



NHPC'23

SEATTLE

CONFERENCE PARTNERS:



April 17-20, 2022 | Seattle, Washington

LOW-POWER HOME ELECTRIFICATION: THE KEY TO AVOIDING ELECTRIC PANEL UPGRADES

PRESENTERS



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Office of
ENERGY EFFICIENCY & RENEWABLE ENERGY

| LEARNING OBJECTIVES

- What are panel capacities in the US housing stock?
- How common are upgrades? And how many will need to be upgraded if we fully electrify?
- How much will that cost?
- What can we do to limit upgrades, associated costs and time delays?

DOE STUDY OF PANEL CAPACITY AND UPGRADES IN THE US

- Funded by DOE 23'-24'
 - Partnership between national labs, utilities and industrial partners
1. Characterize the problem (data gathering, modeling)
 2. Review and evaluate solutions (technology review, case studies)
 3. Develop new digital capacity management solution
 4. Technoeconomic analysis (evaluate how to avoid unnecessary upgrades)
 5. Market transformation (code revision, stakeholder engagement)



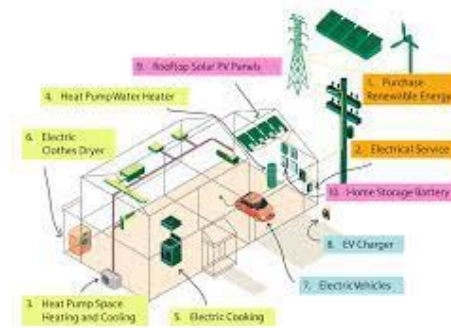
BACKGROUND/INTRODUCTION

ELECTRIFY EVERYTHING?

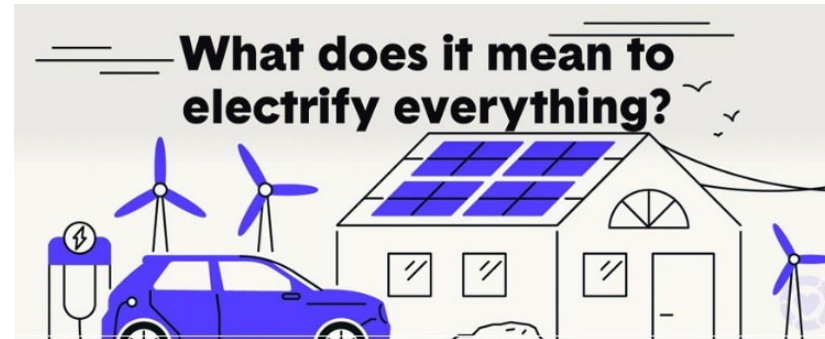
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WHAT ELECTRICAL LOADS ARE WE ADDING TO HOMES?

Replacing gas appliances:

Cooking: 10-12 kW

Hot Water: 3-5 kW or >10kW with instant ER

Clothes Drying: 4-7 kW

Heating: 2-5 kW, or >10kW with ER

New Electric Loads:

EV charger adds 7 kW (or more)

New Panel Constraints:

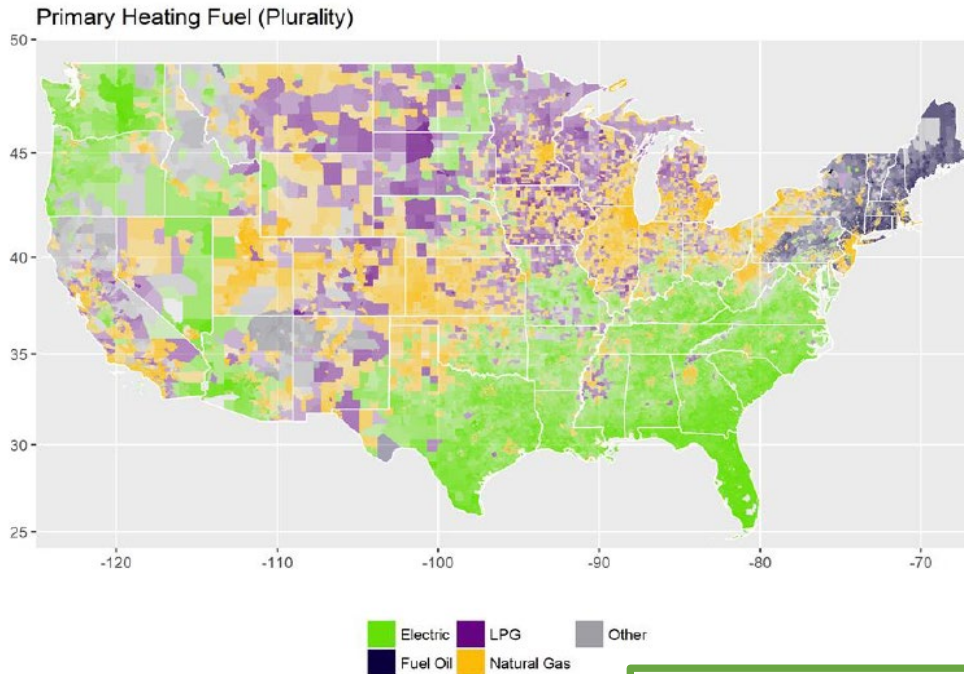
Solar PV 4-8 kW

Adds up to about 100A of “new” load
Where does it all go...?

HOW MANY HOMES NEED A NEW PANEL?

Potentially 30-50%

40% of homes have electric
primary heating
>25% of homes are already all-
electric
75% of homes have central AC



Data from the American Community Survey (2016).

We need a better estimate of how many homes
We need to find ways to avoid panel
replacement

WHY NOT JUST REPLACE ALL THE PANELS?

What does it cost?

Circuits: **\$250-\$750 each**

Panel: **\$1,000-\$5,000**

Service: **\$1,000-\$25,000** to homeowner + similar amount for utility

National cost (very rough): **\$250 billion**

Time delays

3-6 months project delay each upgrade

>1-year lead time on transformers

Utility might reject your interconnection

Additional ratepayer costs for:

- Utility distribution system upgrades
- New generation/storage

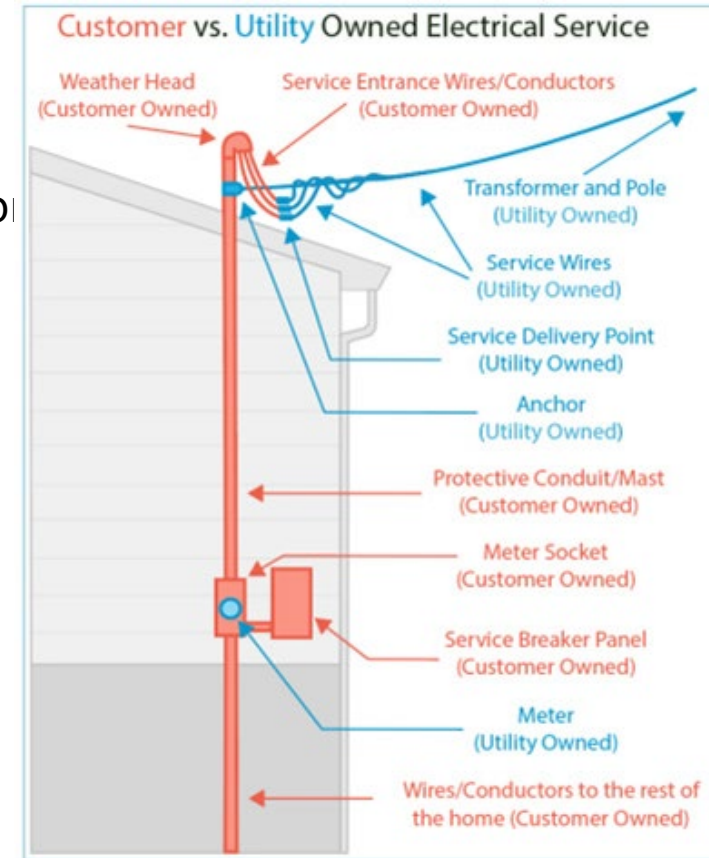


Image courtesy of Redwood Energy

WHY NOT JUST REPLACE ALL THE PANELS?

