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Solving the Panel Puzzle

Avoiding and streamlining electric panel and service upsizing to accelerate building decarbonization

Acknowledgments

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The findings and recommendations of this report are SPUR's and do not necessarily reflect the views of those listed here. Any errors are the authors' alone.

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The problem with panels: Why panel and service upgrades stand in the way of California's climate goals

The State of California has adopted the goal of creating 3 million climate-ready and climate-friendly homes by 2030 and 7 million by 2035. These goals are supplemented by another state goal: the installation of 6 million heat pumps in homes by 2030. Electrifying homes is considered the lowest-cost strategy for California to achieve a 40% reduction in greenhouse gas emissions by 2030 and an 80% reduction by 2050, relative to 1990 levels.1 Yet the state can only meet its climate and clean air goals if the transition to electrified homes is simple and affordable.

Many homeowners and landlords set out to electrify their homes, only to give up when they learn they need a new electric panel, new wiring, or—worst of all—an electric service upgrade that requires extensive paperwork and that will cost thousands of dollars. News stories about climate-conscious homeowners who become bogged down in panel and service upsizing have become a cottage industry for journalists. Consider this April 1, 2023, *San Francisco Chronicle* headline: "This S.F. homeowner tried to go all-electric. Her case shows the extraordinary effort that can take."

The service upgrade process is infamous for being confusing and expensive. If millions of homeowners apply for service upgrades in the next two decades, the utility's work queues could become clogged, slowing electrification and diminishing customer satisfaction. Building electrification will be a resounding success if customers can install energy-efficient heat pumps, cutting-edge induction cooktops, and electric vehicles that cost less than gas vehicles. However, if building owners are confused and priced out by panel and service upgrades, a public backlash could result.

This policy brief explains the potential for panel and service upsizing to be a massive barrier to building electrification, and it lays out three types of solutions: avoid electric panel and service upsizing, streamline upsizing when it's necessary, and fill knowledge gaps. It also details two pathways for safely electrifying while minimizing the need for upsizing: optimizing electric panels (so-called watt dieting) and updating the National Electric Code.

Electrical panel and service upsizing is often the most expensive step in electrification retrofits.

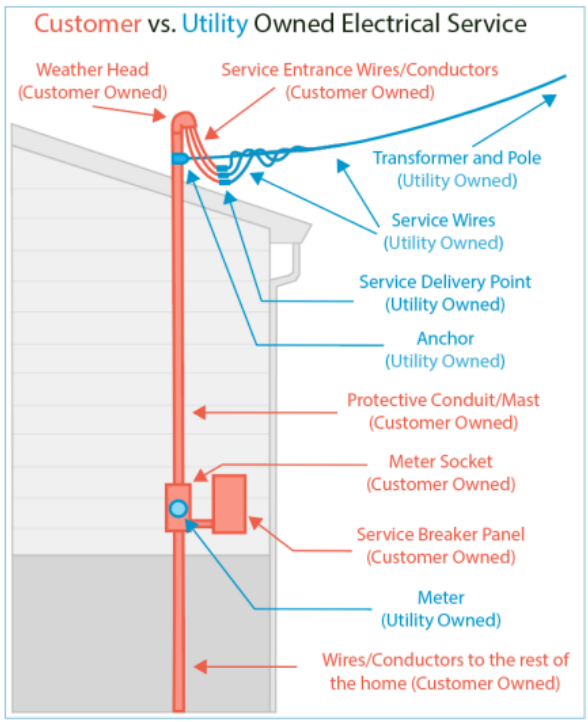
Panels are the electrical hub of a building, connecting the utility's infrastructure to the building. There are three main reasons why property owners might replace their electrical panel: because adding electric equipment means they need to increase the capacity of the panel to deliver a higher maximum electrical current (measured in amps at 240 volts), because the panel is out of circuit breaker slots to connect new equipment, or because the panel is unsafe or outdated. Replacing the

[1] California Energy Commission, Deep Decarbonization in a High Renewables Future, 2018, https://www.ethree.com/wp-content/uploads/2018/06/Deep_Decarbonization_in_a_High_Renewables_Future_CEC-500-2018-012.pdf.

electric panel costs between $2,000 and $4,500 and requires a complex approval process with the electric utility.[2] On top of that, panel upsizing to increase the amperage of the panel often (but not always) triggers electrical service upsizing from the energy utility, which is a changeout of the service wire that connects the utility infrastructure to the customer (Exhibit 1).

Exhibit 1. Electrical Service Upsizing

Utility-owned electrical service infrastructure (shown in blue) connects the grid to customer-owned infrastructure (shown in red). Electrical service upsizing involves a changeout by the electric utility of the service wire that connects the utility infrastructure to the customer.



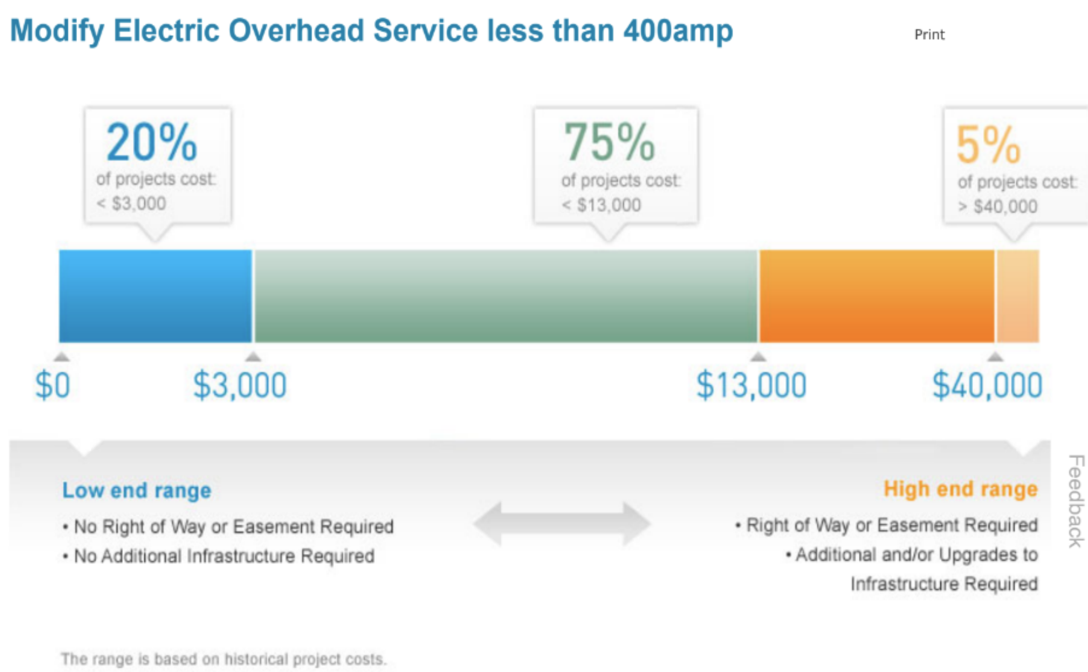
Source: NV5 Inc. and Redwood Energy, *Service Upgrades for Electrification Retrofits Study Final Report*, 2022, https://www.redwoodenergy.net/research/service-upgrades-for-electrification-retrofits-study-final-report-2. Courtesy of Redwood Energy Research Director Emily Higbee.

Service upgrade costs for the utility vary widely. The utility typically covers the first $2,000 to $3,500 with an allowance; customers pay the remainder. In 20% of cases, the utility allowance covers the full costs. According to Pacific Gas & Electric (PG&E), which serves much of California, customers pay as much as $7,500 to $10,000 in post-allowance costs in 55% of cases and upward of $30,000 in 5% of cases (Exhibit 2).

[2] NV5 Inc. and Redwood Energy, *Service Upgrades for Electrification Retrofits Study Final Report*, 2022, https://www.redwoodenergy.net/research/service-upgrades-for-electrification-retrofits-study-final-report-2.

Exhibit 2. PG&E Estimates of Service Upsizing Costs for Customers

In 80% of cases, customers bear a cost of at least $2,500 to have PG&E modify their electric overhead or underground service wire connection under 400 amps. This cost is in addition to anything they pay to alter their own electrical system (so-called behind-the-meter infrastructure, such as electrical panels). The overhead/underground distinction refers to where the service wire is located.



Source: PG&E, "Building and Renovation Services—Project Cost Range," accessed March 7, 2024. Available at: https://www.spur.org/sites/default/files/Project_Cost_Range_modify_underground_service_line_under_400_amp.pdf and https://www.spur.org/sites/default/files/Project_Cost_Range_modify_overhead_electric_service_under_400_amp.pdf.

When modifying the electric panel triggers service upsizing, the process can take months to years.

In 2023, California State Senator Scott Wiener asked the three largest investor-owned utilities (IOUs) how long it took them to energize commercial and multifamily projects once they were constructed, inspected, and ready to be connected to the grid. Although the responses didn't include information on the timelines for electric service modifications for existing buildings, the timelines to energize new construction are likely similar to those for existing buildings. PG&E reported that 95 of 319 (30%) of projects had been waiting more than 90 days, Southern California Edison reported that none of 111 projects were waiting longer than 60 days, and San Diego Gas & Electric (SDG&E) reported that all but a few projects affected by transformer supply chain problems were energized within 30 days. Detailed responses from these IOUs are shown in Appendix C.

A report prepared for PG&E and SDG&E on single-family residential service upgrades found that PG&E couldn't share fixed timelines for each step in its energization process. SDG&E shared time frames for each step in its process, which in total takes 7 to 17 weeks.[3]

Exhibit 3. Steps and Timelines for Service Upgrades by PG&E and SDG&E

Two key differences between PG&E and SDG&E, highlighted in green, are that PG&E conducts more inspections than SDG&E and that SDG&E can communicate the time frame for each of its steps in the service upgrade process, whereas PG&E cannot.

