Power Efficient Management Report

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Introduction

Overview of Power-Efficient Management

Electrification of the existing single-family residential housing stock is essential to meet California's goals to be carbon neutral by 2045, reduce carbon emissions by 85% from 1990 levels (AB 1279), and ensure 100% of electricity comes from renewable and zero-carbon resources (SB 100). Achieving these targets requires "home electrification"—switching to electricity as the fuel source for heating, hot water, cooking, and clothes drying—while also accommodating the increasingly common additions of solar photovoltaic (PV) and electric vehicle (EV) charging.

However, as households transition away from legacy fossil-fuel-based equipment, the primary electrical constraint is often no longer total energy use, but peak power demand and the amount of electrical infrastructure needed to support it. A major barrier to home electrification is the cost and time delays associated with the perceived need to replace service panels and utility services. The need to replace panels can result from physical space constraints (i.e., a lack of available breaker slots) and/or electrical load constraints (i.e., insufficient power or amperage capacity). These constraints are most common in homes with electrical panels rated at 100 amps (A) or less. Current estimates suggest one-third of California's single-family housing stock has 100A panels or smaller[1][2][3], and only 40% of California homes have 5 or more unused breaker spaces to accommodate new equipment. These challenges are expected to disproportionately affect lower-income households and disadvantaged communities (DAC).

Traditionally, when a panel lacks the capacity to accommodate new electric loads, the default approach has been an expensive and disruptive service upsize. An evaluation of 329 CA single-family homes by the CPUC found that 33% and 19% of their sample were breaker space and capacity constrained, respectively[4]. If all constrained homes in California were to upsize to a 200A service and panel, we estimate it would add an estimated $10 billion in costs (at a conservative

[1] Murphy, Sean, Lixi Liu, Brennan Less, et al. 2026. "Characterizing Electrical Panel Capacity, Breaker Space, and Loads in U.S. Single-Family Homes." *Journal of Building Engineering* 120 (February): 115576. https://doi.org/10.1016/j.jobe.2026.115576.

[2] Fournier, Eric Daniel, Robert Cudd, Samantha Smithies, and Stephanie Pincetl. 2024. "Quantifying the Electric Service Panel Capacities of California's Residential Buildings." *Energy Policy* 192 (September): 114238. https://doi.org/10.1016/j.enpol.2024.114238.

[3] Less, Brennan D., Iain S. Walker, Sean P. Murphy, and Eric Fournier. 2024. "Electrical Service Panel Capacity in California Households with Insights for Equitable Building Electrification." Paper presented at ACEEE Summer Study on Energy Efficiency in Buildings. *ACEEE Summer Study on Energy Efficiency in Buildings*, August. https://www.aceee.org/sites/default/files/proceedings/ssb24/event-data/bio/YmRsZXNzQGxibC5nb3Y%3D#:~:text=Panel%20Capacity%20in-,California,-Households%20with%20Insights.

[4] Guidehouse Inc. and Opinion Dynamics Corporation. 2024. *Fuel Substitution Behind the Meter Infrastructure Market Study*. Final Report No. 221115. California Public Utilities Commission. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/building-decarb/fs-infra-ms_overall-report_20240606.pdf.

estimate of $4,500 per panel). Furthermore, increasing household peak electric demand leads to massive utility grid infrastructure upgrades—such as replacing transformers, distribution wires, and adding generation—which could cost orders of magnitude more and increase future costs for all ratepayers[5]. Power efficiency is a viable alternative that maintains safe, reliable, and comfortable homes while managing these electrical capacity and physical space constraints through smarter technology choices and design strategies.

Presently, technologies and strategies are accessible that can reduce electrical demand without sacrificing functionality. In some cases, this is achieved by selecting lower-power equipment. In others, it is accomplished through load management, shared circuits, or other design approaches that reduce the impact of new loads on the home's electrical system. These choices interact with the National Electrical Code (NEC)[6] through specific calculation methods, demand factors, and installation requirements that can support avoiding an electrical service upsize.

Purpose of this Report

This report is intended for homeowners, contractors, electricians, program administrators, policymakers, and other stakeholders seeking practical pathways to electrify existing single-family homes without unnecessary electrical panel or service upsizing. It is designed to support equipment selection, and code-compliant decision-making, and planning.

Additionally, this report serves as foundational knowledge for a broader statewide initiative led by Build It Green (BIG) in partnership with Central California Asthma Collaborative (CCAC), Good Gridizen, Home Energy Analytics (HEA), Lawrence Berkeley National Lab (LBNL), QuitCarbon, Redwood Energy, SPUR, and TRC Engineers Inc.. This team is pooling its expertise to develop, validate, and demonstrate a free, open-source electrification decision tool (i.e. the Home Power Planner Tool) for existing single-family homes. By utilizing the power-efficient technologies, NEC calculation methods, and other strategies to add electrical loads on smaller panels outlined in this report, the Home Power Planner Tool will allow more users to access cost-effective, power-efficient plans easily without needing prior knowledge. Furthermore, this project aims to increase market confidence, speed up contractor planning processes, and provide software developers and researchers with scalable modules to accelerate the energy transition.

How to Use this Report

This report is intended to be a resource to understand the key factors to stay on existing panels while adding electrical loads, while providing strategies and tools to undertake electrification

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[5] Priyadarshan, Constance Crozier, Kyri Baker, and Kevin J. Kircher. 2025. "Distribution Grids May Be a Barrier to Residential Electrification." *Cell Reports Sustainability*, September, 100518. https://doi.org/10.1016/j.crsus.2025.100518.

[6] NFPA 70. NFPA is the National Fire Protection Association and is the standards body that advances the National Electrical Code, also called NFPA 70. States and localities adopt this code in part or in full based on the publication year. https://www.nfpa.org/codes-and-standards/nfpa-70-standard-development/70

projects with a power-efficient mindset. The sections that follow review appliance and equipment options in each major end-use category, including cooking, clothes drying, water heating, space heating and cooling (i.e., HVAC[7]), EV charging, and pool/spa/hot tub equipment. Additional sections address load controls, adding new power sources, NEC considerations, panel space saving strategies, other considerations, calculation tools, and emerging innovations. An outline of these sections along with brief descriptions is provided below:

- **Section 1 - Appliances and Equipment:** A review of power-efficient alternatives across major end-uses, including cooking, laundry, space heating and cooling, and EV charging.
- **Section 2 - NEC Primer for 220.83 and 220.87:** A guide to understand how to employ the National Electrical Code (NEC) load calculation methods for NEC 220.83 and 220.87 to maximize existing panel capacity for existing single-family homes. This section will provide an overview on the load considerations in selection of differing appliances, equipment, and load controls.
- **Section 3 - Load Controls:** A review of systems (such as circuit-sharing and Power Control Systems) that control single or multiple loads to support lowering power demand on a home's panel.
- **Section 4 - Adding New Power Sources:** Strategies are spotlighted for safely attaching large solar arrays, battery storage systems, or other power sources to 100A panels.
- **Section 5 - Panel Space Saving Strategies:** Practical approaches are shared—like multi-circuit breakers and subpanels—to physically fit new circuits into a panel when space is constrained. Physical space in the panel could become a more common barrier for home electrification even if it has capacity to fit all their new electrical loads.
- **Section 6 - Other Considerations:** An outline of other existing house factors to potentially take into account when implementing electrification projects in general.
- **Section 7 - Panel Calculation Tools:** A comparative analysis of available digital tools designed to assist with electrification planning and/or NEC-compliant load calculations.
- **Section 8 - Emerging Innovations:** A look at emerging trends and hardware that will continue to shape power-efficient home management.

Finally, this report includes several Appendices that provide deeper technical context and supplementary data for specific topics. For readers who may be less familiar with general electrical systems, Appendix A: Electrical Terms and Details serves as a foundational resource. It offers a clear breakdown of common electrical terms and technical details – providing a helpful starting point before diving into the more specialized sections of the report.

Important Notes

The prices and product characteristics presented throughout this report are based on available market data, published sources, and convenience samples at the time of writing. Actual costs, availability, model specifications, and local code interpretations may vary by region, installer, and

[7] Heating, Ventilation, and Air Conditioning

project conditions. Final equipment selection and installation decisions should be verified by qualified professionals.

Section 1 - Appliances and Equipment

Overview of Power-Efficient Appliances and Equipment

Energy-efficiency in homes is a concept with a long history and is well-developed and understood. Power-efficiency is a new concept that is related to the maximum power a home (or individual end-use) uses, rather than its energy use. Maximum power is becoming increasingly important because we want to avoid the costs and time delays associated with electrical equipment replacement required to accommodate higher power needs, both from a home's and grid perspective. A key challenge for power efficiency is that it is in direct contradiction to current practice that favors upsized electric panels, oversized appliances, etc. This work is establishing power efficiency as a viable alternative that maintains safe, reliable and comfortable homes.

Choosing the right appliances and equipment is the first step in designing a power-efficient home, whether a project is a new build or a renovation to an existing space. These choices affect how much power the home needs, energy bills, and the overall daily experience. Selecting power-efficient models can: (1) help reduce the total power demand and avoid the high cost of upsizing an electrical panel, and/or (2) use fewer breaker "slots" for new equipment and avoid the need for panel replacement or subpanel. Additionally, some modern appliances are easier and cheaper to install and can even be controlled digitally to save energy during peak times.

The subsections below review appliance and equipment options in each end-use category, including cooking, clothes drying, water heating, Heating, Ventilation, and Air Conditioning (HVAC), electric vehicle charging, and pool/spa/hot tub equipment. The contents focus on describing power-efficient options and considerations, and comparing them against conventional options in the same categories.

There are considerable price variations between technologies, so we have given potential pricing guidance at the time of writing this document. Note that within each category there are often large variations depending on features, brands, etc. These can be greater than the differences between different equipment types. For some devices, the available information does not always allow for a price range estimate. In these cases we have provided a single value that is our current best estimate. Specific products available on the market are tabulated in Appendix B1: Specific Appliances & Equipment in the Market.

National Electrical Code (NEC)

Electricians use NEC to ensure that home electric systems are safe and reliable. The NEC includes calculation procedures to figure out how much power a home needs and the required electric panel capacity. The reduced requirements for power-efficient appliances and equipment can be reflected

in NEC calculations and provide industry and code officials with the technical background to support avoiding panel replacement. The NEC includes "demand factors" that acknowledge that not all end-uses operate at the same time, and also derate some appliances (such as for cooking). This often makes it easier to add new loads without having to upsize your entire electrical service. In this report we refer the reader to the appropriate NEC sections for each appliance or piece of equipment.

Power-Efficient Appliance Types

Appliances can be grouped by the specific ways they help manage home electricity demand:

- **Low-power appliances:** Devices designed to do the same job while using less power than standard models.
- **Combined appliances:** Machines that perform multiple roles (like a combination washer/dryer), which saves space and avoids needing separate, dedicated electrical circuits.
- **Battery-integrated appliances:** Appliances with built-in batteries that can store energy, allowing them to draw less power from the home's main system during use.
- **Load shed appliances:** Appliances that can automatically pause or reduce their power use when they receive a signal or based on a schedule.

Appliance Electrical Features

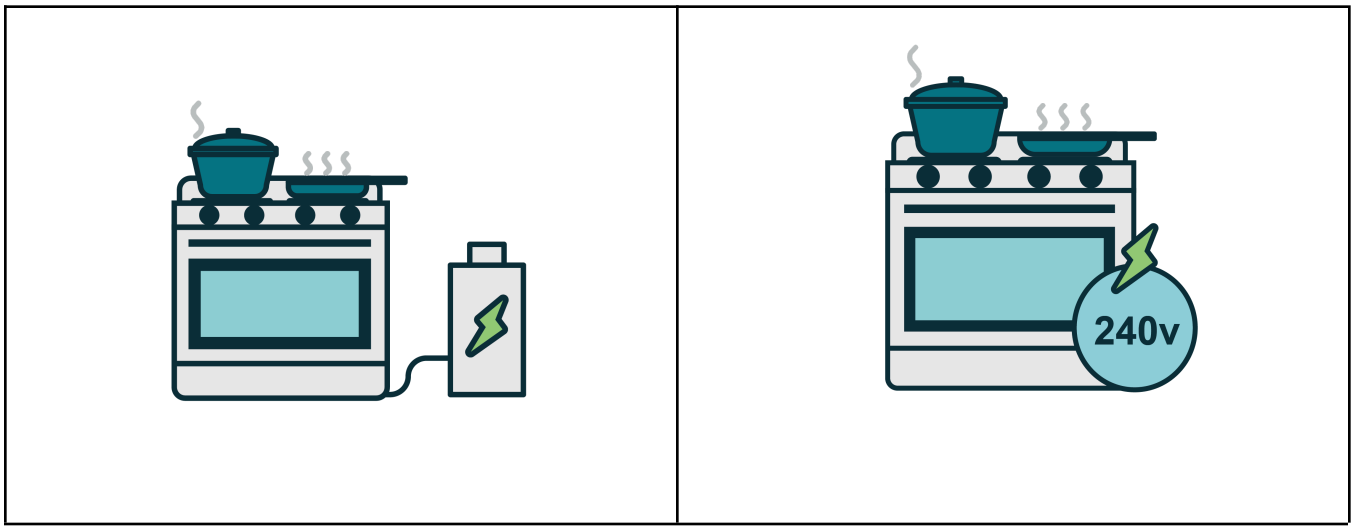
When adding an appliance, there are six key electrical factors to consider:

1. **Voltage (Volts, V):**. Most small items use standard 120V outlets, while large appliances often need 240V. Note that some 120V appliances require a dedicated circuit and others do not.
2. **Current (Amps, A):** Appliances that draw more current need thicker wires and larger breakers.
3. **Power (Watts or Volt-Amperes, W or VA):** Power represents the rate of electricity use. This may be listed on a "nameplate" sticker on the back of the appliance, or can be calculated as the rated volts times the rated amps.
4. **Connection Type:** Whether the device simply plugs into a wall outlet or must be "hardwired" directly into the home's electrical system by a professional.
5. **Number of Required circuits**: Most high power end uses require their own dedicated circuit together with a breaker in the electrical panel. Limit space for adding breakers to a panel needs to be considered. Options to avoid replacing the panel are to use a subpanel or replace some breakers with tandem circuit breakers (where two circuits share a single standard breaker slot).
6. **Dedicated vs Shared Circuits**: Many appliances with higher power ratings are required to be installed on a dedicated circuit that serves only that one single device. This requirement could stem from the electrical code or manufacturer's installation instructions. Other

appliances are permitted to be installed on a general purpose shared circuit that serves a variety of devices, such as overhead lights and wall receptacles.

Additional technical details on these electrical features are provided in Appendix A: Electrical Terms and Details.

Cooking



While there are many ways to save power in the kitchen, finding power-efficient options that look and feel like a standard stove can be a challenge. Some solutions can reduce a stove's power rating by 80% to 90%. However, these are usually non-traditional—like portable countertop burners—or are more expensive, such as stoves with built-in batteries.

A middle-ground approach is to select smaller, high-quality standard equipment with fewer cooktop burners, or that combine cooktop and oven into a single device (i.e., a traditional range). These can reduce power needs by 20% to 30%. Cooking equipment often has the highest power requirements of any appliance in the home. Even though they can use a lot of power, most households rarely cook using the full capacity, meaning they do not actually contribute much to the home's "peak" power demand[8].

Types of Cooking Appliances

- **Cooktop:** A surface with burners for pots and pans. These can be gas or electric, which includes resistance elements/hotplates, radiant glass cooktop or induction (which uses an electromagnetic field to heat the pan directly).
- **Oven:** An enclosed space for baking or roasting. Most use gas or electric resistance heating elements.

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

- **Range (or "Stove"):** A single unit that combines both a cooktop and an oven(s). In this report, the terms "Range" and "Stove" are used interchangeably.

Strategies

If looking to reduce the home's peak power, consider these strategies in the kitchen:

- **Fewer Burners:** Choose a 3 or 4-burner cooktop instead of a 5 or 6-burner model.
- **Single Ovens:** Avoid double ovens if multiple large dishes are not frequently cooked at once.
- **Avoid "Boost" Modes:** Features like "Power Boil" significantly increase the power draw.
- **Battery-Integrated Units:** These can plug into a standard outlet but perform like a high-powered stove by using stored battery energy[9].
- **120V Managed Ranges:** These use smart technology to limit the total power used by the burners and oven at the same time, but without integrated batteries.

Real-World Cooking Habits

Most of the time, households only use two burners or less while cooking. Additionally, most cooking events last less than an hour. This data is helping manufacturers create new, power-efficient 120V induction ranges that plug into standard outlets but can still handle the needs of most families.

Summary Specifications on Cooking Appliances

Table 1. Power Specifications for Cooktops, Ovens, and Ranges

Cooking Appliance	Low Power	Volts	Amps	Power (W[10])	Breaker Slots Required[11]	Dedicated Circuit Required	Potential Price[12]
Cooktop							
Induction (4-burner)	No	240	37	9,000	2	Yes	$900 - $2200
Induction (5-burner)	No	240	46	11,000	2	Yes	$1700 - $2300

[9] Anderson, Dylan et al.“120V Induction Stoves with Battery Backup.” CalNEXT. Accessed April 21, 2026. https://calnext.com/wp-content/uploads/2025/01/ET23SWE0064_120V-Induction-Stoves-with-Battery-Backup_Final-Report.pdf.
[10] NEC load calculations are done in volt-amperes (volts x amps, va). In this report, we use the term “watts”, as most readers are more familiar with this terminology. For purely resistive loads, volt-amperes = watts. For loads with power factors < 1, watts are a marginal underestimate of the va.
[11] A zero indicates that the cooking appliance can use an existing kitchen circuit.
[12] For a 30 in. unit - not including installation or new electrical wiring.

Cooking Appliance	Low Power	Volts	Amps	Power (W)	Breaker Slots Required[13]	Dedicated Circuit Required	Potential Price[14]
Induction, with battery	Yes	120/240	13	1,500	0 or 1	No	$6,000
Induction, portable	Yes	120	15	1,800	0	No	$200 - $300
Cooktop							
Resistance (4-burner)	No	240	37	9,000	2	Yes	$899 - $1221
Resistance (5-burner)	No	240	46	11,000	2	Yes	N/A
Oven							
Single Oven - Resistance	Yes[15]	240	19	4,500	2	Yes	$1899 - $3099
Double Oven - Resistance	No	240	34	8,200	2	Yes	N/A
Range							
Induction with Battery	Yes	120	12	1,400	0 or 1	No	$4000 - $6000
Induction (4-burner)	No	240	48	11,500	2	Yes	$1600 - $2300
	Yes	120	15	1,800	1	No	$1400 - $1800
Induction (5-burner)	No	240	57	13,600	2	Yes	$2300 - $3000
Resistance (4-burner)	No	240	48	11,500	2	Yes	$929 - $1249
Resistance (5-burner)	No	240	57	13,600	2	Yes	N/A
Dual Fuel, Single Oven	No	240	27	6,500	2	Yes	$2000 - $3300
Dual Fuel, Dual Oven	No	240	37	8,800	2	Yes	$2000 - $3300

[13] A zero indicates that the cooking appliance can use an existing kitchen circuit.
[14] For a 30 in. unit - not including installation or new electrical wiring.
[15] Lower power option only if a separate oven is installed

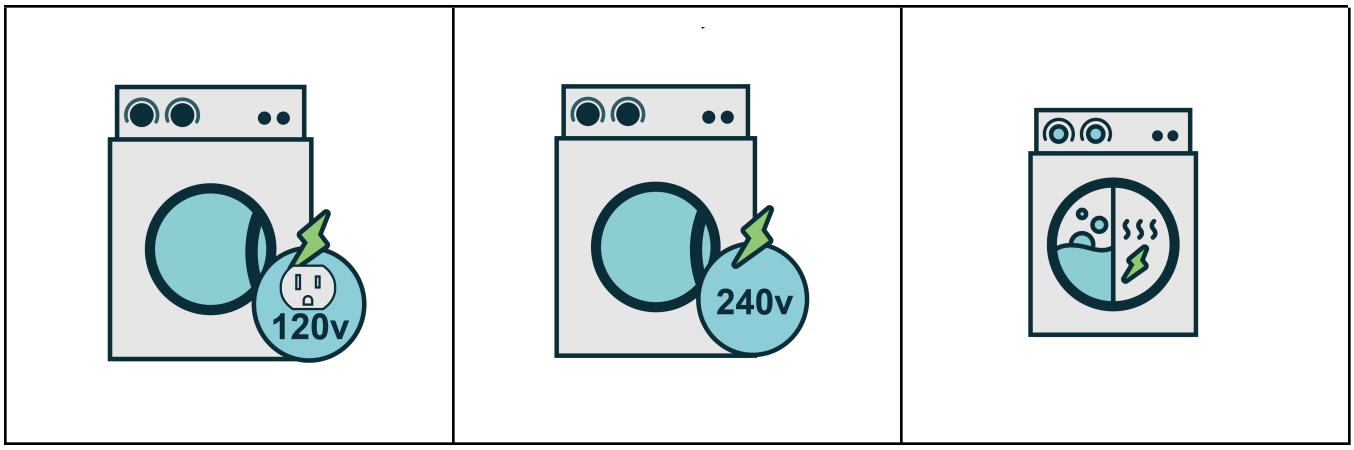
Installation & Safety

When switching from gas to electric, there are a few things to keep in mind:

1. **Wiring Upgrades:** Switching to a full 240V electric range usually requires a new, heavy-duty wire and two-pole circuit in the panel. Typical costs are around $1,400 (commonly ranging from $400-$1,600).
2. **120V Options:** Battery-powered or power-managed stoves can often use the same simple outlet your gas stove used for its clock, timer, ignition circuit, etc.
3. **Capping Appliance Gas Line:** If a gas stove is removed, the gas supply line to the stove must be capped for safety.
4. **Ventilation:** Even with electric or induction, a good vent hood is recommended to keep your kitchen air clean and humidity levels within acceptable limits.

The NEC also has specific installation requirements for cooking appliances. For more details, please refer to Appendix B2: Cooking Appliances Installation.

Laundry – Dryers



Power-efficient clothes drying options exist on the market that are capable of reducing power demand by 50 to 80%, and requiring anywhere from 0 to 2 breaker slots in the panel. Lower power options include heat pump technologies, condensing (ventless) technologies, and combined appliance types.

Types of Dryers

There are three main types of electric dryers:

Type 1: Heat Pump Dryers

Heat pump dryers are newer to the market, are unvented, and use a heat pump element to dry clothes. Several evaluations have documented the installed performance of heat pump clothes dryers in Florida homes[16] and in the Upper Midwest[17].

- **Power efficiency:** These are power-efficient and are most commonly rated at 240V and less than 1 kW. Only one 120V unit is available in US markets. All heat pump dryers reduce power demand, but 240V units require two breaker spaces just like traditional resistance electric dryers.
- **Other features:** They often have similar drum sizes to traditional dryers, so they can accept the same size load of laundry.
- **Drawback:** A drawback of heat pump dryers is that they can take a bit longer to dry clothes than an electric resistance or gas dryer. They also need a drain line for condensate or manual emptying of a tank, and also require frequent cleaning of lint filter(s).

Type 2: Combination Washer/Dryers

Combination washer/dryers (also known as all-in-one washer/dryer or washer dryer combo) combine washing and drying into a single device. Most 120V combination units are unvented, whereas the 240V options are vented.

- **Heat pump version:** The heat pump combination washer/dryers are faster and energy efficient, delivering clean dry clothes in approximately two hours.
- **Condensing version:** The condensing combination washer/dryers are slower and use more resistance electric energy per load while delivering clean dry clothes in about 3 hours.
- **Power efficiency:** The heat pump combination washer/dryers are power-efficient and operate on the regular 120V washing machine receptacle.
- **Benefit:** A primary benefit is that clothes do not need to be moved between two machines in order to complete an entire washing and drying cycle. Also unvented dryers do not need a vent and simplifying installation.
- **Drawbacks**: A drawback of 120V dryers is that they can take a bit longer to dry clothes than 240V options or a gas dryer. They also have slightly smaller drum sizes than stand-alone dryers.

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[16] Martin, E., Sutherland, K., & Parker, D. (2016, August). Measured Performance of Heat Pump Clothes Dryers. ACEEE Summer Study on Energy Efficiency in Buildings. ACEEE Summer Study on Energy Efficiency in Buildings. https://www.aceee.org/files/proceedings/2016/data/papers/1_160.pdf

[17] Pigg, S., Lord, M., Schoenbauer, B., & Bensch, I. (2021). Field and market assessment of heat pump clothes dryers (Conservation Applied Research and Development (CARD) FINAL Report Contract 139379). Slipstream. https://slipstreaminc.org/sites/default/files/documents/research/heat-pump-clothes-dryers.pdf

Type 3: Electric Resistance Dryers

Electric resistance dryers are the traditional electric choice.

- **Vented version:** Most electric dryers are vented outdoors to expel moisture. These have electrical ratings of 5-6 kW at 240V.
- **Unvented, condensing version:** Condensing electric resistance dryers condense and drain moisture through a plumbing pipe, and they avoid venting exhaust air to outside. These dryers typically have power ratings roughly half of their vented counterparts'.
- **Power efficiency:** Vented units are not considered power-efficient because of the high power draw of the electric resistance heating element (5-6 kW). Unvented options offer a moderately lower power option for those looking to avoid heat pump or combination appliances.

Summary Specifications on Dryers

Table 2. Specifications for Clothes Dryers

Dryer Type	Low Power	Volts	Amps	Power (W)	Breaker Slots Required	Potential Price[18]
Heat Pump Dryer (unvented)	Yes	240	3.3	800	2	$1,300 - $2,300
		120	8.3	1,000	0	$1,600
Combination Washer/Dryer - Heat Pump	Yes	120	13	1,600	0	$1200 - $3000
Combination Washer/Dryer - Condensing	Yes	120	12	1,200	1	$1,400
	No	240	24	5,760	2	$3,000
Combination washer/dryer (vented)	Yes	120	12	1,400	1	$1,700
	No	240	30	~5,000	2	$2,000
Electric Resistance Dryer (condensing/unvented)	No	240	11	2,600	2	$1,100 - $1,600
Electric Resistance Dryer (vented)	No	240	24	5,670	2	$700 - $1,100

[18] Not including installation or new electrical wiring

Installation & NEC

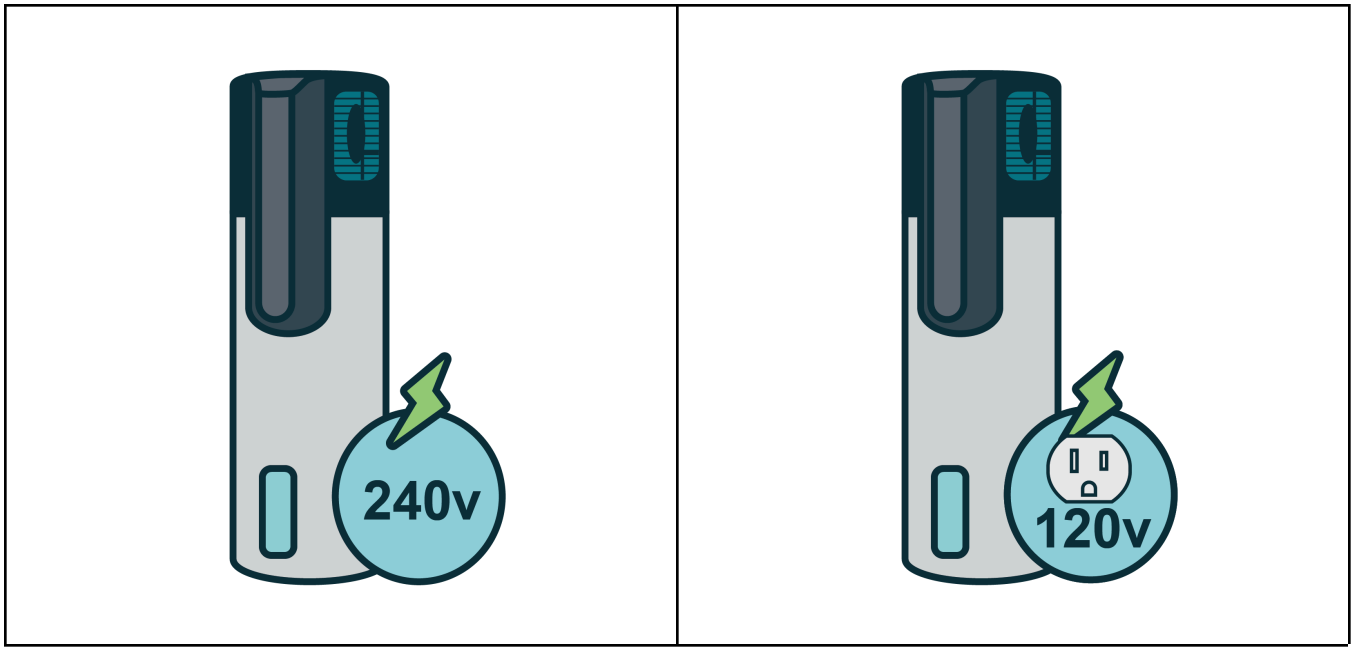
The following are installation considerations when replacing and electrifying an existing dryer:

- **Replacing existing gas dryer**. Requires installation of a new 240V branch circuit to serve the new dryer, unless a 120V unit is selected that can re-use the existing dryer outlet.
- **Replacing dryer and washer with 120V Combination Washer/Dryer**. This is the easiest of the installs and simply connects to all the same ports as the prior washing machine (i.e. 120V receptacle, hot water line, cold water line and drain line).
- **Replacing existing electric resistance dryer**. Can re-use existing 240V receptacle for new dryer. If replaced with a 120V clothes dryer, one can re-use the existing 120V outlet. Frees up two breaker slots in the panel.
- **Existing venting**. If a vented dryer is replaced with an unvented dryer, the previous vent opening should be sealed.
- **Capping Appliance Gas Line:** If switching from a gas water heater or dryer, the old gas line will need to be capped for safety along with the exhaust vent.

NEC treatment:

- **Installation of a 120V heat pump dryers**
    - **Electrical Connection:** Dryer uses the existing clothes washer 20A, 120V receptacle outlet.
    - **NEC Treatment:** That circuit is already treated with a default of 1.5 kVA in 220.83, so the new dryer adds 0 VA to the calculated load. If using 220.87, no default values are included, so the new dryer is treated at its nameplate power rating.
- **Installation of 240V electrical dryers**
    - **Electrical Connection:** Dryer uses a new 240V circuit.
    - **NEC Treatment:** New dryer is treated at its nameplate power rating (or 5 kVA). This treatment would occur for installations of 240V dryers in spaces with no existing 240V outlet.
- **Installation of 120V heat pump combination washer/dryer**
    - **Electrical connection:** Dryer uses the existing clothes washer receptacle outlet.
    - **NEC Treatment:** Clothes washers fall under the required 20A, 120V laundry circuit provision (NEC 210.11 (C)(2)), which assumes a 1500 VA load. Since clothes washers are designed to meet this specification, they are considered load-neutral for calculation purposes and require no further consideration. This treatment would occur for installations of 120V heat pump combination washer/dryer.

Water Heating



In recent years, several new water heating solutions have entered the market that can reduce home peak power. Some of these power-efficient models are designed to plug into standard 120V wall outlets, which can save significant time and money on installation because they avoid running new wiring.

Types of Water Heaters

Water heating can be either tank (which keeps a large volume of water hot and ready) or tankless (which heats water instantly as you need it), including both electric and fuel-fired options in each category. By far the highest power demand options are electric tankless, which vary substantially by their hot water output rates. For electrifying existing water heaters, it would be most power-efficient to replace it with the tank type - i.e. storage water heaters.

Electric storage water heaters come in the following types:

Storage Type 1: 120V Heat Pump

120V heat pump water heaters (HPWHs) are the most power-efficient electric options. They work like a refrigerator in reverse, pulling heat from the surrounding air to warm the water. Measured

field performance of 120V HPWHs has been evaluated in numerous field studies[19] [20] [21]. Most of these are integrated units with the heat pump physically connected to the storage tank. Some integrated units include a small electric resistance heating element, making them a hybrid. 120V HPWH also have split versions, which locate the heat pump outside and connect it to an indoor storage tank.

Storage Type 2: Hybrid Heat Pump

Hybrid HPWHs come with backup electric resistance heating elements along with their heat pump compressor. Most often, these backup heating elements are the same capacity of those in electric resistance water heaters. As a result, most 240V hybrid HPWHs are not a power-efficient solution for panel load calculations (though their actual real-time power demand may indeed be very low). Measured field performance of hybrid HPWHs has been evaluated in numerous field studies[22] [23] [24].

Storage Type 3: Electric Resistance

These use resistance heating elements and typically require a dedicated 240V circuit.

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[19] Slipstream, Focus on Energy, ComEd, Consumers Energy, and Xcel Energy. "The Midwest 120V Heat Pump Water Heater Field Study." December 20, 2024. Accessed April 21, 2026. https://slipstreaminc.org/sites/default/files/2025-03/120V%20HPWH%20-%20Field%20Study%20-%20Final%20Report.pdf.

[20] New Buildings Institute. "Plug-In Heat Pump Water Heater Field Study Findings & Market Commercialization Recommendations." August 2023. Accessed April 21, 2026. https://newbuildings.org/wp-content/uploads/2023/07/PlugInHeatPumpWaterHeaterFieldStudyFindingsAndMarketCommercializationRecommendations_NBI202308.pdf.

[21] Butzbaugh, Josh et al. “Field Study of 120-volt Heat Pump Water Heaters in the Big Easy.” 2024 ACEEE Summer Study on Energy Efficiency in Buildings. 2024. https://www.aceee.org/sites/default/files/proceedings/ssb24/pdfs/Field%20Study%20of%20120-volt%20Heat%20Pump%20Water%20Heaters%20in%20the%20Big%20Easy.pdf.

[22] Shapiro, Carl and Srikanth Puttagunta. “Field Performance of Heat Pump Water Heaters in the Northeast.” U.S. Department of Energy. February 2016. Accessed April 21, 2026. https://docs.nrel.gov/docs/fy16osti/64904.pdf.

[23] Colon, C., and D. Parker. "Side-by-Side Testing of Water Heating Systems: Results from the 2010–2011 Evaluation." U.S. Department of Energy. March 2013. Accessed April 21, 2026. https://fsec.ucf.edu/en/publications/pdf/FSEC-RR-386-12.pdf.

[24] Sparn, B., K. Hudon, and D. Christensen. "Laboratory Performance Evaluation of Residential Integrated Heat Pump Water Heaters." National Laboratory of the Rockies. June 2014. Accessed April 21, 2026. https://docs.nrel.gov/docs/fy14osti/52635.pdf.

What Makes a Water Heater "Power-Efficient"?

Many standard 240V Hybrid Heat Pump units have a high power rating, because they include backup electric resistance heating elements[25]. For power efficiency, look for other options:

- **120V HWPHs:** These plug into a standard outlet. Because they heat water more slowly, they usually require a slightly larger tank (like a 65 or 80-gallon tank instead of a 50-gallon) to ensure you do not run out of hot water. They may also store water at a higher temperature and use a mixing valve to temper water before delivery.
- **Low Power 240V Units:** These use the heat pump for most of the work and have much smaller backup resistance heating elements (e.g., 15A, 240V rated units), keeping the power draw low.
- **Split HPWH Systems:** These separate the water tank from the compressor (which is placed outside). Some of these systems use very low power, but require two breaker spaces in the electrical panel. These systems can be quieter because the compressor is outside the home, but they do require external space for the outdoor unit.
- **Combination Space and Water Heating Systems:** Some advanced systems can handle both a home's heating and hot water in one unit.

More information on sizing storage water heaters can be found in Appendix B3: Water Heater.

Summary Specifications on Water Heaters

Table 3 below lists general specifications of electric water heaters across different types.

Table 3. Specifications for Water Heaters

Water Heater Type	Low Power	Volts	Amps	Power (W)	Breaker Slots	Potential Installed Cost (Equipment + Labor) ($)	Dedicated Circuit Required
Split Heat Pump	Yes	120	7	850	1 or 0	$8,300 - $11,400	Yes
	Yes	240	7	1,700	2		Yes
Storage Heat Pump	Yes	120	7.5	900	0 or 1	*50-Gal:* $2,900 - $3,500 *66-Gal:* $4,200 - $5,500 *80-Gal:* $5,100 - $5,900	No

[25] In operation, 240V hybrid HPWHs still use much less power when operating in compressor mode, except during periods when backup heating elements are turned on.

Water Heater Type	Low Power	Volts	Amps	Power (W)	Breaker Slots	Installed Cost (Equipment + Labor) ($)	Dedicated Circuit Required
Storage Hybrid Heat Pump	Yes	120	11	1,300	0 or 1	*50-Gal:* $3,800 - $6,800 *66-Gal:* $4,300 - $6,400 *80-Gal:* $4,600 - $7,100	Yes
	Yes	240	10	2,300	2		Yes
	Yes	240	16	3,800	2		Yes
	No	240	21	5,000	2		Yes
Storage Resistance	No	240	19	4,500	2	$2,600	Yes
	No	240	23	5,500	2		Yes

Note 1: Price ranges reflect the 20-80th percentile installed cost values from a segment of the TECH Clean California and LBNL cost database. Values are normalized to 2023 $USD and US national average costs.

Note 2: Hybrid heat pumps include resistance backup heating elements along with a compressor.