Triggers rewiring: knob
and tube replacement

Another **\$10,000-
\$30,000**



SOMETIMES AN UPDATE IS NEEDED

Old, unsafe or damaged panels

Fuse Boxes

Zinsco/GTE Sylvania and Federal Pacific panels are dangerous





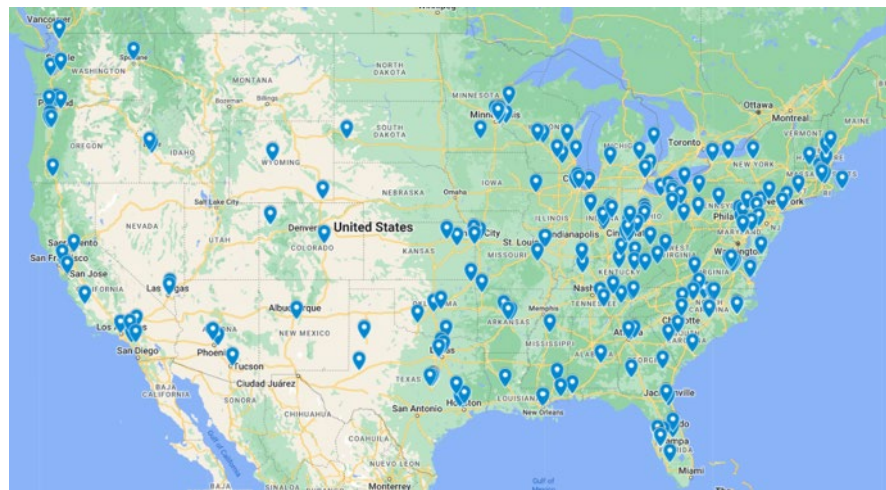
THE STATE OF PANELS IN THE NATION?

FINDING OUT MORE – CITIZEN SCIENCE

- Survey single-family homes on Amazon Mechanical Turk
- Questionnaire and photos of electrical panels.
- Compensation of \$2-\$7/participant was provided.
- Characteristics collected: location, floor area, building age, primary heating fuel, major electrical appliances, major gas appliances, existence of PV/battery/EV.

Results:

- Collected ~300 homes
- About 60% of single-family homes have 200A panels.
- Gas-heated homes have panels with lower capacities than electrically heated homes.



FINDING OUT MORE – CITIZEN SCIENCE



OTHER DATA SOURCES

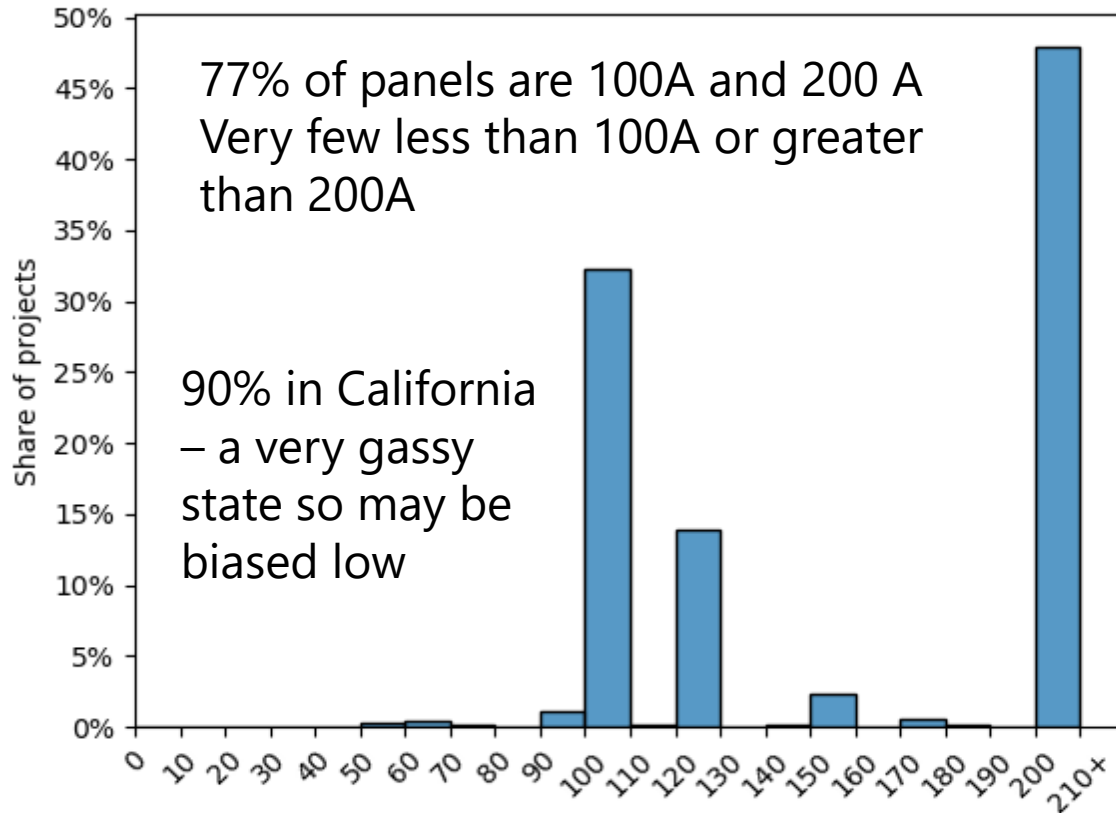
Source	Single-family	Multi-family	Project Count	Panel Amperage Data	Panel Space Available	Panel Upgrade Data	Peak Demand Data	Upgrade Cost Data	State
TECH Clean CA	x	x	9609	x		x		x	CA
BayRen	x		6461	x	x				CA
NEEA RBSA	x	x	1279	x			~180 homes		OR, WA, ID, MT
Home Energy Analytics	x		497	x			x		CA
Eden Housing		x	80 MF Buildings (1000's of units)	x	Visual review?				CA
EPRI Survey			>3,000	x	x				US
TOTAL			17,846						

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Home Energy Analy									CA
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EPRI Survey			>3,000	x	x				US
TOTAL			17,846						

- Most data sets represent homes engaging in EE programs (not random)
- Very strong bias to California housing stock
- Mostly single-family data
- Robust statistical models should allow us to over-come most of these limitations

WHAT'S ACTUALLY INSTALLED?



Vintage	Mean	Median	Mode
<1940	175	125	200
1940s	172	125	200
1950s	156	125	200
1960s	147	125	100
1970s	141	125	100
1980s	143	125	100
1990s	160	200	200
2000s	204	200	200
2010s	202	200	200
2020s	227	200	200
Unknown	163	200	200

CoolingType	Mean	Median	Mode
Unknown	165	200	200
central_ac	163	175	200
evaporative_cooling	162	200	NA
heat_pump	179	200	200
no_cooling	157	125	100
room_ac	156	100	100

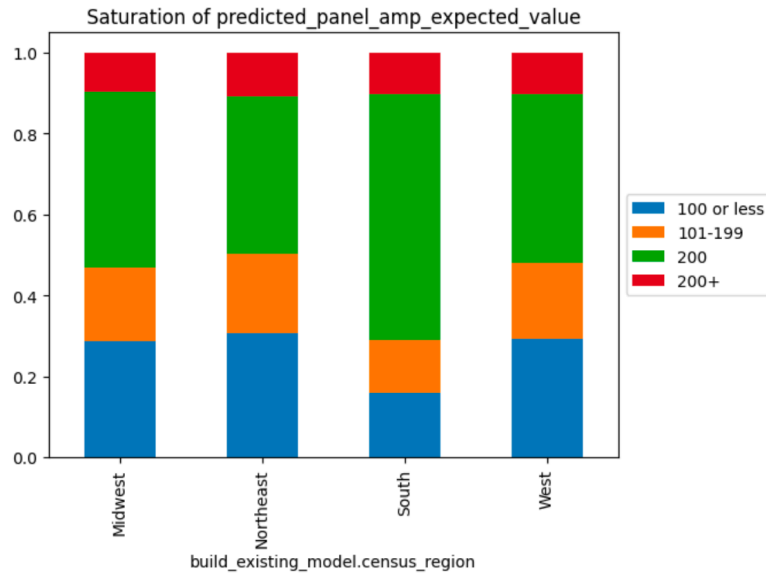
Has PV	Mean	Median	Mode
FALSE	163	125	200
TRUE	166	200	200

PREDICTIONS FROM MACHINE LEARNING MODEL FOR US HOUSING STOCK

PRELIMINARY RESULTS (Note the difference in panel amp bins between plots)

