AFFORDABLE HOME ELECTRIFICATION: AVOIDING ELECTRIC PANEL AND SERVICE COSTS

PRESENTERS

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LEARNING OBJECTIVES

At the conclusion of this session, participants will:

- Identify the potential costs associated with panel and service changes

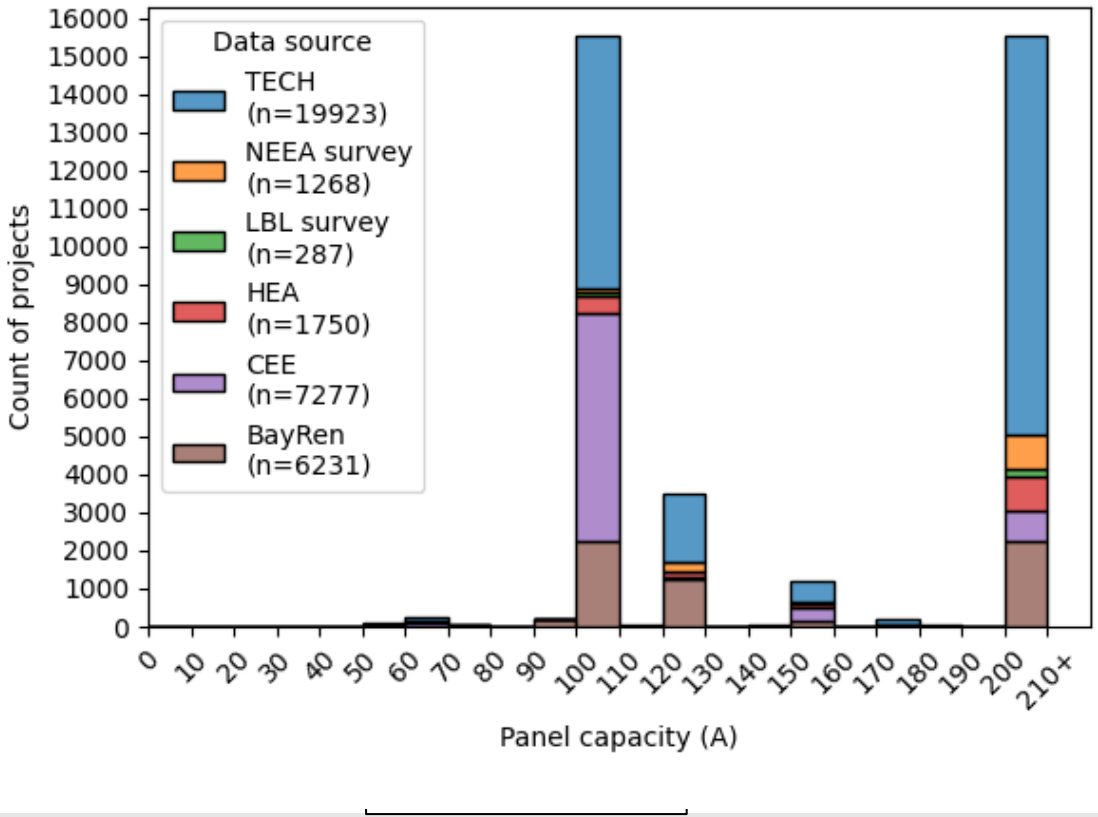
- Understand solutions for avoiding electrification challenges

- Improve understanding of current electric code requirements and how best to use existing codes

- Understand potential applications of emerging technologies when electrifying homes

Panel Amperage and Replacement Costs

Installed Panel Capacity in US Homes



Smaller panels in:

- Older homes
- Smaller homes
- Gas appliances

Important regional variation

VERY few panels <100A or >200A

WHY NOT JUST REPLACE ALL THE 100A PANELS?

What does it cost?

Depends on location, need for panel relocation, underground service drop, and home modifications

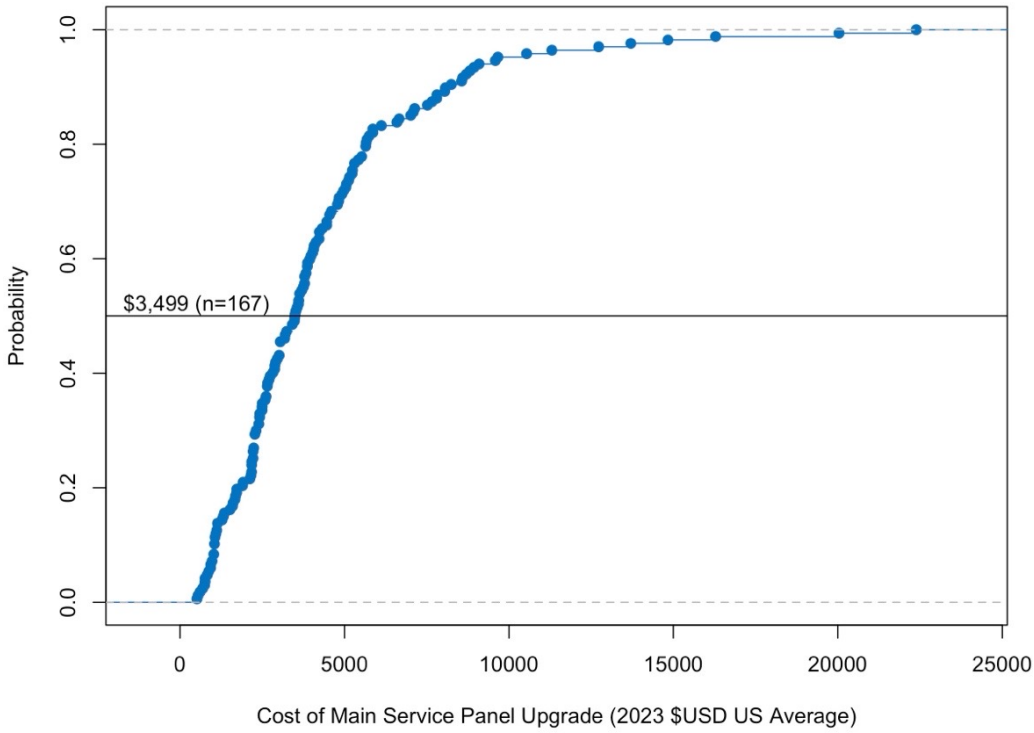
- Panel: $3,500 ($1,000-$5,000)
- Circuits: $1,384 ($500-$1,500 each)
- Service: $1,000-$25,000
- National cost (very rough): $250 billion

Time delays

3-6 months project delay each upgrade
Shortage of skilled electrician workforce
>1-year lead time on transformers
Utility might reject your interconnection

Additional ratepayer costs

- Utility distribution system upgrades + New generation/storage



WHY NOT JUST REPLACE ALL THE PANELS?

Triggers rewiring: knob and tube replacement

Another $10,000-$30,000

SOMETIMES REPLACEMENTS ARE NEEDED

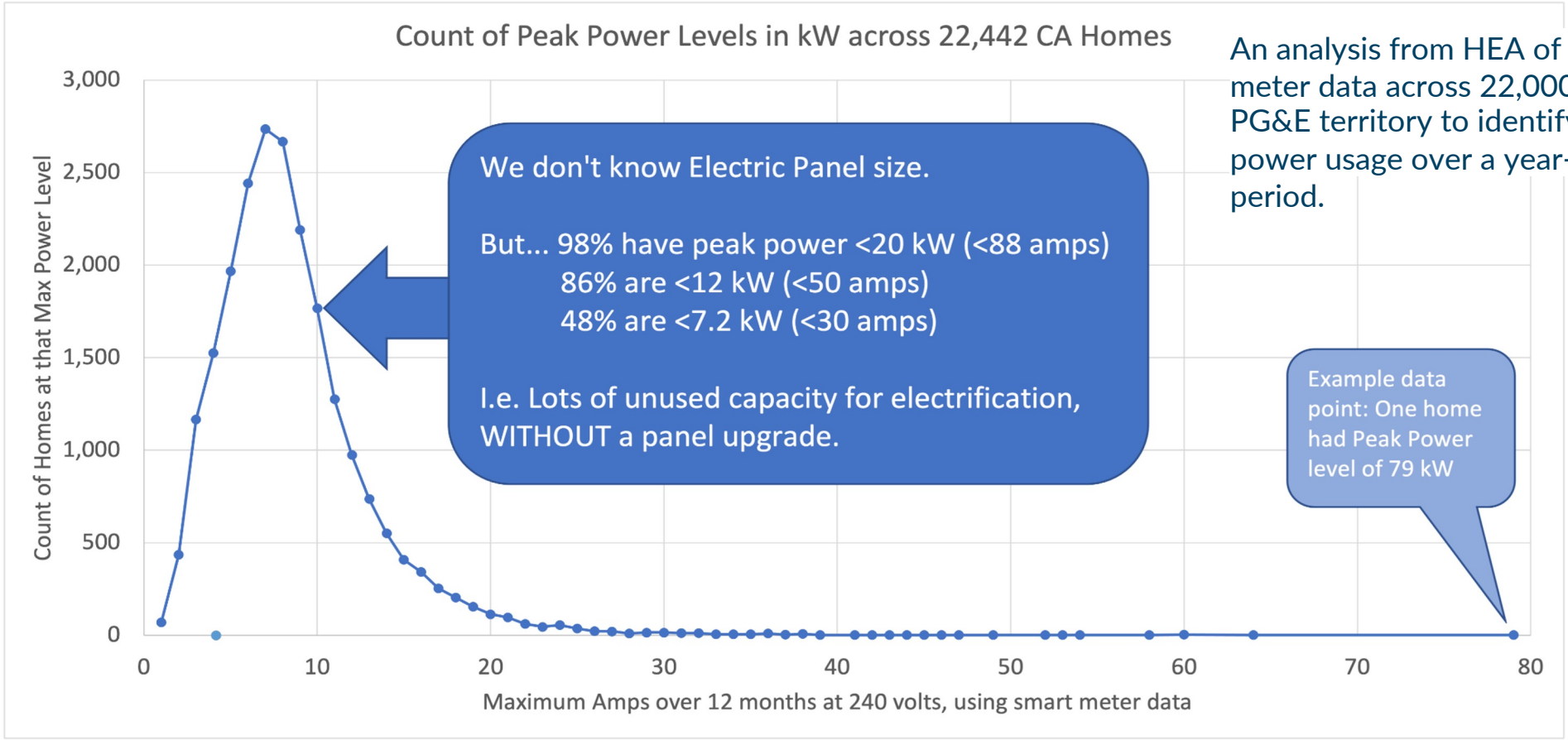
Old, unsafe or damaged panels

Fuse Boxes

Zinsco/GTE Sylvania and Federal Pacific panels have dangerous design flaws and should be removed

