



Electrical Panel Technology Review: The Challenges and Solutions for Electrification

How Many May Need to be Upgraded?

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U.S. Survey of Residential Electrical Panels

- Primary Research Questions:
 - How many homes might need a panel/service upgrade to accommodate full electrification?
 - What are the leading indicators for needing panel/service upgrade?
 - Are there regional trends?

Goal: Gather first national dataset on residential electrical panels in order to help inform utility decision-making around electrification



Survey Overview

- Survey was hosted online by third party survey provider from Aug-Oct 2022. Inclusive of all home types.
- Each respondent was asked 15 questions and had to take a picture of their home's electrical panel
- Final sample included 2950 responses; 624 from western states, 239 from CA
 - Margin of Error:
 - Overall: +/- 2.0
 - Northeast: +/- 4.9
 - Midwest: +/- 4.2
 - West: +/- 4.5
 - South: +/- 3.0



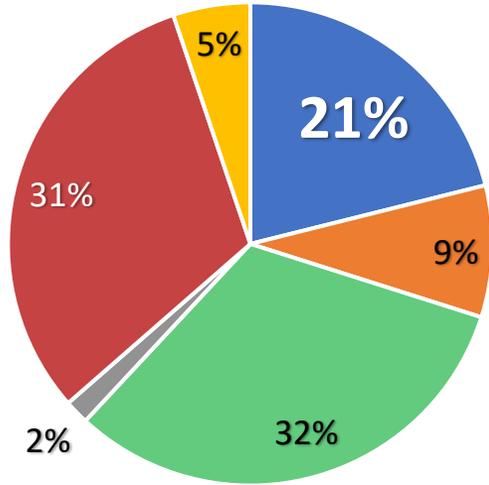
Pictures From Respondents



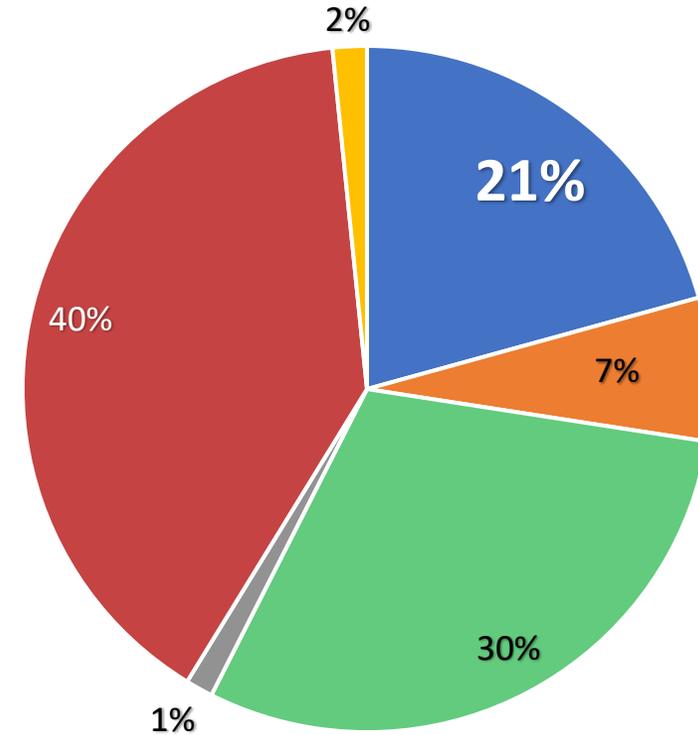
What is the amperage of your main breaker?

n=2,950; 624

U.S. – All Regions



West



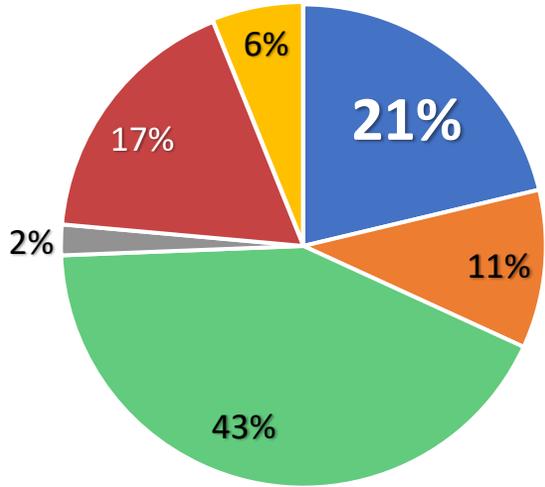
- 100 Amps or Less
- 151-200 Amps
- I couldn't find the main breaker
- 101-150 Amps
- 201+ Amps
- I don't see a label

Over 20% of surveyed households have 100A or less breakers

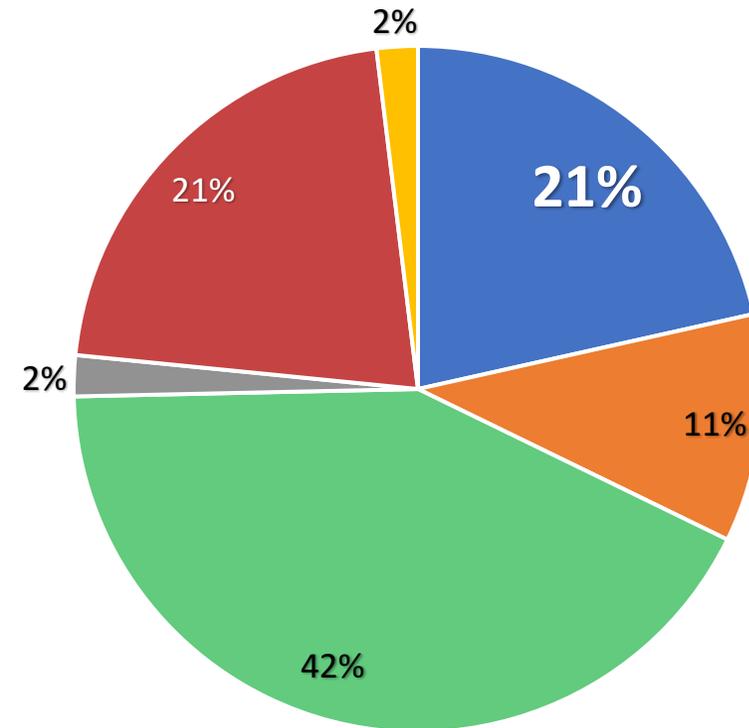
Main Breaker Size – Single-family Detached Houses