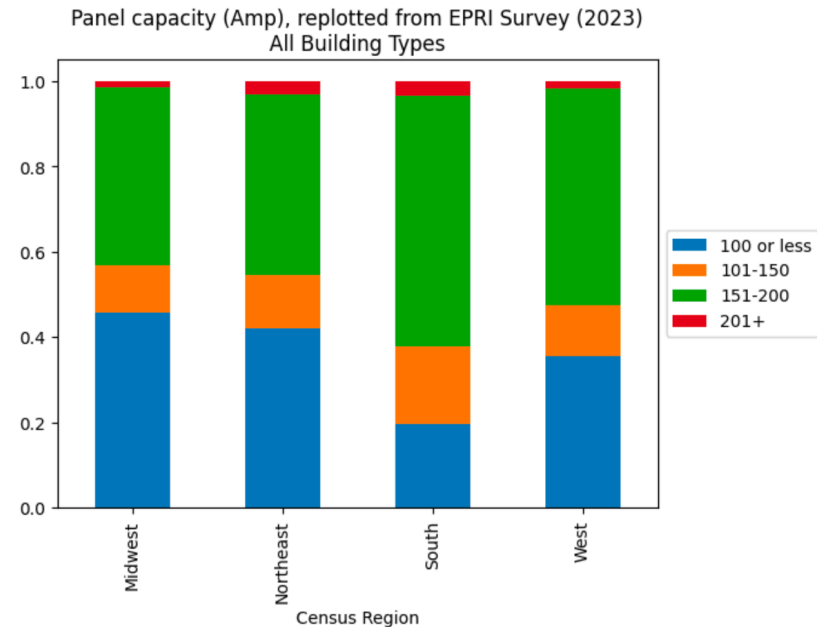
LBNL-model applied to ALL ResStock

n=549,000



EPRI (2023), ACEEE Hot Air/Hot Water Forum

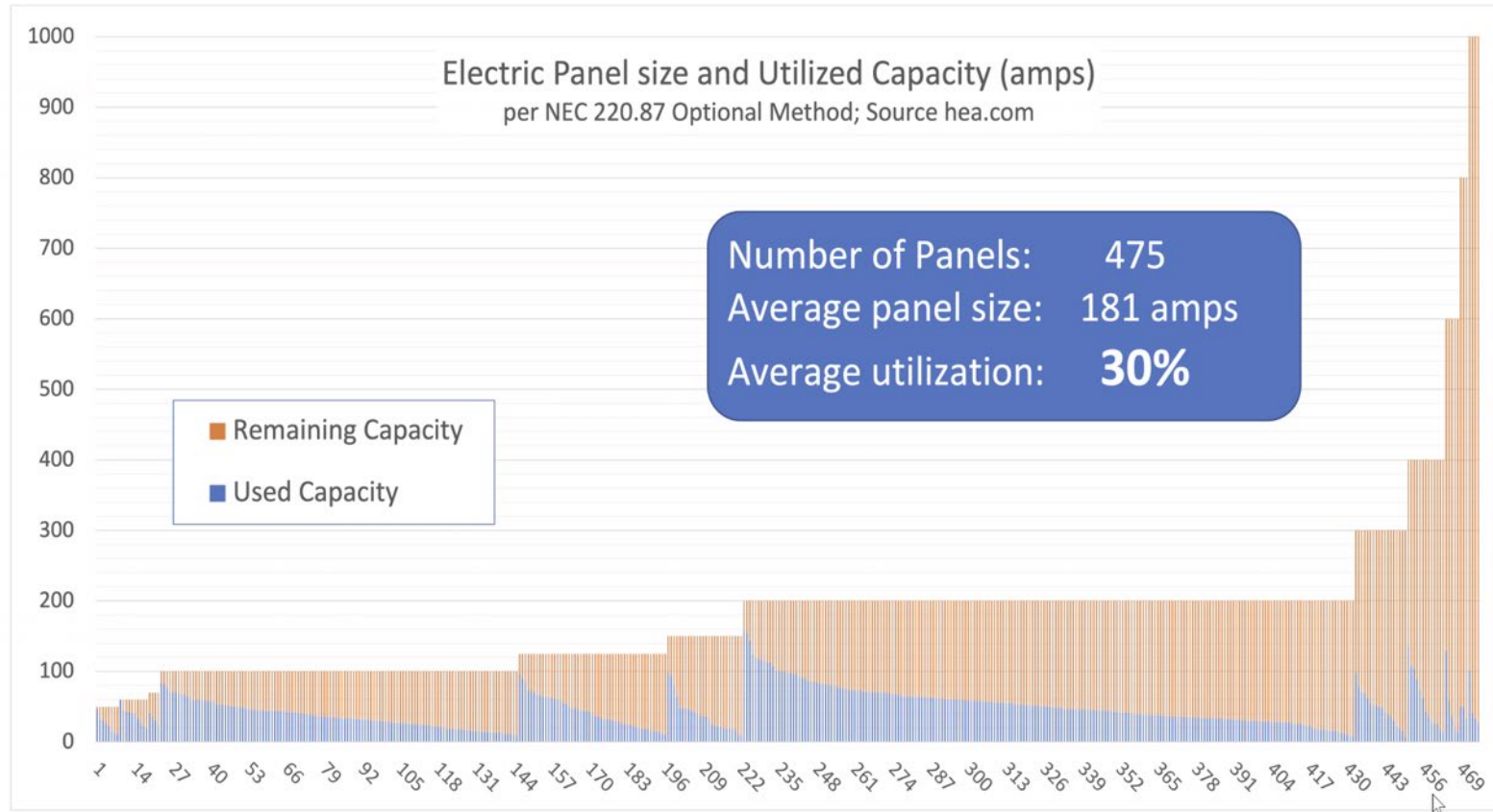
n=2,950 (surveyed)





CAN OUR PANELS HANDLE
NEW LOADS?

AVAILABLE CAPACITY FROM METERED DATA

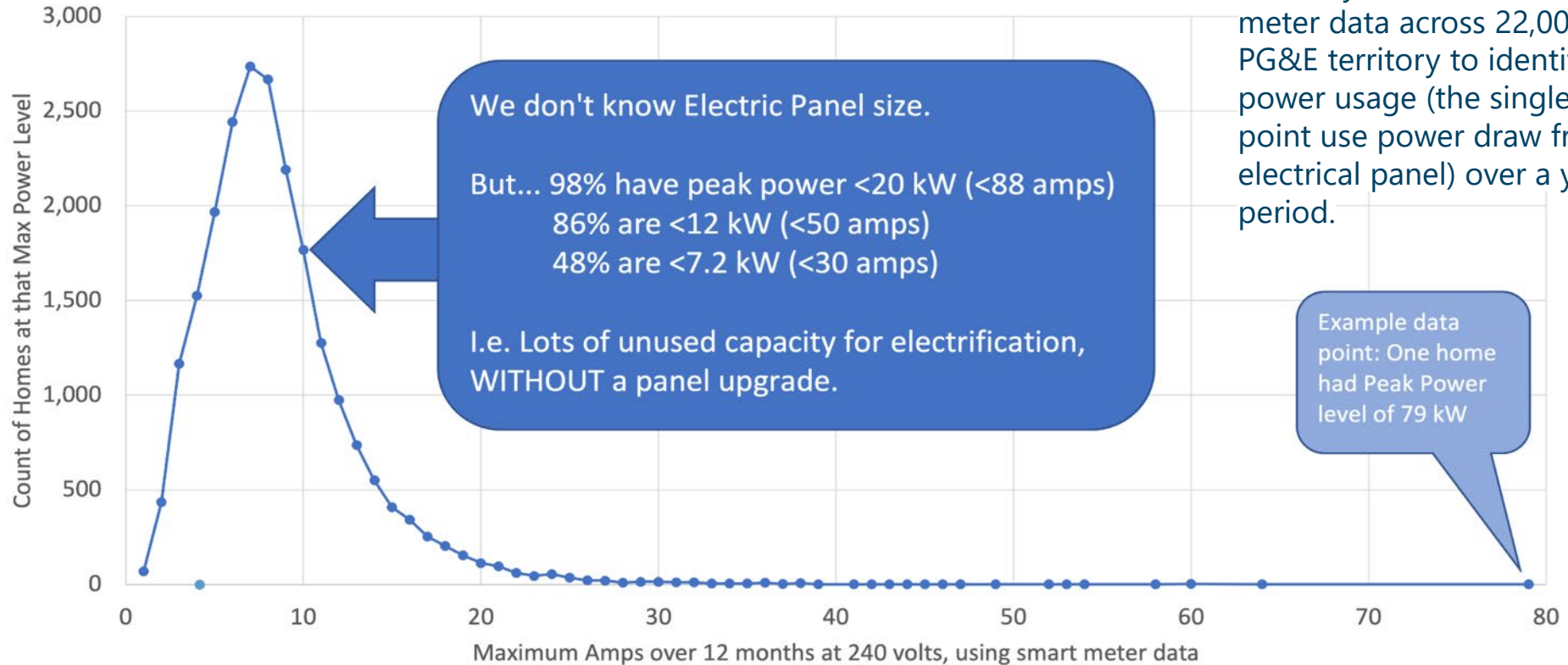


*Not a representative sample of all CA homes, and mix of all electric and electric + gas.

