals) and are not associated with changes in electricity demand.
- Transmission and distribution outages from PG&E have been on the rise in both frequency and duration due to planned safety shutoffs initiated to mitigate potential wildfire and weather-related impacts on critical infrastructure. However, PG&E is taking action through powerline undergrounding and the reform of the public safety power shutoff (PSPS) process to reduce these instances.
- New loads from zero-NOx HPWH and HP HVAC are being planned for as part of the State and Utility grid expansion and forecasting process. Accordingly, new electric loads from BAAQMD's zero-NOx rules are not expected to lead to grid reliability issues as they are already being included in California's grid level planning processes.
- The effects of the Rules are smaller than other load impacts (e.g., increased ZEV adoption) that are also being included in State grid planning and forecasting.

Section 4 Zero-NOx Appliances and Resilience

Does having an electric appliance decrease resilience by relying on one energy source?

Summary of Findings

- Many modern gas water heaters and furnaces have electric components that would also cease to work during a power outage. This means they also need electricity to operate their controls, fans, and other equipment.
- Tanked water heaters stay hot for several hours, or longer, even without power. The average PG&E customer experiences 1.6 outages per year on average, or a total of 114 minutes per year.
- Bay Area residents and businesses could pursue resiliency options like solar, battery, and bi-directional vehicle charging to increase building and appliance-level continued functionality and resilience during power outages.

This analysis explores these key concerns using best available information regarding PG&E's interconnection process, triggers that would require a panel and service upgrade, appliance reliability, and the relationship between electric grid and zero-NOx appliance load additions.

The information presented here represents the best available data and sources as of May 2024.

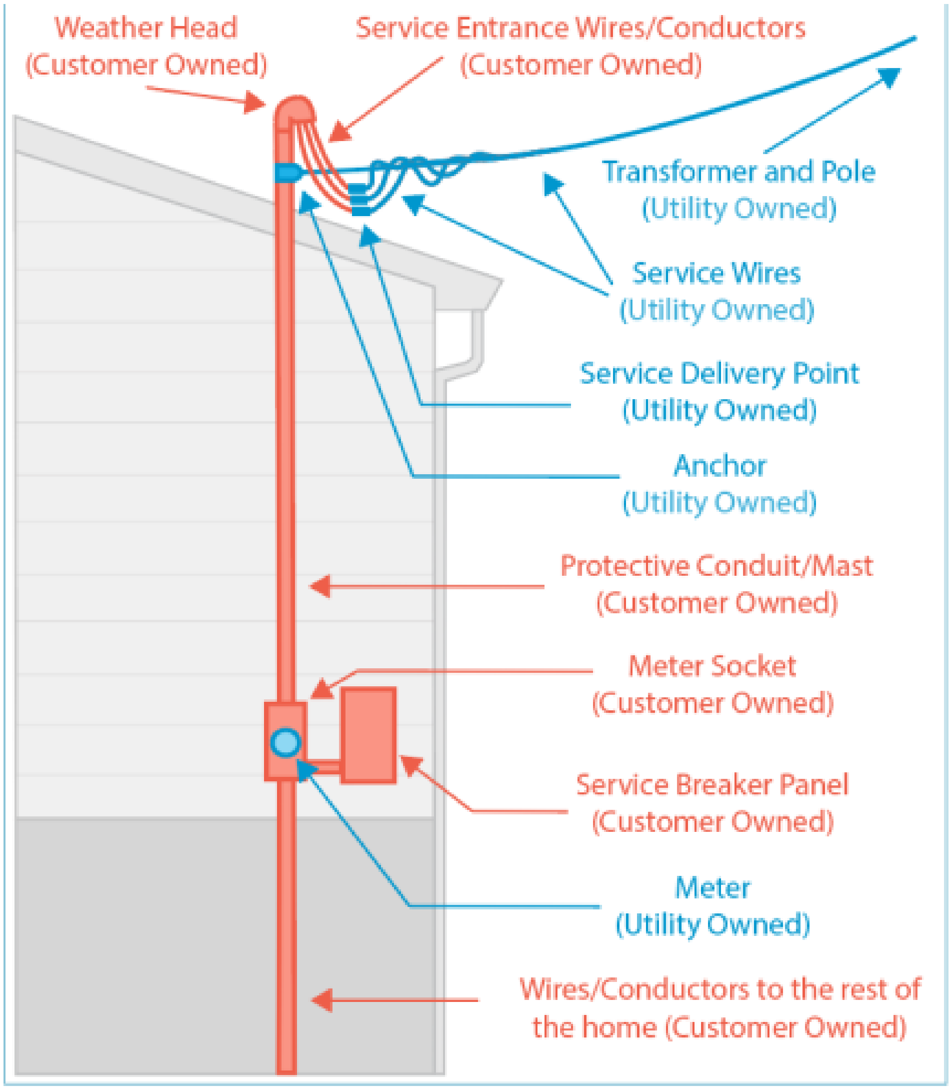
2 Utility Interconnection Lag Times

One concern identified by BAAQMD is the potential for extended timelines for appliance replacement if electric zero-NOx appliances trigger a panel and subsequent service upgrade. This section explores the causes of interconnection and service line upsizing, as well as the costs and timelines borne by the utility and consumer to upgrade these pieces of equipment. It also explores potential solutions to the sometimes lengthy and challenging residential interconnection process.

This report is mostly focused on the costs and schedules associated with service upsizing. For more information on panel upsize costs, please see the Task 1 report on costs. While the panel is owned by the building owner, the service is owned by the utility. It is the last piece of the electrical grid that delivers electricity to an individual building. A breakdown of the various electrical components and whether they are owned by the customer (building owner) versus owned by PG&E, is shown below in Figure 1.[6]

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

Figure 1 Customer vs. Utility-Owned Electrical Service



Courtesy of Emily Higbee, Redwood Energy Research Director

When a building or facility adds enough load to increase the size of the electrical panel, it can necessitate an electrical service upgrade depending on the size of the existing service line. According to PG&E, key variables that impact the complexity of implementing a service upgrade include panel location and its distance from the nearest distribution point, number of customers on a transformer, as well as the location of the service (above ground or underground). Since most of the Bay Area is served by PG&E (with the exception of areas served by Publicly Owned Utilities [POU]), this will require going through PG&E's Added Load Process. Before understanding the impacts of a service line upsize, it is important to distinguish how customer replacement of NOx-emitting gas water and space heating appliances could trigger a panel upsize, followed by a service upgrade.

2.1 When is a Panel Upsize Required?

An increasing body of research shows that switching from gas to zero-NOx water and space heating appliances is feasible on a 100-amp panel. As shown below, some portion of homes that have a 100-amp panel will not only be able to switch to zero-NOx water and space heating appliances, but also other electric appliances as well. Recent Peninsula Clean Energy analysis found that 99 percent of both gas using and all-electric homes never draw more than 100 amps of current at any one time.[7] This analysis is supported by studies from Rewiring America, Redwood Energy, and the San Mateo Office of Sustainability which have found that whole-home electrification, including electric vehicle charging, induction burners, and electric dryers can be accommodated on a 100-amp panel. As Rules 9-6 and 9-4 will only affect space and water heating end-uses, this analysis supports the feasibility of switching from gas to zero-NOx HPWH and HP HVAC on a 100-amp panel without the need for subsequent panel or service upsizing.

As described above, most buildings do not use the whole capacity of their electric panel at any one time. However, accommodating new electric loads on an existing panel sized 100-amps may entail additional planning, selection of high-efficiency electric appliances, additional efficiency retrofits, and potentially purchase of power sharing devices and load shifting technologies.[8]

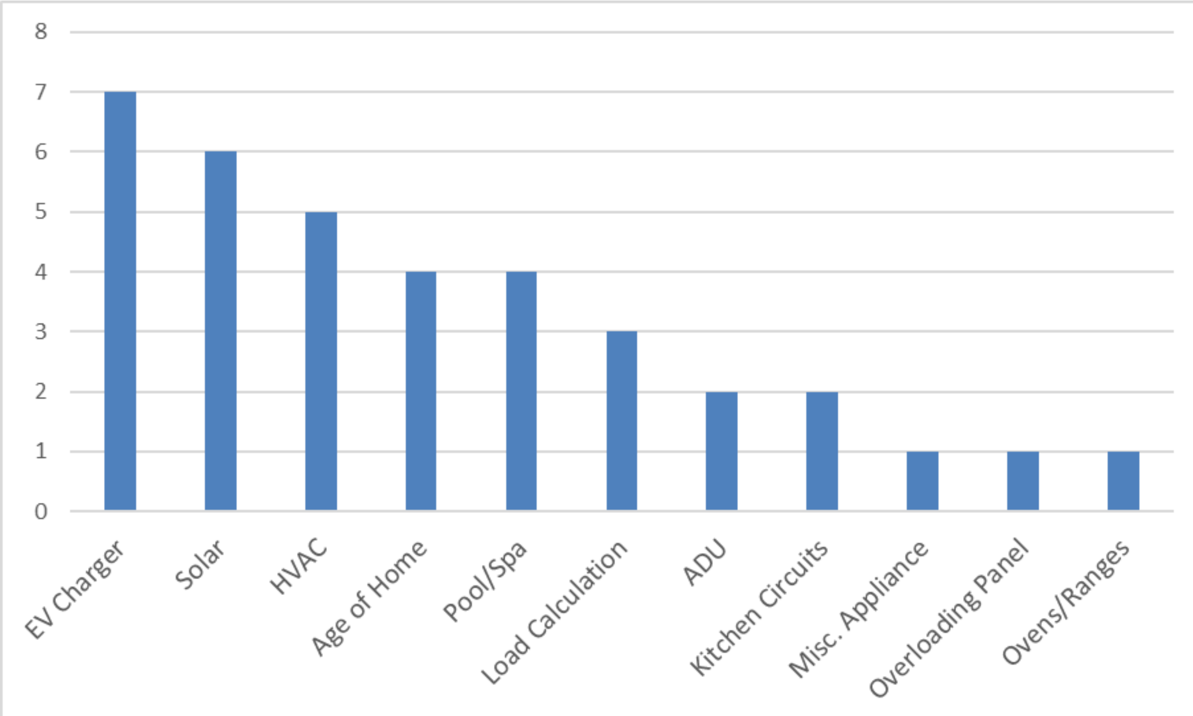
Zero-NOx appliance installation on a 100-amp panel and the “watt-diet” approach will be further described in the Interconnection Solutions section.