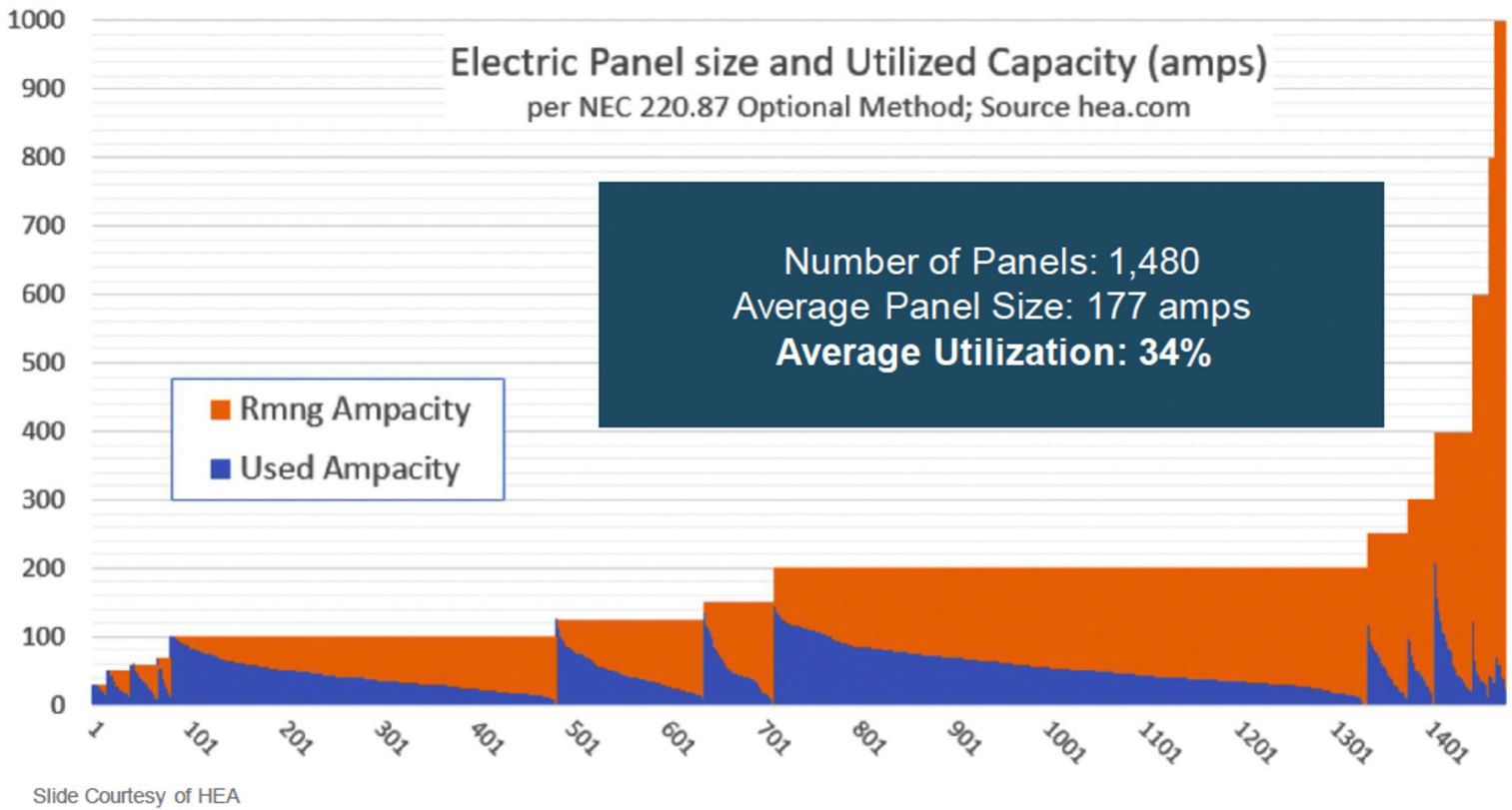
Fitting new loads onto existing panels - Amps and physical space

CALIFORNIA SMART METER DATA – PEAK DEMAND



An analysis from HEA of smart meter data across 22,000 homes in PG&E territory to identify peak power usage over a year-long period.

CALIFORNIA SMART METER DATA – AVAILABLE CAPACITY



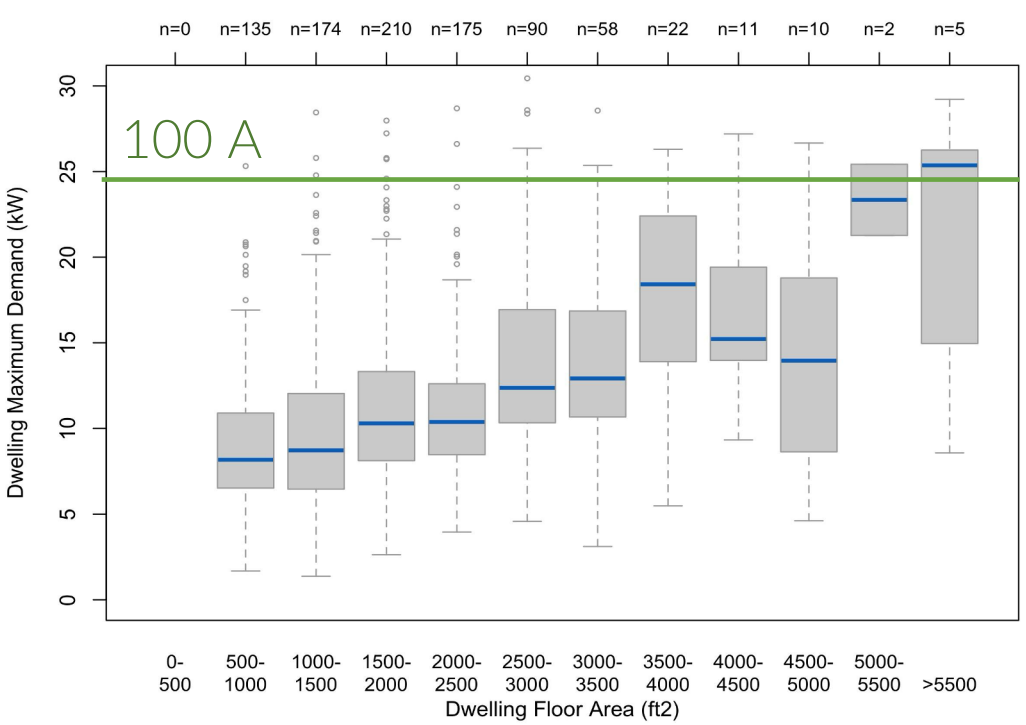
Slide Courtesy of HEA

*Not a representative sample of all CA homes, and mix of all electric and electric + gas.