Source:
HEA, HomeIntel

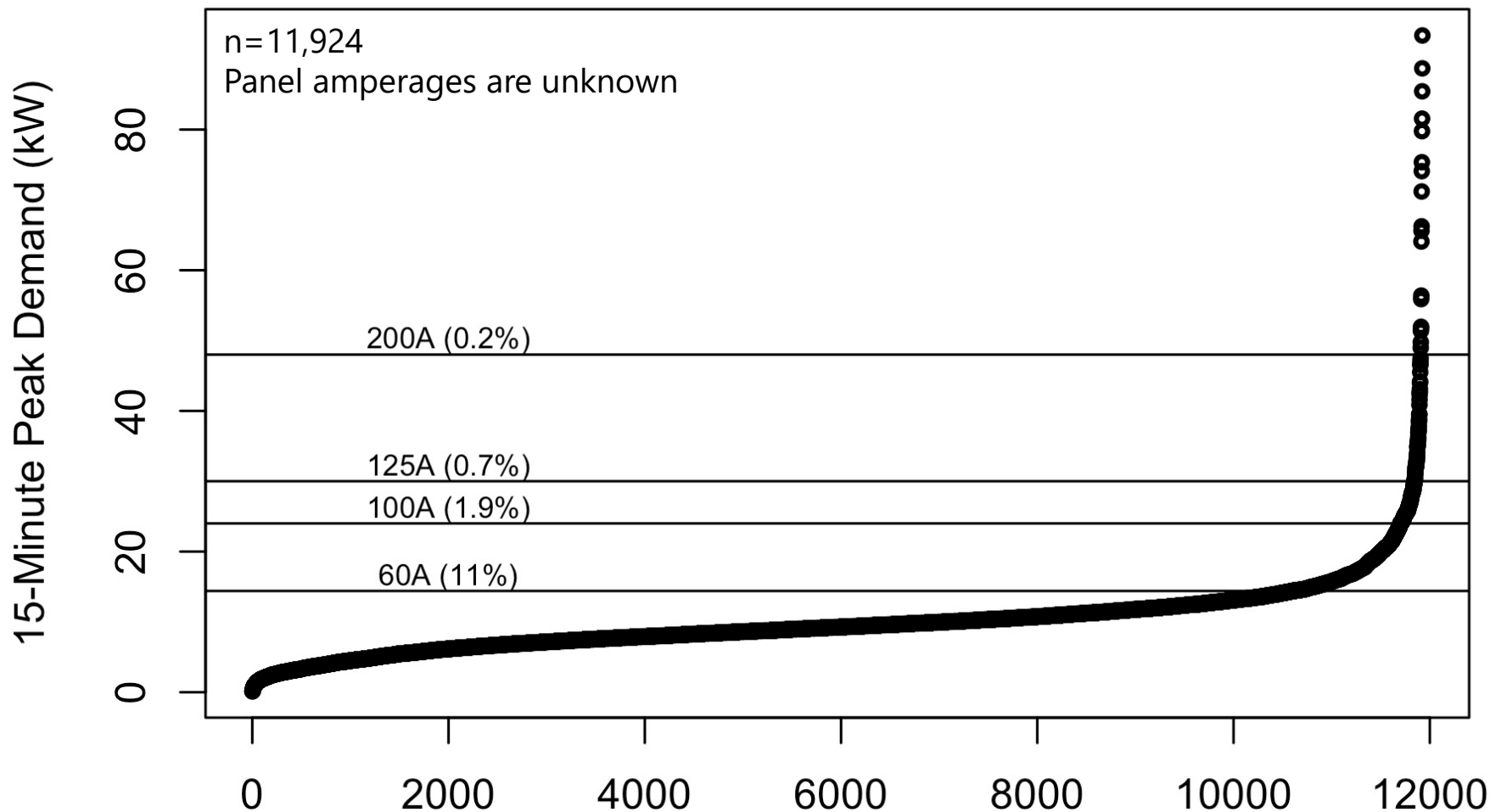
PEAK FROM METERED DATA

Count of Peak Power Levels in kW across 22,442 CA Homes



An analysis from HEA of smart meter data across 22,000 homes in PG&E territory to identify peak power usage (the single greatest point use power draw from their electrical panel) over a year-long period.

PEAK FROM METERED DATA



DO WE HAVE ENOUGH PHYSICAL SPACE IN PANELS?

- BayRen Home Electrification Checklist
 - 100A: 31% have free space (70% need "space" solutions to add loads)
 - 200A: 48% have free space
- Visually evaluating this in Citizen Science study as well

NO SPACE



LOTS OF SPACE

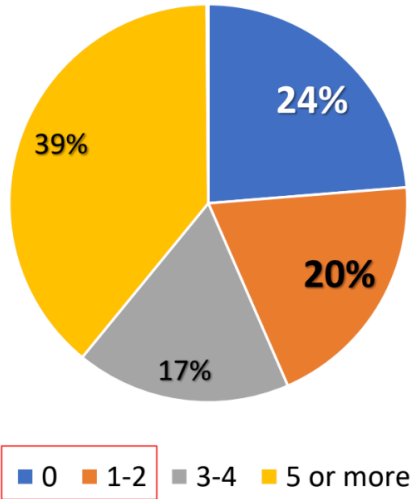


DO WE HAVE ENOUGH PHYSICAL SPACE IN PANELS?

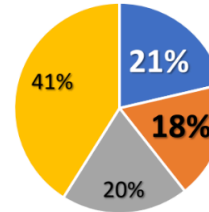
How many open breaker slots does your panel have?

n=2,950

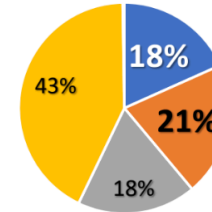
U.S. Summary



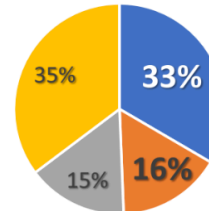
Midwest



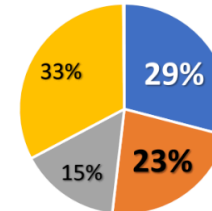
South



Northeast



West



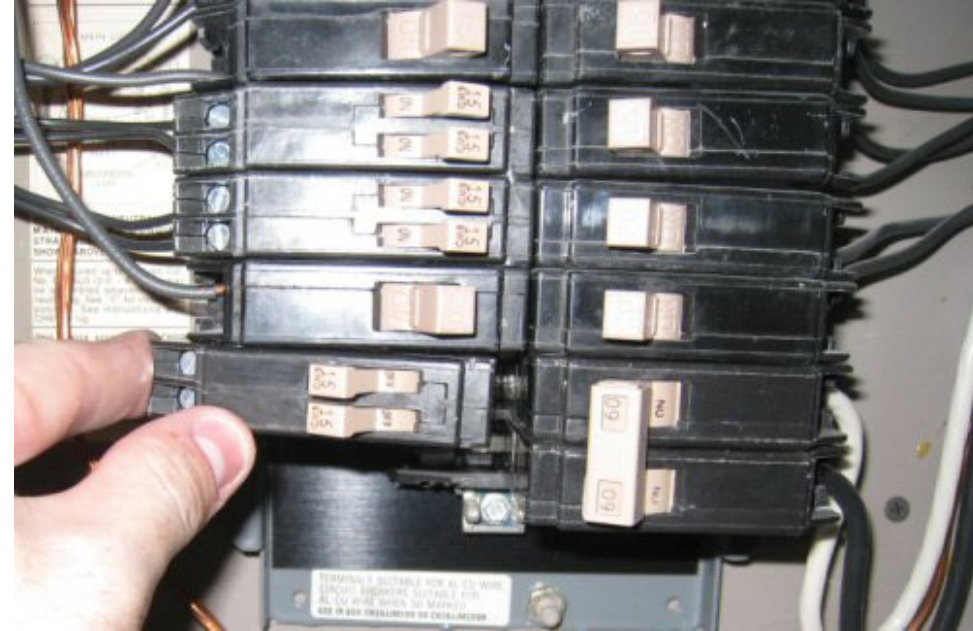
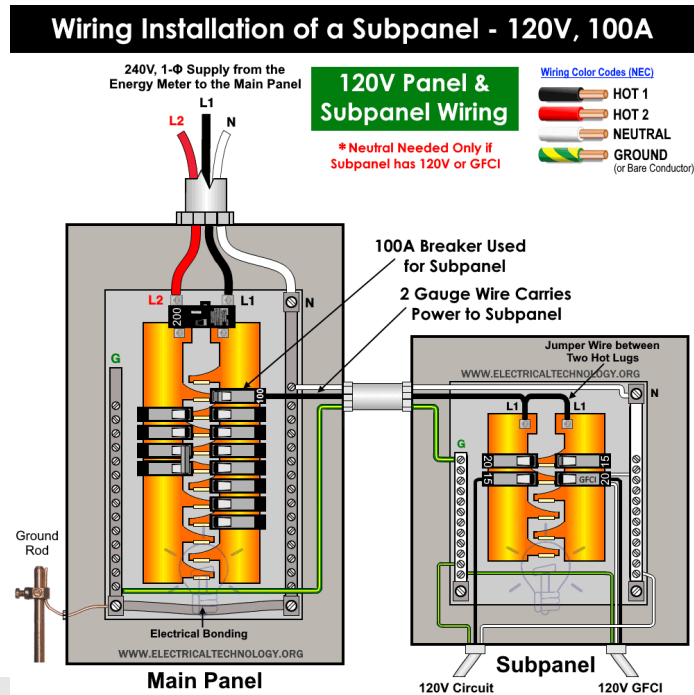
44 % of households have two or less open breaker slots

