ELECTRIC SERVICE OPTIMIZATION FOR BUILDING OFFICIALS

Minimizing electrical service upgrades while ensuring public safety and code compliance in retrofit projects

Submitted to:

SILICON VALLEY CLEAN ENERGY

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PREFACE

Acknowledgements

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About SVCE

Silicon Valley Clean Energy (SVCE), a Community Choice Energy agency, was formed as a Joint Powers Authority in 2016, and now serves approximately 270,000 residential and commercial electricity customers across a service area comprised of the following 13 communities: Campbell, Cupertino, Gilroy, Los Altos, Los Altos Hills, Los Gatos, Milpitas, Monte Sereno, Morgan Hill, Mountain View, Saratoga, Sunnyvale and Unincorporated Santa Clara County. 97% of electricity customers in SVCE's service area receive their electricity from SVCE. SVCE was formed with the primary intention to address climate change through a variety of services provided to residential and business customers. Since SVCE-provided energy is significantly less carbon-intensive than both general grid power and methane gas combustion, much of SVCE's work has centered on encouraging and supporting building electrification.

About RHA

Richard Heath & Associates, Inc. (RHA) is a Minority Business Enterprise and leading California program design and management firm, specializing in delivering equitable access to energy efficiency and beneficial electrification. Founded in 1980, RHA's earliest initiatives included partnering with a California utility to pioneer one of the state's first income-qualified energy efficiency programs. RHA has since built on this legacy and operates over 50 programs as a program administrator/implementer, government and utility technical consultant and training organization. This work has helped lead over 2.7 million Californians to more efficient, cleaner energy solutions, healthier homes and lower utility bills.

Disclaimer

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Revision Table

Version	Date	Description
1.0	03/21/24	Initial draft
2.0	04/26/24	Incorporated reviewer feedback, updated calculation tool
3.0	05/17/24	Added stakeholder feedback

Table of Acronyms, Abbreviations, and Definitions

Abbrev.	Definition
A	Ampere
AHJ	Authority Having Jurisdiction
AMI	Advanced Metering Infrastructure
BEV	Battery Electric Vehicle
CEC	California Electric Code
EMS	Energy Management System
EVSE	Electric Vehicle Supply Equipment
GHG	Greenhouse Gas
HEA	Home Energy Analytics
HPWH	Heat Pump Water Heater
IPMT	Intelligent Power Management Technologies
NEC	National Electric Code
NFPA	National Fire Protection Association
PHEV	Plug-in hybrid electric vehicle
RHA	Richard Heath & Associates, Inc.
SME	Subject matter expert
SVCE	Silicon Valley Clean Energy

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PURPOSE

When adding new electrical loads such as heat pumps or air conditioning, the default decision is often to upgrade electrical service in existing buildings with less than 200A, causing significant project delays and increasing project costs. The good news is that panel upgrades are often unnecessary. This guide is intended to provide actionable information for permit application plan reviewers, practical solutions to aid contractors submitting permit applications and insights into the tactics that minimize the need for costly electric service upgrades and associated electric panel replacements.

WHAT'S INCLUDED

Aimed at older residential buildings built before 200A electrical service became common practice in new buildings and informed by the latest California Electrical Code (CEC) and National Electric Codes (NEC), new technologies and industry practices, this guide supports local authorities having jurisdiction (Community Development, Building Departments) as they address the increasing number of applications for existing residential building projects adding new electrical loads.

Strategies for Optimizing Electrical Service: Residential energy retrofit projects with electrical panels less than 200A can often avoid costly electrical service upgrades by implementing one or more of the following strategies: Alternative Load Calculations, Low-Power Appliances, or Energy Management and Non-Coincident Load Devices

Building Codes and Load Calculations: This document covers a range of safe, code-compliant methods for estimating total electrical demand when adding new electrical loads. The information is designed to educate contractors and building departments, promoting the safe and code-compliant use of these calculation methods across various construction projects and building types. Additionally, templates for load calculations to assist in practical applications is included.

Common Technologies to Reduce Peak Electrical Loads: An important element of optimizing existing electrical service without requiring service upgrades includes the careful selection of new equipment and appliances. Included are insights into over a dozen of the most common technologies.

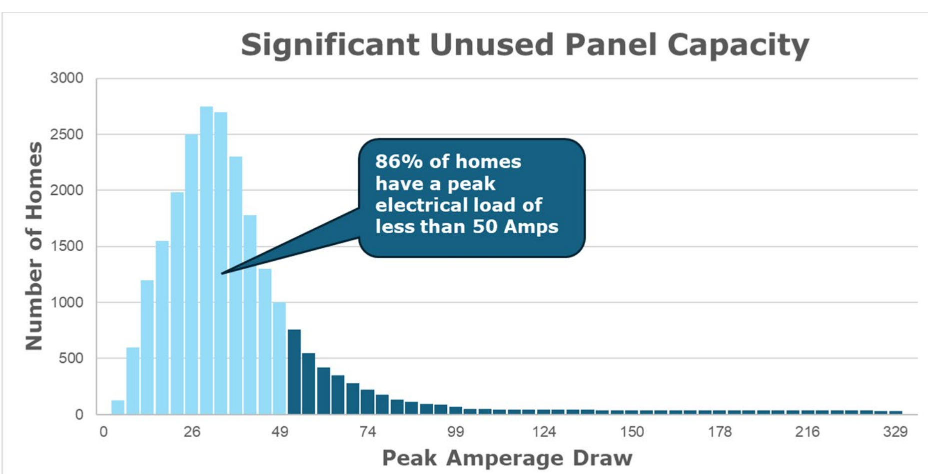

Figure 1: Peak Power Draw in Homes[2]

BACKGROUND

Senate Bill 32 (SB 32) requires California to reduce statewide greenhouse gas emissions (GHG) to a level 40% below 1990 levels by 2030. This legislation has spurred a significant increase in energy retrofits that include new all electric appliances replacing fossil fuel appliances (electrification).

Silicon Valley Clean Energy (SVCE) recognizes that existing residential building electrification efforts often result in unnecessary and costly electrical service upgrades. As many as 60-70% of homes (50-60 million) likely have electrical panels with less than 200A service[1]. According to a 2023 Electrical Power Research Institute survey, 62% of respondents reported having less than 200A capacity electrical panels. Factors like equipment choice, load calculations, code compliance and utility upgrade requirements often lead to costly and time-consuming electrical service upgrades. However, recent data from thousands of residential smart meters determined that peak electrical demand is less than 50A[2] in 86% of residential buildings (Service panel capacity unknown). SVCE aims to equip local building officials with information and resources validated by current electrical codes, local regulations and industry best practices, reducing the need for such upgrades.