n=1,858; 364

U.S. – All Regions



West



100 Amps or Less

151-200 Amps

I couldn't find the main breaker

101-150 Amps

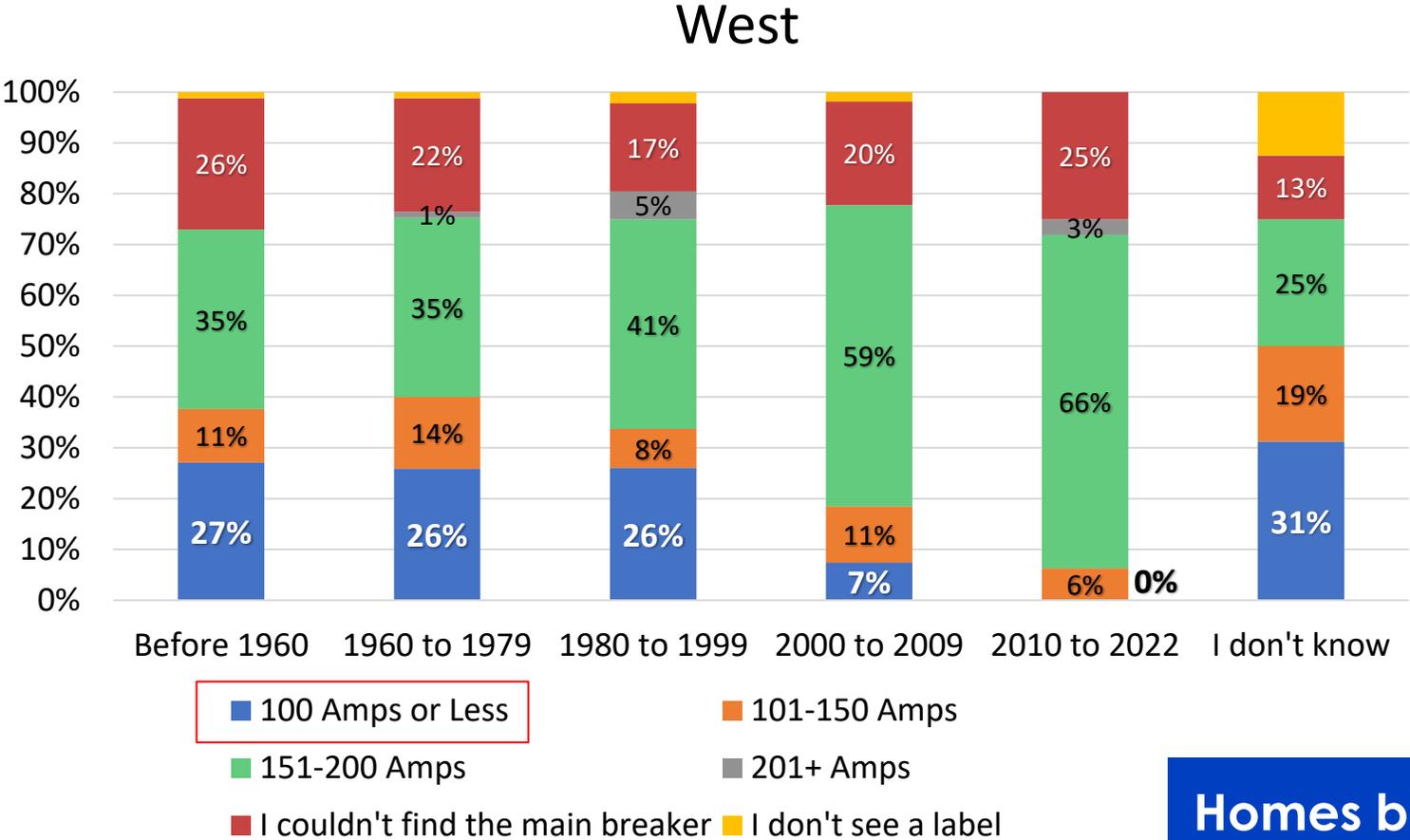
201+ Amps

I don't see a label

200A panel much more likely in a single-family house

Building Age Correlates with Main Breaker Size – Single Family Homes

n=364

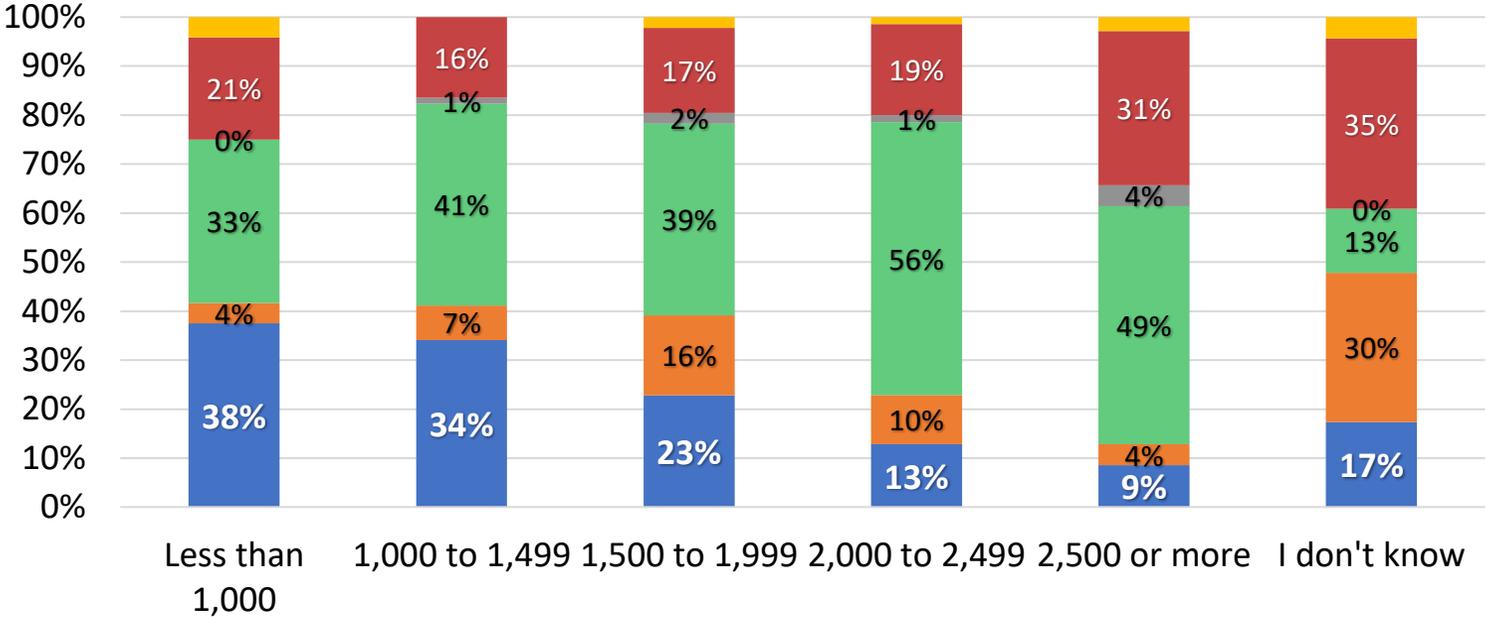