However, panel upsizing is occurring throughout the Bay Area as buildings are adding electrical loads. A recent analysis conducted on behalf of PG&E delved into the most common triggers reported by contractors for an electrical panel upsize that could trigger a service upgrade as shown in Figure 2. The top three triggers were:

- Addition of Level 2 EV Charging
- Addition of Solar Photovoltaic
- An HVAC Upgrade/addition of Air Conditioning[9]

[7] https://www.canarymedia.com/articles/electrification/yes-its-possible-to-electrify-a-home-on-just-100-amps
[8] Source(s): *https://www.smcsustainability.org/energy/decarbonizing-homes/;* https://assets-global.website-files.com/62b110a14473cb7777a50d28/639a356754b8a56402cc37be_SF-Retrofit-Guide-One-Pager-21-08-02.pdf
[9] While heat pump water heaters do not appear on this list, it could be due to a lack of installs rather than a lack of impacts. More recent data which reflects heat pumps increasing popularity will be needed to clarify this point.

Figure 2 Electrician-Reported Reasons for Service Panel Upsizes That Trigger a Service Upgrade (N=36)[10]



An analysis was conducted to evaluate the number of households across the Bay Area that likely already have a 200-amp panel and to conservatively identify the number of homes which do NOT require panel upsizing. This analysis was completed using publicly available data from the National Renewable Energy Laboratory's (NREL) ResStock, a national dataset representing the United States residential building stock. ResStock provides geospatial granularity at the county-level, including key building stock characteristics such as vintage, building system, and energy consumption.

To determine the number of households that likely already have a 200-amp panel, the following criteria were used:

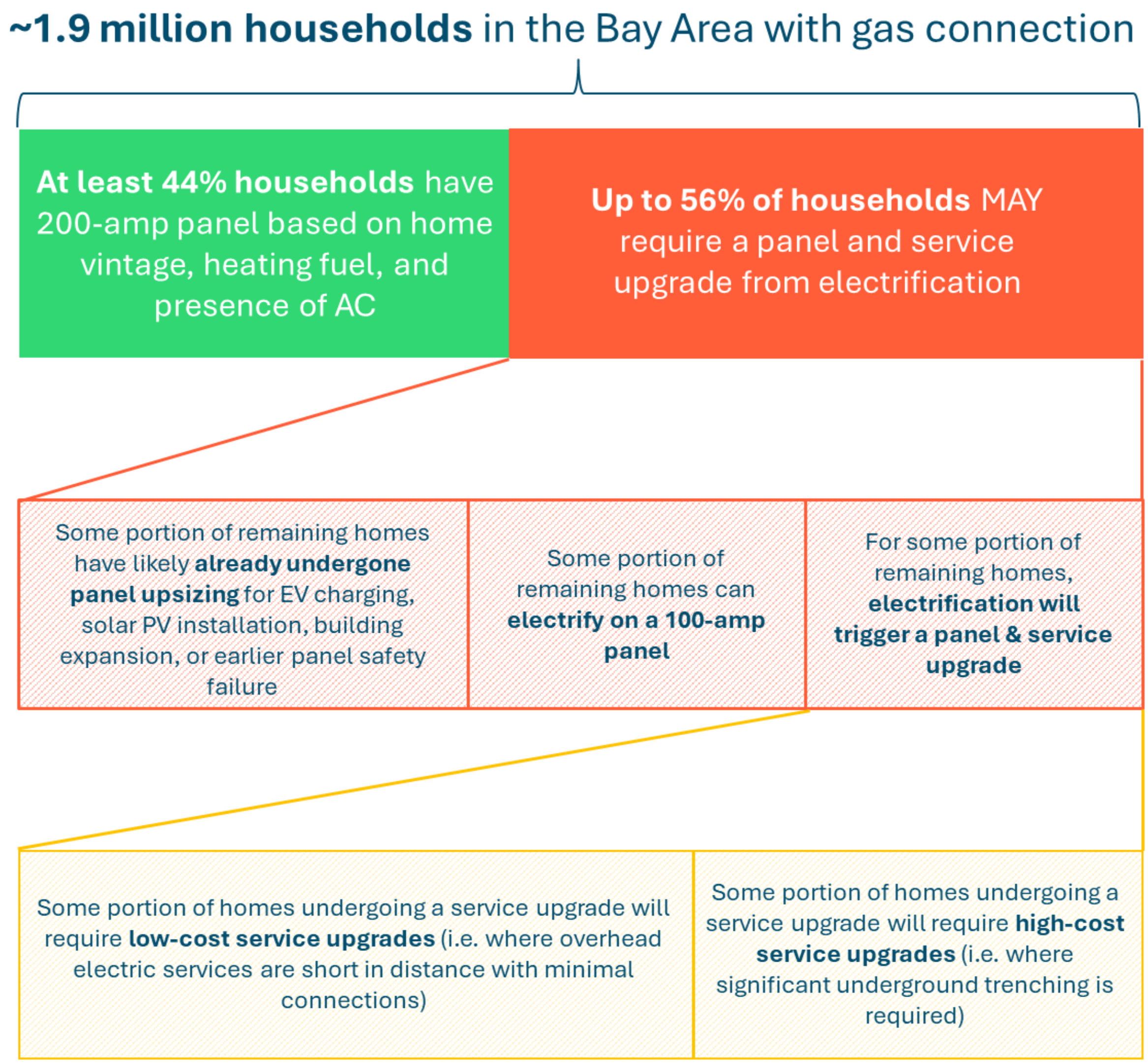
- Currently has electric heating system; or
- Currently has air conditioning; or
- Building vintage later than 1980.

While having a panel less than 200-amps is not a guarantee of needing an upsized panel, this analysis provides a conservative starting place by identifying the building stock that would not require any upsizing. Following the criteria listed above, approximately 44 percent of all households in the Bay Area have a 200-amp panel. Of the remaining 56 percent of units, some number of additional households have likely already undergone electric panel upsizing for electric vehicle charging, PV solar installation, building expansion or accessory dwelling unit (ADU) addition, or earlier panel safety failures. Additionally, another portion of households will be able to electrify space heating and water heating appliances on the existing panel which is less than 200-amps. This breakdown of households in the Bay Area can be seen below in Figure 3. In addition, many

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

households may already be planning for the addition of air conditioning due to increased temperatures in the region.[11]

Figure 3 Breakdown of Households in the Bay Area with Gas Connection



A recent study conducted by UCLA added more detail to the proportion of homes needing panel upgrades. The study found that only 3% of single family residential and 10% of multi-family properties will need panel upgrades in order to fully electrify, while an additional 32% (single-family) and 59% (multi-family) will require further load management or watt diet approaches to electrify on their current panel.[12]

[11] https://www.sfgate.com/local/article/san-francisco-lacks-air-conditioning-17685873.php
[12] https://www.sciencedirect.com/science/article/pii/S0301421524002581

2.2 Interconnection Hurdle Overview

As described in the section above, buildings with 200-amp panels and many homes with smaller panels will not need to upsize their electrical panel to install HPWH and/or HP HVAC. However, if a panel upsize and subsequent service upgrade are required because of zero-NOx appliance installation, then an interconnection upgrade could be required.

Heightened public scrutiny regarding heat pump installation and interconnection lags could be attributed in part to recent media coverage of interconnection project delays, particularly for new construction. Recent media coverage of long interconnection times for new construction should be differentiated from the types of interconnections that may be necessitated by zero-NOx appliance installation. Many of these high-profile cases are new construction projects with much larger loads (e.g., large multifamily housing developments, commercial campuses) that also needed significant electric system infrastructure upgrades (e.g., substation or transformer upgrades), which is very different than smaller service line upgrades that might be required for zero-NOx retrofits in existing buildings.

Recent press conferences this March by San Francisco Mayor London Breed highlighted this problem, referencing 75 projects that include critical housing developments that are delayed because PG&E has not yet connected them to the power grid; costing San Franciscans upwards of 35 million dollars.[13] In February of 2023; PG&E had logged 134 construction ready projects in the Bay Area, 95 of which had been waiting more than 12 weeks for connection to the grid.[14] Large new multifamily housing projects are among the most notable projects of this kind to suffer from slow interconnection times. Interconnection for new construction projects could also be impacted by even more lengthy lag times if substantial parts of the distribution grid (e.g., substations or transformers) need to first be upgraded before the project can come online. Reporting by KQED in 2023 also notes that PG&E’s average time to interconnect finished new construction to the grid was 64 days, six times as long as Southern California Edison’s nine-day interconnection time.[15]