[1] https://www.rewiringamerica.org/circuit-breakers/the-grid

[2] https://corp.hea.com/home-electrification

Section 1: Overview

This section provides a high-level summary of the scope of electrification, key technologies to reduce peak building loads, and their benefits. The content may be a review for some readers but is provided here for completeness and to provide contextual information for readers less familiar with the topics or technologies.

1.1 Definition and Scope of Residential Electrification

Federal and state rebates and tax incentives combined with advances in appliance technology have spurred greater demand for converting traditionally fossil fuel (natural gas, propane, fuel oil) fired appliances with higher efficiency electric models. Due to the scope of the projects, which may include calculating building energy and electrical loads and adding new electrical circuits, permits are almost always required. Additionally, the new electrical loads may require new electrical panels, which in some cases involves submitting load calculations to the local utility. Contractors and customers can benefit from reduced project costs and delays by carefully selecting equipment, calculating loads using alternative methods approved by the CEC and submitting applications compliant with the unique requirements of locally adopted codes.

1.2 Summary of key technologies: Electric heating and cooling systems, smart home technologies, electric vehicle charging infrastructure

Residential electrification efforts are focused on space heating and cooling, water heating, cooking, clothes drying, electric vehicle (EV) charging and energy management systems (EMS).

Heat pump systems have dramatically improved in efficiency, reliability, application and operating temperature range. In addition to reducing GHGs when paired with a clean electrical supply, heat pumps can improve indoor air quality as they do not require the venting of combustion gases. The recent introduction of 120V HPWH condensers provides an opportunity to further reduce peak electrical demand compared to traditional 240V HPWH condensers.

Induction cooking is another technology quickly gaining popularity in both residential and commercial applications. Induction cooking removes the dangers associated with cooking over open flames and is more efficient than electrical resistance models.

Heat pump clothes dryers are approximately 30% more efficient than standard electric units, even with the longer drying times associated with these models.

Lower power level 2 EV chargers (20A) reduce total peak demand and can often share circuits with other appliances in the home.

Figure 2 provides a simple visual summary of many of the appliance options available to customers when replacing gas burning models. Section 4.1 provides more detailed description of these appliances and their application.

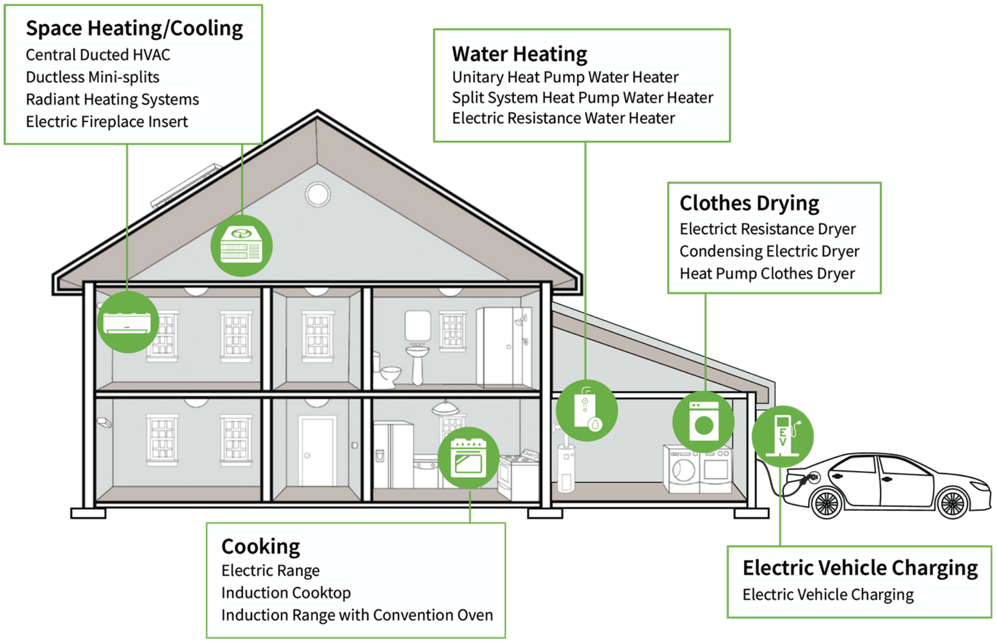

Figure 2: Key Load Reduction Technologies

Section 2: Strategies for Optimizing Electrical Service

Residential energy retrofit projects with electrical panels less than 200A can often avoid costly electrical service upgrades by implementing one or more of the following strategies: Alternative Load Calculations, Low-Power Appliances, or Energy Management and Non-Coincident Load Devices.

2.1 Alternative Load Calculations

When assessing the maximum planned post-retrofit electrical loads in existing buildings, approved alternative load calculation methods from the CEC are key to minimizing unnecessary panel upgrades. These methods accommodate either historical usage monitored by Advanced Metering Infrastructure (AMI) data (CEC Section 220.87) or simplified load calculations using appliance nameplate ratings (CEC Section 220.83). These calculations may produce slightly different results, and both should be considered when AMI data is available. See Section 3 for a detailed explanation of when and how to use or evaluate alternative load calculations.

2.2 Low-Power Appliances

To reduce the peak incident electrical load in buildings, selection of high-efficiency, low-power appliances is often considered. Examples of such appliances include 120V heat pump water heaters, low-current EV chargers and inverter-driven condensing units. These appliances reduce the number of 240V circuits and peak electrical demand. Refer to Section 4.1 for a more comprehensive list of low power appliances.

2.3 Energy Management and Non-Coincident Load Devices

Advancements in electrical safety and circuit level controls provide load management by digitally monitoring and controlling individual circuits, and disconnecting or regulating which appliance can access a circuit when electricity usage becomes too high. Load management and energy management systems (EMS) are common in commercial buildings but relatively new in residential applications. Refer to Section 4.2 for details on four common energy management and non-coincident load devices and their associated code references.

Section 3: Building Codes and Load Calculations

This section provides detail on the various methods for estimating total electrical demand when adding new electrical loads and the preparation of permit application documents. The intent is to inform contractors and building departments and promote the safe, code-compliant use of these calculation methodologies for different construction projects and building types.

3.1 Alternative Load Calculations

A survey was conducted of contractors and consultants experienced in utilizing the alternative calculation methods allowable by the CEC and conducted additional independent analysis, evaluating real-world and model electrification retrofit plans. It is important to acknowledge that every project is unique and requires specific engineering calculations to determine loads. Observations here are for informational purposes and should not be used to establish rules applicable to any individual project.