Homes built before 2000 are 3-4x more likely to have 100 amps or less compared to homes built after 2000

Building Size Correlates with Main Breaker Size – Single Family Homes

n=364

West

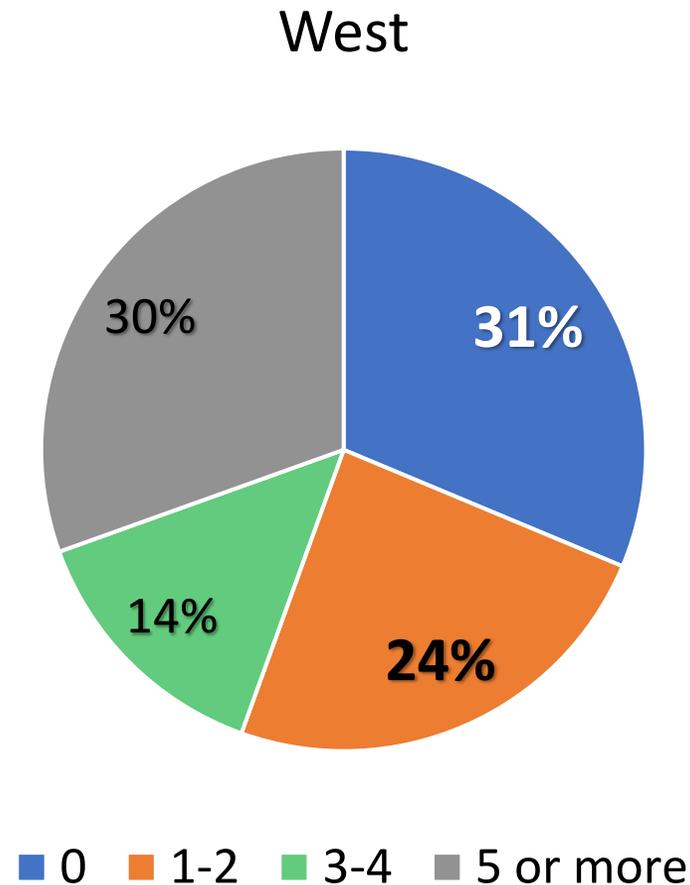


- 100 Amps or Less
- 101-150 Amps
- 151-200 Amps
- 201+ Amps
- I couldn't find the main breaker
- I don't see a label