PG&E	SDG&E
Start: Customer applies for service upgrade.	**Start:** Customer applies for service upgrade.
PG&E assigns a staff member (job owner) to understand the project.	**4–8 weeks** SDG&E fields the job and assigns final submittal date.
Customer pays an engineering advance.	**5–7 days** SDG&E creates service order with fees and job package.
PG&E conducts engineering reviews and develops estimate.	**1–7 days** Customer pays SDG&E. Varying additional time: if necessary, customer obtains local permits, right-of-way, and trench inspections.
Customer signs a contract with PG&E for the work.	**1–2 days** SDG&E schedules crews.
3 days–6 months Customer completes any work on their end, such as trenching; then PG&E conducts two inspections.	**2–6 weeks** SDG&E performs energization.
9 days–13 weeks Customer obtains local permits and schedules disconnect; PG&E conducts inspection in collaboration with the authority having jurisdiction, then performs energization.	**1–3 days** SDG&E reconciles the job in its billing system and job is complete.

[3] Ibid.

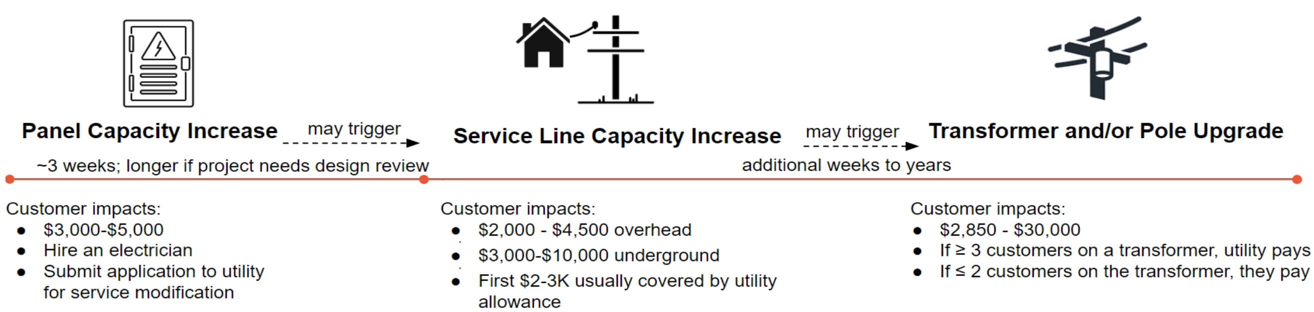
Total time frame: uncertain **No time frame was identified for four steps.**	**Total time frame: 7–17 weeks** **A time frame for every SDG&E-initiated step was identified.**
PG&E identified a list of steps and responsible parties and reported that an overall timeline is highly variable because it depends on circumstances.	SDG&E identified a detailed 11-step process and responsible parties.

Source: NV5 Inc. and Redwood Energy, Service Upgrades for Electrification Retrofits Study Final Report, 2022, https://pda.energydataweb.com/api/view/2635/Service%20Upgrades%20for%20Electrification%20Retrofits%20Study%20FINAL.pdf.

Modifying the electric panel or service adds more than cost and time to an electrification project. It means the job can no longer be performed simply by a specialty contractor, such as a plumber or HVAC contractor, without an electrician's license. Instead, the property owner will need to hire a general contractor or an electrician.[4] Modifying the panel in any way also means that the building owner must ask the utility for a service modification, triggering a utility inspection and requiring the owner to bring the electric service up to code. Typically, that means that older electric meters, which in the past could be installed inside a residence or near the gas meter, must now, to meet PG&E's current *Greenbook*[5] requirements, be moved outside of the residence at a specified minimum distance from the gas meter—work that can be expensive and time-consuming.[6]

Exhibit 4. Impacts of Panel Upsizing for the Customer

Upsizing a panel costs thousands of dollars and takes weeks; even worse, it can trigger tens of thousands of dollars and years of additional work to upgrade the service or distribution infrastructure.



Source: PG&E, "Building and Renovation Services—Project Cost Range," accessed March 7, 2024. Available at: https://www.spur.org/sites/default/files/Project_Cost_Range_modify_underground_service_line_under_400_amp.pdf and https://www.spur.org/sites/default/files/Project_Cost_Range_modify_overhead_electric_service_under_400_amp.pdf

[4] Laura Feinstein, *Streamlining Electric Service Connections to Accelerate California's Clean Air & Climate Goals*, paper presented at the TECH Clean California Webinar, January 23, 2024, https://techcleanca.com/events/good-stewardship-of-the-panel-webinar/.

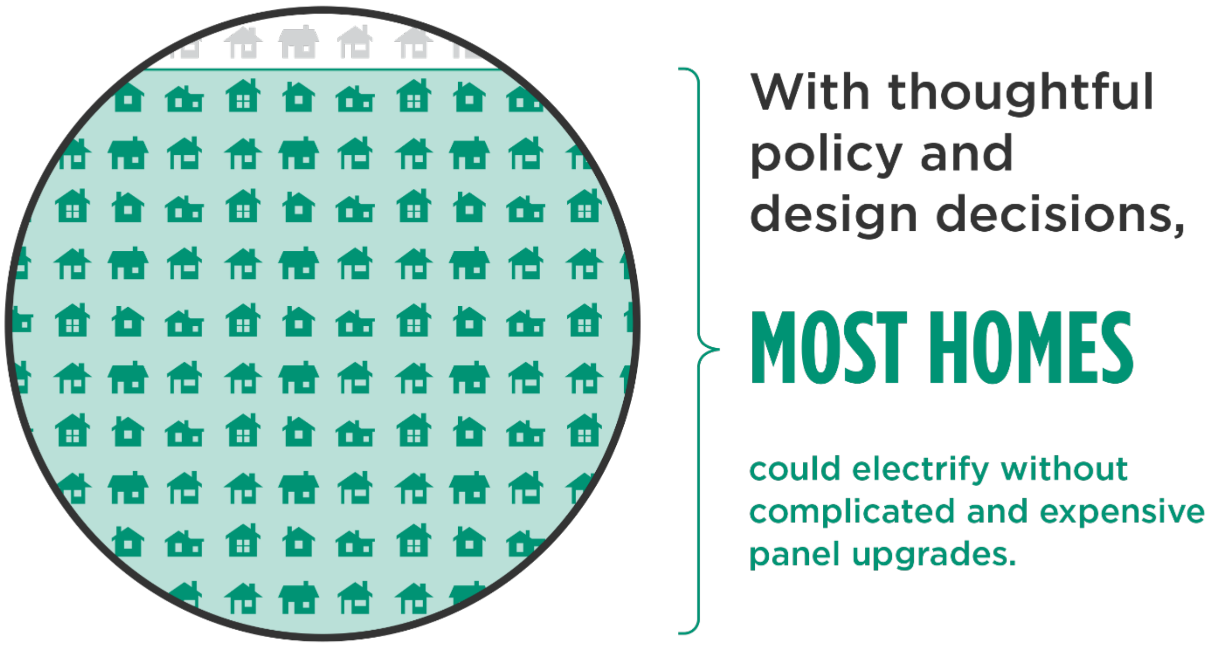
[5] PG&E's *Greenbook* contains the utility requirements for establishing gas or electric service to new or remodeled customer installations.

[6] Section 5.4.3 of PG&E's *Greenbook Manual*, 2022–23 edition, specifies the minimum distance between the gas and electric meter. See https://www.pge.com/en_US/large-business/services/building-and-renovation/greenbook-manual-online/greenbook-manual-online.page.

Nearly half of California's homes have panels under 200 amps.[7] If all of those homes upsized their panels and service, aggregate customer costs would total some $62 billion (see Appendix D). But as the next section explains, that outcome is hardly inevitable because the 47% of homes with panels of more than 100 amps and less than 200 amps are well positioned to electrify without replacing the panel.

Exhibit 5. Residential Electrification Without Panel or Service Upsizing

About half of single-family and multifamily homes in California have panels with capacities of at least 200 amps. Another 47% of California homes are in the 100-plus amp range and could allow owners to fully electrify without upsizing their panel or service.



Source: Laura Feinstein, Closing the Electrification Affordability Gap: Planning an Equitable Transition Away From Fossil Fuel Heat in Bay Area Buildings, SPUR, 2024, https://www.spur.org/publications/spur-report/2024-02-26/closing-electrification-affordability-gap.

[7] Data for single-family homes: Less Brennan, Iain Walker, Sean Murphy, and Eric Fournier, Electrical Service Panel Capacity in California Households With Insights for Equitable Building Electrification, forthcoming, American Council for an Energy-Efficient Economy. Data for single-family and multifamily homes: Doug Lindsey, Residential Electrical Panels—How Many Need to Be Upgraded?, paper presented at the 2023 POWER Meeting.

Paving the way for building electrification with panel optimization and an updated National Electrical Code

Higher-capacity panels are future-proof. For owners of homes with a 200-amp panel, adding nearly any electrical equipment is relatively easy. So why not convert most homes to 200-amp panels as the first step toward achieving a fully electrified building stock by 2035?

Avoiding and minimizing panel and service modifications whenever possible offers three key benefits:

- Owners incur fewer expenses and spend less time electrifying residences.
- Energy ratepayers and utilities avoid costly and time-consuming infrastructure upgrades.
- Utilities reduce their energization and interconnection backlogs.

