Upsized Homes Panel Loads Assessment Report

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1 Executive Summary

The purpose of the Past Upsized Homes Panel Loads Assessment is to analyze homes that have already undergone a panel upsizing to determine if the panel upsizing was necessary to accommodate the loads that were added. The assessment will support the development of the Home Power Planner tool for the California Energy Commission (CEC) that is intended to assist in electrifying homes with limited electrical capacity to avoid panel and service upsizing. The assessment included measured pre and post upsizing peak demand measurements, and used both the 220.83 and 220.87 methods in the 2023 National Electrical Code (NEC). This assessment will also investigate the potential for avoiding panel upsizing if the homes were fully electrified using twelve power-efficient strategies. The findings will show that the Home Power Planner (HPP) should utilize both NEC compliance paths and include Power Efficient Design (PED) strategies, and provide multiple options for users to ensure flexibility and usability by a wide range of households. The results can be used to guide future policy and program recommendations by illustrating the potential for homes to avoid infrastructure costs using the HPP. The assessment focused on demand requirements and did not include any in-depth analysis of available breaker space. This is because it is relatively inexpensive and easy to add a subpanel to increase the number of available breakers compared to full panel and service upsizing.

The panel loads assessment recruited 25 single-family homes that had recently upsized their electrical panels with 100 A capacity to panels with 200 A, or greater. Home characteristics, electrical appliance and equipment information, and about a year of measured electrical utility data before and after the panel upsizing occurred were collected. The homes were distributed across California climate zones and Investor Owned Utilities (IOUs) and included a wide range of home sizes and occupancies. While not a large enough sample to be a true statistical representative, these homes are reasonably representative of California single-family homes and they allow us to examine key panel upsizing issues. These homes all added one of these five key loads: heating/cooling, water heating, cooking, clothes drying or electric vehicle (EV) charging.

The key findings are:

- **All 25 homes could be fully electric on a 100 A panel following the NEC and using PED plans.**
- 20 of the 25 of the homes could have stayed on a 100 A panel from an NEC perspective using either NEC 220.83 or 220.87. Generally, the 220.87 method allowed fewer homes to stay on a 100 A panel because the new loads are simply added to the measured load and load diversity factors used in 220.83 cannot be applied[1].

[1] The amendments in 2026 NEC (which should be in effect in CA in 2029) will allow load diversity factors to be applied to new loads when using 220.87.

- Using PED would allow all 5 remaining homes to comply with the NEC on both 220.83 and 220.87.
- Using PED would provide multiple strategies for every home to comply with the NEC on their original 100 A panel when *fully electrifying*.
- Given the success of PED, these approaches will be included in the Home Power Planner being developed in this study.
- All but one[2] of the homes had measured peak demand less than 100 A post panel upsizing, indicating that they could have added their various loads without panel upsizing. The average peak load was 38 A and the maximum measured peak load across all homes was 71 A.
- The added loads increased the measured peak demand by 9 A on average with a maximum increase of 49 A. Eight homes reduced peak after adding load[3].
- The NEC 220.83 and 220.87 calculations significantly over-predict the measured peak loads on average by factors of 2.5 (55 A) and 2.7 (66 A), respectively. The overpredictions for the 220.83 approach ranged from 18 A to 91 A. For the 220.87 approach the range was from 13 A to 123 A. This indicates the conservative nature of the NEC calculation methods.

2 Introduction

The primary electrical infrastructure constraints faced when adding new appliances and equipment to existing dwellings are:

1. **Electrical capacity** - refers to the capacity of the electrical panel ampacity rating or the main disconnect. A constraint occurs when the calculated National Electrical Code (NEC) electrical service load for a planned project exceeds the rating of the existing electrical equipment. The home's service load is referred to as "demand" in this document and is the focus of the assessment.
2. **Physical space** - refers to the breaker slots or breaker spaces available for adding new branch circuits. A constraint occurs when the number of new breaker slots

[2] One home had a peak of 101 A. This is likely because this home had its measured peak demand estimated by converting from 60- to 15 minute data. The conversion calculation is not exact in all homes and can both over and under-estimate the increase in loads when converting to smaller time periods. It is also possible that additional power consuming equipment was brought to the home, e.g., for food preparation/cooking.

[3] The reasons for this are unclear but likely include: adding solar systems that could be coincident with big loads (for four homes), pre-existing large loads (three homes already had air conditioning, a couple had EVs), or only adding one new load.

needed for a planned project exceeds the slots available in the existing panel(s). Breaker space optimization was not the focus of this assessment, but breaker counts were reported as part of the field study.

Standard practice in industry is to resolve these constraints with panel upsizing and an accompanying service rating increase. These practices result in high costs and project time delays for homeowners or project denials related to utility infrastructure updates to accommodate new loads. New approaches are needed to minimize these costs and utility impacts.

The assessment will resolve or manage these constraints with these two key approaches:

1. **Perform strategic NEC load calculations** (utilizing actual rather than assumed appliance power) and examining both paths in the NEC: 220.83 (whole home appliance inventory) and 220.87 (historic electric measured demand).
2. **Use Power Efficient Design (PED)** that involves choosing the right appliances and equipment (e.g. "right-sizing", low power selection or combining functions in a single unit), using load controls, and optimizing panel space. In this report we use the terms "Power" and "Peak", depending on context. For example, panel Amps (A) are expressed as demand and the kilowatt (kW) rating for appliances are expressed as power.

Homes that have previously undergone a panel upsizing will be analyzed to determine if the panel upsizing was necessary to accommodate the loads that were added by performing load calculations with the NEC 220.83 and 220.87 methods. Additional analyses will examine if the homes could stay on a 100 A panel when fully electrified. The potential for avoiding panel upsizing will be evaluated using twelve PED strategies. The findings will inform the development of Home Power Planner and guide future policy and program recommendations.

25 single-family homes that had recently upsized their electrical panels from 100 A to ≥ 200 A were recruited. These homes all added one of these key electrical loads: heating/cooling, water heating, cooking, clothes drying or EV charging. About a year of pre and post panel upsizing demand (either 15- or 60-minute) data were obtained for each home along with the necessary home and electrical appliance/equipment metadata for NEC calculations. The homes were distributed across California climate zones and IOUs, as illustrated in Figure 1, and included a wide range of home sizes and occupancies. While not a large statistical sample, these homes are reasonably representative of California single-family homes, and allow us to examine key panel upsizing issues.

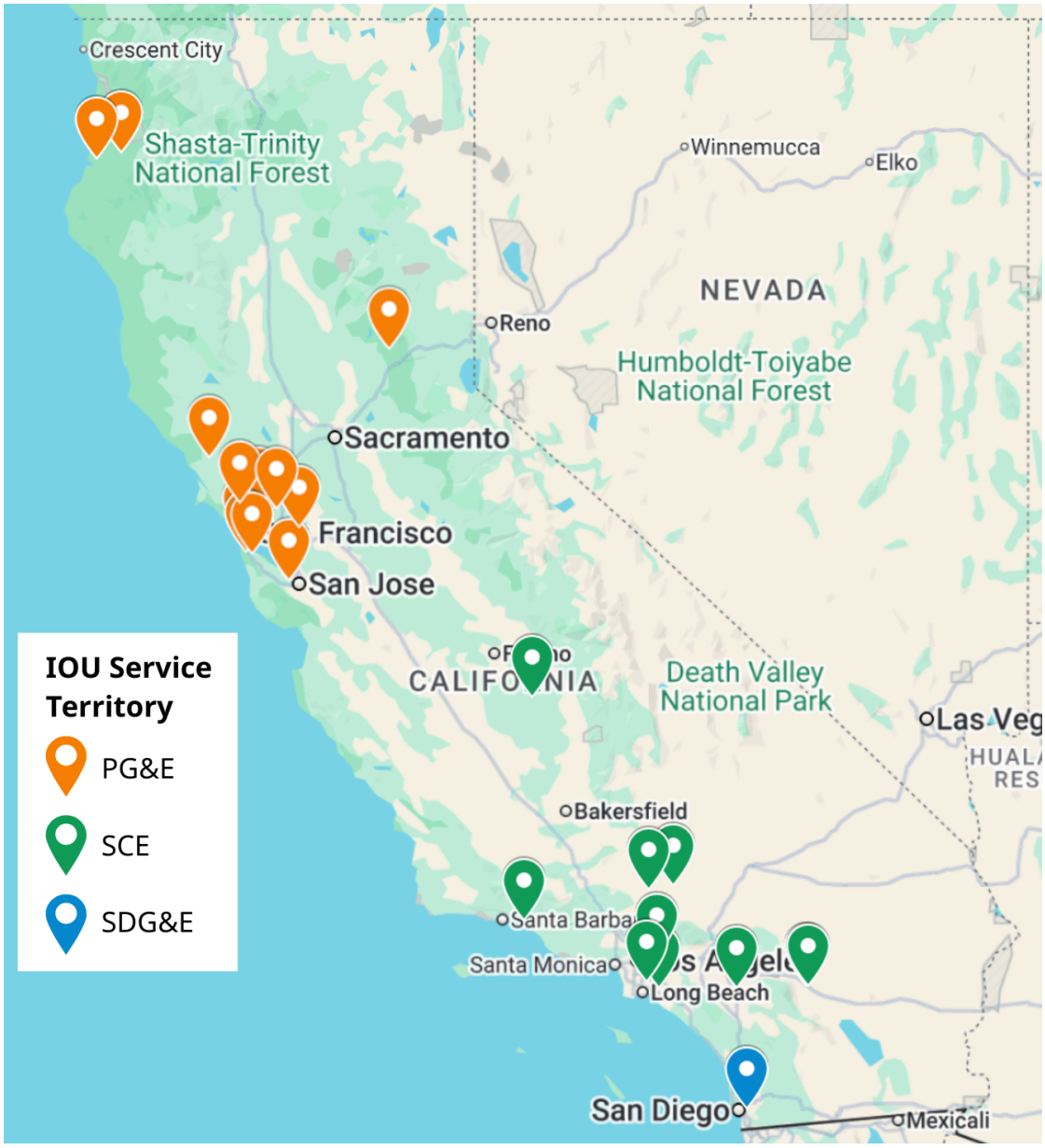


Figure 1. Locations of homes that previously upgraded their electric panels.

The assessment will address the following questions

- Based on NEC calculations, did the new loads installed in each home require panel upsizing?
- What electrical panel capacity is required under NEC load calculation methods?
- How often was PED required to avoid panel upsizing?
- How do results differ between NEC 220.83 calculations and NEC 220.87 load analysis?

- How much did the measured peak demand change when new loads were added to homes?
- How much difference is there between measured loads and NEC calculations?

The relative costs of the PED strategies compared to the panel upsizing costs were not assessed. Similarly, other HVAC related sizing factors, such as envelope upgrades, duct system sealing and insulation, etc. were not included in the analysis. Due to the small sample size, the results should only be interpreted as reasonably representative of California single-family homes that allow us to examine key panel upsizing issues. We also did not assess whether homes changed their utility service capacity when upsizing their panels.

3 Methodology

This methodology summarizes the home recruitment approach, home sampling plan methodology, home recruitment, pre and post electrification data collection methodology, and measured electrical usage calculation. It also covers NEC panel load calculation approach and survey approach to understand the homeowner's upsizing reasons.