Note 3: Storage Resistance water heater cost is a point estimate based on the NREL ResDB cost estimate ($1,078.80 fixed + ($2.36 * 50 gallons) + $1,384.00 for new branch circuit)

Key Installation Considerations

Excellent guidance on design and installation of HPWH for homes has been published elsewhere. Switching to a power-efficient heat pump water heater is a great move, but there are five main things to consider:

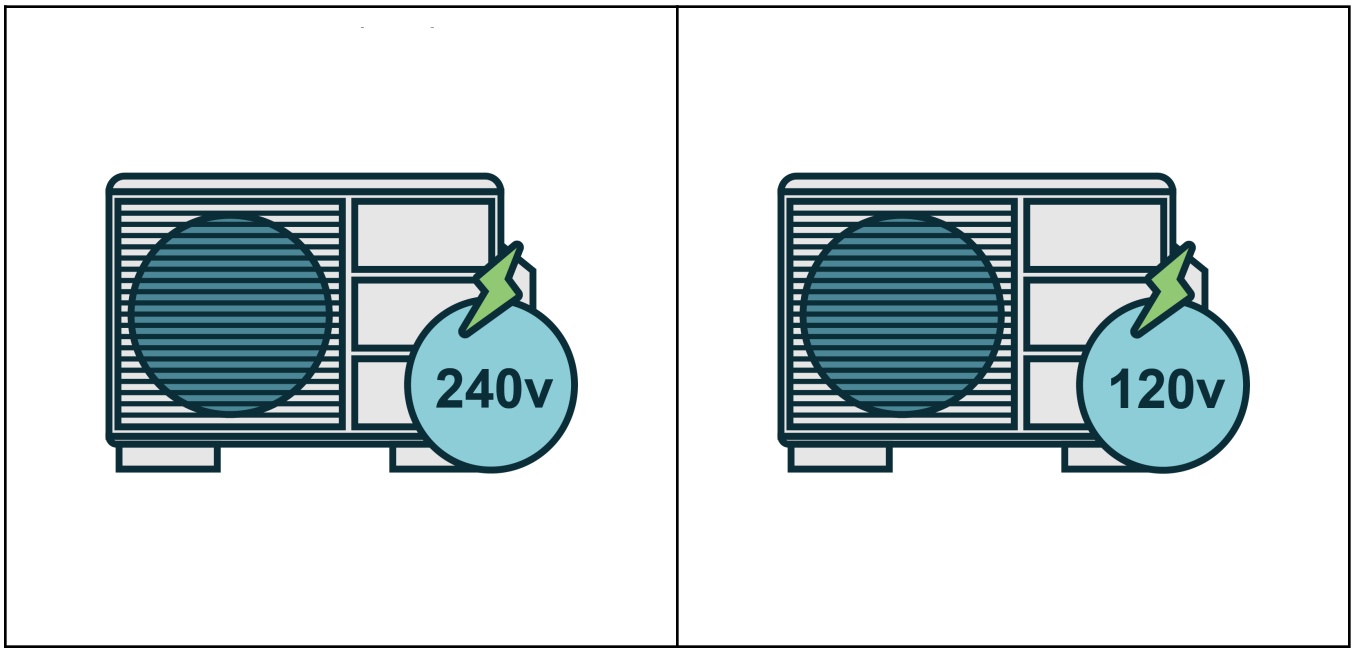
1. **Tank Size:** Since HPWHs heat water more slowly than traditional elements, one may need to go up one or two sizes (for example, moving from a 50-gallon tank to an 80-gallon tank) to reduce the risk of running out of hot water.
2. **Airflow and Venting:** Because these units pull heat from the air, they "release" cold air. They need to be in a room of a certain size, have a louvered (slotted) door or have ducts installed

so they do not overly cool themselves. Beyond manufacturer guidance, research has been done evaluating efficiency impacts of room/closet size and venting approaches.[26]

3. **Water Drainage (Condensate):** As they pull heat from the air, they also pull out moisture (like an air conditioner). This water needs to be drained away. If there is not a drain nearby, a small "condensate pump" may need to be installed.
4. **Electrical Needs:** While some can use existing 120V outlets, if that outlet is shared with other heavy appliances, a dedicated circuit to avoid tripping the breaker may be required[27].
5. **Capping Appliance Gas Line:** If switching from a gas water heater, the old gas line to the prior water heater will need to be capped for safety along with the exhaust vent.
6. **Settings:** Selection of heat pump only mode for hybrid HPWHs would minimize the use of back-up resistance heat and save energy[28].

The NEC also has specific installation requirements for water heaters. For more details, please refer to Appendix B3: Water Heater.

Space Heating and Cooling



[26] Larson, Ben, and Sam Larson. "Heat Pump Water Heaters in Small Spaces Lab Testing: 'The Amazing Shrinking Room.'" NEEA. November 2022. Accessed April 21, 2026. https://neea.org/wp-content/uploads/2025/03/Heat-Pump-Water-Heaters-in-Small-Spaces-Lab-Testing.pdf.

[27] Existing 120V circuits serving other loads can be loaded up to 50% of their capacity by a new 120V HPWH. This limits HPWH ratings to 900W (15A, 120V) or 1200W (20A, 120v) circuits. Any HPWH that exceeds these limits requires a dedicated 120V branch circuit.

[28] Besson, Amélie, Dirr, Nick, and Helen Liu. “Heat Pump Water Heater Daily Load Shifting: Advanced Load Up and Evaluation Challenges.” ACEEE Summer Study on Energy Efficiency in Buildings. 2024. Accessed August 12, 2026. https://www.aceee.org/sites/default/files/proceedings/ssb24/pdfs/Heat%20Pump%20Water%20Heater%20Daily%20Load%20Shifting%20-%20Advanced%20Load%20Up%20and%20Evaluation%20Challenges.pdf

Heating and cooling systems are often the most complex parts of a home because there are so many different types. While we provide information for all major categories, we do not currently separate them by specific efficiency ratings or their ability to handle extreme "cold-climate" conditions. In California, heat pumps have outsold furnaces every year since 2022 and the state has a goal to install 6 million heat pumps by 2030. Energy performance and emissions rules in the state are also leading to more heat pump installations. Incentive programs, such as TECH Clean California, are further encouraging heat pump adoption. This makes power efficiency considerations for heat pumps extremely important in order to reduce additional cost burdens related to electric infrastructure in homes and to reduce the added load on the electric grid.

The Heat Pump Advantage

Many California homes already have air conditioning (about 72% in 2020 according to the EIA[29]), and this number is increasing as coastal climates are experiencing warmer summers and more homeowners are adding air conditioning. Technically, an air conditioner is just a heat pump that only works in one direction (cooling). If an old air conditioner is replaced with a modern heat pump, the ability to both heat and cool a home is gained. Because the electrical requirements are similar for air conditioners and heat pumps, a new circuit, electrical panel upsize or additional breaker space is not often required.

Avoiding "Emergency" Backup Heat

The amount of power a system needs depends on its size (capacity). A major challenge in power management is electric resistance heat (sometimes called “Emergency Backup”) for use on the coldest days when heat pump capacity may be insufficient to adequately heat the home. This electric resistance heat is the same as heating elements in a hair-dryer and some heating systems are purely resistance heat: such as electric furnaces and baseboards. Because this backup heat is inefficient, it’s best to avoid it entirely. However, there is often a balance between the extra cost of a larger heat pump to cover all the building loads with the power-efficiency related costs of less electrical infrastructure being required to accommodate backup heat. Backup heat can also help increase the heat output of systems that are limited by existing ducts sized for cooling. Such ducts can be under-sized for the heating load, so some designers size the heat pump according to the cooling load and make up the difference with resistance heat.

Cold Climates and "Dual-Fuel" Systems

In parts of the country where it gets extremely cold, even a powerful heat pump might struggle to produce enough heat during the coldest hours. In these cases, a **"dual-fuel"** system may be a good solution. This uses the electric heat pump the majority of the time but switches to a gas or propane furnace when the temperature drops exceptionally low (usually around 5 degrees Fahrenheit). This prevents the need for high power electric resistance heaters, which can require 25 kW of power or

[29] U.S. Energy Information Administration. "Highlights for Air Conditioning in U.S. Homes by State, 2020." Office of Energy Demand and Integrated Statistics. March 2023. Accessed April 29, 2026. https://www.eia.gov/consumption/residential/data/2020/state/pdf/State%20Air%20Conditioning.pdf.

more. Extreme cold is rare in California, so most residents will find that a standard heat pump without gas backup or electric resistance heat works adequately. In some extremely cold California climates we might consider dual-fuel approaches, or use cold-climate heat pumps that are designed to operate efficiently as low as -20F. The choice depends on local weather conditions, the home's insulation, utility bill tariffs, and several other factors that are beyond the scope of this report.

Efficiency Tips: Thermostats and Ducts

Steady Temperatures. Many modern systems are "modulating," meaning they run most efficiently when they maintain a steady temperature. If the heat is turned down at night and way up in the morning (a "setback"), the system has to use higher power operating modes to catch up and is often less energy efficient when it does so. This only impacts electric power if a larger capacity heat pump (or backup heating) is installed to accommodate a large setback.

Efficient Ductwork. If a home uses ducts to move air, leaks and poor insulation are a large concern. Sealing and insulating ducts before buying a new unit lets a designer install a smaller heat pump, which can reduce power demand and energy use by 20-30%[30] [31] [32] [33].

HVAC Capacity Sizing

Determining the right size for a heating and cooling system is a balancing act. If a system is too small, your home will not stay comfortable on the hottest or coldest days. If it is too large, it will cost more to purchase and install and will have higher peak power requirements. There can be a tradeoff in sizing, however, if a larger heat pump avoids the need for high power backup heat it may be worthwhile from a power efficiency perspective. Figuring out this balance is best left to HVAC professionals.

Categorizing Heating and Cooling Equipment

Choosing the right heating and cooling system often comes down to how much of your home you want to condition and how the equipment is physically set up. We categorize these systems into two main groups: **where** the air goes and **type of** equipment.

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[30] Siegel, J.A., McWilliams, J.A., and Walker, I.S. (2003). "Comparison Between Predicted Duct Effectiveness from Proposed ASHRAE Standard 152P and Measured Field Data for Residential Forced Air Cooling Systems". ASHRAE Trans., Vol. 109., Pt.1, pp. 503-512, ASHRAE, Atlanta, GA. LBNL 50008.
[31] Jump, D.A., Walker, I.S. and Modera, M.P., (1996), "Field Measurements of Efficiency and Duct Retrofit Effectiveness in Residential Forced Air Distribution Systems.", Proc. ACEEE 1996 Summer Study, Vol. 1 pp. 147-156. American Council for an Energy Efficient Economy, Washington, D.C. LBNL 38537.
[32] Palmiter, L, and P. W. Francisco. 1994. "Measured Efficiency of Forced-Air Distribution Systems in 24 Homes". Proc. ACEEE Summer Study 1994. 3:175-187.
[33] Cummings, J.B., Tooley, J., and Dunsmore, R. 1990. Impacts of Duct Leakage on Infiltration Rates, Space Conditioning Energy Use, and Peak Electrical Demand in Florida Homes. Proc. 1990 ACEEE Summer Study. Pacific Grove. Ca.. August 1990. American Council for an Energy Efficient Economy, 1001 Connecticut Ave. N.W., Suite 335, Washington, D.C. 20036.

Where: Ducted vs Non-ducted Systems

- **Central Ducted Systems:** These are designed to heat or cool multiple rooms at once using a duct system. Some central systems have "zones," allowing you to set different temperatures for upstairs and downstairs using motorized doors (dampers) inside the ducts. It is also possible to install more than one ducted system - typically this is done with separate upstairs and downstairs systems, or a very large home may need more than one system.
- **Non-ducted Systems:** These are smaller in capacity and only focus on one room or small area of a home. They individually require less power than a central system, but the total home power requirement may be similar. These can include mini-split, multi-split or unitary window, wall or transportable heat pumps.

Type: Split vs. Packaged Systems

Split System. In a split system, the equipment is divided. The compressor sits outside, and the air handler sits inside. They are connected by refrigerant lines and wires for power and thermostat controls.

- **Mini-Split:** This is a "one-to-one" setup where one outdoor unit connects to one indoor unit. These can be ductless (where they connect to a single indoor supply unit) or ducted (using ducts to distribute to multiple rooms). Most outdoor compressors are side-discharge[34].
- **Multi-Split:** One outdoor unit connects to *multiple* indoor units throughout the house. The outdoor unit is "smart"—it can ramp its power up or down depending on how many rooms need cooling at that moment. Most outdoor compressors are side-discharge.
- **Traditional Split:** One outdoor unit paired with one ducted indoor unit. Traditional split systems tend to be larger and have higher capacity and power than mini-splits, although the differences are not well-defined. Most outdoor compressors are top-discharge.

Packaged Systems. In packaged systems, every mechanical part is housed in a single metal cabinet (with the compressor and air handler together). There is no separate outdoor and indoor unit. Examples include:

- **Rooftop Units**: These sit on the roof and pump air through ducts.
- **PTAC/PTHP Units**: Packaged Terminal Air Conditioners (PTAC)/Heat Pumps (PTHP) are often found in multifamily applications - they sit directly in a wall sleeve and heat or cool the room they are in.
- **Window Units**: Traditionally, these were cooling only, but are now available as heat pumps. While simple, these are often treated as “plug-in” appliances rather than permanent home

[34] “Side discharge” refers to the orientation of the fan in the outdoor unit. Traditionally, split air conditioners and heat pumps in the US have been top discharge, where the fan blows air vertically upwards. Mini- and multi-split air conditioners and heat pumps commonly use a side discharge design, where the fan blows air horizontally.

equipment[35]. Advanced window heat pumps have been evaluated as solutions in a handful of field studies[36],[37].

- **Transportable Units:** These units are freestanding on the floor and require a ducted connection to a nearby window for heat exchange. These are the easiest and fastest to install of all heat pump types, though they are uncommon for whole home comfort.

Summary Characteristics for Heat Pump Systems

Table 4 summarizes relevant characteristics of heating and cooling for split and central heat pump systems. The nameplate rating in Volt-Amperes (VA) of heat pumps for HVAC depends on the heating and cooling output capacity (i.e., in kilo-British Thermal Units per hour (kBtu/hr) or tons). Example relationships are given in the footnotes based on a convenience sample of HVAC equipment product data from the Department of Energy's Energy Star program listed heat pumps. Every home's electrical load calculation is ideally based on the nameplate of the actual equipment installed.

Table 4. Split and Central Heat Pump Systems

Device Description	Volts	Amps	Power (W)	Breaker Slots	Potential Installed Cost (Equipment + Labor) ($)	Dedicated Circuit Required
Heat Pump Outdoor Unit	120	6.5-17.5	800 - 1,900	1		Yes
	240	9-40	Depends on Capacity (1,200 - 7,300 VA)[38]	2	1-ton: $4,100 - $8,800 2-ton: $8,100 - $18,600 3-ton: $11,200 - $22,100 4-ton: $12,200 - $23,500	Yes

[35] Even though a window unit may fall under plug loads for load calculations in some instances, it is not necessarily a power-efficient device and must be evaluated on a case-by-case basis.
[36] Beaini, S., Quinn, S., Tam, A., Daher, M., Showunmi, D., Langsdorf, A., Romanin, V., Sander, J., Higbee, E., & Phillip, C. (2024, August). Field deployment of Window Heat Pumps in Multi-Family and Single-Family Low-Medium Income Homes. ACEEE Summer Study On Energy Efficiency in Buildings 2024. https://aceee2024.conferencespot.org/event-data/pdf/catalyst_activity_48501/catalyst_activity_paper_20240722163144234_21fee6c0_d8df_48f6_b308_bb81ed054c45
[37] Erik March, Jake Marin, James Mannarino, Maelyn Southers, & Sinan Chen. (2024). Super-Efficient Room Conditioners as a Multifamily Market Mover. ACEEE Summer Study on Energy Efficiency in Buildings. ACEEE Summer Study on Energy Efficiency in Buildings.
[38] Based on a convenience sample of HVAC equipment product data, Linear regression calculated: **kVA = 230 * (0.626(kBtu/hr) + 1.634)**

Air Handler (for All-Electric Equipment) (Mini- or Multi-Split)	Power provided from outdoor unit above				Price included above	No
Air Handler (for All-Electric Equipment) (Split) (230V)	230	3-16	Depends on Capacity (600 - 3,600 VA)[39]	2	$600 - $2100 (depends on Capacity)	Yes
Air Handler (for Gas or Mixed Fuel Equipment) (115V)	115	4-16	Depends on Capacity (100 - 1,500)[40]	0 or 1		Often

Note 1: Price ranges reflect the 20-80th percentile installed cost values from a segment of the TECH Clean California and LBNL cost database (n=10,591). Values are normalized to 2023 $USD and US national average costs.

Note 2: "All-Electric Equipment" refers to either air conditioning or heat pump without any fuel burning

Note 3: "for Gas or Mixed Fuel Equipment" refers to either a fuel-fired furnace or a furnace and air conditioning (or heat pump) combination.

Note 4: amps and power are derived from the minimum circuit ampacity (MCA) reported on HVAC heat pump nameplate labels.

Table 5 below provides similar information for packaged systems. These data are based on heating capacity, rather than cooling. Because of this, the presence of electric resistance heating in some models can result in that model not being considered low-power.

Table 5. Packaged Terminal Air Conditioners and Heat Pumps

Device Description	Low Power	Volts	Amps	Power (W)	Breaker Slots	Potential Installed Cost (Equipment + Labor) ($)	Dedicated Circuit Required
Packaged Terminal Heat Pumps (PTHP)	Yes	120	4-11	500-1,300	0 or 1	$3,000 - $7,400	Often
	Sometimes[41]	240	3-19.5	700-4,700	2		Yes
PTAC - Electric	No	240	10-22	2,400-5,300	2		Yes

[39] Based on a convenience sample of HVAC equipment product data, Linear regression calculated: **kVA = 230 *(0.111(kBtu/hr) + 2.220)**

[40] Based on a convenience sample of HVAC equipment product data, Linear regression calculated: **kVA = 115 * (0.105(kBtu/hr) + 3.563)**

[41] 240V PTAC/PTHP's can be low-power, but only if they do not utilize an electric resistance heating element.

Resistance Heating							
Note 1: Price ranges for PTHP reflect the 25-75th percentile installed cost values from TECH Clean California installations (n=27) as of 2026-04-28. Values are normalized US national average costs.							

Installation & NEC

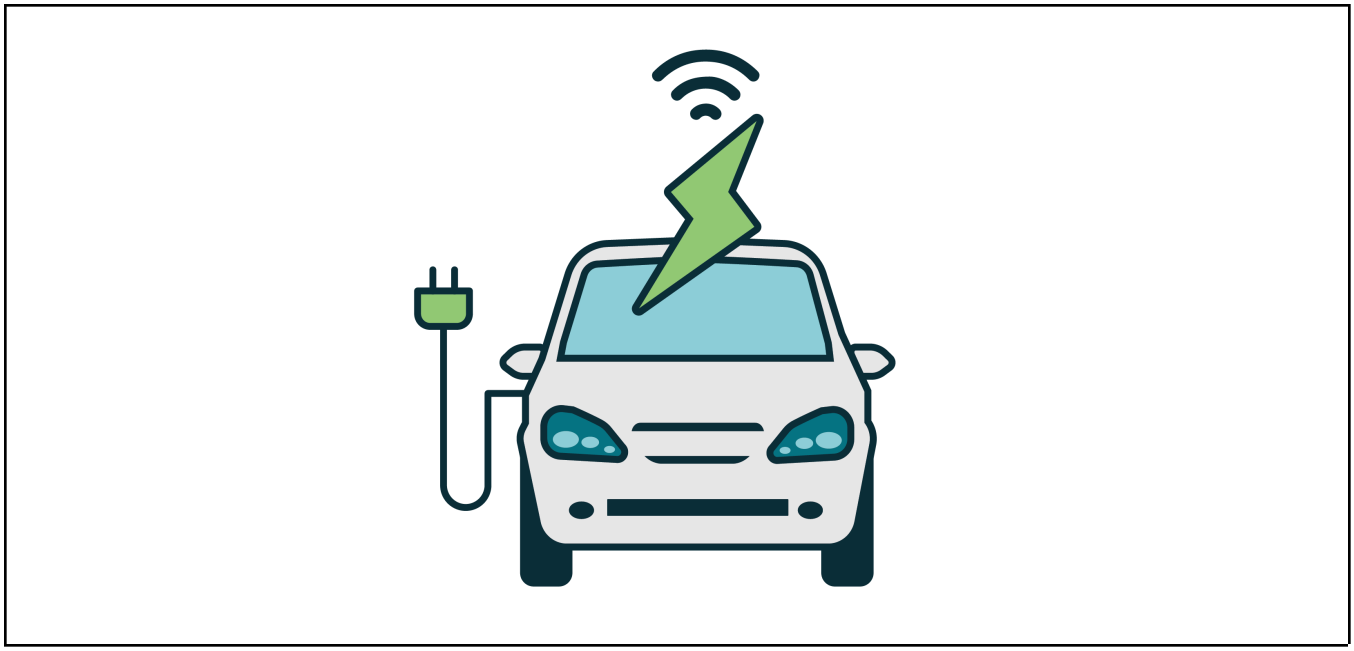
Table 6 summarizes the relevant NEC subsections for heating and cooling equipment. For more detail on how to handle these equipment in load estimates with NEC 220.83 and 220.87, please reference Appendix B4: Space Heating and Cooling.

Table 6. NEC Subsections for HVAC Equipment

NEC Section	***Description***
220.60	Noncoincident loads (e.g., heating and cooling) may be calculated using only the larger of the two loads.
440.22	Overcurrent protection must not exceed the manufacturer's specified maximum rating on the nameplate.
440.32	Air conditioning and refrigeration equipment with hermetic motors must have branch-circuit conductors sized to 125% of the rated-load current.
440.6[42]	Air conditioning and refrigeration equipment load calculations must use the nameplate rated load current.

[42] Note that implementing 440.6 can be complex, challenging and open to interpretation. We include it here for completeness.

Electric Vehicle Charging



Electric Vehicle Supply Equipment (EVSEs or commonly known as EV Chargers) are one of the most common additions that can lead to service and panel upsizing in homes[43]. This occurs because this equipment combines a high power draw with long operating times—often several hours at once. Uncontrolled vehicle charging can substantially increase household electrical loads and peak demand. However, many solutions already exist to help shift EV charging to hours when other loads are not in operation (e.g. shifting to the middle of the night when other appliances are off).

Making EV Charging More Power-Efficient

EV electrical loads can be reduced in several ways.

Level 1 120V Charging. Many EVSEs are plugged into an existing, conventional 120V wall outlet in the garage or home exterior. Typical charge rates are 1.4 kW. This is often the lowest cost and least likely solution to increase electrical demand or require panel or service upsizing. Charging requires long time periods, sometimes in excess of 24-hours. This approach may not be appropriate for very high-use households with long daily commute requirements, where charging cannot be supplemented at work or at public charging stations.

Level 2 Low Power Charging. Low power level 2 charging is defined as 16A, 240V or lower. This can be achieved either by purchasing specific lower-power charging equipment, or by installing an EVSE with an adjustable nameplate rating (permitted under NEC 625.42(B)). This approach will more than double the charging rate compared with level 1 charging.

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[43] Redwood Energy. "Service Upgrades for Electrification Retrofits Study Final Report." Accessed April 21, 2026. https://www.redwoodenergy.net/research/service-upgrades-for-electrification-retrofits-study-final-report-2.

Managed Level 2 Charging. Using load controls to manage EV Charging is another option that is increasingly popular (permitted under NEC 625.42(A) and 220.70). This approach allows use of higher-powered EVSEs with fast charging rates while staying on your existing panel These load controls will also often permit energy management of EV charging to take advantage of lower electricity rates or to provide grid services (e.g., demand response).

EV load controls operate in two main ways–load modulating and load balancing. Load modulating involves metering of the service or feeder the EV is connected to, and when non-EV loads operate at a high power, the EV is temporarily turned off or reduced. Load balancing occurs when two devices are connected to the same circuit, and either only one is allowed to operate at a time, or the total power is distributed to the two loads, such as two EVSEs balanced and served by a single 30A, 240V electrical circuit. The modulating approach can include multiple EVSEs or an EVSE and another device (e.g., a clothes dryer).

Smart EV Equipment come with load controls integrated into the EVSE itself**.** These are generally Level 2 and can utilize several methods of load control, including monitoring the total load on the electrical panel. In some cases, products marketed as Smart EVSEs may only provide scheduling functionality, which is insufficient on its own to be considered a method of load control for panel sizing because it does not consider the panel load in real time.

EV Equipment in the NEC

EV Equipment installations are addressed in Article 625, and load calculations including EVSE are addressed in Article 220 (see details in Section 3 - Load Controls). Managed charging through load controls is also relevant for EVSE in the NEC. Optimizing load calculations for power-efficient EV charging requires careful application of NEC rules. Two primary methods allow for reduced calculated load:

1. **Use Nameplate Ratings and Demand Factors:** Standard load calculations (Article 220, Part III) typically mandate a minimum 7200 W for EVSE treated at 100% (NEC 220.57). To use the *actual* lower nameplate rating of low-power or adjustable EVSEs, optional calculation methods (Part IV, 220.82 and 220.83) must be used. These optional methods bypass the 7200W minimum and allow the EVSE to be treated as a general load with a 40% demand factor.
2. **Take Credit for Load Controls:** Under NEC 625.42(A) and 220.70, load controls can reduce calculated demand. Managed systems that monitor only the EVSE set the load to the specific control limit. Systems monitoring the entire service or feeder, which throttle charging during high-demand periods, can set the EVSE load to its minimum power setting (often 0 VA). Reference the Power Control System (PCS) in Section 3 of this report for more details.

Appendix B5: Electric Vehicle Supply Equipment (EVSE) in the NEC has more details on the treatment and handling of EVSE in the NEC.

Summary Characteristics for EVSEs

Table 7 summarizes the various types and capacities of EVSEs.

Table 7. Types and Capacities of EVSEs

EVSE Type	*Volts*	*Amps*	*Power Output (kW)*	*Charging Speed*	*Typical Use Profile*	*Potential Price*	*Installation Requirements, Dedicated Circuit*
Level 1	120	12–16	1.3–1.9	3–5 mi/hr	Daily Overnight	$0 (usually included with EV)	2026 NEC requires dedicated circuit, otherwise can be shared
Level 2 (Low Power)	240	12-16	2.9-3.8	8.7–11 mi/hr	Daily home charging	$300–$800	NEMA 14-50 or Hardwired. Dedicated 240V circuit, unless using load control, 15 or 20A breaker
Level 2 (Medium Power)	240	24–32	5.8-7.7	17–23 mi/hr	Daily home charging	$300–$800	NEMA 14-50 or Hardwired. Dedicated 240V circuit, unless using load control, 30 or 40A breaker
Level 2 (High Power)	240	40	9.6	28.8 mi/hr	Home charging for a longer commute	$600–$1,200	NEMA 14-50 or Hardwired. Dedicated 240V circuit, unless using load control, 50A breaker
Level 2 (Smart, High Power)	240	40–48	9.6–11.5	30–35 mi/hr (at full capacity)	Home charging for a longer commute	$600–800	NEMA 14-50 or Hardwired. Can often be its own load control device, 50 or 60A breaker, but may be able to share capacity or mitigate power

Note: The sources for the above table include Redwood Energy's internal database and a convenience sample product review.

Note: Costs in this table exclude installation, which we anticipate at least including a new 240V branch circuit at roughly $1,400, typically ranging from $400 - $1,600.

Heating for Swimming Pools and Hot Tubs

Heating for residential swimming pools and hot tubs represents a significant energy load, making the choice of heating technology a key factor in home electrification efforts.

Pool Heating

Technologies

Heated residential pools primarily use one of three technologies: gas-fired, electric resistance, or heat pump pool heaters.

- **Gas-Fired Pool Heaters:** These are the most common type of heater currently in use. They typically require a 120V connection to power their controls and can effectively heat very large residential pools (>30,000 gallons).
- **Electric Resistance Pool Heaters:** These heaters are typically 240V appliances. While simple, they are less efficient than heat pumps and their high power draw often makes them less suitable for primary pool heating.
- **Electric Heat Pump Pool Heaters:** These are the most efficient electric option and are a central component of pool electrification. Most models are 240V appliances and are capable of heating large pools. Some smaller, 120V models exist but are limited in their heating capacity.

Key Design and Sizing Considerations

The required heating capacity for a pool is influenced by several factors, including the pool's volume, its location (indoor or outdoor), local climate, and the owner's desired usage season. The single most effective way to manage heating demand is by using a pool cover.

Covering a pool when not in use can reduce the heating load by over 40%[44], especially if the cover is designed to absorb solar heat. This dramatic reduction in daily energy consumption can decrease the size or number of heat pumps required to maintain a desired temperature, thereby lessening the impact on the home's electrical panel.

For larger pools, especially those operated year-round in cooler climates, multiple heat pump units may be necessary. As a general guideline, for much of California (e.g., CEC Climate Zone 4), uncovered pools larger than 15,000 gallons may require more than one 240V heat pump to maintain temperature year-round. Manufacturers like AquaCal offer online sizing

[44] U.S. Department of Energy. "Swimming Pool Covers." Accessed April 21, 2026. https://www.energy.gov/energysaver/swimming-pool-covers.

tools[45] that can provide specific equipment recommendations based on these design parameters.

For electrical code and safety requirements associated with pools and spas, Appendix B6: Pools and Spas has more information.

Spas and Hot Tubs

Spas and hot tubs have unique heating requirements compared to swimming pools. While they hold less water, they are maintained at much higher temperatures, which demands significant heating capacity. Most existing installations rely on either gas heaters or 240V electric resistance heaters. Adding a new electric spa or hot tub to a home with 100A service introduces a substantial new load. This often requires a service panel upsize unless smart load management strategies are implemented to balance power demand.

Primary types include:

- **In-ground:** These feature site-assembled heating, pumping, and control systems that are often separate from the tub itself.
- **Above-ground (Unitary):** These are off-the-shelf products with integrated heating and pumping systems, typically using electric resistance heat.

Replacing an existing electric resistance heater with a high-efficiency heat pump model can significantly reduce a home's overall electrical load. However, retrofitting integrated above-ground units is complex; using non-manufacturer components may void warranties, so compatibility should be verified with a local dealer.

[45] AquaCal. “Pool & Spa Sizing and Savings Estimator.” Accessed April 21, 2026. https://sizing.aquacal.com/.

Equipment Specifications

The following tables provide a sample of typical specifications for various types of electric pool and spa heating equipment.

Table 8. Pool and Spa Heaters

Pool and Spa Heater Type	*Low Power*	*Volts*	*Amps*	*Nameplate (VA)*	*Breaker Slots*	*Potential Price*[46]	*Dedicated Circuit Required*
Heat Pump	Yes	120	14	1,600	1	$800 - $2000	Yes
	No	240	15	3,600	2	$2100 - $6200	Yes
	No	240	38.5	9,240	2	$4,800	Yes
Electric Resistance	No	240	113	27,000	2 or 4	$800 - $2500	Yes

[46] Prices exclude installation and new wiring costs.

Section 2 – NEC Primer for 220.83 and 220.87

Overview of NEC Load Calculation Frameworks

When planning for home electrification or adding significant new electrical loads (e.g. a heat pump or electric vehicle supply equipment (EVSE)), calculating the home's total electrical load provides households opportunities to ensure safety, leverage their existing panel and save costs. The National Electrical Code (NEC)[47] provides two distinct optional methods for these calculations in existing single-family homes: NEC 220.83 and NEC 220.87. While both aim to determine if a home's electrical panel can handle new electric appliances and equipment, they employ fundamentally different approaches, each with unique strengths and strategic applications as summarized in Table 9.

Table 9. Strategic Applications and Hybrid Approaches for NEC 220.83 and 220.87

	NEC 220.83 "Bottom up" (Estimated)	**NEC 220.87** "Top down" (Data Driven)
Methodology	Bottom-up; based on square footage, circuits, and nameplate loads with demand factors. Demand factor assumptions for HVAC differ when adding any new HVAC equipment.	Top-down; based on actual peak utility data.
Best Use Case	Adding multiple new electrical loads at the same time; Inform phased, multi-stage home electrification planning. When metered demand data is unavailable or does not meet requirements of 220.87.	Adding 1-2 new electrical loads to an existing system. Staging multiple new loads over time.

[47] NFPA 70. NFPA is the National Fire Protection Association and is the standards body that advances the National Electrical Code, also called NFPA 70. States and localities adopt this code in part or in full based on the publication year.
https://www.nfpa.org/codes-and-standards/nfpa-70-standard-development/70

	NEC 220.83 “Bottom up” (Estimated)	NEC 220.87 “Top down” (Data Driven)
Limitation	Can be overly conservative and overestimate peak load due to high demand factors.	Assumes occupancy and usage patterns will remain stable into the future. Using data from different time periods will result in different calculated loads.
Data Requirement	Home square footage; Number of kitchen small appliance and laundry branch circuits; Appliance nameplate data for both existing and new loads.	30 days of 15 minute utility interval data OR 365 days of either 60 or 15 minute utility interval data. Appliance nameplate data for new loads.

NEC version in CA

As of Spring 2026, California has adopted the 2023 NEC version. The NEC updates every three years, and key changes have been enacted in the 2026 version that makes it less conservative for 220.83 (or 120.83 in 2026 NEC) and 220.87 (or 120.87 in 2026 NEC). For more information, see Appendix C: Differences in 2023 and 2026 NEC for 220.83 and 220.87. California will adopt the 2026 NEC in 2029 at the earliest.

Solar and Other Power Sources in Load Calculations

Solar and other power sources (e.g., a fuel-fired generator, energy storage system) are not considered loads, so they are not included in NEC load calculations. However, other power sources, like solar PV, can impact panel requirements and upsizing decisions, depending on how they connect to the home’s electric power system. For example, if solar PV (or other power sources) are backed through a breaker and use the panel busbar to distribute power, the breaker and solar system capacity are limited by the NEC's 120% rule (705.12(B)), which limits the sum of the main breaker and the solar breaker to a maximum of 120% of the panel's busbar rating. See detailed explanations of the limits and solutions to connecting other power sources to existing panels in Section 4 - Adding New Power Sources.

NEC 220.83: The Estimated, Bottom-Up Method

NEC 220.83 is a "bottom-up" method that calculates an estimated peak load based on a set of standard values and appliance specifications.

How it Works

This calculation starts with a general load determined by the home's square footage and adds loads for required kitchen small appliances and laundry circuits. Then, it adds the nameplate ratings of fixed appliances like HVAC systems, water heaters, dryers, and cooking equipment. Crucially, it applies demand factors—or coincidence factors—to these loads, which are percentages used to estimate the portion of these loads that are likely to be running simultaneously.

In the 2023 NEC, two distinct paths through 220.83 are possible based on whether or not any new HVAC equipment is being installed. 220.83(A) is used when not adding new HVAC, and all loads are treated the same. 220.83(B) is used when adding any new HVAC, and all HVAC is treated distinctly from all other loads. In both paths, use only the larger of the heating or cooling loads, but not both. See detailed calculations for both paths below.

> connected_load_kW = (3 * floor_area_ft2) + (1500 * # of small appliance and laundry circuits[48]) + (*max(heating_kW, cooling_kW)) +* (nameplate loads of all other equipment)
>
> ***[220.83(A)]***
>
> *IF no new HVAC:*
>
> *IF connected_load_kW[49] < 8 kW:*
> *220.83(A) Calculated Load = connected_load_kW*
>
> *ELSE:*
> *220.83(A) Calculated Load = 8 kW + (connected_load_kW - 8 kW) x 40%*

[48] Typically at least three
[49] In the no new HVAC condition, connected load includes HVAC and all other loads.

[220.83(B)]

ELSE IF new HVAC:

connected_load_kW = connected_load_kW - max(heating_kW, cooling_kW)

IF connected_load_kW + max(heating_kW, cooling_kW) < 8 kW:
220.83(B) Calculated Load = connected_load_kW + max(heating_kW, cooling_kW)

ELSE:
220.83(B) Calculated Load = 8 kW + (connected_load_kW - 8 kW) x 40% + max(heating_kW, cooling_kW)

Comparing 2023 and 2026 NEC

See Table 10 on the next page for more specifics on these demand factors along with the differences between 2023 NEC version and the recent 2026 NEC update. Reference Appendix C: Differences in 2023 and 2026 NEC for 220.83 and 220.87 for additional information on the base load and differences in this code between 2023 and 2026 versions.

Table 10. Summary of 220.83 in 2023 NEC vs. 2026 Update

2023 NEC 220.83	**2026 NEC 120.83**
General lights and plugs = 3 watts per ft^2 Exclude clothes dryers connected to the default laundry branch circuit. The installation of "new" HVAC changes the demand factors applied. 2023 applies the demand factors as follows: (A) If **not** adding new HVAC, take • first 8 kVA of all loads at 100% • remainder loads at 40% (B) If adding new HVAC, take • HVAC load at 100% • first 8 kVA of all other loads at 100% • remainder loads at 40%	General lights and plugs = 2 watts per ft^2 Exclude any loads connected to the default general lights/plugs, kitchen small appliance or laundry branch circuits. Demand factors distinguish between existing and new loads. 2026 applies the demand factors as follows: • New EVSE at 80% • New central electric resistance space heating at 80% • First 8 kVA of existing and new load at 100% • Remainder existing load at 40% • Remainder new load at 50% (e.g., HVAC heat pumps, air conditioners)

Advantages and Limitations

The strength of 220.83 lies in long-term planning. For electrifying multiple end uses either all at once or phased over time, this method allows a homeowner or electrician to create a detailed "amperage budget". By mapping out all desired end uses, one can make informed decisions, such as selecting more power-efficient appliances to ensure all planned devices fit within the panel's capacity.