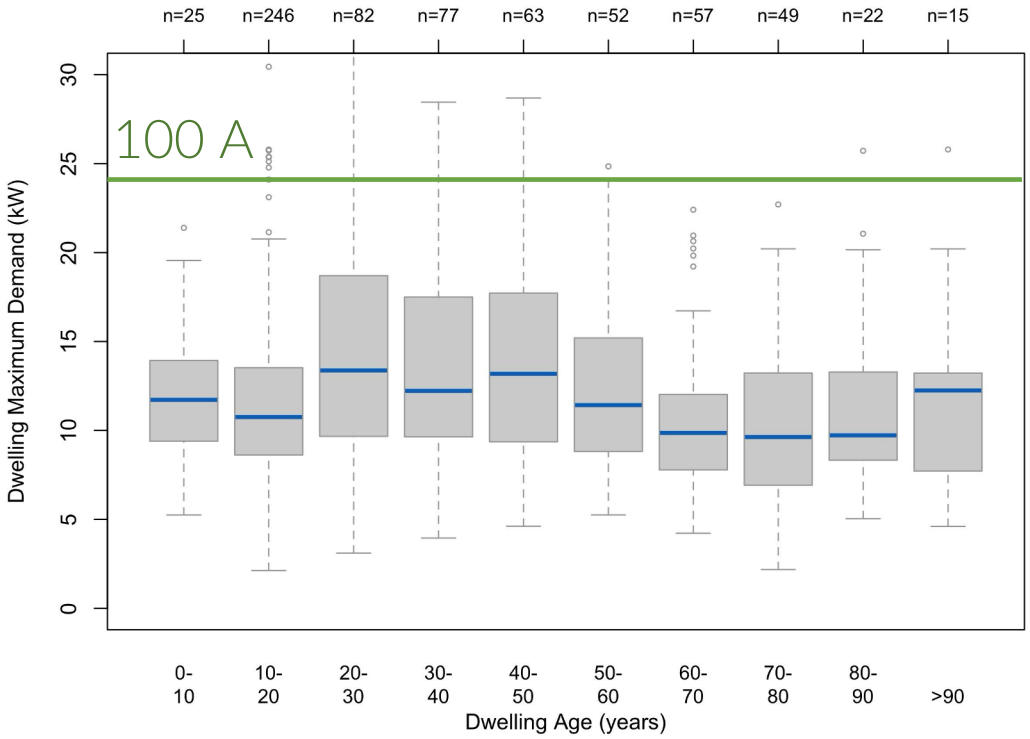
Source:
HEA, HomeIntel

HIGHEST 15 MINUTE DEMAND

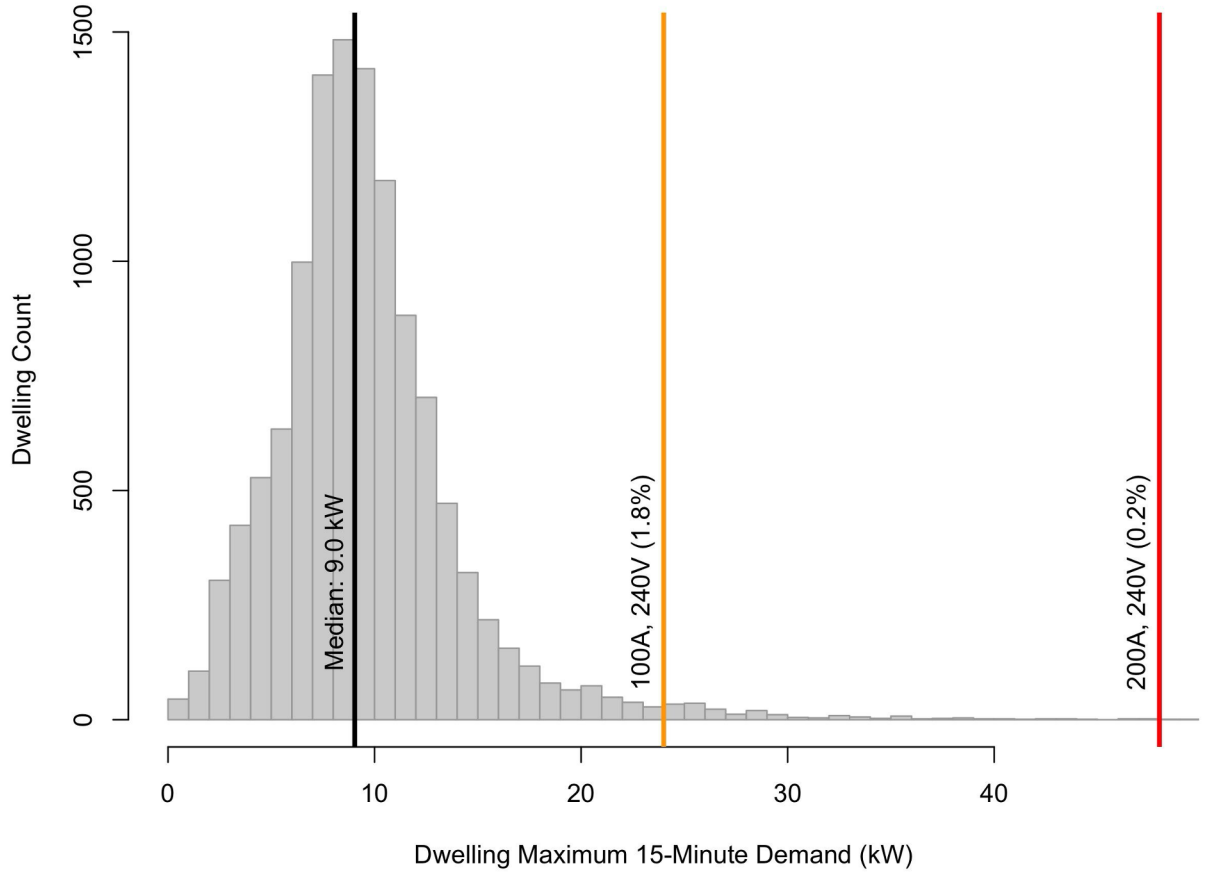
Bigger homes have bigger peak



Age doesn't matter

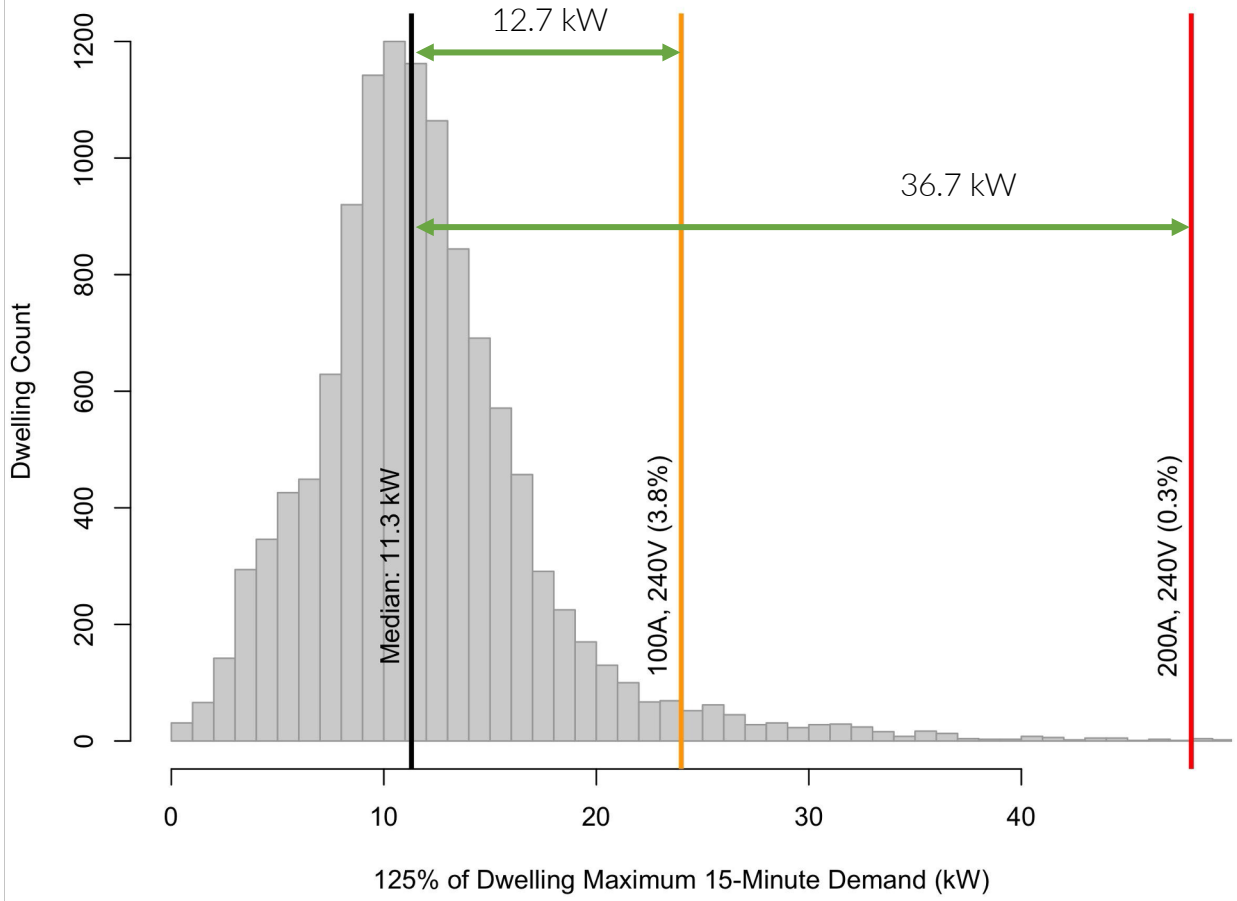


HIGHEST 15 MINUTE DEMAND



Vast majority of homes never exceed 100A

AVAILABLE CAPACITY FOR ADDING NEW LOAD?