Figure 3: Upgrading utility service capacity is expensive and time consuming

The CEC, Chapter 2, Article 220[3] provides methodology for calculating the total electrical load for:

1) Noncoincident Loads (220.60): Allows for circuit splitting/sharing/pausing equipment.
2) Dwelling Units (220.82): Provides a standard load calculation methodology for new construction and is commonly used by Authorities Having Jurisdiction (AHJ's).
3) Existing Dwelling Units (220.83): Provides methodology appropriate for existing residential retrofits adding electric loads.
4) Multifamily Dwelling Units – 3 or more (220.84): Provides methodology used when calculating electric loads for three or more dwelling units.
5) Two Dwelling Units Supplied by a Single Feeder (220.85): Provides methodology used for calculating electric loads when two dwelling units are supplied by a single conductor circuit from the utility (feeder) to the dwelling units.
6) Determining Existing Loads (220.87): Utilizes existing peak electrical load, as determined by AMI utility data, when calculating a dwellings total electrical load.

Some jurisdictions have begun adopting sections of the 2023 NEC to provide approved requirements for applying EMS, including in residential buildings. The use of EMS in residential buildings reduces the need for electrical service upgrades by prioritizing loads and ensuring that total loads do not exceed the electrical service capacity while still meeting occupant needs. Supplemental electrical load calculations from the NEC adopted from NFPA 70 code are sections:

1) Energy Management Systems (220.70): This section determines the rules for establishing an EMS "setpoint," or the maximum load an EMS will allow to be drawn from the control system.
2) Article 750 Energy Management Systems[4]:
    a. EMS is explicitly permitted to control multiple loads to a single current setpoint, which is equal to a single value equal to the maximum ampere setpoint…for calculating the connected loads.

[3] CEC 2022, Chapter 2, Article 220 Branch-Circuit, Feeder, and Service Load Calculations
[4] NEC 2023 Chapter 7 Special Conditions, Article 750 Energy Management Systems

b. Per Span IO, a leading manufacturer in UL listed EMS equipment in electrical panels: 750.30 Load Management: "Energy management systems shall be permitted to monitor and control electrical loads unless restricted."

c. The full language from Article 750 is provided in the Appendix of this document

3) Article 625.41 was added to the new NEC Code 2023: It covers the electrical conductors and equipment external to an electric vehicle that connects an electric vehicle to an electricity supply.

3.1.1 Limitations of 100A Electrical Distribution Systems

Homes built before 1965 are five times more likely to have electrical service under 200A. With an estimated 60% of US homes having less than 200A service[5], the potential impact of electrifying homes with existing electrical infrastructure is significant. However, not all homes can be electrified safely and in compliance with electrical codes. Large electrical loads, including those created by, but not limited to, pool pumps/heaters, motors from power tools and 240V EV chargers, limit available capacity for additional electrical equipment.

Scenarios where 100-150A service may not be adequate to accommodate significant new loads include:

1) High capacity 240V Level 2 EV chargers (over 20A)
2) 220V hot tub spas
3) Pool pumps/pool heaters
4) Multiple HVAC systems or systems over 5 tons
5) Accessory dwelling units (ADUs), garage conversions or shops with power tools

3.2 Data requirements for calculating electrical loads

The required data and information needed to carry out load calculations using the four methodologies include:

1) Existing panel size
2) House square footage
3) Name plate rating for AC or electric space-heating equipment
4) Name plate rating for appliances
5) Number of small appliance branch circuits
6) AMI data
7) Per circuit load

Table 1 summarizes which load calculation methods use specific data inputs. The subsequent sections list the data used for each methodology.

[5] EPRI 2022 Survey of US Electrical Panels

Table 1: Data Needed to Compute Load Calculations by Methodology

Load Calculation	Existing Panel Size	House Square Footage	Name Plate Rating for AC or Electric Space-Heating	Name Plate Rating for Appliances	Number of Small Appliance Branch Circuits	AMI Data	Per Circuit Load
CEC 220.83	●	●	●	●	●		
CEC 220.87	●		●	●		●	
CEC 220.60	●			●			●
NEC 220.70	●						●

3.2.1 Using CEC 220.83

Section 220.83 is used "to determine if the existing service or feeder is of sufficient capacity to serve additional loads." Required information includes:

1. Existing panel size
2. Home square footage
3. Name plate rating for AC or electric space-heating equipment
4. Name plate rating for all appliances, including:
    a. Ranges, ovens, cooktops
    b. Clothes dryers not on laundry branch
    c. Water heaters
    d. Other appliances fastened in place
5. Number of small appliance branch circuits and laundry circuits

3.2.1 Using CEC 220.87

Section 220.87 is used to determine the service load for existing installations using "actual maximum demand." Required information includes:

1. Existing panel size
2. Access to AMI data
    a. Work with homeowner via 'Green Button Data' download
3. Determine the maximum load from one year of AMI data
    a. If maximum demand data isn't available for a one-year period, it is permissible to use 15-minute interval data from a 30-day period
4. If the feeder or service has renewable, such as solar or wind, then 220.87 is disallowed

3.2.2 Using CEC 220.60

Section 220.60 applies when *"two or more noncoincident loads will be in used simultaneously."* When used for determining the total load of a feeder or service calculations, *"only the largest load(s) that will be used at one time"* is needed. Required information includes:

1. Existing panel size
2. Per-circuit load

3.2.3 Using NEC 220.70

Section 220.70 is used to determine *"a single value equal to the maximum ampere setpoint of the EMS"* to be used in load calculations. EMSs are explicitly permitted to control multiple loads to a single current setpoint, which is equal to a single value equal to the maximum ampere setpoint. Required information includes:

1. Existing panel size
2. EMS manufacturer specifications for setpoint
3. Per-circuit load

Section 4: Common Technologies to Reduce Peak Electrical Loads

An important element of optimizing existing electrical service without requiring service upgrades includes the careful selection of new equipment and appliances. This section is intended to provide specific examples of equipment contractors may select and include in permit applications. Included in Section 4.1 is a list of appliances and equipment that typically have lower power demands than comparable models. Section 4.2 provides details on four common energy management and non-coincident load devices.

4.1 Appliances used in Load Reduction Strategies

There are several commercially available appliances that, when selected, reduce total peak load in buildings. Careful consideration of customer usage patterns and building configuration should be taken to ensure the customer's needs are met. These are provided herein as a consolidation of the research. Table 2 below outlines the most common products and appliances that can be employed to reduce incident peak electrical demand.