3.1 Sampling Plan

The sampling plan identified the criteria for selecting the homes for study. This was developed based on research questions, contractual requirements, and feedback from the project's Technical Advisory Committee and the Community Advisory Board. The sampling plan included both required and representative criteria.

3.1.1 Required Criteria

The main criterion for the homes was that they had undergone electric panel upsizing where the main disconnect was upsized from 100 A or less, to 200 A, or greater. A couple of constraints were that the electric panel upsizing was not part of a home addition (adding square footage or an ADU), and that the electric panel upsizing was within the last two years.

The home had to be a single-family home or townhouse that the owner had lived in for at least the last 12 months. The home had to be served by one of the three California IOUs for electrical service (PG&E, SCE, SDG&E), including those with a Community Choice Aggregator (CCA), and by one of the three California IOUs for natural gas service (PG&E, SCG, SDG&E).

3.1.2 Representative Criteria

The sample size was too small to be considered statistically representative of all California homes; however, it was desirable to include homes served by different IOUs, in different climates and with a range of home characteristics.

Electric IOU Service Territories Representation

To ensure statewide representation, homes were selected across the three electric IOU territories, as shown in Table 1. Sample proportions are based on the estimated distribution of single-family homes within IOU service areas. This excludes homes served by Publicly Owned Utilities (POUs), such as Los Angeles Department of Water and Power (LADWP) and Sacramento Municipal Utility District (SMUD).

Table 1. Electric IOU Service Territories Representation

IOU	Approximate % of State Population Covered by IOUs	Target Homes in Sample
PG&E	~60% of IOU-served households	15 – 17 homes
SCE	~30% of IOU-served households	6 – 8 homes
SDG&E	~10% of IOU-served households	2 – 3 homes

Climate Zone Representation

California has 16 climate zones (CZs)[4]. Homes across climate zones will have different heating and cooling loads with variation in the capacity and operation of large loads, such as HVAC equipment. Given the sample size constraints, the study used climate binning to select homes, as shown in Table 2.

[4] Climate Zones are defined by the California Energy Commission (CEC) under Title 24, Part 6, which categorizes regions based on temperature patterns, seasonal energy demand, and geographic features. Climate Zone tool, maps, and information supporting the California Energy Code

Table 2. Climate zone representation

Climate Type	Coastal CZs	Inland CZs	Rationale	Target Sample Distribution
Mild	3, 4, 5, 6, 7	11	Moderate heating/cooling loads	~9 homes (6 coastal, 3 inland)
Hot	8, 9, 10	13, 14, 15	High summer cooling demand	~8 homes (4 coastal, 4 inland)
Cold	1, 2	12, 16	Significant heating loads, snow in some areas	~8 homes (4 coastal, 4 inland)

Home Characteristics Representation

The homes were selected based on the following characteristics:

1. **House size.** Larger homes may have higher electrical demand, making them a useful case study for panel upsizing needs. Smaller homes that upsize panels may reveal cases where large added loads dominate size-related factors.
2. **Occupancy.** Homes with higher occupancy are likely to need larger or higher power appliances/equipment to meet its occupants' needs (e.g. larger water heater size for a large family).

Home vintage (year built) was not a specific criteria, with the expectation that natural selection will tend towards older homes.

The specific criteria are summarized in Table 3.

Table 3. Home Characteristics Representation

Characteristic	Categories	Target Distribution
Home Size	≤1000 sq ft, 1001–1999 sq ft, ≥2000 sq ft	At least few homes ≤1000 sq ft, and some homes ≥2000 sq ft
Occupancy	≤2 occupants, 3–4 occupants, 5+ occupants	At least a few homes with 5+ occupants will be included, but occupancy criteria are optional. The remaining distribution will be balanced across the sample

Potential Key Panel Upsizing Drivers

Several loads have been identified as drivers of panel upsizing:

1. **Solar PV** may influence whether a panel upsize was thought to be necessary because of additional limits for busbar ratings. Additionally, homes with Solar Photovoltaic (PV) are challenging to analyze whole home energy consumption trends.
2. **EV charging** can be a large long duration load.
3. **Fully electrified homes** were included because they represent the case where the combined new loads could be large and that there is little likelihood of the need to reserve capacity for added loads in the future. A fully electrified home is defined as a home with no gas permanent equipment remaining —all major end uses (heating/cooling, water heating, cooking, clothes drying, and car[5]) are electric.

The specific key driver criteria are summarized in Table 4.

Table 4. Potential key drivers of panel upsizing

Equipment	Targeted Representation
Presence of Solar PV	Not too many, keep below 50%
Presence of EV Charging	At least some but not all
Fully Electrified Home	At least some

3.2 Home Recruitment and Data Collection

25 homes were recruited following the sampling plan via two routes: (1) project team's direct outreach and (2) collaboration with existing utility programs. Both routes collected the core data outlined in the sampling plan.

All 25 homes have equipment data on equipment and fuel type of heating system, clothes dryer, cooking equipment, and water heater before and after the home's panel upsizing project. The direct outreach collected additional information on the presence of an EV charger, solar panel, battery, pool heater, spa heater, and dishwasher. Advanced metering infrastructure (AMI) energy usage data was collected for about a year before and after the panel upsizing occurred at these homes. Energy use was converted to power by assuming that the power was constant over the measuring period. Most of the analysis was in terms

[5] In this study we are including EV charging in our analyses because of the impact on peak demand and NEC calculations, and we note that the definition of "Fully Electrified" in other studies and programs might not include EV Charging.

of peak demand in amps. Power was converted to demand (in amps) using 240 or 120 V depending on the individual load. For more details on the information collected from these two recruitment routes, refer to Appendix A.

3.3 NEC Panel Load Calculations

For each home, National Electrical Code (NEC version 2023) electric load calculations were performed under articles 220.83 (whole home appliance inventory) and 220.87 (historic electric peak readings). A home only has to comply with one of these NEC load calculations, not with both. The details of the NEC calculations are given in the Task 2 Power Efficient Management Report for this project.

Analysis Scenarios

We used 220.83 and 220.87 to determine whether a home could stay on a 100 A panel based on two distinct scenarios: (1) the current project and (2) the same home but with full electrification.

Scenario 1: Current Project

Under the current project scenario, we conducted the NEC analysis at the home's current level of electrification. We ran analyses that answer the following questions:

- Could the home have remained on the prior 100 A panel with their current electrification choices under 220.83 and/or 220.87?
- For the homes that could not accommodate their loads on a 100 A panel, could they have employed the PED Plans in Table 5 below to allow them to stay on a 100 A panel with their current electrification choices?

Scenario 2: Full Electrification

Under the full electrification scenario, we conducted the NEC analysis for full electrification of the home. We ran analyses that answer the following questions:

- Could the home have remained on a 100 A panel with their current electrification choices and also adding conventional power-intense appliance/equipment to be fully electrified?
- Would the home's current electrification choices impact the success of employing the PED Plans in Table 5 to fully electrify and stay on a 100 A panel?

We considered two different starting points for the Full Electrification calculations. The first starting point is for the homes before they added any key electric loads or changed their panels. We call this “Full Electrification”. The second starting point is for the homes as they are now, with the electric loads they already added. We call this “Continued Electrification”. In the first scenario we can apply PED to all the added loads. In the second, PED is only applied to the additional loads needed for full electrification.

For the 220.83 calculations, from the first starting point, all the equipment necessary for full electrification could be changed based on the PED Plan. The second starting point had the constraint that any current electrification appliance/equipment choices stay the same and only additional loads follow a PED.

For the 220.87 calculations, from the first starting point, the calculations are based on measured peak demand before any loads were added. The second starting point is based on measured peak demand that includes the current electrification appliance/equipment choices that did not follow PED.

PED Plans

We created 12 PED plans that cover a range of added loads in several common combinations. While not exhaustive, it does cover most likely scenarios, and other PED plans could be developed to provide additional options and consumer choices. We considered five key loads: heating/cooling, water heater, cooking, clothes drying, and EV charging. Solar PV and batteries do not directly impact loads and were considered separately. Table 5 summarizes these plans.

Table 5. Summary of PED plans

PED Plan Type	Specific PED Plan Choices
Appliance/Equipment Selection	
Combination Device	1. Washer Dryer Combo
	2. Harvest Thermal & Washer Dryer Combo
Low Power Appliance	3. 120 V Range (with battery)
	4. 120 V Water Heater & 120 V Range (with battery)
Low Power Appliance & Combination Device	5. 120 V Water Heater & Washer Dryer Combo

Low Power Appliance & Combination Device	6. 120 V Water Heater, 120 V Range (with battery), & Washer Dryer Combo
	7. 120 V Water Heater, 120 V Range (with battery), 120 V Heat Pump (or 120 V EV Charger) & Washer Dryer Combo
Load Control	
Load Share	8. Share: Water Heater AND Range (or Dryer)
	9. Two Shared Circuits: One for Water Heater AND Range and a second for Dryer AND EV Charger
Load Shed	10. Pause EV Charger
	11. Smart Panel
Load Share & Load Shed	12. Share: Water Heater AND Range Pause EV Charger

3.4 Measured Electric Usage

In the analysis of the 25 homes, AMI electric usage data was collected from each property and filtered to identify the pre- and post- panel upsizing periods with the installation of a new electrical panel being the point of separation for the periods. The periods were mostly one year in length. The month that the panel upsizing occurred was removed for the two data periods so that there is a clean “pre” and “post” data series that limits the possible complications of the residence being without power for a stretch of time. This helps ensure that comparisons are made during normal operating conditions. However, it does not address the possibility that some appliance replacements or other circumstances may have resulted in changes in the usage data throughout the observation periods, and this, in fact, does occur at times and can be observed in some of the AMI data. All the homes complied

with the NEC 220.87 requirements that heating or cooling operate during the monitoring period.

The AMI electric usage data for the homes provided either 60- or 15-minute intervals of kWh that had been accumulated in the previous time increment. For homes with 60-minute interval data, Equation 1 was applied to convert to simulated 15-minute data. Equation 1 is based on data collected from over 11,000 US homes[6].

$$\text{Simulated 15-minute peak value} = \text{60-minute_value} * 1.09 + 1.5 \text{ kW} \quad (1)$$

The peak demand (in amps) was determined for both the pre and post panel upsizing period to compare changes in demand these homes experience through their electrification activities. The annual peak demand pre- and post- panel upsizing was categorized based on additional factors to see which were significant: Solar/Battery Presence, Climate Types, Number of Occupants, and Number of End Uses Electrified. For these comparisons, in addition to annual peak demand, annual kWh energy consumption was compiled for the homes. For homes with Solar PV and batteries the AMI data represents the net value of consumption and production from solar combined.

3.5 Homeowner Panel Upsizing Reasons

For the homes recruited through direct outreach (11 homes in total), homeowners were surveyed to understand why they upsized their panel. The homeowners were asked the following question:

What were the primary reasons for upsizing your Electric Main Panel? (select all that apply)

1. Changed from natural gas to electric appliances
2. Added solar panels
3. Added home battery
4. Added Electric Vehicle (EV) charging
5. Planned future electric needs
6. Needed additional breaker space/slots
7. Due to safety, code compliance, or insurance reasons (for example older panel)
8. Other, please specify:

[6] Less, B.D. and Walker, I.S. 2026. " Characterizing Peak Electricity Demand for U.S. Households: An Assessment of End-Use Loads and Demand Factors". *Applied Energy*. https://doi.org/10.1016/j.apenergy.2026.127422

4 Results

4.1 Summary of home characteristics

This section summarizes key characteristics of the 25 homes used for the analysis. More details can be found in Appendix B.

