Residential Electric Panel & Service Upsizing Alternatives

Efficiency Vermont R&D Project: Decarbonization

December 2025

AJ Rossman
Bob Kogut
Li Ling Young

Efficiency Vermont
20 Winooski Falls Way
Winooski, VT 05404

Contents

Executive Summary 3

Definitions and Acronyms 4

Industry standard terms and acronyms for electrical service equipment 4

Introduction 7

Electrification goals, existing infrastructure, and the capacity barrier 7

Background 7

Code pathways that enable upsizing avoidance 7

Technologies that enable upsizing alternatives 10

Methodology 11

Results 12

Stakeholder insights 12

Technology demonstrations 14

Technology Demonstration 1 – Stove Electrification With 100A Service 14

Technology Demonstration 2 – Heat Pump Installation with Two Car Chargers 15

Market research 16

NEC observations 16

Discussion 17

Efficiency Vermont Opportunities, Recommendations, and Future Research 18

Executive Summary

Vermont's residential decarbonization strategy depends on electrifying heating, water heating, cooking, and transportation, but many homes face a capacity barrier because their existing 100-amp electrical service may not support added loads without costly upsizing. In this report, "upsizing" means increasing electrical capacity, typically from 100A to 200A. Service "upgrades" involve modernizing or improving electrical service components, often for safety reasons. Sometimes both upsizing and upgrading are needed, but this report focuses on cases where additional amperage is needed, and the existing service otherwise meets safety standards. The utility typically pays for equipment outward of the service point, while the customer pays for equipment inward, including the meter socket, service disconnect, service entrance conductors, and main panel. These costs can exceed $10,000 and delay projects for months. In some cases, the capacity barrier is real; in others, it is perceived. Unnecessary electrical upsizing increases project costs and, in many cases, causes customers to defer or abandon electrification of major home appliances.

This Efficiency Vermont research examined decision-making around panel and service upsizing when new electrical loads are added, investigated how the National Electrical Code (NEC) is applied in practice for existing dwellings, and identified UL-listed intelligent power-management technologies that can enable electrification with existing 100A service. Some of these technologies are widely available and are gaining acceptance among utilities, electricians, and electrical inspectors nationwide. In Vermont, adoption of panel and service upsize alternatives is slowed by limited electrician awareness of these technologies and by consumer misconceptions.

Stakeholder interviews and two Vermont demonstrations confirmed that these technologies can enable electrification without panel or service upsizing, reducing costs and shortening project timelines. Market research also shows rapid innovation, with both startups and major suppliers introducing solutions to the residential capacity barrier.

Efficiency Vermont can accelerate appropriate adoption of panel and service upsize alternatives by building internal understanding of NEC load calculations, coordinating with utilities to make measured peak load data accessible to decision-makers, developing electrician training materials, and executing a public awareness campaign for homeowners. Future work should encourage alternative electrical load calculation methods where appropriate and support pilot projects that use energy management devices and systems to enable electrification without requiring service upsizing. Broader awareness of emerging technologies that support practical, cost-effective electrification will help Vermont continue progressing toward its decarbonization goals.

Definitions and Acronyms

Industry standard terms and acronyms for electrical service equipment

ELECTRICAL SERVICE EQUIPMENT TERMS:

Distribution transformer – Transformer that steps down medium-voltage power (e.g. 4 to 13 kV) to 120/240V split-phase for one or more residences, typically mounted on a utility pole near the residence(s) or in a ground mounted enclosure

Service drop / lateral – Wires that run from the distribution transformer to the service point of the building, drop is used for overhead wires, lateral is used for buried wires

Service point – The point where wires from the distribution transformer connect to the outside of the building or to a ground-mounted pylon – this is the dividing line between utility-owned equipment (out towards the transformer) and customer-owned equipment (in towards the building)

Meter socket – A customer-owned enclosure that the electric meter plugs into

Electric meter – Utility-owned meter that measures total building electrical use. In Vermont, this is often an AMI meter.

AMI meter, Advanced Metering Infrastructure meter – A digital utility-owned electric meter that is connected to a data network

Service disconnect – A manual shutoff or breaker after the service point mounted on the outside of the building

Service entrance conductors, line-side – The wires that run from the service point to the service disconnect

Service entrance conductors, supply-side – The wires that run from the service disconnect to the main panel

Main service panel AKA Main electrical panel AKA Main panel AKA Load center - The primary indoor distribution panel containing the main breaker and branch-circuit breakers

OTHER TERMS:

Binary controllers – Load management devices that either fully energize or fully de-energize (shut off) a controlled electrical load

Branch circuit – A wire run from a main or subpanel to a load or loads in a building. Controlled by a single circuit breaker.

