BERKELEY LAB

LAWRENCE BERKELEY NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY

All-electric homes on a 100A panel

Iain Walker & Brennan Less

February 2023

FORUM ON DRY CLIMATE

HOME PERFORMANCE

What's the issue?

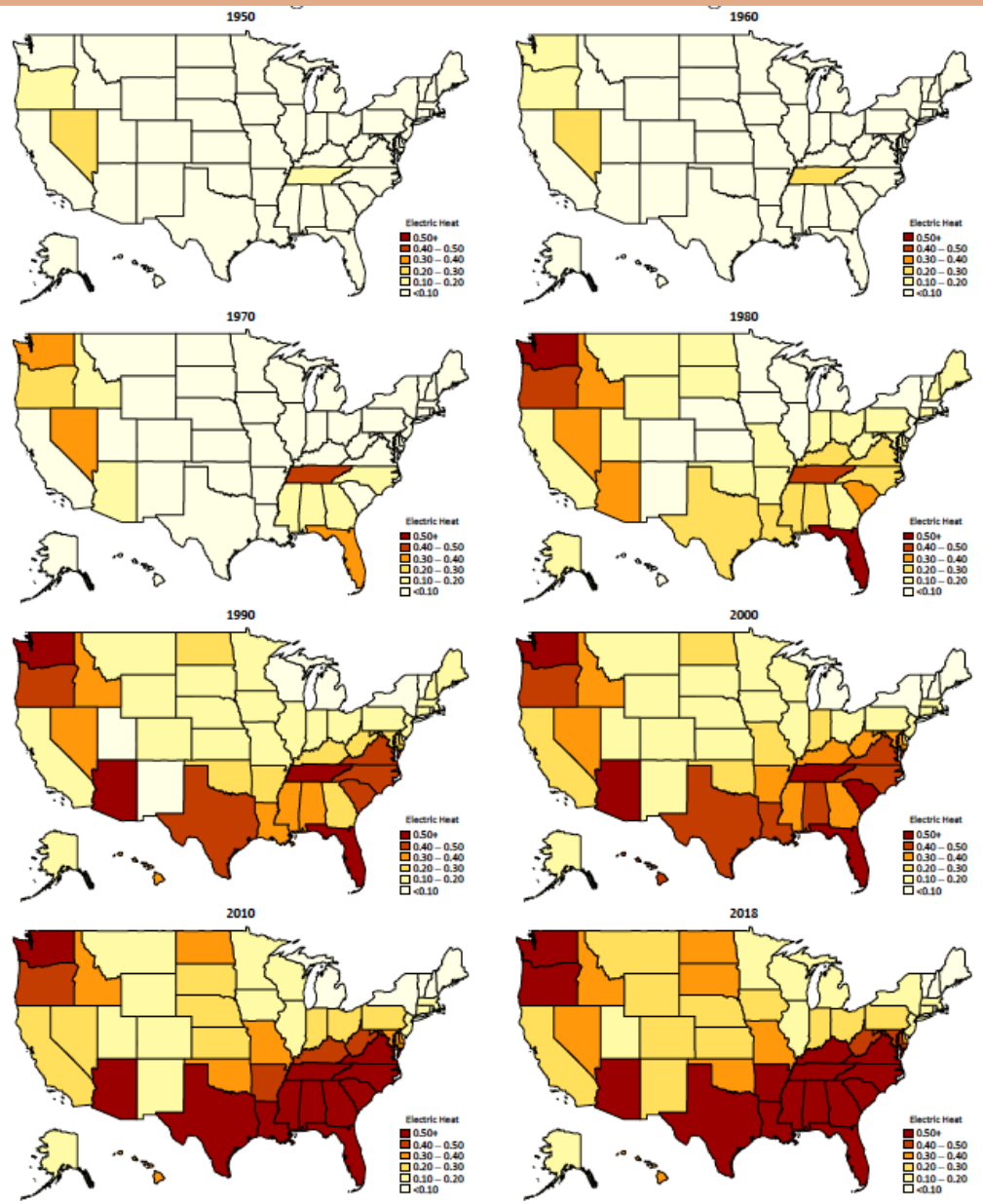
Decarbonization Retrofits

- New homes almost always have enough panel capacity – 200A typical
- Existing homes likely do not have 200A
- Panel/wiring/service upgrades are costly (many thousands of dollars)
  - A big barrier to electrification/decarbonization