Data source: Twelve homes were recruited via direct outreach and 13 through related programs.

Electrical panel main disconnect size: All homes were 100 A before the electrical panel was upsized. After upsizing, 24 homes were 200 A and one was 320 A.

Home Type: All homes met the criteria as single family homes.

Climate Zone Type: Six homes were in cold climate zones, 10 homes in hot climate zones and 9 in mild climate zones. 14 of the 16 California climate zones were represented.

Electric Investor-Owned Utility: Thirteen homes were in PG&E territory, 11 in SCE, and one in SDG&E.

Home Size: Two homes were small (< 1000 square feet), 17 homes medium (between 1000 and 2000 square feet), and six homes large (> 2000 square feet).

Occupancy: Ten homes had 1-2 occupants, five homes had 3-4 occupants, six homes had 5 or more occupants, and four homes had unknown occupancy.

Solar PV: Eight homes had Solar PV before replacing the electrical panel. Six homes added Solar PV at the time of electrical panel upsizing. 11 homes have no Solar PV.

Home Battery: One home added a home battery at the time of electrical panel upsizing.

EV Charging: Five homes had EV charging before replacing the electrical panel. Three homes added EV charging at the time of electrical panel upsizing, and 17 homes had no EV charging[7].

Heating/cooling: Eleven homes had gas heating and air conditioning before the electrical panel upsizing and transitioned to a heat pump. Eleven homes had gas heating and no air conditioning before the electrical panel upsizing and transitioned to a heat pump. Three homes had gas heating and no air conditioning and made no change.

[7] 14 homes came from recruitment through existing utility programs, so the existence of EV charging is unknown. For the purposes of the assessment, these homes were assumed to not have an EV charger. Reviewing their interval loads did not reveal periodic large steady multi-hour loads indicative of 240 volt EV charging

Water Heating: Twenty-one homes had gas water heating before the electrical panel upsizing and transitioned to a heat pump water heater at the time of electrical panel upsizing. Four homes had a gas water heater and made no change.

Cooking: Eleven homes transitioned from gas cooking to electric cooking at the time of the electrical panel upsizing. Four homes had electric cooking before the electrical panel upsizing. 10 homes had gas cooking before the electrical panel upsizing and made no change.

Dryer: Eleven homes transitioned from gas drying to electric drying. Seven homes had electric drying before the electrical panel upsizing. Six homes had gas drying and made no change. One home transitioned from electric drying to gas drying.

Full Electrification: Fourteen homes were fully electrified after the electrical panel upsizing. Eleven homes were partially electrified after the electrical panel upsizing.

4.2 Measured Electric Usage

The analysis results detailed in the rest of the this section are as follows:

- **Annual Peak Demand**. This is the peak demand of the home, in amps, that can be compared to panel capacity
- **Annual kWh Energy Consumption.** While not a key metric for panel capacity and replacement analyses, this provides important insight showing that peak demand is distinct from energy use and needs separate, individual assessment. The energy consumption is net of solar because the available AMI data is net-metered. This metric also provides insight to the potential costs associated with energy use changes.
- **Annual Peak Demand by Solar/Battery Presence.** This determines if these demand and load modifiers lead to changes in peak demand.
- **Annual Peak Demand by Climate** to determine if home heating and cooling thermal loads are important we divided the homes into three climate types (hot, mild or cold). Our sample size did not justify further disaggregation.
- **Annual Peak Demand by Number of Occupants**. Used to determine if peak demand scales with occupancy.
- **Annual Peak Demand by Number of End Uses Electrified**. Examines how multiple loads interact and combine.

4.2.1 Annual Peak Demand

The results in Figure 2 show that 17 of the 25 homes have an increase in the maximum peak demand after adding loads. The average pre-project peak demand is 30 A, and the average

post-retrofit peak demand is 42 A, an increase of 36%. The highest peak post panel upsizing demand was 101 A, and the largest increase in peak demand was 49 A.

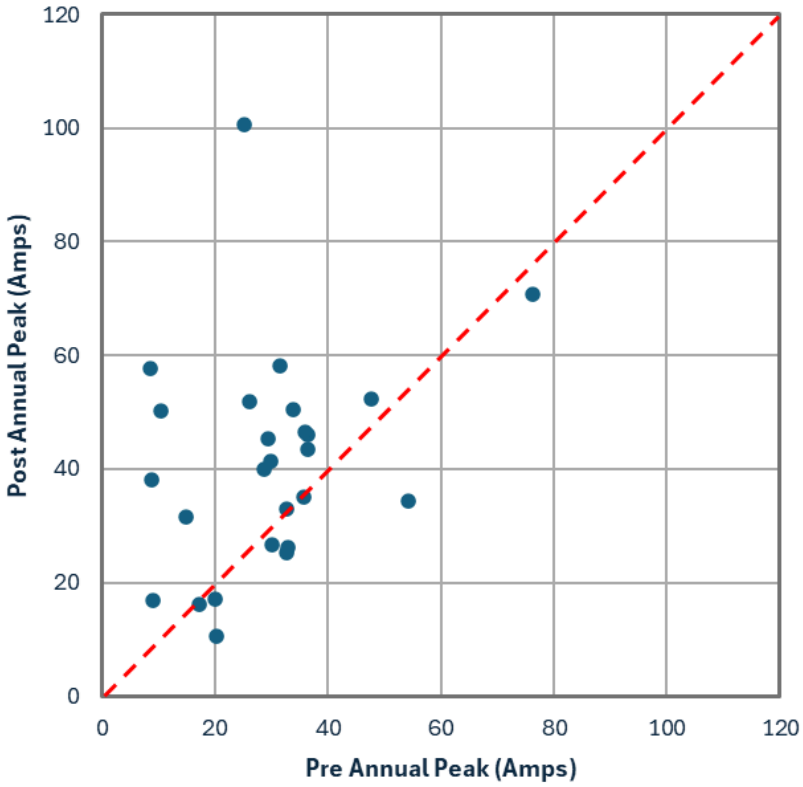


Figure 2. Pre and post peak Amps over a year for the 25 evaluated homes. *Data for homes that reported 60-minute intervals have been adjusted using the formula described in Section 3.5. Homes above the diagonal line represent increased peak demand in the post panel upsizing period.*

Eight homes (33% of the sample homes) recorded a decline in the peak demand values, with an average decline of 20 percent. While electrification activities will normally cause an increase in the electrical demand, the peak in some homes may be influenced more by other changes that ultimately led to the declines observed.

One example might be if an old, relatively inefficient air conditioner or electric resistance heat is replaced by a modern and more efficient heat pump, the overall impact of that change might be a decrease in the peak amperage that the home records[8]. Another might be if solar panels were added during the electrification process and the pre-electrification

[8] Tudawe, R., C. Emenike, E. McPherson, and J. Quinell. 2022. "Investigation of Air Source Heat Pumps as a Replacement of Central Air Conditioning Potential Benefits, Market Research and Technical Analysis." Center for Energy and Environment, Minnesota Department of Commerce, Division of Energy Resources.

home condition had maximum demand happening during times of high solar PV output. However, analysis of the homes in this study indicates that adding solar panels can not be presumed to automatically lead to a peak reduction – see Figure 3.

The results show that most homes will have increased peak demand after adding loads. Except for one home, these are all below 100 A. All but two homes are below 60 A, indicating that they have significant capacity for adding new loads using the 220.87 method.

4.2.2 Annual kWh Energy Consumption

The results in Figure 3 show that 13 of the 25 homes show an increase in net meter energy consumption in the year after the panel upsizing and addition of new electrical loads. The average pre-retrofit net consumption value for homes in this study is 10,329 kWh and the average post-retrofit consumption value is 12,059 kWh, an increase of approximately 1,730 kWh (17%). Twelve homes recorded a decline in energy use, with an average reduction of almost 20 percent.

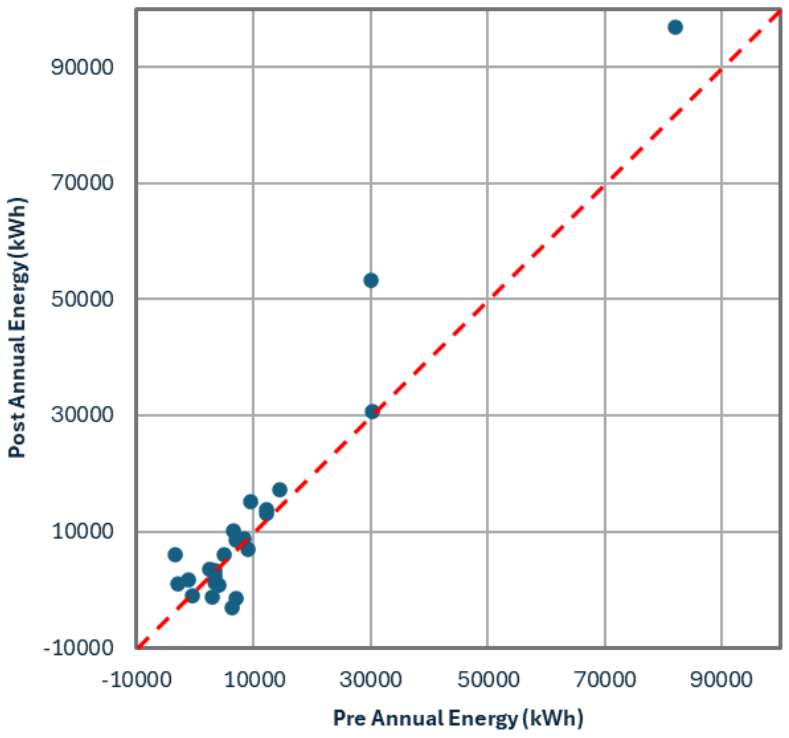


Figure 3. Pre and post normalized annual net meter energy use. *Homes above the diagonal line represent increased meter-recorded energy consumption in the post panel upsizing period.*

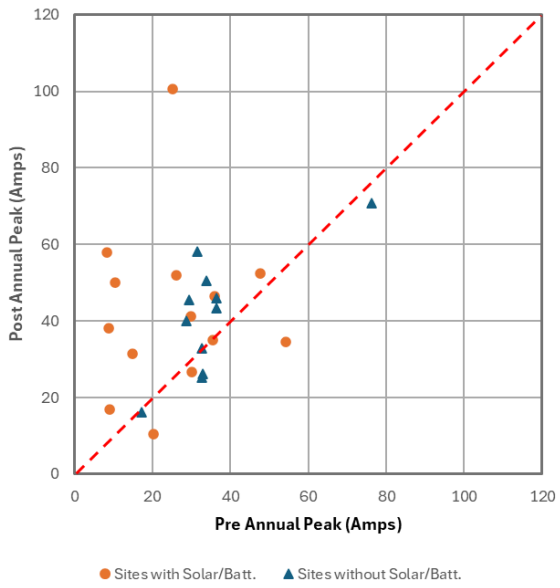
While electrification activities will normally cause an increase in electric energy consumption, some homes may be influenced more by other factors, including replacing existing equipment with more efficient HVAC (e.g., removing electric resistance heating or upgrading to more efficient cooling) or other home improvements, such as improved duct sealing, or adding adding solar PV. The largest increase was about 23,000 kWh for a home that added electric heating, water heating, clothes drying, and cooking and had a very large increase in peak demand observed in the AMI data. While this home did not include information on the presence of an EV charger, the 24-hour load profiles suggest there is the presence of a high-speed EV charger as well. This home is the same one in Figure 2 that peaks over 100 A.