Current limiting – See load limiting.

Current Transformer (CT) – A device used to measure the current in a conductor. It typically clamps around the outside of an insulated wire.

Curtail – In the context of electrical loads, means either turning off (disconnecting power) or reducing the power supplied to a particular circuit.

Electrical distribution – The equipment used to conduct electricity from a utility's power generation assets around its service area

Electrical service – The equipment used to deliver electrical power from the utility-owned distribution conductors to a building

EMS – Energy Management System – Control equipment that monitors and manages electrical loads to ensure total power usage remains below a pre-set limit

Load center - See Main service panel below.

Load limiting – Restricting the maximum current supplied to a circuit to certain limit

LMT - Load management technology – Any electrical device that measures current and enables or disables loads

Load shedding – Completely cutting off power to an electrical load

LSD - Load shed device – An electrical device that monitors current and will shut off a connected load if that current (measured at the building mains or at a subpanel) reaches a preset limit

Main electrical panel – See Main service panel below.

Main panel - See Main service panel.

Main service panel - The central electrical box that receives electricity from the utility company and connects with loads

Modulating controllers – Load management devices that can energize or de-energize a controlled circuit or can ramp the supply current up or down to stay within preset limits without completely shutting off the connected equipment

Panel upgrade – Replacing a building's main electrical panel with same or larger electrical capacity. This may be done for a variety of reasons including correcting code non-compliance issues, creating space for the addition of new circuit breakers, and accommodating a service upsize where the current capacity to the panel was increased.

Panel upsizing – Replacing a building's main electrical panel with a larger electrical capacity. See panel upgrade above.

Service upsizing – The labor and equipment (wire) required to increase a building's electrical service capacity

Service upgrade – Replacement and installation of any electrical equipment that is part of the electrical service, does not necessarily include service upsizing

Introduction

Electrification goals, existing infrastructure, and the capacity barrier

For existing homes with fossil-fueled appliances, electrification involves adding new electrical loads to a fixed electrical load panel and service capacity. Upsizing a home's load panel and/or service conductors is typically costly and can take months, depending on the utility. This barrier to adoption is especially difficult for low- and middle-income households. This project addresses the "capacity barrier" by examining the low adoption rate of alternatives that enable safe, code-compliant electrification without costly panel & service upsizing for homes with existing 100A infrastructure.

Background

Code pathways that enable upsizing avoidance

The purpose of the Vermont Electrical Safety Rules is to protect people in buildings from fire or electrocution due to unsafe electrical installations. This is done by the adoption and enforcement of nationally recognized safety codes and by the licensure, education, and training of those doing the electrical installation work. The National Electrical Code (NEC) provides guidance to electricians and authorities having jurisdiction (AHJs) for determining whether an existing dwelling can safely accommodate additional loads given the home's existing electrical infrastructure.

Electricians typically use NEC-defined load calculations, or load calcs, to determine whether existing service conductors between the panel and utility transformer have sufficient capacity for new loads. Existing electrical infrastructure can remain in use if it is in good condition, the load calculation is below the service conductor rating, the panel capacity does not exceed the service conductor capacity, and the panel has room for additional circuit breakers. If the load calculation, including new loads, exceeds existing service capacity, electricians commonly recommend replacing the service panel and service conductors to provide higher capacity. For 100A panels, this typically means installing a new 200A load center. For service conductors, this typically means upsizing wires from #4 copper or #2 AWG aluminum to 2/0 AWG copper or 4/0 AWG aluminum. Homeowner costs for service upsizing can range from about $2,000 for short service conductor runs to as much as $20,000 in extreme cases. One homeowner interviewed had a long underground service that required significant site work, including replacing a service conductor under a road to reach the utility transformer.

NEC Article 220 provides comprehensive guidance on how to determine if branch circuits, feeders, and service conductors are sufficient for new loads to be added. Subsections of the code shown in Table 1 offer different ways to perform load calcs for existing dwellings depending on available information and load control technology used. Load calcs for an

existing home are used to determine the unused, spare capacity, sometimes known as "headroom," available for new loads to be added safely.

