Market Study of Household Electric Infrastructure Upgrade Alternatives for Electrification

Final Report

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Executive Summary

This report provides a market assessment of commercially available intelligent power management technologies (IPMTs) – which shut off circuits when current draw exceeds a maximum limit and may minimize or avoid cost and time associated with residential household electrification projects. This report is informed by a market scan of the IPMT landscape, combined with vendor interviews which validated and built upon the secondary research. This report is also informed by stakeholder engagement which included comprehensive interviews of key market actors including investor-owned utility (IOU) program managers and program implementers, direct install contractors, and staff at community-based organizations (CBOs).

Product Groups

There are four distinct IPMT Product Groups on the market: Smart Electrical Panels, Smart Control Units, Smart Breaker and Relays, and Outlet Splitters.

- **Smart Electrical Panels** are generally the most expensive product category but offer the most functionality since they can control all loads in the house. Market-leading smart electrical panels allow for user-friendly load prioritization and can provide insight into home energy usage. Primary barriers to adoption include cost and lack of variable control capability.
- **Circuit Control Units** are generally low cost per circuit but can increase in cost as more circuits need to be controlled. They are relatively easy to install due to their ability to be added to existing circuits and typically do not require programming or other complex set up requirements. They cannot provide whole home controllability but offer a workable solution for simple applications.
- **Smart Circuit Breakers and Relays** are similar in function to smart electrical panels but are modular and can be installed on a per circuit basis, as devices are electrified – potentially reducing up-front cost. They are generally easy to install and allow for remote monitoring and control. Some products require Wi-Fi connectively to operate – which may not be suitable for all installations – and some products require that a central hub be installed – which can significantly increase up-front cost and add extra maintenance.
- **Outlet Splitters** are a low-cost option which can be installed easily by the user but require loads to be collocated near the same outlet and can only serve loads with a plug such as EVSE or dryers.

IOU program managers and implementers, direct install contractors, and staff at CBOs have varying levels of familiarity, awareness, and perceived benefits and barriers associated with IPMTs.

- Program managers, contractors, and CBOs exhibited varied familiarity with IPMTs, with smart electrical panels being the most-known product type.
- Program managers were generally aware of the potential benefits IPMTs may provide – such as avoiding cost associated with upgrades (i.e., at the circuit, panel, or service-level).
- Contractors and CBOs noted other benefits such as energy monitoring capability, controllability, and whole home load management (for smart electrical panels).
- Program managers identified the following barriers to adoption: lack of awareness and familiarity among customers and contractors; perceived customer concerns related to

behavioral change; lack of confidence regarding ongoing manufacturer support; permitting and inspection uncertainty; lack of suitability for multi-family dwellings (which may have central energy systems); and cost.

- Contractors and CBOs identified additional barriers to adoption which include: questionable compatibility across IPMT products; uncertain adherence to building codes; potential spatial constraints; limited contractor experience with IPMTs; inconsistent treatment and knowledge base of IPMTs across authorities having jurisdiction (AHJs); connectivity, obsolescence, and utility control concerns; cost; and equity (related to app use, language accessibility; and tenant/owner dynamics for rental properties).
- Program managers, contractors, and CBOs generally acknowledge the potential for IPMTs to support residential and small commercial electrification.
- Some respondents recommend a targeted approach to encourage IPMT adoption, such as low-cost IPMTs for retrofits. Some view IPMTs as a low-cost, bridge solution to enable faster, partial electrification, but assume traditional upgrades will likely be required for full electrification. Some contractors and CBOs view IPMTs as a critical tool to avoid utility service upgrades.

Through this work, the project team recommends the following actions. Detailed recommendations are included in the Recommendations section at the end of this report.

- IOU energy efficiency, beneficial electrification, or other relevant program managers may consider developing consumer-facing educational materials to increase customer awareness and familiarity with IPMTs.
- IOU energy efficiency, beneficial electrification, or other relevant program managers may consider developing IPMT training and educational materials for contractors and electricians to increase awareness, operational knowledge, and installation experience.
- IOU energy efficiency, beneficial electrification, or other relevant program managers, and/or product manufacturers may consider engaging with code officials and local inspectors to provide IPMT training and solicit feedback to inform program design and product development.
- Lab and/or field demonstrations may be completed to evaluate basic functionality, inform utility program integration, develop consumer-facing education, provide contractor training, and inform code official engagement.
- IOU energy efficiency, beneficial electrification, or other relevant program managers may consider providing customer incentives for low-cost IPMTs, through electrification programs and on energy efficiency marketplaces.
- Modeling may be considered to compare the full costs of IPMTs versus a traditional infrastructure project – in partial and full electrification scenarios.

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Abbreviations and Acronyms

Acronym	Meaning
ADU	Accessory Dwelling Unit
ASHP	Air Source Heat Pumps
BE	Beneficial Electrification
CBO	Community Based Organization
CCA	Community Choice Aggregator
DAC	Disadvantaged Communities
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
HTR	Hard-to-Reach
HPWH	Heat Pump Water Heaters
HVAC	Heating, Ventilation, and Air Conditioning
IOU	Investor-Owned Utility
IPMT	Intelligent Power Management Technologies
NEC	National Electrical Code
PV	Photovoltaic

Introduction

California's ambitious climate goals include a 40 percent reduction in greenhouse gas emissions by 2030; an 80 percent reduction in greenhouse gas emissions by 2050 (relative to 1990 levels); and three million new, climate-ready homes and six million new heat pumps by 2030 (California, 2022). To achieve these goals, residential electrification must accelerate.

There are numerous barriers to residential electrification, some of which include "consumer acceptance, familiarity, and risk aversion," and lacking "building energy code and appliance and equipment standards." (Deason, Et al, 2018). Another barrier to adoption is the potential lack of existing electrical capacity to serve new electric end-uses. Depending upon the size and location of the new load, a homeowner may be constrained by the circuit capacity, panel capacity, or even the utility service capacity.

It is currently challenging to estimate the potential magnitude of this barrier to adoption because whole home electrification is relatively uncommon in California. Rewiring America estimates that within the United States, "50-60 million single-family homes (or approximately 60-70 percent) have electrical panels with ratings less than 200 amps," (Calisch and Wyent 2023) which would likely require a panel upgrade—and potentially a service upgrade—to achieve electrification. A recent report by the Electric Power Research Institute (EPRI) found that 62 percent of survey respondents reported having a main breaker of at least 200 amps, with breaker size decreasing with increasing age of the building – homes built before 1960 are five to ten times more likely to have 100-amp main breakers, compared to those built after 2000 (EPRI 2023).