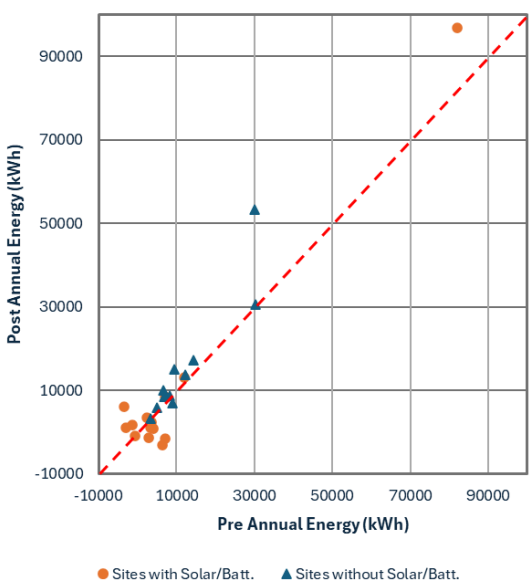
These results indicate that electrifying gas appliances and equipment does not necessarily lead to increased electric energy consumption and electric utility bills. This is important in the context of the overall project that is aimed at reducing costs for California households when adding electric loads.

4.2.3 Annual Peak Demand and Energy Consumption Impacts of Solar/Battery Systems

Figure 4 below on the left disaggregates peak demand between homes with and without Solar PV and/or battery systems. Only one home has a battery system, so general observations cannot be determined on batteries' impact on peak demand. Some homes are known to have had solar before the panel upsizing and others are known to have added solar after or during the panel replacement, but the timing is not always clear. Some homes do include negative net kWh values at times, representing a higher solar generation than the home was simultaneously consuming during the same interval. The results show that the presence of Solar PV does not appear to have a significant influence on the change in peak demand values from pre to post, with a similar distribution of those with and without Solar PV on both sides of the neutral line. The highest demand home in the dataset is one that includes Solar PV.

Figure 5 below on the right disaggregates the annual energy consumption of the same homes with and without Solar PV. The majority of the Solar PV homes fall in the lower end of the range in the post data with three of them having a negative net meter reading for the year in the post period (i.e., they were net generators). Several of the homes that were net generators in the pre period became net energy users after adding new loads and upsizing their panels. These homes had solar prior to the panel replacement, and the added electric loads are consuming more than the previously generated solar energy can supply.





Figures 4 (left), 5 (right). (Left) Pre and post measured peak demand. (Right) Pre and post normalized net meter energy use. *Both are disaggregated by presence of Solar PV and/or battery systems. Data points above the diagonal line represent an increase.*

These results indicate that the peak demand of homes with Solar PV systems could either increase or decrease, and these systems do not consistently result in lower peak demand. Homes with Solar PV can have higher peak demand due to two phenomena. The first is power availability compared to power distribution throughout the typical day. If the peak demand is an evening/nighttime peak and the solar/battery peak contribution is in the daytime, then the noncoincident peak times between availability of solar power and the power demand will result in no reduction to the peak power observed on the home. This is especially true in the case of high-power EV charging, which many people do late at night to take advantage of low nighttime EV rates.

The second phenomenon that can occur that would increase peak demand even in the presence of Solar PV is the full electrification of the home, including a high power EV charger. This is reflected by several of the homes in the dataset where all gas appliances were removed and replaced with electric devices and also included the addition of EV chargers (two were added on one of the homes). These homes both have considerable increase (about 30 A and 50 A, both more than tripling their peak demand) in the panel amps recorded. However, one of the two had a decrease in the normalized energy and the other had an increase in normalized energy.

4.2.4 Annual Peak Demand and Climate Type

The disaggregation by climate type is intended to examine if more extreme climates (e.g. colder climates) with bigger thermal envelope loads may have greater peak loads due to

larger heating and cooling system capacity. Looking only at homes with electric heat, Table 6 shows that there were differences in peak power between climates. However, they do not scale with the heat pump capacity. Also, the results indicate that the sizing of heat pumps relative to the home size did not get bigger in more extreme climates. This is a function of industry practices for sizing that do not strictly adhere to standardized sizing calculations, and variability in thermal envelope performance. Furthermore, the homes were not of the same size, vintage, occupancy, insulation/airtightness levels, etc., within each climate type. Since the sample size is small, this limitation makes observation of climate dependent loads (heating and cooling) challenging. There was also a non-uniformity of added electric loads among the homes, so in addition to the existing physical differences in the homes, the electrification changes add additional variability to the results. For example, four out of six homes in the mild climates added EVs but the cold and hot climates only added one between them.

Table 6. Peak demand and HVAC characteristics for different climates.

	Cold Climate	**Mild Climate**	**Hot Climate**
Number of homes with electric heating and/or cooling	5 homes *EV added in 1 home*	6 homes *EVs added in 4 homes*	11 homes *EV added to 1 home*
Average change in peak power between pre and post measured demand (in amps)	26.4 A	14.8 A	2.5 A
Average Heat Pump Capacity (Tons)	3	3.6	3.8
Average Heat Pump Capacity Normalized to House Size (ft^2/Ton)	640	515	485

4.2.5 Annual Peak Demand and Occupancy

Figure 6 shows the peak demand disaggregated by occupancy ranges for the pre and post panel upsizing period. There are 21 homes shown as some homes had unknown occupancy. The property that recorded the highest peak demand (101 A) is not included for that reason.

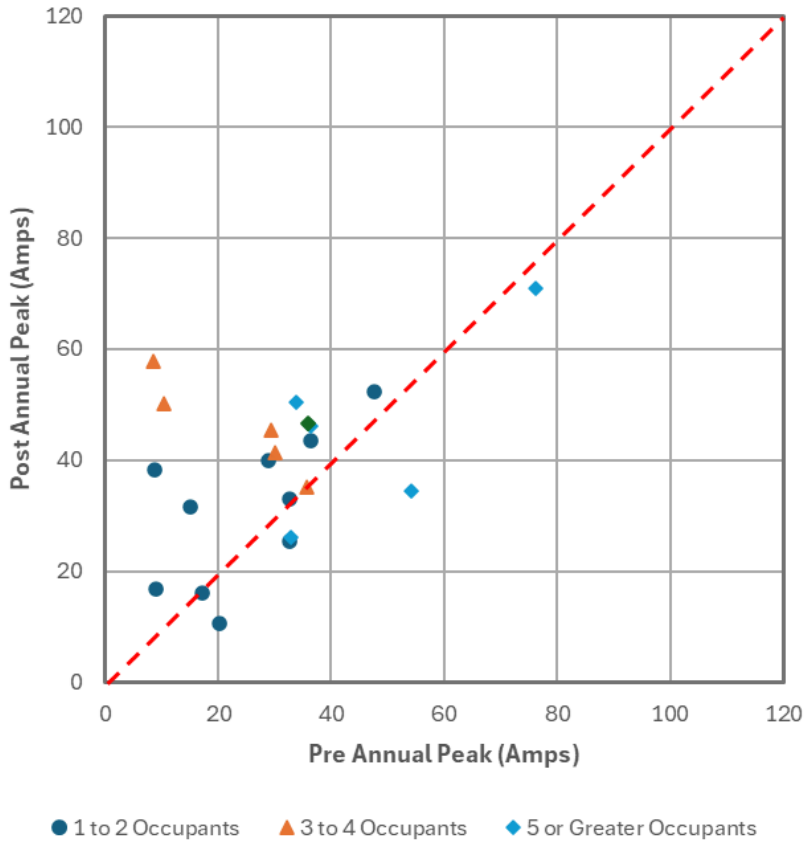


Figure 6. Pre and post measured peak demand disaggregated by occupancy. *Data above the diagonal line represent increased peak demand. The green diamond is for a single outlier home with 10 occupants.*

The peak demand appears to have some dependence on the number of occupants in the home; there is a grouping of low occupant homes (one to two occupants) with peak demand around 40 A, or less. The one and two occupant homes increased peak demand from about 25 A to 31 A, the three to four occupancy homes from 23 A to 46 A, and the five or greater occupancy homes decreased from 49 A to 45 A. This dataset is too small to draw any other significant conclusions because there are variables that are not being factored in with this small sampling, including nonuniformity of added electric loads, socioeconomic factors, size of home, etc.

4.2.6 Annual Peak Demand and Total Number of Large Electric Loads

When counting the total number of large loads, we included five key loads: heating/cooling, hot water, cooking, clothes drying, and EV charging. Solar and/or battery systems are not

considered because they are not considered a direct load and their impact on panel capacity is related to busbar capacity rather than total amperage. Several homes had other large electric loads (e.g., a kiln or a hot tub) that are not captured as one of the “five” key loads. When more than one load is added of the same type, it is counted as a single load (e.g. two 50A EV chargers would be counted as a single EV charging load, and dual ovens or separate oven/cooktops are counted as a single “cooking” load).

Figure 7 and Table 7a below show the difference in pre and post panel upsizing annual peak demand disaggregated by the total number of electrical appliances in the home post panel upsizing. For the 13 homes where we did not know if an EV Charger was added we only counted non-EV appliances. The results show that, on average, having three or more loads resulted in similar peak demand; however, the homes with the most large loads had larger increases from their pre panel upsizing peak. Given the small number of homes in each added load category it is difficult to draw any other conclusions from these data.

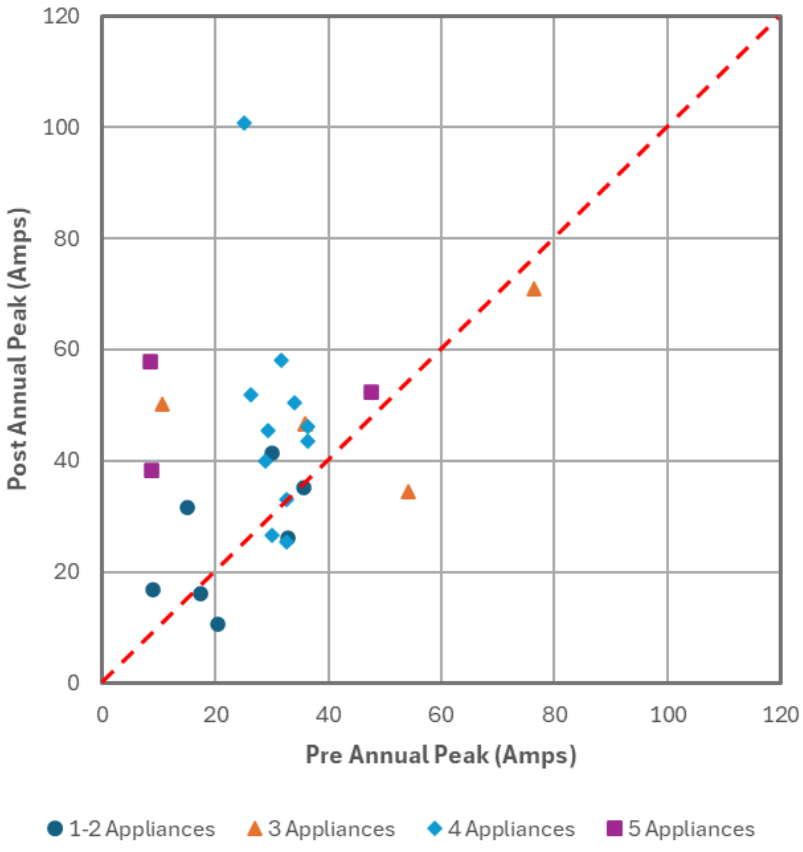


Figure 7. Pre and post measured peak demand disaggregated by the number of large loads in post panel upsizing. *Data above the diagonal line represent increased peak demand.*

Table 7a. Average pre and post peak demand, depending on the number of loads post panel upsizing.