Table 2: Low Power Alternative Appliances

Section Ref. #	Technology / Product	Application Type	Pros	Cons
4.1.1	120V HPWH	1-2 bedroom residences	○ Avoids need/costs of adding new circuit	○ Reduced capacity and first hour ratings
4.1.2	Level 1 EVSE <20A	Residences with an electric vehicle	○ Avoids need for a dedicated circuit ○ Not required in load calculations	○ Slow charging times ○ Reduced driving miles per overnight charge
4.1.3	Heat pump clothes dryer	All residences	○ Lower peak electrical draw ○ 30% more efficient	○ Longer drying times ○ Smaller capacity ○ Increased maintenance
4.1.4	Induction cooking	All residences	○ More efficient than electric resistance ○ Reduced heating times	○ Some modification to cooking styles ○ Requires ferrous cookware
4.1.5	Level 2 EVSE <30A	Residences with an electric vehicle	○ Lower peak demand compared to standard Level 2	○ Slower charging times ○ Reduced driving miles per overnight charge
4.1.6	Induction cooktop with battery	Residences with cooktops	○ Uses standard 110V outlet ○ Lower peak demand	○ Not widely available ○ Limited brands
4.1.7	Hydronic space and water heating	Residences up to 4-ton HVAC loads	○ Reduces number of circuits ○ Lowers peak demand	○ Limited products available ○ Complex installation
4.1.8	Inverter driven condensing units	All residences	○ Where applicable, decreases peak power and noise	○ Limited availability of products ○ Not applicable for all HVAC designs
4.1.9	120V electric fireplace	Residences with fireplace insert	○ Provides comfort and ambiance of gas fireplace	○ Reduced heat output may impact customer experience

4.1.1 120V Heat Pump Water Heaters

A 120V HPWH is an energy-efficient appliance that heats water using a heat pump. It is ideal for areas where incoming water temperature is always 55°F or higher and for smaller homes with 4 or less occupants. Some units require a dedicated 120V circuit while others can share a standard 15A circuit. 120V HPWH's experience longer recovery times than their 240V counterparts and require a more conservative approach to hot water use.

4.1.2 Level 1 EVSE (less than 20A)

Level 1 EVSE provides charging through a common residential 120V AC outlet. It can take 40-50+ hours to charge a battery electric vehicle (BEV) to 80% from empty and 5-6 hours for a plug-in hybrid electric vehicle (PHEV).

4.1.3 Heat Pump Clothes Dryers

A heat pump clothes dryer uses heat pump technology to remove moisture from wet clothes. Unlike traditional dryers, which vent hot air outside, heat pump dryers recycle hot air and use it to dry clothes, making them much more energy efficient. Many units operate on 120V power.

4.1.4 Induction Cooking

Induction cooking uses electromagnetic induction to heat the cookware directly, making it faster and more energy efficient than traditional cooking methods. Induction options can be found in cooktops and ranges. They are still energy intensive but require less peak electrical demand than electric resistance counterparts. Induction cooking requires the use of ferrous (iron containing) cookware. Traditional, non-ferrous products like aluminum will not work with induction equipment and may need to be replaced.

4.1.5 Level 2 EVSE (less than 30A)

Low power, level 2 EVSE offers higher-rate AC charging through 240V (in residential applications) or 208V (in commercial applications) electrical service. It can charge a BEV to 80% from empty in 4-10 hours and fully charge a PHEV in 1-2 hours.

4.1.6 Induction Cooktops with Battery

An induction cooktop with a battery is a portable standalone appliance that uses electromagnetic induction to heat cookware directly. It is partially powered by a battery, significantly reducing peak electrical demand and providing cooking capabilities during a temporary power outage. These units are new in the marketplace and still available in limited quantities.

4.1.7 Hydronic Space and Water Heating

A hydronic heating system provides space heating by circulating a hot liquid, typically water, through a series of pipes, distributing heat to the entire house. The cooled liquid returns to the heater and the process repeats. The hot water also serves the residence's domestic hot water needs. Because the compressor provides domestic hot water and space heating, it can reduce total electrical demand compared to separate systems.

4.1.8 Inverter-HVAC Driven Condensing Units

Inverter-driven HVAC condensing units use an intelligent compressor drive module that provides highly-efficient, quiet, variable-speed operation. This allows the unit to continuously regulate the temperature based on the space's specific requirements. These units require less current to start the compressor motor.

4.1.9 120V Electric Fireplace

A 120V electric fireplace is a heating appliance that mimics a traditional fireplace. It plugs into a standard 120V outlet and can provide supplemental heat for areas of up to 400 square feet.

4.2 Energy Management Systems and Non-Coincident Loads

EMS and load-sharing devices reduce coincident loads, allowing two or more devices to operate, but not at the same time. These devices are not permitted in all jurisdictions but are an invaluable tool for reducing the need for electrical service upgrades. Four types of wiring technologies reduce the need for service upgrades by combining circuits on the customer side: 1) smart panels, 2) outlet splitters, 3) circuit control units and 4) smart circuit breaker and relay. When using circuit sharers or pausers, some appliance combinations, summarized in Table 3 below, are more favorable than others. Some building departments are reluctant to allow smart panels and circuit-sharing devices due to limited knowledge of existing equipment and minimal code language addressing EMS (CEC 220.60, NEC 220.70). Customer education and expectation setting is an essential component in these technologies' success.

Additionally, while a circuit control device may power any combination of two appliances, it is not recommended for several combinations. Careful consideration of the impact on both customer experience and equipment performance is recommended. Specifically, circuit sharing/controls are not recommended for air conditioners, ranges or some heat pump water heater applications

Table 3: Energy Management and Load Sharing Technologies

Section Ref. #	Technology / Product	Application Type	Pros	Cons	Load Calculation
4.2.1	Smart Panels	○ Main Panel Replacement	○ Control loads in the home ○ Provides per-circuit energy consumption	○ Cost ○ Challenges with AHJ's approval	○ CEC 220.70 ○ CEC 220.83
4.2.2	Outlet Splitters	○ Dual EVSEs ○ Dryer and EVSE	○ Single circuit in panel can power two appliances	○ Only one appliance at a time ○ Close proximity of appliances	○ CEC 220.60 ○ CEC 220.83
4.2.3	Circuit Control Units	○ Induction Range and EVSE* ○ Two EVSEs ○ HPWH and Dryer	○ Single circuit in panel can power two appliances	○ Electrician unfamiliarity ○ Not compatible with all appliance combinations	○ CEC 220.60 ○ CEC 220.83
4.2.4	Smart Circuit Breakers and Relays	○ Dryer ○ EVSE ○ Induction Range ○ HPWH	○ Per circuit modularity ○ Integrates directly into existing panel	○ Often requires Wi-Fi for functionality ○ Challenges with AHJ's approval	○ N/A

*Frequently power cycling a range results in the clock being reset and flashing every time the power goes out.