Awareness and interest in electrification are growing in California in part due to an increase in incentive programs offered to encourage the adoption of electric end use devices. Although incentives are available, electrical upgrades associated with residential electrification projects may be costly, and it may be challenging to estimate the primary cost driver because reasons for upgrade are nuanced and depend on many factors. Even where project data are available, the driver can vary on a project-by-project basis depending on project goals, long-term electrification and renewable energy integration goals, and existing infrastructure. Primary drivers may include the type of device being installed (i.e., heat pump water heater, heat pump, heating, ventilation, and air conditioning (HVAC) system, electric vehicle service equipment (EVSE), etc.), whether an accessory dwelling unit (ADU) is a factor, or whether solar photovoltaic (PV) is part of the project.

Adding electric capacity to serve new electric loads has an upfront cost and may require a significant amount of time to implement. A 2022 study by NV5 Inc. and Redwood Energy estimates that installation of additional capacity may cost anywhere from "approximately $2,000 to well over $30,000" and require a "lead time up to 6 months" if utility work is required (PG&E 2022).

There are IPMTs which may address this barrier, but the product space is relatively nascent, and homeowners and contractors are often not aware of these types of products. One main finding of the NV5 Inc. and Redwood Energy study is that "most customers and contractors are unaware of available options to mitigate the need for a panel upgrade that would trigger a Service Upgrade" (PG&E 2022).

IPMTs may allow household electric loads to be strategically managed and prioritized through end-use hierarchies in software via user-designated priority settings or manufacturer-designed algorithms, or via physical means such as a switch that prioritizes one end use pathway vs another. These technologies may make more efficient use of existing capacity by switching off lower (or lowest) priority loads to operate within installed capacity limits, which can minimize or avoid the need to install additional electric circuit, panel, or service capacity. As these new products ease the transition to electrify more household devices, greenhouse gas emissions will also decrease, which progresses California's climate and clean energy deployment goals. Moving forward, another long-term benefit may be demonstrating the ability of these technologies to manage load given installed capacity constraints, which utilities may consider incorporating into their planning or demand-side management programs.

This market study assesses IPMTs. The study focuses on smart panels, circuit control units, circuit breakers and relays, and outlet splitters—which may optimize existing electric capacity and minimize or potentially avoid the need to increase capacity. The study brings additional knowledge to existing investor-owned utilities (IOU) energy efficiency and beneficial electrification programs. This knowledge will inform emerging HVAC measures technology electrification measures including space heating projects which involve air source heat pumps (ASHP), water heating projects which involve heat pump water heaters (HPWH), and plug load measures such as heat pump clothes dryers, electric vehicle (EV) chargers and induction stovetops.

Objectives

This project identifies existing and emerging technologies that can minimize or avoid infrastructure upgrades (at the circuit, panel, or service-level) to reduce barriers to residential electrification and increase the adoption of efficient electric end-use devices in the IOU portfolios. This market study complements existing research and identifies new technologies with the following objectives:

1. Review existing literature and conduct secondary research on commercially available technologies and emerging technologies in early stages of commercialization;
2. Categorize existing and emerging technologies into meaningful groups based on functionality and compare key characteristics of the technologies in each category;
3. Conduct vendor interviews to validate secondary research and collect more targeted information regarding product features, maturity, functionality, and favorable use-cases;
4. Conduct stakeholder engagement to collect insights and explore additional potential barriers to adoption related to consumer knowledge, experience, interest, and motivations. (Stakeholders will include IOU program managers, homeowners and property managers, electric and installation contractors, and disadvantaged community and hard-to-reach community representatives);
5. Translate the categorization of existing technologies into a written report.

Methodology & Approach

This report summarizes the work associated with this study, which included three main phases: (1) a Market Scan, (2) Vendor Interviews, and (3) Stakeholder Engagement. During the Market Scan, the team identified and evaluated commercially available devices that can minimize or prevent electrical infrastructure work when electrifying residential homes. The findings from the Market Scan informed Vendor Interview questions, which target more nuanced information about currently available device features, the stage of device development, and each device's ability to perform circuit-level load management. During the Stakeholder Engagement phase, the project team interviewed program implementers, contractors, and other key stakeholders to assess awareness of and experience with these technologies and products, to discuss barriers to adoption, and to inform future efforts related to this technology group. A detailed description of each phase is provided below. The contents of this report reflect the best available information as of the report date.

Market Scan

The team conducted market research to inventory devices. The team focused on devices that are intended to be installed between the electric utility meter and end-use devices and may deliver whole home or circuit-level load management. Information was reviewed and gathered from related studies (Redwood Energy, 2021), marketing literature, and technical specification sheets. Product features and functionality were compiled in a comprehensive technical matrix. Devices were evaluated based on their technical capabilities, such as load switching characteristics, ease of installation, and intended and potential uses. Additional features such as cost, technical development milestones, and end-user interface were also documented. Devices were grouped into four main categories based on their overall functionality within the home energy ecosystem. A detailed description of each of the four Product Categories can be found in the Findings section of this report.

Vendor Interviews

Vendor interviews were then conducted to fill knowledge gaps from the Market Scan and to further understand technical definitions in the marketing and technical literature. For instance, while many technologies and devices offer a user interface, it was important to understand the level of control a user would have over installation, settings, and load management. Often, this was not clear, and varied from device to device or technology to technology. The team held vendor interviews with questions tailored to the device categories and focused on each device's ability to service circuit and home-level load management. Vendors were asked questions about the technical features and limitations of their products to further understand how they might meet electrical code requirements and achieve the overall goal of minimizing or avoiding electrical infrastructure work. The answers were used to fill knowledge gaps in the technical features list and refine the categorization and feasibility in this application.

The project team attempted to engage 12 vendors, based on the suitability of their product for this application. 11 have been successfully contacted and interviewed for the project. The project team was unable to connect with the remaining one. The project team conducted phone interviews with sales or application staff from the vendor using a list of questions. The questions focused on:

- Suitability of the product for the project application
- Maturity of the product and company
- Barriers to product implementation
- "Blind spots" in project team approach

The results from these interviews have informed the product categorization and recommendations in the Findings section of this report. The Vendor Interview process provided the project team insight into the operational theory of many of these devices and allowed the team to categorize the products based on function and physical form, rather than manufacturer marketing. For example, certain products are marketed as smart panels, when in fact, they function as a smart breaker. Using information gathered in the interviews combined with information from vendor specification sheets, the project team was able to identify key attributes for each segment based on product features and technology maturity.