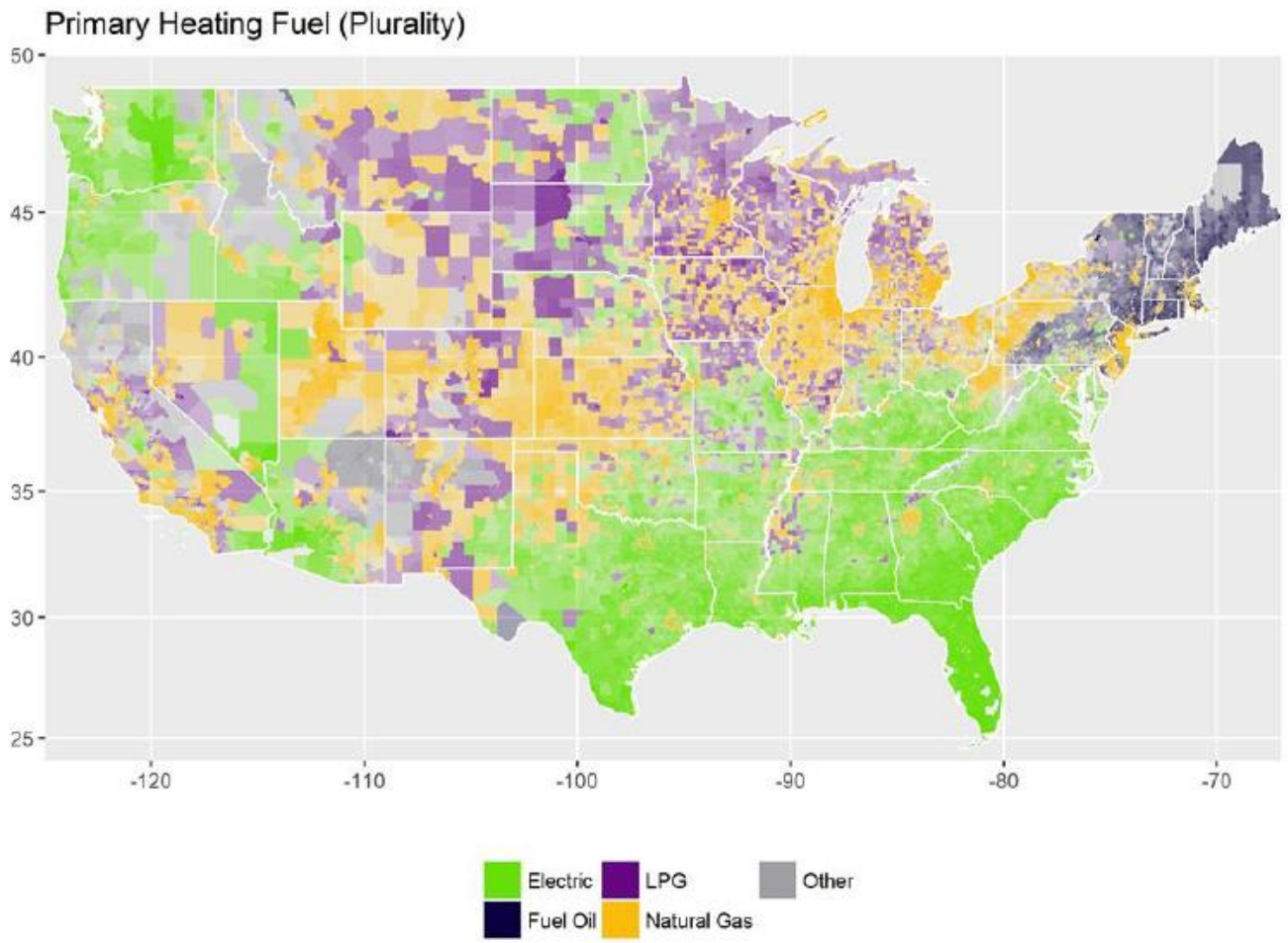
- *How do we minimize the cost to electrify existing homes???*
- Electrify for under 100A…and avoid that panel replacement