The smaller the house, the more likely the panel is 100A or less

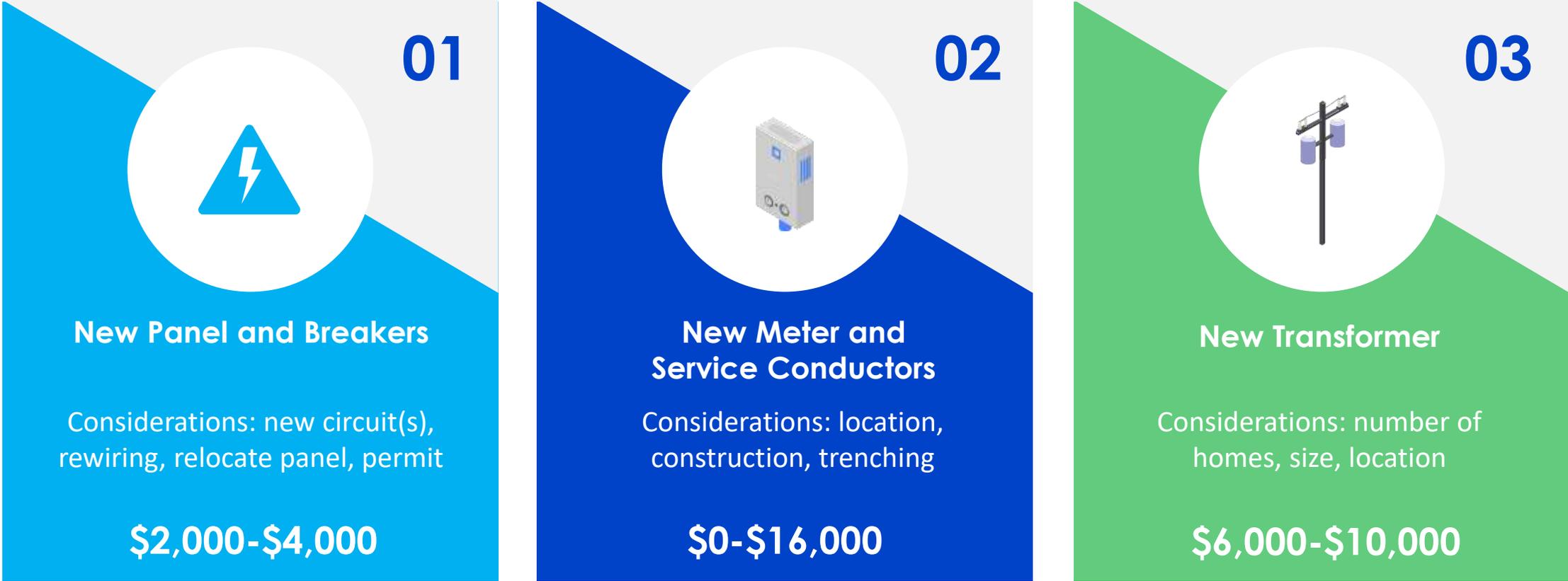
How many open breaker slots does your panel have? Single Family Homes

n=364



Over 50% of western homes surveyed have 2 or less open breaker slots

How much does it cost to upgrade to a 200A panel?



Source: *Service Upgrades for Electrification Retrofits Study Draft Report, NV5 and Redwood Energy, 2022*

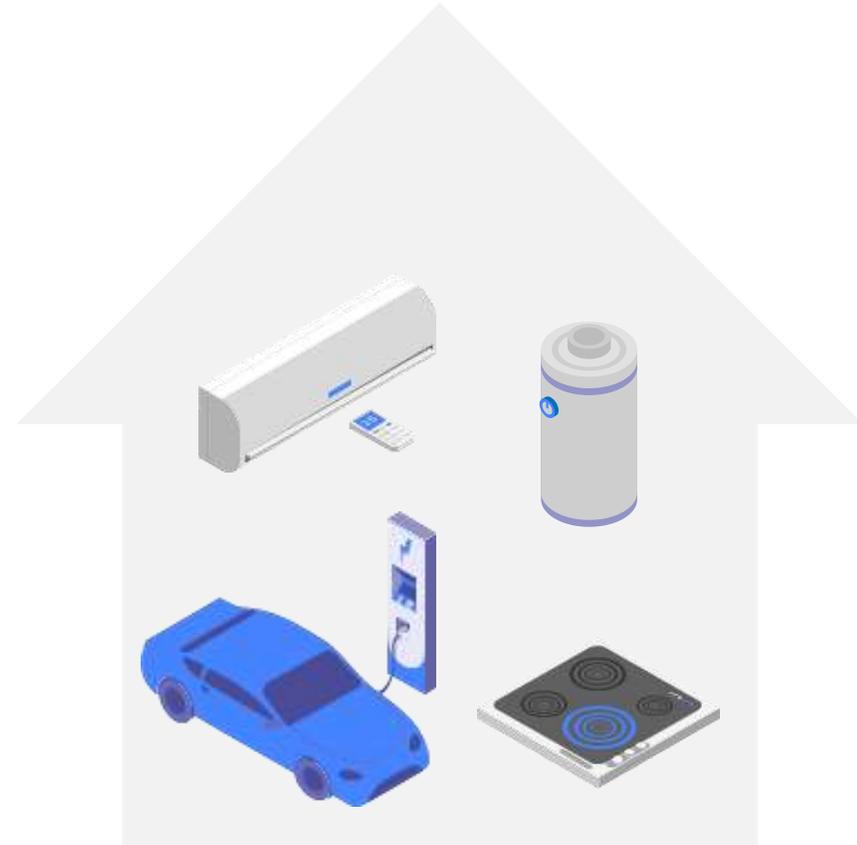
Potential of \$2,000-30,000 per home

Rough Estimate of Cost to Upgrade Electrical Infrastructure in Single-family Detached U.S. Houses

82 million single-family detached houses in U.S.

30% may need a panel/service upgrade to fully electrify

\$123 Billion in potential upgrade costs, assuming \$5,000 per home



Possible Alternatives to Panel Upgrades



Amp Diet

Minimizing the size of the electric loads – no backup strip heat, smaller appliances, slow charging



Load Switches

Manually switch between two large electric loads (e.g., dryer and EV charger)



Smart Panels

Potentially mitigate the service upgrade with automated load balancing in the home



■ Meet the Manufacturers



North Carolina-based startup founded in 2014. Closed \$17.8M in Series B funding in June 2020. Siemens is the lead investor; Eaton is also an investor.



Multinational power management corporation founded in 1911. Headquarters in Dublin, Ireland. \$21.4B in 2019 sales.



Electrical equipment manufacturer founded in 1906 and headquartered in Melville, NY. \$1.46B annual revenue.



Charlottesville, VA-based startup founded in 2016. Closed \$6.43M in Series A funding in September 2020. Accepted to Dominion Energy Innovation Center incubator.



French multinational company with over 135,000 employees worldwide, founded in 1836. \$27.2B in 2019 revenues.



San Francisco-based startup founded in 2018 by former head of storage for Tesla. \$13.8M in Series A funding, second round in May 2020. ArcTern Ventures is the lead investor.

Summary: What can Smart Panels do for Load-Serving Entities?