Stakeholder Engagement

The project team deployed a comprehensive stakeholder engagement strategy to uncover barriers related to electric infrastructure upgrades associated with residential whole building electrification. As part of this effort, the project team investigated the current level of knowledge and adoption, experience of early adopters, market actors' perception of the technologies of interest, and motivation for adoption. In addition, the project team sought to validate key assumptions for each alternative considered under this project (e.g., cost and schedule requirements, usability of panel alternatives, among others). The project team first identified and prioritized stakeholders to be interviewed and identified the best qualitative data collection instruments to be deployed. These included one-on-one interviews, online surveys, and/or group interviews. The project team then implemented a staggered approach to qualitative data collection.

The first round of interviews collected input and insights from IOU program managers and other relevant program implementers. The project team reassessed objectives and methodology for a second round of qualitative data collection that was focused on input and insights from electric and installation contractors, community-based organizations, technology providers and manufacturers. For the residential homeowners and property managers segments, qualitative data of interest was collected directly and indirectly via contractors and community-based organizations. All qualitative insights collected have informed the project team's understanding of barriers and potential for technology adoption. This analysis has informed the project team's recommendations for next steps and additional follow-up projects.

Findings

Overview

This section compares numerous emerging technologies that can be used to minimize or avoid household electric infrastructure work and encourage the adoption of more electric end-use devices. While many products exist in the market for energy management, the technologies have been grouped into one of the following four product categories for the purpose of this study:

Smart Electrical Panels

Figure 1: Smart electrical panels.

Circuit Control Units

Figure 2: Circuit control units.

Smart Breakers and Relays

Figure 3: Smart breakers and relays.

Outlet Splitters

Figure 4: Outlet splitters.

To minimize or avoid household electric infrastructure work, products need to be capable (at a minimum) of the following basic function: shutting off circuits when current draw exceeds a maximum limit and turning them back on when the current draw returns to a lower level. Some products can perform this function, and some cannot. Throughout the report, this function is referred to as circuit-level load management. This approach is effective at reducing demand to avoid overloading a limited electrical supply. However, it leads to situations where, because the control is binary, additional capacity is left unused, and the user's needs are unmet. Most IPMTs on the market do not offer integration with devices to allow for variable load control. For example, an EVSE reducing power output to accommodate someone using one hob on an induction stove. In this case, both devices can remain active without exceeding any maximum current limits. As loads become integrated with energy management products, system performance and user experience will improve.

Out of Scope

This project focused on devices intended to be installed between the electric utility meter and end-use devices, which may deliver whole home or circuit-level load management and may minimize or avoid electric infrastructure work, to allow for electrification of residential devices. Though related, the following technologies are out of scope for the purpose of this report:

- Multi-family EVSE
- Equipment intended for off grid or backup power use
- Solar plus storage management systems
- Home energy management or automation systems
- Individual smart appliances
- Smart thermostats
- Smart lighting wall switches
- 120v smart outlet controls with Wi-Fi connectivity

Product Groups

The following sections describe each Product Group and discuss key features, advantages and drawbacks, and knowledge and market gaps.

Product Group 1: Smart Electrical Panels

Description

Figure 5: Smart electrical panels.

Main electrical panels receive power from the service feeds delivered by the electrical utility. The residential electrical panel is the component of a home's electrical system that divides electrical power to the branch circuits, while providing overload protection for each circuit in a common enclosure. A smart electrical panel is an integrated device that fully replaces a traditional electrical panel. Based on a review of market products labeled as smart panels and their functionality, a typical smart electrical panel will have many of the following features to allow for control, monitoring, and management of circuits: energy consumption monitoring; remote access capabilities; energy automation; and load, circuit, or end-use prioritization. Load management functionality allows residential electric consumption to stay below installed electrical capacity limits, avoiding the need for an electric service upgrade.

KEY FEATURES

This product category is differentiated from the other categories in this report by its ability to holistically manage all circuits in the house without specialized hardware configuration. Products allow users the ability to prioritize end-use loads, and adjust those designations if the priority changes – all via an app. These systems are designed to shed loads by circuit, based on installer-set priority if the total panel load exceeds an installer-set maximum amperage level. Some products in this category also offer integration with loads such as EVSE, which allows them to regulate power for car charging rather than simply shutting off power. Products that can fully leverage the whole home coverage and integrate with loads such as EVSE and HVAC will provide the best user performance in this category. Also, the opportunity to integrate with energy storage and utility control could increase the desirability of products in this category.

ADVANTAGES AND DRAWBACKS

- Advantages include whole home control and 'all-in-one' design. Focused on providing insight on load consumption and overall energy use. Other advantages include remote access and a focus on the user experience.
- Drawbacks include cost, related to high equipment costs and additional costs associated with professional installation.

KNOWLEDGE AND MARKET GAPS

Overall, smart panels have not been widely deployed as an alternative to a service upgrade although some manufacturers have supplied equipment for pilot projects. One market gap is the inability to integrate with devices to offer variable control capability (i.e., not simple binary, on/off control) for certain loads such as HVAC or water heaters, especially related to integration with non-EV related loads. This functionality will be especially useful for managing electric space and water heating loads, which can be stored or shifted during periods of low demand.

Product Group 2: Circuit Control Units

Figure 6: Circuit control units.

DESCRIPTION

Circuit control units are a type of stand-alone load management device that controls a circuit based on the load drawn by another circuit or the whole panel. The devices are hardwired between the panel and load(s). The load is controlled based on input from an external or internal sensor (current transformer) which reads current being used by other devices. These products typically do not include overcurrent protection but rely on external circuit breakers in the main panel. One exception to this is when these devices are fed from a supply side tap (connection between service entrance and main overcurrent protection device). In this scenario an overcurrent protection device may be included in the circuit control unit. These products are different from smart relays as they are not mounted inside the electric distribution panel.

KEY FEATURES

Products within this group offer a simple solution to increasing electrification within a capacity constrained situation. Since these products intercept existing wiring or use wiring that is being added for the installation of a load, their installation tends to be less invasive, and easier to setup. Additionally, because of their simplicity, these products can be installed in a wide range of situations without special knowledge. Because these products only need to interface with wiring, they face less compatibility issues compared to products that interface with breakers, distribution panels, or outlets. Most products in this category only offer the ability to control one circuit. Products that offer simple load control at an affordable price represent the ideal space in this product category providing an elegant solution at a price point. Products that focus on providing a simple, yet configurable installation process and compact, weatherproof enclosures offer the best features in this product category.