EPRI Study of
Electrical Panels in
US Homes

By Doug Lindsey

SOLVING THE "NO SPACE" PROBLEM

- Tandem breakers (panel and code limits)
- Sub-panels
- Circuit sharing/splitting



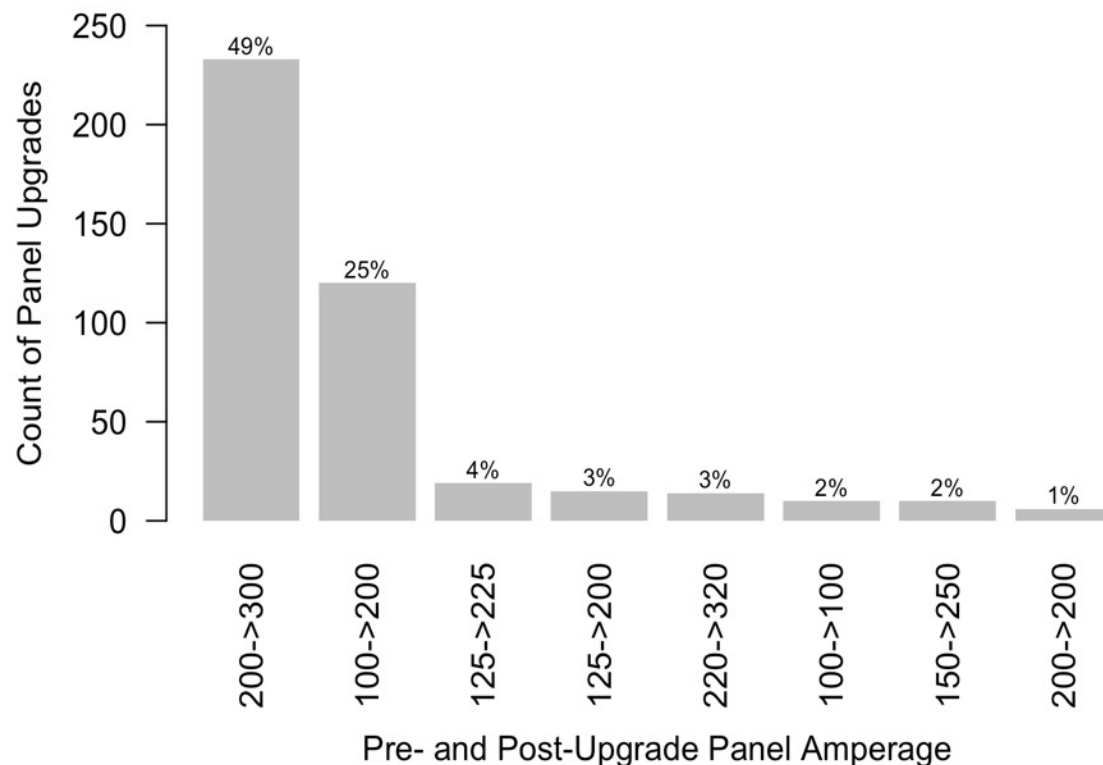


HOW FREQUENT ARE PANEL
UPGRADES?

PANEL UPGRADES AND HEAT PUMPS

TECH Clean California

- 480 panel upgrades out of 10,446 heat pump upgrades (**4.6%**)
 - **Most panel upgrades were from 200A to 300A**
 - Smaller set of upgrades were from 100A to 200A



PANEL UPGRADES AND SOLAR

SolarApp+ Data
from NREL for
residential solar
permits

8,043 permitted
systems

Mostly AZ and CA

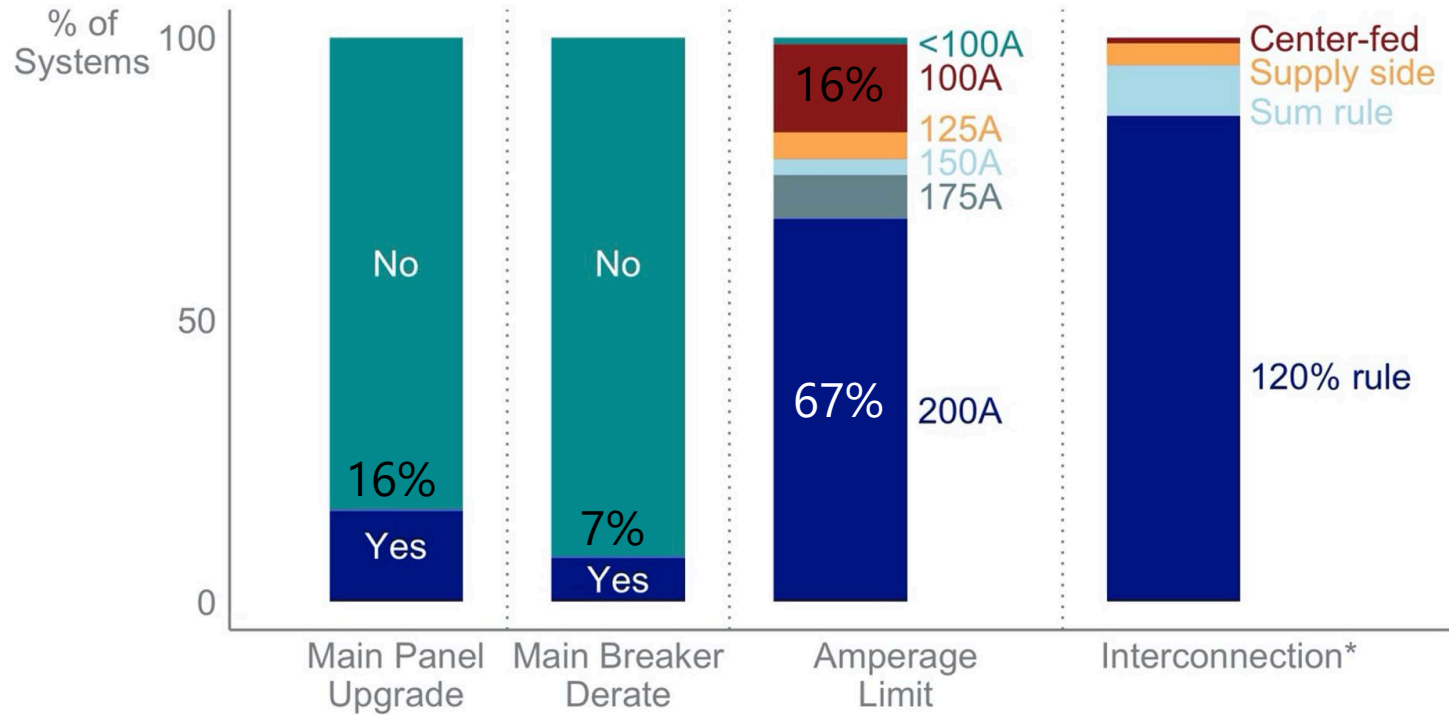


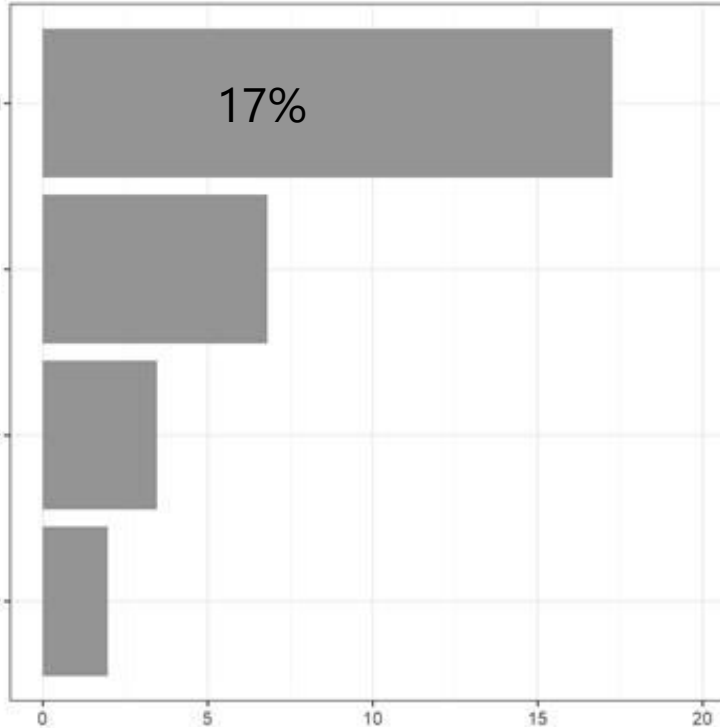
Figure 25. Electrical upgrade features of SolarAPP+ systems

*Sum rule = sum of breaker rule; supply-side = supply-side connection; center-fed = 120% rule on center-fed panels |

PANEL UPGRADES IN GENERAL POPULATION?