NEC 220 Part III, the standard method, and Part IV, the optional method, are the most widely used approaches for performing load calculations for existing dwellings today. Both are time-consuming, and many electricians still use spreadsheets or paper worksheets that can introduce errors. The research team found that Part III tends to be more conservative than the optional method and that calculations are sometimes skipped and upsizing is automatically recommended. A site visit is required to inventory the electrical ratings of connected equipment and new equipment being added. These calculations require the full-load ampere nameplate rating of each piece of equipment, which can be overly conservative compared with actual maximum current use. Load calculation spreadsheets and paper worksheets often include default amperage values when nameplate ratings or manufacturer specifications are unavailable, and these defaults are also often conservative. New web-based tools make load calculations easier, but they still require nameplate values for each appliance.

Section 220.87 of the NEC is less well known and less commonly used than the standard and optional load calculation methods. It provides guidance on using metered or measured load data to establish a dwelling's baseline maximum electrical load instead of adding the nameplate ratings of existing equipment, as required by prescriptive methods. A year of utility data is required. If a full year of utility data is unavailable, 30 days of 15-minute demand data collected by an AMI utility meter or logging ammeter can be used. The 30-day collection period must occur when the building is occupied, cannot be used in dwellings with solar, and must reflect the higher of cooling or heating loads or other seasonal variations. The peak 15-minute interval is multiplied by a 125% demand factor to establish existing demand. The total demand, including existing and new loads, must remain below the maximum service conductor rating unless load control technologies are used.

Table 1: NEC articles relevant to load calculations for existing single-family dwelling

NEC Section	Key Details	Observations
220 Part III Standard Calculation	***Different demand factors for loads: General, HVAC, Fixed Appliances, Dryers, Cooking and Motors***	***Prone to error when done by hand or spreadsheet, commonly overestimates the required capacity for electrification, takes time with apps.***
220 Part IV Optional Calculation	*Single demand factor for loads - (A) First 8 kVA @ 100%, remainder @ 40% (B) add AC, central space heading and <4 separately controlled space-heating units at 100%*	*Still difficult when done by spreadsheet, not always accepted by AHJs, usually lower calculated capacity that standard method, takes time with apps*

NEC Section	Key Details	Observations
220.87 Measurement based	*Requires 1-year utility demand data, or if not available: 30-day continuous recording @ 15-min intervals. Peak interval multiplied by 125% for establishing demand. Cannot be used if dwelling has solar or load shed devices.*	*Least conservative and relatively unknown. Some pushback from AHJs.*

Several NEC sections, specifically NFPA 70-2023, enable control technologies to reduce calculated demand and create headroom for new appliances without requiring service conductor upsizing (Table 2).

NEC 220.60 (Noncoincident Loads section) states that if two or more noncoincident loads are unlikely to be in use simultaneously, then only the highest of those loads needs to be considered by the load calc. Circuit or plug splitters are simple devices that connect two loads to the same outlet or branch circuit. They ensure that only one of those two loads can operate at a time. These devices are often used with a hot water heater and a clothes dryer or a clothes dryer and an EV charger.

NEC 220.70, added in 2023 and adopted in Vermont in December 2025, provides guidance for energy management systems (EMS) when used in accordance with NEC 750.30. EMS actively monitor and control electrical loads in a home to ensure the total current draw never exceeds a configured set point that is usually 80% of the capacity of the existing panel and service. Instead of upsizing the panel or service conductors, the EMS enforces this limit dynamically by shedding or throttling non-critical loads and/or deploying generation or stored electricity when necessary. This rule allows for the controlled load(s) to be removed from the load calc because they will be disconnected, and in some cases limited, so they never exceed the capacity of the service conductors.

NEC 625.42 has been updated to include EV EMS, explicitly enabling EVSEs to be "removed" from standard and optional (220.83) load calculations.