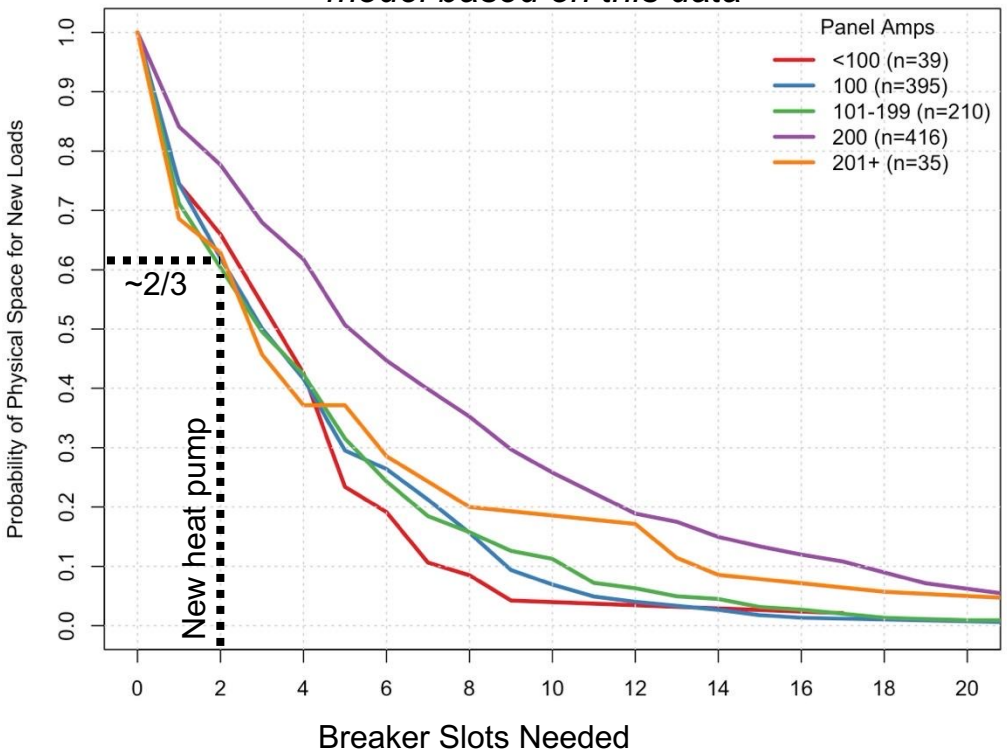


NEC Load is peak demand x 125%

Vast majority have lots of spare power

BEYOND AMPS – SPACE FOR BREAKERS?

From BayRen data and LBNL survey.
We are building a more detailed predictive model based on this data



NO SPACE

LOTS OF SPACE

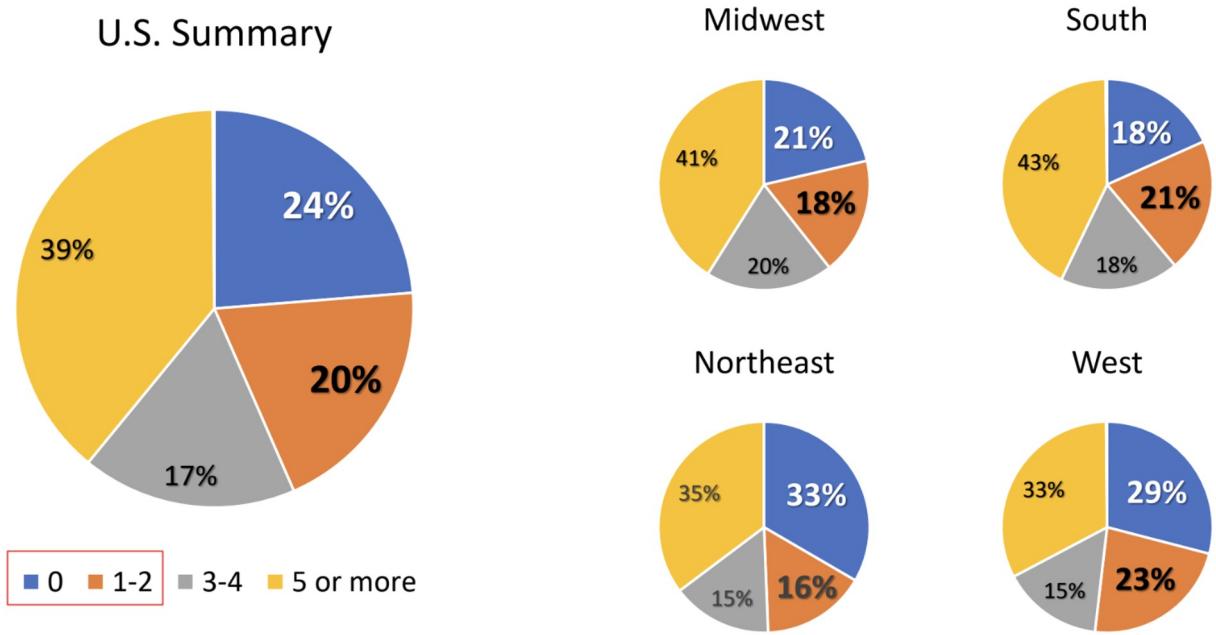
BEYOND AMPS – SPACE FOR BREAKERS?

EPRI Study of Electrical Panels in US Homes

By Doug Lindsey

How many open breaker slots does your panel have?

n=2,950



44 % of households have two or less open breaker slots

Panel replacements and what drives them?

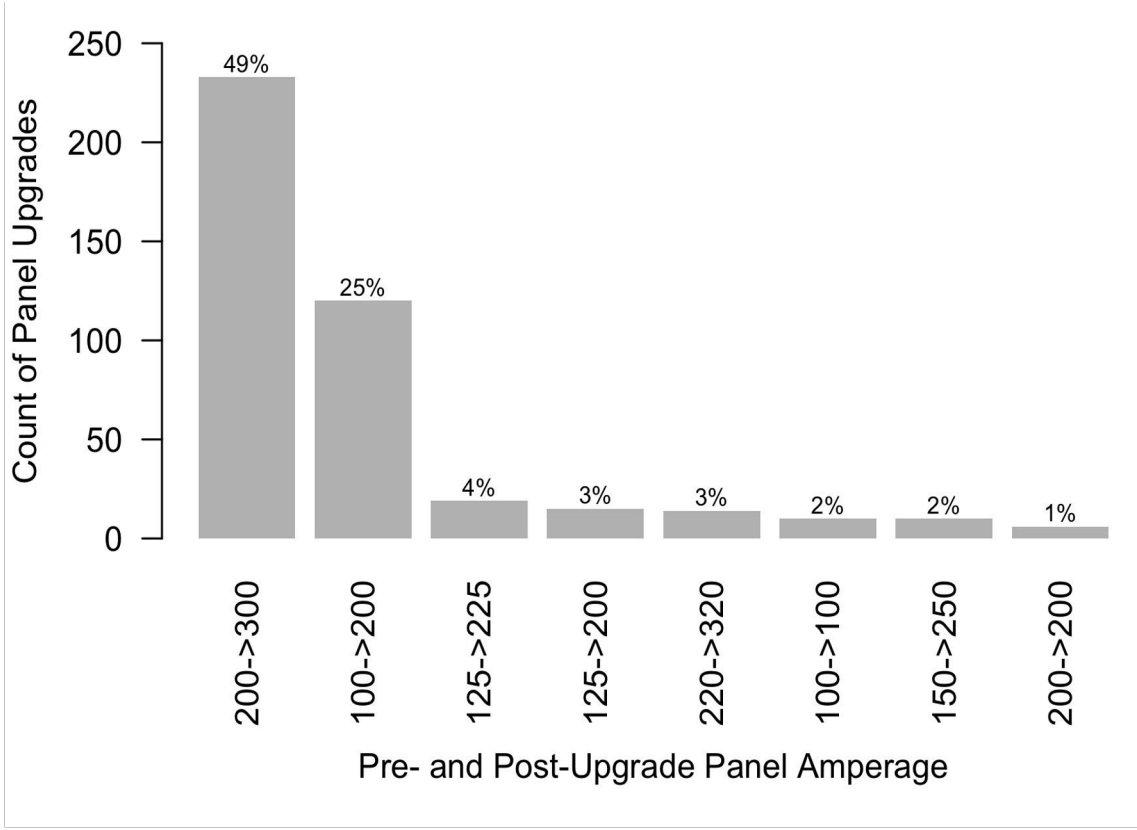
HOW FREQUENT ARE PANEL UPGRADES WITH HEAT PUMPS?

TECH Clean California

- 6% of 21,146 heat pump projects replaced panels
- Most panel upgrades were from 200A to 300A
- Smaller set of upgrades were from 100A to 200A
- More replacements with heat pump water heaters, in part due to incentive structure

Cadmus ccASHP study found

- 8% service panel replacement
- 10% subpanel installs
- 1% utility transformer replacement