4.2.1 Smart Electric Panels

A smart electric panel, certified to UL 916 as energy management equipment, can be used to monitor and control multiple electrical circuits within a home. Section 220.70 of the 2023 NEC states the EMS shall be permitted to be used in load calculations for the feeder and service load calculations. As whole-home current approaches the maximum, software opens or limits noncritical circuits to prevent overloading the system.

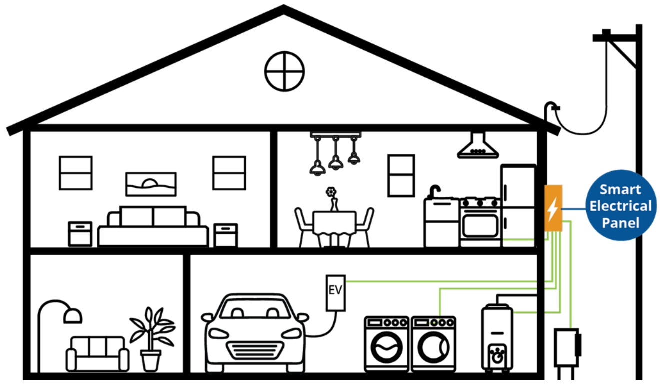

Figure 4: Smart Electric Panel

4.2.1.1 SPAN.io

Figure 5: Span.IO Smart Panel

SPAN.io's EMS makes it possible to shift loads within a home so as to not exceed the capacity of the feeder wires. Span.IO's application note[6] sites NEC codes NEC 750.30 Load Management and NEC 220.70 to commission their product. Additionally, SPAN.io equipment is listed in UL 916 and has downloadable documents for the permit counter readily available.

4.2.1.2 Leviton

The Leviton smart[7] panel is currently undergoing UL testing and has not yet achieved the UL 916 certification. Once testing is complete, the smart panel will offer the ability to control loads when connected to a backup battery system.

4.2.2 Outlet Splitters

Outlet-splitting devices alleviate the need to install additional circuits to power two appliances. When incorporating an outlet splitter into load calculations, CEC 220.83, CEC 220.60[8] indicates to use *"the largest load(s) that will be used at one time for calculating the total load of a feeder or service."* This means that when a circuit-sharing device is commissioned, instead of using both loads, only the higher power draw load is used. Common circuit sharer appliance combinations are: 1) two EVSE chargers or 2) a dryer and an EVSE charger. Equipment like the Neo Charge[9], or BSA Appliance Buddy do not typically require a permit, as they are plugged directly into a 220V outlet.

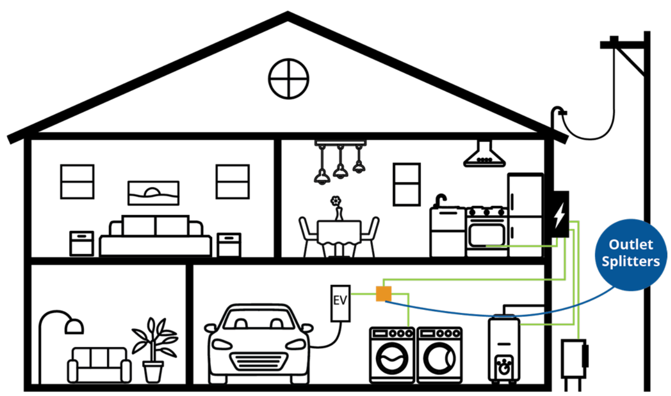

Figure 6: Outlet Splitter

[6] https://techportal.span.io/s/powerup-quickstart
[7] https://www.leviton.com/en/products/residential/load-centers
[8] CEC 2022, Article 220 Branch-Circuit, Feeder, and Service Load Calculations, Part 1 section 220.60
[9] https://getneocharge.com/products/neocharge-smart-splitter

4.2.3 Circuit Control Units

Circuit control units power two appliances but require an additional circuit for the new appliance. Equipment like the Simple Switch[10] requires a permit as a new circuit is required, as shown in Figure 8. Common circuit pauser appliance combinations are: 1) an air conditioner and an induction range; 2) an induction range and an EVSE; 3) two EVSE chargers; or 4) a heat pump water heater and a dryer. It is important to note that the appliances used in circuit pausers need a common "ON" state when power is restored. Further investigation is needed around the impacts of frequent power cycling.

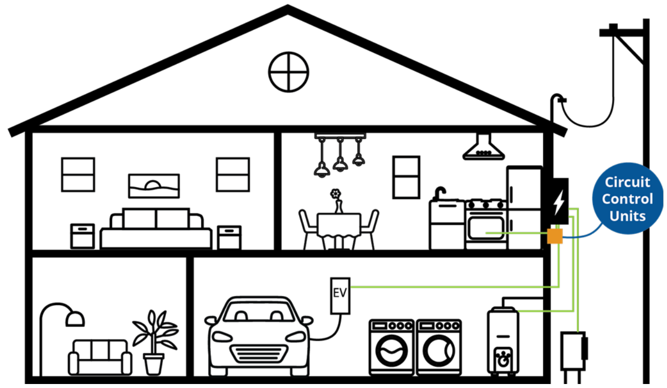

Figure 7: Circuit Control Unit

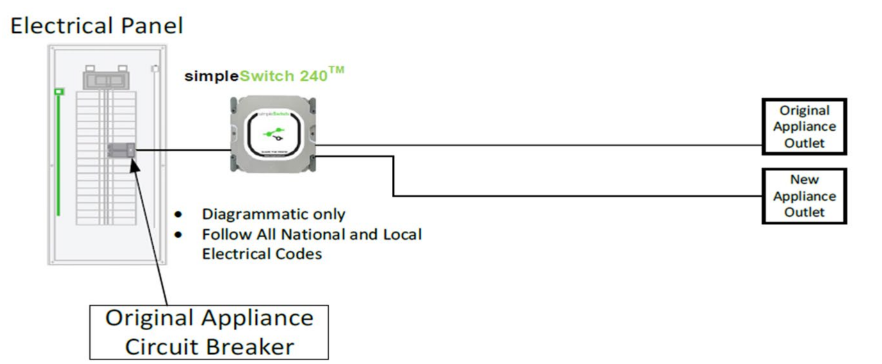

Figure 8: Simple Switch Circuit Control Unit Configuration

4.2.4 Smart Circuit Breakers and Relays

A circuit breaker is an electrical switch designed to automatically open a circuit, preventing damage to components should an overload or short-circuit occur. A smart circuit breaker has the added capability to collect and monitor electrical system data from circuit and load equipment, and often integrates easily into an existing electric panel on a per circuit basis. Smart circuit breakers are commonly used for turning off or monitoring a single appliance such as: 1) A clothes dryer, 2) an induction range, 3) an EVSE charger or 4) a heat pump water heater.