The drawback is that the demand factors stipulated by the code can be conservatively large, assuming a higher simultaneous usage than what occurs in reality. This can lead to an overestimation of the peak load – potentially indicating a need for an expensive panel upsizing when one might not be necessary.

NEC 220.87: The Data-Driven, Top-Down Method

NEC 220.87 is a "top-down" calculation method that utilizes a home's actual electrical usage data, often accessible via "Green Button" data from California utility providers or upon request. This calculation determines the existing load by multiplying the measured peak demand by a 1.25 safety factor. Under the 2023 NEC, the full nameplate ratings of all new loads are then added at 100%. If the resulting total remains less than the panel's rated capacity, the new loads are permitted. However, the 2026 NEC introduces more flexibility by allowing the use of demand factors and load assumptions from other sections, such as 220.83 (see Appendix C: Differences in 2023 and 2026 NEC for 220.83 and 220.87). Additionally, the 2026 version permits installers to deduct the loads of equipment being removed from the metered peak, applying similar demand factors or assumptions from Article 120.

> *220.83(A) Calculated Load = (1.25 * measured_peak_demand_kW) + new_load(s)_nameplate_rating_kW*

How it Works

The calculation relies on finding the peak electrical usage in either 15-minute or 60-minute intervals[50] over a specific, recent period.

- **With Solar/Load Management:** If the home has a solar PV system or peak load management controls, a full 365 days of utility data is required to find the true peak demand.
- **Without Solar/Load Management:** A full year of data can still be utilized or, for a quicker assessment, as little as 30 days of recent 15-minute interval data. However,

[50] Notably, the .87 code section does not specify the required metering interval. We recommend using data metered at least hourly, and ideally targeting 15-minute interval data.

if this 30-day period doesn't include the seasonal peak (i.e., the hottest part of summer or coldest part of winter), the full nameplate rating of the HVAC equipment must be manually added to the calculation, including the larger of the heating or cooling equipment, but not both.

Advantages and Limitations

The primary advantage of 220.87 is its ease of use when utility data is accessible. It is particularly well-suited for quickly adding one or two new appliances, as it reflects the reality of how a household actually consumes power. For this calculation method, only the nameplate of the new load(s) needs to be known, which can often be looked up on an appliance's specification sheet or manufacturer website. The second advantage of this method often reveals that a home's real-world peak load is significantly lower than theoretical estimates based on 220.83, potentially freeing up more capacity for new loads.

The limitations of 220.87 is that it assumes occupancy and usage patterns will remain stable into the future. Also, as 220.87 is dependent on measured peak demand, using data from different time periods will result in different calculated loads.

Counted Loads

The treatment of loads differs between NEC 220.83 and 220.87. In NEC 220.83, specific loads are defined to be counted and vary in the demand factors applied (see Appendix C: Differences in 2023 and 2026 NEC for 220.83 and 220.87 for more information). In contrast, NEC 220.87 has any added load be counted at 100%. Furthermore, differences arise between the 2023 NEC version and the recent 2026 NEC update for 220.83 (or 120.83 in 2026 NEC) and 220.87 (or 120.87 in 2026 NEC). Table 11 below outlines this different handling of counted loads and Figure 1 and Figure 2 illustrates the different treatment of counted loads under 2023 NEC using Homes A and B, which reflect real homes whose data was collected during our project's field study.

Table 11. Comparison of Counted Loads for 2023 and 2026 Versions of NEC 220.83 and 220.87

NEC 220.83	NEC 220.87
2023 Version	
Requires loads to be counted for: ● Heating and cooling equipments ● Water heaters ● Clothes dryer (not connected to a laundry circuit) ● Ranges, wall-mounted ovens, counter-mounted cooking units ● Anything that is "fastened in place, permanently connected, or located to be on a specific circuit"	Requires loads to be counted for: ● Any "new" appliance/equipment added at 100%
2026 Version	
Required loads to be counted for: ● Same requirements as 2023 Excludes: ● Any load connected to a branch circuit that is already treated with a default value, which includes general lights/plugs, kitchen small appliances, and laundry circuits. For example, loads connected to a general outlet.	Required loads to be counted for: ● Any new appliance/equipment added at appropriate demand factors or load assumptions from other sections, such as 220.83 ● Permitted to similarly deduct appliances being removed from the metered peak demand.

As seen in Figure 1 on the following page, when Home A fully electrifies from all gas appliances and equipment, most new loads are counted at 40% in the 2023 NEC 220.83 and at 100% in NEC 220.87. For example, the 21A heat pump water heater is treated at 21A in 220.87 and at 40% (8.4A) in 220.83. The heat pump clothes dryer, the heat pump water heater, and the induction range all have values lower under NEC 220.83. The only exception is for HVAC equipment (31.1A in Home A), because new HVAC is treated at 100% in both 220.83 and 220.87.

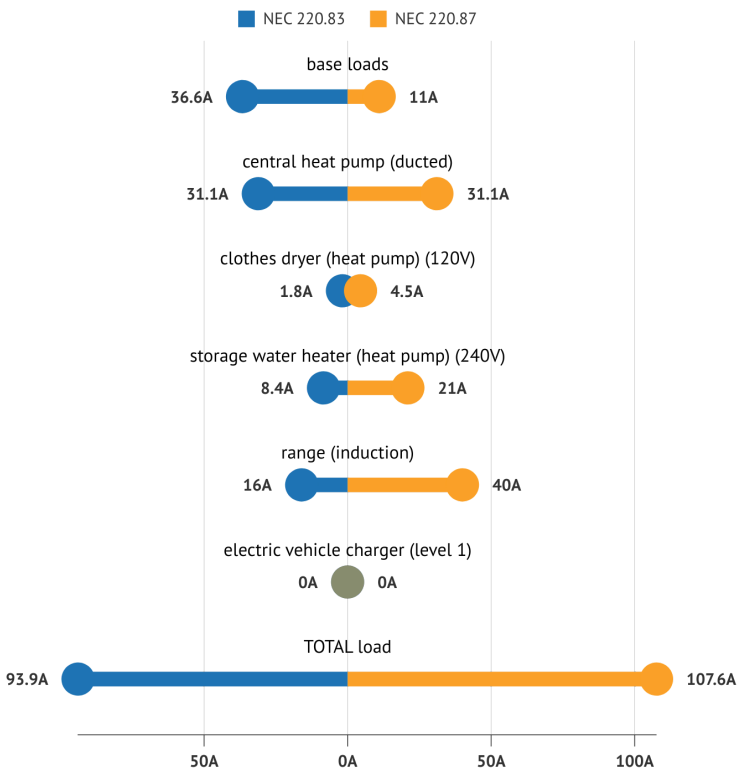


Figure 1. Counted loads for Home A under 2023 NEC

Home A

Location: Carpinteria, CA

Home characteristics:

- 1300 sq ft
- 3 bedrooms
- 2 bathrooms
- Built in 1969
- 100A panel

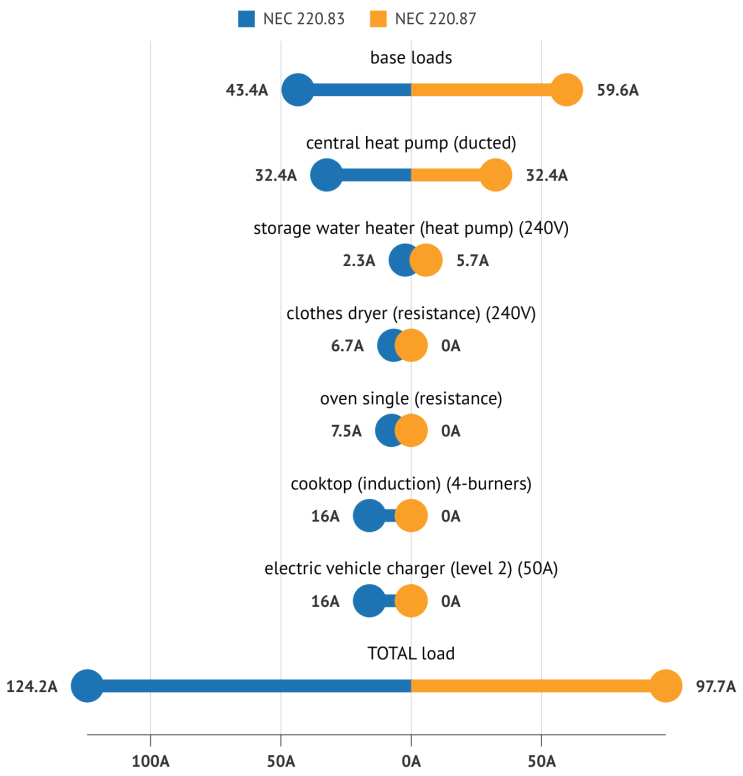
Pre-project:

- Central Heating and Cooling - Gas
- Clothes Dryer - Gas
- Water Heater - Gas
- Cooking - Gas

Electrification Project:

- Central Heating and Cooling - Electric
- Clothes Dryer - Electric
- Water Heater - Electric
- Cooking - Electric
- EVSE - Added

As shown in Figure 2 on the following page, using NEC 220.87 typically results in lower calculated loads for homes that already have multiple electric appliances. The base load in this method represents the actual metered peak demand, which naturally accounts for the fact that devices like ovens, cooktops, dryers, and EVSEs rarely run at the same time (resulting in a 0A addition for these existing items in the calculation example for Home B). In contrast, NEC 220.83 requires counting and applying standard demand factors to every appliance, regardless of actual usage. Because real-world simultaneous usage is usually much lower than these standard assumptions, NEC 220.87 often reveals significant available capacity on existing panels.



Home B

Location: Alameda County, CA

Home characteristics:

- 2400 sq ft
- 4 bedrooms
- 2 bathrooms
- Built in 1941
- 100A panel

Pre-project:

- Central Heating and Cooling - Gas
- Water Heater - Gas
- Clothes Dryer - Electric
- Cooking - Electric
- EVSE

Electrification Project:

- Central Heating and Cooling - Electric
- Water Heater - Electric

Figure 2. Counted Loads for Home B under 2023 NEC

120V plug-in appliances

While the code is subject to interpretation, our interpretation of what loads are considered “fastened in place, permanently connected, or located to be on a specific circuit”, aligns with the examples from the Informative Annex D section of the 2023 NEC. Table 12 summarizes which 120V plug-in appliances are accounted for in each load calculation. For a summary of changes between 2023 and 2026 NEC versions for 220.83 and 220.87, please reference Appendix C: Differences in 2023 and 2026 NEC for 220.83 and 220.87.

Table 12. Summary of Plug-in Appliance Nameplate Accounting in Load Calculations

Load	Fastened In Place	Permanently Connected (hard-wired)	Specific Circuit	Listed in 220.83 (A)(3)(B-D)	Included in Calculations			
					2023, 220.83	2026, 120.83	2023, 220.87	2026, 120.87
Refrigerator/Freezer	No	No	No	No	No	No	N/A	N/A
Dishwasher	Often	No	Often	No	Yes	Yes	N/A	N/A
Garbage Disposal	Yes	No	Often	No	Yes	Yes	N/A	N/A
Microwave (Built-In)[51]	Yes	No	Sometimes	No	Yes	Yes	N/A	N/A
Garage Door Opener	Yes	Sometimes	No	No	Yes	Yes	N/A	N/A
Ventilation Fan (Bathroom exhaust)	Yes	Yes	No	No	Yes	Yes	N/A	N/A
Ventilation Fan (Kitchen exhaust)	Yes	Yes	No	No	Yes	Yes	N/A	N/A
Storage Water Heater (Heat Pump) (120V) (Shared Circuit)	Yes	No	No	Yes	Yes	No	Yes	Yes
Clothes Dryer (Heat Pump) (120V)	No	No	No	No*	No	No	Yes	Yes
Range (Induction with Battery)	No	No	No	Yes	Yes	No	Yes	Yes
EVSE (Level 1)	No	No	No	No	No	No	Yes	Yes
Combined Washer and Dryer (Heat Pump)	No	No	No (on washer circuit)	No	No	No	Yes	Yes

*Per 220.83(A)(3)(B-D), clothes dryers are already counted on the dedicated laundry circuit. If the dryer is connected to their own branch circuit, then they would be individually included in load calculations.

[51] Only applies to permanently fixed in place microwaves, such as a Microwave/Range Hood combo in a cabinet above the range in the kitchen. The total nameplate of the Microwave appliance and Range Hood is used in this case, unless it is a single listed device.

Removed Loads

Loads can be removed from NEC load calculations when they are either physically removed from the home, or when a listed load control is used to reduce the calculated load (e.g., a smart EVSE). The handling of removed loads in the calculations differs between NEC 220.83 and 220.87. In 2023 NEC 220.83 (and 2026 120.83), loads removed from the home are simply excluded from the load calculation. In 2023 NEC 220.87, loads removed that are part of the metered data are not allowed to be deducted in the calculation. For example, if a home replaces an air conditioning unit with a heat pump or uses a load control to lower power demand, no deduction is made in 2023 NEC 220.87. However, the updated 2026 NEC specifies that in 120.87, the loads that are replaced, removed or controlled are allowed to be deducted from the calculation. Table 13 below outlines these different handling of loads removed between 220.83 and 220.87 in both the 2023 and 2026 NEC versions. Removal can be either physical or due to load controls.

Table 13. Comparison of Removed Loads for 2023 and 2026 Versions of NEC 220.83 and 220.87.

NEC 220.83	NEC 220.87
2023 Version	
Loads removed from home: • Removed loads are excluded from the calculations	Loads removed from home: • Removed loads cannot be deducted from the metered peak demand.
2026 Version	
Loads removed from home: • Same as 2023	Loads removed from home: • Removed loads can be deducted using their nameplating rating and appropriate demand factors

Figure 3 illustrates a generic scenario that highlights the difference in load removal treatment between the 2023 NEC 220.83 and 220.87 calculation methods when a load control is applied to an existing device. Consider a home with an existing high-power load, such as a Level 2 EVSE, and a planned addition of a central heat pump system and a 240V storage heat pump water heater. Applying a load control to the existing EVSE allows the project to pass under the 2023 NEC 220.83 because the controlled load is fully excluded from the calculation. However, under the 2023 NEC 220.87, the calculated load would still include the EVSE's contribution to the metered peak demand, often causing the calculation to fail. The 2026 NEC addresses this issue by allowing the controlled load to be deducted in the 120.87 calculation, demonstrating a key benefit of the updated code.

Home C

Home characteristics:

- 1250 sq ft
- 2 bedrooms
- 1 bathrooms
- 100A panel

Pre-project:

- Central Heating and Cooling - Gas
- Water Heater - Gas
- Clothes Dryer - Electric
- Cooking - Electric
- EVSE

Electrification Project:

- Central Heating and Cooling - Electric
- Water Heater - Electric
- Load Shed Control on EVSE

Figure 3. Generic electrification scenario in Home C

Strategic Applications and Hybrid Approaches of NEC 220.83 and 220.87

A powerful strategy for homeowners involves using both calculation methods in sequence. For a full-home electrification project, you can initially use NEC 220.83 to plan and receive permits for the first few appliances—such as the three or four units that nearly reach your panel's current capacity. After these items have been installed and in use for at least 30 days, you can then perform an NEC 220.87 calculation. This data-driven approach allows you to add the remaining appliances by taking credit for the actual power usage of your new equipment, rather than relying on the NEC's more conservative theoretical assumptions. This phased process can be repeated as needed to maximize your existing electrical infrastructure without a costly service upsize.

Section 3 – Load Controls

Overview of Electrical Load Controls

Upgrading a home with modern, high-power equipment such as heat pumps, electric vehicle supply equipment (EVSE), and hot tubs places significant pressure on its existing electrical system. When a home's electrical panel lacks the capacity or physical space to accommodate these new additions, load control systems provide a smart alternative to an expensive and disruptive service upsize. Functioning as a traffic controller for electricity, these systems ensure that the total power demand never exceeds what the panel can safely handle. While these technologies have been available for some years, they are still relatively rare and are an emerging technology in the sense of widespread adoption and acceptance. Several recent research reports have characterized solutions in this space[52], documented the performance, pros and cons of these types of load controls in both laboratory[53] and household[54] settings. Other research has asked California electricians about their use of load controls and the associated installation costs[55].

This section categorizes and explains the primary types of load control solutions available today, highlighting their functions, ideal applications, and treatment under the National Electrical Code (NEC). Specific market products for each category are tabulated in Appendix D1: Starting List of Specific Load Control Devices in the Market.

Load controls are typically applied when an initial NEC calculation indicates an electrical panel upsize is required due to capacity constraints. Users should identify large loads appropriate for control (see Section 2 - NEC Primer for 220.83 and 220.87); EVs are almost always the best candidate, with water heaters a distant second. We recommend controlling only the devices necessary to avoid the upsize, as controls typically increase costs without

[52] Baranow, Natasha et al. "Market Study of Household Electric Infrastructure Upgrade Alternatives for Electrification." CalNEXT. December 15, 2023. Accessed April 29, 2026. https://calnext.com/wp-content/uploads/2023/12/ET22SWE0057_Market-Study-of-Electric-Infrastructure-Upgrade-Alternatives-for-Electrification_Final-Report.pdf.

[53] Graeber, Keith, Andrew Harper, and Jonathan Bryant. "Laboratory Evaluation of Residential Smart Panels." CalNEXT. October 15, 2025. Accessed April 29, 2026. https://calnext.com/wp-content/uploads/2025/10/ET24SWE0039_Laboratory-Evaluation-of-Residential-Smart-Panels_Final-Report.pdf.

[54] Koli, Srushti et al. "Electrification Enablement via Load-Balancing Solutions Focused Pilot." CalNEXT. December 16, 2025. Accessed April 29, 2026. https://calnext.com/wp-content/uploads/2025/12/ET24SWE0063_Electrification-Enablement-via-Load-Balancing-Solutions-Focused-Pilot_Final-Report.pdf.

[55] Guidehouse Inc. and Opinion Dynamics Corporation. "Fuel Substitution Behind the Meter Infrastructure Market Study." Prepared for the California Public Utilities Commission. May 17, 2024. Accessed April 29, 2026. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/building-decarb/fs-infra-ms_overall-report_20240606.pdf.

contributing to energy or utility bill savings. A final load calculation that includes impacts of load controls should then be completed to confirm the safe design that avoids upsizing. Notably, the NEC section being used can impact the change in load associated with a control (see Section 2 - NEC Primer for 220.83 and 220.87). For example, controlling a new load in a .83 existing dwelling calculation typically removes 40% of the nameplate rating from the calculated load, while the same control in a .87 calculation using metered demand can remove 100% of the nameplate rating from the calculated load.

Characteristics

Load controls are most effective when paired with traditional, high-power appliances. Their primary role is to manage which devices receive power at any given time. It is important to note that while these devices protect the home's panel from overheating, they typically do not lower overall energy consumption or utility costs, unless specifically configured for that purpose. The following are some key features of many currently available load control solutions:

- **Optimized for Conventional Equipment:** These systems are ideal for homes utilizing traditional, high-powered devices where a panel upsize is not desired.
- **Lack of Grid Interaction:** Unless these systems are networked and enrolled in a utility program, they primarily benefit the individual home rather than the local power grid.
- **Communication Features:** Load control communication features fall into two categories:
    - **Non-Communicating:** Many load controls lack communication functionality. They make only local decisions based on directly available information. They cannot be coordinated with other local or remote devices, and they usually lack user-interfaces, the ability to receive updates, etc.
    - **Digital communication:** Other controls use "two-way digital communication" (e.g., WiFi), allowing them to exchange signals with other appliances or utility aggregators to coordinate energy use in real-time.
- **Load control capabilities:**
    - **De-energize:** Most currently available load controls simply turn power off to a device under a high demand condition. Power is turned back on after high demand ends.
    - **Modulate:** Some emerging solutions, especially for EV Charging and HVAC, are beginning to offer power modulation capabilities, where power use is dynamically reduced but not necessarily completely turned-off. This approach currently requires communication with the power-using device, such as through a communicating thermostat or EV telemetry.

Smart Features Considerations

While advanced "smart" features provide technical advantages, they introduce important questions regarding long-term performance and reliability:

- **Software Lifespan:** Many controls rely on smartphone apps and cloud internet connections. Consideration must be given to whether a manufacturer will support the software ecosystem over a 10, 20, or 30-year period.
- **Durability and Maintenance:** If a network connection fails or a company goes out of business, the physical protection and functionality of the control must remain intact locally.
- **Inspectability:** The system should be documented clearly, so that future home inspectors or electricians can easily understand how the home's power is being managed.

Selecting a load control system is an effective way to solve space or capacity constraints, provided the chosen solution adequately addresses these questions.

Load Controls vs. Power-Efficient Appliances

Load controls have the benefit of allowing the use of systems with plenty of reserve power that may be useful for rare events: extreme weather, extreme occupancy, etc. Higher-powered equipment are also more dynamically controllable and can take advantage of time-of-use pricing or help maximum on-site consumption of renewables (e.g., by aligning high-powered car charging with peak solar hours or lower electricity price periods). Homeowners and designers should weigh the use of controls that curtail end uses against the alternative of choosing power-efficient appliances. Both approaches have potential downsides that should be considered. While a load control can prevent a panel from overloading, it may introduce lifestyle impacts—such as an EV that charges slower than expected because its power was interrupted by the control, or a water heater that runs out of hot water during power curtailment. In contrast, power-efficient appliances solve the capacity problem at the source, reducing the overall demand and often removing the need for complex control hardware that may face long-term software support or reliability risks. Many power-efficient options can also increase runtimes and require their own lifestyle adaptations.

Which Loads Are Suitable for Control?

To minimize occupant disruption and maximize reduced electrical loads, we suggest controlling large, non-essential 240V loads. These are appliances/systems that can be temporarily paused without significantly impacting comfort or daily routines. Conversely, critical loads like cooking and space heating should be avoided for load controls. The

suitability of each major appliance is based on engineering judgment regarding occupant acceptance of service interruptions. Our suitability recommendations address load shed controls and circuit sharing controls. For the latter, we distinguish between secondary loads, which are interrupted whenever the primary load operates.

Table 14. Circuit Sharing or Circuit Pausing Logic for Least Occupant Disruption

End-use	Suitability for Control		Reasoning
	Load Shed	Circuit Sharing	
EVSE	Excellent	Excellent (secondary)	Charging is flexible and can easily be paused for short periods, with minimal user impact. EVSE power modulation allows for effective, flexible power demand control, avoiding on/off cycling. Turning power off has no known negative impacts on equipment durability.
Pool/Spa Equipment	Good	Good (secondary)	Heating is highly flexible and can be deferred without disruption thanks to the pool or spa's large thermal volume. A short interruption would rarely, if ever, be disruptive to the user. Specialized pump controllers exist for pools. Pool filter pumps should run 8-10 hours over the day. In-ground hot tub jet pumps must be properly controlled, if at all, to avoid disruption. Care should be taken to avoid disrupting use of spa jets.
Water Heater	Good	Good (secondary)	The thermal storage of a hot water tank acts as a buffer, allowing the heater to be turned off for an hour or more with little noticeable effect in most cases. Most water heaters cannot modulate power demand, so controls must turn them off. Interruption of compressor cycles may impact equipment durability.
Clothes Dryer	Poor	Excellent (primary)	Interrupting a drying cycle is highly disruptive, resulting in wet clothes, lost control settings, etc. Dryers should be excluded from load shed or secondary control.
Cooking Appliances	Poor	Excellent (primary)	Interrupting cooking is highly disruptive, so cooking appliances are excluded from load shed or secondary control.

End-use	Suitability for Control		Reasoning
	Load Shed	Circuit Sharing	
HVAC Systems[56]	Poor	Poor	Excluded due to the potential for occupant discomfort, especially in extreme weather. Also discouraged in circuit sharing controls, because of long runtimes (10-50% of annual hours) and disruption of the secondary shared load. Interruption of compressor cycles is known to impact equipment durability[57].

Note: "primary" devices are always on, "secondary" devices are turned off when the primary is on.

[56] We note that demand response programs often control residential air conditioners and other HVAC equipment to relieve utility grid congestion and loading. So controlling HVAC is clearly sometimes acceptable. A key distinction is that utility demand response programs have built-in limitations to the frequency and duration of the interruption, whereas no such promises exist for load controls providing capacity management. Furthermore, individual households can opt out of demand response events, as needed with compromising safety, whereas electrical capacity management controls must work every time in order to ensure safe operation.

[57] Leddy, Laura et al. Measuring and Valuing Resilience: A Literature Review for the Power Sector. Golden, CO: National Laboratory of the Rockies. August 2023. Accessed April 21, 2026. https://www.nrel.gov/docs/fy23osti/87053.pdf.

Types of Load Control Systems

Under the National Electrical Code (NEC), specifically in the 2026 reorganization (see Article 120), two primary types of load controls are recognized for managing capacity and avoiding service capacity increases:

1. **Non-coincident Load Controls (Section 120.6)[58]:** This method is used for two or more loads that are unlikely to be in use at the same time (such as heating and air conditioning). Listed hardware is used to ensure that two devices *cannot* run simultaneously. Only the larger of the two loads is used in the panel's capacity calculation.
2. **Power Control Systems (PCS) (Section 120.7):** These are more advanced, listed systems that actively monitor and limit the total current on a busbar or conductor. A PCS can dynamically "throttle" controlled loads (like a smart EVSE) based on real-time demand from the rest of the home. These controls are expected to operate less frequently, and in fact, may never operate in some homes, because they only activate controls when whole home demand nears the panel capacity limit, which metering data suggests is extremely uncommon in homes[59].

Installation best practices and field implementation for these load control systems can be found in Appendix D2: Load Control Installation Best Practices and Field Implementation. The 2023 NEC acknowledges Energy Management Systems (EMS) for use in load calculations in Section 220.70, where EMS loads are considered continuous; EV EMS are similarly acknowledged in Section 625.42(A). Some load controls listed to UL 916 as EMS can be used for panel capacity management under older versions of the NEC. Overall functionality may appear similar, but EMS are not specifically evaluated for preventing electrical overloads or for protecting conductors, busbars, etc.

Load Control and Energy Management Systems (EMS)

It is critical to distinguish between systems that provide true electrical capacity management (e.g. load controls) and those that are merely Energy Management Systems (EMS) (e.g. demand response, scheduling, networked communication). As noted above, in the 2023 NEC, controls listed as EMS can be used for capacity management and be reflected in load

[58] Load controls that operate on this principle (e.g., circuit sharing) can still be justified/used in the 2023 (or earlier) NEC versions, because they ensure that two devices are “unlikely” to operate at the same time. These controls are expected to operate more frequently (e.g., daily or weekly) and with short duration (e.g., 15-60 minutes), but this depends on the specific devices sharing a circuit

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

calculations. Some hardware performs both PCS and EMS functions, such as a smart panel that manages electrical capacity limits, and also provides a variety of other energy management functions and interfaces. As noted above, in the 2023 NEC, controls listed as EMS can be used for capacity management and be reflected in load calculations. Some hardware performs both PCS and EMS functions, such as a smart panel that manages electrical capacity limits, and also provides a variety of other energy management functions and interfaces.

Table 15. Comparison of Load Control/PCS and Standard EMS

Feature	Load Control / PCS	Standard EMS
Primary Goal	**Safety & Capacity:** Prevents panel/service overloads.	**Optimization:** Scheduling, saves money or optimizes solar use.
NEC Recognition	Can be used to reduce calculated load for panel sizing in 2026 NEC.	Some can be used in load calculations in the 2023 NEC to avoid a panel upsize.
Function	Actively limits power draw based on physical capacity.	Responds to prices (TOU), Demand Response, user inputs, or solar output.

While an EMS might help a home take advantage of cheaper electricity rates at night, it does not necessarily have the safety-rated "lockout" or "throttling" capabilities required by the 2026 NEC to prove that the home will never exceed its panel's physical limit. In the 2026 NEC, only systems listed as a PCS or listed equipment that ensures non-coincident operation provide the regulatory "credit" needed to avoid a service upsize. The 2023 NEC is somewhat more flexible, allowing equipment listed as EMS to be used in load controls.

Type 1: Non-Coincident Load Controls

Non-coincident load controls are specialized devices designed to ensure that two or more high-power appliances never operate at the same time. This approach works best for appliances that either run infrequently or can easily tolerate being paused for short periods, such as EVSEs, water heaters, and pool pumps. However, it is generally not recommended

for heating and cooling (HVAC) systems, as their long runtimes and the constant need for temperature regulation make them poor candidates for sudden power interruptions.

NEC: 2023 vs. 2026

This strategy is officially recognized under the National Electrical Code (NEC), which permits a home's total power calculation to include only the larger of the two "sharing" loads, rather than adding them together.

- **2023 NEC:** Left some room for interpretation regarding which specific calculation methods could use this rule.
- **2026 NEC:** Provides much more clarity, explicitly allowing the use of safety-certified hardware to manage these loads across all types of home electrical assessments.

Circuit Sharing Controls

A Circuit Sharing Control allows two large appliances to share the same electrical circuit. The code refers to these as non-coincident loads, meaning they will not run at the same time. This solution addresses both physical space (needing fewer breakers) and electrical capacity constraints. Automated switching circuit sharing controls are the focus in this report, as they have improved usability and reliability (in contrast to those that manually switch or have no switching between loads like a power strip).

How They Work: One appliance is "Primary" and is always powered (like a clothes dryer) and the other is "Secondary" and may have power interrupted (like an EVSE). If the primary is operating (such as a dryer starting) and exceeds a threshold (e.g. 100W), the controller pauses the secondary appliance (EVSE). The secondary resumes when the primary demand stops (i.e. once the dryer finishes, the EV starts charging again), or after a fixed time interval like 15-minutes. Some circuit sharing controls offer features that ensure a continuous low current flow to both devices to avoid impacting user settings, onboard clocks, etc.

Primary Types:

- **Receptacle-based solutions**: A simple "plug-and-play" box, often used two electrical loads are close together such as in garages, where a dryer and EVSE are close together and can share a single 240V electrical outlet.
- **Hardwired solutions**: A professionally installed wired version that can manage appliances/equipment in different parts of the home.

Receptacle-based load controls are usually lower cost than the hardwired ones.

Type 2: Power Control Systems

A Power Control System (PCS) is a load control designed to ensure a home's (or subpanel's) electrical power demand stays within safe limits (on a branch circuit, feeder or service). These systems must be listed to a safety standard known as UL 3141.

A PCS typically includes monitoring of the power for the whole home and circuits being controlled. For example, a PCS controlling a water heater might include metering of the whole panel power demand and the water heater power demand. A professional sets a specific limit (e.g., 80% of the panel rating), and the PCS automatically manages connected devices to ensure that the whole home power limit is never exceeded. PCS can be configured to control anywhere from one single device up to all major equipment in a home, along with renewables and battery systems. Real world experience has shown that PCS in homes typically only need to step in and manage loads very infrequently.

NEC: 2023 vs. 2026

The NEC is currently evolving to better support these technologies:

- **2023 NEC**: Section 750 specifies installation requirements for EMS. Section 220.70 specifies how EMS are used in NEC load calculations. In load calculations, the EMS' maximum control setting can be used and must be treated as continuous (at 125%). It is unclear how the control setting is to be "used", or under what circumstances. Typically, this approach would apply to a smart panel or subpanel with EMS capabilities, where the control setting is established at 80% of the overcurrent protective device for the panel (i.e., the main breaker), and the control setting becomes the calculated load for the panel.
- **2026 NEC**: Section 130 specifies installation requirements for PCS. Section 120.7 specifies how PCS are used in NEC load calculations. The treatment of loads controlled by a power control system depends on the metering and control configuration, with the controlled loads treated either using the control setting or the minimum operating value of the controlled load(s). Loads the PCS does not have control over are treated using conventional load calculation procedures in Section 120. See example load calculations using PCS in Annex D.15 of the NEC[60].

Smart Panels

A smart panel is a high-tech version of a traditional electrical panel. They are a type of PCS that combines breakers, sensors, and computer processing into one unit to manage the home's power fully (as the main panel) or partially (as a subpanel). Many smart panels

[60] National Fire Protection Association. "NFPA 70: National Electrical Code (NEC) Code Development." Accessed April 29, 2026. https://www.nfpa.org/codes-and-standards/nfpa-70-standard-development/70.

provide load control (for panel capacity management), energy management, grid demand response, and other functions.

How They Work: By measuring power at the main source, the panel can automatically "shed" or slow down lower-priority items (like a water heater) based on a user's preferences if the home approaches its power limit.

Load Shed Controls

A load shed control is a separate piece of hardware installed outside the panel (most commonly between the circuit breaker and the controlled load). It acts as an automated "off switch" for a specific high-power appliance. This is a type of PCS that usually controls 1-2 devices, though it could be set-up to control an entire subpanel.

How They Work: It monitors the total current in the home or panel through sensors on the home's main electrical lines or similar. If the house uses too much power, the device cuts electricity to one specific appliance (such as an EVSE) it controls until the power demand drops. Many load shed controls lack communication hardware, cannot be remotely updated, and cannot manage coordination of multiple devices or dynamically changing power limits/settings. Some emerging products are beginning to include communication hardware and networking capabilities, which potentially expands their use-cases and functionality.

Controllable Circuit Breakers

There are controllable (or "smart") circuit breakers that have onboard power metering and built-in controls that allows them to be turned on or off remotely. They are best suited for scheduled operations or setting current limits for individual circuits. Future updates are under development that will offer integrated coordination between groups of smart breakers, such that they create something akin to a "virtual smart panel". These breakers require professional installation.

How They Work: They connect to a central hub or smartphone app. These breakers can be set to run based on a schedule, user's preferences or signals from a larger PCS (e.g. a smart panel).

Smart Electric Vehicle Supply Equipment (EVSE)

Smart EVSE come in two primary varieties that help manage electrical capacity: **load modulating** and **load balancing**. Both types are designed to avoid expensive home electrical upsizing while offering advanced features like smartphone apps and solar-optimized charging.

Load Modulating EVSE

This equipment acts like a dimmer switch for a vehicle's power intake. Rather than simply being "on" or "off," a load-modulating EVSE can smoothly adjust the charging speed in

real-time based on how much electricity the rest of the home is using. Control options might also include response to time-of-use pricing or other grid demand response signals from the utility or aggregator.

How They Work: This equipment requires the installation of sensors on the home's (or subpanel's) main electrical lines. By monitoring the total electricity flow, the EVSE establishes a safety limit (usually **80%** of the home's or subpanel's capacity). If a high-power appliance like a dryer is turned on and the 80% limit is exceeded, the EVSE automatically "throttles" (or turns off) the car's power draw downward to stay within safe limits. This prevents the home's main breaker from tripping, while allowing the car to continue charging at a reduced rate until the other appliances are finished.

Load Balancing EVSEs

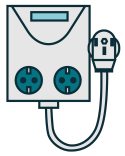
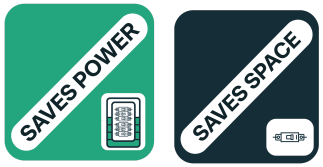
Load-balancing EVSEs, also called Automatic Load Management Systems (ALMS), are designed for homes with multiple electric vehicles. They allow two or more cars to share a single electrical circuit and one set of breakers, distributing power dynamically between them.

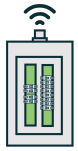
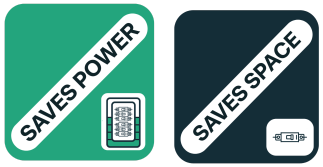
How They Work: These systems operate as an isolated energy management network for the EVSEs themselves. When only one car is plugged in, it can draw the full available power (e.g., 7.2 kW). If a second car is connected, the system intelligently splits the available power between both vehicles (e.g., 3.6 kW to each vehicle). Unlike modulating EVSEs, these typically do not monitor the rest of the home's power use; they simply ensure that the combined draw of the vehicles never exceeds the limit of their specific circuit. They often have a smartphone user interface.

Comparison of Load Control Solutions

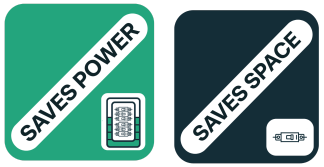
Choosing the right solution depends on the specific constraints, budget, and desired level of control for a given home. We include a non-comprehensive but representative list of specific products in Appendix D1: Starting List of Specific Load Control Devices in the Market. There are considerable price variations between technologies, so we have given typical pricing guidance at the time of writing this document. Note that within each category there are often large variations depending on features, brands, etc. For some devices, the available information does not always allow for a price range estimate. In these cases we have provided a single value that is our current best estimate. Permit fees are not included in the cost estimates. Permit requirements vary between jurisdictions, but broadly speaking, a permit may be required in most jurisdictions for any system that involves hardwiring or modifying the electrical load. Simple "plug-and-play" systems generally avoid permit requirements.

Table 16. Load Control Systems Comparison

Technology	Potential Total Cost	Advantages	Limitations	NEC Treatment
Non-Coincident Load Controls				
Circuit Sharing Control (Receptacle) 	**Total:** **$200 - $700** *Installation:* $0 - $200 *Equipment:* $200-500	**Panel Constraint(s) Addressed:**  **Best For:** Adding a new 240V load, like an EVSE, for homes with full panels that lack physical space or a new breaker and/or electric power capacity. Can be a DIY installation.	This only manages two specific devices; it is not a whole-home solution. It is also not ideal for HVAC systems, which need to run frequently. Expected to interrupt power more frequently than most PCS solutions.	These devices ensure non-coincident operation, which is addressed in NEC 220.60 (120.6 in the 2026 NEC). Allows an electrician to include only the larger of the two loads in the home's electrical load calculation, freeing up capacity for the new appliance.