ADVANTAGES & DRAWBACKS

- Advantages include usability; ability to reduce load-related barriers to charging EVs; ease of installation due to simple operation; and lower unit cost than smart panels,
- Drawbacks include an inability to control the whole home load; and higher installation cost (compared to outlet splitters).

KNOWLEDGE AND MARKET GAPS

The best use case in this situation is switching between a low-priority system and a high-priority system, between two units that will not be running concurrently (e.g., separate heating and cooling end-use appliances), or limiting operation of a non-priority device (e.g., EVSE or water heater) based on total panel load. Market gaps include flexible prioritization and load control integration.

Product Group 3: Smart Circuit Breakers and Relays

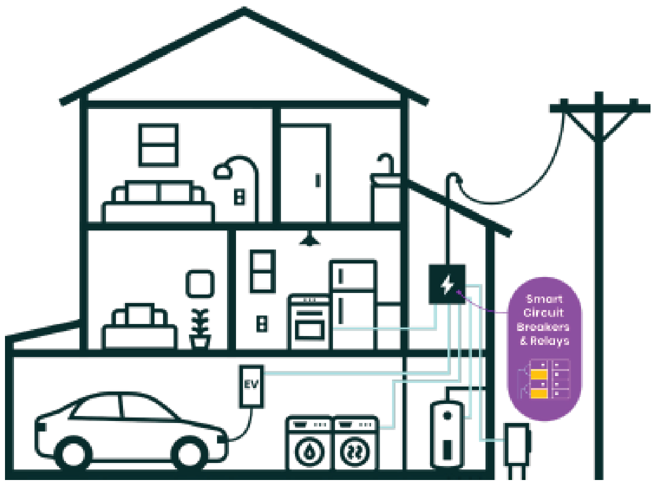

Figure 7: Smart circuit breakers and relays.

DESCRIPTION

A circuit breaker is an electrical switch designed to automatically open a circuit to prevent 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. As an internet-connected device, smart circuit breakers enable remote monitoring and control of loads, temperature settings, and other system information. A smart circuit relay is an electronically operated switch installed in series with the breaker that can control the flow of electricity from the breaker and can be activated remotely or via an app-controlled schedule. A smart circuit relay is not designed to function as an overcurrent protection device. These products both reside in the existing breaker panel.

KEY FEATURES

Products in this category convert conventional circuit breaker panels into “smart panels,” on a per circuit basis. This allows for the ability to monitor and enable power to individual circuits. This product category allows energy management to be scalable allowing for the system to be built up over time as new loads are installed. This product category offers the features of a smart panel without the need to replace the panel enclosure and internals. Products that offer easy integration with a wide array of distribution panel models and have a similar form factor to a conventional breaker. Additionally, because these products are configurable, products that offer a simple set up process and do not require custom integration work will provide a better user experience overall.

ADVANTAGES AND DRAWBACKS

- **Advantages** include ease of installation; user-friendly setup; modular and ability to communicate with most existing main panels; no panel replacement required; simple operation; and ability to provide high level information to homeowner. Assuming physical space is available, smart circuit breakers and relays have the advantage of easy integration with existing panels and wiring, meaning the homeowner does not need to perform a panel replacement or sacrifice wall space for another control device. Furthermore, the modular setup allows the user to choose to control only certain circuits as they begin to electrify, reducing the initial upfront cost.
- **Drawbacks** include a need to purchase and install numerous devices to achieve whole home control; potential high initial cost (if a hub is required); and limited single circuit control (by device). When attempting to electrify an entire household, this option may not be the most cost-effective. However, it could be a useful tool in the pathway to whole home electrification as individual relay costs can be spread out over time, and the homeowner could potentially avoid a panel upgrade in the process. Relay devices take up limited panel space.

KNOWLEDGE AND MARKET GAPS

This technology may not meet code requirements if it is not programmed to prevent all loads from simultaneously switching on. Many products in this product category require advanced programming to meet this application need. Additionally, many rely on Wi-Fi connection for operation. Some products require the purchase of an external hub to connect devices to the internet and with each other, adding additional cost. A few devices also require integration with third-party or accessory energy monitoring systems to provide load management functionality.

Product Group 4: Outlet Splitters

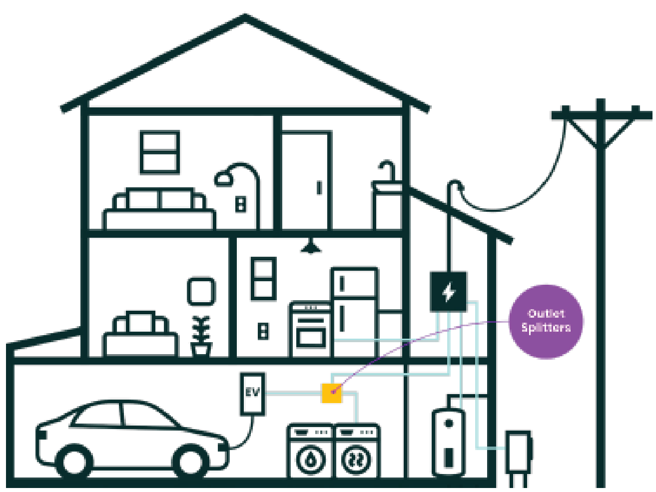

Figure 8: Outlet Splitters

DESCRIPTION

Outlet splitters (also known as circuit switches or smart splitters) are a type of circuit sharing switch that splits an outlet between two loads but prevents both loads from simultaneously drawing power. The functionality lies in the product's ability to select which device to power. Outlet splitters plug directly into an outlet reducing the need for an additional circuit to supply electricity to appliances or equipment with different use priorities. They are ideal where electric devices are in the same room – such as an EV charger and electric dryer, which may be collocated in a garage. Since these products plug directly into pre-existing outlets, they do not require professional installation and do not need configuration to meet electrical code when installed in a code compliant outlet.

KEY FEATURES

This product category provides a low-cost solution for situations where the loads are collocated, and where non-permanence (such as a rental unit) is important. This product class can only support non-hardwired loads, and the device can be installed by the customer, saving on installation cost. Products that offer a wide variety of plug and outlet types and support higher current levels provide greater flexibility for the user. Additionally, internet connectivity allows for additional benefits such as energy monitoring and notifications.