Value Streams

1. Solar/Storage: Since smart panel project economics today hinge on integration with solar/storage, a discussion of value must start here. However, the benefit here is primarily to customers instead of LSEs. Smart panels are unlikely to move the needle in driving greater adoption of solar/storage.

2. Energy Monitoring: LSEs can use smart panels to gain greater insight into how customers use electricity at the circuit level or better. There are other products that provide this capability at a lower cost, however.

3. Building Electrification: This is the biggest potential benefit of smart panels for LSEs. Smart panels can help add electrified building loads in capacity-constrained environments. Software controls allow for overloading the existing panel rating and avoiding expensive distribution upgrades. The current barriers are electrical codes.

4. Demand Response: Smart panels can unlock more residential end-use loads for LSE demand response programs without requiring that each individual appliance be connected and DR-capable. They can also schedule circuit use to align with TOU programs. Not every circuit will be a good fit for DR.

LSE Value

LSE Cost-Effectiveness

Product Market Readiness

Low

Low

High

Medium

Low

High

High

High

Low

Medium

Medium

High

Value 1: Streamlined Solar/Storage & Backup Power Flexibility

Customer Value Proposition

The smart panel value proposition today is based on integration with solar/storage – **without storage, the product is neither cost-effective nor provides significant value.** A major reason for this is that smart panels provide software-based control over which circuits remain powered during an outage, eliminating the need for a separately wired critical load subpanel.

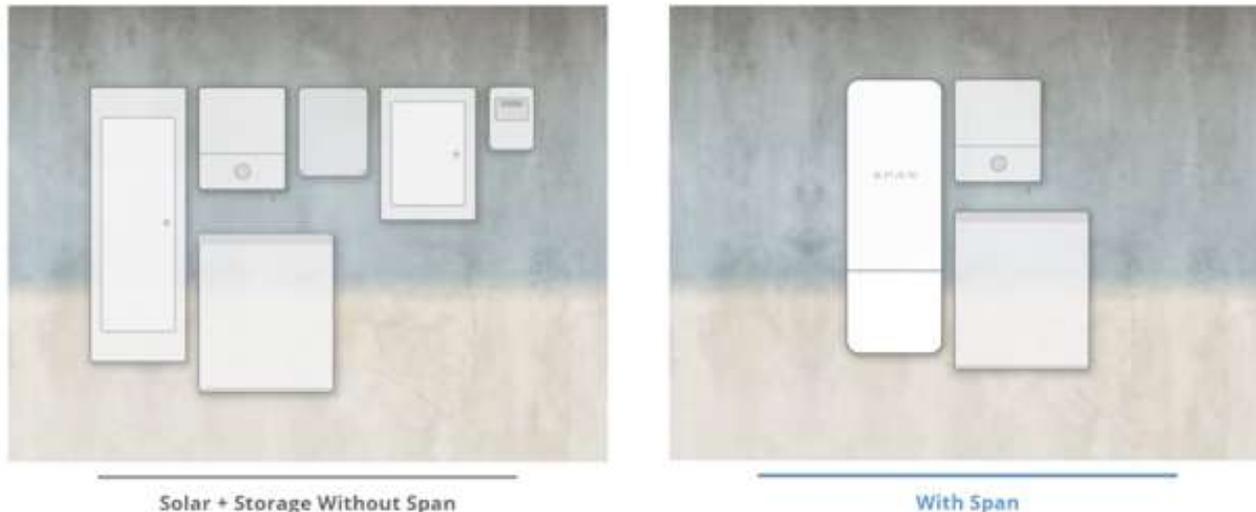


Figure 14: Span reduces hardware required for residential solar and storage

Image source: [Span](#)

- Eliminating the critical load subpanel **simplifies and reduces the cost of installation**
 - Less wiring
 - Less hardware - fewer boxes on the wall, more aesthetically pleasing
 - Per Span, eliminating the parts & labor from the critical load subpanel offsets a significant amount of the smart panel premium
- Smart panels provide **dynamic control of critical loads**
 - Traditional subpanels hardwire the critical loads; if the building or occupant needs change, the panel needs to be rewired.
 - Smart panels can adjust which circuits remain powered during an outage at any time, and even adjust during the outage.
- Provides TOU integration with DERs

Value 2: Energy Management, Monitoring, Metering & Control



Figure 16: Leviton app with smart breakers

Customer Value Proposition

- Insight into end-use electricity consumption (“How much electricity is my washing machine using?”)
- Advanced failure warning (“My refrigerator is not cycling properly. I better call a repairman.”)
- Monitoring home device statuses (“Wait, did I leave the oven on?”)
- Remote breaker control (“Turn the downstairs lights off.”)
- Home security (“I’m not home and someone opened the garage!”)
- TOU/Rate scheduling

Load-Serving Entity Value Proposition

- Better understanding of how customers are using electricity in their homes and MUDs
- Revenue-grade circuit-level metering could allow for rate schedules for dedicated circuits (e.g. EV, solar), facilitate M&V for energy programs
- Knowing about product failures could help LSEs design efficiency programs, collaborate with trade ally networks
- TOU/Rate scheduling

LSE Bottom Line: Most LSEs need a better understanding of how their customers use their product, but there are more cost-effective technologies for this.

Value 3: Building Electrification – Panel Overloading

Deeper residential electrification is limited by infrastructure, both at the building panel and the local distribution node. Upgrading panel sizes can lead to even more expensive distribution upgrades. Smart panels are “Power Management Systems” that can control the amount of power being drawn by each circuit. This means that a smart panel could theoretically support more total connected loads than the amperage for which it is rated, unlocking new electrification opportunities.

National Electric Code (NEC) 625.42 allows for power management systems to add EVSE in excess of the overall panel capacity. How do smart panels differ?