Number of loads	Number of homes	Average peak before panel upsizing (A)	Average peak after panel upsizing (A)	Average change in load (A)
1-2	7	23	25	+2
3	4	44	51	+7
4	11	31	47	+16
5	3	22	49	+27

Another way to disaggregate these results is to look at the peak demand based on the number of added loads. Table 7b shows the average peak demand depending on the number of added loads. These results show that the average change in peak demand did not change very much as the number of added loads increased. As with the total number of loads, given the small number of homes in each added load category, it is difficult to draw any other conclusions from these data.

Table 7b. Average pre and post peak demand, depending on the number of added loads.

Number of added loads	Number of homes	Average peak before panel upsizing (A)	Average peak after panel upsizing (A)	Average change in load (A)
1-2	8	29	34	+5
3	9	29	46	+17
4	5	33	49	+16
5	1	20	33	+13

4.2.7 Annual Peak Demand and Floor Area

Figure 8 shows the peak demand disaggregated by house size ranges for the pre and post panel upsizing period. There are no clear trends with floor area for these homes – some of the smaller homes show the highest pre and post panel upsizing peak demand values, while some larger homes show some of the smallest values. This reflects that many loads in a home are not dependent on floor area directly. It is possible a larger sampling might show a

correlation that does not appear to be present in the existing collected data, as has been found in other studies of larger datasets[9].

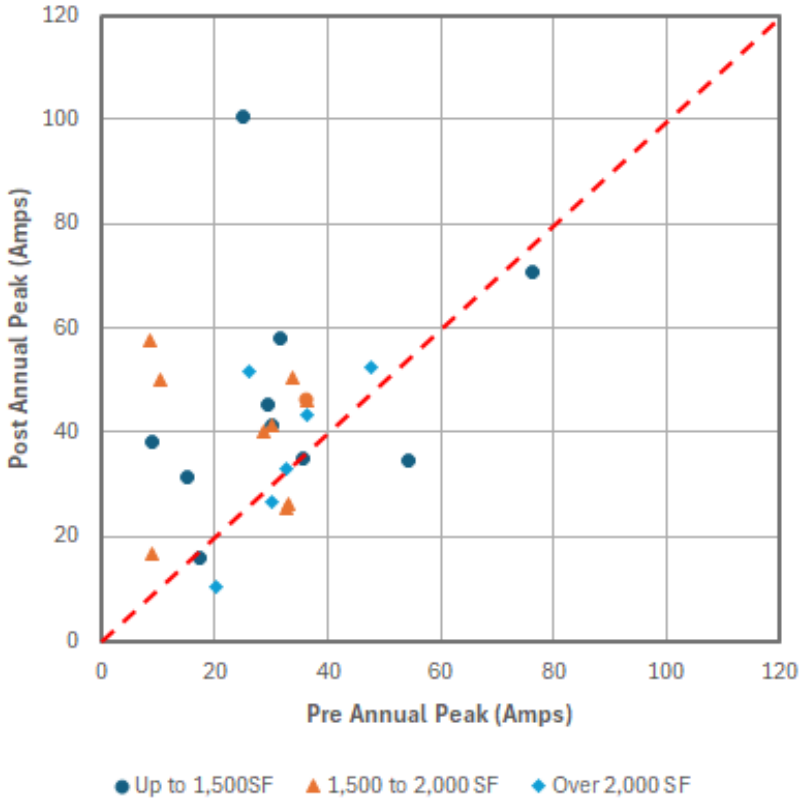


Figure 8. Pre and post measured peak demand disaggregated by floor area.

4.3 Free Breaker Slots

Based on visual observation of panel photographs, there was a large range of available breaker slots in the new panels. Six panels had no free slots, and one panel had 31 free slots (35 before adding Solar PV and a heat pump). Seventeen homes had three or fewer free slots. For 21 homes we have photographs of the panels that were replaced. For the replaced panels, six had no free breaker slots and 14 had three or fewer. Two panels had 11 free slots (and zero and three with the new replacement panels). There was no alignment between the number of free slots on the old and new panels.

[9] Less, B.D. and Walker, I.S. 2026. " Characterizing Peak Electricity Demand for U.S. Households: An Assessment of End-Use Loads and Demand Factors". Applied Energy. https://doi.org/10.1016/j.apenergy.2026.127422

There is data for only 10 subpanels. As with the main panels, the range of free slots is large, from zero to 23, and half the subpanels has three or fewer free slots. The subpanels with the most free slots were installed in the same homes where the main panels had the highest number of free slots. These results indicate that the ability to add multiple new loads may be restricted in many homes unless subpanels are added, or double pole breakers (where two smaller breakers occupy the same space in the panel as a single breaker) are used on some circuits. These results also indicate that physically oversized panels are not uncommon and that panel sizes (in terms of breaker slots) are not always decided by the number of circuits to be served. The reasons for the wide variability in the number of free breaker slots in the new panels is unknown.

4.4 NEC Panel Load Calculations

4.4.1 Current Project Analysis

4.4.1.1 NEC Results of Current Project

From an NEC perspective, 20 out of the 25 homes could have stayed on their 100 A panel with the current electrification choices they undertook using either NEC 220.83 or 220.87. As shown in Figure 9, ten homes could pass on both 220.83 and 220.87, nine homes could pass on only 220.83, and one home could pass on only 220.87. The average calculated load using 220.83 was 91 A and using 220.87 117 A. Generally, the 220.87 method allowed fewer homes to stay on a 100 A panel because more than two loads were added for most homes. For the home that only passed 220.87 (Home H), this might be because this home already had two large loads already electrified (an induction cooktop and a resistance clothes dryer) and other homes did not. These loads would normally contribute significantly to the NEC load calculation. The measured peak demand approach in 220.87 approach resulted in them having a much smaller contribution to the NEC load calculations and provided a lower baseline for adding new loads (heat pump and heat pump water heater).

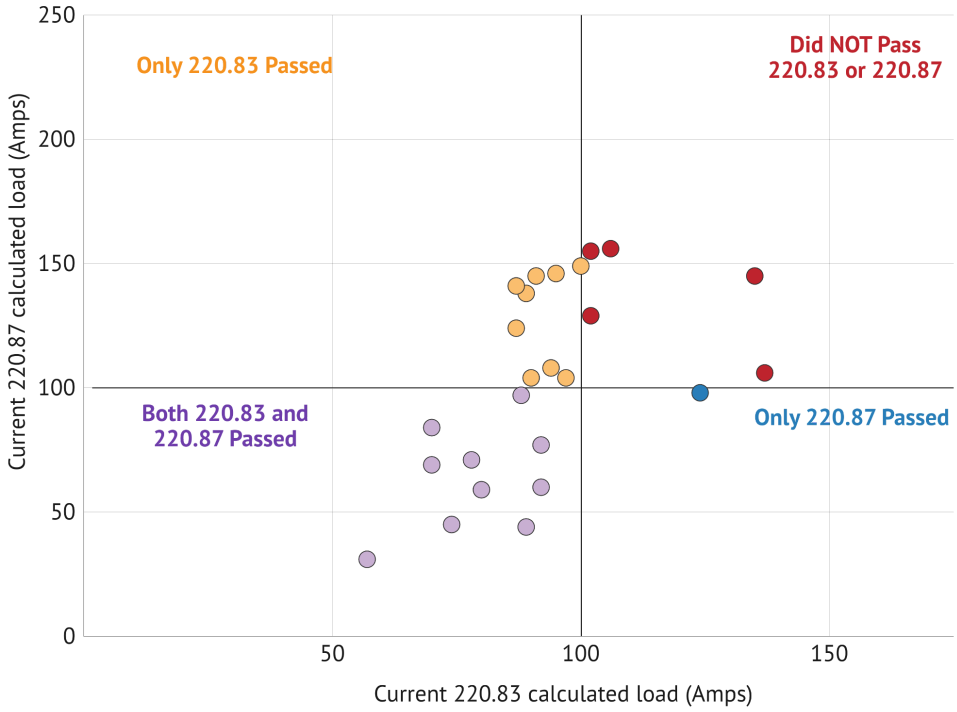


Figure 9. Summary of NEC analyses for project homes

There appears to be a correlation on the number of added loads and panel upsizing need. As shown in Figure 10, homes with one or two added loads could stay on their 100 A panel. These one to two added new loads were large loads, such as a heat pump, as summarized in Table 8 below. For the five homes that did not pass 220.83 or 220.87, these homes had three or more new loads. The one home with five loads (Home G) that could stay on a 100 A panel had a Level 1 EV charger and a 120V heat pump dryer as two of its added loads.

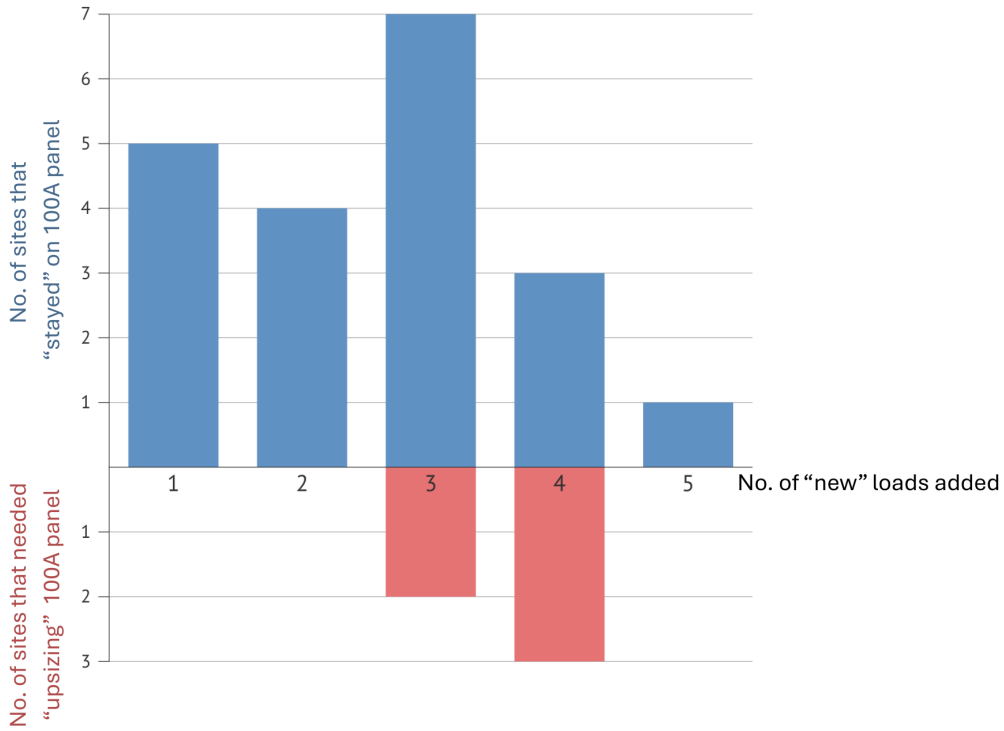


Figure 10. Dependence of panel replacements required by the NEC on number of added loads

Table 8. Details of the types of appliance/equipment for homes that added 1-2 loads.