ADVANTAGES AND DRAWBACKS

- Advantages include usability; low cost; suitability to reduce load-related barriers to charging EVs or other plug load devices.
- Drawbacks include the need for end-uses to be in close proximity to the same outlet; collocated devices are required to have the same plug type.

KNOWLEDGE AND MARKET GAPS

Market gaps include lack of control integration to allow simultaneous power draw up to the installed capacity of the existing circuit. Control integration would be especially useful to throttle load from multiple EVs charging simultaneously, which would allow both vehicles to continue charging, though at a lower kW per vehicle.

Code Considerations

IPMTs, and more specifically, energy management systems, are being deployed as an alternative to capacity upgrades in household electrification scenarios, faster than their usage is being socialized with code enforcement agencies. Therefore, rejection of these solutions by Authorities Having Jurisdiction (AHJs) stems from unfamiliarity with the technology, paired with risk aversion and a lack of guidance for non-EVSE loads in the 2020 National Electric Code (NEC) currently adopted by California. With IPMTs as alternatives to electrical service upgrades, the demand from installed electric end-uses could exceed the available capacity without management intervention. Without sufficient understanding of IPMTs, AHJs may play it safe and deny the application due to uncertainty about whether the IPMT will properly limit energy use below the maximum service capacity – see Interview section. However, code updates have begun to consider the use of IPMTs. In the 2020 version of the NEC, use of energy management systems is specifically called out for EVSE: 625.42 Rating. *"Where an automatic load management system is used, the maximum equipment load on a service and feeder shall be the maximum load permitted by the automatic load management system."* The code does address the topic of energy management systems broadly but does provide guidance on how they can be applied in a non-EVSE context: 750.30 (C) Capacity of Branch Circuit, Feeder, or Service: *"An energy management system shall not cause a branch circuit, feeder, or service to be overloaded at any time."*

With current trends in the market, it is recommended and expected that future code revisions will include more specific guidance around IPMTs, which will support AHJs to make better determinations in the field and will reduce overall confusion involving the applications of these technologies. For reference, in the NEC 2020 code book, other NEC codes relevant to the topic of IPMTs include 220.6 Noncoincident Loads, and 408.36 Overcurrent Protection.

Stakeholder Engagement

The following sections describe key takeaways from 18 interviews with program managers, contractors and community-based organization staff.

Program Manager Interviews

Nine interviews were completed, which included:

- Eight staff at three IOUs
- Six staff at three program implementers
- Two staff at one advocacy organization
- One staff member at one community choice aggregator (CCA)
- One staff member at one municipal utility

FAMILIARITY

All respondents interviewed had heard of at least one type of IPMT. Smart panels were the best-known product type, followed by outlet splitters. Familiarity with IPMTs as a technology class or with individual product types varied significantly by respondent—some had only heard of smart panels, while others had integrated or had considered integrating an IPMT incentive into a program, and one had installed a smart panel in their home.

BENEFITS

All respondents believe IPMTs can play a role in electrification retrofits. Using an appropriate IPMT can avoid a panel or service upgrade, which has the potential to save costs and shorten project timelines (service upgrades take time—a factor that one respondent indicated has been exacerbated recently in procuring equipment). Cost savings from avoided service upgrades can accrue to the customer and, if a transformer upgrade would be required, to the utility. According to one respondent, "From a utility standpoint, they want to do these electrification programs, but when it comes to the grid side, it's too costly and it takes them way too long. It's not a priority for them."

Additional future-state benefits respondents identified as possibly being enabled by IPMTs:

- Automatically turn off certain circuits during peak periods to help customers with TOU rates save money.
- Automated switching between a grid input and onsite storage depending on time of day or other factors.
- Allowing demand response program managers to control in-home energy use at the circuit level.
- Allow expanded EV charging in a multifamily building by automated switching between chargers (i.e., allow a number of EV charging stations that exceeds the service capacity).

BARRIERS

Respondents identified the following challenges to successful implementation of IPMTs for electrification retrofits:

- Customer awareness and familiarity
- Customers have little awareness of IPMTs and may therefore be hesitant to consider them when presented with one as an option as part of an electrification project.
- Contractor awareness and familiarity
- Many contractors do not currently promote IPMTs. "[They] seem to have the brand [of electrical panel] they like to install and that they carry and for the most part [the panels] aren't smart." In addition to gaining familiarity with, and a positive perception of, IPMTs, contractors would need to learn how to install IPMTs and set them up.
- Reliance on customer behavior
- Using an IPMT to enable exceeding a building's service capacity requires customers to accommodate the switching between appliances. Unlike in most homes, a home using an IPMT in this way would not have ongoing access to all appliances simultaneously. "I want dry clothes and I might need those immediately to go to my job [in an EV], so I need both [the dryer and the charger to operate] at the same time." One respondent suggested this could be an equity issue—some customers might not have the flexibility to accommodate inconsistent access to their appliances. Another respondent discussed the customer education this would require.
- Ongoing manufacturer support
- Some functionality of some IPMTs is tied to manufacturer software and web-based ecosystems. If those manufacturers go out of business or otherwise cease to support their products, the costly IPMT's customers installed may cease to provide critical functions. One respondent who works at a municipal utility that offers an incentive for smart panels (if installed as part of an electrification project) said that they have identified some smart panels that would operate effectively in the absence of manufacturer support but that they have searched for and not been able to find a smart circuit breaker that meets this criterion.
- Permitting and inspection
- Would a permitting office allow a home's electrical panel capacity to be exceeded via these products? "When you get a building inspector out there to look at a smart electrical panel, will they have the knowledge and tools to conduct the inspection, or will they start to erroneously fail some of these jobs because they don't know what's in front of them?"
- Not suitable for many multifamily buildings
- IPMTs may have limited value in many multifamily buildings due to the frequently centralized nature of high energy demand appliances (e.g., heating and cooling) and the placement of EV chargers distant from the EV owner's unit.
- Cost
- Although less costly than a service upgrade, they are still expensive.

SUITABILITY FOR RESPONDENTS' PROGRAM AREAS

Although most respondents have limited (or no) practical experience with IPMTs, they generally see this class of product as having potential for supporting their electrification portfolio in residential and small commercial applications.

Most respondents emphasized the potential for IPMTs in retrofits (the focus of this research). Multiple respondents suggested that retrofit programs should focus on lower-cost IPMTs (i.e., not smart panels) because they include the critical feature of switching between loads at a lower cost than smart panels. Two respondents suggested that IPMTs are a bridge, not a permanent solution, for electrification retrofits—they can enable lower-cost and faster electrification projects in some contexts, but “after a while, the utility is going to have to consider upgrading service to a neighborhood, and they might as well upgrade all of the service at that point.”