Circuit Sharing Control (Hardwired)	**Total: $900 - $1,500** *Installation:* $300 - $400 *Equipment:* $600 - $1,100			
Technology	**Potential Total Cost**	**Advantages**	**Limitations**	**NEC Treatment**
Power Control Systems (PCS)				
Smart Panel 	**Total: $4,700 - $9,000** *Installation:* $2000-$5000 + *Equipment:* $2,700 - $3,500	**Panel Constraint(s) Addressed:**  **Best For:** Ideal for homes adding multiple high-power devices (EVs, heat pumps) where electrical capacity and breaker space are constrained. It is also suitable when a panel replacement is necessary (e.g., due to safety or age) or when a service upsize is prohibitively expensive or time-consuming. Owners who want an app or platform to monitor and manage solar, battery storage, EV charging, and energy use. For example, a smart panel can ensure maximum use of onsite energy generation or optimize real-time demand based on price signals from the utility.	This is the most expensive option and requires a full replacement of the existing electrical panel or installation of a new subpanel. Some may also have fewer breaker slots than traditional panels.	Smart panels are treated like any other panel by the NEC. Load calculations for smart panels that are listed as EMS or PCS can use Sections 220.70 (2023) or 120.70 (2026) in load calculations to add new loads without a service upsize.

Technology	Potential Total Cost	Advantages	Limitations	NEC Treatment
Load Shed Control 	**Total: $400 - $1,300** *Installation*: $300 - $400 *Equipment:* $100 - $900	**Panel Constraint(s) Addressed:**  **Best For:** Preventing a single, high-power device from overloading a panel. Breaker spaces are available to accommodate new load.	It only controls one or two items and does not solve the problem of a physically "full" panel with no room for new breakers or other household loads (that it does not control) from overloading the panel.	For 2023 NEC load calculations, a load shed device can most appropriately be treated as an EMS, with its load counted as zero in service or feeder load calculations. For NEC 2026 load calculations, a load shed device must be listed as part of a Power Control System.
Controllable Circuit Breaker 	**Total: $500 - $850** *Installation:* $300 – $600 *Equipment:* $200 - $250	**Panel Constraint(s) Addressed:**  **Best For:** Acting as modular components within a larger Power Control System. Controlling individual circuits to save money (e.g. running equipment during “off-peak” hours or participating in demand response programs). Compatible with many existing panels, permitting “smart” adaptations of an existing panel without replacement or upsizing.	On their own, they do not usually manage "capacity." They need to be part of a larger PCS to keep the home’s total power draw safe, typically including the breaker itself, a power monitoring module for the panel mains, and a control module/actuator. These all require additional breaker spaces in the panel. Bad fit for space-constrained panels or otherwise unsafe panels.	For a controllable breaker's load management to be recognized in NEC load calculations, it must be part of a listed Power Control System.

Technology	Estimated Total Cost	Advantages	Limitations	NEC Treatment
EVSE, load modulating 	**Total*:** **$700 - $900** *Installation:* *Equipment*: $500 **Note: A very limited sample was used to determine these costs*	**Panel Constraint(s) Addressed:**  **Best For:** This technology is ideal for homes with tight electrical capacity constraints where a standard high-power EVSE might otherwise cause an overload. It is especially useful for homeowners who want the flexibility of high-speed charging but also want to integrate their vehicle into a broader energy management plan—such as charging only when solar panels are producing excess energy or when utility rates are at their lowest.	A primary drawback is the need for additional metering hardware on the home's main power lines. In some residences, the electrical panel may be too crowded to fit these sensors, or the physical layout of the property may make it difficult for the sensors to communicate with the EVSE. Additionally, these systems do not automatically help the broader power grid unless the home is specifically enrolled in a utility-led "demand response" program.	For load modulating EVSEs to be recognized in NEC load calculations, it must be part of a listed EMS (220.70), PCS (120.7) or EV Energy Management System (625.42(A)). This allows this EVSE type to be counted as a much smaller electrical load (often 0) for service and feeder load calculations.
EVSE, load balancing 	**Total*:** **$700 - $900** *Installation:* *Equipment*: $500 **Note: A very limited sample was used to determine these costs*	**Panel Constraint(s) Addressed:**  **Best For:** This setup is best for households that have—or plan to have—multiple electric vehicles but lack the electrical capacity and physical space in the breaker panel for separate charging circuits. It provides a way to charge multiple cars simultaneously without compromising the home's safety or requiring a major electrical overhaul.	Like modulating EVSEs, these systems require reliable communication between the devices to share power correctly. Because they usually do not "see" what the rest of the home is doing, they cannot throttle down if the home's overall power use spikes; they only manage the power specifically allocated to the car EVSEs. They also require compatible hardware that can talk to other EVSEs on the same network.	These are treated as an EV Energy Management System (625.42(A)). Because the hardware ensures the cars will never exceed a specific power limit, the home's electrical calculation only needs to include that maximum shared limit, regardless of how many vehicles are actually plugged in.

Section 4 – Adding New Power Sources

Overview of Integrating Distributed Energy Resources

Solar installations have driven a large majority of panel and service upsizing as business-as-usual results in larger solar systems being installed on larger panel sizes. It is often standard practice when a homeowner gets solar to increase the size of a 100A electrical panel to 200A[61] under the assumption that a larger panel is required to have a larger solar array.

As seen in Figure 4 below, SolarAPP+[62] 2023 data for solar-only projects (N=33,359 projects)[63] shows the median system size installed is 6 kW.

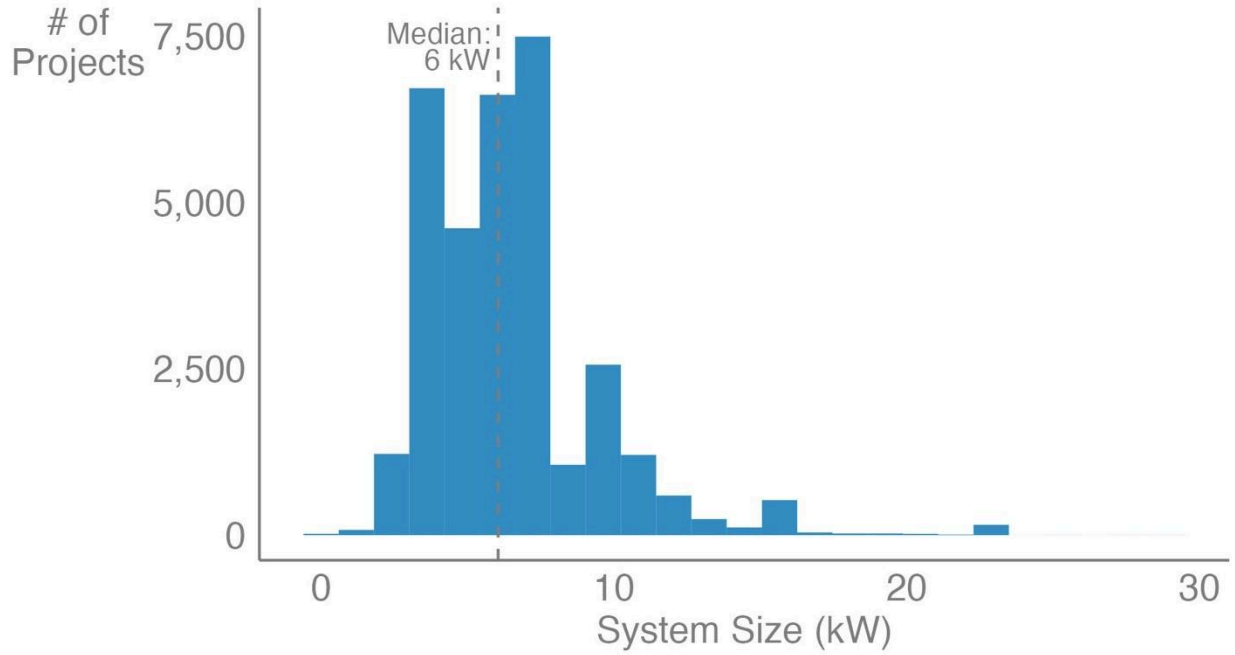


Figure 4. System size from SolarAPP data (Source: (NREL, 2024) Figure 22)

[61] Cook, Jeff et al. SolarAPP+ Performance Review (2023 Data). Golden, CO: National Laboratory of the Rockies. June 2024. Accessed April 21, 2026. https://www.nrel.gov/docs/fy24osti/89618.pdf.
[62] "The Solar Automated Permit Processing Plus (SolarAPP+) platform … an online portal designed to facilitate and expedite residential rooftop solar photovoltaic (PV) and battery storage permitting processes…In 2023, 668 installers submitted 18,906 permits through the SolarAPP+ platform, including 4,834 permits for PV+storage systems."
[63] Cook, Jeff et al. SolarAPP+ Performance Review (2023 Data). Golden, CO: National Laboratory of the Rockies. June 2024. Accessed April 21, 2026. https://www.nrel.gov/docs/fy24osti/89618.pdf.

With the evolution of solar equipment and connection methods, large solar arrays are able to be installed on smaller panels like 100A. These alternative methods are generally accepted by codes and local jurisdictions. While default methods limited solar arrays to about 3.8 kW in homes with 100A panels, these new alternative methods allow solar arrays to be sized 7-10 times larger. Functionally, these evolved connection methods apply not only to solar, but also batteries, wind, and other home scale power sources.

Below these new alternative methods are introduced to size solar arrays larger and their connection methodology are outlined. Also, the standard practice – the 120% Rule – is shared to provide a reference of comparison.

Load-Side Interconnections

Load-side interconnections refer to being made on the load side - i.e. downstream - of the main disconnecting breaker. This means all the connections are made on the customer side of the meter. Both the solar breaker rating and main service disconnect[64] rating must not exceed the rating of the electrical service to the meter, or the panel busbar[65]. These load-side interconnections can be made into the main panel (which is standard), into a subpanel (i.e. Hawaiian Tie-in), or into a feeder to a subpanel (i.e. Breaker Sandwich). For each of these scenarios, the wire size must be able to accommodate the size of the solar being added.

The 120% Rule[66] [67]: Under NEC 705.12(B)(2)(3)(b), this rule applies to all load-side methods of adding a new power source. It is most often applied when adding solar. This is often the least expensive option in terms of labor and equipment. In this method, the solar system and its in-feed breaker are sized to be no larger than 20% of the main panel's rating, which allows the main disconnect breaker to remain unchanged.

For example, this would permit a 5.5 kW Direct Current (DC)-rated solar PV system with a clipping[68] inverter to supply 3800W of continuous power through a 20A in-feed breaker for

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[64] *The main service disconnect is the main breaker that can turn all utility power to the home on or off at one location. It is the primary safety control for the entire electrical system and must be readily accessible for maintenance and first responder use, as required by the NEC*

[65] *An electrical busbar is essentially a solid strip of metal within an electrical panel that acts as the central highway for electricity, channeling power from the utility meter to all the different circuit breakers in the electrical panel. There are generally two, one for each 120V leg in a residential North American electrical panel, collectively referred to as "the busbar".*

[66] "705.12 Load-Side Source Connections." UpCodes. Accessed February 24, 2026. https://up.codes/s/load-side-source-connections.

[67] "The 120% Solar Rule Explained & When to Derate Your Breaker." GoGreenSolar. Accessed February 24, 2026. https://blog.gogreensolar.com/120-percent-rule-derate-breaker-for-solar.

[68] *Direct Current (DC) flows in a single, constant direction and is the type of power generated by solar panels and stored in batteries. Alternating Current (AC) periodically reverses direction and is the standard format used by the utility grid and household appliances.*

a 100A panel home. Inverters convert DC power from the solar panels to the type of power used by the grid, typically 240V Alternating Current (AC). The new inverter must be rated at no more than 80% of the rating of its breaker, so breakers are sized at 120% of the inverter rating. Using just this rule alone, installers are likely to assume that a larger system, say 7600W, would require a 200A panel.

For reference, below are 120% Rule equations used for sizing the solar circuit breaker and solar inverters:

Solar circuit breaker sizing. The following is the 120% Rule equation used to calculate the size of the solar circuit breaker being added to the main panel:

Max_solar_inverter_breaker
*= (main_panel_busbar_rating *1.2) - main_service_disconnect_rating*

Solar inverter sizing. The following is the equation used to calculate the size of the solar inverter that can fit on the largest allowable solar breaker.

*Max_solar_inverter_amps = 0.8 * Max_solar_inverter_breaker*

This 120% Rule can be used as a standalone interconnection method or combined with the other load-side interconnection methods discussed below.

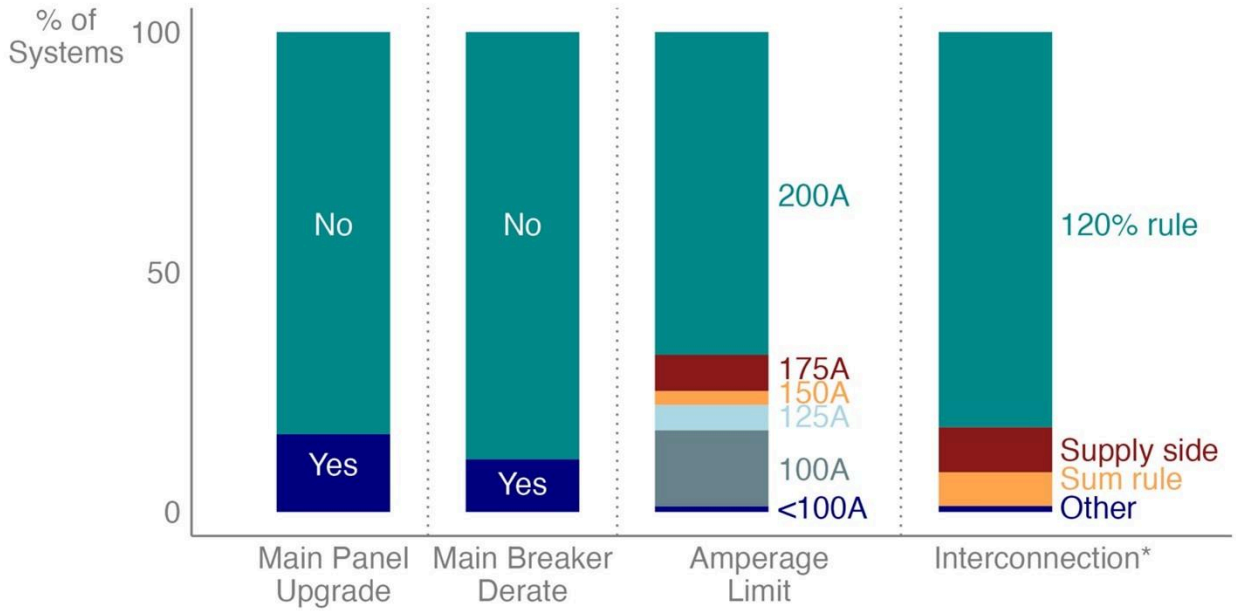
De-rating the Main Breaker[69]**:** This method creates additional capacity for a new power source at the expense of available capacity for the home's other loads. It is considered the second-least costly option. Whether this option is available will depend on the capacity of the busbar and the service wires from the utility.

For example, on a 125A panel, the calculated household loads will be relocated from the "original" 125A main breaker to a "new" main breaker rated at 100A. In this way, the main breaker is "de-rated" from 125A to 100A. Applying the 120% Rule, the de-rating allows the solar in-feed breaker to be sized to 50A, dependent on the panel busbar (50A = (125A*1.2) - 100A). Without de-rating, the solar in-feed breaker would only be 25A.

As seen in Figure 5 on the following page, from SolarAPP+ 2023 data, approximately 10% of solar installations "De-Rate the Main Breaker" to install more solar.

Clipping *is when a PV inverter "clips off" excess DC power from the solar panels attached to it, allowing larger installed array capacity and more lower-sun condition energy generation.* See section on Clipping Inverters

[69] "What Does It Mean to 'Derate' a Main Breaker?" Project Solar. Accessed February 24, 2026. https://knowledge.projectsolar.com/what-does-it-mean-to-derate-a-main-breaker.



Sample sizes: Panel upsize N = 25,890; breaker derate N = 19,922; amperage limit and interconnection N = 14,335. *Sum rule = sum of breaker rule; supply-side = supply-side connection; "Other" includes 120% rule on center-fed panels, power control system, and 100% rule

Figure 5. SolarApp data on main breaker derating (Source: (NREL, 2024) Figure 26)

The performance review of 2023 data from SolarAPP+ shows that approximately 10% of solar installations (N=19,922) "De-Rate the Main Breaker" to install more solar[70]. De-rating is a common practice in the field, which leads to many homes with nominal "100A panels" - i.e. these homes likely have a 125A panel busbar that has a 100A panel disconnect. Electrical panels are often field "de-rated" to allow 125A panels to have a larger solar in-feed breaker by replacing the original 125A main breaker with a 100A main breaker.

Hawaiian Tie-In: This method allows for larger solar by feeding the solar through a subpanel and relocating household loads onto the same subpanel[71]. While requiring the most labor due to migrating circuits, this method can reduce equipment costs and avoid service upsizing.

For example, on a 100A main panel, the household loads (i.e. the home's branch circuits) would be moved to a new subpanel that can be sized at 200A. This new 200A subpanel will

[70] Cook, Jeff et al. SolarAPP+ Performance Review (2023 Data). Golden, CO: National Laboratory of the Rockies. June 2024. Accessed April 21, 2026. https://www.nrel.gov/docs/fy24osti/89618.pdf, Figure 26.

[71] "Eliminate Main Panel Upgrades Part 5: Calculating Backfeed." San Diego Learn. Accessed April 21, 2026. https://lms.sandiegolearn.com/learn/courses/273/eliminate-main-panel-upgrades-part-5-calculating-backfeed/lessons.

be connected by a 100A feeder breaker to the 100A main panel; thus, the subpanel would not draw more than 100A from the main panel. The solar array would also be connected to the new 200A subpanel. In this scenario, the main panel has no home branch circuits remaining, but operates primarily as a bypass feeder. Must conform with NEC Article 705.12 for load side connection of sources.

Breaker Sandwich: This method creates a standalone breaker for larger solar by tapping into the feeder that connects the main panel to a subpanel in a home. The solar would be able to supply energy to either panel – i.e. the main panel and the subpanel. This solar breaker sits between the main panel's breaker to the subpanel and the subpanel's disconnect breaker; thus, this method is referred to as "Breaker Sandwich"[72]. The Breaker Sandwich requires the sum of the home branch breakers in the main panel to be equal to or less than main panel disconnect rating. So if all the home's branch circuits reside in the subpanel, similar to the Hawaiian Tie-In method, the Breaker Sandwich would allow a solar breaker to be sized up to 100A in a 100A main panel. If a 100A main panel has 20A of existing circuits and 80A breaker feeding a subpanel, then the solar breaker would be sized up to 80A.

Line-Side Interconnections

Line-side interconnections[73], also known as supply-side taps, are made between the main disconnecting breaker and the electric meter. Because this supply-side tap is made upstream the main breaker, all the connections are made on the utility side of the meter. As a result, line-side interconnections require coordination with the utility. These line-side interconnections can be made with a meter socket adapter or a line-side tie-in.

Meter Socket Adapter (MSA): This approach involves adding a branch circuit between the load-side of the meter and the line-side of the service bus **lugs**[74]. This requires coordination with the utility, as in most Investor Owned Utilities, a representative must come to the site to pull the meter. More information on MSAs can be found in Section 5 - Panel Space Saving Strategies.

[72] Personal communication with Reuben Veek, Operations Director at SunWork Renewable Energy Projects.
[73] Casalegno, Marco. "PV Interconnection: Load-Side vs. Line-Side." Greentech Renewables. Accessed February 24, 2026. https://www.greentechrenewables.com/article/pv-interconnection-load-side-vs-line-side.
[74] A **lug** in electrical terms is simply a connector that helps attach a wire or cable securely to a panel or breaker.

Line-side Tie-In[75]**:** For panels with accessible wires from the meter, a power source up to as powerful as the main disconnect can be attached downstream of the meter and upstream of the main disconnect. This interconnection requires coordination with the utility, as a representative must come to the site to pull the meter. This is also referred to as a supply-side tap or line-side tap.

[75] "Supply-Side Tap (Line-Side Connection)." Renvu. Accessed February 24, 2026. https://www.renvu.com/blogs/learn/supply-side-tap-line-side-connection.

Comparison between Load-side and Line-side Connections

Below is a table outlining the different interconnections options shared above with a 100A panel, and some comparisons to more typical 200A panels.

Table 17. Comparing Solar Systems Size Across Varying Interconnection Methods

Connection Method	Service Rating	Main Service Disconnect Rating	Main Panel Busbar Rating	Max Solar Breaker	Max Solar Inverter output *80% of solar breaker*	Max Solar array size DC rating (kW)
Load-side Interconnections						
business as usual: Upsizing to 225A busbar with 200A disconnect	200 A	200A	225A	70A	56A 13.4 kW AC	No clipping: 13.4 kW DC Clipping: 26.8 kW DC
business as usual: 120% Rule[76]	100A	100A	100A	20A	16A 3.8 kW AC	No clipping: 3.8 kW DC Clipping: 7.6 kW DC
De-rating 100A panel	100A	N/A	Derating is not allowed to go below a 100A disconnect[77]			

[76] A large majority of solar installations seen by SolarAPP+ utilize the 120% rule, most commonly with a 200A main disconnect. But it is possible to install solar on a 100A panel, even just using the default 120% Rule, and below more examples of alternative methods are shown.

[77] Since approximately 1962, NEC does not allow single-family homes to have less than a 100A Main Service Disconnect.

Connection Method	Service Rating	Main Service Disconnect Rating	Main Panel Busbar Rating	Max Solar Breaker[78]	Max Solar Inverter output *80% of solar breaker*	Max Solar Array Size DC rating (kW)
De-rating 125A panel	100A	100A	125A	50A	40A 9.6 kW AC	No clipping: 9.6 kW DC Clipping: 19.2 kW DC
Hawaiian Tie-in	100A	100A	100A	100A	80A 19.2 kW AC	No clipping: 19.2 kW DC Clipping: 38 kW DC
Breaker Sandwich *Note: Requires the sum of the home branch breakers in the main panel to be equal to or less than main panel disconnect rating*	100A	100A	100A	100A *0A of branch circuits are on main panel*	80A 19.2 kW AC	No clipping: 19.2 kW DC Clipping: 38 kW DC
	100A	100A	100A	80A *20A of home branch circuits are on main panel*	64 A 15.4 kW AC	No clipping: 15.4 kW DC Clipping: 30.7 kW DC

[78] Max_solar_inverter_breaker = (main_panel_busbar_rating *1.2) - main_service_disconnect_rating

Connection Method	Service Rating	Main Service Disconnect Rating	Main Panel Busbar Rating	Max Solar Breaker	Max Solar Inverter Output *80% of solar breaker*	Max Solar Array Size DC rating (kW)
Line-side Interconnections						
Meter Socket Adapter	**100A**	**100A**	100A	60A *Limited by MSA's capability or serving rating, whichever is smaller*	48A 11.5 kW AC	No clipping: 11.5 kW DC Clipping: 23 kW DC
Line-side Tie-in[79]	**100A**	**100A**	100A	100A *Limited to service rating*	80A 11.5 kW AC	No clipping: 11.5 kW DC Clipping: 23 kW DC

[79] Line-side-tie-in's, are often not economical because the installation can interfere with required UL listings of devices

Figure 6 below compares the maximum sizes of solar arrays using the different connection methods shared earlier.

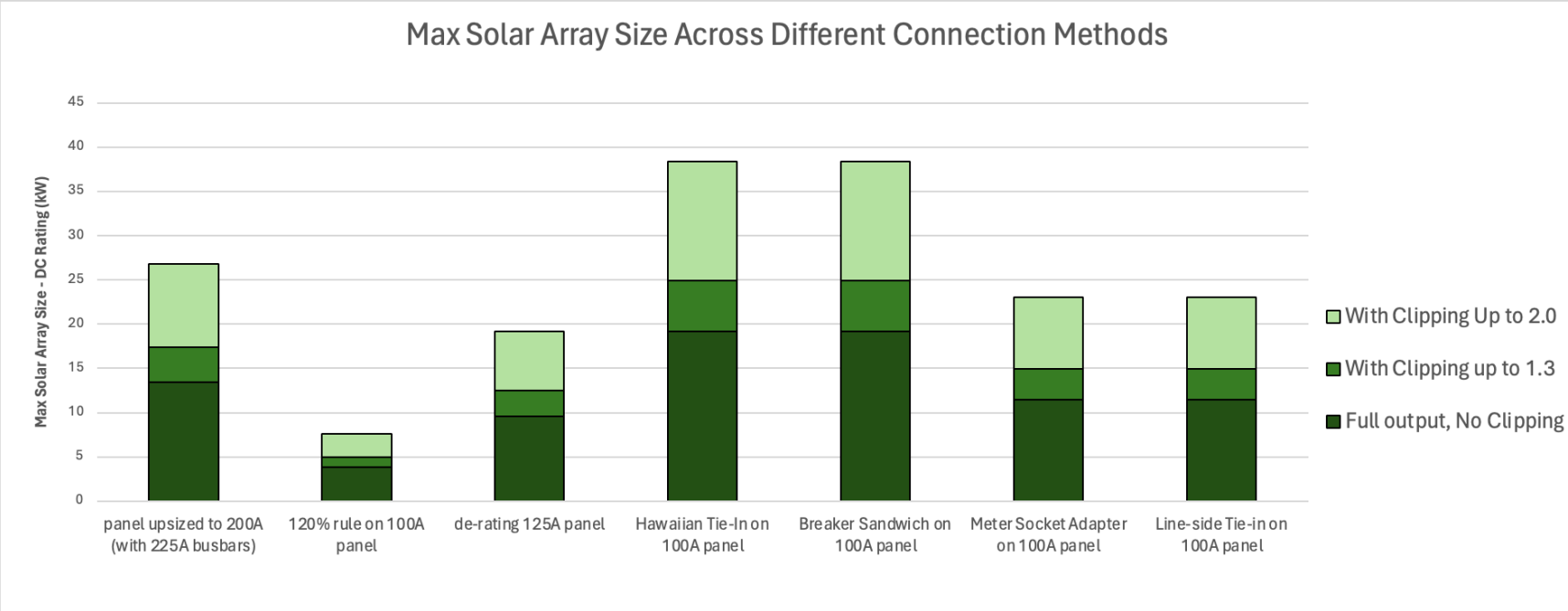


Figure 6: Results of different methods of attaching solar

PCS for Solar (Power Control Systems)

Another important way to put large solar arrays on 100A homes is using a Power Control System (PCS) for solar. These PCS are used with modern solar plus battery storage systems and can be used with solar-only systems as well.The PCS controls and directs output from the solar array into either the inverter or the battery or both. The PCS is set to allow the inverter to put out power up to the allowed long duration flow of the branch breaker. With a DC coupled battery, the PCS allows the solar array to produce more DC power than the inverter can deliver with the excess DC energy flowing to the battery. The inverter is able to deliver its rated AC output to the panel during sunny times and during other times the battery is supplying energy.

The PCS allows large solar arrays on small panels by shunting excess DC energy to the battery and/or by clipping the solar array output if needed in the sunniest hours. PCS solar array sizing is not dependent on the size of the solar breaker (see Appendix E: Clipping Inverters). The controllability of PCS for solar allows the solar breaker to be sized larger than under the 120% rule. In addition, because large PCS solar systems can shunt energy into the battery, less clipping loss occurs. The PCS is typically mounted to the wall on a garage and can be interconnected on either the load-side or line-side. Examples of PCS for solar include Enphase's IQ8 system, Tesla's Powerwall 3, and SolarEdge's HD Wave.

Emerging Technology: Home DC Nanogrids

Part-home DC Nanogrids[80] present a potential solution to avoiding a panel upsizing. These systems couple high-power loads (like EVSEs) with generation (solar) and storage (batteries) on a dedicated behind-the-meter DC bus[81].

A centralized power-converter box connects all devices to the DC bus and manages the system's connection to the main panel, which can be rated at a lower amperage than the sum of the individual devices. For example, the dcbel system[82] couples solar (20A), storage (30A), and two EVSEs (50A each) on a DC bus, compressing a potential 150A load down to a single 30A connection on the main panel. The battery storage is used to manage energy flow between peak generation and peak load times.

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[80] "GFO-23-308 – DC HVAC Nanogrid Module Development and Demonstration." California Grants Portal. Accessed February 24, 2026. https://www.grants.ca.gov/grants/gfo-23-308-dc-hvac-nanogrid-module-development-and-demonstration/.

[81] DC Nanogrid systems are designed with a dedicated DC-only busbar, which is completely separated from the main panel busbar.

[82] "Meet Ara: The Ultra-Efficient and Intelligent Home Energy Station." dcbel. Accessed April 21, 2026. https://www.dcbel.energy/ara/.

Key advantages of a DC nanogrid include:

- **Overload Prevention:** A bidirectional inverter ensures a programmable current limit from the main panel, preventing overload conditions that would violate NEC guidelines on a standard AC subpanel.
- **Centralized Management:** The system centralizes the operation of all connected devices, making coordination between end-uses far easier.
- **Core Benefits:** DC microgrids offer high efficiency, power capacity, and power quality.

While promising, this solution is an emerging technology and requires a significant upfront investment in solar, batteries, and other equipment, which may be a barrier for homeowners looking to add only a single appliance. Presently, DC Nanogrids are a design-build solution, requiring the help of an electrical professional to create a solution for an individual home.

Another simple version of this concept includes integrated solar and battery systems. Products like the Tesla Powerwall 3 contain an integrated solar inverter, allowing DC power from solar panels to feed directly into the battery. The internal inverter then converts and manages the power for the home or for export to the grid from a single point of connection.

Section 5 – Panel Space Saving Strategies

Overview of Physical Panel Space Optimization

While electrical capacity is a common concern in home upgrades, physical space constraints (the number of available breaker slots) are equally critical and may become more prevalent in future scenarios. Notably, breaker space constraints can exist in both small and large capacity panels. Addressing this involves two distinct phases: (1) breaker space scoping and (2) implementing a solution hierarchy ranging from low-cost appliance selection to installing new hardware.

Phase 1: Breaker Space Scoping

To determine if a panel has a breaker space constraint, the difference between available space and the requirements of the new equipment must be calculated.

1. **Count Available Slots**
   Identify unused slots in the main panel and any subpanels. These are typically identified by a 1-inch metal cutout aligned with existing breakers or could be covered by a plastic cover that is not occupied by a switch (breaker). Annotated images showing unused slots in residential panels are provided below in Figure 7.

2. **Calculate the Net Change in Breaker Slot for a Set of Upsizing**
   Determine the net change in slots required by the project using the following formula:

   Net Change = (Total New Slots Required) - (Total Old Slots Freed Up)

   where net-change is the total (sum) of new breaker slots required minus the total (sum) of any existing breaker slots freed up.

   For breaker slot requirements for new equipment, refer to the appliance and equipment summary tables in Section 1 - Appliances and Equipment. Note that some upsizing may actually reduce the total number of slots needed. For instance, replacing a 240V electric resistance water heater with a 120V heat pump water heater (HPWH) can free up one or two slots, while removing an existing air conditioner yields two additional spaces. Breaker spaces can also be freed up by reorganizing existing circuits to combine loads (see Strategy 3 - Circuit Reorganization) or use multi-circuit breakers (see Strategy 2 - Multi-Circuit Breakers (MCB)).

The net change can be positive or negative. For example, replacing an AC unit with a new HVAC heat pump results in a net change of zero (2 slots added, 2 removed). Conversely, replacing both an AC unit and a 240V wall heater with a single heat pump results in a net change of -2 (2 slots added, 4 removed).

Breaker slot requirements are primarily determined by the voltage and electrical ratings of the equipment:

- 120V Devices (e.g., standard outlets, lighting): Typically 1 slot.
- 240V Devices (e.g., dryers, EVSEs, AC units): Typically 2 slots.
- High-Power Loads (e.g., tankless water heaters): May require multiple 240V circuits, totaling 4 or 6 slots.

3. **Determine Space Constraint**
   To determine if the project is feasible with the existing panel, subtract the Net Change from the Available Slots counted in Step 1:

   Space Constraint = (Available Slots) - (Net Change)

   - If the result is Positive: Sufficient space exists to add new equipment
   - If the result is Negative: A space constraint exists. The number will indicate exactly how many extra slots are still needed.

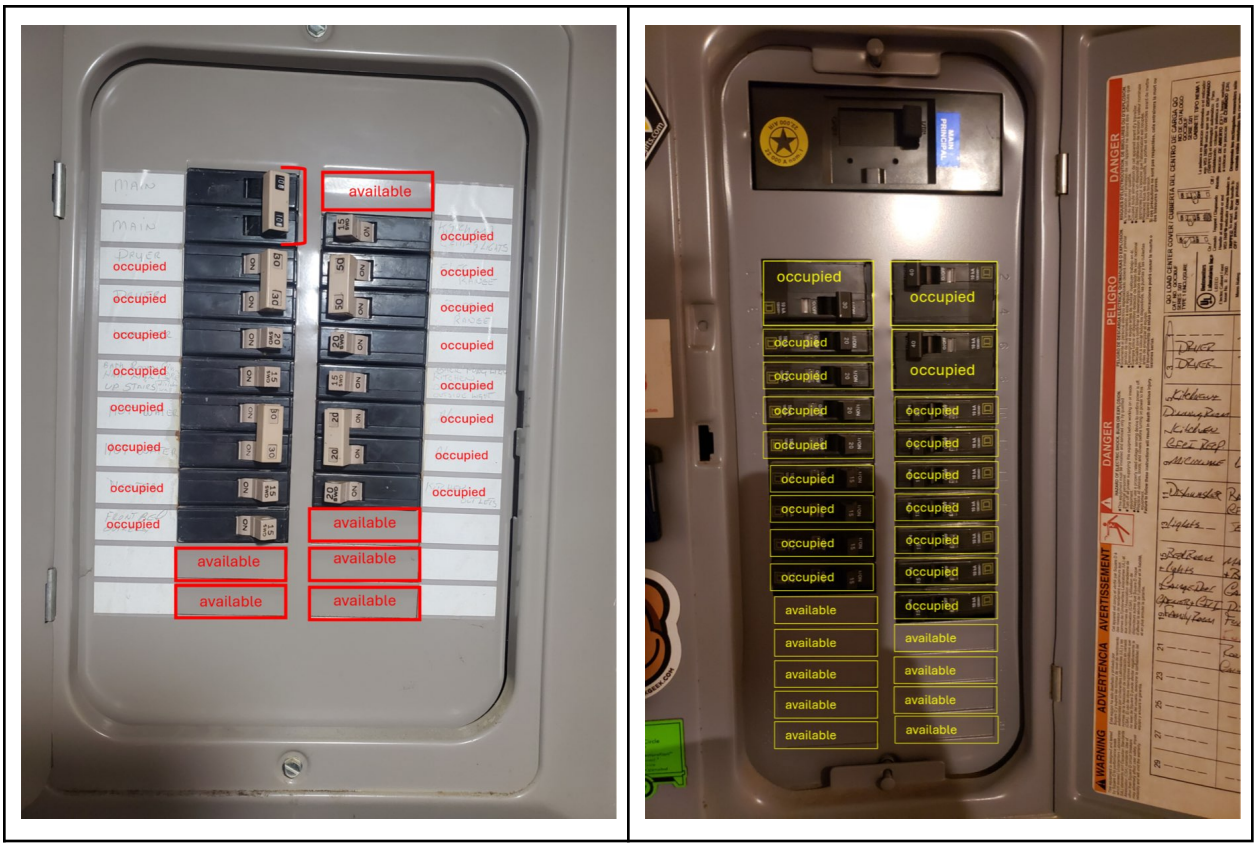


Figure 7. Example panels labelled to show available versus occupied breaker slots in residential electrical panels.

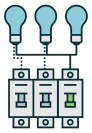
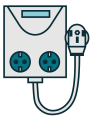
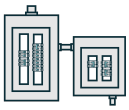
Phase 2: Space Saving Strategies

If a constraint exists based on the previous calculation (a Negative result in step 3), a full panel replacement can potentially be avoided based on the following strategies. They are prioritized below by estimated cost based on a survey of California electricians[83], combined with a convenience sample review of retail costs. All costs are normalized to 2023 US dollars, and represent US national average costs (i.e., not local California costs[84]). There are considerable price variations between technologies, so we have given typical pricing guidance at the time of writing this document. Note that within each category there are often large variations depending on features, brands, etc. For some devices, the available information does not always allow for a price range estimate. In these cases we have provided a single value that is our current best estimate.

[83] Guidehouse. "2023 Energy Efficiency Potential and Goals Study." Prepared for the California Public Utilities Commission. June 2023. Accessed February 25, 2026. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/energy-efficiency/2023-potential-goals-study/final-2023-group-e-pg-study-report.pdf.

[84] Costs can be adjusted to 2026 $USD (multiplier of 1.08) and typical California costs (multiplier of ~1.2).