Electric Heating

Growth in Electric Heating



Distribution of Electric Heating



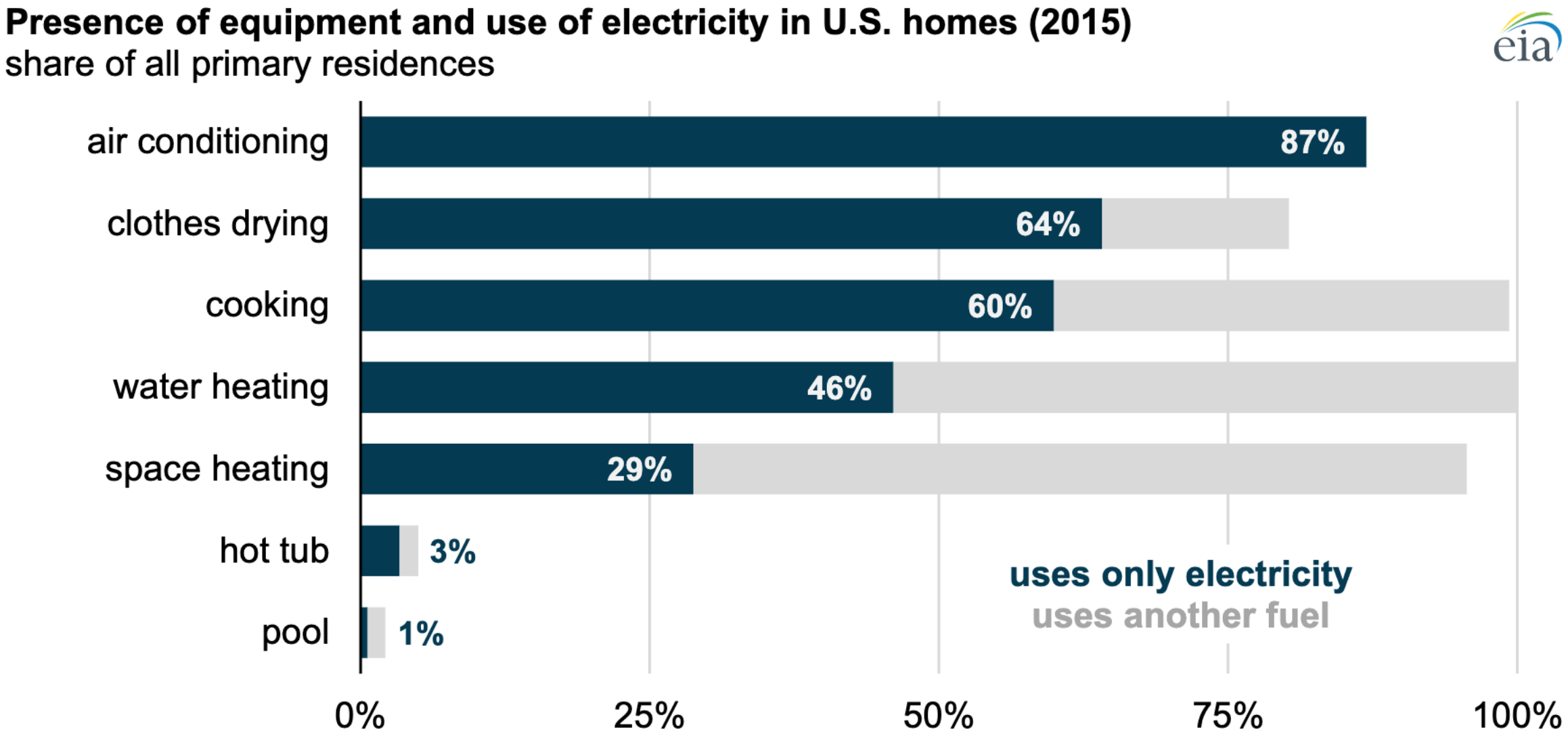
Data from the American Community Survey (2016).