All too often, homeowners are advised that they need at least 200 amps to electrify a major home appliance. But by taking watt dieting approaches, owners of single-family homes can easily electrify all common end uses—heating, ventilation, and air conditioning, or HVAC, as well as wall outlets, lighting, cooking, water heating, clothes drying, and electric vehicle, or EV, charging—with panels of at least 100 amps.[8] A 1,000-square-foot apartment can easily electrify all end uses, including powering an in-unit electric resistance clothes drier, on an 80-amp panel.[9]

In addition, panels are underused. The vast majority of homes—including single-family homes with 100-amp panels and multifamily dwellings with panels under 100 amps—use less than 50% of their panel's electric capacity. That means there's plenty of opportunity to electrify equipment without upsizing the panel. A SPUR analysis of TECH Clean California program data showed that of 1,764 homes with a 100-amp panel, 96% could add a heat pump water heater, heat pump HVAC, or both without upsizing the panel.[10]

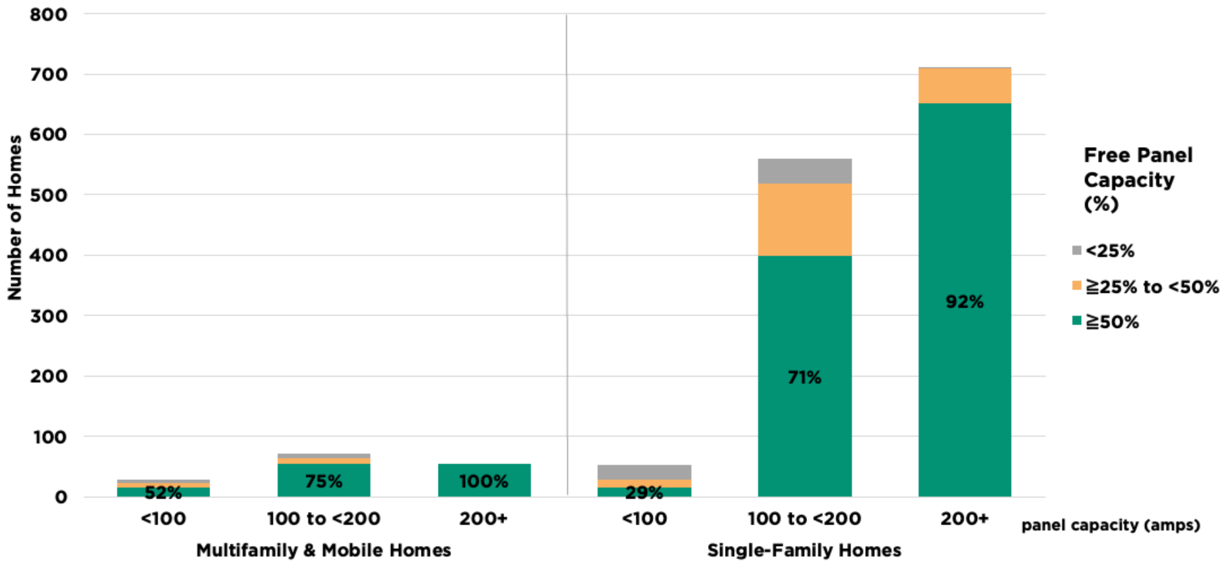
[8] Sean Armstrong, Emily Higbee, and Dylan Anderson, *A Pocket Guide to All Electric Retrofits of Single-Family Homes*, 2022, Redwood Energy, https://www.redwoodenergy.net/research/a-pocket-guide-to-all-electric-retrofits-of-single-family-homes.

[9] Tom Kabat and Emily Higbee, "Watt Diet Calculator V2—Multifamily Units," 2022, https://buildingdecarb.org/wp-content/uploads/watt_diet_calculator_2020-09-09_v2.xlsx.

[10] TECH Clean California, "Public Data," https://techcleanca.com/public-data/.

Exhibit 6. Underuse of Electric Panel Capacity

Most panels have at least 50% unused capacity, which would allow homeowners to add electric equipment without increasing panel capacity. Only single-family homes with panels under 100 amps use more than half their panel capacity in the majority of cases.



Source: Home Energy Analytics (HEA), "Dataset on Residential Panel Capacity and Utilization." Shared by Steven Schmidt of HEA.

Note: Data are from 1,477 homes in PG&E service territory.

The cost of electrical panel and service upsizing is not borne solely by utility customers. It is also borne by utilities and ratepayers in the form of upstream investments in the local distribution grid—the part of the grid that delivers electricity to homes and businesses—to meet the new demand for electricity. A recent study forecast that the State of California will need $50 billion in distribution grid infrastructure investments to accommodate electrification unless measures are taken to mitigate costs and manage loads.[11] Minimizing the rate of service upgrades can moderate skyrocketing electric rates and avoid adding to the backlog for distribution grid work and new energy-source interconnections.

As the old saying goes, the best way to solve a problem is not to have it. This brief outlines an alternative path for electrification that employs electrical and panel service upgrades only when they serve the best interests of building residents.

[11] Kevala Inc., *Electrification Impacts Study Part I: Bottom-Up Load Forecasting and System-Level Electrification Impacts Cost Estimates*, prepared for the California Public Utilities Commission, Proceeding R.1-06-017, May 9, 2023, https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M508/K423/508423247.PDF.

Panel optimization strategies, also known as watt dieting, can help homeowners avoid service and panel upsizing.

Homes can be electrified without a service or panel upsize or with a marginal increase in service capacity by using strategies often referred to as the Watt Diet.[12] The concept of the Watt Diet is that every panel has an upper limit of watts it can accommodate (amps*volts=watts), and trimming a few watts here and there can prevent the dreaded panel bloat. Strategies include the following:

- *Opt for moderate- or low-speed EV charging.* Charging an electric vehicle enough to drive 81 miles takes 12 hours connected to a 15-amp, 240-volt circuit (also known as a low-level Level 2 charger).[13] That's enough miles for even a mega-commuter to trek to work each day. Yet many homeowners install EV chargers that allow them to commute upward of 100 miles per day, using a massive amount of panel capacity.
- *Use power-efficient appliances.* Power-efficient equipment has a relatively low peak demand and, therefore, requires a lower-capacity circuit breaker than power-inefficient equipment.[14] For example, a 120-volt water heater typically requires just 15 amps, whereas its 240-volt cousin typically requires 30 amps. Two hundred and forty volts gives a water heater a higher first-hour hot water output than 120 volts because it can power a backup electric resistance heater. However, a 120-volt water heater with a larger tank than a 240-volt water heater can accomplish the same end.[15]
- *Use multifunctional equipment.* The best-known multifunctional equipment is the combination cooktop and oven, which has a lower peak demand than a separate cooktop and wall oven.
- *Improve whole-home efficiency.* Strategies such as insulation, air sealing, and duct sealing enable the use of more power-efficient appliances.
- *Use circuit controllers.* Load controls can throttle or switch off loads to reduce the whole-home load for the panel. Ideally, load controllers manage loads in ways that don't sacrifice comfort or convenience for the customer. For example, a household that charges an EV at night might find a circuit splitter between the cooktop and the EV charger to be convenient; others might benefit from a circuit pauser that moderates demand from two EVs. Some households, such as those with many people using energy around the clock, may not be well served by circuit controllers.
- *Take a strategic approach to the National Electrical Code's two pathways for calculating panel and service capacity*. Use both pathways when permissible, and rely on the lower estimate.

[12] Redwood Energy, "Watt Diet Calculator," 2022, https://www.redwoodenergy.net/watt-diet-calculator; Tom Kabat, *Using the Watt Diet for Whole Home Electrification: Helping Contractors Be Good Stewards of the Panel*, paper presented at the TECH Clean California Webinar, January 23, 2024, https://techcleanca.com/events/good-stewardship-of-the-panel-webinar/.

[13] Tom Kabat, *Using the Watt Diet for Whole Home Electrification: Helping Contractors Be Good Stewards of the Panel*, p. 65.

[14] Build It Green, "Panel Optimization Work and Electrical Reassessments (POWER)," https://www.builditgreen.org/blog/panel-optimization-group/.

[15] Notably, energy-efficient appliances are not as useful for freeing electrical panel capacity as power-efficient appliances. Energy-efficient appliances, such as tankless electric water heaters, use less energy per unit of time, sometimes by operating quickly, which requires higher instantaneous power demand for short periods.

Exhibit 7. Controls to Manage Electrical Load and Avoid Panel Upsizing

Four devices can manage electrical load: smart panels, circuit splitters, circuit pausers, and meter socket adapters. Their incremental costs—measured as costs above equivalent baseline equipment—range from as little as $200 to $3,000.

Image by Leviton

Smart panels prioritize loads to ensure that panel capacity is not exceeded.
Incremental cost: $500–$3,000 over standard panel

Image by BSA Electronics

Circuit splitters allow two devices to plug into one receptacle. Some allow only one device to be supplied at a time; others keep a small supply for the primary device at all times while toggling the secondary device on and off. Circuit splitters are used interchangeably with circuit sharers.
Incremental cost: $200–$400

Circuit pausers read the instantaneous electric demand of the entire home, then reduce the power supplied to the associated device to remain below peak load. Some models, such as EVduty, supply the power available, while others, such as Thermolec DCC, pause supply to the associated device. The simpleSwitch 240M supplies two devices: One is always on, and the second is only on when total demand is below 80% of the panel capacity. The NeoCharge Smart Splitter supplies two electric vehicles and can throttle to remain below peak load.
Incremental cost: $750–$1,750

Meter socket adapters allow a solar array and battery to plug into the meter socket, bypassing the service panel. Solar panels are allowed to take up only 20% of the electric capacity of the main panel (technically, the main bus bar rating). A meter socket adapter avoids this limitation. The most common type is a circular collar installed between the meter and the meter socket.* Adapters are under development that would be compatible with EV chargers. In cases where there is sufficient service capacity but not enough panel capacity, the meter socket adapter can prevent panel upsizing. Each make and model of meter socket adapter needs to be approved for use by the local utility, which has slowed their market penetration.

* National Electrical Manufacturers Association (NEMA), *NEMA US 80016-2022: Meter Socket Adapters*, 2022, https://www.nema.org/docs/default-source/technical-document-library/nema-us-80016-2022-aspublished.pdf?sfvrsn=a4caa6df_3.

Image credits: Leviton, BA-Electronics, simpleSwitch, and ConnectDER

Sources: Blake Herrschaft, Design Guidelines for Home Electrification, Peninsula Clean Energy, 2023, https://www.peninsulacleanenergy.com/wp-content/uploads/2023/02/Design-guidelines-for-home-electrification-v021023.pdf; Emily Higbee, Sean Armstrong, Maria Diaz, and Anissa Stull, A Pocket Guide to All-Electric Retrofits of Commercial Buildings, Redwood Energy, 2022, https://www.redwoodenergy.net/research/redwood-energys-pocket-guide-to-all-electric-commercial-retrofits.

Updating the National Electrical Code would advance building electrification.

The National Electrical Code (NEC) is a model code developed by the National Fire Protection Association (NFPA). It is updated every three years. The California Building Standards Commission (BSC) uses the NEC as the model for the California Electrical Code two years after the NEC is published. Local officials who set building codes in their area—also known as authorities having jurisdiction (AHJs)—then adopt and implement the California Electrical Code in January of the following year. The 2023 edition of the NEC is the most current; the next planned update is in 2026. As of 2024, the 2022 California Electrical Code is in effect, and it is based on the 2020 NEC.