VERMONT HEAT PUMP PROGRAM

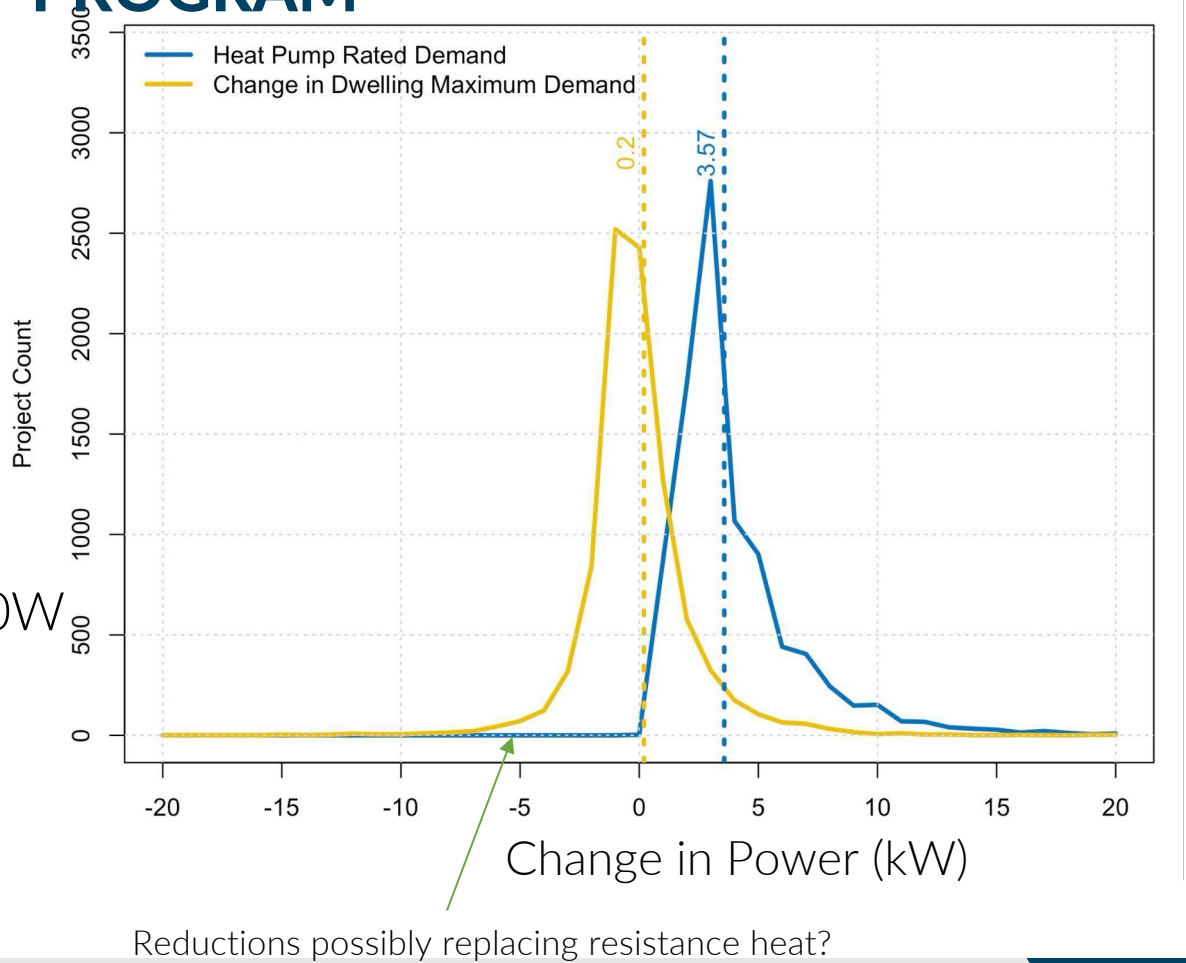
~10,000 homes in Vermont program installed cold-climate heat pumps

15 minute electric power before and after adding heat pumps

Mean nameplate rating 3.6 kW

Average addition to peak demand 200W

Heat pumps don't contribute much to peak?



Reductions possibly replacing resistance heat?

INDIRECT SUB-METERING

~1,000 homes (TX, CA, NY, CO)

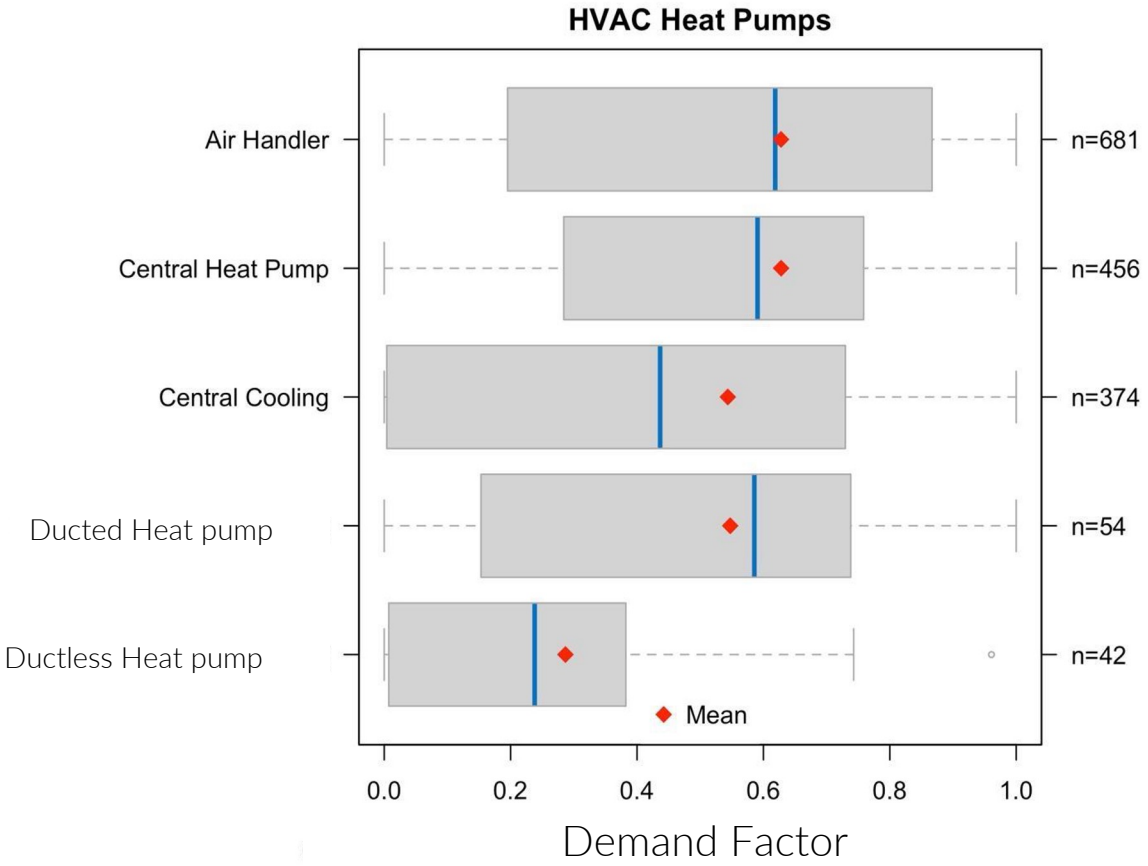
15 minute electric power for every circuit

Uses sub-metered heat pump loads to estimate contribution to peak

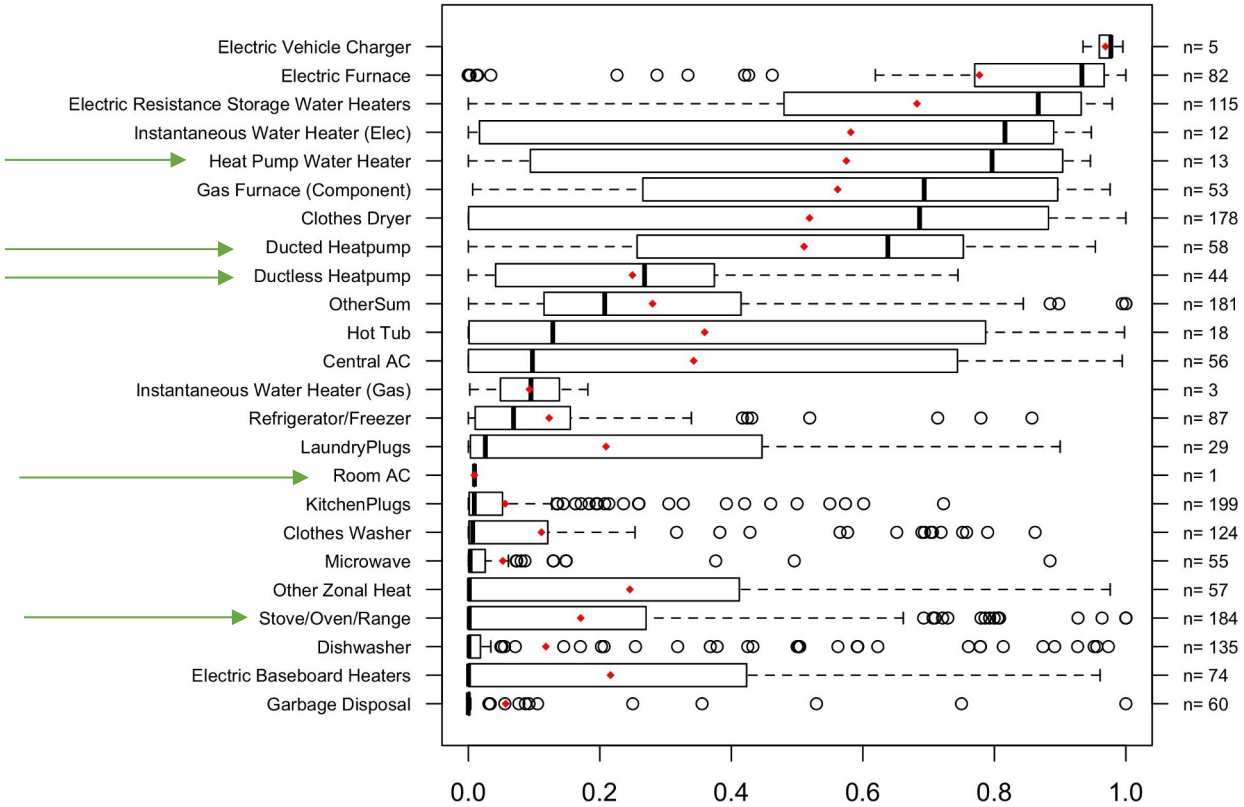
Demand factor = fraction of nameplate load that heat pump contributes to home peak

20-60% of rated power added to peak

Not as small a contributor as VT homes



HOW MUCH DOES EACH END USE CONTRIBUTE TO THE HOME PEAK?