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

Current Electric Appliances in the US

https://www.eia.gov/todayinenergy/detail.php?id=39293

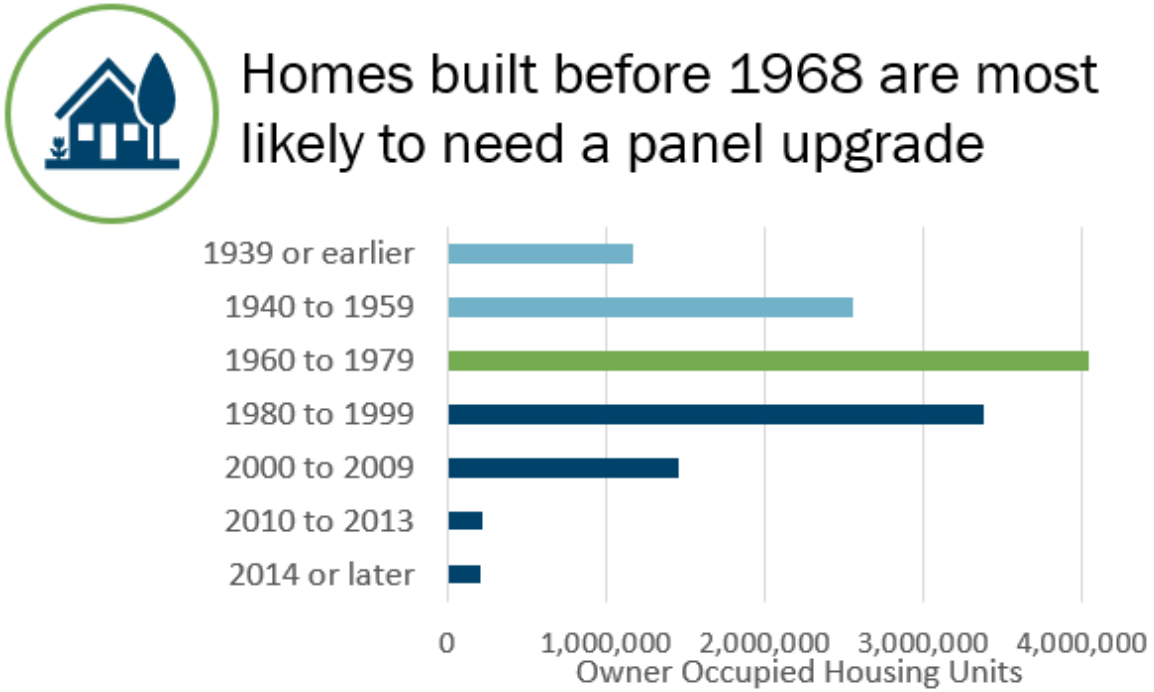
#RESNET2022



Source: U.S. Energy Information Administration, 2015 Residential Energy Consumption Survey

What's Actually Installed: California Kitchens and 100A Panels

- Single Family Homes older than about 1968 in California were not required to have 20-amp kitchen circuits, and are much more likely to not already have A/C (which ultimately required a 100-amp panel)



What's Actually installed? Citizen Science

Background: It is difficult to estimate the extent to which panel capacities are a barrier to electrification because there is no national data on panel capacities

Approach: We recruit occupants of single-family homes with a national survey tool (Amazon Mechanical Turk).

Each recruit:

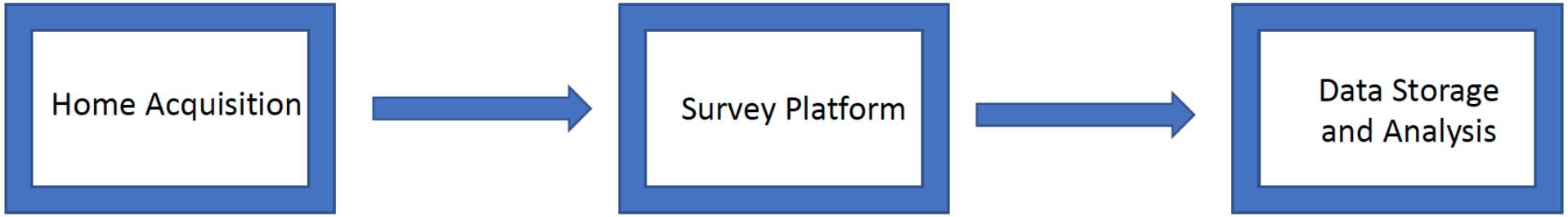
- fills out a short survey of appliances in homes, age of house, size, location, fuels used for heating, etc.
- photographs their electrical panel
- gets paid $2- $5

Results:

- ~135 homes (increasing 10 - 15/week @ $5/home)
- histogram of panel capacities for homes by fuel, age, floor area, location
- available circuits for electrification

What's Actually installed? Citizen Science

Approach to Acquiring Data on Panel and Home Characteristics



Amazon Mechanical Turk **Survey Monkey** **Google Sheets**

What's Actually installed? Citizen Science

Survey Questions (1)

The Worker sees this survey form

* 1. Please select the type of single family home you live in (if you do not live in a single family home, we kindly ask that you do not fill out this survey and stay tuned for another survey)

- Single-family detached
- Single-family attached

* 2. What state do you reside in?

* 3. What city do you reside in?

* 4. What is your 5-digit zipcode?

* 5. What is the approximate year your house was constructed?

* 6. What is your home's approximate floor area? (in square feet)

Summary of Questions

- Location (state, city, zip code)
- House year of construction
- Electric appliances in house
- Gas appliances in house
- 2 photos of electrical panel
- Input value of panel capacity (between 20-1000)

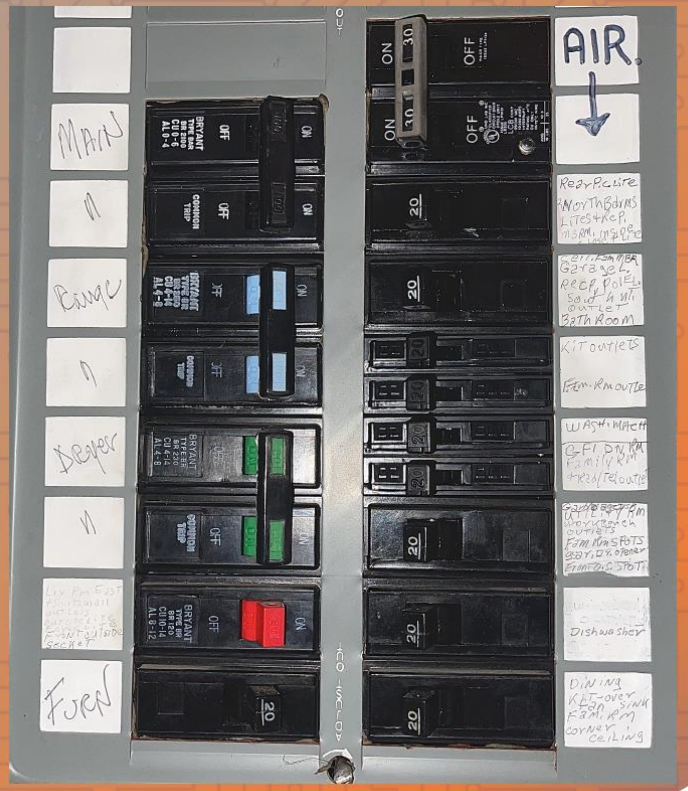
* 7. Please select all major electric appliances that you use in your home

- [ ] Central air conditioner
- [ ] Room air conditioner
- [ ] Heat pump
- [ ] Electric resistance space heating
- [ ] Electric stove/range/oven
- [ ] Electric water heater
- [ ] Electric clothes dryer
- [ ] Electric vehicle and charger
- [ ] Electric fireplace
- [ ] Electric heater for spa or pool
- [ ] Photovoltaic (PV) panels
- [ ] Battery storage for PV
- [ ] Well pump or pool pump
- [ ] Other (please specify)