There are a few ongoing and upcoming opportunities to modify the NEC and the California Electrical Code.

Exhibit 8. National Electrical Code and California Electrical Code Update Cycles

Waiting for the next NEC update is slowing changes needed in the California Electrical Code.

	2026 National Electrical Model Code Published by National Fire Protection Association	2025 California Electrical Code[a]	2028 California Electrical Code[b]
Opportunity to improve the electrical code	Lawrence Berkeley National Laboratory submitted public inputs to update the code.	Targeted changes adopted in the 2026 NEC could be fast-tracked for adoption in the 2025 California Electrical Code and could take effect in January 2026.	Following normal procedure, amendments to the 2026 NEC will be reflected in the 2028 California code.
Adopted during		2024 triennial adoption cycle	2027 triennial adoption cycle
Based on		2023 NEC	2026 NEC
Process begins	With public input due Q3 2023[c]	Q3 2023	Q3 2026
Final draft published	Q3 2025[d]	Q3 2025	Q3 2028
Effective	Q3 2025[d]	January 1, 2026	January 1, 2029
Intervening code cycle begins (opportunity to amend triennial code)		Q4 2025	Q4 2028

a Updates are based on California Building Standards Commission, “2024 California Code Adoption Cycle,” September 2023, https://www.dgs.ca.gov/-/media/Divisions/BSC/03-Rulemaking/2024-Triennial-Cycle/2024-Triennial-Code-Cycle-Timeline_FINAL.jpg.

b Updates are based on California Building Standards Commission, “2024 Triennial Code Adoption Cycle Timeline,” September 2023, https://www.dgs.ca.gov/BSC/Rulemaking/2024-Triennial-Cycle.

c National Fire Protection Association, “National Electrical Code Next Edition,” 2023, https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=70&tab=nextedition.

d Publication and effective dates aren’t set in advance because the timeline can vary, but the 2020 and 2023 NECs were issued and took effect in Q3 of the revision cycle year.

The NEC offers two approaches for calculating the necessary panel and service capacity for an existing dwelling. The first pathway (Section 220.87), the metered-demand approach, relies on recent metered energy use in the building to determine the maximum peak load for the existing electrical uses. The second pathway, the bottom-up approach (Section 220.83 for single-family dwellings and Section 220.84 for multifamily dwellings), estimates load from existing electrical end uses using appliance nameplate ratings (the maximum operating power of the appliance) and a demand factor—also referred to as a coincidence factor—an estimate of how often electrical devices are expected to be on at the same time.

It's not enough to decrease the actual peak load for a building to decrease the required panel capacity. Rather, reductions need to translate into lower estimated peak load for at least one NEC load calculation approach, which includes assumptions that build in multiple safety factors that tend to overestimate peak load. Because of the trade-offs between the two load calculation pathways, one or the other may yield a lower estimate of required panel and service capacity in different circumstances.[16]

Metered-demand approach (NEC Section 220.87)

The metered-demand approach uses measurements of recent energy consumption multiplied by a 125% safety factor to determine peak load and remaining panel/service capacity. It calculates new loads as being added at 100% of their nameplate rating.

Pros:

- Can be automated at scale using smart meter data infrastructure
- Accurately represents peak load based on actual consumption and usage patterns and usually generates a lower estimate of peak load than 220.83
- Does not require detailed physical inspection to record all the nameplate ratings
- Makes calculations relatively easy

Cons:

- Often produces a higher estimate of the new load than the bottom-up approach (Most users assume 100% coincidence on all new energy uses, which often produces a higher estimate of the new load than the bottom-up approach, which treats most new loads at 40% coincidence.)
- Doesn't make clear when metering data are acceptable for making load calculations (As written, Section 220.87 explicitly allows the use of smart meter data to estimate peak demand for homes with at least 30 days of data, but it is silent on whether such data are acceptable for homes with more than a year of data.)
- Requires the use of often-unavailable 15-minute interval utility meter data for homes with at least 30 days but less than a year of metering data (The code does not specify the required time interval when one year of data is available.)

[16] For a thorough comparison of Section 220.87 and Section 220.83, see Tom Kabat, "Using the Watt Diet for Whole Home Electrification: Helping Contractors Be Good Stewards of the Panel," paper presented at the TECH Clean California webinar, January 23, 2024, https://techcleanca.com/events/good-stewardship-of-the-panel-webinar/.

- Excludes dwellings that use renewable energy or peak load shaving when they have less than one year of metered data (Notably, this shortcoming is not reflected in the 2022 California Electrical Code, which is based on the 2020 NEC. In the 2023 NEC, the renewable energy restriction was changed to apply only when data for less than one year are available. In the 2020 NEC, the restriction applied to all services.)
- Makes no deduction from metered peak demand for loads being removed or replaced
- Relies on recent demand to forecast future demand even though peak demand in homes varies due to changes in behavior, weather, and the like (Similarly, new occupancy in a dwelling might substantially change the calculated load, potentially leading to capacity issues.)

Bottom-up approach (Section 220.83 for single-family dwellings, 220.84 for multifamily dwellings)

The bottom-up approach uses the nameplate rating (the maximum power under standard test conditions) of appliances in the building to calculate existing load. It calculates new loads as being added at the nameplate rating and adjusted by a demand factor. The demand factor varies by circumstance. New HVAC equipment is treated at 100% coincidence for single-family dwellings (220.83) and at a sliding scale for multifamily dwellings (220.84) starting at 45% and falling for larger units (e.g., 44% 6-7 units). All other new loads are treated at 40% coincidence.

Pros:

- Usually generates a lower estimate of new load than the metered-demand approach because it uses demand factors under 100% coincidence for most uses
- Allows exclusion of removed or replaced loads from the load calculation
- Produces standardized estimates of load that are not subject to change when occupancy or use are altered (Changes in ownership or use may impact calculations using Section 220.87, whereas calculations using Section 220.83 will remain static.)

Cons:

- Predicts higher-than-actual loads because conservative assumptions are built into the load calculation (Those assumptions ensure that most dwelling unit loads are predicted to be higher than they really are, which limits additional load that can be added, but they may also provide a margin of safety in dwellings with compromised electrical infrastructure.)
- Requires detailed physical inspections or use of default values, making calculations more time-consuming than calculations using the metered-demand approach
- Currently allows new EV charging to be added to an existing dwelling unit at 40% coincidence, which is inappropriate based on the metered demand of this equipment

The NEC prioritizes safety but needs updating for easier electrification without compromising safety. The recommendations by Lawrence Berkeley National Laboratory (LBNL), based on a study of nearly 1,000 sub-metered dwellings and data from more than 12,000 homes before and after cold-climate heat pump installations, aim to facilitate electrification without panel and service upgrades.[17] Typically, existing dwellings only use 30% of their service capacity. Dwellings with 100-amp service panels commonly have 12.7 kilowatts (kW) of capacity, allowing for up to 25 kW of new load under the proposed code. Similarly, 200-amp service panels offer about 36.7 kW of capacity, accommodating nearly 72 kW of new load. These figures suggest that most California homes could fully electrify fuel-fired end uses without panel upsizing. LBNL submitted public input to the NFPA for the 2026 NEC regarding dwelling unit service and feeder load calculations. Its input is summarized in our recommendations regarding revisions of the electrical code (also see Appendix A).

[17] Brennan Less, Iain Walker, Tom Kabat, Owen Howlett, Farhad Farahmand, and Eric Morrill, Background for Proposed Changes to Existing Dwelling Electrical Load Calculations in the National Electrical Code, 2023.

Recommendations to avoid and streamline panel and electrical service upsizing

Recommendations are grouped into three strategies:

- Avoid—Electrify buildings without touching the electrical panel or service, thereby removing one of the most expensive and time-consuming steps in home electrification and avoiding expensive upgrades to distribution infrastructure.
- Streamline—Make unavoidable service upgrades as quick and affordable as possible, and pass policies to encourage property owners to undertake these upgrades at the least disruptive times.
- Fill knowledge gaps—Improve the state's understanding of the impact of electric panel and service upsizing for property owners, utilities, and electrical rates, and compile better data to support utility planning for distribution grid upgrades.

Avoiding panel and service upsizing

Recommendation 1. Incorporate subsidies in incentive programs for load management technologies that mitigate the need to upsize a panel.

Multiple state agencies, energy providers, and private companies administer California's electrification incentive programs. None of these programs actively offer interventions to prevent unnecessary electrical service upsizing, and some—such as the California Public Utilities Commission's TECH program—offer rebates to upsize panels. Incentive programs should offer subsidies for load management technologies that don't sacrifice convenience before they offer a subsidy for panel upsizing.

Pathway to change: State agencies should include subsidies for load management technologies in their incentive program design.

Who has authority: California Energy Commission (CEC), California Public Utilities Commission (CPUC), Community Choice Aggregators (CCAs), Regional Energy Networks (RENs), and other entities that offer electrification incentives

Recommendation 2. Prioritize funding for power-efficient devices and multifunctional appliances in incentive programs, just as energy-efficient devices are prioritized.

Contractors are already motivated to avoid panel and service upsizing on their projects. The biggest challenge is to incentivize contractors to optimize the panel when there's still plenty of capacity and breaker space so that later projects aren't forced to upsize the panel or add a subpanel. Incentive programs can encourage power-efficient choices throughout the customers' electrification journey, increasing the likelihood that customers will have remaining panel capacity and breaker spaces as they near the final steps. Incentive programs already set minimum requirements for energy-efficiency ratings of eligible appliances; they could similarly set a maximum wattage for eligible appliances.

Pathway to change: Entities offering incentive programs should design them to promote power-efficient devices and disincentivize power-inefficient devices.

Who has authority: CEC, CPUC, CCAs, RENs, and other entities that offer electrification incentives

Recommendation 3. Offer no subsidies to middle- and upper-income households for panel upgrades above 200 amps.