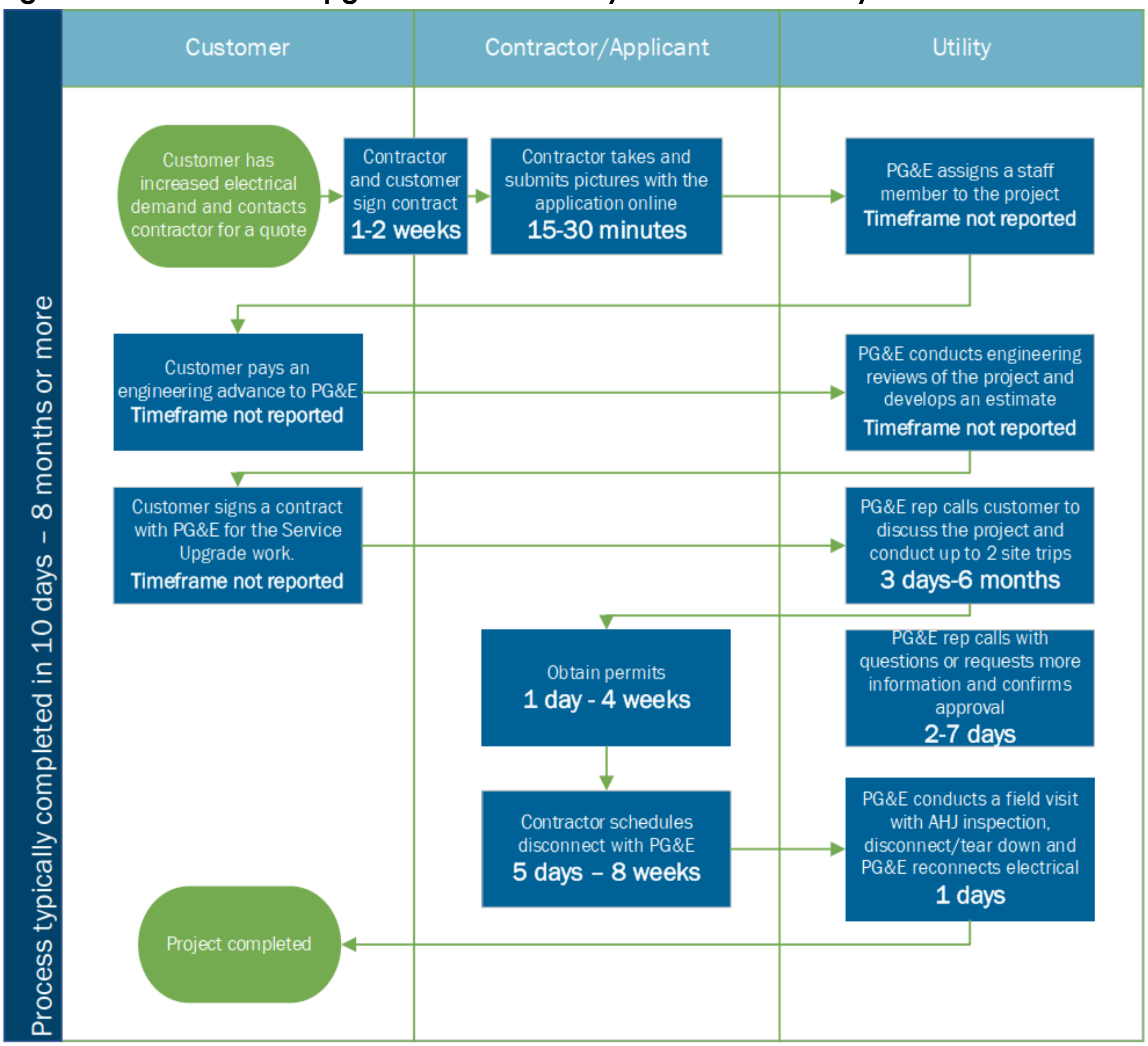
For existing households that require a service upsize, wait times are typically much shorter than the extended timelines being seen for larger new construction projects. The NV5 *Report on Service Upgrades for Electrification Retrofits Study* noted an average timeline of 10-30 days for the service upgrade process.[16] However, the timelines for individual buildings to upgrade following a zero-NOx appliance installation are highly variable and the same report noted project timelines of up to eight months. The linkage between zero-NOx appliance installation, and interconnection and service line upgrades are further explored in this section.

[13] https://www.sfexaminer.com/news/politics/officials-say-pge-delays-are-costing-san-francisco-millions/article_443b89fc-d813-11ee-b203-a3070d4ad98c.html
[14] https://www.northbaybusinessjournal.com/article/article/bills-aim-to-fix-californias-long-delays-in-connecting-construction-projec/
[15] https://www.kqed.org/news/11943157/how-pge-adds-months-long-delays-costs-to-new-housing
[16] Ibid. (KQED);
https://pda.energydataweb.com/api/view/2635/Service%20Upgrades%20for%20Electrification%20Retrofits%20Study%20FINAL.pdf

PG&E's Service Upgrade Process

For customers requiring a service upgrade, Figure 4 below shows the significant range in projected timeline for a service upgrade, which can span ten days to eight or more months. The process requires several steps to be taken by each of the three parties involved including the building owner, contractor, and utility. There is also an engineering advance which the building owner will need to pay PG&E ahead of time to cover any engineering costs incurred while designing the system upgrade.

Figure 4 PG&E Service Upgrades Can Take Anywhere From 10 Days to 8+ Months



Electric Service Upgrade Costs

The project timeline variables described in the figure above are closely related to costs for service upgrades. Generally, the longer the project (e.g., if project requires trenching, long distances from pole to building, or complicated rights-of-way) the more costly it can be. This topic was explored in depth in the first whitepaper of this series *Installation Costs for Zero-NOx Space and Water Heating Appliances*. It is also included here in addition to the discussion of service upgrade project timelines above, as it should be considered a related implementation and equity hurdle for Rules 9-4 and 9-6.

Key variables that impact the cost incurred by an individual customer include panel location and its distance from the nearest distribution point, if a single customer is on a transformer (thus taking on the cost of upgrade), as well as the location of the service (above ground or underground). Types of customer costs that could be incurred include trenching, substructure/conduit installation of a new service conductor, and a new protective structure.[17]

Distribution service upgrade costs were derived using PG&E estimated costs based on three candidate sites in the East Bay for targeted electrification. 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. Residential customers receive a ratepayer-funded allowance of $3,255 paid for through rates collected from electric ratepayers, with the customer responsible for paying the remainder.[18] Generally, PG&E reports a range of between $1,000 and greater than $8,000 for overhead service upgrades and between $1,000 and over $20,000 for underground service upgrades as shown in Figure 5.

2.3 Interconnection Solutions

As described above, the service upgrade process through PG&E's added load program can cause additional costs and/or delays under certain conditions. This section details potential solutions to this implementation challenge, namely through improvements to PG&Es' internal added load processes, recent legislation to streamline interconnection, and a "watt diet" appliance approach.

PG&E Process Upgrades

A recent California Public Utilities Commission (CPUC) study assessed the existing PG&E service upgrade process and identified a number of key recommendations for streamlining. These recommendations included:

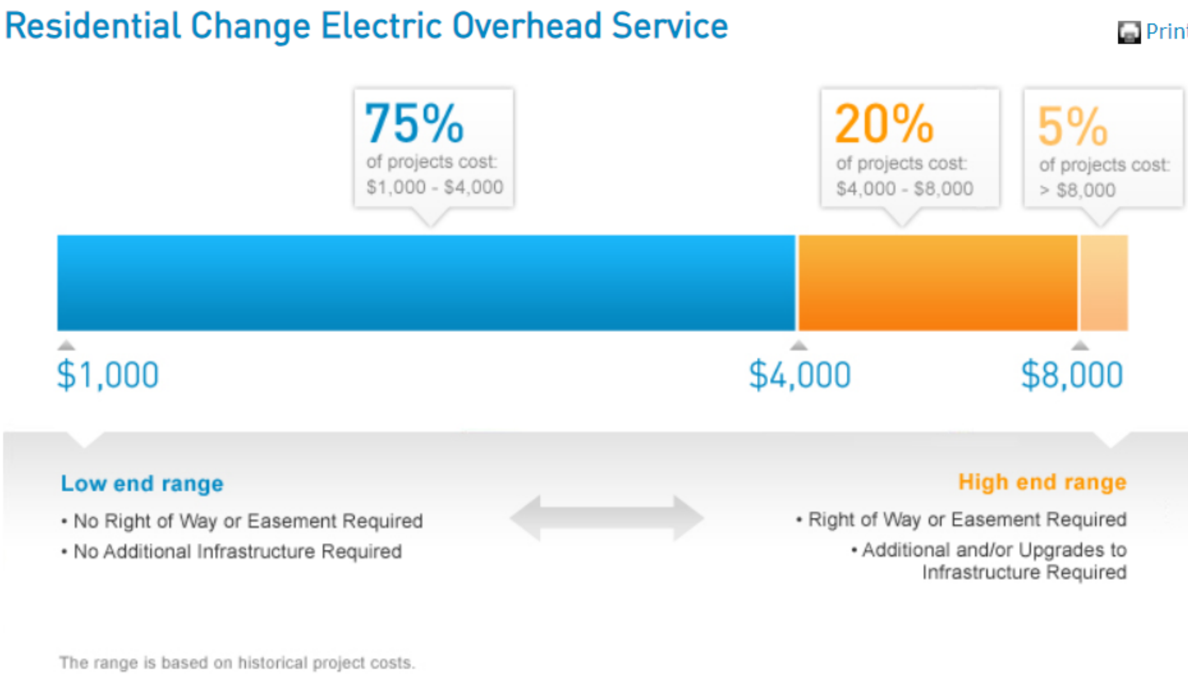
- Educating customers on low-amperage products (e.g., 120-volt HPWH), so customers can electrify on a 100-amp panel. This 'watt diet' approach will be further described below;
- Reforming the 30-day "clock reset" for incomplete applications requesting service upgrades. According to this analysis' interviews with PG&E staff, applications submitted to PG&E void, with a loss of all application materials, if the application is not fully submitted and 'in the cue' within 30 days. The report authors recommend reforming this process so that customers can keep their application materials for longer than 30 days without an application reset, thus streamlining staff and consumer time for the update process.