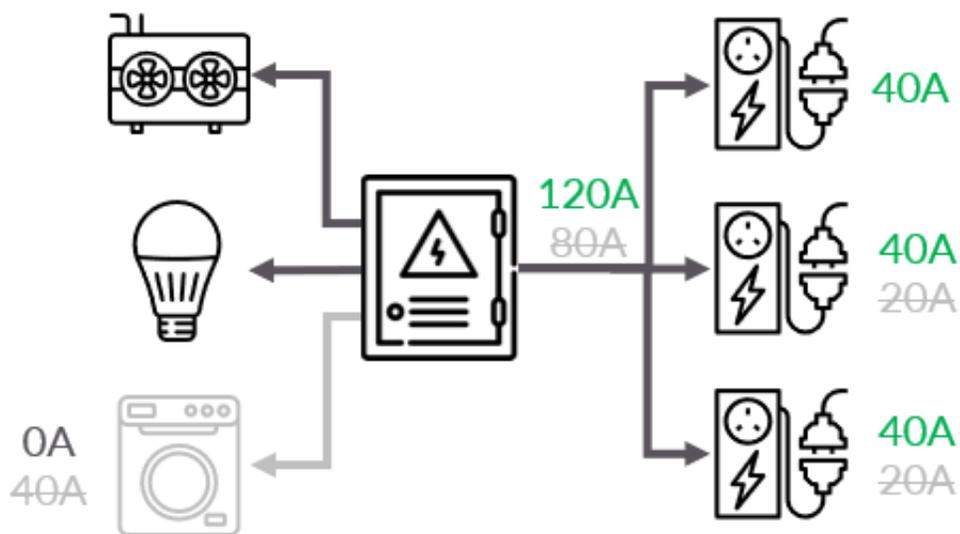


Figure 17: Using a smart panel as a power management system

If a traditional MUD panel has 80A of spare capacity, NEC 625.42 allows 120A (or more) of EVSE to be installed but the EVSE load management system will limit the overall draw to 80A. In this example one L2 charger draws at 40A but the other two are throttled down to 20A each.

A smart panel can determine whether other circuits are in use and potentially redirect extra available power to the EV chargers – if the 40A clothes dryer is off, the bottom two EVSE can ramp up and charge at the full L2 rate. *This is not currently allowed by NEC 625.42, but will be allowed in NEC 2020.*

Value 4: Demand Response

This is not yet commercially available. Residential & MUD demand response (DR) has historically been limited to direct load control of HVAC units. Enabling further loads for DR dispatch typically requires each end-use to be connected, a complex and expensive proposition. Since the electrical panel controls all residential loads, it provides an opportunity to enable more of the building's electrical load for DR.



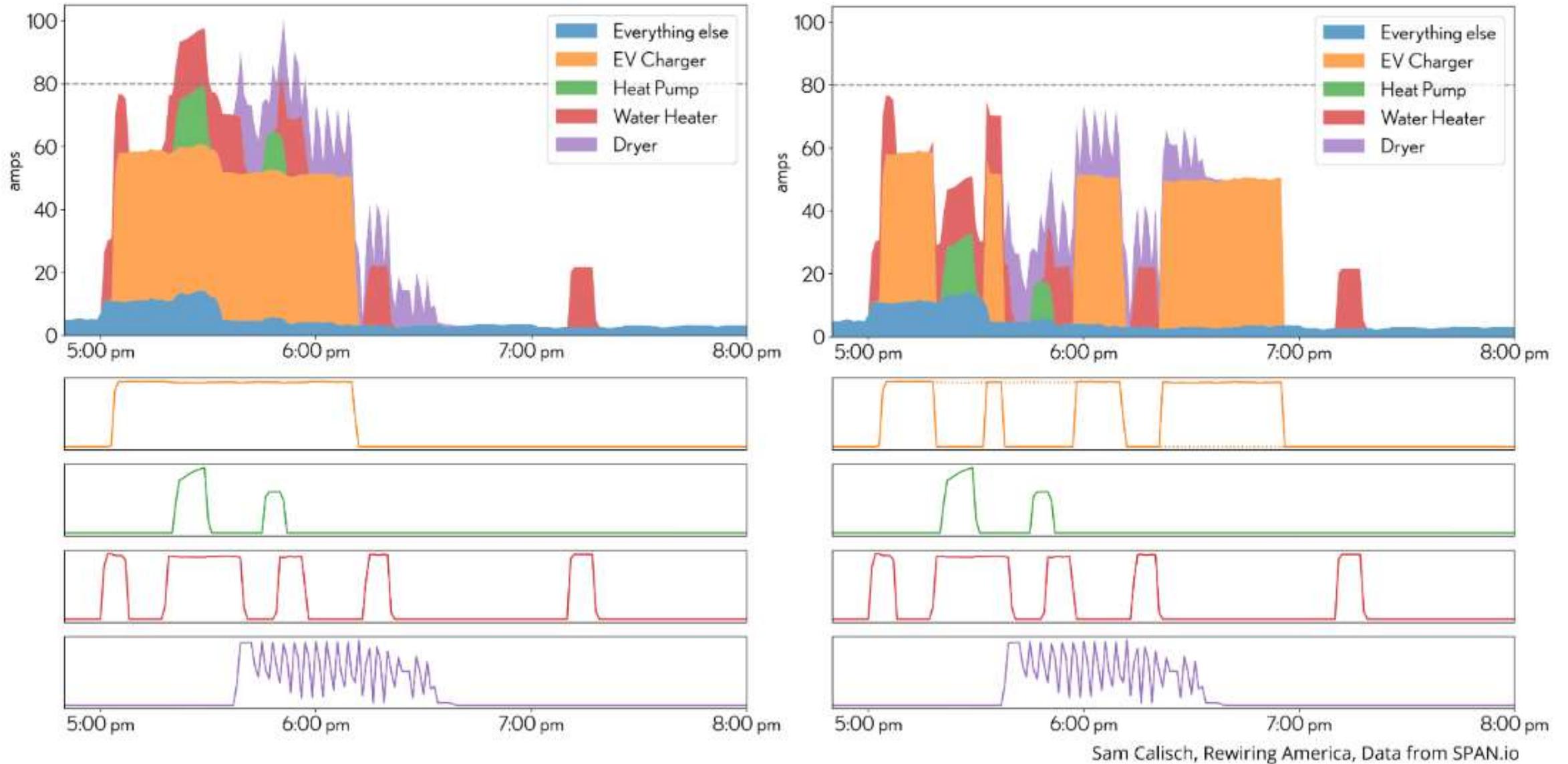
Figure 18: Smart panels can unlock EVs for DR without networked chargers