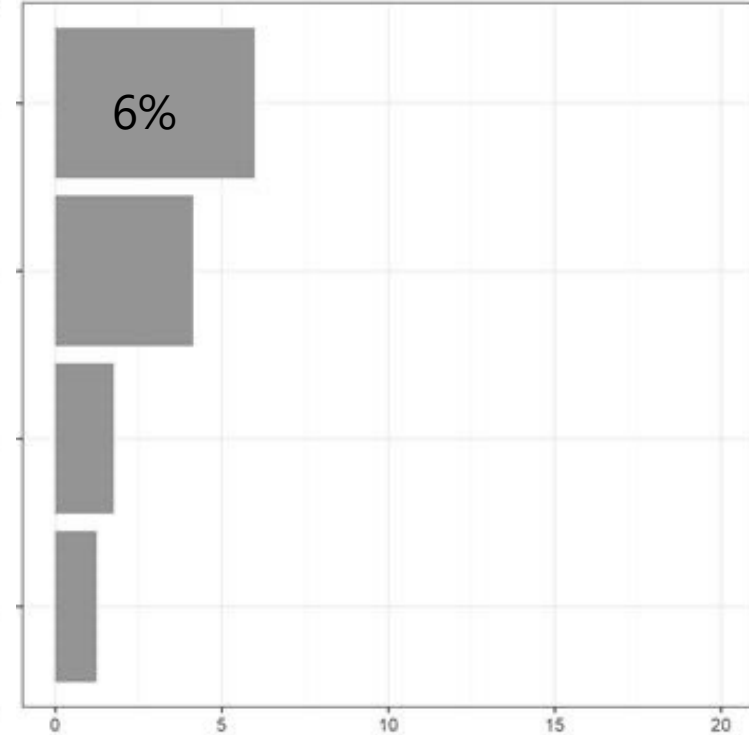
PNNL home occupant survey

What Types of Modification Did You Make to Electrical Wiring, Panels, and/or Backup?



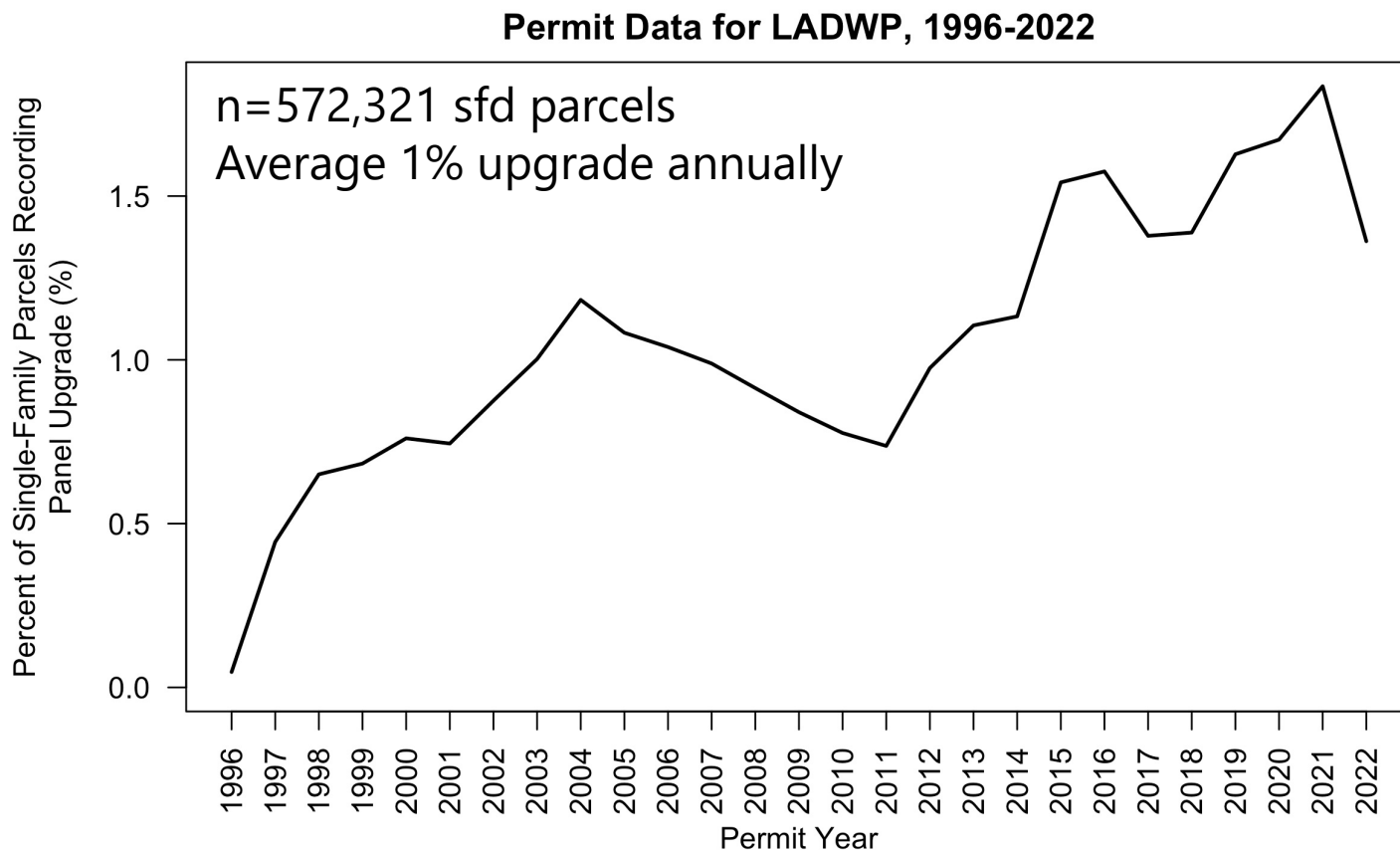
% of 7,024 Homeowners

What Types of Modification Did You Make to Electrical Wiring, Panels, and/or Backup?



% of 2,902 renters

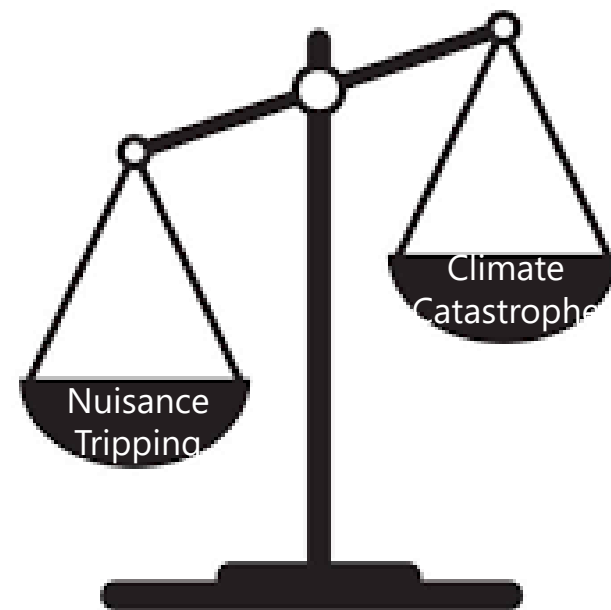
PANEL UPGRADES IN GENERAL POPULATION?



Data courtesy of Eric Fournier, UCLA

UNDERSTANDING WHAT DRIVES PANEL UPGRADES?