Even without power-efficient devices, fully electrified, 2,000-square-foot single-family homes with Level 2 EV charging require only about 155 amps of service.[18] With more power-efficient selections, a fully electrified 2,000-square-foot home with Level 1 EV charging and solar panels requires only about 97 amps of service.[19] To need more than 200 amps of service, a large home would have to have large solar arrays, ultra-fast EV charging, and appliances with high nameplate ratings. Programs that are income-qualified could either not put an upper limit on panel upsizing or could require that contractors submit their NEC calculations as evidence that the capacity increase is needed.

Pathway to change: Incentive programs should not subsidize panel upgrades above 200 amps except for low-income households.

Who has authority: CEC, CPUC, CCAs, RENs, and other entities that offer electrification incentives

Recommendation 4. Issue guidance on how the current California Electrical Code can be interpreted to support climate-friendly, climate-ready homes.

The California Electrical Code language is ambiguous. Offering guidance on how to interpret the code could better support the state's electrification goals and could allow more consistent implementation by the state's authorities having jurisdiction (AHJs). The state could pursue two strategies. First, it could simply issue guidance to interpret the California Electrical Code in line with the 2023 NEC, which

18 Cavan Merski, Addressing an Electrification Roadblock: Residential Electric Panel Capacity, Pecan Street, 2021, p. 4, https://www.pecanstreet.org/2021/08/panel-size/.

19 Sean Armstrong, Emily Higbee, and Dylan Anderson*, A Pocket Guide to All Electric Retrofits of Single-Family Homes*, Redwood Energy, 2022, p. 23, https://www.redwoodenergy.npet/research/a-pocket-guide-to-all-electric-retrofits-of-single-family-homes.

has adopted clearer language. That is, the state need not wait to formally adopt the NEC in 2025 before it uses the NEC. Second, in developing guidance documents, California could reference language developed by Lawrence Berkeley National Laboratory to clarify language in the 2026 NEC (see Appendix A).

Two clarifications of Section 220.87 are recommended:

> First, interval utility meter data (e.g., smart meters) can be used for 220.87 calculations. Specify the minimum interval required for homes with more than a year of data. Fifteen-minute interval data would align with the interval required for homes with at least 30 days of data. Sixty-minute interval data with an adjustment factor would align with practices outside California (see recommendation 5).
>
> Second, the Section 220.87 calculation method can be used by dwellings with one year of data that reflect the use of renewable energy systems and peak demand shaving. Currently, Section 220.87 does not allow homes that have a renewable energy system (such as solar) or that employ a peak load shaving method (i.e., a battery storage system) to use its calculation method. The 2023 NEC clarifies that this exception applies solely to homes with *less than one year of data*. The reasoning here is that the use of renewable energy systems or peak load shaving may obscure seasonal load variability. Therefore, data for a full year are needed.

One clarification of Section 220.60 is recommended:

> Circuit splitters—devices enabling two loads to share a single circuit safely—can demonstrate noncoincidence of load. Only the larger load connected to the circuit splitter should be included in unit load calculations for existing dwellings. Currently, Section 220.60 permits inclusion of only the larger of two loads deemed unlikely to be used simultaneously. Explicitly stating that circuit splitters ensure noncoincidence would promote widespread acceptance by AHJs.

Pathway to change: A collaboration of state agencies led by the California Building Standards Commission should issue an information bulletin with guidance on how to interpret the 2025 California Electrical Code load calculations in ways that are code-compliant while enabling optimization of a home's existing panel. In addition, AHJs should act on their own to adopt electrification-friendly, code-compliant interpretations of the NEC in their cities and counties.

Who has authority: The Building Standards Commission, Office of the State Fire Marshal (SFM), and Department of Housing and Community Development (HCD) have authority over the California Electrical Code for residences. AHJs have authority over interpretations of the code in their jurisdiction.

Recommendation 5. Revise the National Electrical Code (or the California Electrical Code) to reduce overestimates of electrical service and feeder loads while maintaining safety protections.

Lawrence Berkeley National Laboratory (LBNL) has submitted public input to the NFPA to address existing dwelling unit service and feeder load calculations for the 2026 NEC (see Appendix A). According to LBNL's assessment of proposed NEC code changes and suggested policy practices, California homes could roughly double new loads relative to the current code without panel upsizing. Using the proposed code calculations provided safe, conservative predictions 99% of the time for individually metered dwellings in California-like climates and 96% of the time where cold-climate heat pumps are used. In short, the proposed code calculations performed much like current code calculations in predicting safe loads. The state can act now to dramatically increase the capacity of existing dwellings to electrify.

The following actions are recommended:

- Adjust Section 220.87 to explicitly allow use of utility metering data as well as to clarify that 15-minute meter data can be used to calculate peak demand as long as 30 days of data are available and that 60-minute meter data can also be used with an adjustment factor.[20] Include a method based on gross demand, thereby allowing homes with renewable energy systems and less than one year of data to use Section 220.87 load calculations. Allow deduction of load removals and use of demand factors from elsewhere in Section 220.
- Eliminate differential treatment of new HVAC equipment in Section 220.83 load calculations, and adjust demand factors for load additions.
- Reduce general lighting and receptacle loads in dwellings.
- Adjust demand factors to better align with real-world data on energy consumption in dwellings while keeping estimates of loads conservative in 96% to 99% of cases.
- Rely on nameplate ratings for EV and clothes dryer loads rather than default to the values assigned in the electrical code.
- Clarify that circuit controllers can establish noncoincidence of loads.
- Clarify that energy management systems (such as smart panels and circuit pausers) can be used to control branch circuit loads in addition to the whole-home load.

Pathway to change: The state should incorporate electrification-friendly amendments to the California Electrical Code by (1) amending the 2026 NEC and waiting for it to become the 2028 California Electrical Code (in effect January 1, 2029) and (2) amending the 2026 NEC and incorporating new language early, during the 2025 intervening code cycle (in effect Q3 2027).

There is precedent for California to amend model codes to further a state policy objective, as when the California Building Standards Commission worked with the State Fire Marshal to amend the California Building Code to align with Executive Order B-52-18 on expanding the use of mass timber.[21]

[20] Allowing the use of 60-minute interval data with an adjustment factor of 25% is already standard in British Columbia, Canada. See Technical Safety BC, *Information Bulletin: Demand Factors and Use of Rule 8-106 for Single Dwellings*, 2023, https://www.technicalsafetybc.ca/regulatory-resources/regulatory-notices/information-bulletin-demand-factors-use-rule-8-106-single-dwellings.

[21] California Building Standards Commission, "CALCode Quarterly Newsletter Summer/Fall 2020," https://content.govdelivery.com/accounts/CADGS/bulletins/2f9d281.

Who has authority: The NFPA has authority over the NEC. The Building Standards Commission, in collaboration with the state agencies that propose and adopt changes to Electrical Code Article 220, has authority to adopt sections of the NEC early or to amend the NEC when adopting the California Electrical Code.

Recommendation 6. Require utilities to provide information on peak demand for every customer. A less preferred option is for utilities to give easy access to 15-minute interval data.

NEC Section 220.87 allows electrical service and feeder loads to be derived from maximum metered demand, offering a quick, easy, and cost-effective calculation method that minimizes unnecessary panel and service upgrades. Although peak demand can be calculated from metered data, obtaining the data from utilities can be challenging and requires contractors to possess specific tools and training. Ideally, utilities would provide each customer's peak demand as a single figure, eliminating the need for contractors to access detailed meter data and reducing the risk of calculation errors. This approach also enhances customer privacy by minimizing the data shared with contractors. If the utility has less than 12 months of data with intervals exceeding 15 minutes, customers should be informed that their peak demand is inadequate for using Section 220.87.

As a less preferred option, utilities should provide easy access to 15-minute interval data, which would allow contractors to make their own Section 220.87 calculations. In some cases, customer meter data are shared only with customers at 60-minute intervals, which is insufficient for Section 220.87 calculations when less than one year of metered data is available. Irrespective of the NEC, 15-minute metered data will always give a more accurate representation of a dwelling's electrical load.

Pathway to change: The CPUC should require electric utilities to develop a simple tool that calculates a customer's peak usage and to make that peak usage available on the customer's web account to share with contractors. These actions can be accomplished through one of several proceedings at the CPUC. The CEC should develop a similar tool with the publicly owned utilities that have smart meters.

Who has authority: CPUC, CEC, and electric utilities

Recommendation 7. Provide resources for contractors on how to avoid panel upsizing.

Contractors need access to easy-to-use tools for electrification planning and electrical load calculations. Workforce education programs can work with contractors to user-test the tools and disseminate them.

Pathway to change: Public agencies and utilities should fund the development and dissemination of tools. Avenues for dissemination include workforce training programs run by junior colleges and labor unions, the Switch Is On, and the CEC's Building and Home Energy Resource Hub.

Who has authority: Government agencies, electric utilities, and workforce training programs

Recommendation 8. Support whole-home electrification plans that advise building owners on how to avoid panel and service capacity upsizing.

Developing a plan early makes it easier to electrify without upsizing the panel. Property owners should be informed about the pros and cons of choosing panel optimization approaches. Excellent pamphlets and video training are already available. Private companies, including Home Energy Analytics, QuitCarbon, Rewiring America, and Redwood Energy, offer tools for electrification planning. The CEC and CalNEXT are developing publicly funded tools. Community Choice Aggregators plan to offer personalized support for home electrification.[22]

Pathway to change: Entities that offer electrification incentives should provide resources on panel optimization at key moments during customers' electrification journey, such as when they apply for an incentive or a building permit. Programs that provide in-person visits by trained energy auditors who evaluate energy use (such as Home Energy Score audits) and suggest efficiency improvements could offer custom plans.[23]

Who has authority: CEC, CPUC, CCAs, RENs, and other entities that offer electrification incentives; private sector companies that provide electrification services

Recommendation 9. Direct electric utilities to authorize any meter collar adapter that meets a set of minimum specifications.

At present, California gives each electric utility authority to allow meter collars, and manufacturers must seek approval for every model of collar from every utility. By contrast, New Jersey law gives utilities authority to allow the installation and operation of meter collars as long as the collars meet a set of minimum specifications.[24] This law allows much greater market penetration of the devices. Today, meter collar adapters are used to avoid main panel upgrades to accommodate rooftop solar, but collars in beta stage will function similarly for EV charging.