Table 2: NEC articles enabling technologies to increase load calc headroom

NEC Section	Key Details for Load Calcs	Technologies Enabled
220.60 Non-coincident loads	***Only the larger of non-coincident loads used in load calcs***	***Circuit Splitters***
***220.70** Energy Management Systems*	*The set point of the EMS can be used in lieu of a load calculation for controlled loads.*	*Smart Panels and other Dynamic Load Shedding Devices*
***750.30** Energy Management Systems*	***Provides additional detail to section 220.70.***	*Smart Panels and other Dynamic Load Shedding Devices*

NEC Section	Key Details for Load Calcs	Technologies Enabled
625.42	*An EMS can be used to dynamically limit the load used by EVSE or can adjust the EVSE load to remain within a pre-set limit.*	*EV EMS*

The State of Vermont does not enforce the NEC by conducting electrical inspections for owner-occupied, single-family dwellings. Instead, the Authority Having Jurisdiction (AHJ) for enforcing electrical codes lies with individual municipalities, including Burlington, Winooski, and South Burlington electrical inspectors.

Technologies that enable upsizing alternatives

A variety of technological solutions provide pathways to adding new electrical loads to existing 100A residential infrastructure (panel + service). Functionality and capabilities vary widely from simple load shedding to full EMS. Underwriters Laboratory (UL) tests devices for safe operation, and only UL-certified technologies were investigated. Some important distinguishing capabilities include:

- Some control devices monitor the electrical mains and will curtail end uses only when necessary to avoid overcurrent conditions that would trip the main breaker.
- Some control devices can modulate the current supplied to devices rather than just shut them off. This enables operation at partial loading (applies most commonly to electric vehicle charging equipment).
- Some control devices share a circuit between two end uses without monitoring the electrical mains. Only one device can operate at a time; they can never run simultaneously.

Some load management devices replace parts of the existing infrastructure, while others are added onto the system. This results in a wide range of costs between different solutions. Common approaches include:

- Replacement of the home's load center (main breaker panel) to provide space for new circuits and add smart functionality to manage current on service conductors.
- Within a conventional electrical panel, replacement of individual circuit breakers to add remote control.
- Downstream load management controls installed between the circuit breaker and the end use.
- Controls used with plug-in equipment such as a clothes dryer, installed at the outlet.

Finally, some upsizing alternatives only solve the problem of an electrical panel that is too full for a new electric circuit, while others solve the problem of a service limitation, in which the existing connected load of the home does not allow for the addition of a new, uncontrolled load.

All approaches support adding new electric end uses to existing service when limitations might otherwise prevent new loads. Electrification can significantly increase demand on a home's electrical service: an electric stove might add a 50-amp circuit, an electric vehicle charger might add 30 to 48 amps (42.5 to 60A for continuous loading), and a heat pump for heating or cooling can add up to 40 amps. Load management technologies delay or shed lower-priority loads to preserve capacity for higher-priority end uses. Loads that are strong candidates for shedding include those with built-in storage, such as water heaters and electric vehicles, or those where delayed operation is usually acceptable, such as clothes dryers. Prioritized loads are those where deferral would inconvenience occupants, such as cooking and lighting. Active, prioritized load management can enable electrification with 100A infrastructure.

Beyond saving homeowners the time and cost associated with electric service or panel upsizing, load shed devices can provide broader grid-level benefits. As Vermont progresses toward its goal of reducing greenhouse gas emissions by 80%, high-demand devices such as electric vehicle chargers, electric clothes dryers, and heat pumps will become more common in homes. Residential load management can help protect grid infrastructure by reducing concurrent use of high-demand end uses. Load shedding also reduces peak demand upstream on transformers, substations, and the regional grid, mitigating capacity constraints at neighborhood and system levels. Avoiding upstream upgrades may reduce pressure on future rate increases.

By reducing peak demand and enabling dynamic load control, load shed devices can also support carbon arbitrage, demand response programs when internet enabled, and defer costly utility infrastructure upgrades. Empowering customers and stabilizing the grid may prove load shed devices to be a foundational technology for large-scale electrification initiatives.

Methodology

The research identified practical, code-compliant alternatives to residential panel and service upsizing for homes with 100A electrical service and explored strategies that enable electrification of major loads, such as heat pumps and EV chargers, without costly equipment upsizing. The study used primary and secondary research to examine how electricians determine when upsizing is necessary, the barriers to adopting load shed devices and energy management systems, and the role of the NEC in shaping these decisions.

Primary research involved conducting interviews with a diverse group of stakeholders: electricians, authorities having jurisdiction (AHJs), heat pump and electric vehicle supply equipment (EVSE) installers, homeowners, equipment manufacturers, vendors, and utilities. Questions focused on the decision-making process for adding new loads, familiarity with NEC sections 220.83 and 220.87, and perceptions of load shedding technologies, including gaps in awareness and training.