1. **Over-simplified approaches by electricians**
 - Don't use paths in National Electric Code (NEC)
 - Not enough space in the panel
 - Not enough amperage
 - Habit...
2. **NEC not developed for electrification retrofits**
 - Likely too conservative
 - No balance between nuisance tripping and climate calamity
 - Inconsistent national adoption keeps the market behind the code
3. **Local code authorities are not prepared**
 - Some will not allow circuit sharing/smart panels
4. **Current driver is adding PV and EV (and additions/remodels)**
 - 80% rule for back-fed PV interconnections
 - 125% continuous load treatment for EVs
 - Future drivers: cooking, heat pumps, clothes drying, pools





POTENTIAL SOLUTIONS

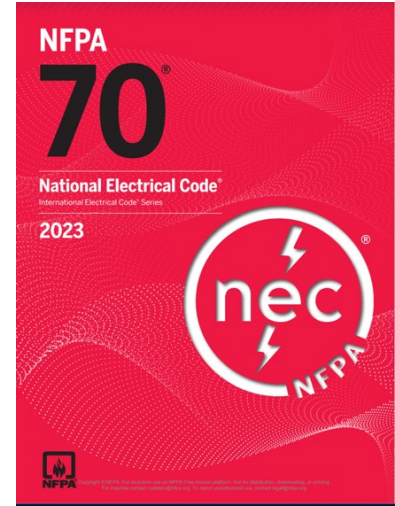
ACTUALLY DO YOUR NEC LOAD CALCS

NEC 220.87 – metered data

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

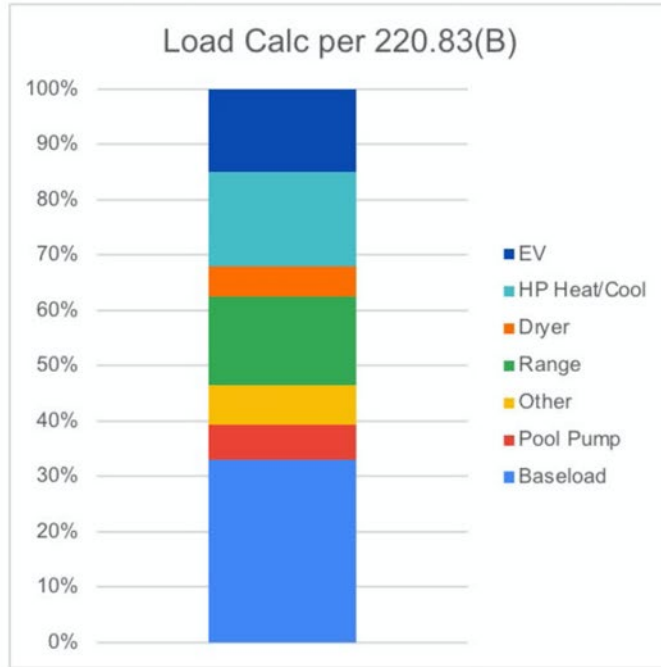
NEC 220.83 – sum connected loads

- 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)

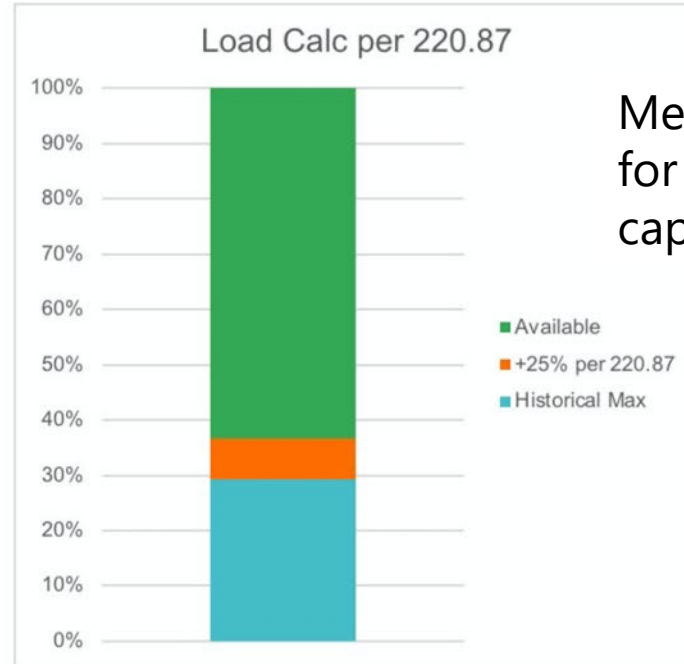


COMPARING LOAD CALCULATION OPTIONS

Same house: Calculations using both 220.83(B) and 220.87



Per NEC 220.83(B): no room left for HPWH



Metered data can allow for more available capacity

Per NEC 220.87: plenty of room for HPWH

Images from Josie Gaillard

REVISING THE 2026 ELECTRICAL CODE?

- Reduce the general receptacles and lighting density from 3 to 1.7 W per ft².
- Eliminate the treatment of new heating and cooling equipment with 100% load fractions.
- Adjustments to the load fraction assumption for adding up nameplate loads.
- Explicit exceptions added for non-coincidence (circuit splitters) and EMS (circuit pausers).
- Migrated 220.87 (use of metered data) in part to 220.83, locating all "existing dwelling" load calculations in one section.
 - Assumes 15-minute data interval, but provides conversion method for 60-minute data.
 - Provides methods for homes with PV and peak shaving.
 - Requires use of same load fractions (e.g., 40%) for adding new load(s) that are used in existing 220.83.
 - Provides an optional method for deducting loads that are removed/replaced.

THE 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.

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

All Electric 100 Amp Home (2,000 square feet)

Ducted heat pump, medium power heat pump water heater, hybrid heat pump dryer

Device		100 Amp Panel		Device	
Volts	Amps			Amps	Volts
120	8	Lights/Plug	15	15	8
120	8	Lights/Plug	15	15	8
120	8	Lights/Plug	15	15	8
120	10	Garbage Disposal	20	20	120
120	7	Refrigerator	20	20	120
120	0	Spare	15	20	120
120	0	Furnace (removed)	15	20	120
240	20	Heat Pump Centrally Ducted	30	20	240
240	20	EV Charger	25	50	240
240	16	Solar Input	20	20	240

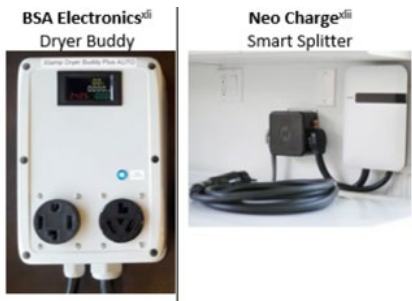
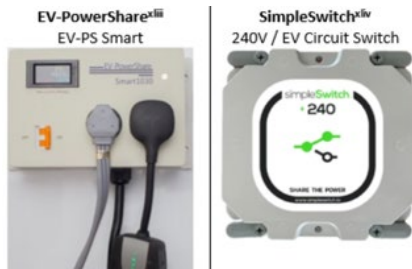


House square footage = 2000

Total Counted Panel Amps = 96.7

NEW LOW POWER PRODUCTS

Smart Circuit Splitters and Sharing



Programmable Subpanels

Eaton
Energy Management
Circuit Breaker (EMCB)






Battery Integrated Stoves



Power-efficient Appliances (120V)



4.5 cu ft Condensing Washer/Dryer Combo	Heat Pump Water Heater	Through-Wall Heat Pump
10A, 1200W	8.3A, 1000W	6.3-15A, ~1400W
LG WM3998HBA	GE GeoSpring	Innova HPAC 2.0
		

Meter Collars







CONVENTIONAL "EFFICIENT" APPLIANCES (240V)

Product Type	Electric Dryer-Energy Star	Heat Pump Water Heater	Split Heat Pump 2-4 Tons
Maximum Rating	30A, 7,200W	19A, 4,500W	18-29 Amps, 4,300W-7,000W
Make and Model	Whirlpool WED5620HW	Rheem Prestige	York YZH060 Series
Image			

Redwood Energy

POWER EFFICIENT APPLIANCES (120V)

Power at the panel is the limiting factor, but reducing appliance voltage can be another strategy

Product Type	4.5 cu ft Condensing Washer/Dryer Combo	Heat Pump Water Heater	Low-Amp Window Heat Pump	120V Mini-Split Heat Pump
Maximum Rating (Amps, Watts)	10A, 1200W	8.3A, 1000W	6.3-15A, ~ 1400W	10.4A, 1090W
Make and Model	LG WM3998HBA	GE GeoSpring	Innova HPAC 2.0	LG LS-120HXV
Image				

POWER EFFICIENT APPLIANCES EXAMPLE CALCULATION

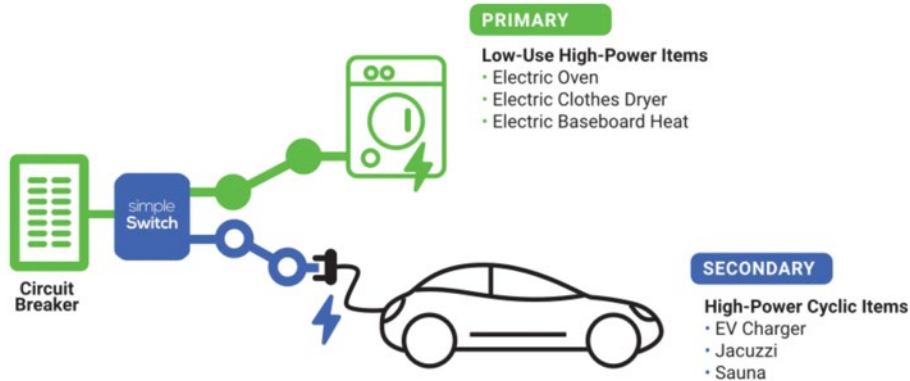
Typical Energy Efficient Appliance		Power Efficient Appliance	
Device	Power (W)	Device	Power (W)
2 ton Heat Pump	4,400	120V minisplits	1,100 (x2?)
Water heater	4,500	120V HPWH	1,000
Clothes Dryer	7,200	120V HP washer/dryer	1,200
Range	9,600	120V 2-burner cooktop and 120V Countertop Oven	1,200 1,200
EV charger	7,200	EV-pauser/circuit sharer	0
Total	32,900		5,700