- **Hypothetical use case:** Installed smart panel is connected to LSE DRMS; during DR events certain interruptible non-critical loads are turned off (pool pumps and EV chargers, not washing machines & ovens)
- Reduces occupant impact from DR by dispatching nonessential loads
- **LSE value:**
 - Flexibility to choose which devices or circuits participate in DR
 - Can ask a larger customer base to shed smaller but less essential loads instead of asking fewer customers to shed more loads and bear negative impacts to occupant comfort or business needs
 - Revenue-grade metering can avoid additional submeter and allowing more seamless customer participation
- **Market readiness level:** **HIGH**. Pilots are underway, no major technical limitations.
- **Current barriers:** Manufacturers will need to pursue OpenADR Certification or other integration with LSE DRMS systems. Eaton's EMCB is integrated with Virtual Peaker but is not OpenADR Certified.

Image source:
[EV Safe Charge](#)

LSE Bottom Line: For LSEs interested in residential demand response, smart panels provide a very compelling opportunity to activate more dispatchable loads without needing to connect with multiple devices.

Smart Panel Load Management Example



Thank you!

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APPENDIX

Atom Power

Solid-State Innovator



Atom Power offers a smart panel for larger facilities utilizing the world's first solid-state circuit breakers.

- **Target Market:** Commercial and industrial
- **Commercialization:** Has only been deployed to evaluation customers – first commercial launch expected end of Q4 2020
- **Technology Details:**
 - Integrated monitoring and ON/OFF control for circuits of interest
 - No need for critical load panel
 - Revenue-grade metering
 - Monitors and predicts battery life
- **Other Capabilities & Benefits:**
 - Solid-state digital breakers close significantly faster than electromechanical breakers for transfer switch applications, making them safer and better equipped for applications such as motors
 - Can account for bi-directional flow of energy with EVs if EVs are properly equipped for VGI
 - Can tether loads (e.g. slow down EV charging if elevator is running)

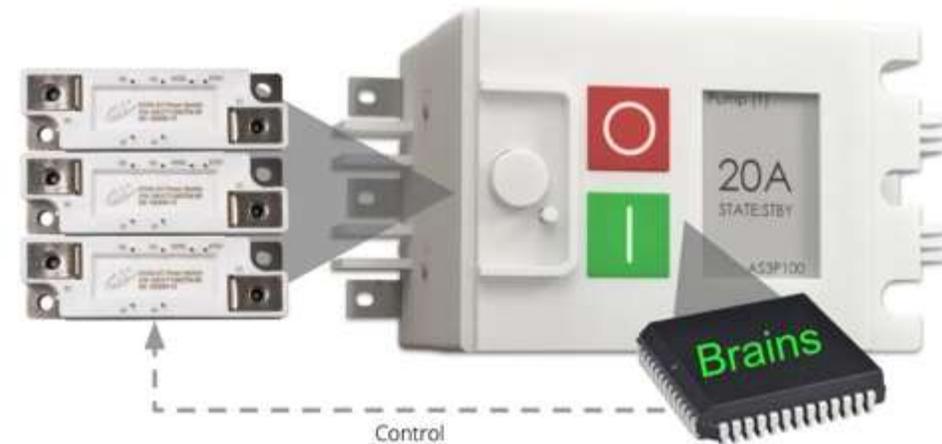


Figure 11: Atom solid-state breaker



Image source: [Atom Power](#)

Eaton – Energy Management Circuit Breaker



A Breaker-Focused Approach

Eaton's smart breakers are a scalable option that help customers monitor and control critical loads.

- **Target Market:** SFH residential and commercial
- **Commercialization:** Deployed product in energy monitoring study w/ 12 US utilities in 2016 – currently have thousands of installations.
- **Technology Details:**
 - EMCBs are compatible with traditional Eaton panels; Eaton hopes to have them work with competitor panels in the future
 - Remote ON/OFF control for every breaker through app
 - Revenue grade metering
 - Customer chooses critical loads to connect to battery
 - Closer monitoring of battery life makes storage last longer
 - No need for critical load panel, installing a few smart breakers may be less expensive than a full smart panel
- **Other Capabilities & Benefits:**
 - Working on DR water heater pilot program with Northeast utility
 - Cold load pickup after power is restored: ensures that when grid power returns that all circuits don't immediately go to a full power draw
 - Frequency response enabled to potentially help utilities balance storage and renewables



Leviton – Smart Load Center



A Solid Offering from an Industry Powerhouse

Leviton's smart circuit breakers are designed for homeowners interested in viewing real-time energy usage and system status.