To complement the interviews, the team conducted two field demonstrations of load shed devices. These installations provided insight into the availability of load shed devices, ease of

installation, the experience of contractors and homeowners, and the functional viability of these technologies as alternatives to full panel upsizes. Observations from these demonstrations helped validate whether such solutions could realistically reduce the need for infrastructure upsizing in Vermont homes.

Secondary research focused on market trends and code review. The research team attended three major electrification trade shows to investigate emerging products and industry developments. Commercially available load shed devices were evaluated for their applicability in Vermont's residential market. This combination of stakeholder input, hands-on demonstrations, and market analysis provided a comprehensive understanding of both technical feasibility and adoption challenges in Vermont.

Data collection and analysis included qualitative and quantitative components. Interview responses were analyzed thematically to identify knowledge gaps, attitudes, and behaviors among practitioners and homeowners. Basic quantitative data were gathered during technology demonstrations, documenting installation costs, time requirements, and device performance.

Results

Stakeholder insights

Interviews with stakeholders, including electricians, AHJs, installers, homeowners, utilities, and vendors, revealed several key insights into current practices, perceptions, and barriers related to electrical capacity management and panel upsizing. These findings highlight the evolving roles of technology, regulatory acceptance, and market awareness in shaping decisions around load shed solutions.

We found that electricians serve as primary decision-makers for service and panel upsizing. Licensed electricians hold professional licenses required by AHJs and must satisfy annual continuing education requirements that keep them current on concepts, though not necessarily on specific new technologies or specific products. Many electricians use rules of thumb in evaluating headroom for new electrical loads when not required by an AHJ. When load calculations are needed, electricians typically use one of several online forms that simplify a code-compliant calculation, but even these forms are considered too time consuming for regular use. Hand calculation based on the NEC itself is rare due to ambiguity within the code and the challenge of faithfully implementing a complicated procedure. Few of the electricians surveyed were aware of NEC 220.87, which allows sizing based on historical demand data, but found it appealing after learning about it.

Of the dozen electricians interviewed for this research, four were interviewed at Efficiency Vermont's Better Buildings by Design conference and participated in the Home Electric Service Upgrade program. These electricians expressed strong interest in learning about upcoming program opportunities from Efficiency Vermont and were particularly enthusiastic about load shed devices. They cited several advantages of these technologies, including quick installation,

reduced effort compared to upsizing equipment, improved profitability, and lower risk by avoiding complications during panel upsizes. These technologies enabled customers to electrify appliances without the costly panel and service upgrade.

AHJs defer to electricians for compliance decisions. Some municipal electrical inspectors in Vermont now accept NEC 220.87-compliant load calculations in select cases, signaling an evolving practice. Vermont's lead state electrical inspector expressed confidence in load shed technology with two caveats: equipment must carry UL listings, and electricians should clearly communicate customer impacts, such as the inability to charge an EV during peak load. The inspector noted that the commercial and industrial sectors have successfully used load shed devices for decades when capacity is constrained.

Installers of heat pump HVAC and water heaters typically outsource electrical work and, in most cases, had limited knowledge of the details of capacity constraints. Some installers reported no sites where constrained electrical service posed an obstacle to installation, suggesting homeowners are self-selecting out of electrification under the assumption their service won't allow it.

Homeowners we surveyed often assumed infrastructure upgrades were required and were unaware of alternatives such as load shed devices or EMS. When they learned about these options, they showed strong interest in potential cost savings and faster installation timelines. One homeowner upsized his electrical service and panel to increase the home's perceived value and marketability when they decide to sell.

Green Mountain Power and the Burlington Electric Department support UL-listed load shed devices that can unlock headroom by taking advantage of underutilized electrical capacity, but they expressed caution about potential reductions in load diversity with widespread adoption. Utilities do not commonly prescribe behind-the-meter solutions, but they value faster interconnections and the additional beneficial load.

Green Mountain Power (GMP) has robust in-home battery energy storage system (BESS) programs. GMP can remotely control those batteries to discharge during high-demand periods through a virtual power plant (VPP) network to reduce peak load on the grid. Note that a BESS alone, without an energy management system (EMS), does not guarantee that a home's electrical demand will remain below a preset limit. Therefore, a BESS alone is not a pathway to avoid a service upsize. However, the combination of a BESS and an EMS can safely ensure that a home's total electrical demand remains within the service capacity. The battery component of that system provides supplemental power when needed, which reduces instances of load curtailment. Many commercial BESS include EMS functionality.