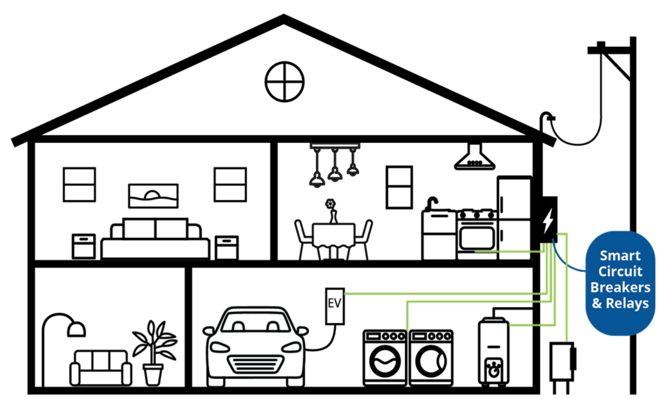

Figure 9: Smart Breakers and Relays

[10] https://simpleswitch.io/collections/all

Section 5: Successfully Electrified Homes

Meet the Davis, Martinez and Kim families. Each family was able to successfully electrify their home using an appropriate approach. Using CEC 220.87 in conjunction with a circuit control unit, the Davis family was able to electrify their home fully, including installing an electric vehicle charging station. Using CEC 220.83, the Martinez family was able to electrify their home fully, eliminating their reliance on propane for water and home heating. Using NEC 220.70, the Kim family was able to electrify their home fully by utilizing a smart electric panel. Here are their pre- and post-upgrade stories:

5.1 Davis Residence

At the Davis's Bay Area residence, a retired couple successfully upgraded their appliances from natural gas to electric (shown in Figure 10) using their existing 100A panel, avoiding the need to upsize their electric service. As indicated in Table 4, both CEC 220.83 and 220.87 load calculations allowed for the upgraded appliances. However, using CEC 220.82 would have required a service upgrade.

Figure 10: Davis Residence with Upgraded Circuit Splitter and HPWH

Calculation Type	Panel Capacity	Peak Existing	Peak New	Headroom (VA)	Pass / Fail
CEC 220.82	24,000	N/A	24,213	(-213)	Fail
CEC 220.83	24,000	N/A	23,013	987	Pass
CEC 220.87	24,000	6,135	16,885	980	Pass

Home information:

- Home Age: 1952
- Square Footage: 1,800
- Number of Residents: 2
- Bed/Bath: 2/2
- Prior Fuel Usage: Natural Gas
- Panel Size: 100A
- AMI Peak Load: 4.9 kW

Prior equipment:

- HVAC: Forced Air Furnace 48kBTU, No Air Conditioning
- Water Heating: 50g Natural Gas Storage
- Cooking: Electric Oven
- Cooking: Natural Gas Cooktop, 4 Burner
- Dryer: 240V Electric

Upgraded equipment:

- HVAC: Energy Efficient Compressor 15.0+ SEER2, 6.7+ HSPF2 Heat Pump Package (3 Ton)
- Water Heating: HPWH 240V, 65 Gallon
- Cooking: 5 Burner, 36" Induction Cooktop
- EVSE: Level 2, 240V 20A
- Dryer and EVSE: Simple Switch 240V Circuit Splitter

5.2 Martinez Residence

At the Martinez's San Mateo County residence, a family of four successfully upgraded their appliances from propane to electric (shown in Figure 11) using their existing 100A panel, avoiding the need to upsize their electric service. As indicated in Table 5, similar to the Davis residence, both CEC 220.83 and 220.87 load calculations allowed for the upgraded appliances. However, using CEC 220.82 would have required a service upgrade. Updating from electric baseboard heating to an efficient heat pump has significant positive bill impacts.

Figure 11: Martinez Residence with Induction Cooktop and HWPH

Calculation Type	Panel Capacity	Peak Existing	Peak New	Headroom (VA)	Pass / Fail
CEC 220.82	24,000	N/A	24,501	(501)	Fail
CEC 220.83	24,000	N/A	23,301	699	Pass
CEC 220.87	24,000	13,213	10,145	643	Pass

Home information:

- Home Age: 1936
- Square Footage: 2,040
- Number of Residents: 4
- Bed/Bath: 3/3
- Prior Fuel Usage: Propane
- Panel Size: 100A
- AMI Peak Load: 10.6 kW

Prior equipment:

- HVAC: Electric Baseboard Heating, No AC
- Water Heating: 1)-40 g Propane Gas Storage; 1)-20g Electric Storage Tank
- Cooking: Electric Oven
- Cooking: Propane Cooktop
- Dryer: Propane

Upgraded equipment:

- HVAC: Energy Efficient Compressor 15.0+ SEER2, 6.7+ HSPF2 Heat Pump Package (3.5 Ton)
- Water Heating: HPWH 240V, 65 Gallon
- Cooking: 4 Burner, 30" Induction Cooktop
- Dryer: High Efficiency 7.3 ft^3

5.3 Kim Residence

At the Kim's Bay Area residence, a family of three successfully upgraded their appliances from natural gas to electric (shown in Figure 12) using their existing 100A panel, avoiding the need to upsize their electric service. As indicated in Table 6, both CEC 220.82 and 220.83 load calculations would require a service upgrade. No AMI data was available, but using NEC 220.70 allowed for the upgraded appliances. Updating from a failing central furnace to a four-zone mini split optimized comfort and heating costs.

Figure 12: Kim Residence with Upgraded Induction Range and Ductless Mini Split

Table 6: Kim Load Calculations

Calculation Type	Panel Capacity	Peak Existing	Peak New	Headroom (VA)	Pass / Fail
CEC 220.82	24,000	N/A	25,864	(1864)	Fail
CEC 220.83	24,000	N/A	24,664	(664)	Fail
NEC 220.70	24,000	N/A	19,200	4800	Pass

Home information:

- Home Age: 1949
- Square Footage: 1,150
- Number of Residents: 3
- Bed/Bath: 2/1
- Prior Fuel Usage: Natural Gas
- Panel Size: 100A
- AMI Peak Load: Not Available

Prior equipment:

- HVAC: Non-operational, Forced Air Furnace 36kBTU, No Air Conditioning
- Water Heating: 1-50 g Natural Gas Storage
- Cooking: Natural Gas Range
- Dryer: Electric

Upgraded equipment:

- HVAC: 4-zone, 48kBTU Ductless Mini Split Heat Pump
- Water Heating: HPWH 240V, 65 Gallon
- Cooking: 4 Burner, 30" Induction Range
- EVSE: Level 2, 240V 20A
- Panel Update: Smart Panel, 80% of 100A

Section 6: Permitting Application and Review

This section provides recommendations from interviews with various stakeholders, including building officials, engineering firms, contractors and others. Every jurisdiction has its own policies, requirements and processes when obtaining building and remodeling permits. These recommendations are not intended to conflict with local policy or requirements, but rather to support more complete applications and reduced permit review times.