No. of Loads Added	Electrified Appliance/Equipment
1	• water heater (added by 2 homes) • heat pump (added by 2 homes) • EV charger
2	• heat pump and induction range • heat pump and water heater (3 homes)

4.4.1.2 Impact of PED Plans to Stay on 100 A Panel

When adding new electrical loads, five homes could not stay on a 100 A panel with their current choices using solely the strategic NEC 220.83 and 220.87 calculation methods. These homes would have required alternate PED approaches. 12 PED Plans were applied to these five homes (see Table 5 earlier for a summary of the PED plans). Table 9 summarizes

the PED plan type and NEC method that would have allowed the home to stay on a 100 A panel.

Table 9. Types of PED plans that achieved NEC Compliance on a 100 A panel

	Combo Device	Low Power	Combo Device & Low Power	Load Control	Smart Panel
home I (3 loads)	220.83				220.83
	220.87		220.87		220.87
home J (3 loads)				220.83	220.83
				220.87	220.87
home Q (3 loads)	220.83	220.83	220.83	220.83	220.83
	220.87		220.87		220.87
home S (4 loads)	220.83	220.83	220.83	220.83	220.83
			220.87		220.87
home T (4 loads)	220.83	220.83	220.83	220.83	220.83
			220.87		220.87

All the homes had multiple PED strategies that allowed the use of a 100 A panel – indicating that plenty of choice remains for consumers and contractors. This is good news for the development of the Home Power Planner tool as the PED strategies used in the tool will be highly effective in avoiding panel upsizing. Because these five homes added three or more loads, more PED strategies passed under 220.83 than 220.87. Under 220.87 presently (2023 NEC version), all newly added loads are counted at 100% coincidence and existing electrical loads are not allowed to be removed from the load calculation.

4.4.1.3 Comparing NEC Results to Measured Peak demand

Figure 11 compares the measured post panel upsizing peak demand to NEC 220.83 and 220.87 calculations. The average calculated load was 91 A using 220.83 and 103 A using 220.87. Compared to the average measured peak demand of 37 A, the NEC 220.83 calculations overpredict by 54 A (a factor of 2.6) and for 220.87 by 66 A (a factor of 2.8). The overpredictions for 220.83 ranged from 29 A to 91 A and for 220.87 from 13 A to 123 A. These large overpredictions are expected because the NEC calculations are, by their nature, conservative – they will overpredict loads. We note that there is considerable variability in

the amount of overprediction between homes and the results here are only indicative and not representative of all homes in the state. For example, homes N and S had measured loads more than 50/100 A lower than 220.83 and 220.87 respectively. At the other end of the scale, house V was only 20 A lower than 220.83/87 - but we note that this is still a significant difference that leaves significant load available if one were to use the 220.87 approach to add future loads to this home. Below we look in detail at a couple of homes to provide more explanation of these results.

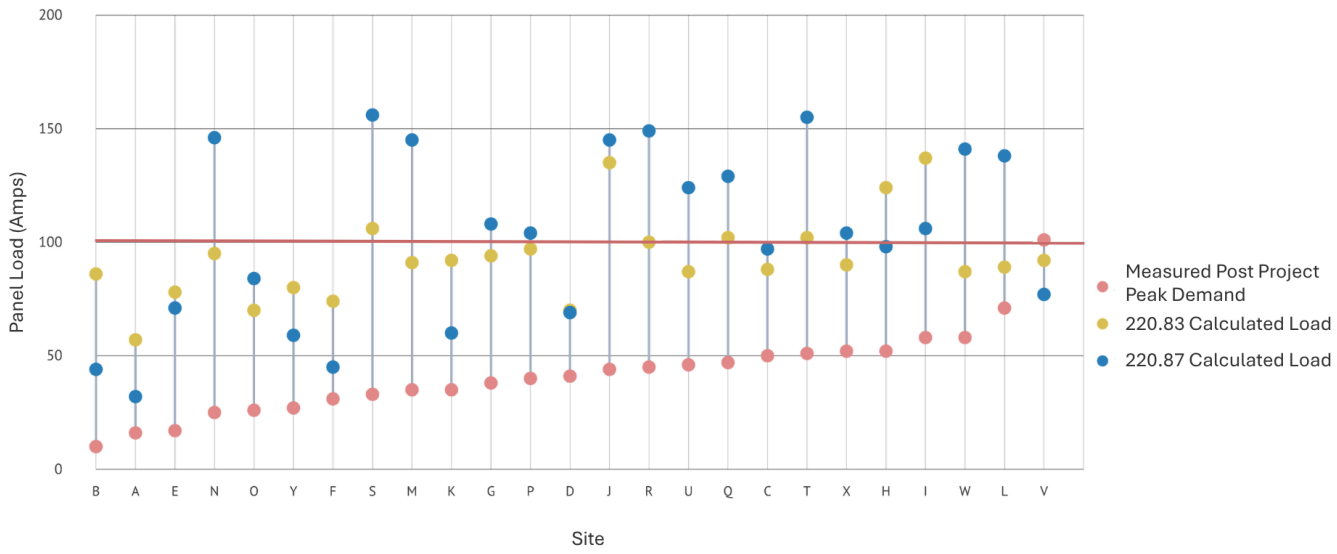


Figure 11. Comparison of NEC and measured peak demand.

Home V stands out in these results because it is the only home with a higher measured post project peak demand than the 220.83 and 220.87 calculated loads. This likely occurred for several reasons:

- Incomplete appliance/equipment data was gathered for the home.
- The peak was on new years eve and it is possible that additional electrification equipment was brought to the home, e.g., for food preparation/cooking.
- This home had its measured peak demand estimated by converting from 60- to 15 minute data. The conversion calculation is not exact in all homes and can both over and under-estimate the increase in loads when converting to smaller time periods. Therefore, it is possible that this conversion over-estimated the measured load.

Home J's electrification project resulted in high calculated loads for NEC 220.83 (135 A) and 220.87 (145 A) in contrast to the low measured post-peak demand (44 A). Table 10 summarizes the end-uses and some home characteristics that can explain this difference.

Table 10. Electrification characteristics for Home J

	Pre-Project	Electrification Project
Heating/cooling	Gas (Central Heating)	Central Heat Pump (Mini-Split) (Ducted) **44.6 A**
water heater	Gas	Storage Water Heater (Heat Pump) (240V) (21A) **220.83: 11.7 A** **220:87: 29.1 A**
cooking	Gas (Cooktop) Electric (Oven Double) (Resistance)	Cooktop (Induction) (4-Burners) **220.83: 12.3 A** **220:87: 30.8 A**
clothes dryer	Electric (Resistance) (Vented)	
EV charger	none	

Home J

Location: San Mateo County

Home characteristics:

- 2030 sq ft
- 4 bedrooms
- 2 bathrooms
- 1959 built
- 100 A panel

Occupants: 1

For the 220.83 calculations, adding the heat pump was the main factor in the high calculated load. Needing to heat and cool a large home had the homeowner install a 4 ton central heat pump unit with a nameplate rating of 44.6 A. Because 100% coincidence is taken for the new HVAC load in 220.83, this heat pump is the primary factor for the high calculated load. All other loads had a 40% coincidence factor applied. Without the addition of the heat pump, Home J could have stayed under 100 A (i.e.,135 A - 44.6 A = 90.4 A). This

also shows an example where better thermal load calculations could result in smaller heating demand. In Millbrae's gentle climate with a design temperatures of 37°F heating and 82°F cooling, more reasonable heat pump sizing would have resulted in a 3 ton heat pump, saving about 11 Amps on the electric panel.

Using 220.87 has a disadvantage when adding multiple loads at once because new loads are all counted using 100% coincidence factors. The total of the three added loads would be 104.5 A under 220.87. If Home J phased their electrification project to add a single new load per year (or 30 days if they are able to obtain 15 minute interval data), then the home could have stayed on their 100 A panel.

4.4.2 Full Electrification Analysis

Because the majority of homes are not fully electric, an assessment was also carried out on how many of the homes could retain a 100 A panel when all end uses are electric. For each home, the ability to stay on a 100 A panel using the 12 PED strategies in Table 5 for both 220.83 and 220.87 was evaluated.

This evaluation was performed for two scenarios: the first scenario is based on achieving full electrification starting from the home's pre-panel replacement state, where PED is applied from the start of the project ("Full Electrification"). The second scenario starts with their current status where some loads were added without explicit use of PED[10], to full electrification ("Continued Full Electrification").

The key result is that: **All 25 homes could be fully electric on a 100 A panel following the NEC and using PED plans.**

4.4.2.1 220.83 Full Electrification

Figure 12 summarizes the number of PED strategies that can be used by each home to fit on a 100 A panel using 220.83. The homes are ranked by the number of PED strategies that could be applied to the homes in their current state. Using PED from the start of home electrification allows for many more PED strategies to carry out full electrification, including with high power appliances/equipment.

[10] The exceptions are Home V that had a combined washer/dryer and Home G that added a Level 1 EV charger and a 120 V heat pump dryer as two of its added loads.