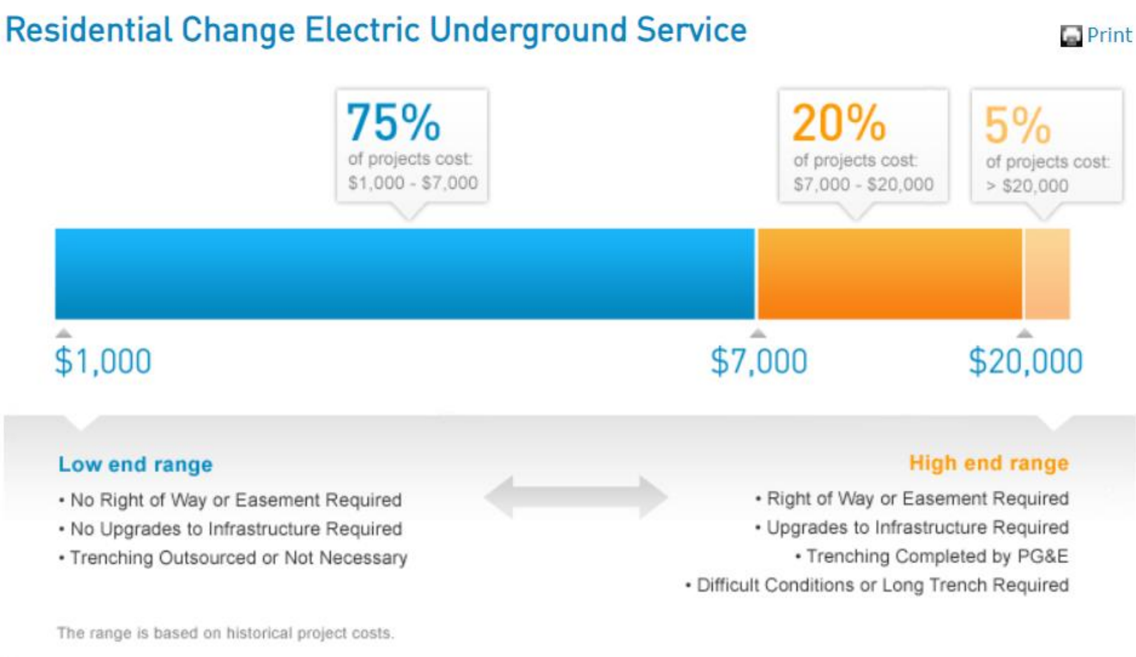
[17] https://pda.energydataweb.com/api/view/2635/Service%20Upgrades%20for%20Electrification%20Retrofits%20Study%20FINAL.pdf; -https://www.oaklandca.gov/topics/service-upgrades-for-electrification-retrofits
[18] https://www.ethree.com/wp-content/uploads/2023/12/E3_Benefit-Cost-Analysis-of-Targeted-Electrification-and-Gas-Decommissioning-in-California.pdf

- PG&E incentives for avoided upgrades, or increased use of low power appliances. Currently, report writers note that there are many cultural and educational factors leading consumers to upgrade electrical service on a 100-amp panel when this may not in fact be necessary. The report writers suggest that PG&E offer streamlined incentives for not pursuing panel upsizing and maintaining a 100-amp panel.

In addition to these suggestions to improve the Added Load Processes run by PG&E, State legislators have also started applying external pressure to provide expedited service upgrades to electric new construction and other residential retrofits.

Figure 5 PG&E Historic Service Upgrade Costs (Overhead vs. Underground)[19]





[19] 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

Legislative Drivers

The October 2023 Powering Up Californians Act (Senate Bill 410) sets a deadline for CPUC to establish maximum target energization timelines and requires utilities to report on non-compliance with these timelines. SB 410 explicitly requires that utilities' annual grid planning and investment specifically align with regional air quality goals like BAAQMD Rules 9-6 and 9-4. This means that SB 410 has set the policy pieces in motion for PG&E to consider new electric loads from HPWH and HP HVAC into future grid planning efforts, while also expediting the interconnection process of these new loads.[20]

Section 3 ("New Electric Loads from Zero-NOx Appliances and Grid Reliability below will further explore recent legislation aimed at expediting the build out of the electric grid in order to match new demand from forecasted electric loads.

120-volt HPWH Technology Highlight

Using 120-volt ('retrofit ready') HPWH technologies are a solution for avoiding extended timelines associated with panel upsizing and electrical service upgrades. Low-voltage HPWH systems can be plugged into the standard wall outlet (120-volt), which was required for the previous NOx-emitting appliance without additional electric work, while standard HPWH mostly require 240-volt service. 120-volt technologies are best suited for smaller units providing hot water to one or-two people.[21]

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 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.[22] 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 upsizing at which point a 240-volt water heater should be installed.

This 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. Table 1 shows the market available 120-volt HPs.

[20] https://www.nrdc.org/bio/max-baumhefner/powering-californians-act-signed-law
[21] https://www.energy.gov/energysaver/sizing-new-water-heater
[22] https://newbuildings.org/wp-content/uploads/2023/07/PlugInHeatPumpWaterHeaterFieldStudyFindingsAndMarketCommercializationRecommendations_NBI202308.pdf

Table 1 120-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 taking a "watt diet" approach instead of panel upsizing and a service upgrade. The 'watt diet' approach describes avoided electrical panel upsizing due to the selection of energy-efficient electric appliances (e.g., variable speed HP HVAC), and the use of load sharing devices as applicable.

Electric vehicle charging is often considered one of the key reasons for upgrading panel sizes but is not covered under Rules 9-6 or 9-4. However, building owners may be considering panel upsizing as a future investment in charging capacity for electric vehicles. The watt diet approach can utilize a prioritized circuit sharing device that can automatically pause car charging while other appliances finish their use, avoiding the need for panel upsizing. Cost savings from the watt diet can include both costs to increase electrical panel capacity size, as well as subsequent service upgrades that may be triggered post panel-upgrade.[23]

Table 2 shows current retailer costs for circuit splitters, prioritized circuit sharing devices, and smart panels. Installation costs for these devices were not available and, therefore, not included. Although the purchase of these devices does require additional upfront costs, they still could be significantly cheaper than panel upsizing and an accompanying service upgrade.

Table 2 Watt Diet Appliance 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 & load control	$236[3]
NeoCharge 240-volt Smart Splitter	Smart load shifting tailored to EV 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/

[23] https://www.redwoodenergy.net/watt-diet-calculator

Loaner Programs and Short-Term Replacements

In addition to the solutions listed above, some programs have focused on providing short term space or water heating solutions which can provide the desired services during the panel/service upsizing process. "Loaner" programs provide installers with a per project incentive to install a short-term replacement water heater for use while waiting for longer installation times, sometimes caused by electric system upgrades. Once the new electrical equipment has been installed, the new zero-NOx water heater installation can be completed. Examples of these projects include the Emergency Replacement Heat Pump Water Heater Market Study.[24]

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

3 New Electric Loads from Zero-NOx Appliances and Grid Reliability

Community members have expressed concern that the addition of new electrical loads for HPWH and HP HVAC will overload the grid and potentially lead to increases in local losses of power. This section explores the root causes of this concern, explaining what causes power outages today, current electric system reliability, and the specific impacts of BAAQMD's zero-NOx rules on the electric grid. It is also important to note that Rules 9-4 and 9-6 apply to natural gas fired appliances. Appliances that use propane as the fuel source are not subject to the zero-NOx requirements. It is BAAQMD's understanding that in rural areas where sustained power outages may be more common than other locations, propane is commonly used as a fuel source and these usages will still be allowed under the amended rules.

Potential power outages have sometimes been cited as a hurdle for electric hot water heating and space heating, with some stakeholders expressing concerns that the increased load will lead to increased power outages, or that existing power outages will prevent customers from heating their water and/or their homes. However, there is little evidence that electrifying these end uses would contribute to additional outages. Today, power outages in California have two primary causes: 1) failures of the electricity system (e.g., damages to equipment or a lack of adequate resources to meet electricity demands), and 2) preventative public safety measures (e.g., planned outages for maintenance and outages to prevent wildfires).[25] A closer look at these causes of power outages can illuminate why electrification of water and space heating is unlikely to have a significant impact on overall grid reliability.

3.1 Challenges and Causes: Power Outages Today

How Reliable is the Electricity System Today?

Two metrics that are commonly used to measure the reliability of the electricity system are:

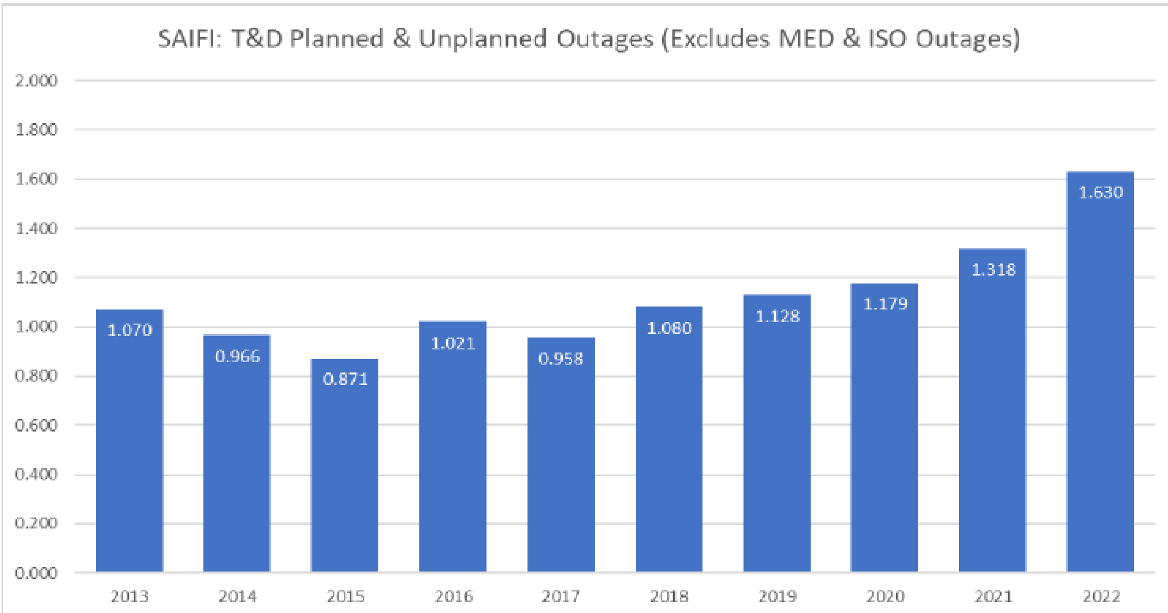
1. System Average Interruption Frequency Index (SAIFI) – the average number of interruptions that each customer experiences
2. System Average Interruption Duration Index (SAIDI) – the average cumulative outage duration for each customer served