6.1 Recommendations for Permit Review Processing for Electrification Projects

1. Publish or display a checklist for applicants that clearly states the items required for permit submittal. This may reduce the number of incomplete or non-compliant applications requiring revisions. Checklist items may include:
    - Scope of work for all proposed equipment
    - Breaker schedule showing amperage of all new circuits, with conductor and conduit information
    - Site plan if equipment will be installed in new locations, including setbacks for exterior equipment
    - Electrical load calculations
    - Photograph showing main service panel and main circuit breaker ratings
    - List of various code references
    - Cutsheets of new equipment
    - Contractor verification checklist for applications with new circuits, which may include:
        - Conductors are sized appropriately
        - Overcurrent protection device is provided and sufficient
        - Conduit specs and conduit fill is compliant
2. Maintain a checklist of necessary fields for applicable load calculation methodologies and provide load calculation examples. Checklist items may include:
    - 220.83
        - Square footage matches records
        - "Small branch circuits" included
        - VA of various appliances match the nameplate rating or industry standard if not available
        - 220.83(a) or 220.83(b) is considered
            - Calculation differs if HVAC is present
    - 220.87
        - 1 year of data at hourly intervals, with the exception of 15-minute data for 1 month if 1 year of data is not available
        - 125% of maximum demand is used
        - No renewable energy system on record or installed

Section 7: Tools & Resources

7.1 Alternative Calculation Templates

An essential part of any electrification permit application is the load calculations. Publicly available load calculation templates and spreadsheets commonly used to determine compliance with CEC 220.82, CEE 220.83 or CEC 220.87 are included below. SPAN.io provides a printable document that supports NEC 220.70 load calculations.

These calculators are provided for informational purposes only. Individuals referencing these calculators should conduct their own evaluation prior to use. The author provides no warranty either expressly or implied as to the veracity of these documents.

7.2 Template for CEC 220.83 and CEC 220.87

A sample Electrical Load Estimator template[11] that may be used to submit along with building applications is available for download by clicking the link.

7.2.1 Spreadsheets and fillable forms for load calculations

A list of sample load calculation tools is provided below.

1. Mike Holt Enterprises includes a NEC 220.82 spreadsheet (part of the online class offering.[12])
2. Span.io Project Planner tool with NEC 220.70 printable documents to take to the permit office counter
3. BayREN provides a calculation worksheet for 220.82 and 220.87
4. Central Electric Inspection Bureau provides a comprehensive calculator, but it is based on the parallel language in NEC, and while almost identical, is not based on the CEC.

7.2.2 Templates for 220.82 and 220.83 from AHJs

Many agencies have downloadable and printable PDFs for 220.82, but they require manual calculations. Here is a list of sample templates with links to the appropriate document:

1. City of Sacramento
2. Huntington Beach
3. San Diego

A few jurisdictions provide a downloadable and printable PDF for 220.83 are included for reference. **Note:** The veracity of these calculators cannot be confirmed and are for reference only.

1. Foster City
2. Concord

[11] As this template was adapted from BayREN, the author provides no warranty either expressly or implied as to the veracity or completeness of these tools and has included them for informational purposes only.

[12] https://www.mikeholt.com/technical-calculations-formulas.php

7.3 Other References and Resources

Additional resources include Pacific Clean Energy's (PCE's) Design Guidelines for Home Electrification[13], Redwood Energy's A Pocket Guide to All Electric Retrofits of Single Family Homes [14] and the CalNext Market Study of Household Electric Infrastructure Upgrade Alternatives for Electrification[15].

7.3.1 CalNext Market Study

The "Market Study of Electric Infrastructure Upgrade Alternatives for Electrification" developed by CalNext offers a comprehensive market assessment of commercially available intelligent power management technologies (IPMTs). These technologies can shut off circuits when current draw exceeds a maximum limit, potentially minimizing or avoiding the cost and time associated with residential household electrification projects. Key components of the study are:

1. *Objectives:* The study aims to bring additional knowledge to existing energy efficiency and beneficial electrification programs.
2. *Methodology & Approach:* The study uses a combination of market scans, vendor interviews and stakeholder engagement to gather data.
3. *Findings:* The findings provide an overview of the market for IPMTs and their potential role in residential electrification.
4. *Product Groups:* The document provides information about various product groups related to IPMTs.
5. *Recommendations:* The study concludes with recommendations for leveraging IPMTs in residential electrification.
    a. Develop consumer-facing educational materials for IPMTs
    b. Develop contractor training guides for IMPTs
    c. Engage with building departments to overcome objections to using IMPTs in local adoption
    d. Conduct pilots and field demonstrations to build market confidence
    e. Develop customer/contractor incentives to reduce perceived first cost barriers
    f. Model the cost comparison of IMPTs versus potential electrical service upgrades

7.3.2 PCE Design Guide

The "Design Guidelines for Home Electrification" by PCE provides practical and technical guidance for homeowners, builders and contractors who are interested in electrifying their homes with clean and renewable energy. Key takeaways include:

1. *Benefits and Costs:* The document discusses the advantages and potential expenses associated with home electrification, identifying ways to limit costly electric panel and service upgrades.
2. *Incentives:* The document provides information about the incentives available for homeowners who choose to electrify their homes, specifically rebates and utility incentives for heat pump water heaters.
3. *Codes and Regulations:* The document outlines the relevant codes and regulations that homeowners, builders and contractors need to be aware of when electrifying a home.

[13] https://www.peninsulacleanenergy.com/wp-content/uploads/2023/02/Design-guidelines-for-home-electrification-v021023.pdf
[14] https://www.redwoodenergy.net/watt-diet-calculator
[15] https://www.veic.org/clients-results/reports/market-study-of-household-electric-infrastructure-upgrade-alternatives-for-electrification

4. *Appliances:* The document provides information about 120v appliances that are suitable for electrified homes.
5. *Best Practices:* The document shares best practices for home electrification, providing practical guidance for those interested in this process, including avoiding Level 2 EVSE chargers.