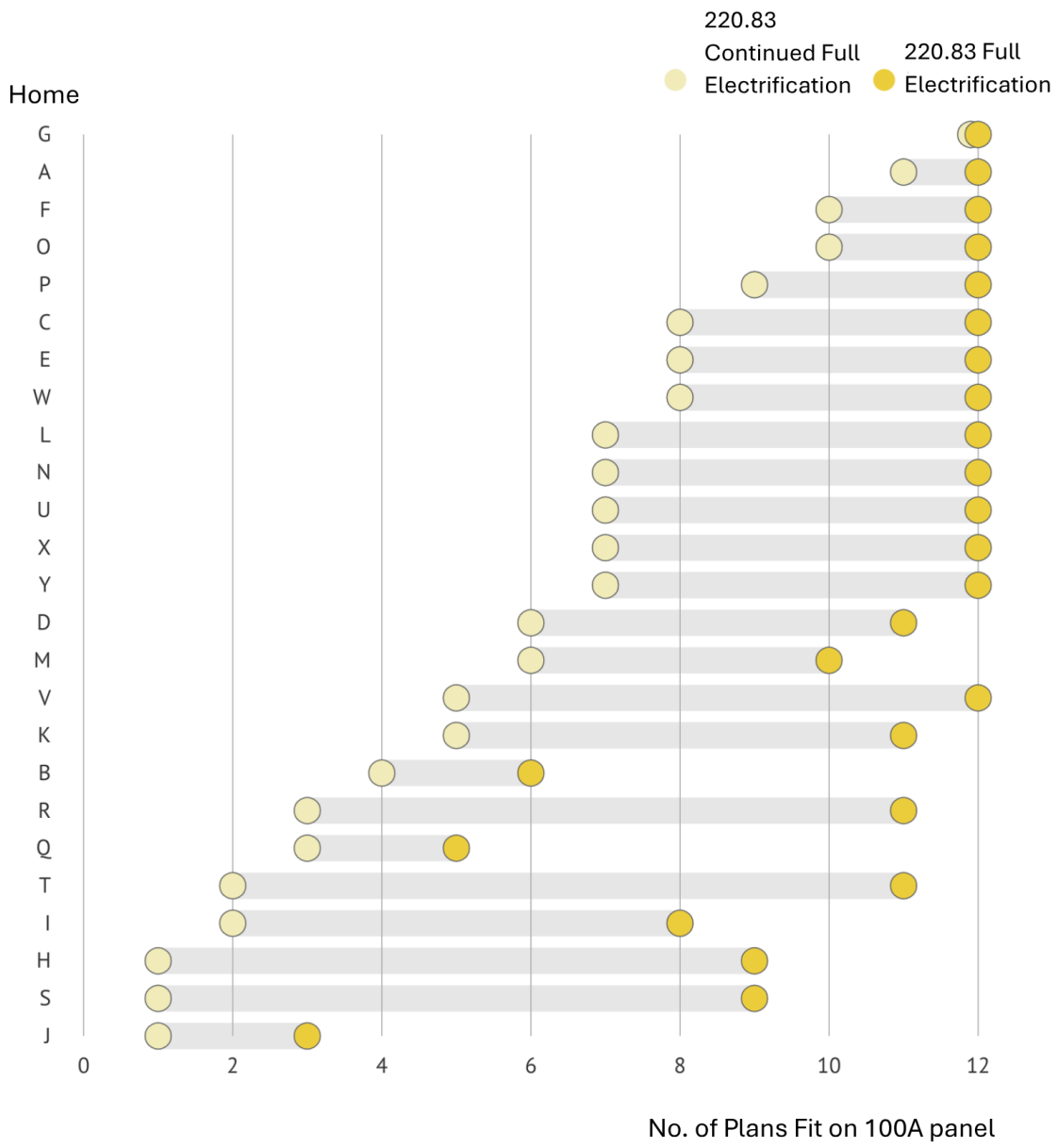


Figure 12. Number of PED strategies for each home that allow for full electrification on a 100 A panel using NEC 220.83

4.4.2.2 220.87 Full Electrification

Figure 13 summarizes the number of PED strategies that can be used by each home to fit on a 100 A panel using 220.87. The homes are ranked by the number of PED strategies that could be applied to the homes in their current state. The results are far less clear than for 220.83. This is due a combination of variability in measured loads used as the baseline for 220.87, and that loads are all added at 100%, making the added loads much larger (with the exception of HVAC) compared to 220.83. Unlike for 220.83, there are some homes that

had fewer usable plans under Start Full Electrification because adding many loads at 100% leads to higher total load, even if 220.87 can take advantage of actual measured peak load. There is also the issue that the current 220.87 does not allow current loads to be removed. For example, Home A has both the dryer and HVAC currently in place. These loads cannot be removed, so a PED strategy that combines these two loads also cannot be used - thus, reducing the number of applicable PEDs. Note that for this study, only the 12 PED plans in Table 5 were evaluated, but other PED plans could be developed to provide additional options and consumer choices.

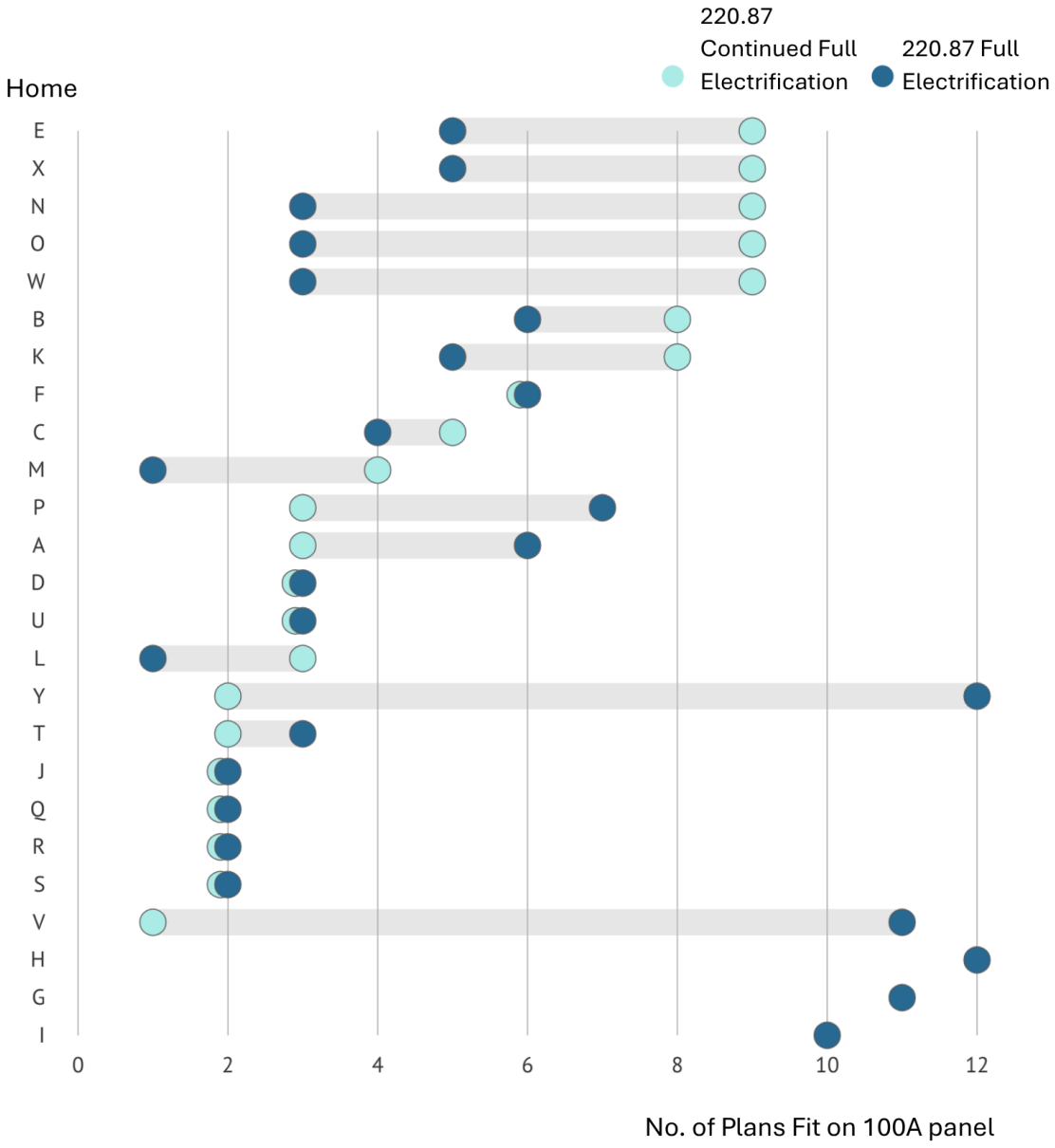


Figure 13. Number of PED strategies for each home that allow for full electrification on a 100 A panel using NEC 220.87

4.4.2.3 Impact of PED on Full Electrification Panel Capacity

Figure 14 summarizes the load/panel capacity reductions using PED for both 200.83 and 220.87. Without PED, full electrification would require all but four homes having panel capacities above 100 A. The PED capacities in Figure 14 are for the PED approach with the lowest required panel capacity. Choosing the lowest PED allows full electrification in every home under 100 A.

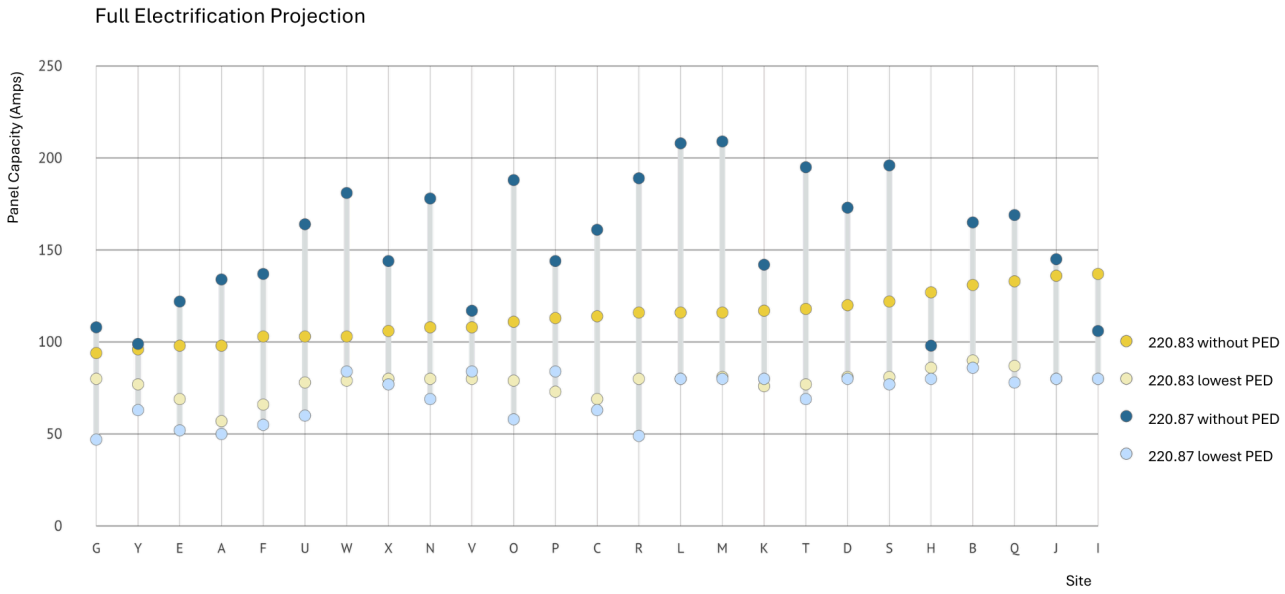


Figure 14. Reductions in load using PED.

4.5 Self-reported drivers of Panel Upsizing from Occupant Surveys

For the 11 homes recruited through Direct Outreach, occupants provided the factors that were considered when upsizing their electric panels. Table 11 summarizes their responses. By far, the main reason was to allow for adding more loads in the future. This is likely because only 4 homes had electrified all the major in-home loads (HVAC, hot water, cooking and clothes drying). Seven homes had EV charging, 9 solar PV, and just a single home had a battery. This implies that many homes had significant scope remaining for adding loads in the future – hence the installation of capacity that is currently not needed. In terms of how PED might address these drivers, Table 12 summarizes the PED approach that would best address each stated reason.