Table 18. Panel Space Saving Strategies and Equipment Options

Strategy	*Potential Cost ($)*	*Key Benefit*
 Power-Efficient Appliance and Equipment Selection	N/A - Based on Selection	Reduces slot requirements via power-efficient equipment choices.
 Multi-circuit Breakers	$100 - 150 (assumes other electrical work is also occurring)	Splits one slot into two circuits (tandem/triplex/quadplex). Can only be installed in certain breaker slots, depending on the panel and type of breaker required.
 Circuit Reorganization	$600 (rough estimate)	Combines low-load circuits (e.g., LED lighting) to free up slots.
 Circuit sharing	$200-1,500	Load control that powers two devices on one branch circuit. Provides both capacity and space management.
 Meter socket adapter[85]	$600 - 2,000	Connects loads upstream of the main utility panel. Provides both capacity and space management. The serving utility has jurisdiction over acceptability of MSA in their territory.
 Subpanel	$1,000 - $3,000+	Adds significant capacity (2-40+ slots)
 Main panel replacement without service upsizing	$1,000 - $5,000	Replacing the main service panel with a new panel with more breaker slots, avoiding service upsizing.

[85] Sometimes also referred to as “meter collar” solutions, or as “green meter adapters” (GMA).

Strategy 1: Efficient Appliance and Equipment Selection

The most cost-effective first step is selecting appliances that minimize breaker usage. This might include transitioning separate units (e.g. washing and dryer or cooktop and oven) into combined appliances, or repurposing dedicated circuits (such as a dedicated air handler circuit that is no longer needed) when upgrading to mini- or multi-split heat pumps. Reference Section 1 - Appliances and Equipment for more information on specific selection criteria.

Strategy 2: Multi-Circuit Breakers (MCB)

Multi-Circuit Breakers (MCBs), such as tandem, triplex, and quadplex breakers, provide a lower-cost solution for panel space constraints by connecting more circuits per slot than traditional breakers. For instance, tandem breakers connect two 120V circuits to one slot, while triplex and quadplex breakers occupy two slots to serve either one 2-pole and two 1-pole circuits (triplex) or two 2-pole circuits (quadplex). These breakers retail for around $130–$150, and their installation costs are minimal when performed alongside other electrical work.

Compatibility for MCBs is determined by the electrical panel's rating, which, for panels manufactured from 1965-2008, specifies both the number of 1-inch slots and the maximum branch circuits (newer panels may also specify). Key indicators of compatibility, such as the model number, wiring diagram showing acceptable slots, max poles, and panel schedule, are often found on the panel door labels. The model number can indicate the ratio of slots to circuits; for example, a "3060" rating means 30 slots can accommodate 60 circuits (allowing all slots to accept MCBs), while a "3030" rating means 30 slots and 30 circuits (meaning no slots accept them). Common ratios are 1:1, 1:2, and "breaker slots plus 10" (e.g., 30/40). An even easier approach to estimating MCB acceptability is to count the 1” breaker slots and compare against the likely maximum number of circuits (maximum circuits estimate = panel rating in Amps x 2 / 10; for example, 20 circuits for a 100A panel). See extensive details regarding the determination of slots versus breakers in the three step process outlined in Appendix F: Determining if a Panel Can Accept MCB[86].

While simple and low-cost, MCBs do not address electrical capacity limits or offer smart control, making them best suited when monitoring or control is unnecessary. A major limitation is the typical lack of arc-fault (AFCI) and ground-fault (GFCI) protection in most models, a significant issue given expanded NEC fault protection requirements. In fact, adding AFCI/GFCI protection to existing circuits may necessitate removing existing MCBs and using an additional slot. Furthermore, there are restrictions on the rating of 2-pole

[86] This YouTube video also provides an excellent overview: https://youtu.be/o5pfQrYWZlc

circuits connected to MCBs; for example, specific models may prohibit a combination like 40A and 50A circuits.



Figure 8. Example images showing use of tandem and quadplex breakers in existing electrical panels. Red rectangles highlight MCB, with two circuits in one breaker slot, or two circuits in two breaker slots.

Strategy 3: Circuit Reorganization

Circuit Reorganization addresses physical space constraints by combining existing branch circuits that have low connected loads, provided the new total load remains acceptable. These strategies require electricians to determine which loads each branch circuit serves, which can be time-consuming and costly. Tools such as "toner tracers" can expedite this determination. Crucially, any circuit combining must also ensure that AFCI or GFCI protection requirements are maintained or resolved.

Some examples of reorganization include:

- Combining two loads that are on dedicated circuits but are not required to be separate (e.g., a dishwasher and garbage disposal).
- Integrating a load on an unnecessary dedicated circuit (e.g., a refrigerator) with other general loads.
- Combining multiple general light and receptacle circuits (e.g., two general light and receptacle circuits serving only LED lighting) if the dwelling currently exceeds the minimum number of circuits required by NEC 210.11(A) and (B) (see Table 19). The 15A and 20A values in Table 19 are not a combined requirement; either one 15A or one 20A breaker would satisfy the requirement in a 500 ft2 home, for example.

Table 19. The minimum number of branch circuits required to serve general light and receptacle loads (NEC 210.11(A) and (B)), based on dwelling floor area and branch circuit rating.

Floor Area (ft^2)	*General Lights and Receptacles Load (VA)*	*Minimum Circuits Required*	
		120V, 15A	*120V, 20A*
500	1500	1	1
1000	3000	2	2
1500	4500	3	2
2000	6000	4	3
2500	7500	5	4
3000	9000	5	4
3500	10500	6	5

Strategy 4: Circuit Sharing

Circuit sharing, often implemented through automatic switching devices or smart switching hardware, allows two high-power appliances/systems to share a single branch circuit. This strategy is particularly effective for adding new 240V loads—such as Electric Vehicle Supply Equipment (EVSE) or heat pump water heaters—without requiring additional breaker slots or increasing the home's total peak demand. Reference Section 3 - Load Controls: Non-Coincident Load Controls for more details.

Strategy 5: Meter Socket Adapters (MSA)

Meter socket adapters (MSAs) offer a strategy to bypass physical space constraints in electrical panels by creating a line-side interconnection (outside of the panel) directly at the utility meter base.

By mounting between the meter and the socket, MSAs provide a connection point upstream of the main service disconnect. This eliminates the need for new breaker slots in the main panel and allows for the connection of new power sources—primarily Solar PV—without triggering the NEC "120% rule" (which limits electrical current back-fed into the busbar). There are also new devices that allow connection of smart subpanels using an MSA.

While currently focused on solar generation, MSAs are evolving to support large load demands such as Electric Vehicle Supply Equipment (EVSE) and entire subpanels. Siting these loads near the meter allows for lower-cost installations that avoid routing wiring through the main panel. Future iterations may also integrate metering and smart load control to further manage capacity constraints.

Deployment is strictly regulated by utility territories and limited by the rating of the utility service conductors as shown in Table 20 below. Furthermore, ambiguity regarding hardware ownership (utility vs. customer) can complicate installation. Because deployment feasibility hinges on local policy, approval criteria vary by service area. The three major California IOUs (PG&E, SDG&E, and SCE) each have a product list of MSAs allowed in their service area.

Table 20. Acceptability of MSAs in Each California IOU Service Area

California IOU	***MSA Acceptability****
PG&E	**Approved** (Green Meter Adapter program)
SDG&E	**Approved** (Meter Socket Adapter program)
SCE	**Approved** (Meter Socket Adapter program)
Liberty Utilities	*Unknown*

PacifiCorp	**Approved** (Specific PacifiCorp requirements must be followed/met)
Bear Valley Electric Service	*Unknown*

**Note: Review of the availability of MSA programs was conducted by visiting the IOU website.*

Strategy 6: Subpanels

Subpanels are distribution panels fed from the main service panel. They offer the greatest volume of space, capable of accommodating anywhere from 2 up to 40 or more new circuits. Although they represent the most expensive space-saving solution per unit (estimated at $1,844), subpanels can substantially reduce the cost per breaker slot in homes with small existing panels where many new electrical loads are planned.

Strategy 7: Main Panel Replacement without Service Upsizing

When a panel has reached its physical limit (or is aged, deteriorated, is otherwise unsafe, or needs to be moved) and the prior strategies are not feasible, a main panel replacement is often the final recourse. This strategy involves replacing the existing physical enclosure and interior busbar with a new, higher-capacity "high-space" panel (e.g., moving from a 12-slot panel to a 40-slot panel) while maintaining the original service amperage.

This approach is distinct from a "Service Upsize" because it does not involve the utility company replacing the service lateral wires or the transformer. By keeping the main breaker rating the same (e.g., 100A or 200A), the homeowner avoids the significant costs and potential "utility-side" delays associated with trenching new lines or upgrading neighborhood infrastructure.

This is most appropriate when the existing panel is a legacy brand with known reliability issues (e.g., Federal Pacific or Zinsco), or when the panel is so physically small that even a subpanel cannot be easily integrated. Installing a high-space panel (typically 40 to 42 slots) provides a "blank slate" for future electrification, allowing for the easy addition of solar, storage, and heat pump technologies over the coming decades. Additionally, "Smart Panels" can be considered during this phase, which integrate electronic load shedding and energy monitoring, though these units currently command a premium price above the national average for standard panels.

Section 6 – Other Considerations

Overview of Infrastructure Risks and Constraints

When planning electrical work, it is crucial to identify pre-existing site conditions and hazards that can impact project safety, cost, and compliance. These factors range from code-related clearance issues to outdated or inherently dangerous electrical components that may persist in older homes. **Please consult with a licensed contractor to confirm any details you may be concerned about at home or work - this guidance is not comprehensive or a replacement for a qualified professional.**

Code Compliance and Clearance Requirements

Gas Meter & Electrical Panel Clearances

Uniform clearance requirements for gas and electrical meters apply to all residential buildings, including new construction and retrofits (when an existing home is altered) (see Appendix G1: Gas Meter & Electrical Panel Clearances). However, in existing homes, strict compliance with these clearances can lead to expensive workarounds, project delays, or even cancellations, including those that would improve safety (e.g. replacement of a known faulty panel).[87]

An update occurred for PG&E Greenbook[88] this February 2026 that allows existing clearances to be “legacied-in” to allow panel replacement for 200A or lower capacity under certain conditions.

Working Space for Retrofits

Code requires a specific working space around an electrical panel to ensure safety for service personnel. This includes:

- A 36-inch clearance in front of the panel or meter.
- A level platform that is at least 30 inches wide (or the width of the panel).
- The space must be permanently cleared of obstructions or stored items.

[87] "The New Insurance Requirements for Your Aging Electrical Panels." Apartment Management Magazine. Accessed February 25, 2026. https://aptnewsinc.com/news/the-new-insurance-requirements-for-your-aging-electrical-panels/.
[88] Pacific Gas and Electric Company. "Greenbook Update 2022-2023." 2023. Accessed April 21, 2026. https://www.pge.com/assets/pge/docs/account/service-requests/greenbook-update-2022-2023.pdf.

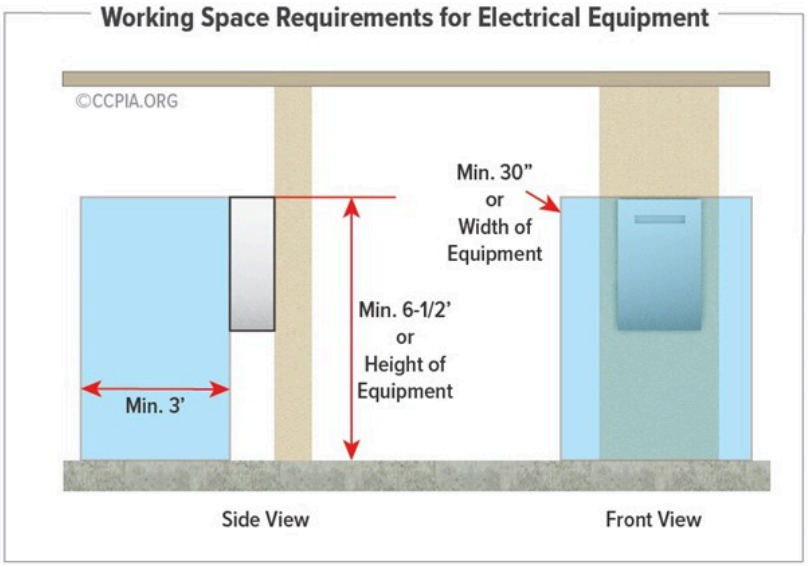


Figure 9. Source: (PG&E, 2023) Working space clearance requirements (NEC diagram)

Many older homes have legacy clearance violations that have not historically impeded utility service. When a new project is initiated, it can trigger the need for compliance with these modern standards. The cost to rectify these pre-existing issues can be high, especially in situations that do not require a service wire capacity upsize. A possible solution could involve allowing utilities to "legacied-in" existing violations if they have not previously caused issues at the site.

Problematic Electrical Panel Brands

The main service panel is a critical safety component of a home's electrical system. Certain brands installed from the 1950s through the 1990s are known for significant safety failures that increase the risk of fire and electrical shock. The most notable brands at issue are Challenger, Federal Pacific (FPE)[89] [90], and Zinsco[91]. These panels should be replaced regardless of other factors, and many home insurance companies now mandate their

[89] Buhr, Douglas. "What's the Deal with Federal Pacific and Zinsco Breakers?" Douglas Engineering. Accessed March 4, 2026. https://douglasengineering.com/whats-the-deal-with-federal-pacific-and-zinsco-breakers/.
[90] "Calibration and Condition Tests of Molded Case Circuit Breakers." Inspectapedia. Accessed March 4, 2026. https://inspectapedia.com/fpe/FPE_CPSC_Investigation.php.
[91] Williams, Lisa. "Why Zinsco Breaker Panels Are a Hidden Hazard in Your Home." Safe Home Management. Accessed February 25, 2026. https://www.safehomemanagement.com/post/zinsco-breaker-panels-electrical-fire-hazards.

replacement to issue or renew a policy.[92] Please see Appendix G2: Electrical Panel Brands for more information about these panel brands.

Other Pre-Existing Electrical Hazards

Visual inspection can identify many pre-existing hazards, which often appear as brown or black discoloration from high temperatures. However, visual inspection alone is insufficient, as wire insulation can be severely damaged from overheating yet appear normal until it is disturbed. See Appendix G3: Details on Pre-Existing Electrical Hazards for a detailed description of some common hazards.

Table 21. Summary of Pre-Existing Electrical Hazards

Hazard	Typical Signs/Indicators	Main Safety/Reliability Risks
Fuse Panel & Overfusing	Glass fuses, mismatched or oversized fuses	Overheating, fire, insurance non-compliance
Lack of Grounding (Ungrounded Systems)	2-prong outlets, missing grounding conductors	Electric shock, appliance/equipment damage, increased fire risk
Poor Electrical Connections/Sparking	Flickering lights, arcing, hot/burnt outlets	Arcing, fire, voltage instability, electric shock
Knob-and-Tube Wiring	Cloth-insulation, porcelain knobs/tubes	Lack of grounding, degraded insulation, overload/fire hazards
Burnt or Discolored Wires/Connectors	Brown/black marks, warm/hot wires/connections	Overheating, fire, equipment failure
Poorly Fastened Cables	Sagging wires, visible unsecured cable runs	Mechanical stress, conductor damage, short circuits
Inaccessible Junction Boxes	Boxes hidden behind walls/insulation	Hidden faults, poor maintenance, undetected code violations
Missing or Broken Breakers	Open slots, missing filler plates, taped breakers	Direct access to live parts, improper circuit protection
Cascading Hazards from Ground Failure	Corroded conduit pipes, multiple failed outlets	Sequential fires, system-wide failures, undetected escalation

Note: Each of these hazards can be latent, hidden by wall finishes or ceilings, and often overlap or cause cascading effects when combined.

[92] "Home Insurance Policies and Zinsco Panels: Navigating Coverage Challenges." Branover Contractors Inc. Accessed February 25, 2026. https://www.branovercontractors.com/home-insurance-policies-and-zinsco-panels/.

Section 7 – Panel Calculation Tools

Overview of Existing Electrification Tools

Assessing whether a home's panel has enough capacity for an electrification project is somewhat complex as Section 2 - NEC Primer for 220.83 and 220.87 spotlighted. There can also be other factors to take into account - e.g., HVAC or water heater sizing for a project. Currently, there is a range of existing and emerging digital tools to help homeowners, contractors, and policymakers implement electrification projects. These tools serve one or both of these roles: high-level electrification planning and formal code-compliant load calculations. By automating the complexities of the National Electrical Code (NEC), these resources help determine if an existing electrical service can safely support new equipment or if a costly service upsize is required. The following section provides a comparative analysis of the panel calculation and planning tools currently available and highlights their specific audiences, technical capabilities, and adherence to various NEC calculation methods.

Electrification Planning and Sizing Software

A comparative analysis was done on these fourteen different tools designed to assist with home electrification planning:

1. AmpWise
2. CalNEXT Panel Tool
3. Clean Energy Calculator
4. Electrification Roadmap
5. Elephant Energy
6. Green Upgrade Calculator
7. HomeIntel
8. Kopperfield
9. Maiven Energy
10. QuitCarbon App
11. Rewiring America
12. WattDiet Calculator
13. Xero Home
14. Zero Homes

While these tools occupy the same space, they are not identical in function. They represent a diverse ecosystem of solutions serving a range of audiences, including homeowners, contractors, utility program managers, and policy analysts.

The tools can be broadly categorized by their main purposes:

1. **Comprehensive Homeowner Planning:** Tools that provide homeowners with a personalized roadmap, including cost estimates and savings.
2. **Contractor and Technical Design:** Specialized tools for professionals to perform detailed electrical calculations, system sizing, and quoting.
3. **High-Level Estimation and Education:** Simple calculators and guides focused on incentives, general savings potential, and technical guidance.

4. **Data Analysis and Program Evaluation:** Tools used by analysts and utilities to assess the cost-effectiveness and impact of electrification on a larger scale.
5. **Full-Service Implementation:** Companies that manage the entire electrification process from assessment to installation.

Several trends are found in the features and offerings:

- **Energy calculations:** All the tools perform this necessary feature.
- **HVAC sizing:** A majority of the tools deliver recommended heating and cooling equipment capacities.
- **Costs:** All the tools contain a cost consideration with some tools more robust in the breadth of costs they integrate.
- **Panel and appliances/equipment**: Almost all the tools included low-power appliances/equipment, but the tools vary widely on considering panel capacity and performing load calculations.

For more information on these tools, please reference Appendix H: Existing Tools Comparison Tables.

NEC Electrical Load Calculation Tools

A comparative analysis was done on twelve tools designed for calculating electrical loads in accordance with NEC:

1. Ask-the-electrician.com - Online Interactive Residential Electrical Load Calculator
2. Building America Solutions Center - Heat Pump Water Heater Tool
3. CalNEXT Panel Tool
4. City of Palo Alto Building Permit Forms - “Residential Electric Load Calculator"
5. City of Sacramento
6. City of Thousand Oaks Building Handouts for Building Permits - “Electrical Service Calculations”
7. Kopperfield
8. Mike Holt’s Electrician Tool Box App
9. SPAN PowerUp
10. TrueLoad
11. Wattson Load Calculator
12. Watt Diet Calculator

The tools evaluated are not all interchangeable; they are built for different users and applications. The tools generally fall into one of the following categories:

1. **Professional Code Compliance Software:** These are robust, feature-rich tools intended for licensed electricians, electrical engineers, and contractors. They are designed for generating formal calculations for permits and construction documents, often covering residential, multi-family, and commercial projects.
2. **Educational and Training Calculators:** Often provided by electrical training organizations, these tools are designed to teach or reinforce the standard NEC calculation methods. They are typically straightforward and excellent for apprentices, students, or professionals looking to verify their manual calculations.
3. **Modern Electrification and Solar Sizing Tools:** This emerging category is focused on planning for the addition of modern, high-draw equipment like EVSEs, heat pumps, and solar panel systems. They are often more user-friendly and may be used by energy advisors and contractors specializing in home decarbonization.
4. **Jurisdictional Compliance Tools:** Some tools are developed and provided by a specific city or county building department (like the Los Angeles Department of Building and Safety (LADBS)). Their primary purpose is to standardize and streamline the process of showing compliance with local code requirements for that specific jurisdiction.

Several trends are found in the features of these NEC calculation tools:

- **Building Type:** The majority of the tools handled existing single-family residential.
- **NEC:** There are some tools that utilize NEC 220.82 and NEC 220.83; Two tools use NEC 220.87; No tool uses 220.84 directly.

For more information on these tools, please reference Appendix H: Existing Tools Comparison Tables.

Section 8 – Emerging Innovations

Overview of Emerging Technologies and Market Trends

Emerging innovations in power efficiency are moving toward load flexibility and enhanced grid integration. If current trends continue, there will be a shift from static appliances and systems to dynamic assets (both load and power sources) that are coordinated to manage electrical capacity at both the house and grid levels in the near future. Recent emerging innovations are detailed in the subsequent subsections.

Power-Efficient Appliances

Some emerging market segments are moving away from traditional high-powered equipment. Instead, they are beginning to offer power-efficient options, including those with lower (or modulating) power and more flexible installation options – e.g., field-adjustable voltage and power settings, as well as, use of either receptacle and hardwired connections. Water heaters and cooking appliances are some of the first to offer these new features. A prime example is the Summit 120V, 1800W range that maintains a 3-burner configuration and oven capacity without requiring battery backup. In addition, many power-efficient appliances will include communication and networking features, which will bring important capabilities (such as grid responsiveness) and challenges in terms of interoperability and reliability.

Advanced Digital Capacity Management for Homes and Grid

Managing power congestion at both the house and grid levels, power control systems are evolving beyond simple relay-based "hard shut-offs". Future approaches are likely to include digital control of power through communication, where networked appliances receive requests to shed, shift, or modulate power usage. This requires a new generation of controls capable of handling both traditional energy management for cost savings (or maximizing on-site consumption), along with electrical capacity management for individual panels, homes and the grid. One of the first applications for capacity management is for multiple EV charging stations, particularly for multifamily, with several companies currently offering solutions, some of which also integrate billing tracking abilities together with power management.

These innovations will also bring increasing complexity and communication requirements. These will present important challenges for long-term performance, maintainability and inspectability of systems relied upon for infrastructure safety and reliability. They also introduce concerns around the longevity of internet/app-based solutions and what happens to systems when internet support is lost.

Home DC Nanogrids

DC nanogrids and storage combine "DC-friendly" equipment, such as solar PV, EVSEs, and stationary batteries. The Ara by dcbel[93] is one such example that can integrate these technologies with one inverter. More information can be found in Section 4 - Adding New Power Sources.

Bi-Directional Power and Integrated Batteries

A growing number and variety of appliances and equipment, including HVAC and water heating systems, will feature integrated batteries. Currently, integrated batteries serve only the individual appliance they are part of, but in the future, innovations will allow these power sources to backfeed electricity to other loads within the home or even to the grid, potentially through standard 120V and/or receptacle-type connections. Being able to access the large battery capacity of EVs for home energy use is likely to be a key topic in the near future. The ability to backfeed power would dramatically change the value proposition for battery-integrated appliances and residential generation assets, particularly as some jurisdictions begin legalizing 120V plug-in “balcony” solar systems, effectively classifying them as plug loads.

Balcony (aka “plug and play”) solar has technically been around for a long time. Since 2016, it has been possible to buy individual systems (e.g. 240 watt panel plus a microinverter) that simply plug into a 120V outlet to offset internal home loads.

More recently, several companies are offering DIY solar plus storage kits with significantly more solar capacity (e.g. 800 to 2,000 W of PV, multiple microinverters, and 2-5 kWhs of storage). These systems can plug into multiple outlets. The systems rely on real time power monitoring and controls to prevent net generation, by either curtailing solar output from the microinverters or storing excess production in local modular batteries. There are also products being developed that are stand-alone devices with no connection to the home electric system (such as the Raya Power[94] integrated battery/solar boxes) - simplifying installation and removing the need for permits and interconnection applications. Energy stored in these device’s batteries can be used later during peak periods or during outages to power individual appliances. According to media reports, several hundred of these systems are already installed in California homes[95].

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[93] "Meet Ara: The Ultra-Efficient and Intelligent Home Energy Station." dcbel. Accessed April 28, 2026. https://www.dcbel.energy/ara/.
[94] "Raya Power." Raya Power. Accessed February 24, 2026. https://rayapower.com/.
[95] ”What to know before you get balcony solar”. CANARY MEDIA. Accessed April 30, 2026. https://www.canarymedia.com/articles/solar/what-to-know-balcony-solar

Appendix A: Electrical Terms and Details

Manufacturer-provided **nameplate power ratings** are used in load calculations, resulting in safe electrical designs. They reflect the maximum power draw of the equipment under expected worst-case usage patterns. The ratings are the result of standardized testing by Nationally Recognized Testing Laboratories, done in accordance with consensus standards. Nameplate power ratings are most commonly reported using apparent power (Volt-Amperes or kiloVoltAmperes, VA or kVA). In cases where the power factor is less than one, the apparent power is greater than the real power (Watts or kiloWatts). Apparent power reflects the electrical current required to power a device, whereas real power is the actual power consumed by a device in order to perform work. Real power is calculated by multiplying apparent power by the device's power factor. Power factor varies between devices and is higher for devices with resistance heating elements or for incandescent light bulbs, and lower for devices with motors, inverters, or compressors. A lower power factor results in a greater difference between real and apparent power.

Voltage requirements impact our tool because they define the required circuit breaker space for the device. The breakers for a 120V device use less space than a 240V device. This is because for the vast majority of panels, the width of the breaker defines if it is capable of addressing one or more “legs” of utility provided power on the busbar of the electrical panel. The panel will very often (since approximately 1960 in California) be configured to accept three wires from the utility transformer, two 120V wires (called legs) and one neutral wire. A 240V device needs to have at least 2 wires that provide a combined total of 240V to the device, if not a third wire for the neutral and a fourth for a ground.

Current rating of the device is often key, because the rating of the required breaker depends on the current rating of the device. If a device can be configured to operate with either 120V or 240V power, then the current requirements will generally be different depending on the configuration.

Electrical connection refers to how an appliance or equipment connects to household wiring, either hardwired or receptacle-based.

- **Hardwired**: Traditionally used for large electrical loads like HVAC equipment, water heaters, hot tubs and fixed-in-place electric cooking equipment (e.g., electric cooktops). These connections require an electrician, are typically more expensive, but are considered more robust and durable. The NEC considers hardwired appliances to be “permanently connected”, because they lack factory-installed cord-and-plug or attachment fitting connections.

- **Receptacle-based**: Used for appliances like clothes dryers, not fixed-in-place cooking appliances (e.g., slide-in electric range), refrigerators, and dishwashers. These connections can be made by homeowners or delivery persons if the receptacle and circuit are present. They are typically less expensive but also potentially less robust.

Typical electrical connection types for each end-use category are tabulated in Table 22.

Table 22. Typical electrical connection types and end-use category

Electric Load type	***Electrical Connection Type***
Cooking	Built-in ovens and cooktop are almost always hardwired to 240V circuits Free-standing and slide-in ranges can be either hardwired or cord-and-plug attached. Manufacturer specifications may stipulate. Mostly determined by installer preference, existing wiring/receptacles, and regional practice
Clothes Dryers	Always cord-and-plug, receptacle-based electrical connection, including both 120V and 240V appliances. 240V clothes dryers, do not typically have factory-installed plugs. This permits installation onto existing 240V circuits that are either 3- or 4-wire and with different NEMA receptacle types. 3-wire circuits and receptacles are more common in older homes and use a combined neutral and ground wire. 4-wire are more common in newer installations and provide separate neutral and ground conductors.
Water Heater	Almost always hardwired, except new 120V plug-in units that are cord-and-plug
HVAC Compressor	Always hardwired unless the compressor is 120V, then the compressor may sometimes be placed on a properly sized circuit and outlet. 120V compressors are often marketed as DIY.
HVAC Air Handler	Typically hardwired for 240V air handlers and cord-and-plug for 120V air handlers when they are powered separately.

Appendix B1: Specific Appliances & Equipment in the Market

In Table 23 below, is a "starting" point list to understand what power-efficient appliances and equipment is out there to help folks remain on their panel when possible. Please note that all prices and product availability are accurate as of the time of publication and are subject to change.

Table 23. Specific Appliance and Equipment List

Cooking Appliances

Cooktop (Induction with Battery)

Manufacturer	Model	Width (in)	# of Burners	Low Power	Volts	Amps	Volt-Amperes	Breaker Slots Required	Dedicated Circuit	Retail Cost	Store URL	Spec Sheet URL
Impulse	Cooktop	30" or 36" (nominal)	4	Yes	120	12.5	1500	0	No	$5,999.00	https://www.impulselabs.com/product	File Link
Impulse	Cooktop	30" or 36" (nominal)	4	Yes	240	8.3	1992	2	Yes	$5,999.00	https://www.impulselabs.com/product	File Link

Cooktop (Induction)

Manufacturer	Model	Width (in)	# of Burners	Low Power	Volts	Amps	Volt-Amperes	Breaker Slots Required	Dedicated Circuit	Retail Cost	Store URL	Spec Sheet URL
Drinkpod	DP-CHEFTOP-2	24"	2	Yes	120	15	1800	1	Yes	$131.00	https://drinkpod.com/products/cheftop-pro-dual-induction-cooktop	File Link
True Induction	TI-1B	12"	1	Yes	120	15	1800	1	Yes	$132.00	https://www.homedepot.com/p/True-Induction-True-Induction-TI-1B-12-in-Single-Element-Black-Induction-Glass-Ceramic-Cooktop-1750W-858UL-Certified-TI-1B/306141204	File Link
True Induction	MD-2B	20"	2	Yes	120	15	1800	1	Yes	$276.00	https://www.homedepot.com/p/True-Induction-True-Induction-MD-2B-20-in-Mini-Duo-Dual-Element-Black-Induction-Glass-Ceramic-Cooktop-1750W-858UL-Certified-MD-2B/306172864	File Link
True Induction	TI-3B	24"	3	Yes	120	27.5	3300	2	Yes	$572.00	https://www.homedepot.com/p/True-Induction-True-Induction-TI-3B-24-in-Triple-Element-Black-Induction-Glass-Ceramic-Cooktop-3300W-858UL-Certified-TI-3B/306175214	File Link
BOSCH	NIT5460UC	24"	3	No	240	30	7,200	2	Yes	$2,049.00	https://www.bosch-home.com/us/en/product/cooking-baking/induction-electric-cooktops/induction-cooktops/NIT8461UC	File Link
Fridgidaire	FCCI3027AB	30"	4	No	240	24	5,760	2	Yes	$899.00	https://www.homedepot.com/p/Frigidaire-30-in-Induction-Modular-Cooktop-in-Black-with-4-Elements-FCCI3027AB/319985895	File Link
GE	PHP7030DTBB	30"	4	No	240	40	9,600	2	Yes	$1,799.00	https://www.homedepot.com/p/GE-Profile-30-in-Smart-Induction-Touch-Control-Cooktop-in-Black-with-4-Elements-PHP7030DTBB/323644351	File Link
GE Profile	PHP9036DTBB	36"	5	No	240	46	11,100	2	Yes	$2,199.00	https://www.geappliances.com/appliance/GE-Profile-ENERGY-STAR-36-Built-In-Touch-Control-Induction-Cooktop-PHP9036DTBB	File Link
Kitchen Aid	KCIG550JBL	30"	5	No	240	33	7,800	2	Yes	$1,699.00	https://www.homedepot.com/p/KitchenAid-30-in-Induction-Modular-Cooktop-in-Black-with-5-Elements-KCIG550JBL/319111737	File Link
Samsung	NZ30K7880US	30"	5	No	240	36	8,600	2	Yes	$2,299.00	https://www.homedepot.com/p/Samsung-30-in-Induction-Cooktop-with-Stainless-Steel-Trim-with-5-Elements-and-Flex-Zone-Element-NZ30K7880US/300762437	File Link

Range (Induction with Battery)

Manufacturer	Model	Oven Cavity (cu ft)	# of Burners	Low Power	Volts	Amps	Volt-Amperes	Breaker Slots Required	Dedicated Circuit	Retail Cost	Store URL	Spec Sheet URL
Copper	Charlie	4.55	4	Yes	120	3-12*	360-1440	0	No	$5,999.00	https://copperhome.com/products/charlie	File Link
Electra	Electra	4.55	4	Yes	120	2-12*	240-1440	0	No	$3,999.00	https://www.electra.com/product-specs	File Link

*amperage is adjustable

Range (Induction) (120V)

Manufacturer	Model	Oven Cavity (cu ft)	# of Burners	Low Power	Volts	Amps	Volt-Amperes	Breaker Slots Required	Dedicated Circuit	Retail Cost	Store URL	Spec Sheet URL
Summit	Watt Sipper 30"	3.0	3	Yes	120	15	1800	1	Yes (on 20 A circuit)	TBD	https://www.wattsipper.com/product/TEM205BW	File Link
Summit	Watt Sipper 24"	2.4	3	Yes	120	15	1800	1	Yes (on 20 A circuit)	TBD	https://www.wattsipper.com/product/WSR2430SS	File Link

Range (Induction) (240V)

Manufacturer	Model	Oven Cavity (cu ft)	# of Burners	Low Power	Volts	Amps	Volt-Amperes	Breaker Slots Required	Dedicated Circuit	Retail Cost	Store URL	Spec Sheet URL
LG	LSIL6336F	6.30	5	Yes	240	11.9	2856	2	Yes	$2,999.00	https://www.homedepot.com/p/LG-6-3-cu-ft-Smart-Induction-Slide-in-Range-with-ProBake-Convection-Air-Fry-Air-Sous-Vide-in-PrintProof-Stainless-Steel-LSIL6336F/324906207	File Link
Fridigaire	PCFI3080AF	6.20	4	No	240	40	9600	2	Yes	$2,099.00	https://www.homedepot.com/p/Frigidaire-Professional-30-in-5-Element-Slide-In-Induction-Range-in-Stainless-Steel-with-Air-Fry-and-Total-Convection-PCFI3080AF/329740753	File Link
Fridigaire Gallery	GCFI3060BF	6.2	5	No	240	40	9600	2	Yes	$1,399.00	https://www.homedepot.com/p/FRIGIDAIRE-GALLERY-30-in-6-2-cu-ft-5-Element-Slide-In-Induction-Range-in-Smudge-Proof-Stainless-Steel-with-Total-Convection-and-Air-Fry-GCFI3060BF/325645579	File Link
LG	LSIL6334FE	6.3	4	No	240	40	9600	2	Yes	$2,599.00	https://www.homedepot.com/p/LG-6-3-cu-ft-Smart-Induction-Slide-In-Range-with-ProBake-Convection-Air-Fry-in-PrintProof-Stainless-Steel-LSIL6334FE/327604161	File Link
GE	JS645SLSS	5.3	4	No	240	40	9600	2	Yes	$1,499.00	https://www.homedepot.com/p/GE-30-in-5-3-cu-ft-Slide-In-Electric-Range-in-Stainless-Steel-with-Self-Clean-JS645SLSS/302557702	File Link
Samsung	NE63B8211SS	6.30	4	No	240	40	9600	2	Yes	$949.00	https://www.homedepot.com/p/Frigidaire-30-in-5-3-cu-ft-4-Element-Slide-In-Front-Control-Self-Cleaning-Induction-Range-with-Convection-in-Stainless-Steel-FCFI3083AS/323867171	File Link
Summit	WEM665W	3	4	No	240	40	9600	2	Yes	$1,900.00	https://www.summitappliance.com/catalog/model/WEM665W	File Link

Clothes Dryer

Clothes Dryer (Heat Pump) (120V)

Manufacturer	Model	Drum Volume (ft3)	Low Power	Volts	Amps	Volt-Amperes	Breaker Slots Required	Dedicated Circuit	Retail Cost	Store URL	Spec Sheet URL
Miele	TXD160WP	4	Yes	120	8.3	996	0	Shared 20 amp	$1,799	https://www.ajmadison.com/cgi-bin/ajmadison/TXD160WP	File Link

Clothes Dryer (Heat Pump) (240V)

Manufacturer	Model	Drum Volume (ft3)	Low Power	Volts	Amps	Volt-Amperes	Breaker Slots Required	Dedicated Circuit	Retail Cost	Store URL	Spec Sheet URL
BOSCH	WTW87NH1UC	4	Yes	240	3.5	840	2	Yes	$1,449	https://www.homedepot.com/p/Bosch-500-Series-4-cu-ft-240-Volt-Home-Connect-White-Stackable-Electric-Ventless-Heat-Pump-Compact-Dryer-ENERGY-STAR-WTW87NH1UC/315280946	File Link
Samsung	DV25B6900HW	4	No	240	30	7200	2	Yes	$1,299	https://www.homedepot.com/p/Samsung-4-0-cu-ft-Smart-Dial-Heat-Pump-Dryer-with-Sensor-Dry-in-White-color-DV25B6900HW/323095588	File Link
LG	DLHC1455W	4.2	Yes	240	3.1	744	0 or 2	Shared 20 amp, or yes	$1,299	https://www.homedepot.com/p/LG-24-in-W-4-2-Cu-Ft-Ventless-Stackable-Compact-SMART-Electric-Dryer-in-White-with-Dual-Inverter-HeatPump-Technology-DLHC1455W/316457781	File Link
LG	wkhc152hwa (Washer and Dryer System)	4.2	Yes	240	5	1200	2	Yes	$2,298	LG 2.4 cu. ft. Washer, 4.2 cu. ft. Dual Inverter Heat Pump Ventless Electric Dryer, Washtower, Center Control AIDD in White WKHC152HWA - The Home Depot	File Link
LG	DLHC5502V	7.8	Yes	240	15	3600	2	Yes	$999	https://www.lg.com/us/washers-dryers/lg-dlhc5502v-electric-dryer	File Link