Pathway to change: State agencies should develop whole-home electrification planning guidance and standardized checklists for energy providers and RENs to integrate into customer-facing services.

Who has authority: CPUC and electric utilities

[22] See, for example, Peninsula Clean Energy's plans for a turnkey program: Peninsula Clean Energy, "Building Electrification Strategy and Home Upgrade Program V2," February 8, 2023, https://www.peninsulacleanenergy.com/wp-content/uploads/2023/01/2023.02.09-CAC-Programs-BE-strategy-RHA-contract-amendment.pdf. Silicon Valley Clean Energy has similar plans for a concierge service; see Silicon Valley Clean Energy, "Request for Proposals for Electrification Concierge Services Consultant," 2023, https://svcleanenergy.org/wp-content/uploads/svce_ffh_concierge_rfp_digital.pdf.

[23] BayREN, "The Home Energy Score (HES)," October 2023, https://www.BayREN.org/HES.

[24] New Jersey S3092, *An Act Concerning Certain Electrical Equipment Used on Residential Electric Meters and Supplementing Title 48 of the Revised 2 Statues*, September 2022, https://pub.njleg.state.nj.us/Bills/2022/S3500/3092_R3.PDF.

Streamlining panel and service upsizing

Recommendation 10. Make incentive dollars available for upsizing of panels under 100 amps in homes even when the upsizing is not performed during an electrification project.

Although relatively small homes can electrify on panels under 100 amps, doing so requires careful planning and layering of multiple Watt Diet strategies. For small units in multifamily buildings, an 80-amp threshold would be appropriate. Newly installed panels should reserve breaker spaces sufficient for future electrification of end uses. Ideally, the whole-home electrification plans recommended above would flag the need for a panel upgrade and recommend a panel capacity and number of breaker slots. In places where electrification mandates are on the horizon, it's particularly vital to get time-consuming electrical upgrades out of the way before old appliances break, thereby allowing people to make emergency replacements quickly.

Pathway to change: In places where electrification mandates for existing buildings are on the horizon, incentive programs should cover upsizing of small (<100 amps) panels as a standalone incentive.

Who has authority: CEC, CPUC, CCAs, RENs, and other entities that offer electrification incentives

Recommendation 11. Direct electric utilities to adopt best practices to process service modification applications, along with target and maximum timelines that reflect streamlined processes.

The CPUC, pursuant to Senate Bill 410 (Becker, 2023) and Assembly Bill 50 (Wood, 2024), opened a rulemaking in February 2024 to streamline timelines for energization.[25] The rulemaking will set target and maximum timelines. SPUR and a coalition of five nongovernmental partners have called for the CPUC to direct utilities to gather information from the initial implementation of timelines and reporting requirements and to use that information to consider new processes and rule changes needed to further streamline energization projects.[26]

Pathway to change: The CPUC should adopt target and maximum energization timelines that reflect best practices by utilities. Public utilities can follow suit.

Who has authority: CPUC, electric utilities, and public utilities

[25] CPUC, "Order Instituting Rulemaking to Establish Energization Timelines," 2024, https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/energization.

[26] SPUR, Act Now Bay Area, Earthjustice, NRDC, RMI, and PODER, "Re: Rulemaking 24-01-018 to Establish Energization Timelines," 2024, https://www.spur.org/publications/advocacy-letter/2024-02-28/joint-letter-cpuc-supporting-flexibility-energization.

Recommendation 12. Evaluate utility Greenbook requirements on panel placement in light of the state's electrification goals.

Older electric panels installed indoors or near the gas meter no longer meet PG&E's current *Greenbook* requirements. These panels must be moved outside of private residences and located at a specified minimum distance from the gas meter.[27] Electrification work may trigger panel relocations, increasing the cost and complexity of electrification projects.
Pathway to change: Electric utilities should evaluate their electrical service requirements in light of the need to quickly and affordably upsize many home panels.

Who has authority: Electric utilities

Recommendation 13. Socialize at least some of the costs of electrical service upsizing for residential electrification as long as the costs have minimal rate impacts.

When a service upgrade from the utility is unavoidable, the customer pays the cost of the upgrade in excess of the standard utility allowance. As noted above (Exhibit 2), in 20% of cases, the costs are mostly covered by the utility allowance. But in 80% of cases, the allowance does not cover the full cost for customers, with post-allowance expenses varying between a few thousand to tens of thousands of dollars. At the high end, in 5% of cases, customers pay upward of $30,000.[28]

In many cases, the costs of electrical service upsizing for residential electrification should be socialized, as they already are for upsizing to accommodate at-home EV charging. Pursuant to AB 841 (Ting, statutes of 2020), if a residential customer needs upgraded service to install an EV charger, the utility will cover the full cost of the work and will recover the costs from ratepayers.[29] This arrangement could be a model for how to handle all energization charges.

Pathway to change: The CPUC should conduct a pilot and should study the rate impacts of making service upgrades a common cost—that is, a cost recovered from ratepayers. To avoid imposing upward pressure on rates, the CPUC should support panel optimization strategies as the first course of action. When service upgrades are necessary, the CPUC should evaluate the extent to which upsizing can be made a common cost without increasing rates, with priority given to equity populations. Publicly owned utilities should adopt a similar approach in their rate-making processes.

Who has authority: CPUC

Recommendation 14. Use a standard set of NEC load calculations for permit applications.

[27] See Section 5.3, "Electric Meters: General Location Requirements," in PG&E, *Greenbook Manual*, 2022–2023 edition, https://www.pge.com/en_US/large-business/services/building-and-renovation/greenbook-manual-online/greenbook-manual-online.page.

[28] PG&E, "Building and Renovation Services—Project Cost Range." accessed March 7, 2024.

[29] PG&E, *Electric Rule Number 16: Service Extensions E.5.7: Policy on Excess PEV Charging Costs*, 2020, https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_RULES_16.pdf.

Some local jurisdictions require unique calculations to estimate electrical load when submitting permit applications. Using a standard set of calculations would streamline processes for contractors working in multiple jurisdictions. Ideally, all AHJs would use the same spreadsheet calculator to make load calculations.

Pathway to change: AHJs should act on their own to adopt a standard set of NEC calculations and a standard workbook. Alternatively, the California Legislature should direct the AHJs to do so, just as it directed AHJs to adopt streamlined solar permitting procedures. An agency such as the CEC could issue a compliance verification tool for AHJs to use for NEC load calculations.

Who has authority: AHJs, California Legislature, and CEC

Recommendation 15. Allow specialty licenses (like plumbing and HVAC) to subcontract to electricians for panel upgrades needed for electrification.

Currently, homeowners often must hire two licensed contractors to install a heat pump water heater: a plumber or HVAC contractor and an electrician. They can have their contractor pay the electrician directly only if they hire a general building contractor, typically a step reserved for significant renovations. Allowing HVAC contractors with a C20-Warm Air Heating, Ventilating and Air Conditioning license or plumbers with a C36-Plumbing license to subcontract electric panel work to an electrician would simplify installations, reduce labor costs, and enable specialty contractors to collaborate with trusted colleagues.[30] This flexibility is crucial because some electrification rebate programs pay only a single contractor, underscoring the need to permit specialty contractors to subcontract to others.

Pathway to change: The California State Licensing Board should authorize C20 or C36 specialty license contractors to subcontract electric panel work for installation of heat pump water heaters to a C10-Electrical contractor under a separate contract.

Who has authority: California State Licensing Board

Filling knowledge gaps

Recommendation 16. Research panel optimization strategies to identify those yielding the greatest benefits.

Research is moving quickly on panel capacity, the triggers for panel upsizing, and the cost and benefits of panel optimization strategies. The state will soon have access to the first dataset on panel capacity from a representative sample.[31] The data show that the many datasets on panel capacity that were already available from energy efficiency programs and surveys were quite accurate. There are

[30] Hal Clay, Classification Deputy, California State Licensing Board, "Re: Heat Pump Water Heaters / Thermostatic Mixing Valves," February 10, 2022, https://drive.google.com/file/d/14VOv4-jK53p3cE5Snbcg6c5Mf_O_rc1H/view?usp=sharing.

[31] Less Brennan, Iain Walker, Sean Murphy, and Eric Fournier, *Electrical Service Panel Capacity in California Households with Insights for Equitable Building Electrification*, forthcoming, American Council for an Energy-Efficient Economy.

in-progress studies on behind-the-meter costs for electrical system upgrades and modeling tools that show the impacts of panel optimization strategies.[32]

This newly available research allows a more complete analysis of the costs and benefits of encouraging panel optimization strategies at scale. For example, many air districts and electric utilities offer rebates for rapid Level 2 home EV charging, which is likely to lock a customer into needing a service upgrade if they later want to electrify another energy use. Would it be more cost-effective for programs to offer circuit splitters to switch between cooking or a clothes dryer and EV charging or to redirect incentive funds to somewhat-slower Level 2 charging?

Pathway to change: Studies should be undertaken to understand which panel optimization strategies should be widely encouraged to yield the greatest customer, utility, and social benefits.

Who has authority: CEC, CPUC, and electric utilities

Recommendation 17. Provide estimates of timelines and service upgrade costs, as well as easy-to-understand information on how the costs are allocated to customers, early in the process.

How costs for service upgrades are allocated to customers when a service upgrade triggers work on utility-owned infrastructure such as transformers and pole tops is hard to decipher, making it difficult for building owners to predict how much they are likely to spend on a service upgrade.[33] Building owners are typically responsible for these costs only if two or fewer customers are served by the transformer, meaning that it's often multifamily buildings with high electrical loads that end up covering the costs. Utilities should provide customer-facing materials that allow property owners to understand the costs they're likely to incur.

In addition, property owners report that it can take a long time after applying for a service upgrade to receive a project-specific estimate of costs and timeline, a disincentive to electrification.[34]

Pathway to change: Energy utilities should develop customer-facing materials to educate property owners about the probable costs and timeline of a service upgrade and the likelihood of needing one. They should provide an initial estimate of costs and timeline after receipt of an application for service modification.