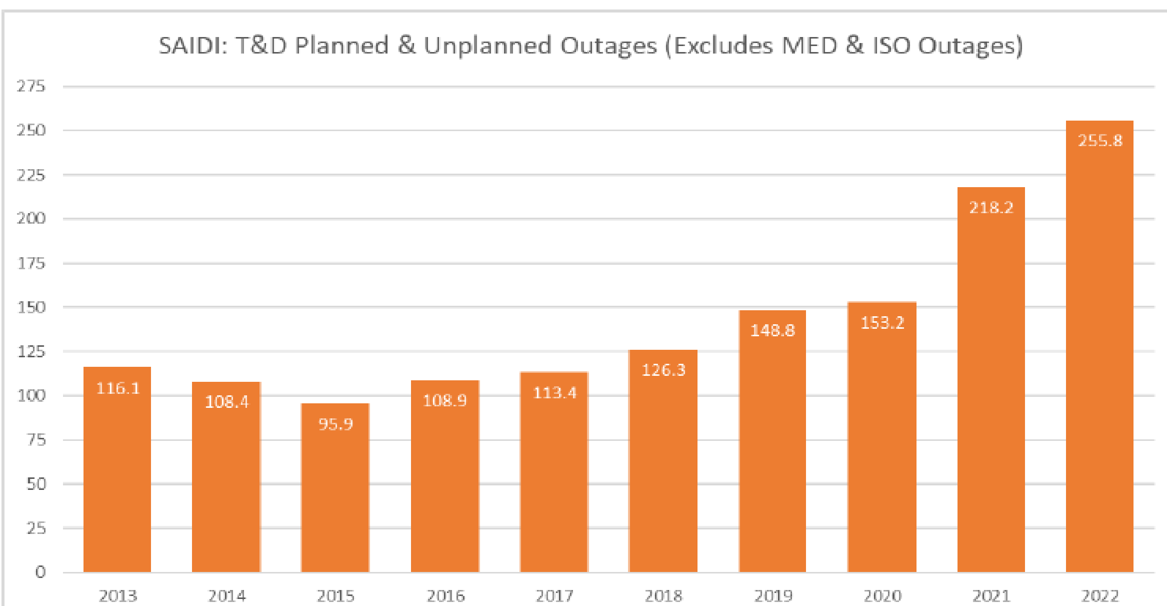
Figure 6 shows the SAIFI and SAIDI on PG&E's system in recent years, as presented during PG&E's virtual town hall on reliability.[26] The figure excludes major event days (MEDs) and Independent System Operator (ISO) outages. This figure shows that on average, the frequency of outages and the annual duration of interrupted service has increased even while new approaches such as EPSS have started to be implemented. PG&E's reliability has been impacted by wildfire mitigation efforts and severe storms. As noted in their virtual town hall, PG&E plans to improve its reliability through investments in system hardening, which include installing stronger poles, trimming vegetation that could damage equipment, and burying powerlines underground to mitigate the risk of failure.[27]

[25] https://www.cpuc.ca.gov/about-cpuc/divisions/safety-policy-division/emergency-management/power-outage-resources#:~:text=Outages%20can%20happen%20as%20a,on%20a%20customer's%20own%20property
[26] https://www.pge.com/assets/pge/docs/about/pge-systems/2023-Electric-Reliability-Presentation-for-2022-Reliability.pdf
[27] https://www.pge.com/assets/pge/docs/outages-and-safety/safety/fs-system-hardening.pdf

PG&E has stated that they plan to bury 10,000 miles of powerline in areas with high wildfire risk.[28] This type of system hardening effort will serve to improve system reliability during severe storms and high wildfire risk days.

Figure 6 SAIFI (Number of Outages) and SAIDI (Duration of Outages) on PG&E's Transmission and Distribution System from 2013-2022





[28] https://www.pge.com/en/outages-and-safety/safety/community-wildfire-safety-program/system-hardening-and-undergrounding.html

Electricity System Impacts: Equipment Damage

The majority of power outages that are caused by failures of the electricity system stem from physical damage or equipment failure. Damage can be caused by severe weather (e.g., a tree branch hitting a power line due to strong winds), or by external drivers (e.g., a squirrel or a stray balloon causing an equipment failure). Most of the damage-related outages occur on the distribution system, which is the part of the electric grid that connects distribution lines to homes and other buildings. Additional electric load from electric space and water heating would not impact the frequency of these outages because they are caused by external drivers that are not related to the amount of demand on the grid.

Electricity System Impacts: Planned Outages to Protect Public Safety

Some power outages may be intentionally implemented as public safety measures. These include planned outages to perform maintenance on the grid, as well as outages to prevent risks from specific events. In California, wildfire risk is a primary driver of this type of outage. During times of high fire danger, PG&E and other utilities can call for planned safety outages to prevent fires. These events are called Public Safety Power Shutoffs (PSPS). PSPS events typically coincide with severe weather events such as high winds that increase the risk of wildfires.[29] In recent times, new strategies have begun to emerge that may lessen the frequency of PSPS events. In 2021, PG&E began implementing a new type of outage to reduce wildfire risk called the Enhanced Powerline Safety Settings (EPSS). The EPSS program works by automatically shutting off power when an abnormal current is detected to de-energize the power lines and mitigate the risk of igniting a fire. Although EPSS outages are more frequent than PSPS events, they are also much shorter. In 2022, EPSS outages averaged less than 3 hours per outage[30], which is significantly shorter than what customers experienced during PSPS events, which averaged 39 hours per event in 2021.[31] The introduction of EPSS has already begun to allow for a decline in outages on EPSS lines and PG&E has stated that they only plan to consider PSPS events as a last resort.[32]

As PG&E continues to refine its wildfire mitigation strategies, customers may be less likely to experience the lengthy PSPS outages that they had seen in past years. This is especially true in the long-term as PG&E continues to work towards more permanent wildfire risk reduction mitigations (e.g., undergrounding) that will limit the need for PSPS and EPSS events in the future. Implementing strategies that avoid the need for service interruptions are a key component of PG&E's wildfire mitigation plan.[33] New policies may further expedite this transition away from PSPS events. For instance, in 2023, Senate Bill No. 884 became a law, establishing a program for expediting undergrounding of distribution infrastructure. The law requires utilities to show how their expedited undergrounding plans will reduce the use of public safety power shutoffs as part of the approval process.[34] The shift away from planned long outages in favor of shorter outages may minimize the negative impacts that customers experience.

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[29] https://www.pge.com/en/outages-and-safety/safety/community-wildfire-safety-program/public-safety-power-shutoffs.html#tabs-6e3912efa4-item-4ee7a81a03

[30] https://www.cpuc.ca.gov/-/media/cpuc-website/industries-and-topics/meeting-documents/20230317-workshop/pge--fast-trip-unplanned-outages-and-distribution-reliability-workshop-presentation.pdf

[31] https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/safety-and-enforcement-division/meeting-documents/psps-readiness-briefings-august-2021/pge-psps-public-briefing-832021.pdf?sc_lang=en&hash=465EA8A6AAE040B6E4F87409B3695842

[32] https://www.cpuc.ca.gov/-/media/cpuc-website/industries-and-topics/meeting-documents/20230317-workshop/pge--fast-trip-unplanned-outages-and-distribution-reliability-workshop-presentation.pdf

[33] https://www.pge.com/en/outages-and-safety/safety/community-wildfire-safety-program.html

[34] https://www.cpuc.ca.gov/about-cpuc/divisions/safety-policy-division/risk-assessment-and-safety-analytics/electric-undergrounding-sb-884

Electricity System Impacts: Resource Adequacy Challenges

Another very rare cause of outages is when there is a shortage of electricity generation to meet demand.[35] When electricity demand is higher than supply, the California Independent System Operator (CAISO) can call for a rotating power outage to reduce demand. Rotating outages are short outages (typically 1-2 hours) that rotate amongst different communities to minimize the impact to individual customers.[36] These outages are very uncommon in California. The last rolling outages were called for on August 14th and Augst 15th, 2020, but prior to that it had been nearly two decades since outages were caused by energy shortages in California.[37]

Electricity planners plan for a "1-in-10" planning standard to ensure that the electricity system will have enough resources to avoid all but one outage in a ten-year period.[38] The careful considerations put into electricity system planning are what makes these generation shortfall-related outages such rare occurrences. It is important to understand that these rare generation shortages only occur during peak load periods. In California, these peak load periods occur in the summer months when there is a high level of demand due to air conditioning during extreme heat events. Although extreme weather events may become more frequent in the future due to climate change, electricity system planners will continue aiming for a 1-in-10 standard that takes these extreme events into account. Planners are continuously evaluating the best approaches to accounting for climate change in their plans, and there is an ongoing effort to improve upon the use of weather and climate data in electricity system planning models.[39]

Notably, space heating demands are highest in the winter months, far from today's peak demand times for the electricity in California, which occur during summertime extreme heat events. Although peak electric loads currently occur during the summer months, there is a chance that in the future, high market penetration of heat pumps could eventually shift the peak loads to the winter months. This shifting could potentially make the grid more efficient and less expensive as more electricity would flow over the same amount of infrastructure.[40] Electricity planners are also paying close attention to the potential for high levels of building electrification and are accounting for this in their plans. Grid planners are also including building and vehicle decarbonization policy impacts (including the specific projected impacts of Rules 9-6 and 9-4) into the grid expansion forecasts that inform utility plans for grid adequacy. This is further described in the sections below.

[35] https://www.cpuc.ca.gov/about-cpuc/divisions/safety-policy-division/emergency-management/power-outage-resources#:~:text=Outages%20can%20happen%20as%20a,on%20a%20customer's%20own%20property.