Combined Washer and Dryer (Heat Pump)

Manufacturer	Model	Drum Volume (ft3)	Low Power	Volts	Amps	Volt-Amperes	Breaker Slots Required	Dedicated Circuit	Retail Cost	Store URL	Spec Sheet URL
LG	WM3998HBA	4.5	Yes	120	10	1200	0	No	$2,199	https://www.homedepot.com/p/LG-4-5-Cu-Ft-SMART-Electric-All-in-One-Washer-Dryer-Combo-in-Black-Steel-with-Steam-Turbowash-Technology-WM3998HBA/313550124	File Link
GE Profile	PFQ97HSPVDS	4.8	Yes	120	11	1320	0	No	$2,899	https://www.homedepot.com/p/GE-Profile-4-8-cu-ft-UltraFast-Combo-Washer-Dryer-with-Ventless-Heat-Pump-Technology-in-Carbon-Graphite-PFQ97HSPVDS/324668085	File Link
Koolmore	WAD-3CF-W	2.7	Yes	120	11	1320	0	No	$1,890	https://www.homedepot.com/p/Koolmore-2-7-cu-ft-All-in-One-Washer-and-Dryer-Combo-in-White-WAD-3CF-W/320171749	File Link

Combined Washer and Dryer (Heat Pump)

Manufacturer	Model	Drum Volume (ft3)	Low Power	Volts	Amps	Volt-Amperes	Breaker Slots Required	Dedicated Circuit	Retail Cost	Store URL	Spec Sheet URL
GE	PFQ83HSSWWW	4.6	Yes	120	11	1320	0	No	$1,799	https://www.bestbuy.com/product/ge-profile-ultrafast-4-6-cu-ft-high-efficiency-smart-front-load-washer-and-electric-dryer-combo-with-steam-and-ventless-heat-pump-white/J7645SP8ZX/sku/6589803	File Link
LG	WM6998HBA	5	Yes	120	12	1440	0	No	$2,999	https://www.homedepot.com/p/LG-5-0-cu-ft-Mega-Capacity-Smart-Front-Load-Electric-All-in-One-Washer-Dryer-Combo-with-TurboWash360-WiFi-in-Black-Steel-WM6998HBA/327850792	File Link
LG	WM3555HWA	2.4	Yes	120	13	1560	1	Yes	$1,799	https://www.homedepot.com/p/LG-24-in-W-2-4-cu-ft-SMART-All-in-One-Compact-Front-Load-Washer-Ventless-Dryer-Combo-in-White-with-Steam-WM3555HWA/318060806	File Link
LG	WM3555HVA	2.4	Yes	120	13	1560	1	Yes	$1,899	https://www.homedepot.com/p/LG-24-in-W-2-4-cu-ft-SMART-All-in-One-Compact-Front-Load-Washer-Ventless-Dryer-Combo-in-Graphite-Steel-with-Steam-WM3555HVA/318062283	File Link
Magic Chef	MCSCWD27S5	2.7	Yes	120	15	1800	1	Yes	$1,249	https://www.homedepot.com/p/Magic-Chef-2-7-cu-ft-All-in-One-Washer-and-Dryer-Combo-in-Silver-MCSCWD27S5/311970319	File Link
GE	GFQ14ESSNWW	2.4	Yes	120	20	2400	1	Yes	$1,399	https://www.homedepot.com/p/GE-2-4-cu-ft-Compact-White-120-Volt-Ventless-Electric-All-in-One-Washer-Dryer-Combo-GFQ14ESSNWW/312481993	File Link
Samsung	WD90F53AVBUS	5.3	No	240	30	7200	1	Yes	$1,999	https://www.samsung.com/us/business/home-appliances/all-in-one-washer-dryer-combo/electric/5-3-cu-ft-bespoke-ai-laundry-combo-vented-all-in-one-ultra-capacity-washer-and-electric-dryer-with-ai-home-in--brushed-black-wd90f53avbus/	File Link

Clothes Dryer (Resistance) (Unvented)

Manufacturer	Model	Drum Volume (ft3)	Low Power	Volts	Amps	Volt-Amperes	Breaker Slots Required	Dedicated Circuit	Retail Cost	Store URL	Spec Sheet URL
BOSCH	WTG86403UC	4	Yes	240	10.5	2520	2	Yes	$1,149	https://www.homedepot.com/p/Bosch-300-Series-4-cu-ft-240-Volt-White-Stackable-Electric-Ventless-Condensate-Compact-Dryer-ENERGY-STAR-WTG86403UC/315280951	File Link
BOSCH	WTG865H4UC	4	Yes	240	10.5	2520	2	Yes	$1,649	https://www.homedepot.com/p/Bosch-800-Series-4-cu-ft-Ventless-Compact-Frontload-Stackable-Electric-Dryer-in-White-with-Home-Connect-ENERGY-STAR-WTG865H4UC/315280947	File Link

Clothes Dryer (Resistance) (Unvented)

Manufacturer	Model	Drum Volume (ft3)	Low Power	Volts	Amps	Volt-Amperes	Breaker Slots Required	Dedicated Circuit	Retail Cost	Store URL	Spec Sheet URL
GE	GFT14ESSMWW	4.1	Yes	240	12	2880	2	Yes	$1,199	https://www.homedepot.com/p/GE-4-1-cu-ft-240-Volt-White-Electric-Ventless-Dryer-ENERGY-STAR-GFT14ESSMWW/307760461	File Link
Electrolux	ELFE4222AW	4	Yes	240	11.3	2700	2	Yes	$1,199	https://www.homedepot.com/p/Electrolux-IQ-Touch-24-in-4-0-cu-ft-White-Electric-Ventless-Dryer-ENERGY-STAR-ELFE4222AW/312831101	File Link

Clothes Dryer (Resistance) (Vented)

Manufacturer	Model	Drum Volume (ft3)	Low Power	Volts	Amps	Volt-Amperes	Breaker Slots Required	Dedicated Circuit	Retail Cost	Store URL	Spec Sheet URL
GE	GTD42EASJWW	7.2	No	240	24	5760	2	Yes	$779	https://www.homedepot.com/p/GE-7-2-cu-ft-Electric-Dryer-in-White-with-Wrinkle-Care-GTD42EASJWW/206355459	File Link
GE	GTD33EASKWW	7.2	No	240	24	5760	2	Yes	$699	https://www.homedepot.com/p/GE-7-2-cu-ft-vented-Electric-Dryer-in-White-GTD33EASKWW/206824723	File Link
LG	DLE3400W	7.4	No	240	30	7200	2	Yes	$899	https://www.homedepot.com/p/LG-7-4-Cu-Ft-Vented-Stackable-Electric-Dryer-in-White-with-Sensor-Dry-DLE3400W/312429301	File Link
LG	DLE6100W	7.3	No	240	30	7200	2	Yes	$749	https://www.homedepot.com/p/LG-7-3-Cu-Ft-Vented-Electric-Dryer-in-White-with-Sensor-Dry-Technology-DLE6100W/324433081	File Link
Whirlpool	WED5010LW	7	No	240	30	7200	2	Yes	$849	https://www.homedepot.com/p/Whirlpool-7-cu-ft-White-Top-Load-Electric-Moisture-Sensing-Dryer-WED5010LW/317845390	File Link
Samsung	DV25B6900EW	4	No	240	30	7200	2	Yes	$1,099	https://www.homedepot.com/p/Samsung-4-0-cu-ft-Smart-Dial-Electric-Dryer-with-Sensor-Dry-DV25B6900EW/323095575	File Link

Water Heater

Storage Water Heater (Heat Pump) (120V) (Shared Circuit)

Manufacturer	Model #	Tank Volume (gal)	First Hour Rating (GPH)	Low Power	Volts	Amps	Volt-Amperes	Breaker Slots Required	Dedicated Circuit	Retail Cost	Store URL	Spec Sheet URL
Rheem	XE40T10HM00U0	40	45	Yes	120	15	1800	0	No	$2,019.00	https://www.homedepot.com/p/Rheem-Performance-Platinum-ProTerra-40-Gal-Tall-0W-Element-Residential-Electric-Water-Heater-w-Heat-Pump-and-10-Year-Warranty-XE40T10HM00U0/317100795	File Link
Rheem	XE50T10HM00U0	50	55	Yes	120	15	1800	0	No	$2,119.00	https://www.homedepot.com/p/Rheem-Performance-Platinum-ProTerra-40-Gal-Tall-0W-Element-Residential-Electric-Water-Heater-w-Heat-Pump-and-10-Year-Warranty-XE40T10HM00U0/317100795	File Link
Rheem	XE65T10HM00U0	65	55	Yes	120	15	1800	0	No	$2,519.00	https://www.homedepot.com/p/Rheem-Performance-Platinum-ProTerra-40-Gal-Tall-0W-Element-Residential-Electric-Water-Heater-w-Heat-Pump-and-10-Year-Warranty-XE40T10HM00U0/317100795	File Link
Rheem	XE80T10HM00U0	80	72	Yes	120	15	1800	0	No	$2,798.00	https://www.homedepot.com/p/Rheem-Performance-Platinum-ProTerra-40-Gal-Tall-0W-Element-Residential-Electric-Water-Heater-w-Heat-Pump-and-10-Year-Warranty-XE40T10HM00U0/317100795	File Link
Rheem	PROPH40 T0 RH120-M	40	45	Yes	120	15	1800	0	No	$2,119.00	https://www.homedepot.com/p/Rheem-ProTerra-40-Gal-120-Volt-Plug-in-Smart-Heat-Pump-Water-Heater-with-Leak-Detection-and-Auto-Shutoff-and-10-Year-Warranty-XE40T10HMS00U0/317100818	File Link
Rheem	PROPH50 T0 RH120-M	50	55	Yes	120	15	1800	0	No	$2,103.00	https://www.homedepot.com/p/Rheem-Performance-Platinum-ProTerra-50-Gal-120-Volt-Plug-in-Smart-Heat-Pump-Water-Heater-with-10-Year-Warranty-XE50T10HM00U0/317100789	File Link
Rheem	PROPH65 T0 RH120-M	65	55	Yes	120	15	1800	0	No	$2,698.00	https://www.homedepot.com/p/Rheem-Performance-Platinum-ProTerra-65-Gal-120-Volt-Plug-in-Smart-Heat-Pump-Water-Heater-with-10-Year-Warranty-XE65T10HM00U0/317100785	File Link
Rheem	PROPH80 T0 RH120-M	80	72	Yes	120	15	1800	0	No	$2,799.00	https://www.homedepot.com/p/Rheem-Performance-Platinum-ProTerra-80-Gal-120-Volt-Plug-in-Smart-Heat-Pump-Water-Heater-with-10-Year-Warranty-XE80T10HM00U0/317100774	File Link

Storage Water Heater (Heat Pump Hybrid) (120V) (Dedicated Circuit)

Manufacturer	Model #	Tank Volume (gal)	First Hour Rating (GPH)	Low Power	Volts	Amps	Volt-Amperes	Breaker Slots Required	Dedicated Circuit	Retail Cost	Store URL	Spec Sheet URL
A.O. Smith	HPV10-66H01DV	66	76	Yes	120	15	1800	0	Yes	$2,649.00	https://www.lowes.com/pd/A-O-Smith-Electric-Heat-Pump-Water-Heater/5014375291	File Link
A.O. Smith	HPV10-80H01DV	80	93	Yes	120	15	1800	0	Yes	$3,098.00	https://www.lowes.com/pd/A-O-Smith-Electric-Heat-Pump-Water-Heater/5014375299	File Link
GE	PF40S10FPY	40	46	Yes	120	15	1800	0	Yes	$2,269.00	https://www.totalhomesupply.com/p/ge-pf40s10fpy-40-gallon-geospring-smart-hybrid-heat-pump-water-heater-with-flex capacity-120-volt	File Link
GE	PF50S10FPY	50	59	Yes	120	15	1800	0	Yes	$2,369.00	https://www.totalhomesupply.com/p/ge-pf50s10fpy-50-gallon-geospring-smart-hybrid-heat-pump-water-heater-with-flex capacity-120-volt	File Link
GE	PF65S10FPY	65	77	Yes	120	15	1800	0	Yes	$2,547.00	https://www.totalhomesupply.com/p/ge-pf65s10fpy-65-gallon-geospring-smart-hybrid-heat-pump-water-heater-with-flex capacity-120-volt	File Link
GE	PF80S10FPY	80	94	Yes	120	15	1800	0	Yes	$3,039.00	https://www.totalhomesupply.com/p/ge-pf80s10fpy-80-gallon-geospring-smart-hybrid-heat-pump-water-heater-with-flex capacity-120-volt	File Link
Rheem	XE40T10H15U0	40	45	Yes	120	15	1800	1	Yes	$2,119.00	https://www.homedepot.com/p/Rheem-ProTerra-40-Gal-120-Volt-Plug-in-Smart-Heat-Pump-Water-Heater-with-Leak-Detection-and-Auto-Shutoff-and-10-Year-Warranty-XE40T10HMS00U0/317100818	File Link
Rheem	XE50T10H15U0	50	55	Yes	120	15	1800	1	Yes	$2,103.00	https://www.homedepot.com/p/Rheem-ProTerra-50-Gal-120-Volt-Plug-in-Smart-Heat-Pump-Water-Heater-with-Leak-Detection-and-Auto-Shutoff-and-10-Year-Warranty-XE50T10HMS00U0/317100816	File Link
Rheem	XE65T10H15U0	65		Yes	120	15	1800	1	Yes	$2,698.00	https://www.homedepot.com/p/Rheem-ProTerra-65-Gal-120-Volt-Plug-in-Smart-Heat-Pump-Water-Heater-with-Leak-Detection-Auto-Shutoff-and-10-Year-Warranty-XE65T10HMS00U0/317100806	File Link
Rheem	XE80T10H15U0	80	72	Yes	120	15	1800	1	Yes	$2,798.00	https://www.homedepot.com/p/Rheem-ProTerra-80-Gal-120-Volt-Plug-in-Smart-Heat-Pump-Water-Heater-with-Leak-Detection-and-Auto-Shutoff-and-10-Year-Warranty-XE80T10HMS00U0/317100803	File Link

Storage Water Heater (Heat Pump Split Water Loop) (120V)

Manufacturer	Model #	Tank Volume (gal)	First Hour Rating (GPH)	Low Power	Volts	Amps	Volt-Amperes	Breaker Slots Required	Dedicated Circuit	Retail Cost	Store URL	Spec Sheet URL
Eco-Logical	OMNI-50HP1	50	50	Yes	120	14.4	1,730	1	Yes	$3,950.00	https://www.conservationmart.com/eco-logical/?srsltid=AfmBOorepSqRswWUQOVlx6zF-R6_XcHByqGvElXKKhhlgrXG-hPsx5pU	File Link

Storage Water Heater (Heat Pump Split Water Loop) (240V)

Manufacturer	Model #	Tank Volume (gal)	First Hour Rating (GPH)	Low Power	Volts	Amps	Volt-Amperes	Breaker Slots Required	Dedicated Circuit	Retail Cost	Store URL	Spec Sheet URL
Eco-Logical	OMNI-50HP2	50	56	No	240	18.5	4,440	2	Yes	$3,950.00	https://www.conservationmart.com/eco-logical/?srsltid=AfmBOorepSqRswWUQOVlx6zF-R6_XcHByqGvElXKKhhlgrXG-hPsx5pU	File Link
Eco-Logical	OMNI-80HP2	80	62	No	240	19.8	4,752	2	Yes	$4,500.00	https://www.conservationmart.com/eco-logical/?srsltid=AfmBOorepSqRswWUQOVlx6zF-R6_XcHByqGvElXKKhhlgrXG-hPsx5pU	File Link

Storage Water Heater (Heat Pump Hybrid) (240V) (15A)

Manufacturer	Model #	Tank Volume (gal)	First Hour Rating (GPH)	Low Power	Volts	Amps	Volt-Amperes	Breaker Slots Required	Dedicated Circuit	Retail Cost	Store URL	Spec Sheet URL
Rheem	PROPH40 T2 RH375-15*	40	46	Yes	240	11.0	2650	2	Yes		https://www.pacesupply.com/Product/RHEN40HP515A	File Link
Rheem	PROPH50 T2 RH375-15*	50	54	Yes	240	11.0	2650	2	Yes		https://www.pacesupply.com/Product/RHEN50HP515A	File Link
Rheem	PROPH65 T2 RH375-15*	65	54	Yes	240	11.0	2650	2	Yes		https://www.pacesupply.com/Product/RHEN50HP515A	File Link
Rheem	PROPH80 T2 RH375-15*	80	67	Yes	240	11.0	2650	2	Yes		https://www.pacesupply.com/Product/RHEN50HP515A	File Link

**succeeded to PROPH40 T2 RH400-15 model*

Storage Water Heater (Heat Pump Hybrid) (240V) (16A)

Manufacturer	Model #	Tank Volume (gal)	First Hour Rating (GPH)	Low Power	Volts	Amps	Volt-Amperes	Breaker Slots Required	Dedicated Circuit	Retail Cost	Store URL	Spec Sheet URL
Hubbell	PBX50	50	58	Yes	240	16	3800	2	Yes	Must request a quote or locate an authorized provider	https://hubbellheaters.com/products/electric/heat-pump-water-heater	File Link
Hubbell	PBX80	80	86	Yes	240	16	3800	2	Yes	Must request a quote or locate an authorized provider	https://hubbellheaters.com/products/electric/heat-pump-water-heater	File Link

Storage Water Heater (Heat Pump Hybrid) (240V) (16A)												
Manufacturer	Model #	Tank Volume (gal)	First Hour Rating (GPH)	Low Power	Volts	Amps	Volt-Amperes	Breaker Slots Required	Dedicated Circuit	Retail Cost	Store URL	Spec Sheet URL
Hubbell	PBX120	119	105	Yes	240	16	3800	2	Yes	Must request a quote or locate an authorized provider	https://hubbellheaters.com/products/electric/heat-pump-water-heater	File Link
Vaughn	MP55FHPT-CN	55	62	No	240	18.75	4500	2	Yes	Must request a quote or locate an authorized provider	https://www.vaughncorp.com/products/featherweight-heat-pump-water-heater	File Link
Vaughn	MP80FHPT-CN	80	86	No	240	18.75	4500	2	Yes	Must request a quote or locate an authorized provider	https://www.vaughncorp.com/products/featherweight-heat-pump-water-heater	File Link
Vaughn	MP119FHPT-CN	119	115	No	240	18.75	4500	2	Yes	Must request a quote or locate an authorized provider	https://www.vaughncorp.com/products/featherweight-heat-pump-water-heater	File Link

Space Heating and Cooling

Nameplate ratings for space heating and cooling equipment are highly variable, and they are strongly related to output capacity and other features. Existing product lists (e.g., AHRI, Energy Star) include many thousands of individual listings, and none include nameplate power ratings. Therefore, we will not list specific appliances that are considered "power efficient". Instead, we share the following draft guidelines for defining power efficient household appliances and equipment from LBNL (Less, Walker and Graessle (2025), in review). These were derived statistically based on a manually asembled sample of convenience including over 100 compressor-based residential HVAC systems.

Baseline - Non Power Efficient	Tier 1 - Power Efficient	Tier 2 - Power Efficient	Notes
3.5 kW per ton (230V, 14.6A per ton)	1.887 kW per ton (230V, 8.2A per ton) (120V, 15.7A per ton)	1.624 kW per ton (230V, 7.1A per ton) (120V, 13.5A per ton)	Baseline is purely resistive heating Tier 1 is based on the median for compressor-based systems we reviewed Tier 2 is based on the 25th percentile for compressor-based systems we reviewed No auxiliary resistance heat allowed

EVSE (L1 - L2 medium)

Manufacturer	Model	Volts	Amps	kW Rating	Breaker Slots Required	Dedicated Circuit	UL Listing	Retail Cost	Store URL	Spec Sheet URL
Schumacher Electric	SEV1670 (Level 1)	120 VAC	12	1.44 kW	1	No (standard outlet)	UL 2594	$129.00	https://www.homedepot.com/p/Schumacher-Electric-Level-1-Portable-EV-Charger-12-Amp-120-Volt-NEMA-5-15-Plug-Indoor-and-Outdoor-Charging-Universal-J1772-Connector-SEV1670/336397668	File Link
Lectron	Portable Tesla L1	120 VAC	12	1.44 kW	1	No (standard outlet)	UL 2594	$149.99	https://ev-lectron.com/products/lectron-portable-level-1-tesla-ev-charger-wifi-with-app-control-120v-12-amp-nema-5-15-16-ft-cord	File Link
Type S	Level 1/2 Portable	120/240 VAC	16	1.9 kW (L1) / 3.8 kW (L2)	1	No for L1, Yes for L2	UL 2595	$199.00	https://electricvehiclegeek.com/product/type-s-16a-level-1-ev-charger-review/	File Link
Leviton	EV320 (Level 2)	208–240 VAC	32	7.6 kW	2	Yes	UL 2596	$649.00	https://www.homedepot.com/p/Leviton-Level-2-EV-Charger-Station-32-Amp-208-240-VAC-7-6-kW-Output-18-ft-Charging-Cable-Hardwired-White-EV320-EV320/323401964	File Link
Enphase	HCS-D40 (Dual Port)	208–240 VAC	32	7.7 kW	2	Yes	UL 2597	$2,300.00	https://enphase.com/store/ev-chargers/commercial-ev-chargers/hcs-d40-dual-ev-charger-hardwired-32	File Link

Pool Heaters

Pool Heater (Heat Pump) (120V)

Manufacturer	Model	Output (kBtu/hr)	Volts	Amps	Volt-Amperes	Breaker Slots Required	Dedicated Circuit	Retail Cost	Store URL	Spec Sheet URL
Xtreme Power US	75219	14.9	115	7	805	0	No	$499.00	https://xtremepowerusa.com/products/75219	File Link
Xtreme Power US	75219	14.5	115	15	1725	1	Yes	$499.00	https://xtremepowerusa.com/products/75219	File Link
FibroPool	FH135	35	120	20	2400	1	Yes	$1,299.00	https://fibropool.com/products/fh135-heat-pump	File Link

Pool Heater (Heat Pump) (240V)

Manufacturer	Model	Output (kBtu/hr)	Volts	Amps	Volt-Amperes	Breaker Slots Required	Dedicated Circuit	Retail Cost	Store URL	Spec Sheet URL
Xtreme Power US	75210	53	230	10.8	2484	2	Yes	$2,249.00	https://xtremepowerusa.com/products/super-quiet-swimming-pool-heat-pump-pool-spa-heater-53-000-btu-digital-display	File Link
Xtreme Power US	75211	65	230	13.2	3036	2	Yes	$3,149.00	https://xtremepowerusa.com/products/ultra-quiet-65k-btu-swimming-pool-heat-pump-spa-heater-digital-led-65-000btu	File Link
Hayward	HP21205T	120	240	30	7200	2	Yes	$5,729.00	https://www.vitafilters.com/products/hayward-w3hp21105t	File Link
AquaCal	SQ166R	126	230	43.3	9959	2	Yes	$6,450.00	https://immerspa.com/product/heatwave-superquiet-sq166r/	File Link

Appendix B2: Cooking Appliances Installation

Table 24. NEC Requirements for Installing Cooking Appliances

NEC 2023 Section	Requirement
210.23(B)	Fastened in place utilization equipment requires dedicated circuit if rated >50% of circuit rating
220.55	Alternative load calculation for cooking appliances
210.8(D)	GFCI protection for electric ranges
422.31(B)	Disconnecting means for appliances over 300 VA

For a 40A circuit, 8 AWG (American Wire Gauge) copper conductors are standard; for 50A, 6 AWG copper is typically required. Electric ranges must be on a dedicated branch circuit per NEC 210.23(B) and NEC 220.55. A 9,600 VA range would be allowed to be placed on a 40A circuit. A means of disconnect must be provided per NEC 422.31(B) for appliances over 300 VA. This can be a breaker or a separate disconnect switch.

Despite being allowed to be protected by a 40A, 240V branch circuit, the NEC does not specifically allow the use of the corresponding power value (9600 VA) in load calculations. Treatment of electric cooking equipment in NEC load calculations depends on the type of load calculation being performed. Branch circuits for electric cooking equipment should be sized based on manufacturer recommendations and using NEC 220.55. When sizing services or feeders that include electric cooking equipment, such as a home, the requirements of the section being used should be followed. For example, optional load calculations, such as 220.82 and 220.83, specify the use of nameplate ratings for cooking equipment. Conversely when using Part 3 of Section 220 for a service or feeder load calculation, NEC 220.55 governs how to calculate the electrical load for household cooking appliances. It allows the use of demand factors to reduce the calculated load when multiple appliances are installed, recognizing that not all units operate at full capacity simultaneously. This section helps electricians size service and feeder loads more efficiently without overestimating demand. For instance, for two ranges each with 9.6 kW nameplate rating, you use the demand factor from NEC Table 220.55, which gives: 11 kW total for 2 ranges, as opposed to simply adding the nameplates together, which would give 19.2 kW. For a single range up to 12 kW, the full nameplate rating is used. If the range exceeds 12 kW, adjustments are made using a separate table.

Appendix B3: Water Heater

Table 25. NEC Requirements for Water Heaters

2023 NEC Section	*Description*
Manufacturer Spec / 422.10 (A)	Standard residential electric water heaters operate at 240V (some 120V models)
422.31(B)	Disconnect switch must be in sight or circuit lockable at breaker
210.23(B)	Water heater must be on its own dedicated branch circuit with no other loads (some models of 120V HPWH can share a circuit)
422.13	Circuit sized based on heater's rated current. Continuous load must be calculated at 125% of rated current, 18A × 1.25 = 22.5A yields 30A circuit breaker
310.16	Conductor sized to match circuit amperage, 10 AWG copper for 30A

Water Heater Sizing

Step 1: Establish the minimum required First Hour Rating.
Water heater sizing requirements in the 2022 California Plumbing Code[96] Table 501.1(2) mimic those found in the Uniform Plumbing Code[97]. These set the minimum required First Hour Rating (FHR) for water heaters in residential occupancies. The FHR specifies the number of gallons of hot water a water heater needs to deliver based on the number of Bathrooms and Bedrooms in the dwelling, as shown below in a reproduction of Table 501.1(2).

Table 26. Reproduction of Table 24 in the 2024 Uniform Plumbing Code

Number of Bathrooms	1 to 1.5			2 to 2.5				3 to 3.5			
Number of Bedrooms	1	2	3	2	3	4	5	3	4	5	6
First Hour Rating, in Gallons	38	49	49	49	62	62	74	62	74	74	74

[96] California Building Standards Commission. 2022 California Plumbing Code. Sacramento, CA, 2022. Accessed April 21, 2026. https://law.resource.org/pub/us/code/ca/2022_California_Plumbing_Code.pdf.
[97] International Association of Plumbing and Mechanical Officials. 2024 Uniform Plumbing Code. Ontario, CA, 2024. Accessed April 21, 2026. https://epubs.iapmo.org/2024/UPC/.

FHR = First Hour Rating, 1 gal=3.7854 L, 1 gph=1.5 mL/s

1. Tankless Water Heaters shall be sized and installed per manufacturer's recommendations
2. Water heaters for single family dwellings having more than six bedrooms and/or 3 1/2 baths shall be sized per manufacturer's recommendations.
3. Table 506 reflects the total minimum requirements for one or multiple water heating units.

Step 2: Use optional sizing approaches to select the most appropriate water heater.

Optional sizing guidance specifically developed for heat pump water heaters is produced by several organizations, including the following:

- PNNL HPWH online interactive sizing tool[98]
- 240V HPWH sizing guidance from RHA retrofit guide[99] (tank size by # of occupants)
    - 40-50 gallons <=2 adults
    - 66 gallons <= 3 adults OR 2 adults AND 2 kids
    - 80 gallons 5 or more people
- 120V HPWH sizing guidance from Slipstream Upper Midwest study[100]
    - Always consider 240V alternatives.
    - Shared circuit units: Upsize old water heater size by two categories.
    - Dedicated circuit units: Upsize old water heater size by one category.
    - Size by occupancy (or potential occupancy (i.e., bedrooms + 1):
        - 5 or more occupants, avoid 120V units entirely
        - 4 occupants, install dedicated circuit or ensure water demand is LOW
        - <= 3 occupants, shared circuit.

[98] U.S. Department of Energy. "Hybrid Water Heater Installation Tool." Accessed April 21, 2026. https://basc.pnnl.gov/hpwh_installation_tool.
[99] Richard Heath & Associates, Inc. "Best Practices for the Retrofit Installation of Heat Pump Water Heaters." Accessed April 21, 2026. https://basc.pnnl.gov/sites/default/files/2023-11/RHA%20Best%20Practices%20for%20the%20Retrofit%20Installation%20of%20Heat%20Pump%20Water%20Heaters%202023rev1.pdf.
[100] Jon Koliner. “Midwest 120-Volt heat pump water heater field study.” Slipstream. Accessed April 21, 2026. https://slipstreaminc.org/research/midwest-120-volt-hpwh-study.

Appendix B4: Space Heating and Cooling

When a contractor visits a home to install a new system, the standard of care is to follow three official industry guides:

- **Manual J (Load Calculation):** This estimates how much heat a house gains in the summer and loses in the winter. It looks at windows, insulation, and even which way the house faces (orientation).
- **Manual S (Equipment Sizing):** Once the "load" is determined, Manual S is used to select the specific air conditioner or heat pump that matches that need.
- **Manual D (Duct Design):** This ensures ductwork is the right size to move that air efficiently through the house.

Because full professional calculations take a lot of time, an "educated estimate" can be made using several different methods.

- **Standard Rules of Thumb**: A simple calculation based on floor area (for example, "one ton of cooling for every 400 square feet"). *Note: A "ton" is just a unit of cooling power, equal to 12,000 BTUs per hour.*
- **California-Specific Rules:** A more refined estimate (e.g., 550 square feet per ton) based on data from thousands of actual equipment installations across California[101].
- **Smart Statistical Models:** This method uses a "predictive model" that compares a home's characteristics—like its age, size, and local climate—against a massive database of similar California homes to predict needs.
- **Smart Meter Analysis:** This is one of the most accurate "shortcuts." By looking at actual hourly gas or electricity use from a smart meter, it can be determined exactly how the home performs when it's very hot or cold outside[102]. This provides information on how much power a specific house needs to stay comfortable.

[101] 548.53 ft2 per ton was derived from whole-home heat pump systems (n=37,104) in the TECH Clean California data downloaded on 2025-10-02 and filtered to remove 'Mini-Split' and 'Small Duct High Velocity' entries.
[102] Dorsett, Dana. "Replacing a Furnace or Boiler." GreenBuildingAdvisor. Accessed April 21, 2026. https://www.greenbuildingadvisor.com/article/replacing-a-furnace-or-boiler.

Appendix B5: Electric Vehicle Supply Equipment (EVSE) in the NEC

Below are details on the treatment and handling of EVSE in relevant NEC sections:

Table 27. Relevant NEC Sections for EVSE

NEC Section	*Description*
110.3	EVSE must be listed and installed in accordance with manufacturer instructions.
220.57	Dedicated EVSEs must be included in service and feeder load calculations as *continuous loads* at 7,200 VA or the nameplate rating, whichever is higher. Applies only to Standard Part III load calculations. *Note: 2026 NEC updates to allow use of nameplate ratings less than 7200.*
220.70	Permits use of Energy Management Systems (EMS) in load calculations, including for EVSE. Energy Management Systems (EMS) are treated as a continuous load, meaning the control setting is 80% of the relevant breaker rating. *Note: 2026 NEC updates this to section 120.7, which applies generally throughout all load calculations*
220.82 and 220.83	New and existing dwelling unit service and feeder load calculations. The 2023 NEC does not specify how EVSE loads are treated. We recommend that both .82 and .83 calculations include EVSE nameplate loads in the general load categories, where a 40% demand factor is used after an initial 8 or 10 kW at 100%. The 220.57 minimum of 7200 W is not relevant in these calculations. *Note: the 2026 NEC updates these sections. .82 calculations are required to treat EVSE at 100% and incorporates the .57 requirements; and .83 calculations specify that newly installed EVSE are treated at 80% (existing can still be treated at 40%)*
625	Installation requirements for EVSEs
625.40	EVSEs greater than 16 amps or 120 volts must be supplied by a dedicated branch circuit.
625.42(A)	EVSE circuits and wiring must be sized for continuous loads at 125% of the rated current individual branch circuits unless managed by an energy management system (EMS).
625.42(B)	EVSE equipment with adjustable power settings may use the adjusted power rating listed if adjusted per manufacturer instructions
625.44	Portable or fastened-in-place EVSEs must have appropriate receptacle selection based on conductor ampacity and load.

Appendix B6: Pools and Spas

Electrical Code and Safety Requirements

Due to the wet environment, all electrical equipment associated with pools and spas—including heaters, pumps, and lighting—must have Ground Fault Circuit Interrupter (GFCI) or Special Purpose Ground Fault Circuit Interrupter (SPGFCI) protection.

Table 28. 2023 NEC Sections Relevant or Specific to Pool and Spa Heaters

2023 NEC Section	*Application*	*Key Requirements*	*Cross References & Notes*
220.50	Heat Pumps	When doing a Part III Standard calculation, 100% of nameplate rating must be used in load calculation	Refer to Article 220.82(B)(4) and Article 440.6.
220.60	Non-Coincident Loads	If two or more devices will not be in use simultaneously, the largest may be used to size the feeder or service	Useful for various applications. Applies to pool pumps with controllers if configured accordingly.
680.10(A)	Electric Pool Water Heaters (Resistive)	Branch circuit sized ≥125% of nameplate; i.e. heating elements ≤48A, protected ≤60A	Refer to Article 240 for overcurrent protection
680.10(B)	Heat Pumps & Chillers	Must be listed and rated; branch circuit and protection per nameplate	Refer to Article 110.3(B) for listing compliance
680.6	Listing Requirements	All equipment must be listed (UL, ETL, etc) for pool use	Applies to heaters, pumps, controllers, etc.
680.44(C)	Gas-Fired Heaters	Circuits above intrinsic safety voltage require GFCI/SPGFCI	Applies if gas heater wiring exceeds 15V Alternating Current (AC) or 30V Direct Current (DC)

Under Article 220.50, heat pump pool heaters are considered refrigeration equipment (like air conditioners and HVAC heat pumps) and must be calculated as loads at 100% of their nameplate rating when doing a Part III Standard load calculation. This is not necessarily the case for Optional calculations using Part IV, such as 220.82-.84. Heat pump water heaters for home hot water usage are classified as domestic water heating appliances and not subject to that requirement.

To mitigate the impact of a heat pump pool heater on a home's load calculation, it may be practical to install these devices on circuit-sharing equipment, such as an EMS or a Power Control System (PCS), if done according to manufacturers instructions.

Appendix C: Differences in 2023 and 2026 NEC for 220.83 and 220.87

NEC 220.83 in 2023 vs 2026

Table 29 outlines our interpretation of section NEC 220.83 per 2023 and 2026 revision.

The key differences between the two vintages of the code are the general lighting/receptacle load (i.e., the VA/sqft is reduced from 3 in 2023 to 2 in 2026) and the demand factors used to derate different portions of the total load (e.g., the 2026 revision removed the demand factor dependency on new HVAC and new EVSE is derated less in 2026 than in 2023).

Table 29. Summary of section 220.83 in 2023 NEC vs. 2026 revision

	2023	2026 revision
General lighting / receptable load	3 VA/ft^2	2 VA/ft^2
Kitchen small appliance circuit	Two branches at 1.5 kVA each	
Laundry circuit	One branch at 1.5 kVA	
Nameplate electric loads	• HVAC (larger of heating or cooling) • Water heaters • Clothes dryers (not already on laundry circuit) • Ranges, wall-mounted ovens, counter-mounted cooking units • All appliances “fastened in place, permanently connected, or located to be on a specific circuit” • EVSE interpreted per “fastened in place”	Same as 2023, except permitted to exclude any loads connected to the small appliance, laundry or general lighting and receptacle circuits (similar to allowance for clothes dryers in 2023) • EVSE on a specific circuit

Demand factors	Both existing and new loads have the same demand factors applied - i.e. all loads are treated the same. The installation of "new" HVAC changes the demand factors applied. 2023 applies the demand factors as follows: (C) If **not** adding new HVAC, take • first 8 kVA of all loads at 100% • remainder loads at 40%. (D) If adding new HVAC, take • HVAC load at 100% • first 8 kVA of all other loads at 100% • remainder loads at 40%.	Demand factors distinguish between existing and new loads. The installation of "new" EVSE and "new" central resistance space heating have their own specific demand factors applied. 2026 applies the demand factors as follows: • New EVSE at 80% • New central electric resistance space heating at 80% • First 8 kVA of existing and new load at 100% • Remainder existing load at 40% • Remainder new load at 50%
Loads removal	Loads removed from home: • Specified NOT to be included in the calculation (i.e. the load removed is deducted)	Same as 2023

VA: volt-amp (equivalent to watt)
HVAC: heating, ventilation, and air conditioning
EVSE: electric vehicle supply equipment

NEC 220.87 in 2023 vs 2026

Section 220.87 of the 2023 NEC allows the use of metered data (either provided by the utility or gathered from installed metering equipment) to determine the panel capacity occupied by existing loads and if it has sufficient headroom for additional loads. The existing panel service is sufficient if 125% of the metered maximum demand plus the new load (at 100%) does not exceed its rated service capacity.