7.3.3 Redwood Energy's Pocket Guide

The "Guide to All-Electric Retrofits of Single-Family Homes – Quick Facts" developed and published by Redwood Energy offers a comprehensive guide for homeowners, renters, utilities and policymakers interested in transitioning to efficient electric alternatives. Key takeaways are:

1. *Benefits of Electrification:* The document highlights the numerous benefits of home electrification, including improved health due to reduced indoor air pollution, increased comfort from using heat pump heating and cooling and a lower environmental impact by reducing emissions.
2. *Electrification Strategies:* The document provides strategies for home electrification, which can start with a deep retrofit, including insulation and energy efficiency upgrades or by switching one gas appliance at a time.
3. *Cost-Effective Solutions:* The document includes information on how to electrify on a tight budget and how to save money by avoiding electric service upgrades, also known as the Watt Diet.
4. *Case Studies:* The document features 25 all-electric home retrofit case studies from across the U.S., located in the coldest climates of the Midwest to temperate climates in California.
5. *Product Guide:* The document includes a product guide comprised of over 60 potential electrification appliances.

Section 8: Appendix

This is the Appendix for Service Optimization Guide for Building Officials documentation.

8.1 National Electric Code Article 750 Energy Management Systems

750.1 Scope. This article applies to the installation and operation of EMS.

Informational Note: Performance provisions in other codes establish prescriptive requirements that may further restrict the requirements contained in this article.

750.6 Listing. Energy management system shall be one of the following:

1. Listed as a complete energy management system
2. Listed as a kit for field installation in switch or overcurrent device enclosures
3. Listed individual components assembled as a system

750.20 Alternate Power Sources. An energy management system shall not override any control necessary to ensure continuity of an alternate power source for the following:

1. Fire pumps
2. Health care facilities
3. Emergency systems
4. Legally required standby systems
5. Critical operations power systems

750.30 Load Management. Energy management systems shall be permitted to monitor and control electrical loads and sourced in accordance with 750.30(A) through (C).

A. **Load Shedding Controls.** An energy management system shall not override the load shedding controls put in place to ensure minimum electrical capacity for the following:
    1. Fire pumps
    2. Emergency systems
    3. Legally required standby systems
    4. Critical operations power systems
B. **Disconnection of Power.** An energy management system shall not cause disconnection of power to the following:
    1. Elevators, escalators, moving walks or stairway lift chairs
    2. Positive mechanical ventilation for hazardous (classified) locations
    3. Ventilation used to exhaust hazardous gas or reclassify an area
    4. Circuits supplying emergency lighting
    5. Essential electrical systems in health care facilities

C. **Capacity of Branch Circuit, Feeder, or Service.** An energy management system shall not cause a branch circuit, feeder or service to be overloaded. If an EMS is used to limit the current on a conductor, 750.30(C)(1) through (C)(4) shall apply:

1. **Current Setpoint**. A single value equal to the maximum ampere setpoint of the EMS shall be permitted for one or more of the following:

   a. For calculating the connected load per 220.70

   b. For the maximum source current permitted by the EMS control

2. **System Malfunction**. The EMS shall use monitoring and controls to automatically cease current flow upon malfunction of the EMS.

3. **Settings**. Adjustable setting shall be permitted if access to the setting is accomplished by at least one of the following:

   a. Located behind removable and sealable covers over the adjustment means

   b. Located behind a cover or door that requires the use of a tool to open

   c. Located behind locked doors accessible only to qualified personnel

   d. Password protected with password accessible only to qualified personnel

   e. Software that has password protected access to the adjusting means accessible to qualified personnel

4. **Marking.** The equipment that supplies the branch circuit, feeder or service shall be field marked with the following information:

   a. Maximum current setting

   b. Date of calculation and setting

   c. Identification of loads and sources associated with the current limiting feature

   d. The following or equivalent wording: "The setting for the EMS current limiting feature shall not be bypassed"

   e. The markings shall meet the requirements in 110.21(B) and shall be located such that they are clearly visible to qualified persons before examination, adjustment, servicing or maintenance of the equipment.

750.50 Directory. Where an energy management system is employed to control electrical power through the use of a remote means, a directory identifying the controlled device(s) and circuit(s) shall be posted on the enclosure of the controller, disconnect or branch-circuit overcurrent device.

8.2 References

Calisch, Sam., Wyent, Cora., July 2022. "Electrification won't break the grid, it will make it smarter." R*ewiring America.* https://www.rewiringamerica.org/circuit-breakers/the-grid

Home Energy Analytics, "Population Analysis - Available Panel Capacity." *Home Energy Analytics.* https://corp.hea.com/home-electrification

Herrschaft, Blake. February 2023. "Design Guidelines for Home Electrification." *Peninsula Clean Energy.* https://www.peninsulacleanenergy.com/wp-content/uploads/2023/04/Design-guidelines-for-home-electrification-v041223.pdf

"Joint Analysis Shows On-Bill Savings By Switching From Gas To Electric Appliances." *Peninsula Clean Energy.*https://www.peninsulacleanenergy.com/joint-analysis-shows-on-bill-savings-by-switching-from-gas-to-electric-appliances/

Pena, Shoshana., Smith, Collin. Et al., May 2022. "Service Upgrades for Electrification Retrofits Study Final Report" NV5, INC., Redwood Energy-PG&E CALMAC STUDY ID: PG&E0467.01

Armstrong, Sean. Higbee, Emily., et al. "A Pocket Guide to All Electric Retrofits of Single Family Homes." *Redwood Energy.* https://www.redwoodenergy.net/research/a-pocket-guide-to-all-electric-retrofits-of-single-family-homes

"Lessons in Residential Electrification Project and Report." May 2021 *Community Climate Collaborative.* https://theclimatecollaborative.org/lessons-in-residential-electrification

Electrical Training Products. *Mike Holt Enterprises.* https://www.mikeholt.com/electrical-training-products.php

"Part 1: Bottom-Up Load Forecasting and System-Level Electrification Impacts Cost Estimates." May 2023. Kevala. Proceeding R.21-06-017 (Order Instituting Rulemaking to Modernize the Electric Grid for a High Distributed Energy Resources Future) https://www.kevala.com/resources/electrification-impacts-study-part-1

Baranow, Natasha., Neverisky, Nick,. December 2023 "Market Study of Household Electric Infrastructure Upgrade Alternatives for Electrification." CalNEXT & VEIC https://www.veic.org/clients-results/reports/market-study-of-household-electric-infrastructure-upgrade-alternatives-for-electrification

Takemura, Alison F. December 2023. "Yes, it's possible to electrify a home on just 100 amps." *Canary Media.* https://www.canarymedia.com/articles/electrification/yes-its-possible-to-electrify-a-home-on-just-100-amps

California Electric Code. 2022, Chapter 2, Article 220 Branch-Circuit, Feeder, and Service Load Calculations

Electrical Power Research Institute 2022 "Survey of US Electrical Panels" Product ID 3002024056 https://www.epri.com/research/programs/063638/results/3002024056