[36] https://www.pge.com/en/outages-and-safety/outage-preparedness-and-support/understanding-electric-outages/rotating-outages.html#accordion-6f0c78d1dc-item-55509c13ce

[37] https://www.caiso.com/Documents/Rotating-Power-Outages-Fact-Sheet.pdf

[38] https://www.caiso.com/about/Pages/Blog/Posts/2023-Summer-Loads-and-Resources-Assessment-has-been-posted.aspx

[39] https://www.esig.energy/wp-content/uploads/2023/10/ESIG-Weather-Datasets-full-report-2023b.pdf

[40] ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf

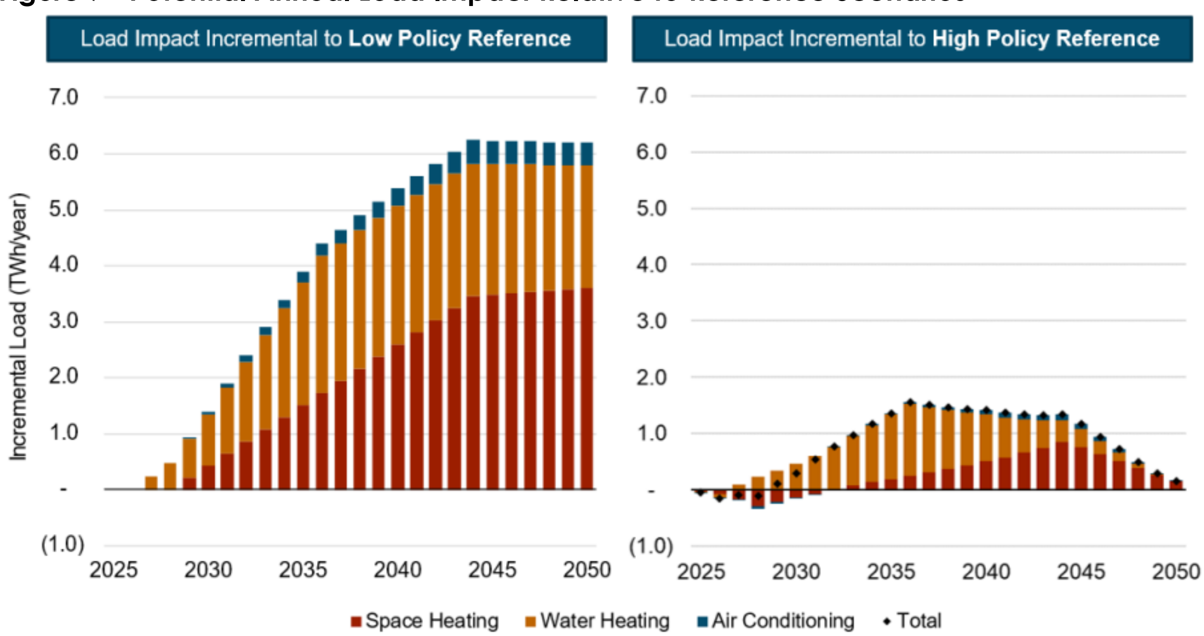
Capacity and Reliability Impacts from Adoption of Rules 9-4 and 9-6

E3 authored a report on the projected electric infrastructure (grid) impacts from the proposed amendments to Rules 9-6 and 9-4 prior to the March 2023 passage of the Rule updates. E3's analysis measured the grid impact of Rules 9-4 and 9-6 relative to two different policy assumptions to assess its incremental contribution to increases in heat pump adoption.

- The Low Policy Reference Scenario assumes a business-as-usual (BAU) future where Rules 9-4 and 9-6 are the sole driver of increased heat pump adoption because the State has taken no additional action to meet its 2030 or 2045 greenhouse gas (GHG) emissions targets. The Low Policy Reference Scenario is consistent with the 2022 Draft Scoping Plan BAU Reference Scenario.
  - Model results from the Low Policy Reference Scenario show more grid impact from BAAQMD's rule updates pushing grid capacity to accommodate new loads from zero-NOx appliances.
- The High Policy Scenario assumes major new policy advancement on the state level to decarbonize all sectors of California's economy and meet state decarbonization targets.
  - Model results from the High Policy Reference Scenario show less impact from BAAQMD's rule updates as they would be a smaller part of larger State policies driving the economy towards heat pump adoption.

The comparative results of these load impacts for Low Policy vs. High Policy reference are shown below in Figure 7, demonstrating the comparative load impacts. The low policy reference will be referenced as part of this analysis as it is considered the more conservative of the two scenarios. Compared to the Low Policy Reference, the zero-NOx standards are expected to result in 6.2 TWh (terawatt-hours) of electric load by 2050.

Figure 7 Potential Annual Load Impact Relative to Reference Scenarios



Impacts from the zero-NOx appliance standards will not be limited to just TWh needed, but also distribution capacity, transmission capacity, and—given utility renewable procurement requirements—additional solar generation and battery storage. Table 3 below shows the impact on the different parts of grid infrastructure. Table results show that for both low and high policy references, BAAQMD's zero-NOx rules will have a range of projected impacts on grid infrastructure at every level. New loads will require some level of utility-planning and investment, most of which is already being planned for as part of the State's grid planning efforts which will be described further below. However, these new loads should not directly impact reliability as long as utilities and community choice aggregators (CCAs) are planning for them.

Table 3 Summary of Potential 2050 Electric Grid Impacts of Zero-NOx Standards

	Impact relative to Low Policy Reference	Impact relative to High Policy Reference
Utility-scale solar *to serve electric loads*	2,180 MW new solar by 2050	70 MW new solar by 2050 *+ accelerated build in 2030s & 2040s*
4-hour battery storage *for generation capacity*	680 MW new batteries by 2050	< 10 MW new batteries by 2050 *+ accelerated build in 2030s & 2040s*
Transmission Capacity	460 MW impact by 2050	< 10 MW impact by 2050 *+ accelerated build in 2030s & 2040s*
Distribution Capacity	420 MW impact by 2050	< 10 MW impact by 2050 *+ accelerated build in 2030s & 2040s*

A low vs. high-policy reference scenario is included in this analysis to assess BAAQMD rule impacts on the grid in context of State legislation and policies for vehicle and building electrifiication, as these rules will likely necessitate large-scale planning and investment in the State's grid capacity.[41] The incorporation of zero-NOx and decarbonization targets into grid forecasting and expansion will be described further in the section below.

3.2 Power Outages Solutions Overview

Solutions to power outages include supply-side and planning solutions that lay the policy and forecasting foundations to plan for new electrical loads decades into the future. Meanwhile, non-wires solutions like shifting peak loads with heat pump water heaters, battery storage, and bi-directional charging offer technology solutions to reduce peak load and increase customer resiliency during power outages.

[41] E3 on behalf of BAAQMD: 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?rev=2c9ddef1ee9e4d5f8fafea0f68c9c932&sc_lang=en

Supply-Side & Planning Solutions for Resource Adequacy

Updated State Load Forecasting Preparing for New Electrical Loads Beyond Rules 9-6 and 9-4

The State of California has multiple plans and forecasts to supply carbon-free electricity by 2045 while keeping pace with future increased electrical demand.[42] By 2035, planners are assuming an approximate 27 percent increase in statewide electrical demand from 2023 levels: this increase includes new electrical loads from economic and population growth, building, and vehicle electrification.[43]

Investor-owned utilities (IOUs) including PG&E and CCAs are required to consider these forecasting thresholds and incorporate them into their submitted plans for resource adequacy. The bi-annually updated California Energy Commission Integrated Energy Policy Report (IEPR) guides procurement and investment in electrical bulk generation (e.g., solar and wind power) by utilities including PG&E as well as other Bay Area CCAs like AVA, Silicon Valley Clean Energy, and Peninsula Clean Energy. Most utilities are planning resource adequacy around the current summer peak, which also features a buffer called the "planning reserve margin" to account for extreme weather like extreme heat that may increase energy demand during the summer peak beyond what would be expected of past forecasted trends.[44]

Table 4 shows that that the latest 2023 IEPR forecast includes not only the projected impact of BAAQMD Rules, but also building and vehicle decarbonization policies beyond the Rules. This indicates that new loads from BAAQMD Rules are not only being actively planned for by the State but are also only a part of the State's electric forecast. Simply put, this means that BAAQMD's zero-NOx rules are not expected to cause any resource adequacy issues because the State is actively planning ahead for these new loads. Accordingly, new electric loads associated with BAAQMD's zero-NOx rules are not expected to contribute to bulk or transmission-related power outages, which are the primary fear of many community members when they link new electric loads with potential grid instability.

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[42] CPUC Presentation to May 2023 RICAPS Group: https://docs.google.com/presentation/d/10ATvDA6jULdbEiAnGVSscp9WWP_k6dBp/edit?usp=sharing&ouid=105799344088771997660&rtpof=true&sd=true CEC IEPR 2021 Forecast; 2023 Integrated Energy Policy Report; California Energy Commission [CEC]: https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2023-integrated-energy-policy-report, Adopted 2023 Integrated Energy Policy Report with Errata, Introduction

[43] https://www.energy.ca.gov/sites/default/files/2024-02/2023_Integrated_Energy_Policy_Report_Highlights_ADA.pdf; note that the percent increase was calculated by project team comparing 2023 actual peak to the 2035 managed peak.