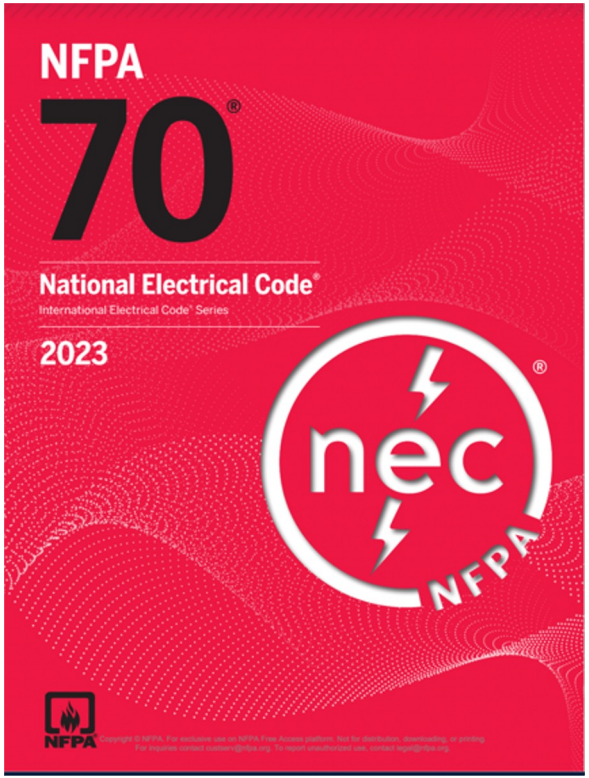
End use load during home peak load/End use peak load

When the Home Peaks, the EV charger or Electric Furnace is on + big electric resistance devices

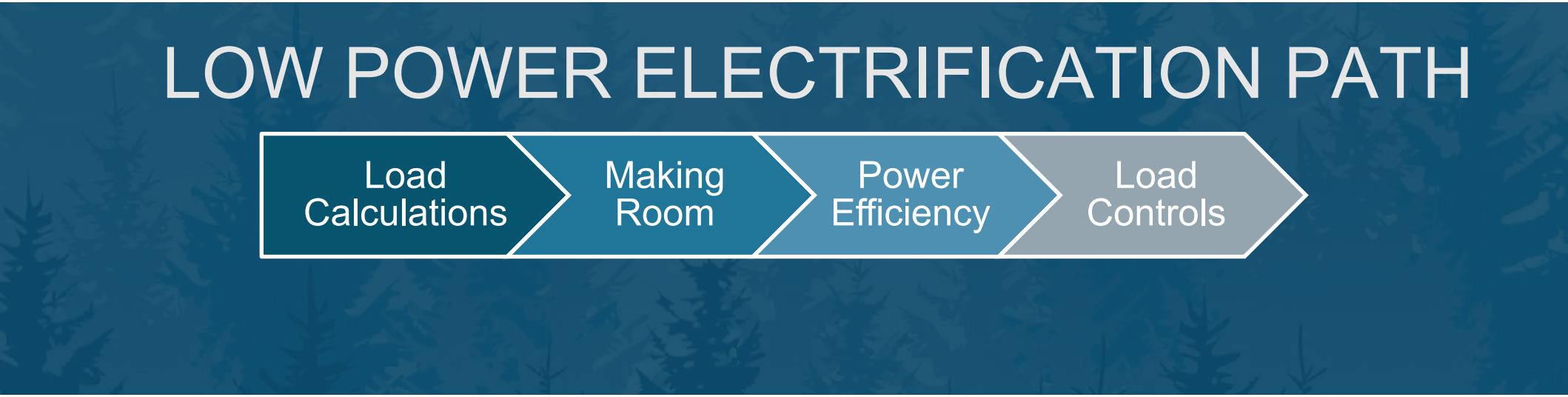
When the Home Peaks, the plugs and many other loads are off

WHAT IS DRIVING PANEL REPLACEMENT AND SERVICE CHANGES?

1. Reports from utilities: Current main drivers are adding Solar PV and EV Charging
2. Simplified approaches by electricians
    - Not using existing paths in the National Electric Code, e.g., using metered data
    - Profitable upsell?
    - Habit/comfort
3. NEC unclear and not developed with home electrification in mind
4. Local code authorities unprepared
    - Some will not allow circuit sharing or smart panel controls



Avoiding panel and service replacements



USE EXISTING METHODS IN NEC

NEC 220.87 – metered data

- Existing loads based on metering data (15 minute)
- Total load = (Metered Load) x 1.25 + New Load at 100%

We are working on improvements: based on measured load coincidence + adding a 60 to 15 minute converter so we can use smart meter data

NEC 220.83 – sum connected loads

- Existing loads = sum of connected loads with different treatment when adding HVAC
- No New HVAC: 100% of first 8,000 watts + 40% of remaining loads (including heating and cooling)
- New HVAC: 100% of first 8,000 watts + 40% of remaining loads + max(heating, cooling)

THE WATT DIET CALCULATOR

https://www.redwoodenergy.net/watt-diet-calculator

Watt Diet Strategies

Basic strategies for avoiding an electrical panel upsize can include:

01 - Select appliances that combine two functions into one machine

For example, the kitchen range (combining an oven and cooktop in one slide-in appliance), which lets us avoid a separate high power circuit for wall ovens. Another example is a combined washer/condensing dryer machine that lets us avoid needing a circuit for the clothes dryer.

02 - Select power efficient versions of the appliances

Choose the 15-amp version of a heat pump water heater instead of the 30-amp nearly identical version. Selecting high performance, power sipping versions of heat pumps instead of lower performance versions. Select power efficient and energy efficient heat pump dryers if you want a separate clothes dryer.

03 - Reduce heat loss and cooling loss by insulating and air sealing

04 - Use prioritized circuit sharing devices

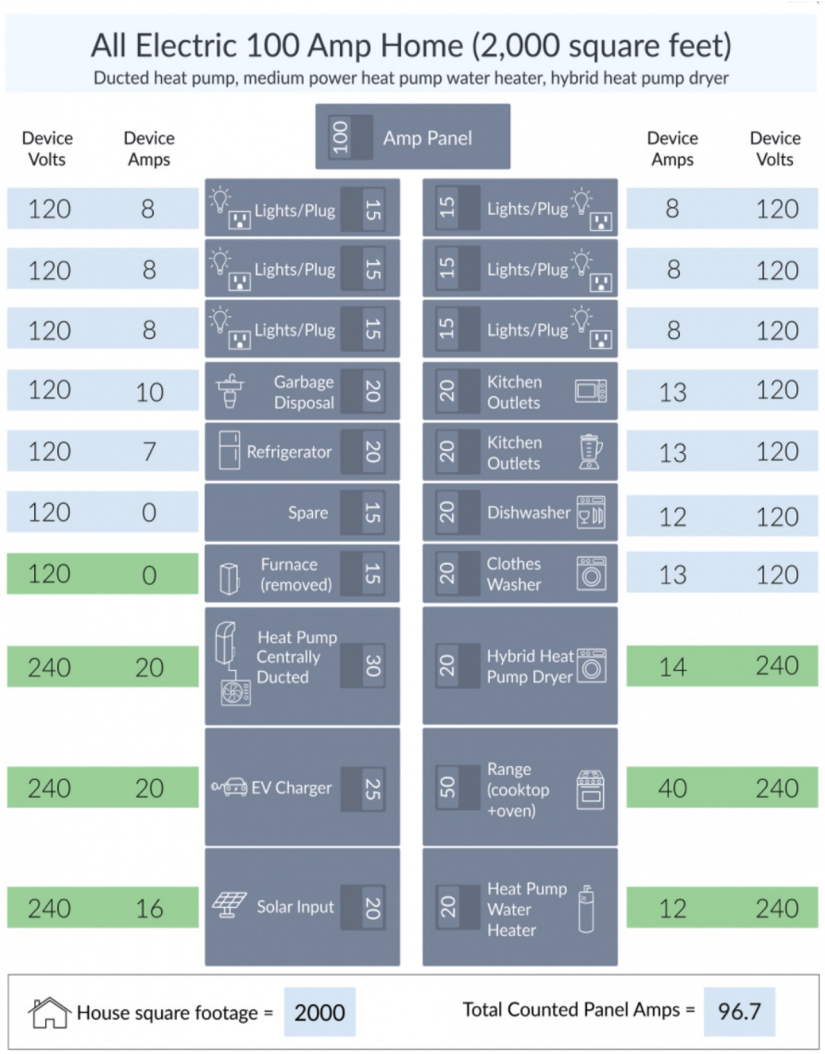
These handy devices can automatically pause car charging while other appliances, like the dryer, finish.

05 - Use EV charger pausing circuits

These briefly pause EV charging if many devices are on at once and the main breaker is at risk of popping.

06 - Avoid overkill in your EV charger settings.