Who has authority: Electric utilities and CPUC

[32] Opinion Dynamics and Guidehouse, *Fuel Substitution Infrastructure Market Study*, 2024, https://www.cpuc.ca.gov/about-cpuc/divisions/energy-division/building-decarbonization/fuel-substitution-in-energy-efficiency; David Douglass-Jaimes, Michael Mutmansky, Abhijeet Pande, Laura Feinstein, and Jenny Low, "Residential Electrical Service Upgrade Decision Tool," CalNEXT, 2024, https://calnext.com/approved-projects/.

[33] NV5 Inc. and Redwood Energy, *Service Upgrades for Electrification Retrofits Study Final Report*, PG&E and SDG&E, 2022, https://pda.energydataweb.com/api/view/2635/Service%20Upgrades%20for%20Electrification%20Retrofits%20Study%20FINAL.pdf.

[34] SPUR, Act Now Bay Area, Earthjustice, NRDC, RMI, and PODER, "Re: Rulemaking 24-01-018 to Establish Energization Timelines," 2024.

Plan of Action

Strategy		Who has authority
Avoid	1. Incorporate subsidies in incentive programs for load management technologies that mitigate the need to upsize a panel.	CEC, CPUC, CCAs, RENs, and other entities that offer electrification incentives
	2. Prioritize funding for power-efficient devices and multifunctional appliances in incentive programs, just as energy-efficient devices are prioritized.	CEC, CPUC, CCAs, RENs, and other entities that offer electrification incentives
	3. Offer no subsidies to middle- and upper-income households for panel upgrades above 200 amps.	CEC, CPUC, CCAs, RENs, and other entities that offer electrification incentives
	4. Issue guidance on how the current California Electrical Code can be interpreted to support climate-friendly, climate-ready homes.	The Building Standards Commission, SFM, and HCD have authority over the California Electrical Code for residences. AHJs have authority over interpretations of the code in their jurisdiction.
	5. Revise the National Electrical Code (or the California Electrical Code) to reduce overestimates of electrical service and feeder loads while maintaining safety protections.	The NFPA has authority over the NEC. The Building Standards Commission, in collaboration with the state agencies that propose and adopt changes to Electrical Code Article 220, has authority to adopt sections of the NEC early or to amend the NEC when adopting the California Electrical Code.
	6. Require utilities to provide information on peak demand for every customer. A less preferred option is for utilities to give easy access to 15-minute interval data.	CPUC, CEC, and electric utilities
	7. Provide resources for contractors on how to avoid panel upsizing.	Government agencies, electric utilities, and workforce training programs
	8. Support whole-home electrification plans that advise building owners on how to avoid panel and service capacity upsizing.	CEC, CPUC, CCAs, RENs, and other entities that offer electrification incentives; private sector companies that provide electrification services

	9. Direct electric utilities to authorize any meter collar adapter that meets a set of minimum specifications.	CPUC and electric utilities
Streamline	10. Make incentive dollars available for upsizing of panels under 100 amps in homes even when the upsizing is not performed during an electrification project.	CEC, CPUC, CCAs, RENs, and other entities that offer electrification incentives
	11. Direct electric utilities to adopt best practices to process service modification applications, along with target and maximum timelines that reflect streamlined processes.	CPUC, electric utilities, and public utilities
	12. Evaluate utility *Greenbook* requirements on panel placement in light of the state's electrification goals.	Electric utilities
	13. Socialize at least some of the costs of electrical service upsizing for residential electrification as long as the costs have minimal rate impacts.	CPUC
	14. Use a standard set of NEC load calculations for permit applications.	AHJs, California Legislature, and CEC
	15. Allow specialty licenses (like plumbing and HVAC) to subcontract to electricians for panel upgrades needed for electrification.	California State Licensing Board
Fill Knowledge Gaps	16. Research panel optimization strategies to identify those yielding the greatest benefits.	CEC, CPUC, and electric utilities
	17. Provide estimates of timelines and service upgrade costs, as well as easy-to-understand information on how the costs are allocated to customers, early in the process.	Electric utilities and CPUC

Comments Submitted to the National Fire Protection Association Committee on the 2026 National Electrical Code by Brennan Less of Lawrence Berkeley National Laboratory

Purpose: Align the required ratings for feeders to match those for services, which are based on Section 220 loads. Eliminate the special accounting at 125% for continuous loads for feeders, which are unlikely to overheat.
Feeder conductor and overcurrent ratings—proposed language to modify base feeder conductor and overcurrent ratings on loads calculated in Sections III, IV, or V of 220.
Public Input No. 4384-NFPA 70-2023 (Section No. 215.2(A)(1))
Public Input No. 4369-NFPA 70-2023 (Section No. 215.3)

Purpose: Refine demand factors to better reflect observed data from field studies.
Fixed electric space heating demand factor—proposed applying 100% demand factor to only central electric resistance space heating, and proposed 75% for heat pumps and 30% for room electric resistance heating.
Public Input No. 4361-NFPA 70-2023 (Section No. 220.51)

Appliance load in dwelling unit(s)—proposed changing the demand factor for appliances from 75% to 30%, and eliminated the minimum of four appliances for applying the demand factor.
Public Input No. 4144-NFPA 70-2023 (Section No. 220.53)

Electric cooking appliances in dwelling units and household cooking appliances used in instructional programs—proposed a reduction from 60%-80% down to 50% demand factor for electric cooking appliances in Table 220.55.
Public Input No. 4160-NFPA 70-2023 (Section No. 220.55)

Heating and air conditioning load—proposed revisions to the list of heating and air conditioning types and their associated demand factors, including central electric resistance space heating (increased from 65% to 100%), air conditioning and heat pumps (reduced from 100% to 75%), and room electric resistance heaters (reduced from either 65% or 40% to 30%).
Public Input No. 4169-NFPA 70-2023 (Section No. 220.82(C))

Purpose: Use nameplate ratings rather than default value; refine demand factors to better reflect observed data from field studies; add an option for heat pump clothes dryers.
Electric clothes dryers in dwelling unit(s)—added option for heat pump clothes dryers and eliminated the default 5000-watt rating in favor of the dryer nameplate rating(s). Proposed a reduction from 100% to 80% demand factor that applies to one to five dryers.

Public Input No. 4151-NFPA 70-2023 (Section No. 220.54)

Purpose: Use nameplate ratings rather than default value.
EVSE loads—allow EVSE loads based on nameplate rating if available; otherwise, rely on the 7.2 kW default (7.2 kW was the previous minimum value). Note allowance for controls specified in 625.42(a) and (b).
Public Input No. 3145-NFPA 70-2023 (Section No. 220.57)

Purpose: Include electric load management technologies in load calculations.
Noncoincident loads—clarified that controls can be used to ensure noncoincidence.
Public Input No. 3024-NFPA 70-2023 (Section No. 220.60)

Energy Management System loads—proposed expanding to include branch circuit load calculations, eliminate treatment as continuous load, and specify different approaches for EMS that control all loads vs. only some of the loads.
Public Input No. 3025-NFPA 70-2023 (Section No. 220.70)

Purpose: Eliminate different treatment of new HVAC versus other new loads; reduce assumption for general lighting and receptacle loads; refine demand factors to better reflect observed data from field studies.
Public Input No. 3028-NFPA 70-2023 (Section No. 220.83)
Public Input No. 3319-NFPA 70-2023 (Section No. 220.83)

Purpose: Clarify existing code language and intent around metering hardware, time periods, and intervals; allow use of metering data in homes with renewable energy systems; refine demand factors to better reflect observed data from field studies.
Public Input No. 3303-NFPA 70-2023 (Section No. 220.87)
Public Input No. 3320-NFPA 70-2023 (Section No. 220.87)

Purpose: Reduce base demand assumption for general lighting and receptacle loads.
General lights and receptacles—proposed an optional path for reducing general lights and general receptacle loads based on the percentage of high-efficacy light fixtures in the dwelling, based on either a lighting audit or proposed lighting design.
Public Input No. 3236-NFPA 70-2023 (Section No. 220.41)
Public Input No. 3239-NFPA 70-2023 (Section No. 220.82(B))
Public Input No. 3242-NFPA 70-2023 (Section No. 220.84(C))

National Electrical Code Sections Discussed in This Brief

Text reproduced from the 2022 California Electrical Code and the 2023 National Electrical Code. The 2022 California Electrical Code is based on the 2020 NEC model code.[35] The 2023 NEC will be the model code for the 2025 California Electrical Code.

1. 220.83 Existing Dwelling Unit

Version from 2022 California Electrical Code is reproduced below. 2023 NEC 220.83 makes minor changes that aren't material to this policy brief.

220.83 Existing Dwelling Unit. This section shall be permitted to be used to determine if the existing service or feeder is of sufficient capacity to serve additional loads. Where the dwelling unit is served by a 120/240-volt or 208Y/120-volt 3-wire service, it shall be permissible to calculate the total load in accordance with 220.83(A) or (B).

(A) Where Additional Air-Conditioning Equipment or Electric Space-Heating Equipment Is Not to Be Installed. The following percentages shall be used for existing and additional new loads.

Load (kVA)	Percent of Load
First 8 kVA of load at	100
Remainder of load at	40

Load calculations shall include the following:

(1) General lighting and general-use receptacles at 33 volt-amperes/m^2 or 3 volt-amperes/ft^2 as determined by 220.12
(2) 1500 volt-amperes for each 2-wire, 20-ampere small-appliance branch circuit and each laundry branch circuit covered in 210.1 (1)(C)(1) and (C)(2)
(3) The nameplate rating of the following:
  (a) All appliances that are fastened in place, permanently connected, or located to be on a specific circuit
  (b) Ranges, wall-mounted ovens, counter-mounted cooking units
  (c) Clothes dryers that are not connected to the laundry branch circuit specified in item (2)
  (d) Water heaters

(B) Where Additional Air-Conditioning Equipment or Electric Space-Heating Equipment Is to Be Installed. The following percentages shall be used for existing

(2) 1500 volt-amperes for each 2-wire, 20-ampere small-appliance branch circuit and each laundry branch circuit covered in 210.1 (1)(C)(1) and (C)(2)
(3) The nameplate rating of the following:
  (a) All appliances that are fastened in place, permanently connected, or located to be on a specific circuit
  (b) Ranges, wall-mounted ovens, counter-mounted cooking units
  (c) Clothes dryers that are not connected to the laundry branch circuit specified in item (2)
  (d) Water heaters

[35] National Fire Protection Association, 2024, https://www.nfpa.org/education-and-research/electrical/nec-enforcement-maps.

and additional new loads. The larger connected load of air conditioning or space heating, but not both, shall be used. Load (kVA) — Percent of Load Air-conditioning equipment — 100 Central electric space heating — 100 Less than four separately controlled space-heating units — 100 First 8 kVA of all other loads — 100 Remainder of all other loads — 40 Other loads shall include the following: (1) General lighting and general-use receptacles at 33 volt-amperes/m^2 or 3 volt amperes/ft^2 as determined by 220.12	

2.220.87 Determining Existing Loads

Specifies that "actual maximum demand" can be used to determine load. The text is silent on what forms of data are acceptable for making this demand calculation. The exception for homes with less than one year of demand data specifies that 15-minute interval data from a recording ammeter or power meter (such as a smart meter) is acceptable to calculate demand. Some interpret the section as requiring a measure of instantaneous demand (i.e., not 15-minute interval smart meter data) if there is at least a year of data for a home.