Some respondents mentioned the potential, or lack thereof, of IPMTs for new construction. One respondent believes that new construction should not use IPMTs and should instead use a less expensive traditional panel and include adequate electrical service capacity for full electrification. Two others (in a single interview) think smart panels in new construction “would be a no-brainer” to allow the homeowner centralized control. This difference in opinion emphasizes the multifaceted benefits available from IPMTs. If considering only electrification and service capacity, IPMTs may not be the best solution for new construction. But if considering a broader range of IPMT capabilities, products like smart panels may be able to benefit new construction homes, not by limiting panel capacity, but by increasing user and utility insight and control into electricity usage.

Only one respondent, a program manager at a municipal utility, manages an active program that includes a residential incentive for smart panels installed as part of an electrification project. Two other respondents working at an implementation company had considered using IPMTs for a low-income electrification program but the IPMTs they considered did not meet their cost-effectiveness requirements. Only panels that the utility has determined will retain critical function without manufacturer support are eligible. Smart panel incentives are available when: 1) the customer is doing an electrification measure that would be enhanced or enabled by a smart panel, and 2) the project includes installing a circuit for a heat pump hot water heater (the heat pump water heater does not need to be installed, only the circuit). The initial cost for purchase and installation is about $7,000. The incentive value for market-rate customers is $2,000. The incentive value for income-qualified customers is $4,000. They are considering expanding eligibility to include lower-cost IPMTs like outlet splitters. The current program has had little uptake. The program manager speculates that this limited participation is due significantly to the large cost, even after incentives, and perhaps due to the increasing availability of 110v heat pump hot water heaters, which reduce the value of having a heat pump hot water heater circuit installed as part of the project (a requirement of the incentive program).

QUESTIONS/NEEDS TO ADDRESS IF INCLUDING THESE PRODUCTS IN PROGRAMS

Respondents identified a range of uncertainties related to using IPMTs to enable electrification retrofits.

- Cybersecurity – “If there’s some wireless element to it, I’d want to know more about that… And how well that data is protected.”
- After how much overloaded capacity does it make sense to do a service upgrade rather than use an IPMT? At some point too many appliances would have shared power, creating a poor user experience.
- What additional “smart” services can these products include? Are there certain smart features (e.g., integration with and control by a utility) that should be prioritized when selecting models for incentive eligibility?
- What communications protocols do these products use to connect with other devices or the utility?

- Are IPMT's power monitoring accurate enough for utilities to use the data (e.g., identifying when to apply a special EV charging rate to a circuit)?
- How do IPMTs, which allow an excess quantity of load to be connected to a panel, fit within building codes?
- How do the lifespans of IPMTs compare to the lifespans of traditional electrical panels?

Contractor and CBO Interviews

Nine interviews were completed, which included:

- Six staff at four community-based organizations (CBOs)
- Eight staff at five contractors who deliver Energy Savings Assistance Program direct install services

FAMILIARITY

The respondents displayed varying levels of familiarity with the IPMT technologies presented. Some had extensive expertise having worked with these types of systems for many years, while others had only minimal exposure to a few of the technologies. Only one respondent was familiar with all four IPMTs presented. One of the contractors is a SPAN certified installer but has not installed a SPAN panel yet, due to costs associated with the panel itself.

Overall, most respondents were unfamiliar with most Smart Circuit Breakers and Relays, Circuit Control Units, and plug-in type Outlet Splitters. Respondents had the most direct experience or knowledge with Smart Electrical Panels.

All respondents expressed openness to utilizing these types of smart electrical technologies more extensively, provided certain challenges can be addressed.

BENEFITS

All respondents felt that IPMTs could play an important role in electrification programs generally. Many also identified the potential for IPMTs to support low-income energy conservation programs (an area of focus for these respondents). The core benefits contractors and CBOs identified focused on avoiding service upgrades, monitoring/controlling usage, reducing bills, and ease of installation—especially for homes with older wiring. A summary of benefits identified include:

- **Monitoring** – IPMTs can help customers track energy use. This helps inform homeowners and contractors of the overall energy usage and provides insight into how the home electrical systems function
- **Control** – IPMTs can manage loads and high demand charges. During outages, IPMT can allow for prioritization of critical loads (if onsite back-up generation is available).
- **Device Coordination across circuits** – Smart panels specifically allow for whole home load management and offer more robust capabilities than simpler IPMTs like outlet splitters.
- **Plug-and-play solutions for load sharing** – Technologies like outlet splitters provide an easy load-sharing functionality that does not require rewiring. Useful for rentals or manufactured homes, the outlet splitters are inexpensive, easy to install, good for DIY applications, and avoid the need to hire an electrician.

Lastly, respondents mentioned that hardwired, panel-based solutions seem best suited for larger scale retrofits of conventionally built homes that need wiring upgrades.

BARRIERS

The biggest challenges identified involved costs, lack of professionally trained, certified, or licensed labor to install, connectivity and technology limitations in older homes, and coordination with utilities. Contractors and CBO staff recommended targeted incentives based on household income, rural/remote location, or disadvantaged community/hard-to-reach status, along with education to overcome these barriers.

- Compatibility Concerns
- In older homes, the existing condition of the panel and wiring of the house presents challenges including the need to bring a home up to code before or during the installation of an IPMT. For example, the prevalence of knob and tube wiring can reduce adoption of IPMT due to compatibility issues.
- For newer homes, respondents questioned compatibility with solar, storage, and other technologies like EV charging. How do IPMTs expand or adapt if a customer installs PV or storage down the line? How future proof are the IPMTs under consideration?
- With regards to the Smart Circuit Breakers and Relays, not all smart circuits fit in all brands of panels. They are not universal and require specialized knowledge to correctly select models that function within the existing panel.
- Additionally, contractors often wonder whether Smart Electrical Panels would work in cases where short wiring and sub-panels are required. For example, whether the sub-panels would need to be removed or whether a house with sub-panels would need to be rewired to accommodate the IPMTs.
- Other questions arose around whether a Smart Panel would fit in the small interior spaces where some homes' panels are installed (e.g., a bedroom or hallway closet).
- Customer Knowledge and Awareness
- Awareness and education about the benefits of IPMTs is needed among homeowners. Demonstrating how IPMTs can help homeowners achieve their energy goals, whether electrification or savings, is necessary to gaining customer support for these technologies.
- Contractor Education, Training and Liability Concerns
- Contractor education and training is paramount to adoption and a lack of qualified contractors presents a tangible barrier to greater adoption of IPMTs. A shortage of "certified" labor was cited as a major challenge. Licensed electricians are required to install or oversee the installation of three out of the four types of IPMT under investigation.
- Further training and certification may be necessary to ensure installations meet electrical code requirements to avoid liability concerns. One interviewee mentioned that, until contractors at large are more familiar with IPMTs, homes could be assessed by licensed electricians then refer suitable projects to program contractors for IPMT installation to ensure code requirements are met.
- Building Code Requirements & Variations
- Jurisdictional variances in building codes exist and may limit adoption. A contractor described an installation of a circuit control unit that failed inspection due to lack of inspector knowledge around the unit and whether it was allowed by code. Some authorities having jurisdiction (AHJs) are more "advanced" than others. Thus, if a contractor works in more than one area, the process will likely be case by case. Overall, building codes and officials may restrict certain products.