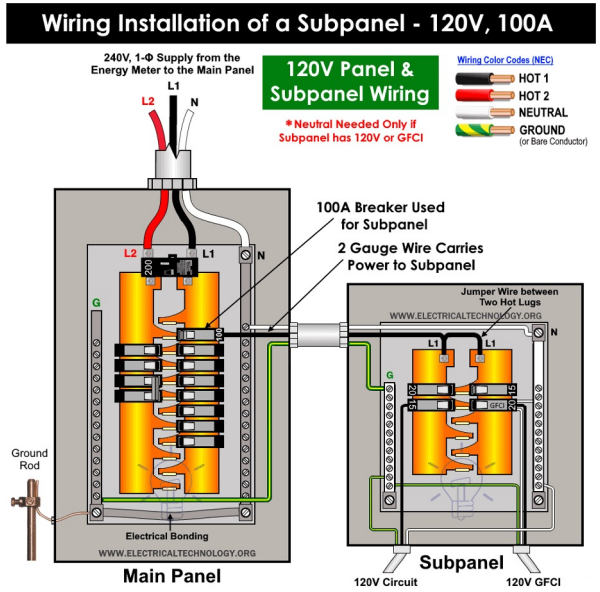
For example, pick a 20-amp or 30-amp outlet for your EV charging and avoid 50-amp chargers at home. A 20-amp outlet can deliver 100 miles of charge overnight and more than 50,000 miles of charge in a year. Bigger car batteries don't require bigger circuits; they give you flexibility about when you charge.



Source - Tom Kabat & Sean Armstrong

SOLVING THE ”NO SPACE” PROBLEM

- Meter collars or Dual Lug for meter socket connects prior to the main breaker for additional connections.
- Tandem, triplex or quad breakers
- Re-organize general lights/plugs circuits
- Combined appliances
- Low-power appliances
- Sub-panels
- Circuit sharing/splitting



Solutions for Avoiding Panel and Service Upgrades

Smart Electrical Panels

$3-5k + install

Most complicated and flexible

Circuit Sharing

$300-600 + install when hard-wired

Least complicated, sometimes DIY

More frequent operation

Others

Low Power Appliances

Meter collar solutions

Smart circuit breakers

Circuit Pausing

$400-900 + install

Medium complicated, requires CTs

Infrequent operation

LAUNDRY APPLIANCES

Description	*Volts*	*Amperage*	*Volt-Amperes*	*Retail Price*
Resistance dryer, vented	240	24	5760	$832
Heat pump dryer, unvented	240	5	860	$1,412
Resistance dryer, unvented	240	11.0	2640	$1,299
Washer/dryer heat pump combo, unvented	120	13.1	1575	$2,042
Fuel-fired dryer, vented	120	6	720	

COOKING APPLIANCES

Type	*Retail Cost*	*Connected Load kW*	*MCA x Volts*
Induction range	$2,106	12	9,600
Electric range	$1,042	11.8	9,600
Wall oven, single	$2,218	4.5	2,400
Wall oven, double		8.2	9,600
Electric Cooktop	$1,086	8.5	8,400
Induction cooktop	$2,205	8.4	5,657
Battery-integrated induction	$5,500	1.8	1,800

Battery Integrated Stoves

Channing Street Copper

Impulse Labs - $5,500

WATER HEATING

Type	*Volts*	*Power (kW)*	*Gallons*	*Retail Cost*
Heat pump water heater (shared circuit and dedicated circuit)	120	1-2.3	40	$2,041
			50	$2,099
			65	$2,499
			80	$3,000
Heat pump water heater	240	4.5	40	$1,672
			50	$1,834
			65	$2,078
			80	$2,843
Resistance water heater	240	4.5-5.5	40	$563
		4.5-5.5	50	$644

Smart Electrical Panels

- Highest cost and highest effort, $3,000 - $5,000 + installation
- Most flexible solution, appropriate for energy management:
  - Optimizing self-consumption, TOU pricing
  - Management of back-up and renewable resources
  - Load prioritization
  - Smartphone / web interface
- Often not necessary to electrify!
- Some jurisdictions do not allow these to be over-loaded and controlled as an EMS.
  - Needs UL listing and way to stop consumers from changing critical settings.

Square D Energy Center

Span Panel

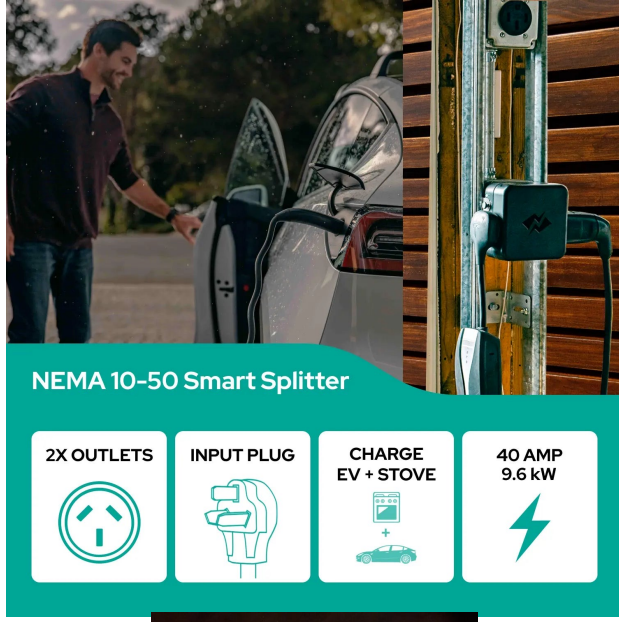
Koben Genius

No over-current protection

Lumin Smart Panel

Circuit Sharing

- Two loads are placed on same circuit and controlled to not operate at the same time
- Only larger of two loads included in electrical load calculation (NEC Section 220.60)
- Low-cost, sometimes DIY solution. $300 - $600
- Saves physical panel space and panel load
- What loads to share/split?
  - Two EV (most common)
  - EV and dryer, cooking appliance or water heater
- How often does sharing occur?
  - < 1% of hours. Outliers might be 5-10%



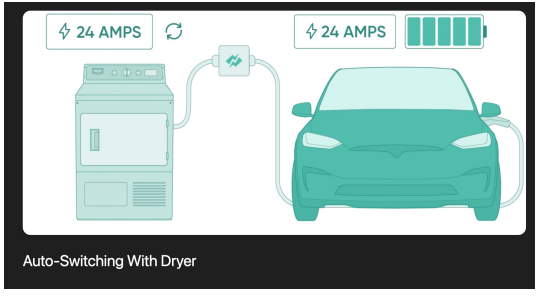
Circuit Sharing

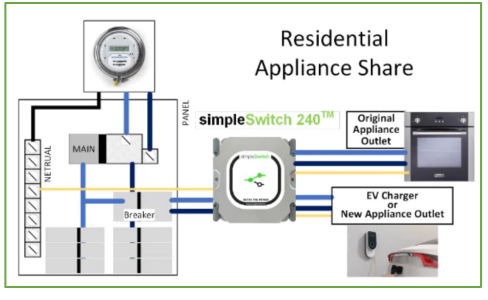
Plug Sharing (sometimes DIY)

- Existing 240v receptacle near new load
- Example: *Existing dryer outlet in garage + new EV in garage*
  - *Neocharge*
  - *Split Volt*
  - *BSA Dryer Buddy (not DIY)*

Circuit Sharing (not DIY)

- Hardwired or plug 240v loads
- Not necessarily co-located
- Like a “smart junction box”
- Example: *Existing DHW in basement + new EV charger in garage*
  - *BSA Intellisplit*
  - *simpleSwitch 240*



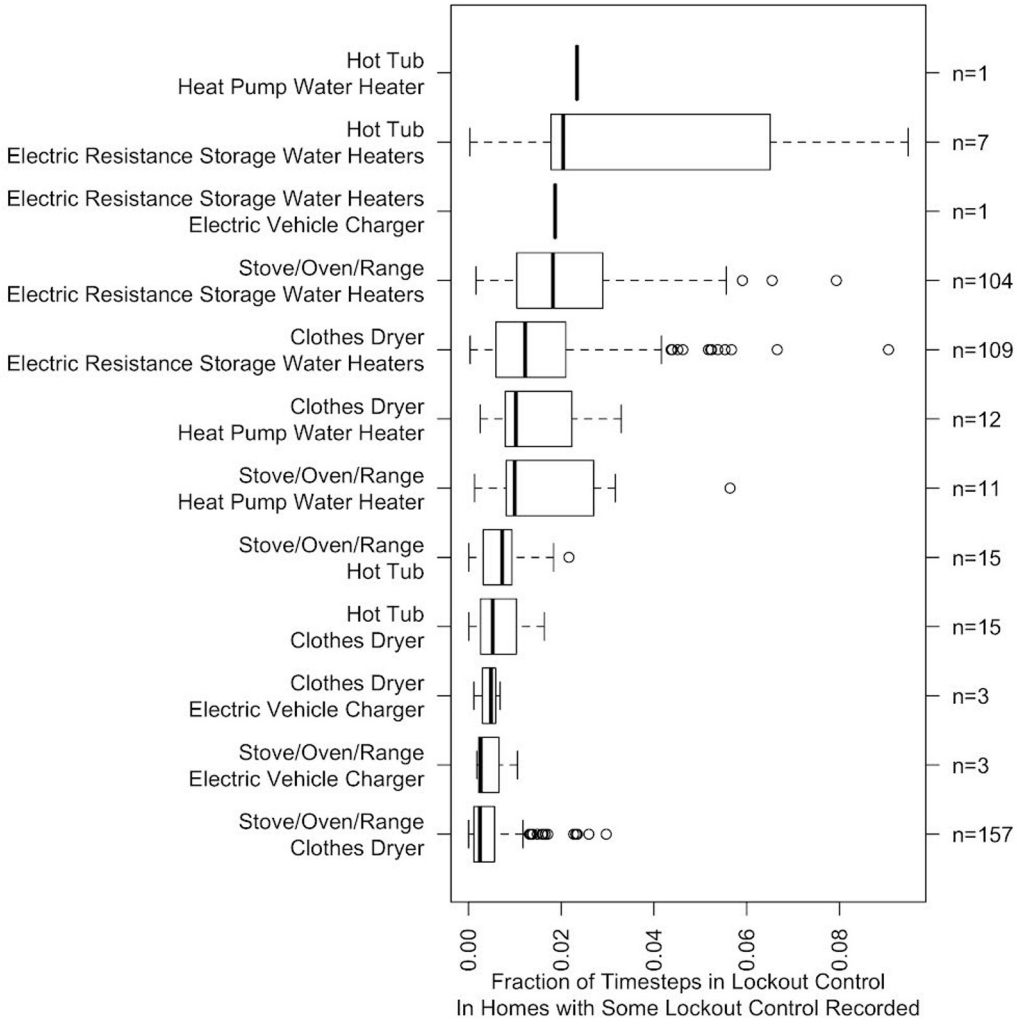


CIRCUIT SHARING POTENTIAL

15 minute data from 1300 homes from NEEA study

If high power devices share a circuit how often would one have to be switched off?