CIRCUIT SPLITTERS AND CIRCUIT PAUSERS

Circuit Splitters

- Connect two loads to same circuit
- Select priority load
- Automated switching
- Count only larger load against panel

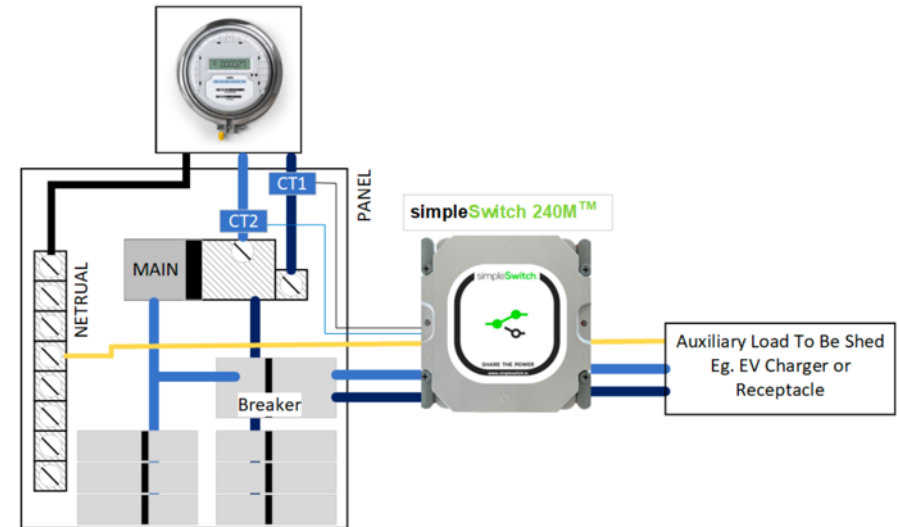
HOW IT WORKS



Share the Power

Circuit Pausers

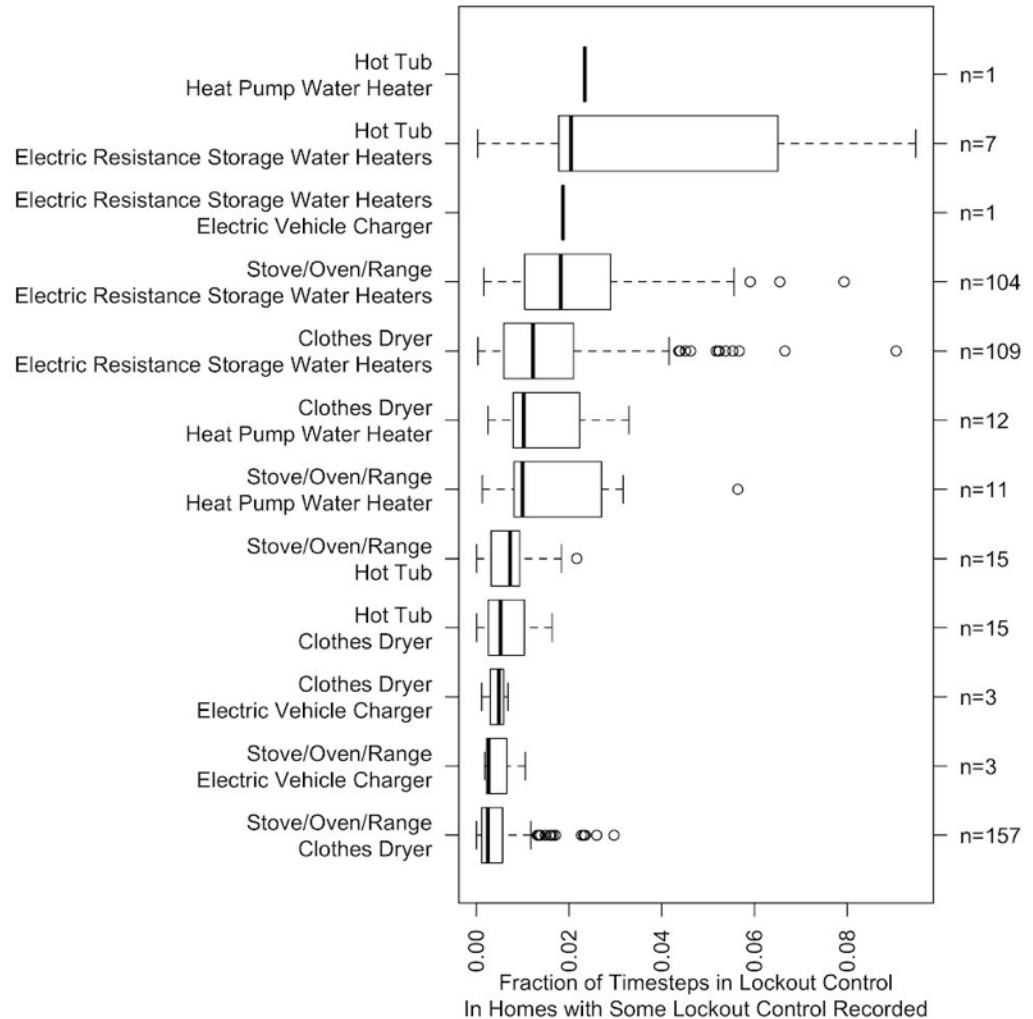
- Controls one load based on demand metered with CTs
- Turns off at 80% of setpoint limit
- Do not count load against panel capacity



CIRCUIT SHARING POTENTIAL

15 minute data from 190 homes from NEEA study

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



LOAD SHARING AND CIRCUIT SPLITTING CHALLENGES

Codes and Regulations

- Does the NEC correctly account for these devices – or include them at all?
- Does your local authority allow their use?
- NEC 220.60 “Noncoincident Loads” appears in 2023!
- NEC 220.70 “Energy Management Systems” appears in 2023!

Home Infrastructure

- If you don’t have an existing electric dryer circuit to share with an EV
- Location of load doesn’t easily integrate with EV pausing

Usability

- Users may not like pausing functionality for important loads
- Most loads do not “pause” easily. Think clothes dryer vs. EV.
- Need more advanced appliances, communications and solutions

METER COLLARS BYPASS INTERNAL BUSBAR CURRENT LIMIT

EXISTING PRODUCT - SOLAR

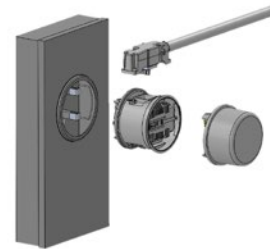
• Solar Adapter

- 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



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






NEW IDEAS?


INTEGRATING VEHICLES

- Current poor public charging infrastructure:
 - Need to be able to charge at home
 - Challenges for multifamily
- EV could easily be the biggest home load: up to 50 A
 - Restrict power to 7.2kW – overnight charge completely recharges most EVs
 - Encourage low-power charging – good for most households
 - Use timers/smart circuit sharing/meter collars



NEW IDEAS?

 American-Made Challenges



2,764

Share

Follow (97)

EAS-E Prize

Supports design solutions, tools, and/or technology innovations that make electrification more affordable and accessible in U.S. homes.

Energy, Environment & Resources

Government

Technology

Stage:
Enter

Prize:
\$2,400,000

SOLVE THIS CHALLENGE

Summary

Timeline

Updates ²

Forum ⁴

Teams ⁹⁷

Resources

FAQ

Overview

Guidelines

Focus on hard to electrify homes

Winners to be announced next week

Challenge Overview

The Equitable and Affordable Solutions to Electrification (EAS-E) Home Electrification Prize provides up to \$2.4 million in prizes for innovative solutions that advance electrification retrofits of residential homes across all building types and geographies.

Leave a Message

RETHINKING REBATES?

- Currently \$2500 for a panel upsize (IRA up to \$4000 + \$2500 for additional wiring)
 - Allows high power devices and higher peak load from home to utility
 - New distribution and transformer upsizing - these costs passed on to ratepayers
- Include rebates for **avoiding** panel replacement
 - 120V HPWH
 - Small split HP systems
 - 120 V cooking
 - Condensing clothes dryers
 - Battery systems (whole home or in appliances)
 - EV pausers
 - Meter collars
 - Reduces grid stress in the future as we electrify

HAVE YOU ELECTRIFIED A HOME ON 100A OR LESS? TELL US ABOUT IT.

Iain Walker iswalker@lbl.gov

Brennan Less bdless@lbl.gov

www.homes.lbl.gov



NHPC'23 SEATTLE

CONFERENCE PARTNERS:



April 17-20, 2023 | Seattle, WA