Burlington Electric Department (BED) recognizes that panel upgrades and service upsizes may be required when adding new electrical equipment to a home. They have an informative section about panel upsizes on their website in the EV chargers section: EV Chargers Website which includes links to financial resources to help with the cost of service upsizes. However, their

website makes no mention of smart panels or load shed devices that can be used to avoid a service upsize.

Vendors such as ConnectDER, Emporia, SimpleSwitch, and Stepwise Tap reported low awareness of load shed technologies among trades and consumers, which they identified as a significant barrier to adoption. They also called for utility programs to raise awareness and improve the cost-effectiveness of devices and installation. At the time of this report, three supply houses in Vermont carried load shed technologies. Green Mountain Electric Supply carries DCC devices marketed specifically for EVs, CED Twinstate carries simpleSwitch, and GreenTech Renewables carries ConnectDER EV. All cited low awareness among tradespeople and suggested that incentives and greater outreach could help increase adoption.

Technology demonstrations

Two case studies were conducted to examine how load calculations are performed in practice, the impact of load shed devices on those calculations, and the broader implications for AHJ acceptance, installation effort, and customer experience. Each case added significant electrical loads, such as an induction stove or EV chargers, to homes with 100A service, providing real-world context for evaluating alternatives to panel upsizes.

In both cases, traditional load calculations proved to be tedious and open to interpretation. Electricians noted that correctly applying NEC requirements often requires time-consuming spreadsheet work they would prefer not to do.

Technology Demonstration 1 – Stove Electrification With 100A Service

An electrical contractor in Vermont was asked by a single-family residential customer to run a new circuit for a new induction range that would replace a gas range. Although the home uses gas for heating and water heating, its 100A service did not leave enough headroom for the 50A circuit that the new induction range required.

With a substantial distance between the home's meter and the nearest transformer, the electrical contractor estimated the customer's share of the cost to upsize electrical service to 200A to be $18,000. The customer rejected the electrical equipment upgrade and put their cooking-electrification project on hold.

The contractor's master electrician learned about the benefits of load shed devices and the possibility that this customer could execute their project without upgrading their electrical service through the research team. Efficiency Vermont offered an incentive to encourage the homeowner and the contractor to install the technology.

The customer gladly agreed to participate in a demonstration project and use a load shed device selected by the electrician. After a review of UL-listed options that were easy to install, readily available, and appropriately scaled to the project, the simpleSwitch was selected. The installed cost of the simpleSwitch was ~$2,000 after a $500 Efficiency Vermont incentive. Approximately half of the cost was the device and wire, and half installation labor.

Figure 2 shows the simpleSwitch installed. Current transformers (CTs) installed on the mains of the load panel measure the total load of the panel main breaker and control power to a Level II car charger. When the CTs on the mains measure a current above 80A, the car charger will be locked out until the load is under 80A for 15 minutes. The simpleSwitch will then re-energize the car charger. Following this experience, the electrical contractor has used load shed devices for a half dozen subsequent projects.

Figure 2: simpleSwitch installation





Technology Demonstration 2 – Heat Pump Installation with Two Car Chargers

This project was taken on by a Vermont contractor that offers weatherization and construction services and solar panel and ductless heat pump installation. They employ an in-house electrician to design the electrical side of solar and heat pump projects. While preparing a load calculation for a customer-request to install a heat pump, the electrician discovered two EV chargers in the home.

The single-family home had 200A electrical service, however with two 50A EV chargers there was insufficient spare electrical capacity for the proposed 40A multizone heat pump. The contractor estimated that the customer portion of the expense to upsize beyond 200A would be over $10,000. Based on that added cost, the customer decided not to install the heat pump.

After learning about low-cost circuit sharing from Efficiency Vermont, the contractor installed a simpleSwitch, a device that allows the EV chargers to share a circuit and charge the cars sequentially, freeing up 50A of electrical capacity.

The cost of the simpleSwitch, including installation, was $1,165. Its installation allowed the customer to move forward with the heat pump project. This contractor has since used load shed devices in subsequent projects with constrained electrical service and promotes their use to other electricians.