The electric peak can be based on data from one full-year or a minimum 30-day period at 15-minute resolution that is representative of typical occupancy and contains seasonal loads.

The 2026 proposed revision differs from 2023 by: (1) relaxing the conditions for how the maximum demand is determined and (2) modifying the addition of the new load from 100% to a net change in load that can be calculated using demand factors from other sections. Table 30 below summarizes our interpretation of the method for the two versions.

Table 30. Summary of Section 220.87 in 2023 NEC vs. 2026 Revision

	2023	2026
Existing load	125% of metered peak from either: ● a one-year period at 15- or 60-minute ● a representative 30-day period minimum recorded at 15-minute	125% of metered peak from either: ● a one-year period recorded at 15- or 60-minute ● a representative 30-day period minimum recorded at 15-minute
Load addition	Any new load at 100%	Any new appliance/equipment added at appropriate demand factors or load assumptions from other sections, such as 220.83
Load removal	Remain in calculation (i.e. nothing is changed in the calculation and the load removed stays)	Deduct load removed using their nameplating rating and appropriate demand factors

Additionally, NEC permits the use of load management devices to reduce the total service load, per 220.60 and 220.87. If two loads are on a circuit splitter such that only one can come on at a time, we take the largest of the two loads as the load for calculation.

Appendix D1: Starting List of Specific Load Control Devices in the Market

In Table 31 below, is a "starting" point list to understand what load controls technology is out there to help folks remain on their panel when possible. Please note that all prices and product availability are accurate as of the time of publication and are subject to change.

Table 31. Load Controls and Expansion Devices

Circuit Sharing

A circuit sharing device allows two or more appliances to share a single branch circuit, preventing them from running at the same time.

Circuit Sharing Control (Receptacle)										
Manufacturer	***Model #***	***Volts***	***Amps***	***Breaker Slots Required***	***Dedicated Circuit***	***Use Case***	***UL Listing***	***Retail Cost***	***Store URL***	***Spec Sheet URL***
Lectron	Socket Splitter	240 VAC	32 A	2, Plug-in	Yes	EV chargers	ETL Certified	$299.00	https://www.smud.org/-/media/Documents/Going-Green/EVs/Circuit-Sharing-Device-QPL.ashx	File Link
NeoCharge	Smart Splitter	240 VAC	32 A	2, Plug-in (NEMA 14-50)	Yes	EV chargers, electric dryers	UL E507438	$449.00	https://www.smud.org/-/media/Documents/Going-Green/EVs/Circuit-Sharing-Device-QPL.ashx	File Link

Circuit Sharing Control (Hardwired)										
Manufacturer	***Model #***	***Volts***	***Amps***	***Breaker Slots Required***	***Dedicated Circuit***	***Use Case***	***UL Listing***	***Retail Cost***	***Store URL***	***Spec Sheet URL***
SimpleSwitch	SS240	120 or 240 VAC	Up to 50 A	1, 2	Yes	EV chargers, electric dryers, water heaters	UL 916 (E510161)	$997.00	https://simple-switch.ca/product/simpleswitch-240/	File Link
SimpleSwitch	SS240M	120 or 240 VAC	Up to 50 A	1, 2	Yes	EV chargers, dryers	UL Listed	$790.00	https://kilowattshop.com/pages/simpleswitch-splitter-switch-ev-charger	Same as SS240
SimpleSwitch	SS240EV	120 or 240 VAC	Up to 50 A	1, 2	Yes	EV chargers	UL Listing pending	$789.00	https://kilowattshop.com/pages/simpleswitch-splitter-switch-ev-charger	Same as SS240

Smart Panel

An intelligent energy management and power control system that addresses an entire panel or subpanel. It actively monitors the total power being drawn from the electrical service or feeder and controls various circuits to ensure the service or feeder conductors are never overloaded.

Manufacturer	*Product / Model*	*Integration*	*Control Features*	*Panel Capacity Management*	*Number of Controllable Circuits*	*Connectivity*	*Retail Price*	*UL Listing***	*NEMA Rating*	*Store URL*	*Spec Sheet URL*
ABB (formerly Lumin)	ReliaHome™ Smart Panel	Retrofit or new build	Circuit-level control for up to 12 circuits; solar + battery integration	Yes (avoids service upgrades)	Up to 12	Wi-Fi/Ethernet, App	Quote Required	UL 916, CSA	NEMA 1	https://electrification.us.abb.com/products/load-centers-meter-combos-accessories/reliahome-smart-panel	File Link
ABB	Lumin Smart Panel	Add-on for existing panels	Smartens up to 12 circuits; integrates with solar batteries	Partial (focus on backup optimization)	Up to 12	Wi-Fi, App	$2,500 (panel only)	UL 916	NEMA 1	https://www.luminsmart.com/platform/smart-electrical-panel	File Link
EcoFlow	Smart Home Panel 3	Whole-home backup integration	Control 32 circuits; automatic switchover (<20 ms); solar + generator compatible	Yes (AI-based load prioritization)	32	Wi-Fi, App	Quote Required	UL Listed	NEMA 1	https://www.ecoflow.com/us/smart-home-panel-3	File Link
Leviton	Smart Load Center	Full panel solution	Individual breaker control; scheduling; energy insights	Yes (via My Leviton app)	12–42	Wi-Fi, App, Voice Assistants	Varies by size	UL 67, UL 489	NEMA 1 / NEMA 3R	https://leviton.com/products/residential/load-centers/the-leviton-smart-load-center	File Link
SPAN	SPAN Smart Panel (SPN-1-00800)	Full panel replacement	Control 16–48 circuits; real-time monitoring; app-based load prioritization	Yes (dynamic load management)	16–48	Wi-Fi, App (SPAN Home)	$2,550–$3,600 + install	UL 67, UL 916, UL 3141	NEMA 3R (indoor/outdoor)	https://www.span.io/panel	File Link

**Many products are being updated to UL 3141.

Load Shed Control

A dedicated piece of hardware outside of the panel that monitors a specific circuit (like the main service or a feeder) and automatically de-energizes a connected load to prevent an overcurrent event.

Manufacturer	Product	Volts	Amps	Breaker Slots Required	Dedicated Circuit	Use Case	UL Listing	Retail Cost	Store URL	Spec Sheet URL
Black Box Innovations	EVEMS Controller	240 VAC	Up to 60 A	No extra breakers needed	Yes	EV chargers, resistive loads	ETL Listed (Intertek)	$650	https://blackboxinnovations.com/products/evems-100a-service-60a-charger	File Link
Siemens	Inhab Load Manager LM1160	240 VAC	Up to 60 A	Connects to branch breaker	Yes	EV chargers, water heaters, HVAC	UL 916	$928	https://www.homedepot.com/p/Siemens-Inhab-60-Amp-Load-Manager-Energy-Management-System-LM1160/330416726	File Link
simpleSwitch	EVEMS Smart Load Manager	120/240 VAC	50 A	1 slot	Yes	EV chargers, induction cooktops	UL 916 (E510161)	$997	https://simpleswitch.io/	File Link
StepWise	Tap Load Manager	240 VAC	Up to 60 A	2	Yes	EV chargers, water heaters, HVAC	UL 916	$780	https://getstepwise.myshopify.com/products/tap?srsltid=AfmBOoohMa1Ugr1ilvdcO5Ayrn3Sel1IDvi79QGW8C5Nf9jA66bpbMii	File Link
Thermolec (RVE)	DCC-9 Series	120/240 VAC	30–60 A	Integrated (Splitter Box)	Yes	EV chargers	UL 916, CSA Certified	$1,155	https://www.shopdccelectric.com/catalog/shop/Warshauer-Green-Energy/DCC-EV-Charging-Energy-Management-Systems/DCC-9-EV-Energy-Management-Systems/dept-8Q3?pagenum=1&itemsperpage=60&a=1	File Link
Thermolec (RVE)	DCC-12	120/240 VAC	Up to 60 A	1 double-pole slot	Yes	EV chargers	UL 916, CSA Certified	$755	https://www.shopdccelectric.com/buy/product/dcc-60-amp-ev-energy-management-system-load-controller-dcc-12/162254	File Link
VEC Electric	VEC Load Control	240 VAC	Configurable	Multi-channel options	Yes	EV chargers, HVAC, hot tubs	UL Listed	Quote Required	https://www.v-electric.com/	File Link

Controllable Circuit Breakers

Looks and installs like a standard breaker but includes onboard power metering, communication functionality, and the ability to be remotely controlled. These devices could be considered a version of a load shed control, but they are distinct in that they are integrated directly into circuit breakers and panels, rather than existing as separate external hardware.

Manufacturer	Product	Integration	Control Features	Panel Capacity Management	Connectivity	UL Listing	NEMA Rating	Retail Price	Store URL	Spec Sheet URL
Eaton	AbleEdge Smart Breakers	Retrofit Eaton BR load centers	Circuit-level monitoring and load shedding	Yes (extends battery backup, avoids overload)	Eaton Home App	UL 67, UL 489	NEMA 1	Quote Required	https://www.eaton.com/us/en-us/products/residential/ableedge.html	File Link
Leviton	2nd Gen Smart Circuit Breakers	Retrofit Leviton load centers	Circuit-level monitoring and load shedding		My Leviton App	UL 489, UL 943 (GFCI), where applicable UL1699 (AFCI), where applicable	NEMA 1	Quote Required	https://leviton.com/products/residential/load-centers/smart-circuit-breakers	File Link
Savant	Smart Panel + Power Modules	Subpanel, Retrofit into existing panels	Monitors and controls circuits (20A–60A), prioritizes loads	Yes (ideal for backup power scenarios)	App-based, real-time alerts	UL 67, UL 916	NEMA 1	Quote Required	https://savant.com/power/smart-panel	File Link

EVSE, Load Modulating

These controllable (or "smart") EV chargers operate like conventional EV chargers but include load control functionality to manage electrical capacity and avoid service upgrades.

Manufacturer	Product	Volts	Amps	Breaker Slots Required	Dedicated Circuit	Use Case	UL Listing	Retail Cost	Store URL	Spec Sheet URL
ELECQ	Level 2 Smart Charger + Power Monitor	240V	Up to 40A	Active Load Management (ALM) dynamically balances home loads; integrates solar charging modes	Yes		UL Certified	$699.00	https://us.elecq.com/pages/elecq-home	File Link
Enphase	IQ EV Charger with PCS	240V	Up to 48A	Power Control Software (PCS) adjusts charging rate based on real-time household load; integrates with solar	Yes		UL 3141	Quote Required	https://enphase.com/ev-chargers/learn/optimize-ev-charging-protect-homes-electrical-overload	File Link
Emporia Energy	Emporia Pro Level 2	240 VAC	Up to 48 A	Plug-in (NEMA 14-50) or Hardwired	Yes	EV chargers for homes with 100A panels	UL 2594	$599.00	https://shop.emporiaenergy.com/products/emporia-level-2-ev-charger-with-load-management	File Link

EVSE, Load Modulating

These controllable (or "smart") EV chargers operate like conventional EV chargers but include load control functionality to manage electrical capacity and avoid service upgrades.

Manufacturer	Product	Volts	Amps	Breaker Slots Required	Dedicated Circuit	Use Case	UL Listing	Retail Cost	Store URL	Spec Sheet URL
PSP Products	SAK-60MS Load Management Controller	240V	Up to 60A	Intelligent microcontroller monitors panel load and only allows EV charging when capacity is available; prevents overload without panel upgrade	Yes		UL 916	$700.00	https://www.pspproducts.com/sak-60ms-series/	File Link
Siemens	Inhab™ EV Load Manager + Compatible Charger	240V	Up to 48A	Continuously monitors home energy use and adjusts EV charging rate to avoid exceeding panel capacity; works with any brand EV charger	Yes		UL 916	$994.00	https://www.siemens.com/us/en/products/energy/low-voltage/new-homes/inhab/inhab-load-manager.html	File Link
Wallbox	Pulsar Plus Model PUP2 + NA Power Meter	120V 240V	Up to 225A Main	Hardwire Preferred		Zero export solar, dynamic load limiting, multiple charger balancing.	UL 2594 UL 2231	$899.00	https://shop.wallbox.com/products/pulsar-plus-48amp-with-nacs-connector-and-power-meter-and-enclosure?variant=46354659049622	File Link
Wallbox	Pulsar Plus Model PUP3 + NA Power Meter	120V 208V 240V	Up to 225A Main	Hardwire Preferred	Yes	Zero export solar, dynamic load limiting, multiple charger balancing.	UL 2594 UL 2231	$999.00	https://support.wallbox.com/na/knowledge-base/pulsar-pro-product-overview/	File Link
Tesla	Gen 3	240V	6A - 48A	Hardwired	Yes	Residential garages, where it can be wired to the EV owner's electric panel	UL 2594 UL 2231	Quote Required	https://www.tesla.com/support/charging/wall-connector	File Link

EVSE, Load Balancing

Controllable (or "smart") EV Chargers with load balancing function like conventional EV chargers but can flexibly dispatch power to multiple connected EV chargers on a single circuit.

Manufacturer	Product	Volts	Amps	Breaker Slots Required	Dedicated Circuit	Use Case	UL Listing	Retail Cost	Store URL	Spec Sheet URL
EverCharge	EV02 SmartPower™	208–240 VAC	48–80 A	Hardwired	Yes	Multi-unit dwellings, fleet charging	UL 2231	Quote Required	https://evercharge.com/products/ev02	File Link
Xeal / Smart Charge America	SCA40 Powered by Xeal	240 VAC	32 A	Hardwired or Bollard Mount	Yes	Apartments, condos, commercial		$2,799.00	https://smartchargeamerica.com/electric-car-chargers/commercial/sca40/	File Link
Enphase	HCS-80 with COSMOS	240 VAC	32, 48 or 64A	Hardwired	Yes	Commercial sites with energy management		Quote Required	https://enphase.com/store/ev-chargers/hcs-80-cosmos	File Link
Grizzl-E	Duo	120-240 V	32A, 24A, 16A	Hardwired	N/A			$899.00	https://grizzl-e.com/store/	File Link
Tesla	Gen 3	240V	6A - 48A	Hardwired	Yes	Residential garages, where it can be wired to the EV owner's electric panel	UL 2594, UL 2231	Quote Required	https://www.tesla.com/support/charging/wall-connector	File Link
Wallbox	Pulsar Pro	240V	Up to 48A	Hardwired	Yes	Residential garages, where it can be wired to the EV owner's electric panel	UL 2594, UL 2231	$999.00	https://support.wallbox.com/na/knowledge-base/pulsar-pro-product-overview/	File Link

Appendix D2: Load Control Installation Best Practices and Field Implementation

Load Sharing & Power Control Systems (PCS)

- **Commissioning Thresholds:** Calibrate sharing thresholds based on actual on-site feeder capacity and high-resolution load profiles rather than generic nameplate ratings.
- **Stress Testing:** Validate the system's dynamic response time by simulating "worst-case" simultaneous loads (e.g., EV charging, heat pump activation, and water heating) to ensure the main breaker does not trip.
- **System Integration:** Prioritize integration with existing Building Management Systems (BMS) or Home Energy Management Systems (HEMS) for unified monitoring and simplified user overrides.
- **Maintenance & Lifecycle:** Establish a schedule for periodic firmware updates to maintain communication compatibility with evolving utility Open Automated Demand Response (OpenADR) protocols.
- **Performance Benchmarking:** Preliminary data from California multifamily pilot programs suggests that properly commissioned load-sharing systems can achieve a ~15% reduction in peak demand, significantly deferring the need for transformer upsizing.

Circuit Splitting & Shedding Devices

- **Circuit Mapping & Labeling:** Meticulously map all downstream loads; use permanent color-coding or digital labeling on splitters to prevent hazardous miswiring during future maintenance.
- **Hierarchy Programming:** Configure load-shed hierarchies that prioritize critical life-safety loads (e.g., medical equipment, lighting) over non-critical deferrable loads (e.g., pool pumps, secondary HVAC zones).
- **Hybrid System Testing:** For homes with Distributed Energy Resources (DERs), test transition sequences specifically during islanding events to ensure the splitter manages the limited battery or solar output without system collapse.
- **Utility Interoperability:** Leverage utility-grade curtailment signals (where available) to enable real-time peak shaving, potentially qualifying the site for "Demand Response" financial incentives.
- **Reliability Feedback:** Field data from recent service-panel retrofit trials indicates that circuit splitting improves load predictability, allowing for tighter tolerances in localized grid modeling.

Appendix E: Clipping Inverters

For the vast majority of the year, a solar array with a DC capacity up to 1.2 times the inverter's AC rating will not actually reach its peak output. Environmental factors like real-world sunlight falling below laboratory standards, dust accumulation, shading, and natural panel degradation all limit the DC power available for conversion. Clipping inverters address this by allowing a home to host a solar array with up to twice the DC capacity of a standard system. These inverters convert all available DC power into AC power up to their internal limit—such as 3.84 kW AC on a 20-amp breaker—and curtail any production that exceeds that threshold.

This design allows larger systems to generate significantly more energy during the hours when the inverter has the spare capacity to process it. While systems with clipping ratios between 1.0 and 1.3 experience very little annual energy loss, ratios between 1.5 and 2.0 will see more substantial curtailment during peak midday hours on sunny days. Essentially, the first 120% of array sizing typically operates without any clipping. Every additional panel added after that point may be clipped during the peak of a clear day, but those same panels provide full power during cloudy weather or the early morning and late afternoon hours. Consequently, doubling the size of an array can provide twice as much power at the beginning and end of the day without ever exceeding the inverter's midday output limit.

Appendix F: Determining if a Panel Can Accept Multi-Breaker Circuits (MCB)

Electrical panels are rated, listed and sold with a specific number of 1" breaker slots and branch circuits allowed. The difference between the number of circuits and the number of slots tells how many of the slots can accept MCB (e.g., 20 circuits, 10 slots, 20-10=10 slots accept MCB). Determining if a panel can accept any MCB and how many can be tricky. Follow the instructions below to get an improved estimate.

Step 1: Rough Estimate Number of Circuits. For panels from 1965 - 2008 with a Circuit Total Limiting label ("CTL"), a quick visual estimation can be made based on the panel rating times the number of poles divided by 10. Reference values are provided in Table 32. If the number of 1" breaker slots is less than the estimated number of circuits allowed, there's a good chance MCB can be accepted into the panel. For example, in a 100A panel with 12 1" breaker slots, 8 slots can likely accept MCB (20 - 12 = 8). Conversely, a 100A panel with 20 1" breaker slots likely cannot accommodate any MCB (20 - 20 = 0).

Table 32. Rough estimates of the allowable number of circuits in panels from 1965-2008

Panel Rating (Amps)	Number of Circuits Allowed
40	8
60	12
90	18
100	20
125	26
150	30
200	40

Step 2: Seek Further Details Confirming Acceptance of MCB. Key indicators of MCB acceptability are often (but not always) found on panel door labels[103], including:

[103] One electrician notes: "*Also, not all panel doors "tell the truth" about the number of available breaker spaces, since some manufacturers ship 16-position doors with 12-position panels, for example, in which case the bottom twist-outs aren't ever supposed to be removed. As such, you can't know how many "free" slots there are until you unscrew the panel cover, expose the wiring, and actually inspect the bus bar.*"

- Model number
- Circuit or wiring diagram (also shows which slots accept MCB)
- Indication of the “max poles”
- Manufacturer-provided panel schedule for naming loads connected to each circuit

Model numbers often, but not always, include values indicating the number of 1” breaker slots and the number of circuits permitted. For example, a model number containing "3060" (30/60, 1:2) panel allows 30 slots and 60 circuits, indicating all slots can use multi-circuit breakers. In contrast, a "3030" (30/30, 1:1) panel allows only 30 circuits, meaning none of the slots can use multi-circuit breakers. Common configurations offered are 1:1, 1:2 and “breaker slots plus 10” (e.g., 30/40). Less common are 2:3 and breaker slots plus 10, 12 or 18. Figure 10 shows an example from Siemens for how to read panel model numbers, with a “1224” (12/24, 1:2) MCB allowance. Detailed explanation of determining MCB acceptance from panel labels is provided in Section MCB Indicators on Panel Labels.

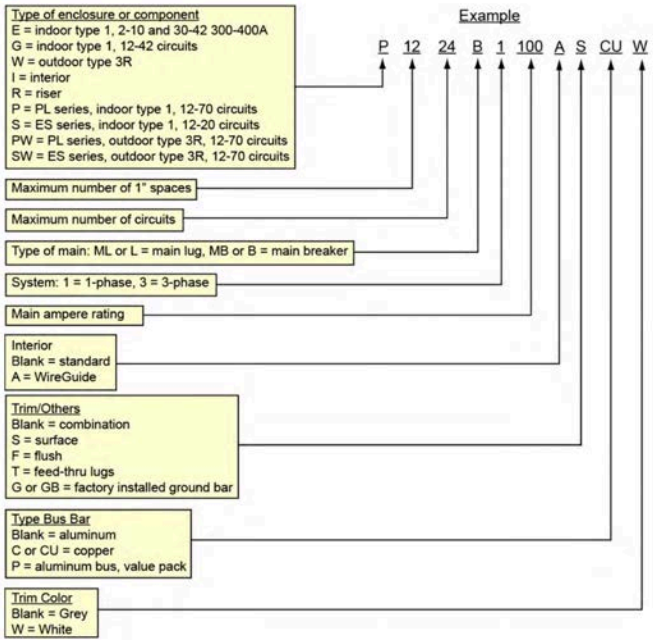


Figure 10. Details on how to read a Siemens load center model number.

As shown in the example in Figure 10, the second value (12) represents the number of 1” breaker slots, and the third value (24) represents the number of circuits. The difference is the number of slots accepting multi-circuit breaker types.

Step 3: Have Qualified Personnel Inspect the Panel Busbar. Qualified personnel, such as your electrical contractor, can open a panel, remove its safety cover (exposing electrical hazards), and inspect the busbar where visible for notches indicating that MCB can be accepted safely in each breaker slot. An image of a panel is shown in Figure 11 with the notched busbar tabs clearly highlighted in red.

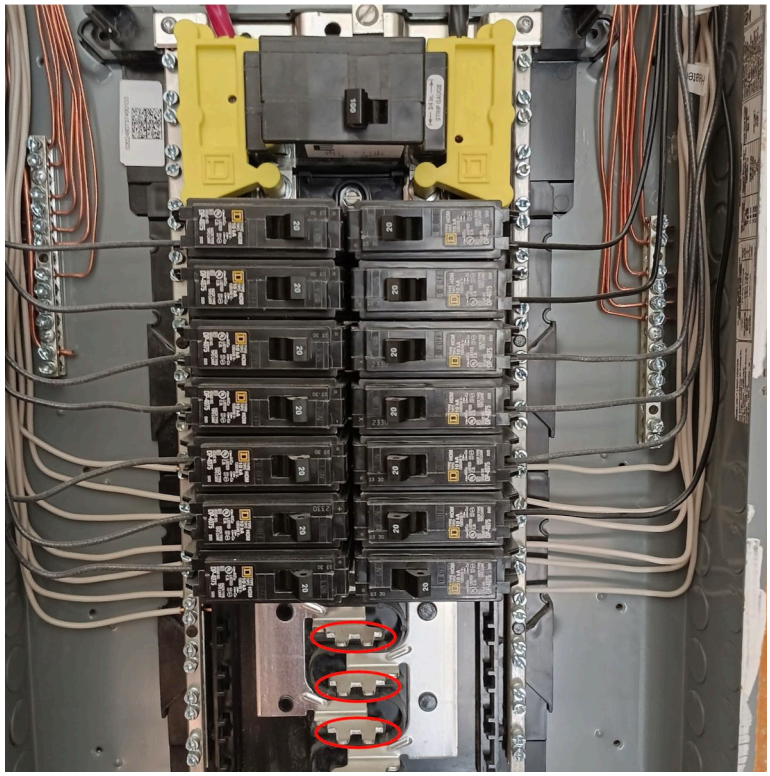


Figure 11. Image of a panel with its safety cover removed, exposing the live conductors and busbar. The notched busbar tabs are circled in red at the bottom. These notches indicate the breaker slots can accept MCB safely. A flat, un-notched tab cannot accept MCB.

MCB Indicators on Panel Labels

Figure 12 below shows an example Siemens electrical panel label, with red markings indicating the places where indicators for accepting multi-circuit breakers can be found. The top left shows the panel model numbers, with “2040” values, indicating 20 1” breaker slots and 40 circuits, which indicates that all breaker slots in the panel can accept multi-circuit breakers (40-20=20). The electrical diagram in the middle of the panel label also shows precisely which breaker slots can accept multi-circuit breakers. Each flat horizontal line below the service disconnect represents a breaker slot (sequentially connected to different poles of the busbar). Each curved horizontal line represents a circuit. In this example, there are two curved breaker lines for each flat breaker slot line, indicating that multi-circuit breakers are acceptable throughout. The numbering next to each circuit can also help determine the total. Finally, the words “40 Poles Max” at the bottom of the diagram indicate the total number of circuits that can be connected. Comparing this against the number of breaker slots clarifies how many can accept MCB. Numerous additional annotated examples are provided below in Figure 12 - Figure 17.

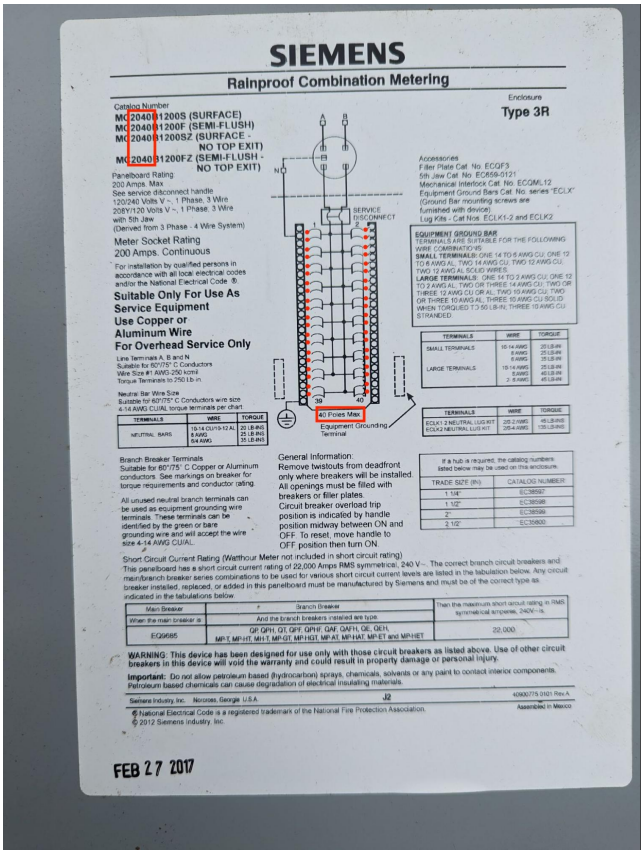


Figure 12. An example of a 20/40 Siemens panel label for a combination metering device. Red call-outs show where multi-circuit breaker use is acceptable.

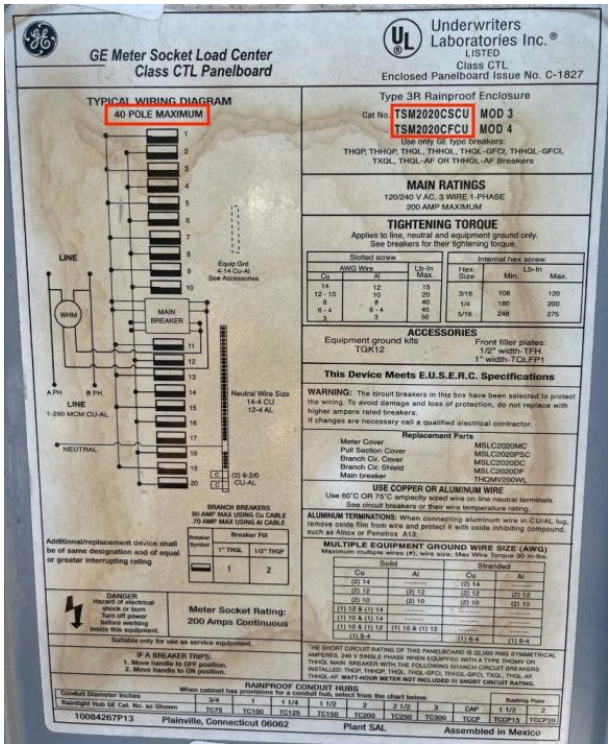


Figure 13. Example GE electrical panel indicating “40 POLE MAXIMUM” (top left) and also model numbers showing the “2020” (1:1) designations. This is an example where the 40 poles max indicator appears to contradict the model number. Note the “Class CTL” indicator in the top right under the UL icon, indicating the panel is rated for a fixed number of circuits. Check with your electrician.

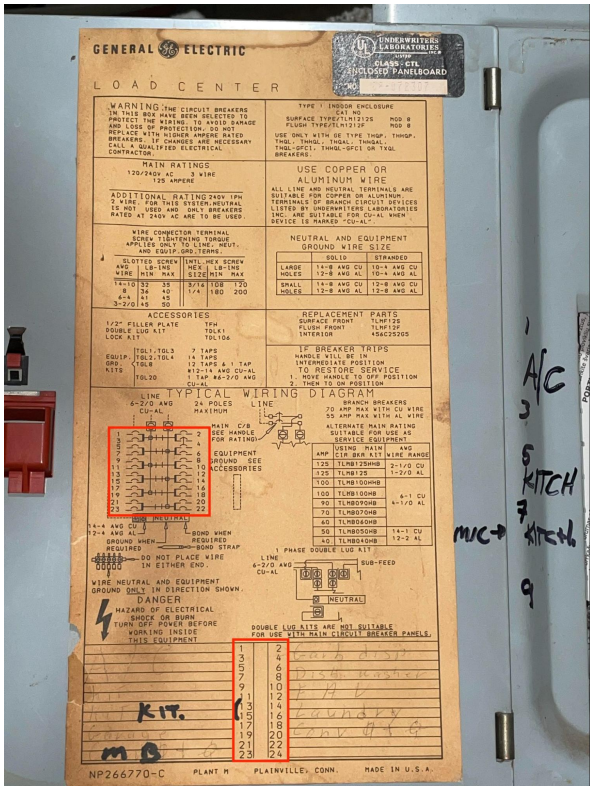


Figure 14. Example GE electrical panel label appears to lack a model number, but does include the circuit diagram (left) showing 12 breaker slots and 24 circuits. Note the built-in panel schedule (bottom) for indicating what loads are served by each circuit includes numbers 1-24, which supports the 24 circuits interpretation. Note the “Class CTL” indicator in the top right under the UL icon, indicating the panel is rated for a fixed number of circuits.

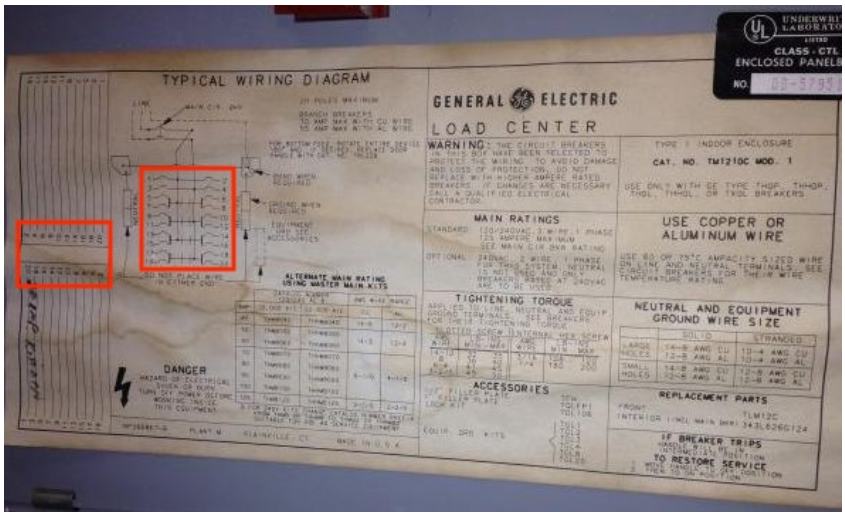


Figure 15. Example GE electrical load center label with no model number, but with a circuit diagram and a provided panel schedule. The diagram shows 12 breaker slots (6 flat horizontal lines, two poles) with 20 circuits allowed. Note how the top two rows of breaker

slots have only one curved horizontal line, compared with the 4 rows below with two curved lines. The slots with only one curved line cannot accept MCB. Once again, the panel schedule (far left) confirms the 20 circuit allowance. Note the “Class CTL” indicator in the top right under the UL icon, indicating the panel is rated for a fixed number of circuits.

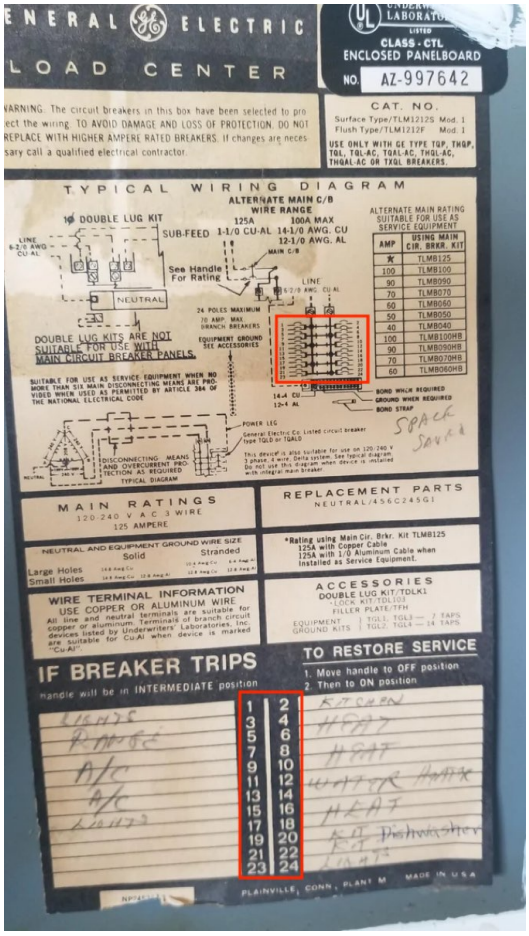


Figure 16*.* Example GE electrical load center label with no model number, but with a circuit diagram and a provided panel schedule. The diagram shows 12 breaker slots (6 flat horizontal lines, two poles) with 24 circuits allowed. Note how all breaker slots are indicated with two curved lines, indicating MCB are acceptable. The provided panel schedule at the bottom confirms the 24 circuit allowance. Note the “Class CTL” indicator in the top right under the UL icon, indicating the panel is rated for a fixed number of circuits.

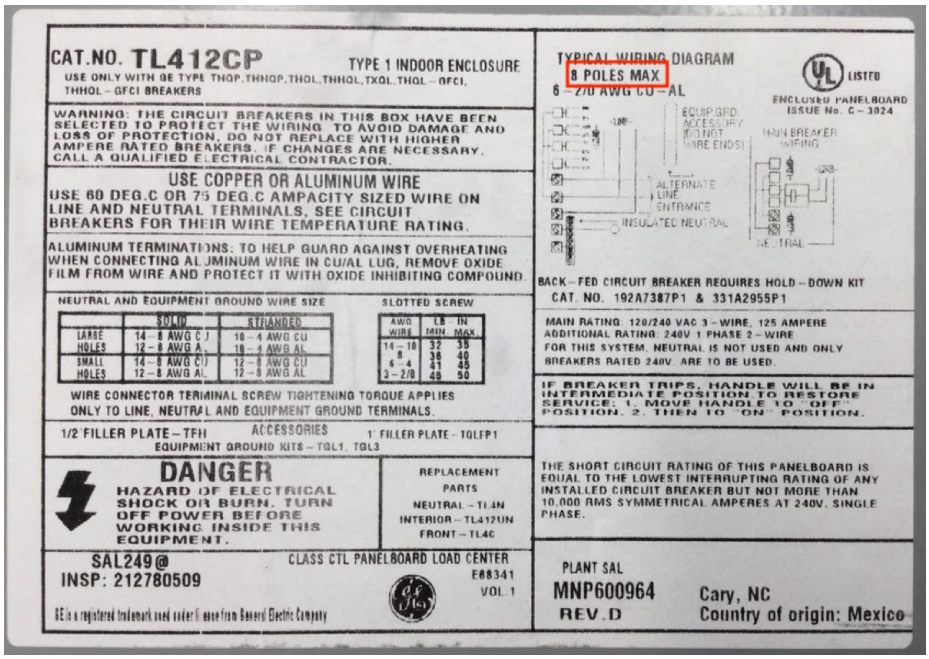


Figure 17. An example GE panel label with "8 POLES MAX" highlighted in the top right, indicating 8 allowable circuits. Note the "Class CTL" indicator in the lower left just above the GE icon, indicating the panel is rated for a fixed number of circuits.

Appendix G1: Gas Meter & Electrical Panel Clearances

While theoretical electrification plans can appear straightforward, real-world implementations often collide with rigid regulatory safety standards regarding gas meter and electrical panel clearances. This section examines the specific challenges encountered at a real project, "987 Home", a case study that exemplifies the logistical and financial hurdles homeowners face when existing site conditions do not easily accommodate modern code requirements. The following photographs and descriptions document the friction between maintaining mandated clearance zones and upgrading electrical infrastructure in tight spaces, illustrating how physical site limitations—such as steep terrain, drainage systems, and underground utilities—can significantly complicate the transition to a fully electrified home.

Figures of Existing Rules

Below is Figure 19 pulled from PG&E Greenbook[104] that outline the clearance requirements for gas meter and electrical panel/meter. Similar rules exist within SCE and SDG&E territories.