- High Upfront Costs
- Respondents suggested that significant incentives are needed to drive adoption for most IPMTs—purchase and installation costs for a smart panel, for example, are substantial. Respondents indicated that some of this sticker shock could be offset by educating customers about the benefits of IPMTs (especially when those benefits could lead to reduced energy costs via mechanisms like enhanced control over energy use for customers on TOU rates).
- The high costs associated with hiring the correct type of labor to install most types of IPMTs are a deal breaker for any ESA program contractor. The equipment is expensive and the cost of the labor to install it is equally prohibitive.
- Concerns Around Connectivity, Tech Obsolescence and Utility Control
- Respondents were concerned that IPMTs would require Wi-Fi connectivity and broadband internet, noting that not all homes (especially in senior-occupied residences or rural communities) have this kind of connectivity and that this could be an equity-related barrier. Another perceived downside of smart circuit breakers is that they are "app-based," which may result in early obsolescence or could result in the inability of IPMTs to communicate with each other unless specifically designed to work together. Router upgrades could also lead to sudden loss of functionality of appliances if IPMTs need to be reprogrammed to operate properly on a password-protected Wi-Fi connection. Additional concerns include the prospect that IPMTs could be accessible and/or controlled by the utilities, thus causing homeowners to lose the ability to control their own appliances. The prospect of controlled shutdowns of household appliances caused wariness among interviewees. It should be noted that not all IPMTs require Wi-Fi connectivity to operate, especially most Circuit Control Units which are controlled by a current transformer.
- Equity of Implementation, Use and "Ease of Use"
- "Control the IPMT with an App" is a feature for some, but this "ease of use" may not be appropriate for all, especially for elderly and non-tech savvy customers. Additionally, it is unclear whether multilingual supports are available, but they would be necessary for certain direct programs. App control of loads or energy usage visibility is not the concern of low-income direct programs.
- It may also be difficult to increase adoption of IPMTs in the low-income housing market because of tenant/owner relationships. Obtaining buy-in from tenants and landlords would have to occur on the basis of who owns the equipment, who pays for it, and who is responsible for maintaining it.

SUITABILITY FOR RESPONDENTS' PROGRAM AREAS

The participants indicated that more electrification projects could be done if IPMTs were available to remove the "deer in the road" that is a utility service upgrade. While the technologies present major benefits and opportunities, significant cost and implementation challenges must be addressed before broader adoption can happen in their program areas. With strategic programs tailored to the unique needs of these communities, wider adoption may become feasible.

QUESTIONS/NEEDS TO ADDRESS IF INCLUDING THESE PRODUCTS IN PROGRAMS

The participants emphasized the need for enhanced training, education, program guidelines, incentives, and customer support to facilitate effective deployment of these technologies within utility efficiency and electrification programs.

- What is the overall process, timeline, and extent of training needed for contractors to install the technologies properly? Installation credentials and standards are important.
- What are the overall costs and are there potential incentives or financing options to improve affordability and adoption? Rebates vs point-of-sale discounts?
- Are there specific guidelines and “measure” requirements from utilities on how to integrate the technologies into programs? More clarity is needed.
- How will homeowners be educated on the benefits, operation, and value proposition of the technologies? Many lack awareness and "selling tools" are needed.
- Who will provide ongoing customer support and troubleshooting for homeowners if issues arise? Is it the IPMT manufacturer, the contractor that installed it, the property owner, the IOU, etc.?
- How can the IPMT be designed or implemented in ways that are simple and understandable for less tech-savvy homeowners? Ease of use is important.
- Have the technologies been adequately evaluated for electrical code compliance? Permitting and inspection process needs review. What does the liability look like in the case of a fire shown to have started because of the IPMT?
- How can the technologies be tailored for manufactured homes, rentals, and other unique building scenarios? One size does not fit all in low-income direct install programs.
- What kind of realistic performance data and comparisons to gas can utilities provide to substantiate benefits claims? Are there any energy savings claims to be made or is the sole benefit avoiding the costs of a service upgrade? Credible data is needed.
- How will the contractor be compensated, and will the compensation cover the additional liability and risk the contractor would need to assume to do this work?
- In the event of power outages, how do the systems respond, and which party is responsible for resetting or reprogramming the equipment?
- Which of the IPMT could have application in multifamily or rural settings?

Recommendations

To leverage IPMTs to drive cost-effective electrification projects, the project team recommends the following:

- IOU energy efficiency, beneficial electrification, or other relevant program managers may consider developing consumer-facing educational materials to increase customer awareness and familiarity with IPMTs. Respondent awareness and familiarity of IPMTs varies widely, but all respondent groups cited consumer education and awareness as a major barrier to IPMT adoption. Respondents were most familiar with the higher-end products, which aren't necessarily the right fit for all customers and projects. Respondents’ perceptions of product functionality did not always align with the actual capabilities of products currently on the market. Finally, some respondents noted perceived downsides such as the need to be Wi-Fi connected (most don't) and IPMTs reliance on an app (which not all are). IOUs may consider developing consumer-facing educational materials and widely distribute them to communicate the potential benefits and increase customer awareness and familiarity with IPMTs. Sample educational materials can be found in Appendix 1 of this report.