2022 California Electrical Code	2023 NEC Moves the text of the second exception to be included as part of the first exception (highlighted in gray). The change makes clear that only units with less than a year of demand data are disqualified from using 220.87 if they have renewable energy or peak load shaving.
220.87 Determining Existing Loads. The calculation of a feeder or service load for existing installations shall be permitted to use actual maximum demand to determine the existing load under all of the following conditions: (1) The maximum demand data is available for a 1-year period. Exception: If the maximum demand data for a 1-year period is not available, the calculated load shall be permitted to be based on the maximum demand (the highest average kilowatts reached and maintained for a 15-minute interval) continuously recorded over a minimum 30-day period using a recording ammeter or power meter connected to the highest loaded phase of the feeder or service, based on the initial loading at the start of the recording. The recording shall reflect the maximum demand of the feeder or service by being taken when the building or space is occupied and shall include by measurement or calculation the larger of the heating	**220.87 Determining Existing Loads.** The calculation of a feeder or service load for existing installations shall be permitted to use actual maximum demand to determine the existing load under all of the following conditions: (1) The maximum demand data is available for a 1-year period. Exception: If the maximum demand data for a 1-year period is not available, the calculated load shall be permitted to be based on the maximum demand (the highest average kilowatts reached and maintained for a 15-minute interval) continuously recorded over a minimum 30-day period using a recording ammeter or power meter connected to the highest loaded phase of the feeder or service, based on the initial loading at the start of the recording. The recording shall reflect the maximum demand of the feeder or service by being taken when the building or space is occupied and shall include by measurement or calculation the larger of the heating or cooling equipment load, and other loads that might be periodic in nature due to seasonal or similar conditions.

or cooling equipment load, and other loads that may be periodic in nature due to seasonal or similar conditions. (2) The maximum demand at 125 percent plus the new load does not exceed the ampacity of the feeder or rating of the service. (3) The feeder has overcurrent protection in accordance with 240.4, and the service has overload protection in accordance with 30.90. Exception: If the feeder or service has any renewable energy system (i.e., solar photovoltaic systems or wind electric systems) or employs any form of peak load shaving, this calculation method shall not be permitted.	This exception shall not be permitted if the feeder or service has a renewable energy system (i.e., solar photovoltaic or wind electric) or employs any form of load shaving. (2) The maximum demand at 125 percent plus the new load does not exceed the ampacity of the feeder or rating of the service. (3) The feeder has overcurrent protection in accordance with 240.4, and the service has overload protection in accordance with 230.90.

3. 220.60 Noncoincident Loads

Version from 2022 California Electrical Code is reproduced below. 2023 NEC 220.83 makes minor changes that aren't material to this policy brief.

220.60 Noncoincident Loads. Where it is unlikely that two or more noncoincident loads will be in use simultaneously, it shall be permissible to use only the largest load(s) that will be used at one time for calculating the total load of a feeder or service. Where a motor is part of the noncoincident load and is not the largest of the noncoincident loads, 125 percent of the motor load shall be used in the calculation if it is the largest motor.	

4. 220.70 Energy Management Systems (EMSs)

Version from 2023 NEC is reproduced below. 220.70 is new in the 2023 NEC.

220.70 Energy Management Systems (EMSs). If an energy management system (EMS) is used to limit the current to a feeder or service in accordance with 750.30, a single value equal to the maximum ampere setpoint of the EMS shall be permitted to be used in load calculations for the feeder or service. The setpoint value of the EMS shall be considered a continuous load for the purpose of load calculations.	

5. Article 750 from 2023 NEC

Adds a definition of energy management systems that was absent in the 2020 NEC and 2022 California Electrical Code.

Energy Management System. The definition shall apply within this article and throughout the *Code*. A system consisting of any of the following: a monitor(s), communications equipment, a controller(s), a timer(s), or other device(s) that monitors and/or controls an electrical load or a power production or storage source.	

6. 220.84 Multifamily Dwelling

Version from 2022 California Electrical Code is reproduced below. 2023 NEC 220.83 makes no material changes.

220.84 Multifamily Dwelling

(A) Feeder or Service Load. It shall be permissible to calculate the load of a feeder or service that supplies three or more dwelling units of a multifamily dwelling in accordance with Table 220.84 instead of Part III of this article if all the following conditions are met:

(1) No dwelling unit is supplied by more than one feeder.
(2) Each dwelling unit is equipped with electric cooking equipment.

Exception: When the calculated load for multifamily dwellings without electric cooking in Part III of this article exceeds that calculated under Part IV for the identical load plus electric cooking (based on 8 kW per unit), the lesser of the two loads shall be permitted to be used.

(3) Each dwelling unit is equipped with either electric space heating or air conditioning, or both. Feeders and service conductors whose calculated load is determined by this.

Table 220.84 Optional Calculations—Demand Factors for Three or More Multifamily Dwelling Units

Number of Dwelling Units	Demand Factor (%)
3-5	45
6-7	44
8-10	43
11	42
12-13	41
14-15	40
16-17	39

18-20	38
21	37
22-23	36
24-25	35
26-27	34
28-30	33
31	32
32-33	31
34-36	30
37-38	29
39-42	28
43-45	27
46-50	26
51-55	25
56-61	24
62 and over	23

Optional calculation shall be permitted to have the neutral load determined by 220.61.

(B) House Loads. House loads shall be calculated in accordance with Part III of this article and shall be in addition to the dwelling unit loads calculated in accordance with Table 220.84.

(C) Calculated Loads. The calculated load to which the demand factors of Table 220.84 apply shall include the following:

(1) 33 volt-amperes/m^2or 3 volt-amperes/$ft^2$for general lighting and general-use receptacles
(2) 1500 volt-amperes for each 2-wire, 20-ampere small-appliance branch circuit and each laundry branch circuit covered in 210.11(C)(1) and (C)(2)
(3) The nameplate rating of the following:
    a. All appliances that are fastened in place, permanently connected, or located to be on a specific circuit
    b. Ranges, wall-mounted ovens, counter-mounted cooking units
    c. Clothes dryers that are not connected to the laundry branch circuit specified in item (2)
    d. Water heaters
(4) The nameplate ampere or kVA rating of all permanently connected motors not included in item (3)
(5) The larger of the air-conditioning load or the fixed electric space-heating load

Responses to Information Requests From California State Senator Wiener

In January 2023 and again in January 2024, the office of Senator Wiener sent information requests to investor-owned utilities (IOUs) on their energization timelines.

The first question was, “How many new multi-family residential or commercial construction projects have been green-tagged and are in the queue to be energized for longer than 30, 60 or 90 days, by IOU service?”

These responses indicate that Southern California Edison (SCE) was able to energize all projects in its queue within 12 weeks; San Diego Gas & Electric (SDG&E) was able to energize all projects in 30 days with a few exceptions; and Pacific Gas & Electric (PG&E) did not have a maximum length of time within which nearly all projects were energized.

Below are responses from PG&E, SCE, and SDG&E.

PG&E

	Calendar Days Since Construction-Ready				
Work Type	**0–30 Days**	**31–60 Days**	**61–90 Days**	**> 90 Days**	**Grand Total**
Commercial	91	46	32	70	239
Multifamily	33	15	7	25	80
Grand Total	**124**	**61**	**39**	**95**	**319**

SCE

	Workdays Since Construction-Ready			
Work Type	**0–30 Workdays**	**31–60 Workdays**	**61–90 Workdays**	**Grand Total**
Commercial	67	12	0	79
Multifamily	27	5	0	32
Grand Total	**94**	**17**	**0**	**111**

SDG&E

SDG&E interprets the definition of “green-tagged” as: applicant has met all project requirements, has received sign-off from inspection, and is ready to be energized; the project is now in the queue to be scheduled. With few exceptions, primarily related to supply chain issues on certain transformer types, SDG&E is able to energize within 30 days once all project requirements are met and have received final sign-off from inspection.

Calculations Showing Aggregate Cost for Households If 50% of California Dwellings Upsize Their Panels and Service

Unit Explanation	Units	Weight	Source
Homes that upsize panels and service	50%	1	
Homes in California (single and multifamily)	13 million	1	A
Mean cost of panel replacement	$4,000	1	B
Cost for 20% of service upgrades	$0	0.2	C
Cost for 55% of service upgrades	$4,750	0.55	C
Cost for 20% of service upgrades	$22,000	0.2	C
Cost for 5% of service upgrades	$32,500	0.05	C
Aggregate cost	$62.3 billion		

Notes: Costs for service upgrades are a blend of overhead and underground service upgrades under 400 amps, assuming a $3,000 utility allowance.

Sources:
A. U.S. Census Bureau, "American Community Survey," 2021, https://www.census.gov/programs-surveys/acs/data.html.
B. E Source, Enhancing the Customer Experience of Upgrading an Electric Service Panel, Building Decarbonization Coalition, 2022, https://buildingdecarb.org/wp-content/uploads/BDC-Panel-Upgrade-Report.pdf.
C. PG&E, "Building and Renovation Services—Project Cost Range," https://www.pge.com/en/account/service-requests/building-and-renovation/services-guides.html. Accessed March 7, 2024.

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