[44] PCE Presentation to May 2023 RICAPS Group, Slide 42; "peak load and resource adequacy": https://docs.google.com/presentation/d/10ATvDA6jULdbEiAnGVSscp9WWP_k6dBp/edit#slide=id.p16; PG&E presentation; slide 28; "forecast development"

Table 4 The State is Planning for New Loads From BAAQMD Rule 9-6 and 9-4 Implementation in Addition to Other Decarbonization Policies [2023 IEPR]

Decarbonization Topic	What's Included in Resource Planning Through 2040?[1]
Building Electrification	**New Construction:** 100% all-electric space and water heating in new construction for residential buildings beginning in 2026; and 2029 for the commercial sector. **Existing Buildings:** 100% replace on burnout for space and water heaters in the Bay Area AQMD territory in 2027 and 2029; and 2030 for the rest of the state. "More ambitious" scenarios that also electrify cooking and clothes drying were modeled not selected for inclusion in the forecast due to high rates of uncertainty for building electrification. **2035 Electrification Load Impact: 5,378 MW**[2]
Vehicle Electrification	**Passenger Vehicles:** 13.7 million ZEVS on road by 2035 **Commercial Vehicles:** 407,000 million ZEVS on road by 2035 **2035 Electrification Load Impact: 4,810 MW**, with most (3,949 MW) coming from passenger vehicles
Projected 2035 Statewide Electrical Demand	Managed Peak by 2035: 56,937 MW, equal to a ~27% increase from the actual 2023 peak of 44,534 MW

[1] 2023 Integrated Energy Policy Report; California Energy Commission [CEC]: https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2023-integrated-energy-policy-report, Adopted 2023 Integrated Energy Policy Report with Errata

A. Building electrification IEPR page and section references: New and existing building model assumptions: Page 119-121- "Zero-Emission Standards Modeling"; Electrification load impacts: Page 212 AAFS 3-6. Note that AAFS 3 is the scenarios used by the State for forecasting; Figure 13- Additional Achievable Fuel Substitution. AAFS= Building Electrification; AAEE= Efficiency – this was used to calculate total increased load from AAFS and combined reductions from efficiency; solar, storage
B. Vehicle Electrification IEPR page and section references: Passenger vehicles number: Page 137; Figure 27 AATE 3 vs. baseline; Commercial vehicles number: Figure 28; Electrification load impact: Figure 13- Light Duty Vehicles – combines light duty and medium/ heavy duty vehicles.
C. Projected 2035 Statewide Electrical Demand: https://www.energy.ca.gov/sites/default/files/2024-02/2023_Integrated_Energy_Policy_Report_Highlights_ADA.pdf; note that the percent increase was calculated by project team comparing 2023 actual peak to the 2035 managed peak.

[2] These increases to load could be significantly reduced through reductions in demand from solar, energy storage, and energy efficiency, cumulatively subtracting -4,785 MW from this total. This also applies to the projections for vehicle electrification.

In conclusion, BAAQMD Rule 9-6 and 9-4 are not projected to lead to bulk-power outages because State planners and utilities are specifically planning to match new electrical loads with the projected electrical impacts of the BAAQMD Rules as well as other policy drivers expected to increase electrical demand.

Legislative Solutions to Address Grid-Side Power Outages

As described above, the State has been pushing PG&E to take action to reduce the duration of PSPS events through EPSS events. Although the EPSS events are more frequent, they are also significantly shorter than PSPS events, averaging less than three hours per outage. PG&E is also working towards more permanent wildfire mitigation, such as grid-interruption reduction strategies that include undergrounding power lines. Recent legislation like Senate Bill No. 884 aims to expedite the undergrounding process, which historically has been lengthy and expensive.[45] Taken together, these initiatives are aimed at reducing business and residential side impacts of PSPS events by reducing their instances all together (undergrounding) or improving the efficiency of the de-energization process (EPSS instead of PSPS).

[45] https://www.cpuc.ca.gov/about-cpuc/divisions/safety-policy-division/risk-assessment-and-safety-analytics/electric-undergrounding-sb-884

There are numerous other pieces of legislation and policy aimed at streamlining the bulk generation and transmission process, as well as increasing the resiliency of existing and future grid infrastructure. Some key pieces of legislation include:

- Senate Bill 619, (2023) authorizes the CEC to certify a broader range of transmission projects, potentially reducing the regulatory review and approval process by years. This means that more transmission projects can be approved by the CEC in lieu of any permit, certificate, or similar document required by any state, local, or regional agency, or federal agency to the extent permitted by federal law. This updated could bring essential new transmission projects online to connect the distribution grid to new bulk renewable energy projects.[46]
- Senate Bill 410 (Powering Up Californians Act; 2023), establishes a deadline for the CPUC to establish an average and maximum target energization timeline, forcing utilities to report on compliance and explain delays. It also requires utilities to train and hire the workforce necessary to electrify the transportation and building sectors. Finally, SB 410 reforms utilities' annual grid planning and investment in grid capacity to align with Federal and State-level decarbonization goals and air quality targets, which include Rules 9-6 and 9-4.[47]

Non-Wires Solutions for Increased Grid Reliability

Load Shifting with Heat Pump Water Heaters and Backup Power

The State (CAISO) also includes "non-wires solutions" which reduce the need to build new transmission lines as part of their Transmission Planning Process. This is an example of an upstream grid-level solution that includes high-efficiency appliances as a solution for larger grid reliability at the transmission and bulk distribution level. These non-wires solutions include energy efficiency, demand response, and renewable resources. In fact, decarbonization policies like installation of energy efficient heat pumps, smart-ZEV charging, and expansion of local renewable energy and backup power could be seen as non-wires solutions for the transmission and bulk-power-generation reliability challenge. These solutions, in particular, battery storage and vehicle-to-home charging will be further explored in the section below.[48]

Resiliency Power Outages Solutions Overview

Resiliency solutions such as battery storage and vehicle-to-home charging can only reduce strain on the grid to invest in larger utility-scale upgrades, but also improve customer resiliency to ensure 24/7 usage of any appliance that uses electricity, like HPWH and HP HVAC. This solution overlaps with Zero-NOx Appliances and Resilience, which will be further expanded upon in the next section.

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[46] https://www.caiso.com/Documents/Transmission-Planning-Process-Overview.pdf

[47] https://www.nrdc.org/bio/max-baumhefner/powering-californians-act-signed-law

[48] https://www.sandiegouniontribune.com/business/story/2022-09-30/newsom-signs-bill-speeding-the-placement-of-underground-power-lines; https://www.nationalgrid.com/sites/default/files/documents/39111-Undergrounding_high_voltage_electricity_transmission_lines_The_technical_issues_INT.pdf; https://insideclimatenews.org/news/11072022/is-burying-power-lines-fire-prevention-magic-or-magical-thinking/

4 Zero-NOx Appliances and Resilience

Related to the overall concern about grid impacts and power outages, is the more specific concern that electric zero-NOx appliances will not work during a power outage. This concern is linked to the ideas that multiple energy options are better than one, and that gas water and space heating appliances can function during a power outage, while electric zero-NOx appliances cannot.

This section explores the comparative reliability (how consistently the appliance will work) and resilience (ability to withstand and recover quickly from disruption) of NOx-emitting gas appliances vs. zero-NOx appliances during a power outage. It also explores emergent solutions to allow for continued power supply and appliance functionality during power outages via battery storage and vehicle-to-home charging technologies.

4.1 Appliance-Level Reliability Overview

There is a common perception that NOx-emitting gas appliances are more "resilient" or reliable than electric appliances because they can continue to operate during an electricity outage. In fact, modern NOx-emitting gas appliances often rely on both gas and electricity to operate. This fundamentally makes them more vulnerable to disruption and service interruptions than zero-NOx HPWH and HP HVAC, which only rely on electricity to function. If a NOx-emitting gas furnace or water heating appliance is plugged into an outlet, it will likely not function during a power outage and provides little to no additional resiliency benefit over a zero-NOx electric appliance.

As shown below in Table 5, traditional style gas tanked water heaters (with a continuous pilot) and gas wall furnaces will likely work during a power outage. However, while a heat pump hot water heater or tanked resistance water heater will not operate during a power outage (without backup power), they can keep water hot for extended periods of time. In fact, Heat Pump hot water heaters can act as a thermal battery, heating water to high temperatures during the day using renewable energy and then providing that water using a mixing valve without any additional power draw through the evening hours.[49] Given that the average power outage for PG&E territory is less than 3 hours, a tanked heat pump water heater could continue to provide hot water through the outage. Furthermore, while older gas appliances may work during an electrical outage, the newer gas appliances which would be used to replace older appliances on burnout (without Rules 9-4 and 9-6) would likely require electricity as well, further reducing the impacts of the Rules on reliability compared to baseline.

In addition to providing minimal additional resiliency during a power outage, NOx-emitting gas appliances introduce their own risks. For example, in the instance of an earthquake, improperly stabilized gas appliances could introduce broken gas lines and gas leaks into homes and buildings.[50]

[49] https://www.nrdc.org/bio/pierre-delforge/heat-pump-water-heaters-clean-energy-batteries#:~:text=Heat%20pump%20water%20heaters%20are,storing%20emissions%2Dfree%20solar%20energy.
[50] https://www.pge.com/en/outages-and-safety/safety/natural-disaster-safety.html#accordion-18f7e695a1-item-d2b4e8a080

Table 5 NOx-Emitting vs. Zero-NOx Space and Water Heating Appliance Reliability During Power Outages[1]

Appliance	Functional Without Electricity?	Explanation
Water Heating Appliances		
NOx-emitting (gas) tanked water heater	Depends	Modern tank-type water heaters often have electronic ignition systems and will not work without electricity. However, traditional tank-type models with a continuously burning pilot light can continue to operate during a power outage. These types of appliances (likely pre-1980) are rare in modern building stock.
NOx-emitting (gas) tankless water heater	No	Modern tankless gas heaters also require electronic controls and will not work without power. Specifically, the appliance requires power to monitor the water's temperature to make sure it does not get too hot; many also have built-in safety systems to prevent them from turning on in a power outage.
Zero-NOx Water Heaters (HPWH; tankless electric)	No	Zero-NOx water heaters are currently all electric and therefore cannot work without electricity.
Space Heating Appliances		
NOx-emitting gas ducted furnace	No	Gas furnaces have multiple electrical components that must operate to function, like fans, motors, and the circuit boards that allow thermostat and furnaces to communicate/ function.
NOx-emitting gas wall furnace	Yes	Gas wall furnaces can typically work during a power outage, as they do not have fan systems to circulate warm air. However, gas wall furnaces are not an efficient form of heat and are more expensive to operate for this reason.
Zero-NOx space heating (HP HVAC; electric space heater)	No	Zero-NOx space heaters are currently all electric and therefore cannot work without electricity.

Source(s): https://oregoncub.org/news/blog/gas-myth-all-gas-appliances-work-in-power-outages/2489/; https://www.peninsulacleanenergy.com/myths-and-facts-about-gas-appliances-during-a-power-outage/

In conclusion, modern NOx-emitting space and water heaters likely have electrical components that are necessary to function—just like electric zero-NOx appliances. Accordingly, the resilience benefit of these appliances is isolated to older technologies. Except for gas wall furnaces that do not have fans to move air and traditional tanked water heaters with continuously burning pilot lights, many NOx-emitting space and water heating appliances will not function during a power outage.