- IOU energy efficiency, beneficial electrification, or other relevant program managers may consider developing IPMT training and educational materials for contractors and electricians to increase awareness, operational knowledge, and installation experience. Respondents noted low contractor awareness, knowledge of and experience with IPMTs as a barrier to adoption. Respondents also noted contractors' brand loyalty, and comfort with a tendency to recommend "non-smart" products as another related barrier to adoption. IOUs may consider developing IPMT training and educational materials for contractors and electricians to increase awareness, operational knowledge, and installation experience. Finally, relevant agencies may consider developing installation credentials and standards to inform training, qualify contractors, and enable a positive customer experience.
- IOU energy efficiency, beneficial electrification, or other relevant program managers, and/or product manufacturers may consider engaging with code officials and local inspectors to provide IPMT training and solicit feedback to inform program design and product development. Contractor and CBO respondents noted the following code-related barriers to adoption: uncertain adherence to building codes and inconsistent treatment and knowledge base of IPMTs across AHJs. Respondents noted some AHJs being more familiar with IPMTs than others, and one instance was cited where a circuit control unit failed inspection due to a lack of inspector knowledge. Code officials and inspectors are critical to the adoption of IPMTs, and more work needs to be done to increase their knowledge and familiarity with the technology. IOUs and/or state-funded programs may consider providing IPMT training and educational materials to achieve this. In addition, IOUs and/or state-funded programs may consider engaging with code officials to perform stakeholder engagement and solicit feedback to inform IOU program design and product manufacturer road mapping.
- Lab and/or field demonstrations may be completed to evaluate basic functionality, inform utility program integration, develop consumer-facing education, provide contractor training, and inform code official engagement. Many of the product manufacturers outlined in this report have plans to incorporate automated load shedding in their products (the core functionality considered in the project), but not all have this capability. With the projected increased adoption of electric devices, automated load shedding will be important, as will the ability to throttle loads. Further, IOU program managers and implementers raised questions related to utility integration to inform program design. Specifically, stakeholders were interested in better understanding of communication protocols, power monitoring accuracy, and "smart" functionality. Lab and/or field demonstrations may be completed to validate load shedding and throttling capabilities, evaluate characteristics and functionality to inform utility program and system integration, and ultimately increase consumer and industry confidence in IPMT product operations and savings.
- IOU energy efficiency, beneficial electrification, or other relevant program managers may consider providing customer incentives for low-cost IPMTs through electrification programs and on energy efficiency marketplaces. All respondents noted cost as a barrier to IPMT adoption, especially with respect to high-end products, like Smart Electrical Panels. Contractor and CBO respondents recommended IOU programs consider income-eligible

incentives for low-cost IPMT products, particularly for targeted use-cases such as single-family retrofits.
- Modeling may be considered to compare the full costs of IPMTs versus a traditional infrastructure project – in partial and full electrification scenarios. For retrofits, customers may not fully electrify all at once, and IPMTs can enable low-cost, fast, partial electrification. However, a traditional upgrade may ultimately be required to achieve full electrification, and/or maintain a positive customer experience where loads are not constantly being switched on/off. Additional research and modeling may be done (ideally, with actual install costs) to better understand all-in project costs, and if the potential cost-savings associated with installing an IPMT for partial electrification is worth it - from both adoption rate and economic perspectives.

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Appendix 1: Product Group Educational Materials

Save On Service Upgrades

Going electric doesn't need to break the bank. Intelligent power management technologies can help you add electrical loads while taking a load off your wallet.

As we make the transition to clean energy, more and more of our household appliances will become electric. Of course, more electric appliances mean more electric demand and some houses can't support the load. Intelligent power management technologies can help contractors and homeowners install more devices like EV chargers and induction stoves, without upgrading electrical service.

Smart Electric Panels

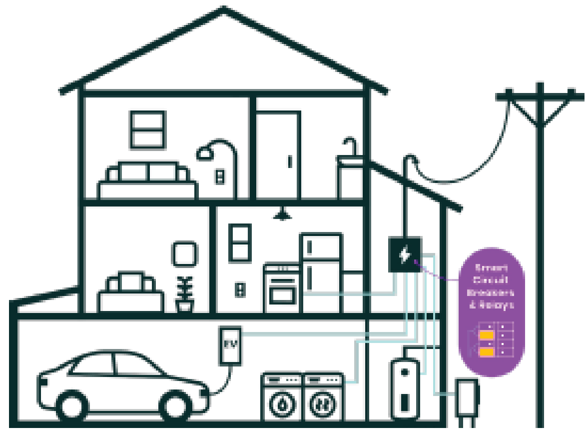
A smart electrical panel is an integrated device that fully replaces a traditional electrical panel but can allocate power based on need, allowing households to make more use of their limited electrical capacity. A typical smart electrical panel will allow for control, monitoring, and management of circuits. Load management functionality allows residential electric consumption to stay below installed electrical capacity limits, avoiding the need for an electric service upgrade.

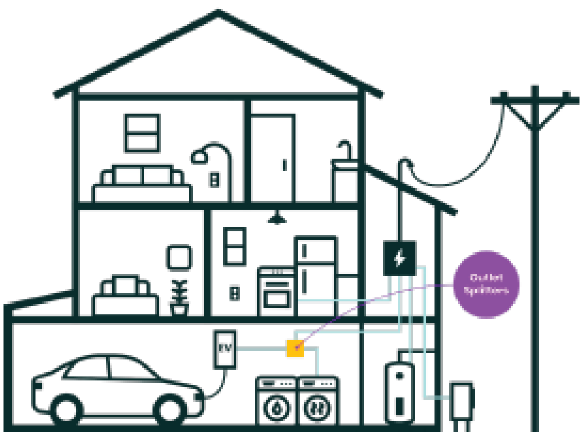
Circuit Control Units

A circuit control unit is an accessory device that can help manage power on one or more circuits, allowing household to make more use of their limited electrical capacity. A typical circuit control unit can manage a single load however multi load models are available. These units are ideal for situations where only one or two new electrical loads are being installed at a home.

Smart Circuit Breakers

Smart Circuit Breakers and Relays are accessory devices that can transform all or part of an electrical panel into a smart panel, allowing household to make more use of their limited electrical capacity. These devices will allow for control, monitoring, and management of circuits. Load management functionality allows residential electric consumption to stay below installed electrical capacity limits, avoiding the need for an electric service upgrade. The number of circuits controlled can be tailored to the needs of the home, potentially saving money.





Outlet Splitters

Outlet Splitters allows for two 240 Volt loads, such as an electric car charger and dryer to share the same outlet, eliminating the need to upgrade electric service when installing a new load. Outlet Splitters are ideal for situations where loads are located near each other and are not likely to be used at the same time.