Market research

The research team identified several UL-listed load shed devices applicable to Vermont at major national industry trade shows, including DistribuTECH, Intersolar North America, and RE+. The team reviewed more than 2,000 trade show booths for relevant devices and interviewed vendors to understand the range of available technologies and their potential fit for Vermont's residential market. These events highlighted a rapidly evolving landscape, with numerous new entrants offering solutions designed to manage electrical loads and support electrification without costly panel or service upsizing. The range of technologies and approaches advertised at these shows supported the research team's hypothesis that capacity is a barrier to electrification. Use cases ranged from electrification initiatives for low- and moderate-income households to customers with disposable income seeking to drive electric or electrify non-essential loads such as hot tubs. Vendors ranged from multinational electrical conglomerates to venture-funded startups.

Feedback from Vermont stakeholders provided insight into load shed technology visibility in the state. Almost all electricians interviewed were familiar with SPAN, a leading smart panel brand, but only a handful had installed its products. Those with SPAN experience noted its high cost as a barrier to broader adoption. Meter socket adapters are far more common and are accepted by most utilities and AHJs in Vermont for PV installations; however, one electrician expressed concern that these adapters could introduce long-term reliability issues. While this was a single concern, it underscores the importance of balancing convenience and system integrity when considering panel upsize alternatives. Meter socket adapters are most applicable when the load to be shed is close to the meter, typically on the exterior of the dwelling. Non-MSA load shed devices are often easier to wire because they are located near the loads they control. Circuit splitters and sharing devices are most useful when the two controlled loads are physically close to each other at the end of a dedicated branch circuit.

Our discussion with the Lead State Electrical Inspector guided our thoughts on classifying these technologies from a new perspective – how the technology impacts (i.e. degrades) the user's electrical capacity. With this new lens, load shed devices fall into two broad categories: binary controllers and modulating controllers. Binary devices fully energize or de-energize a load; they cut power to specific loads when thresholds are reached. Modulating devices, by contrast, can ramp down the current supplied to a connected device depending on real-time dwelling load measurement. This helps maintain system stability while allowing the equipment to continue to operate, albeit at lower capacity. This distinction is critical as Vermont explores solutions that not only meet NEC requirements but also provide flexibility and reliability for homeowners seeking to electrify their homes without major infrastructure upgrades.

NEC observations

Vermont has adopted the 2023 edition of the NEC through its Electrical Safety Rules, as enforced by the Vermont Division of Fire Safety under NFPA 70 by the National Fire Protection Association. Residential electrical work that complies with this code aligns with the most current

safety and performance standards. However, the practical application of certain NEC provisions in the field presents challenges for both electricians and homeowners in the context of decarbonization via electrification.

Section 220.83, which governs dwelling unit load calculations, is widely perceived as cumbersome and inconsistent. Electricians we spoke with described the process as time-consuming, complex, and often of limited value to their work. Many avoid these calculations altogether, citing the added expense for customers and the difficulty of consistently interpreting the code. Spreadsheet-based tools, although common, are problematic because NEC 220.83 can be interpreted in multiple ways, leading to uncertainty and frustration.

Section 220.87, which allows demand-based calculations using measured load data, is rarely used, though it appeals to electricians who are uncertain about how to calculate load accurately. Adoption challenges include access to customer demand data and limited practitioner training in data analysis. Industry experts advocate broader use of 220.87 when adding large electrical loads, noting that long-form load calculations tend to be conservative enough to preclude new loads, while occasionally underestimating demand. Section 220.70, introduced in 2023, represents a paradigm shift by enabling EMS-based sizing that enforces current limits rather than relying solely on overall capacity constraints. This approach has generated significant industry interest and is expected to evolve further in the 2026 NEC edition.

Discussion

The research found that, with new UL-listed load shed devices, electrification barriers are more procedural and educational than technological. Many of these devices have been in use for years and have been accepted by both utilities and AHJs. Electricians who install new electrical loads make the decision and often default to service upsizing, leading to unnecessary upgrades. Because AHJs trust electricians to make decisions about necessary electrical equipment, improving electricians' awareness of NEC alternatives (220.87 and 220.70) is critical.

Overall, the research team found that load shed devices present viable, code-compliant alternatives to upsizing, but their adoption is slow. Some reasons include:

- Limited training for electricians on new NEC provisions
- Confusion about how different types of load shed technologies work and their impact on customers
- Lack of standardized tools for NEC 220.87 demand studies
- Consumer misconceptions about mandatory panel and service conductor upsizing
- Uncertainty in long-term reliability. Electrians do not want callbacks.