Accordingly, the next section explores building-level solutions to ensure continuous appliance and building function during power outages. These solutions include battery backup and vehicle to home bi-directional charging.

4.2 Building-Level Resilience Solutions Overview

The only way for continued appliance functioning during power outages is through establishing backup power solutions. These solutions maintain zero-NOx appliance function during infrequent and localized power outages. In addition, these resilience solutions can provide additional benefits such as running other key services like internet, refrigeration, and more.

Battery Storage

Battery storage offers one potential solution for power outages. Battery storage can provide power for several hours or longer, depending on storage system and power use. Homes that already have solar panels are a particularly good fit to install battery storage as batteries can store excess solar energy and use it when the sun is not shining. A battery storage system when paired with solar can help power devices for days.[51]

Self-Generation Incentive Program (SGIP)

The CPUC has authorized funding for over $1 billion in self-generation (battery) backup installation support, particularly for communities living in high fire zones vulnerable to PSPS events. Self-Generation Incentive Program (SGIP) funding is primarily reserved for single-family homes or low-income multifamily housing with at least five units. The rebate rate is currently $850/ kilowatt-hour and covers approximately 85% of the cost of an average energy storage system.[52]

Switching to PG&E's home charging EV2A rate, or E-ELEC rate could also lead to energy bill savings for buildings that have installed battery storage systems but do not own electric vehicles.[53] A recent bill impact study assessing the impact of decarbonizing single family homes found savings of roughly $380-495/ year for all-electric homes (including zero-NOx appliances) when switching to the E-ELEC or EV-2A rates.[54]

Bidirectional Charging

Bidirectional charging or vehicle-to-home (V2H) charging refers to the potential for electric vehicles to serve as backup batteries during power outages. Bidirectional charging also has a larger potential for increasing overall grid stability as an energy storage asset and could potentially create new revenue opportunities for EV owners.[55]

A typical electric car has a battery that can hold approximately 60 kilowatt hours (kWh) of energy, which is enough to supply power to the average U.S. home for two days.[56] As noted in the sections above, the vast majority of Bay Area homes will not experience a power outage this long, with most experiencing a power outage of 3 hours or less for EPSS events. However, PSPS events occur less frequently than EPSS events but for longer durations of time, averaging 39 hours.[57]

Not all EVs and chargers have V2H capabilities. A recent, though eventually defeated, 2023 State Legislation (Senate Bill-233) would have required all electric vehicles sold in the state to be equipped with bidirectional charging technology.[58] Although this introduced legislation ultimately did not pass, it indicates an increasing State interest in applying pressure to EV manufacturers to

[51] https://www.pge.com/en/clean-energy/battery-storage.html#accordion-ded2b41eb1-item-acbed3a9f6
[52] https://www.cpuc.ca.gov/-/media/cpuc-website/files/uploadedfiles/cpucwebsite/content/news_room/newsupdates/2020/sgip-residential-web-120420.pdf
[53] https://www.pge.com/en/account/rate-plans/find-your-best-rate-plan/electric-vehicles.html#ev2aDetails
[54] https://svcleanenergy.org/wp-content/uploads/SVCE-PCE-Single-Family-On-Bill-Impacts-Results-2023.pdf
[55] https://www.energy.gov/technologytransitions/articles/department-energy-announces-first-its-kind-collaboration-accelerate
[56] https://www.wri.org/insights/how-california-can-use-electric-vehicles-keep-lights
[57] https://www.cpuc.ca.gov/-/media/cpuc-website/industries-and-topics/meeting-documents/20230317-workshop/pge--fast-trip-unplanned-outages-and-distribution-reliability-workshop-presentation.pdf; https://www.cpuc.ca.gov/-/media/cpuc-website/industries-and-topics/meeting-documents/20230317-workshop/pge--fast-trip-unplanned-outages-and-distribution-reliability-workshop-presentation.pdf
[58] https://www.cnet.com/roadshow/news/california-bill-requiring-bidirectional-charging-in-all-evs-is-defeated-in-state-assembly/

provide V2H capabilities.[59] There are currently over 20 vehicles that support bidirectional charging as of Spring 2024.[60]

Current uptake of EVs is not evenly distributed across income brackets or geographic areas in the Bay Area. A recent analysis of statewide ZIP codes showed that 12 of the top 20 zip codes for percentage of electric cars were in the Bay Area, but the demographics of these zip codes were primarily white or Asian, highly educated, with a typical home value of over three million dollars. A good example of this is the town of Atherton in San Mateo County, which has the highest percentage of EVs (14.2%) in California, with a median household income of over $250,000.[61] This same analysis echoes the well documented concerns around EV uptake in low-income, renter, and multifamily populations. To equitably distribute the resiliency benefits of bidirectional charging, EV adoption and charging will have to be more equitably distributed to these populations as well. This will likely entail more robust funding programs, customer education, and likely, reduced rates for electricity to ensure cost competitiveness with gas.

Bidirectional Charging- Emerging Incentives and Programs from PG&E and CPUC

There has been an increasing focus on harnessing EVs as a larger tool for demand-side-management of the electric grid and boosting overall grid-reliability. PG&E launched a 2022 pilot on the use of EVs in vehicle-to-home interconnection. This was part of a larger 11+ million dollar financing effort by the California Public Utilities Commission to support commercial and residential vehicle-grid-integration pilots across PG&E territory.[62] In 2022, PG&E also received approval to establish the nation's first vehicle-to-grid (V2G) export rate structure, which would provide upfront incentives to help commercial customers offsets fleet costs through financial incentives to export power back to support the grid during peak energy demand periods.[63] This indicates that bidirectional charging, and establishing incentive mechanisms for bidirectional charging, is of increasing importance to both IOUs like PG&E, but also to State agencies like CPUC.

The larger promise of bidirectional charging is that not only would EV owners be able to benefit from backup power during power outages, but grid resiliency in general would benefit as a demand-side-management system to provide additional power during peak demand, and charge during off-peak.[64] This space will likely shape options for grid reliability and electric zero-NOx appliances installed in compliance with Rules 9-6 and 9-4.

[59] https://www.cnet.com/roadshow/news/california-bill-requiring-bidirectional-charging-in-all-evs-is-defeated-in-state-assembly/
[60] https://www.dcbel.energy/blog/2024/01/15/new-year-new-bidirectional-cars-2024-edition/
[61] https://calmatters.org/environment/2023/03/california-electric-cars-demographics/
[62] https://www.utilitydive.com/news/california-approves-117m-vehicle-to-grid-pilots-in-pge-footprint/621393/
[63] https://www.pgecurrents.com/articles/3578-pg-e-offer-nation-s-vehicle-grid-export-rate-commercial-electric-vehicles
[64] https://www.nrel.gov/news/program/2023/evs-play-surprising-role-in-supporting-grid-resiliency.html

5 Conclusion

Community members and key interested parties are concerned with a number of grid-reliability related issues connected to the implementation of BAAQMD Rules 9-6 and 9-4. These concerns range from the long timelines required to upsize panels and upgrade electric service, to overall grid reliability concerns related to the introduction of new electrical loads for space and water heating. Many of these perceptions are grounded in real experience with power outages or variable wait times to process service upgrades. However, most of these concerns are being addressed by a blend of improved/reformed processes at PG&E, legislation, and or technology advances like battery storage or bi-directional charging.

5.1 Utility Interconnection Lag Times

It is unlikely that the installation of a HPWH will lead to the need for an electric panel upsize and subsequent service upgrade. Homes with 200-amp panels are unlikely to need a panel upsize in order to accommodate loads from HPWH and HP HVAC. Meanwhile, older homes with smaller panels are able to accommodate these new loads from zero-NOx space and water heating but may require additional selection of low voltage appliances or planning through the “watt-diet” approach. A minimum of 44 percent of Bay Area Households likely have a 200-amp panel. Some proportion of the remaining 56 percent of households will be able to install HPWH and HP HVAC on their existing panel while some have already upgraded their panel to accommodate new loads (e.g., solar, or EV charging). Homes requiring a panel upsize and service upgrade may experience variable, and potentially lengthy project completion times from PG&E. The timeline for a service upgrade ranges from ten days to eight months and may entail increased costs borne by the building owner depending on project type.

Solutions to lengthy service upgrade times include reforming PG&E’s service upgrade process (e.g., through reform to the 30-day “clock-reset” process and potentially providing incentives and education for low-voltage appliances selection or emergency replacement appliance loaner programs). Recent legislation including SB 410 is also aimed at speeding up the interconnection process. On the building-owner side, the ‘watt-diet’ approach could prove promising at avoiding a panel upsize and service upgrade, particularly for homes with a 100–150-amp panel.

5.2 New Electric Loads from Zero-NOx Appliances and Grid Reliability

Although some feedback on the Rules have cited power outages as a concern related to building electrification, there is little evidence that increased levels of building electrification would lead to additional outages. It is very rare for power outages to be caused by a shortfall of generation due to high loads and utilities and system operators are planning for increased electricity demand due to state legislation around building and vehicle electrification. Other more common types of power outages like those caused by equipment damage or those called for to prevent wildfire risks have little connection to electricity demands on the system at the time of the outage. Increased levels of electrification would not impact the frequency of these types of outages. Although the frequency of outages has increased in recent years in PG&E’s service territory, PG&E is planning to make significant investments in hardening its system to improve reliability and reduce outages. In addition to system hardening efforts, PG&E has been exploring new approaches to reduce the impact of outages that they call for during times of high wildfire risk, which may significantly reduce the duration of wildfire risk-related outages.

5.3 Zero-NOx Appliances and Resilience

While some older models of NOx-emitting tanked gas water heaters (with a continuously burning pilot light), and NOx-emitting gas wall furnaces (with no fan to circulate warm air) will continue to operate during an electrical power outage, most modern gas appliances that provide space and water heating will not function without electric power. Accordingly, most natural gas-consuming devices may not offer a solution to this perceived reliability challenge. Battery storage and bidirectional EV charging offer holistic solutions to this appliance resilience challenge.

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