An update occurred for PG&E Greenbook[105] this February 2026 that allows existing clearances to be “legacied-in” to allow panel replacement for 200A or lower capacity under certain conditions.

[104]Pacific Gas and Electric Company. Electric and Gas Service Requirements (TD-7001M). 2022–2023. April 28, 2026. Accessed April 28, 2026. https://www.pge.com/assets/pge/docs/account/service-requests/greenbook-manual-full.pdf.
[105] Pacific Gas and Electric Company. Electric and Gas Service Requirements Update (TD-7001M). 2022–2023. February 5, 2026. Accessed April 28, 2026. https://www.pge.com/assets/pge/docs/account/service-requests/greenbook-update-2022-2023.pdf.

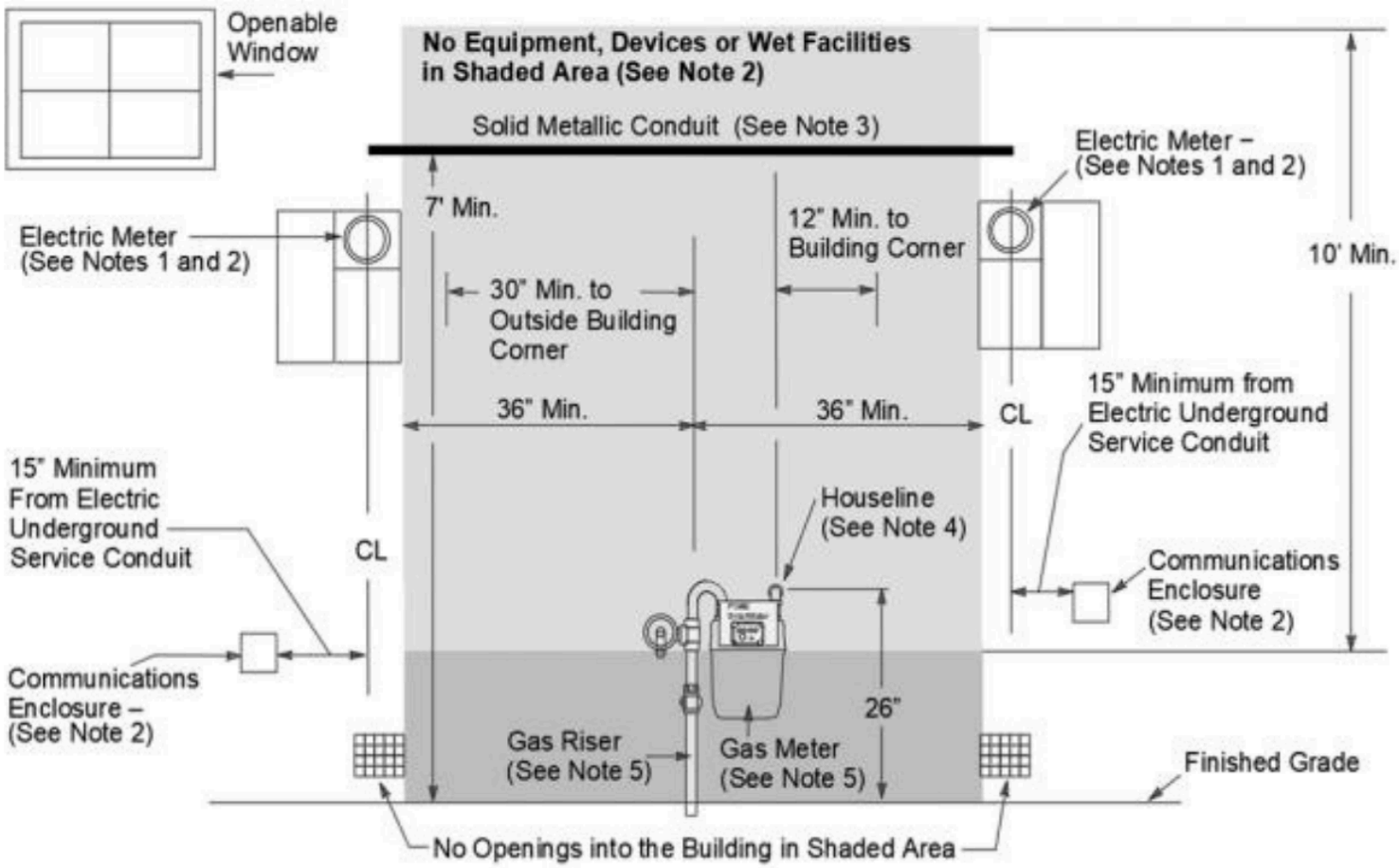


Figure 7-9.
Electric and Gas Meter Set Separation Dimensions and Clearances

Figure 19. Excerpt from PG&E Greenbook regarding clearance requirements for gas meter and electrical panel/meter (Source: (PG&E, 2023))

Pictures of Challenges with Compliance

Below are pictures of a recent home project in the past year that present the challenges with complying with the gas meter and/or electrical panel/meter clearance requirements.

Project Challenge at a Recent Home

For this project, the homeowner needs to modify the service entrance to add a circuit for an electric water heater for their ADU, as both structure subpanels are not easily accessible and full. This project is part of the broader full electrification of the home, thus eliminating gas service entirely, but the electric service needs modifications to achieve that. The available pathways forward given the home existing conditions are:

1. Have the utility move the gas meter to a location that is not easily accessible, have the electrical work performed, and remove the gas meter after the electrification is complete. This pathway adds significant project cost for complying with gas meter clearance for several months before the home is fully electrified.

2. Leave the rented ADU without hot water (which is not permissible by law) by removing the gas meter, then doing electrical work. This pathway could take weeks and would interrupt required services to the ADU.

The following page provides pictures of this recent home project challenge along with accompanying descriptions.



Figure 20. Site overview outside. Hardscrabble up the hill if you move equipment higher. Second story floor begins a couple feet above the garage door opening.



Figure 21. Interior of garage where the gas water heater needs to be replaced with electric. Need to change main service disconnect/panel from 2x100A (to house and garage subpanels) to single main disconnect at garage exterior and distribution panel in garage interior. No breaker slots available on garage subpanel (in apartment above) for additional branch circuits

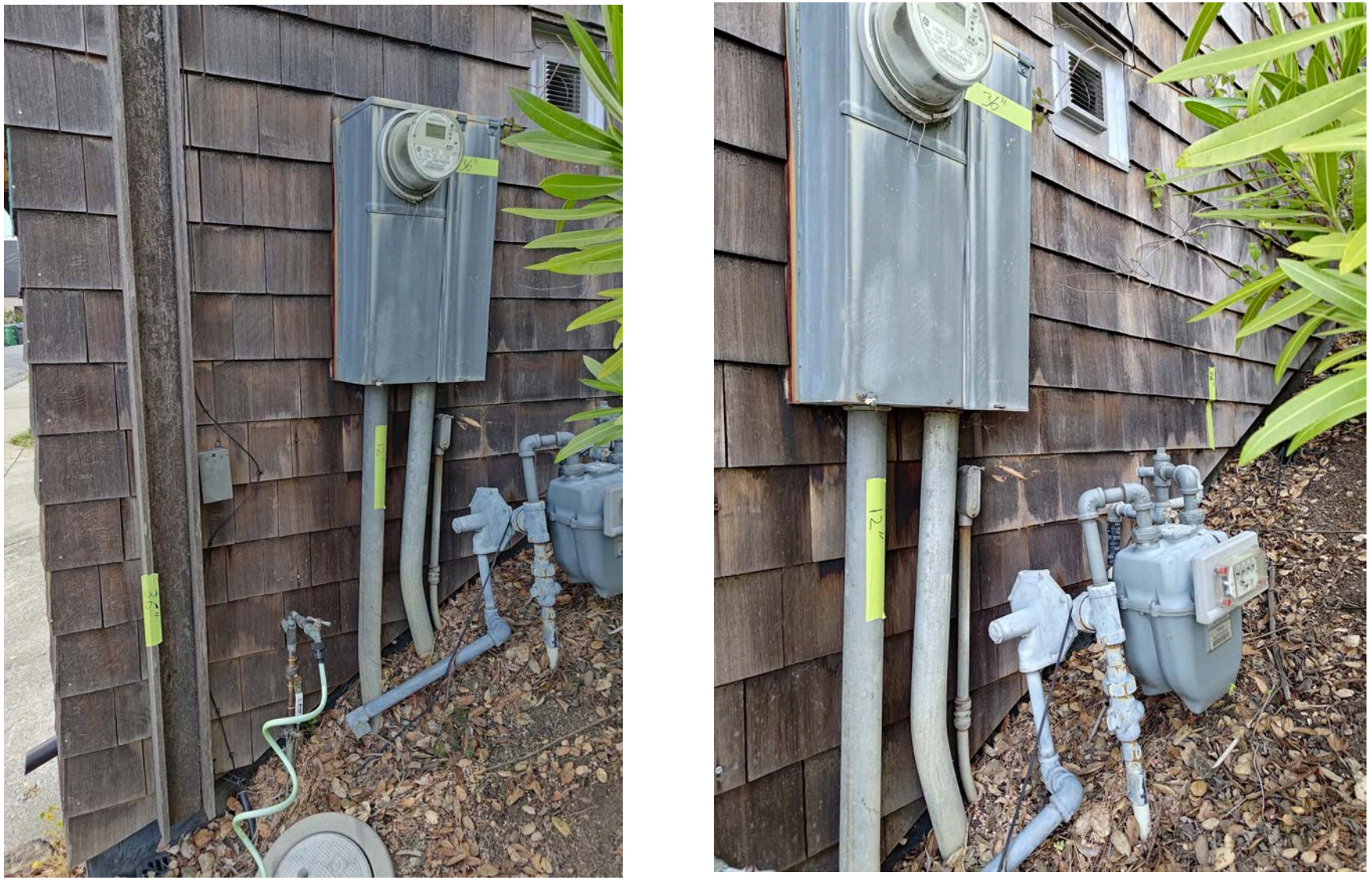


Figure 22. Exterior shot with 12" and 36" clearance marked with green tape. The downspout is located within the potential area for gas meter relocation. The home has a flat roof, so cannot move the downspout without re-decking the roof. The underground services and sewer cleanout to sewer lateral limit space and room for digging.

Appendix G2: Electrical Panel Brands

Challenger

Challenger panels have critical defects.

- **Identified Hazards:** Certain Challenger breaker models have been found to fail to trip during overloads[106]. Poor manufacturing tolerances can also result in loose connections at the bus bar, leading to arcing, overheating, and melting of internal components.
- **Insurance Implications:** While not universally uninsurable, issues are growing. In high-claim states, many insurers will deny policies or exclude electrical fire claims for homes with Challenger panels. Increasingly, these panels are being flagged for mandatory replacement during policy renewals.

It is important to note that homeowners insurance does not typically cover preemptive panel replacement due to age or design defects; however, coverage may apply if the failure is caused by a covered peril like a fire or lightning strike.

Federal Pacific (FPE)

FPE panels, particularly the "Stab-Lok" models, have some of the most severe documented failure modes.

- **Identified Hazards:** The Stab-Lok breakers frequently fail to trip, with some tests showing failure rates as high as 60-80% during overload conditions[107].
- **Insurance Implications:** FPE panels are widely considered uninsurable or high-risk by underwriters[108]. Most major insurers will deny or refuse to renew coverage for homes with these panels and will mandate replacement before binding a policy.

Zinsco

Zinsco panels have well-documented flaws related to material deficiencies and design.

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[106] “Which Challenger Panels Are Unsafe?” Bryan Hindman Electric. Accessed April 30, 2026. https://bryanhindmanelectric.com/blog/which-challenger-panels-are-unsafe

[107] “The Federal Pacific Electric FPE Stab-Lok® Electrical Hazards”. InspectAPedia. Accessed April 30, 2026. https://inspectapedia.com/fpe/FPE_Stab_Lok_Hazards.php

[108] “The New Insurance Requirements for Your Aging Electrical Panels”. Apartment News Publications Inc. Accessed April 30, 2026. https://aptnewsinc.com/news/the-new-insurance-requirements-for-your-aging-electrical-panels

- **Identified Hazards:** The breakers have a high failure rate for tripping during an overcurrent event, with some tests showing over 25% of breakers failing to trip when required[109]. The aluminum bus bars are prone to corrosion[110], which can cause the breakers to fuse permanently to the bar, preventing them from tripping. The connection mechanism is also prone to loosening, which leads to overheating and arcing.
- **Insurance Implications:** Many insurers refuse to cover homes with Zinsco panels or require their immediate replacement. Common responses include outright coverage denial, significantly higher premiums, or allowing a brief grace period for replacement before cancelling the policy[111] [112].

[109] "What's the Deal With Federal Pacific and Zinzco Breakers?" Douglas Engineering Pacific. Accessed April 30, 2026. https://douglasengineering.com/whats-the-deal-with-federal-pacific-and-zinsco-breakers

[110] "Why Zinsco Breaker Panels Are a Hidden Hazard in Your Home". Safe Home Management. Accessed April 30, 2026. https://www.safehomemanagement.com/post/zinsco-breaker-panels-electrical-fire-hazards

[111] "Home Insurance Policies and Zinsco Panels: Navigating Coverage Challenges". Branover Contractors Inc. Accessed April 30, 2026. https://www.branovercontractors.com/home-insurance-policies-and-zinsco-panels

[112] "Zinsco Electrical Panels: A Santa Barbara Homeowner's Guide to a Hidden Fire Hazard". Coastal Shield Home Insurance. Accessed April 30, 2026. https://coastalshieldinspections.com/resource-zinsco-electrical-panels

Appendix G3: Details on Pre-Existing Electrical Hazards

Fuse Panels: Common in homes built before the mid-20th century, fuse panels are prone to dangerous misuse. The primary risk is "overfusing," where a homeowner replaces a blown 15A fuse with a 25A or 30A fuse to prevent it from tripping again. This exposes undersized wiring to excessive current, disabling the circuit's safety protection and dramatically increasing fire risk.

Lack of Grounding: Grounding provides a safe path for fault current, allowing a breaker or fuse to trip during a failure. Homes built before the 1960s often lack grounding conductors. A common but dangerous situation arises when 3-prong outlets are installed on these ungrounded circuits, creating a false sense of security while offering no fault protection.

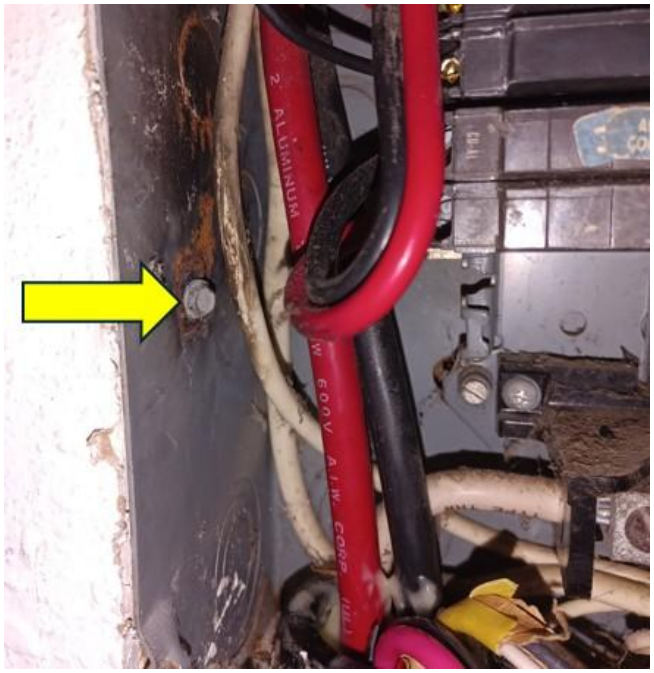


Figure 23. Example of pre-existing electrical hazard with panel rust and wire insulation damage.

The arrow in Figure 23 above indicates an issue in a sub-panel where the panel housing rusted long ago and created a loose grounding lug. That ground wire has been relocated to the ground bus, but the heat generated by the poor ground connection caused surface-level heating damage to the insulation of the white-colored neutral conductor. The white-colored

neutral conductor was able to continue to be used because the insulation was not sufficiently damaged to require removal.

Poor Electrical Connections and Arcing: Loose electrical connections create high resistance, which generates intense, localized heat capable of igniting nearby materials. This can also cause arcing (sparking), which is particularly dangerous as it may not draw enough current to trip a standard circuit breaker.

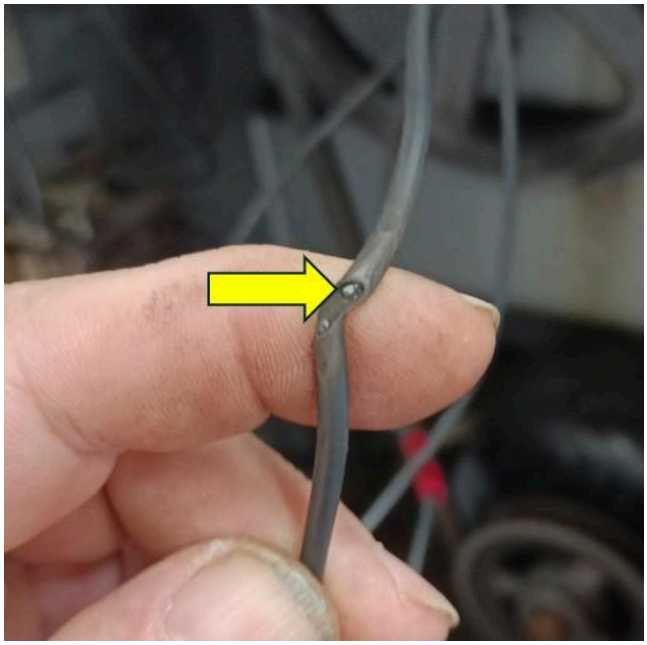


Figure 24. Electrical wiring where the conductive material has deteriorated and is no longer in direct contact.

Knob-and-Tube (K&T) Wiring: Installed in homes before the 1950s, K&T wiring uses single conductors insulated with cloth or rubber. Key hazards include its lack of a ground wire and age-related insulation degradation. Covering K&T wiring with modern insulation is also a fire hazard, as the system relies on open air for cooling.

Burnt or Discolored Wires: Discoloration on wires, outlets, or connectors is a clear sign of overheating. This is typically caused by overloads, high-resistance connections, or other damage.

Inaccessible Junction Boxes: The National Electrical Code (NEC) requires all wire junctions to be housed in accessible boxes. In older homes or poor renovations, these boxes are sometimes hidden inside walls or ceilings. This is a major hazard because if a connection fails inside a hidden box, it can lead to a fire without any opportunity for inspection or repair.

Missing or Broken Breakers: Gaps in an electrical panel from missing breakers or filler plates expose live, energized parts. This creates a severe risk of shock or electrocution and allows contaminants like dust or moisture to enter the panel, which can lead to short circuits or fire.

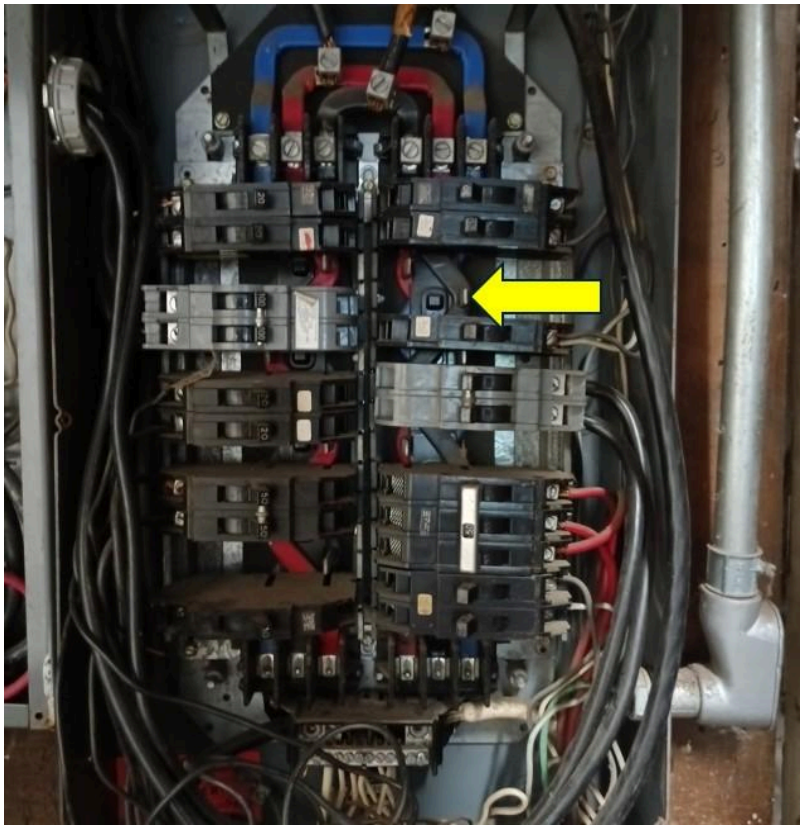


Figure 25. 3-phase, 208-volt, 125-Ampere panel with missing breakers that expose the electrified service bus. Photo credit: Gary Goslin 2025.

Appendix H: Existing Tools Comparison Tables

In Table 33 below, 14 electrification planning tools are compared across various characteristics.

Table 33. Electrification Planning Tools Comparison

	AmpWise	CalNEXT Panel Tool	Clean Energy Calculator	Electrification Roadmap	Elephant Energy
information verified by tool developer	Yes	Yes	No	No	Yes
Purpose of Tool	Determine if an electrical panel needs to be upsized for electrification projects	Program evaluation	Homeowners: help determine bill impacts to energy system changes (such as electrification)	Technical design guide	Remove friction from electrification to speed up adoption
Audience	Contractor	Contractor	Residential customers	Contractor	Residential customers
Performs energy calculations	Yes	Yes	Yes	Examples only	Yes
HVAC sizing	Yes	No	No	Guidance only	Yes
Other sizing (e.g. domestic water heater)	Yes	No	Yes	Guidance only	Yes
Carbon emissions	Yes	No	Future	Examples only	Yes
Utility bills/savings estimates	Upcoming	No	Yes	Examples only	Yes
Rate structure assessment	No	No	Yes	No	No
Incentives or rebates	No	No	Yes	Mentions them	Yes
Project cost estimates	Yes	No	Yes	Yes	Yes
Includes electrical infrastructure safety assessment	No	No	No	Guidance only	No
Includes electrical load calculations	Yes	Yes	No	Guidance only	Yes
Includes panel capacity	Yes	Yes	No	Guidance only	Yes
Includes panel breaker space	Yes	No	No	Guidance only	Yes
Offers low-power appliances/equipment	Yes	Evaluates them	No	Yes	Yes
Offers load controls	Yes	Evaluates them	No	Yes (Discusses)	Yes
Format (spreadsheet, web, etc)	Mobile app	Spreadsheet	Web app	PDF Guide	Web app
Provides API	Yes	No		No	No
Input methods (images, checkbox, drag n drop)	UtilityAPI, images, checkbox, drag n drop, in-person consultation	Manual input (checkbox, drop down menu)		N/A	Users can input quote information and system specifications
Outputs served to users	Personalized plan	Estimates the size of the electrical panel based on different selection choices.	Total Cost of Ownership, Bill Impacts, Rate Recommendation	Technical guidance	Homeowner facing presentation
Installer/contractor network	No	No		No	Yes
Level of adoption (i.e. does the target market like it?)	Recently launched	Unknown	Soft launched in fall 2025	High (Practitioners)	High
Pricing	Freemium	Free (Public tool)	Free (PG&E customers)	Free (Public tool)	Freemium
For more information	https://ampwise.app/	calnext.com/approved-projects/	pge.com/en/clean-energy/clean-energy-calculator.html	redwoodenergy.net	elephantenergy.com
Screenshot	File Link	File Link	File Link	File Link	N/A

	Green Upgrade Calculator	HomeIntel	Kopperfield	Maiven Energy	QuitCarbon App
information verified by tool developer	No	Yes	No	Yes	Yes
Purpose of Tool	Contractors: Design and compare system combinations. Energy Advisors: Provide tailored suggestions to residents. Analysts: Analyze regional impacts of green policies.	Energy audit	Contractor quoting	"One-stop-shop" service, AI-planning	Phased roadmapping
Audience	Energy professionals (contractors, advisors, and analysts)	Residential customers	Contractors	Homeowners, renters, contractors, program administrators	Homeowners
Performs energy calculations	Yes	Yes	Yes	Yes	Yes
HVAC sizing	Yes	Yes	Yes	Yes	Yes
Other sizing (e.g. domestic water heater)	Yes	No	Yes	Yes	Yes
Carbon emissions	Yes	Yes	Yes	Yes	Yes
Utility bills/savings estimates	Yes	Yes	Yes	Yes	Yes
Rate structure assessment	Yes	Yes	No	Yes	No
Incentives or rebates	Yes	No	Yes	Yes	Yes
Project cost estimates	Yes	No	Yes	Yes	Yes
Includes electrical infrastructure safety assessment	Not specified	No	Yes	Yes	No
Includes electrical load calculations	Not specified	Yes	Yes	Yes	Performs electrical capacity budgeting
Includes panel capacity	Not specified	Yes	Yes	Yes	Yes
Includes panel breaker space	Not specified	No	Yes	Yes	No
Offers low-power appliances/equipment	Yes	Indirectly	Yes	Yes	Yes
Offers load controls	Not specified	Yes	Yes	Yes	Yes
Format (spreadsheet, web, etc)	Web app	Web app	SaaS	Web app	Web app
Provides API	Yes	No	Yes	Yes	No
Input methods (images, checkbox, drag n drop)	Users can input quote information and system specifications	Utility data API	Contractor inputs	User Input (photos, self-selection), API, AMI, AI	Questionnaire
Outputs served to users	It provides analyses of lifetime costs, environmental benefits, bill impacts, and emission impacts	Energy reports	Contractor proposals	Personalized Plans	Personalized plan
Installer/contractor network	Not specified	Recommendations only	Tool made for contractors	Yes	Yes
Level of adoption (i.e. does the target market like it?)	Homeowners: help determine bill impacts to energy system changes (such as electrification)	High (In service area)	Growing (B2B)	High	Growing
Pricing	Free (Public tool)	Free (Utility-funded)	$29.99 - $79.99	Free (Utility-funded)	Free
For more information	RMI.org	join.hea.com	kopperfield.com	askmaiven.com	quitcarbon.com
Screenshot	File Link	N/A	File Link	N/A	N/A

	Rewiring America	WattDiet Calculator	XeroHome	Zero Homes
information verified by tool developer	Yes	Yes	No	Yes
Purpose of Tool	Incentive planning	Determine if an electrical panel needs to be upsized for electrification projects	Scaled customized energy recommendations	"One-stop-shop" service, AI-planning
Audience	Residential customers	Homeowners, contractors	Homeowners, local government, utilities	Homeowners, utilities, contractors
Performs energy calculations	Yes	Yes	Yes	Yes
HVAC sizing	No	Yes	Yes	Yes
Other sizing (e.g. domestic water heater)	No	Yes	No	Yes
Carbon emissions	Yes	No	Yes	Yes
Utility bills/savings estimates	Yes	No	Yes	Yes
Rate structure assessment	No	No	Yes	Yes
Incentives or rebates	Yes	No	Yes	Yes
Project cost estimates	Yes	No	Yes	Yes
Includes electrical infrastructure safety assessment	No	No	No	Yes
Includes electrical load calculations	No	Yes	No	Yes
Includes panel capacity	No	Yes	No	Yes
Includes panel breaker space	No	Yes	No	Yes
Offers low-power appliances/equipment	Yes	Yes	Yes	Yes
Offers load controls	No	Yes	Yes	Yes
Format (spreadsheet, web, etc)	Web calculator	Excel spreadsheet	Web app	Mobile app
Provides API	Yes	N/A	No	No
Input methods (images, checkbox, drag n drop)	Simple web form	Manual data entry of building parameters and appliance specifications. Appliance drop down menus.	Automated and virtual energy audit	Automated and virtual consult
Outputs served to users	Savings potential	Estimates the size of the electrical panel needed for a home and a heat pump size.	Personalized plans	Completed project
Installer/contractor network	Yes (Building one)	No	Yes	Partner Contractors
Level of adoption (i.e. does the target market like it?)	High (Advocacy)	Used by homeowners, building owners, and contractors	High	High
Pricing	Free (Non-profit)	Free (Public tool)	Free (Utility-funded)	Freemium
For more information	rewiringamerica.org	redwoodenergy.net	xerohome.com/app/	zerohomes.io
Screenshot	File Link	File Link	N/A	N/A

In Table 34 below, 12 NEC calculation tools are compared across various characteristics.

Table 34. NEC Calculation Tools Comparison

	Ask-the-electrician.com - Online Interactive Residential Electrical Load Calculator	Building America Solutions Center - Heat Pump Water Heater Tool	CalNEXT Panel Tool	City of Palo Alto Building Permit Forms - "Residential Electric Load Calculator"	City of Sacramento
information verified by tool developer	No	No	Yes	No	No
Functionality	Online, interactive calculator for residential electrical load calculations.	Online calculator specifically for determining the electrical load impact of adding a heat pump water heater.	Guided spreadsheet to carry out an electrification project with strategies to avoid panel upsizing by appliance and system choices	Excel spreadsheet designed to help homeowners and contractors determine if an electrical panel upgrade is needed for home electrification.	A static, fillable PDF worksheet for electrical load calculations.
Building Type	Primarily New Single-family Residential	Existing Single-Family Residential	Existing Single-Family Residential	Existing Residential	Primarily New Single-family Residential
Audience	Electricians, contractors, homeowners, property managers	Installers, sales associates, homeowners	Contractors	Permit applicants, contractors	Electricians, Contractors, Homeowners
NEC Standard Part III					
NEC 220.82	Yes		No		Yes
NEC 220.83		Yes	Yes	Yes	
NEC 220.84			No		
NEC 220.87			No		
NEC Year/Version Reflected	2020		2020		2022
Format (spreadsheet, online, PDF, etc)	Web calculator	Web calculator	Spreadsheet	Spreadsheet	PDF Form
Inputs	Multi-step form. Pre-loaded with typical electrical loads for the home. Drop-down menus for selecting equipment.	Asks for panel amperage, home square footage, number of kitchen and laundry circuits, and a list of existing electrical appliances.	Basic property information (e.g. county, home square footage, main panel disconnect rating), existing building loads, and electrification goals	User enters values in highlighted cells for building parameters, design temperatures, and appliance selections.	The user must manually fill out the form with a pen or a PDF editor.
Outputs	Displays the calculated load on the screen.	Determines what the electrical load will look like after installing a heat pump water heater.	Provide various scenario analyses based on NEC calculations to showcase the impacts on electrical panel capacity.	Estimates the required electrical panel size.	The user performs the calculations manually on the form.
Assumptions	Calculations are based on the National Electrical Code.	Based on NEC Article 220.83. Uses default values for appliances if the exact wattage is unknown.	Based on NEC 220.83(B). Uses default values for appliances if the exact wattage is unknown.	The user needs to input most of the data manually. Focuses on strategies to avoid panel upgrades.	Provides examples for calculating air conditioning and heat pump loads.
Limitations / Inaccuracies	The user interface is somewhat dated.	This is a specialized tool with a very specific use case.		Requires Microsoft Excel to use.	Not an interactive tool; it is a form that requires manual calculation.
Pricing/Cost	Free	Free	Free	Free	Free
Additional notes	Includes EVSE in the diversity calculations (10 kVA at 100%, remainder at 40%)				
URL	https://ask-the-electrician.com/residential-electrical-load-calculation.html#beginAdv	https://basc.pnnl.gov/hpwh_installation_tool/electrical_calculator	https://drive.google.com/drive/folders/1o4fY2skz0c1Hd27ZSKgNQND7qmU3oSNz?usp=sharing	https://www.paloalto.gov/Departments/Planning-Development-Services/Development-Services/Apply-for-a-Permit/Apply-for-a-Building-Permit/Building-Permit-Forms	https://www.cityofsacramento.gov/content/dam/portal/cdd/Building/Forms/CDD-0213_Electrical-Load-Calculation-Worksheet.pdf
Screenshot	File Link	File Link	File Link	File Link	File Link

	City of Thousand Oaks Building Handouts for Building Permits - "Electrical Service Calculations"	Kopperfield	Mike Holt's Electrician Tool Box App	SPAN PowerUp
information verified by tool developer	No	No	No	Yes
Functionality	A static, fillable PDF worksheet for electrical load calculations.	Online calculator for residential and commercial load calculations.	Mobile app for various electrical calculations, including residential and commercial load calculations.	Online, interactive calculator for residential electrical load calculations.
Building Type		Existing and new single-family residential, multifamily residential, and commercial. All common nominal voltages (120/240, 208/240, etc)	Residential and Commercial	Existing Single-Family Residential
Audience	Permit applicants, contractors	Electricians, inspectors	Electricians, inspectors, instructors, contractors, engineers	Homeowners, contractors
NEC Standard Part III		Yes	Yes	Yes
NEC 220.82		Yes		Yes
NEC 220.83		Yes		Yes
NEC 220.84		Guidance Only		No
NEC 220.87				No
NEC Year/Version Reflected		N/A		2017, 2020, 2023
Format (spreadsheet, online, PDF, etc)	PDF Form	Web calculator	Mobile app	Web app
Inputs	The user must manually fill out the form with a pen or a PDF editor.	Single-page form. Street address auto-populates square footage. Pre-loaded list of common appliances with editable default values, including quantity and VA values. Can add custom equipment.	User inputs system voltage and loads for different categories (e.g., residential service, motors, A/C).	Multi-step form. Pre-loaded with typical electrical loads for the home. User selects appliance and/or equipment that will be controlled by the SPAN panel
Outputs	The user performs the calculations manually on the form.	Generates a downloadable and shareable PDF report with a detailed breakdown of the load calculation.	Provides protection size, conductor size, equipment grounding conductor size, raceway size, maximum load, and maximum circuit length. Can email the results.	Displays peak data (summer and winter), including the applicable appliance/equipment that contributes and adjustment capability. Displays the NEC calculations and provides a downloadable form with a detailed breakdown of the load calculation.
Assumptions	Provides examples for calculating air conditioning and heat pump loads.	EVSE is multiplied by 125% (continuous load). Default values are drawn from the 2017, 2020, and 2023 NEC.	The specific NEC version is not stated, but it is likely aligned with a recent version.	Calculations are based on the National Electrical Code.
Limitations / Inaccuracies	Not an interactive tool; it is a form that requires manual calculation.	The free version is limited to two uses and up to 4 dwellings for Multfamily	Requires a mobile device (iOS or Android). Some user reviews have mentioned bugs with specific calculations.	
Pricing/Cost	Free	$29.99/month	Free	Free
Additional notes		Existing dwelling calculation does not differentiate between adding (or not adding) new HVAC equipment (220.83(A) vs (B). Defaults to include a gas range and a gas oven at 600W each. User is allowed to edit the multiplier applied to the EVSE load, so you can treat it at 40% per Table 220.83(A).		
URL	https://toaks.gov/corecode/storage/uber_resource/uploaded_pdfs/Electrical%20Service%20Load%20Calculations-2021-12-14%20fillable_1734053340.pdf	https://www.kopperfield.com/free-load-calculator	https://www.mikeholt.com/electrician-toolbox-home.php	https://powerup.app.span.io/explore
Screenshot	File Link	File Link	File Link	File Link

	TrueLoad	Wattson Load Calculator	Watt Diet Calculator
information verified by tool developer	Yes	No	Yes
Functionality	Online, interactive calculator for residential and commercial electrical load calculations.	Online, interactive calculator for residential electrical load calculations.	Excel spreadsheet designed to help homeowners and contractors determine if an electrical panel upsize is needed for home electrification.
Building Type	Existing single-family residential, multifamily (individually metered units or single-metered buildings), and single-metered commercial	Existing Single-Family Residential	Existing Single-Family Residential
Audience	Electricians, contractors, AHJs	homeowners, AHJs	Homeowners, contractors
NEC Standard Part III	No	Yes	
NEC 220.82	No	No	
NEC 220.83	No	No	Yes
NEC 220.84	No	No	
NEC 220.87	Yes	No	
NEC Year/Version Reflected	2023	2023	2020
Format (spreadsheet, online, PDF, etc)	Web app	Web app	Spreadsheet
Inputs	Project and service information (main service rating, voltage, phase). Utility AMI interval data uploaded as a file. New loads selected from a pre-loaded equipment list		User enters values in highlighted cells for building parameters, design temperatures, and appliance selections.
Outputs	Displays the identified peak demand interval with its date and time, the 125%-adjusted existing load, total new loads, remaining capacity, and a PASS/FAIL determination. Generates a downloadable PDF load calculation report formatted for permit submission.	Generate a load calculation PDF on adding new loads.	Estimates the required electrical panel size.
Assumptions	Based on NEC Article 220.87.	Calculations are based on the National Electrical Code.	Calculations are based on the National Electrical Code.
Limitations / Inaccuracies	Requires the customer's utility interval data, which is not uniformly available to contractors across utilities.		Requires Microsoft Excel to use. The user needs to input most of the data manually.
Pricing/Cost	$30 per project or $59/month unlimited. Custom Enterprise Plan available	Free	Free
Additional notes	Purpose-built to produce the compliance document itself rather than to screen or optimize an electrification pathway		Focuses on strategies to avoid panel upsizing.
URL	https://app.trueloadapp.com	https://calculator.reliahome.abb.com/	https://www.redwoodenergy.net/watt-diet-calculator
Screenshot	File Link	File Link	File Link