Table 11. Summary of occupant–reported reasons for Panel Upsizing

Reason	Number of homes
Future Electrification	7
Electrification	5
Adding Solar	5
Needed Breaker Slots	4
Adding EV	3
Safety, Code, Insurance	3
Adding Battery	1

Table 12. PED Alternatives to satisfy interests underlying the occupant cited reasons

Reason	PED Alternative to Meet Interest
Future Electrification	PED allows future full electrification
Electrification	PED allows partial electrification leaving future room for more
Adding Solar	PED allows multiple methods of attaching up to 19 kW of solar and can include batteries
Needed Breaker Slots	PED techniques save breaker slots and some can be repurposed or a sub-panel added
Adding EV	PED techniques can charge 3-9 average cars
Safety, Code, Insurance	Replacing with safe, new, same size panel can save large costs compared to upsizing
Adding Battery	PED can accommodate batteries and put less peak strain on batteries in power outages

4.6 Adding Solar Capacity

While not a direct driver of demand, solar capacity is often limited by panel capacity due to the "120% Rule" that limits the load on the panel's busbar. Of the 25 analyzed homes, 14 have a solar system, 10 of which had pictures allowing the determination of their solar array size. The size ranged from 3.84 kW to 8 kW, with 7.68 kW size being the most common solar array size. Based on these sizes, these homes likely sized their solar system using the 120% Rule, which would allow a maximum of a 3.8 kW sized solar array without clipping[11] and a 7.68 kW sized array with clipping for a 100 A panel[12]. There are other strategies (e.g., Hawaiian Tie-in, Breaker Sandwich, Meter Socket Adapter, and Line-side Tie-In) that would allow adding solar systems above these limits toward a maximum of 19.2 kW without clipping and 38 kW with clipping. Also, a Power Control System for solar can allow for even larger sized solar array to be installed. More information on these alternative solar interconnection strategies can be found in Section 4 "Adding New Power Sources" in the Power Efficient Management Report of the Home Power Planner Tool study.

4.7 Self-reported Costs of Panel Upsizing from Occupant Surveys

Ten of the Direct Outreach homes reported panel upsizing costs and they ranged from $3,000 to $20,000, with the average at $8,000 and the median at $6,000. The higher costs may include additional circuits, panel relocation and/or service upgrade costs. We were not able to determine if these costs included incentives or rebates. The use of PED and the Home Power Planner tool can significantly reduce or completely avoid these costs.

5 Recommendations/Future Activities

The results of this assessment have shown that the combination of NEC calculations and PED approaches can be used to allow homes to stay on their 100 A panel, even when all end-uses are electrified. This supports the integration of NEC calculations and PEDs into the Home Power Planner being developed in the overarching project. The results also show that NEC calculations by themselves will be insufficient and that additional planning and design are needed – an indication that the Home Power Planner tool will be needed for many homes in the state. There was also a great deal of variability in what electric loads were

[11] Clipping occurs when the solar panels produce more power than the inverter can convert to AC and pass on to the panel/busbar. For most residential systems clipping is a deliberate and efficient design strategy that allows for more output on cloudy days or in the winter.

[12] As a reference, the 120% Rule for a 200 A panel would allow a solar array sized 13.4 kW without clipping and 26.8 kW with clipping.

added and their impact on peak demand (and how these varied with home characteristics, such as size, occupancy, etc.). This variability indicates that it would be very challenging to develop simple rules of thumb and that we need a tool that can be customized to individual homes.

Other results support more general conclusions regarding the differences between the necessarily conservative NEC calculations and measured peak demand in homes that may be used in the future to support updates and improvements to the NEC. In order to make implementation of NEC 220.87 calculations more accessible and easier to perform, we recommend that IOUs provide information on household peak demand and their service capacity to ratepayers. This will be of additional value in the future with the next generation of the NEC that better accounts for existing peak demand.

Acronyms

A	Amp
ADU	accessory dwelling unit
AMI	advanced metering infrastructure
CCA	Community Choice Aggregator
CEC	California Energy Commission
CZ	climate zone
EV	electric vehicle
ft^2	square feet
HPP	Home Power Planner
HVAC	heating, ventilation, air conditioning
IOU	Investor Owned Utilities
kW	kilowatt
kWh	kilowatt-hour
LADWP	Los Angeles Department of Water and Power
PG&E	Pacific Gas and Electric
POU	Publicly Owned Utilities
PV	photovoltaic
NEC	National Electrical Code
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric Company
SMUD	Sacramento Municipal Utility District
V	volt

Appendix A – Information Collected from Recruitment Routes

This panel loads assessment recruited 25 homes via two routes: (1) project team's direct outreach and (2) collaboration with existing utility programs. Table 13 below provides the details on the information collected from these recruitment routes.

Table 13. Summary of collected information across recruitment routes

	Direct Outreach	Utility Program 1	Utility Program 2
Number of Homes	11	10	4
Home characteristics			
Location	✓	✓	✓
Year Built	✓	✓	✓
Size (in square footage)	✓	✓	✓
Number of Bedrooms	✓		✓
Number of Bathrooms	✓		✓
Number of Occupants	optional	✓	
Electrical Panel Upsizing			
Upsizing Timeframe	✓	✓	✓
Current Main Disconnect Size	✓	✓	✓
Pre-panel Main Disconnect Size	✓	✓	partial* **Note: homes with unknown size assumed 100 A pre-panel*
Cost of Electrical Panel Upsizing	optional		partial

	Direct Outreach	Utility Program 1	Utility Program 2
Appliance/Equipment Details (e.g. presence, type, etc.)			
Heating/Cooling	✓	✓	✓
Water Heater	✓	✓	✓
Cooktop (or Stovetop)	✓	✓	✓
Oven	✓		
Clothes Dryer	✓	✓	✓
EV Charger	✓		
Solar PV	✓	*pulled from AMI data*	*pulled from AMI data*
Battery	✓		
Pool Heater	✓		
Spa Heater	✓		
Additional loads (e.g. dishwasher)	✓		
Appliance & equipment details			
	Nameplate photos for current electric items	Model number of current electric heating/cooling, water heating, cooking, drying. Some info on previous gas items/AC.	Nameplate photos for current electric heating/cooling, water heating, cooking, drying. Some nameplate photos of previous gas items.
Electric AMI data			
Before panel upsize	Mostly one year	One year	One year
After panel upsize	Mostly one year	Mostly one year	One year

Appendix B – Home Characteristic Details

The details of the past upsized homes are summarized in Table 14 below.

As outlined in Appendix A, different recruitment routes had varying levels of information collected. The following provides the list of which route the homes in Table 14 were recruited under:

- Homes A through K were recruited via direct outreach.
- Homes L through U were recruited via collaboration with Utility Program 1.
- Homes V through Y were recruited via collaboration with Utility Program 2.

As reference, the following notations are used to indicate the fuel source and timing presence of appliance/equipment:

- G indicates gas fueled
- E indicates electric powered
- G&E indicates both gas fueled and electric powered appliances (which occurred in cooking with a gas stove and electric resistance double-oven)
- Under Heating/Cooling, AC indicates (electric) air conditioning and E indicates (electric) heat pumps.
- When a “to” is used, then a transition occurred for that appliance/equipment after the panel upsize (e.g. G to E means the appliance like a water heater transitioned from gas to electric).
- “Yes” or “No” indicates the equipment was present already in the home before the panel upsizing occurred.
- “Added” indicates the equipment was installed after the panel upsizing.

Table 14. Summary of home information, appliances, and equipment before and after panel upsizing.

Home	Climate Type	Climate Zone	IOU	Home Size (sq ft)	No. of Occupants	Heating/ Cooling	Water Heater	Cooking	Dryer	AC / Heat Pump (tonnage)	EV charger	Fully Electrified	Solar	Battery
A	Mild	11	PG&E	735	2	G+AC to E	G	G	E	1	No	No	No	No
B	Mild	3	PG&E	2129	2	G	G to E	G&E	G		Yes (L2 50A)	No	Yes	No
C	Mild	3	PG&E	1800	4	G to E	G to E	G	G	3	Added (L2 60A)	No	Yes	No
D	Cold	1	PG&E	1500	4	G	G	G	E to G		Added (L2 40A)	No	Yes	No
E	Cold	1	PG&E	1700	2	G to E	G	G to E	G	3	No	No	Added	No
F	Mild	4	PG&E	1250	2	G	G to E	G	E		No	No	Yes	No
G	Mild	6	SCE	1300	2	G to E	G to E	G to E	G to E	5	Added (L1)	Yes	Yes	No
H	Mild	3	PG&E	2400	2	G to E	G to E	E	E	3.5	Yes (L2 50A)	Yes	Added	Added
I	Mild	3	PG&E	1790	4	G to E	G to E	G to E	G to E	4	Yes (two L2 50A)	Yes	Added	No
J	Mild	3	PG&E	2030	1	G to E	G to E	G&E to E	E	4	No	No	No	No
K	Mild	7	SDG&E	900	3	G to E	G	G	G	2	Yes (L2 50A)	No	Added	No

Home	Climate Type	Climate Zone	IOU	Home Size (sq ft)	No. of Occupants	Heating/ Cooling	Water Heater	Cooking	Dryer	AC / Heat Pump (tonnage)	EV charger	Fully Electrified	Solar	Battery
L	Hot	8	SCE	1700	5	G to E	G to E	G	G	2.5	Yes (L2 60A)	No	No	Unknown
M	Hot	14	SCE	1979	5	G+AC to E	G to E	G	E	4	Unknown	No	Added	Unknown
N	Hot	9	SCE	1946	1	G to E	G to E	G to E	G to E	3.5	Unknown	No	No	Unknown
O	Hot	14	SCE	1832	5	G to E	G to E	G	G	3	Unknown	No	Yes	Unknown
P	Hot	13	SCE	1430	2	G+AC to E	G to E	E	G to E	3	Unknown	No	No	Unknown
Q	Hot	10	SCE	2548	10	G+AC to E	G to E	G	G to E	5	Unknown	No	Yes	Unknown
R	Hot	15	SCE	1400	4	G+AC to E	G to E	G to E	G to E	4	Unknown	No	No	Unknown
S	Hot	15	SCE	1546	1	G+AC to E	G to E	G to E	G to E	5	Unknown	No	No	Unknown
T	Hot	10	SCE	1744	5	G+AC to E	G to E	G to E	G to E	4	Unknown	No	No	Unknown
U	Hot	8	SCE	1268	6	G+AC to E	G to E	G to E	E	3	Unknown	No	No	Unknown
V	Cold	12	PG&E	2430	Unknown	G+AC to E	G to E	E	G to E	4	Unknown	No	Yes	Unknown

Home	Climate Type	Climate Zone	IOU	Home Size (sq ft)	No. of Occupants	Heating/ Cooling	Water Heater	Cooking	Dryer	AC / Heat Pump (tonnage)	EV charger	Fully Electrified	Solar	Battery
W	Cold	2	PG&E	1267	Unknown	G+AC to E	G to E	G to E	G to E	3	Unknown	No	No	Unknown
X	Cold	2	PG&E	2740	Unknown	G to E	G to E	G to E	E	2.5	Unknown	No	Added	Unknown
Y	Cold	12	PG&E	1382	Unknown	G+AC to E	G to E	E	E	2.25	Unknown	No	Yes	Unknown