The openness of utilities and state electrical inspectors to load shed solutions creates an opportunity for collaborative programs. Messaging should address concerns about load diversity and occupant reliability for critical loads.

A key remaining gap is understanding how much electricity Vermont dwellings actually use in practice and, therefore, the likely need for load shed devices. Traditional load calculations estimate demand using a complex set of demand factors, but those estimates do not always reflect actual household usage. Load coincidence is difficult to model because it depends heavily on occupant behavior, appliance operation patterns, and seasonal variation. As a result, calculated demand can be more conservative than measured demand, potentially overstating the need for panel or service upsizing and, in some cases, the need for load shed devices where they may not be affordable. The research team recommends analyzing actual loads in Vermont dwellings using existing AMI data.

Efficiency Vermont Opportunities, Recommendations, and Future Research

The research indicates that Vermont can accelerate electrification by supporting practical, code-compliant alternatives to electrical service and panel upsizing, including load shed devices and, over time, home-scale energy management systems. Stakeholder feedback also points to the need for targeted education for electricians and AHJs, along with clear consumer outreach, to raise awareness of these alternatives. These efforts can help prevent unnecessary and costly panel and service upsizing, making electrification more practical and affordable for homeowners and small businesses. Based on these findings, the research team recommends that Efficiency Vermont implement a coordinated strategy to promote awareness and appropriate adoption of load shed technologies. The recommended actions follow.

The research points to a need for stronger internal electrical code expertise so Efficiency Vermont technical staff can serve as a resource for customers, trade allies, and industry partners. Efficiency Vermont should create and actively maintain internal guidance on NEC load calculation requirements, home panel safety considerations, and UL-certified load shed devices. Periodic training for engineering and technical staff would help keep internal expertise current as codes, technologies, and market offerings evolve.

The research found that limited access to historical demand data is a key barrier to broader use of NEC 220.87 demand-based load calculations. Efficiency Vermont should work with utilities and trade allies to establish a clear process for sharing customer-authorized demand data with contractors. Efficiency Vermont should also consider developing a tool that helps determine whether a home is eligible for a 220.87 calculation and estimates available electrical headroom.

Stakeholder feedback suggests that customer-facing education materials would help homeowners and small businesses better understand options for addressing electrical panel and service constraints. These materials should clearly describe when upsizing may be necessary, when alternatives may be appropriate, and what questions customers should ask electricians or installers. A coordinated outreach campaign, including web content and social media, could highlight opportunities to electrify without assuming that panel or service upsizing is always required.

Stakeholder interviews indicate that electrician training and continuing education will be important for shifting default assumptions about panel and service upsizing. Efficiency Vermont should explore partnerships with Vermont State University, the International Brotherhood of Electrical Workers (IBEW), vocational schools, and other relevant training providers to incorporate newer NEC provisions that support load shed technologies into curricula and continuing education. For example, Efficiency Vermont could contribute content to the *Vermont Energy Goals* electricians' education training module, a required continuing education component for electricians, to include practical approaches to affordable electrification within existing panel and service constraints.

Stakeholder feedback also suggests that the Efficiency Excellence Network (EEN) is a practical channel for reaching the professionals who most often advise customers on electrification decisions. The EEN should develop and deliver educational content for electricians, heat pump installers, heat pump water heater installers, and EV charger installers. Trainings should address when NEC 220.87 is appropriate, how load shed technologies affect customer experience, and how trade allies can explain alternatives to upsizing clearly and accurately.

The demonstrations and stakeholder interviews point to several areas where additional research would help validate appropriate applications for different load shed technologies and better assess the need for these technologies in Vermont homes. Analysis of household AMI data could help determine how often panel or service constraints are likely to occur, where load shed devices are most cost-effective, and when measured demand may support electrification without upsizing. Looking ahead, NEC 220.70 represents a significant shift in load calculation methodology by allowing energy management systems to enforce a maximum ampere current set point. Future research should focus on best practices for documenting EMS compliance, assessing cost-effectiveness across applications, and developing standardized tools that streamline verification for inspectors and contractors. These steps will help Vermont remain at the forefront of practical, cost-effective electrification strategies.