Usually 1% or less coincident

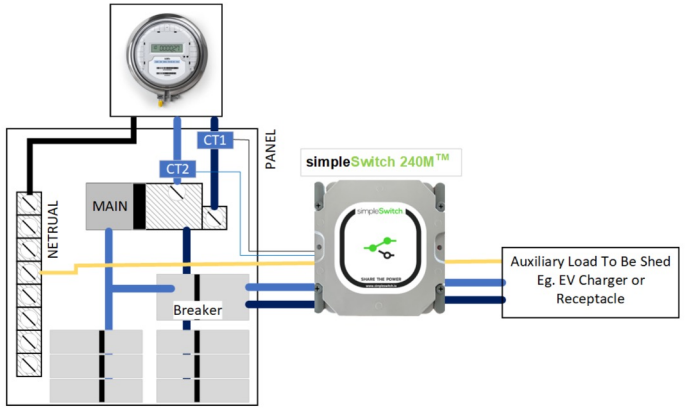


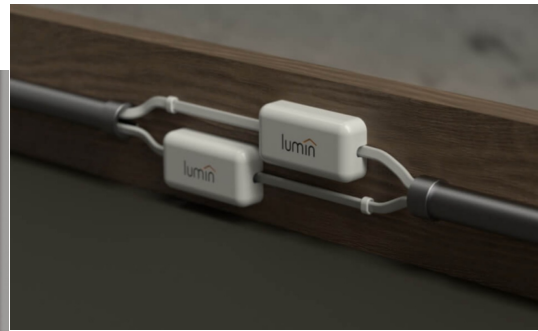
Circuit Pausing & Controllable Breakers

- Control relay for circuit communicates with metering placed on the mains or feeder, turns load off (or down) at 80% of rated capacity.
- Load maybe treated as 0 in NEC electrical load calculations
- $400-900 + installation
- Installation is more complex/$ due to installing CTs
- Saves panel load, does NOT save physical space

- Examples:
  - Lumin Edge
  - Savant Power System
  - simpleSwitch240 with CTs
  - Wallbox EV charger
  - DCC-12, EV Energy Management System
  - Span Drive EV charger

One set of CTs and multiple loads





METER COLLARS BYPASS INTERNAL BUSBAR CURRENT LIMIT

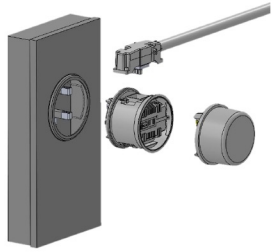
EXISTING PRODUCT - SOLAR

- Solar Adapter
  - UL Listed (414 - Meter Sockets)
  - 5 mins to install, 30 mins to interconnect
  - 200A continuous rating, utility power
  - 80A continuous rating, PV input (15kW)
  - Integrated PV breaker
  - Optional smart module – RGM and cellular comms
  - Approved in 20 states
  - 15,000 units installed

ConnectDER 6

WE TURNED THE METER SOCKET INTO AN ELECTRICAL OUTLET

Our simple, affordable, and universal meter adapter works on virtually every home and eliminates the need for service panel connections or replacements



Plug-in adapter uses meter socket instead of the service panel

ConnectDER 4

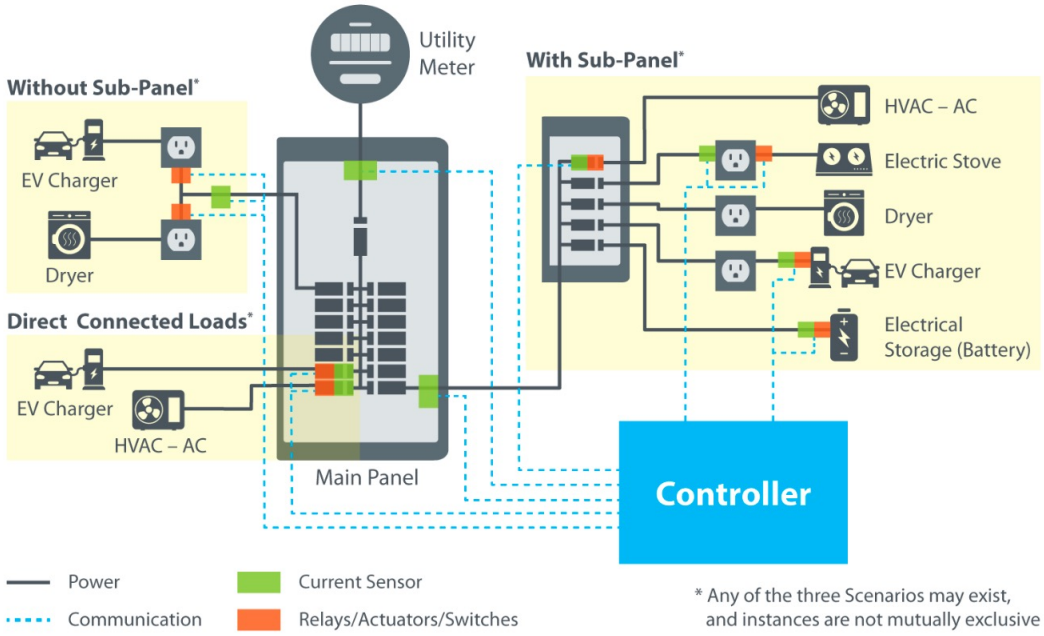
Solutions and opportunities for innovation

Future Innovations

- Integrated control platforms that address and control all levels of the system, including appliances, branch circuits and panel boards.
- Power distribution and allocation determined by available panel capacity.
- Load control with modulation capability.
- Communication-ready appliances and equipment.
- Devices that can be paused mid-cycle and then resumed seamlessly.
- Load control solutions that can respond to local grid conditions.
- Database for “power rating” of appliances similar to “energy rating”.

Digital Capacity Management – A Possible Solution?

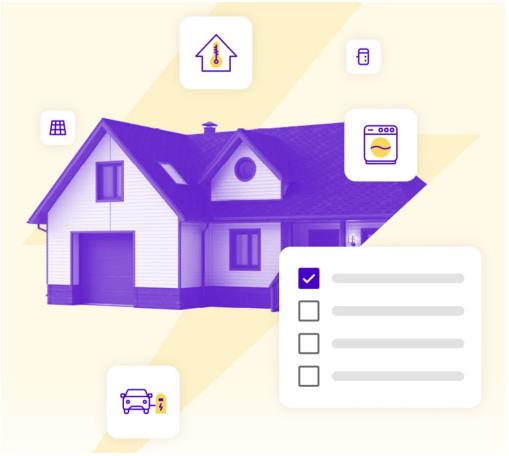
- A novel system to depower non-critical loads when an electrical panel capacity limit is neared or breached, before the circuit overcurrent protection trips any breakers.
- Sensors and controllers can be in the circuits or in the appliances; a simple communication hub will be needed.
- A future open technology standard for manufacturers to create interoperable devices, as they do for many IT ecosystems.



Concept diagram of the digital capacity management solution for powering and controlling large electrical end uses with different configurations

Future Work

- Least cost panel optimization in the US housing stock using ResStock
- Guidance and software planning tools for contractors and homeowners for easy electrification
- Field and lab evaluations of low power electrification approaches
- DOE EAS-E prize
- Rewiring America Planning Tool (homes.rewiringamerica.org/personal-electrification-planner)



Summary

PANEL AND SERVICE REPLACEMENT: ITS NOT AS BAD AS WE MIGHT THINK?

Not an issue for already electric homes

A lot of homes have plenty of capacity

Utilities should make peak demand and service rating data available

Big energy users and CO_2 emitters (heating and hot water) are not driving peak loads, panel and service replacements

Big drivers are EV charging and Solar PV

THERE ARE TECHNICAL SOLUTIONS NOW AND MORE COMING FOR LOW POWER ELECTRIFICATION

Essential to avoid costly grid infrastructure

Limit EV's to 7.2 kW

Low power 120V appliances (some with battery/thermal storage)

Meter collars, circuit sharers, circuit pausers, smart panels

The NEC has approaches we need to popularize (e.g., "Watt Diet") and is (hopefully) going to get better

Coming soon: battery integrated appliances: low input power + high output power when needed

REMAINING CHALLENGES

Getting local authorities to allow low power electrification technologies

Persuading electricians to NOT do panel replacement work

Getting utilities to support lower infrastructure costs/profits

Changing rebate programs to encourage low-power electrification instead of high-power

New technology adoption: e.g., batteries

QUESTIONS?

THANK YOU

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https://www.nrel.gov/buildings/