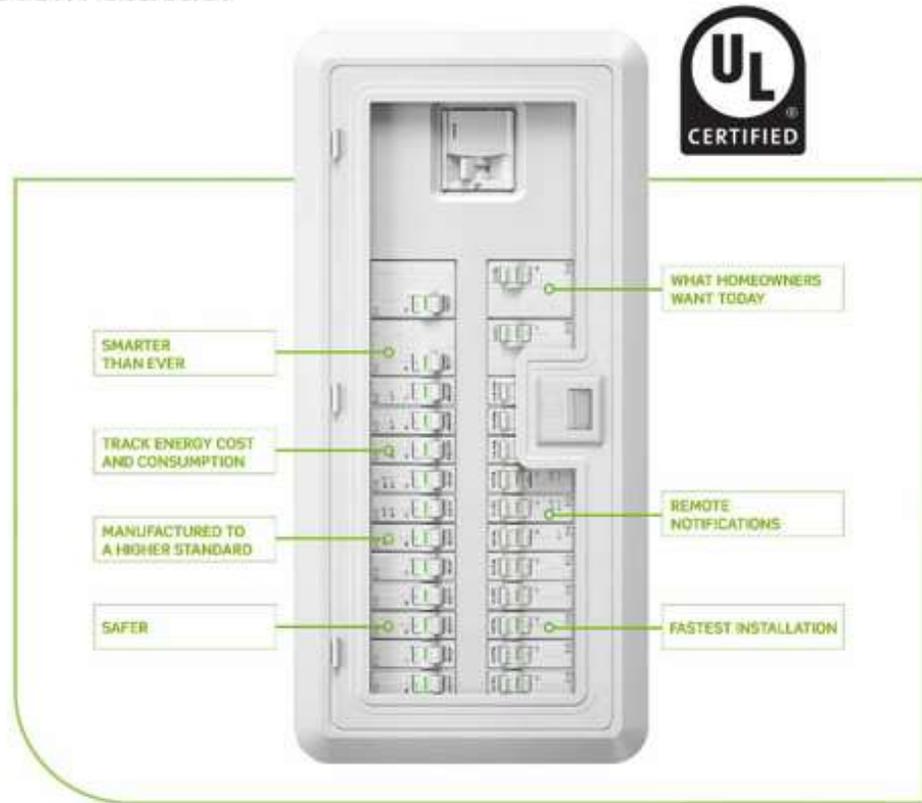


Figure 9: Leviton Load Center with Smart Breakers

Image source: [Leviton](https://www.leviton.com)

- **Target Market:** SFH residential is primary market, MUD capable
- **Commercialization:** Available on the market, unwilling to share number of deployments. Price point \$500 - \$3,000 more than traditional panel.
- **Technology Details:**
 - Able to be installed in existing Leviton load centers
 - Requires installation of individual smart breakers and communications hub
 - Allows for remote OFF control of circuits through app
 - No need for critical load panel, provides flexibility for whole home backup
 - Does not yet have solar PV monitoring functionality, revenue grade metering (+/- 3% currently), or scheduling functionality
- **Other Capabilities & Benefits:**
 - Focused on real-time monitoring of circuits and providing alerts if appliance is not behaving as expected
 - Helps users approximate monthly energy cost

Lumin



A Lesser-Known Retrofit Option

The Lumin device is a hardware add-on to traditional panels to make them “smart” by optimizing home energy storage and adding resilience for customers during outages



- **Target Market:** SFH residential, MUD, and light commercial
- **Commercialization:** “Hundreds” of installations in 32 states, partnering with solar installers. Price point \$2,500 - \$4,500.
- **Technology Details:**
 - Hardware add-on does not require panel replacement
 - Allows for whole home backup by prioritizing critical circuits and also allows for reconfiguration of backed up appliances without rewiring
 - ON/OFF circuit control
- **Other Capabilities & Benefits:**
 - Optimizes solar/storage installation by using solar efficiently, closely monitoring battery life, and providing load control to ensure battery is well below max discharge limit
 - Can detect when appliance is starting to fail
 - Roadmap includes dynamically sensing demand and automatically shedding loads as needed

Figure 12: Lumin add-on panel (lighter grey, below traditional darker grey panel).

Image Source: [Lumin](#)



Schneider Electric



The Sleeping Giant

Schneider Electric did not yet have a residential/MUD smart panel product but expected to launch one in early 2022. When that occurs, their market share suggests they could have a significant impact on the industry.

Current Product: Wiser Energy Monitor

- Not a smart panel/breaker – energy monitor that is installed between the panel and the loads, intended for energy bill monitoring and smart device integration
- Algorithm from startup Sense uses individual device signatures to disaggregate end uses on the same circuit, can provide alerts when appliances turn ON or OFF (garage door, dryer) and monitor solar production

Future Product: SquareD Energy Center (announced Oct. 2020)

- Direct competitor to Span Panel, similar feature set
- Partnership announced with SolarEdge
- Offers EV charging directly from solar
- Sense app for devices, MySolarEdge App for solar/storage



Image source: Schneider Electric

Span.io – Span Panel



The Flashy Smart Panel Startup

Span is designed to streamline adoption of solar and storage. Founded by Arch Rao, the former head of Tesla's energy storage division, it has the biggest name recognition in the market due to its high-profile founder and press in Greentech Media and elsewhere.

- **Target Market:** Single family home (SFH) residences that want to install solar and storage
 - Makes solar and storage more cost-effective by using solar power efficiently and closely monitoring battery life
 - Minimizes the number of boxes (backup panel, meter, switch, gateway, etc.) installed on the wall by integrating equipment into the panel
- **Commercialization:** Currently deploying about 50 installations per month
- **Technology details:**
 - Integrated communications and monitoring
 - Includes autotransformer, inverter, and gateway hardware for adding storage
 - Allows for sub-Hz monitoring of different loads in home, revenue-grade metering
 - Remote ON/OFF control for every circuit through app
- **Other capabilities:**
 - Coincident demand control/scheduling – for example, turn off EVSE if dryer turns on
 - Allows customer to choose and easily change priority for circuits during outages
 - Potential for circuit control sharing with utilities for DR and frequency regulation (balancing solar and storage on the grid) and reverse power flow (vehicle to grid)



Figure 8: Span panel hardware

Image source: [Span](#)