What's Actually installed? Citizen Science

Respondent Photos - Real

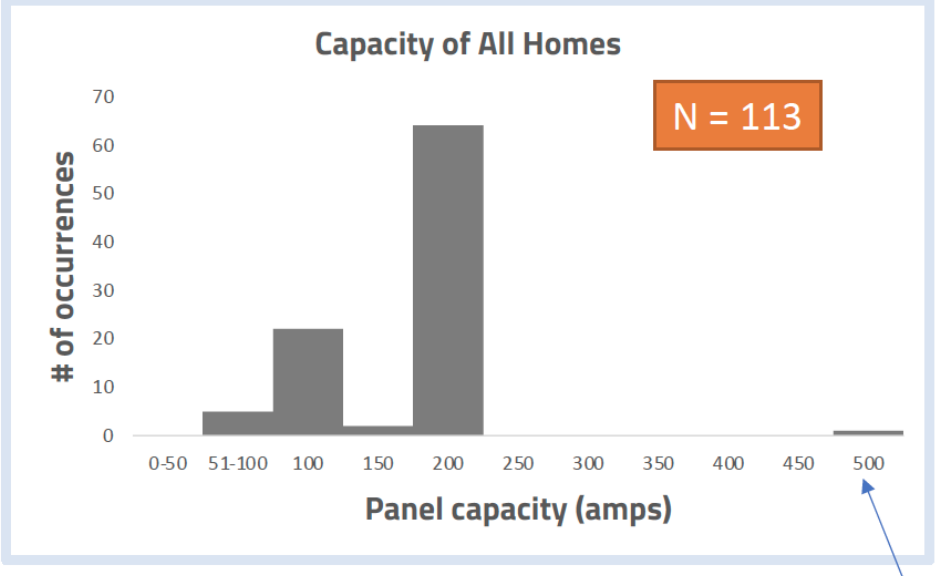
Note unused slots



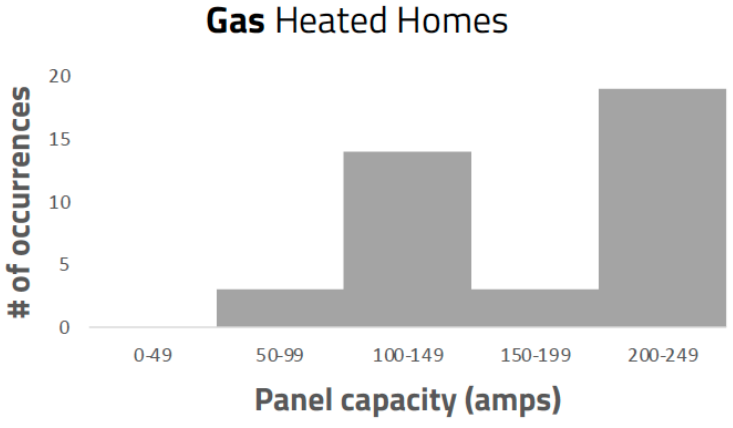
6

What's Actually installed? Citizen Science

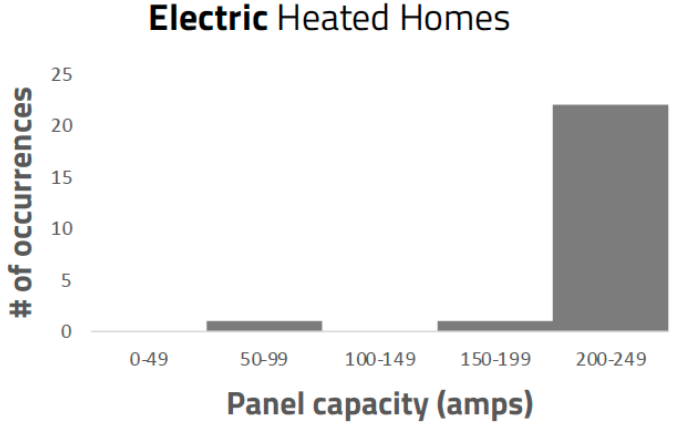
Panel Capacities – Early Results



Bug?



N=49

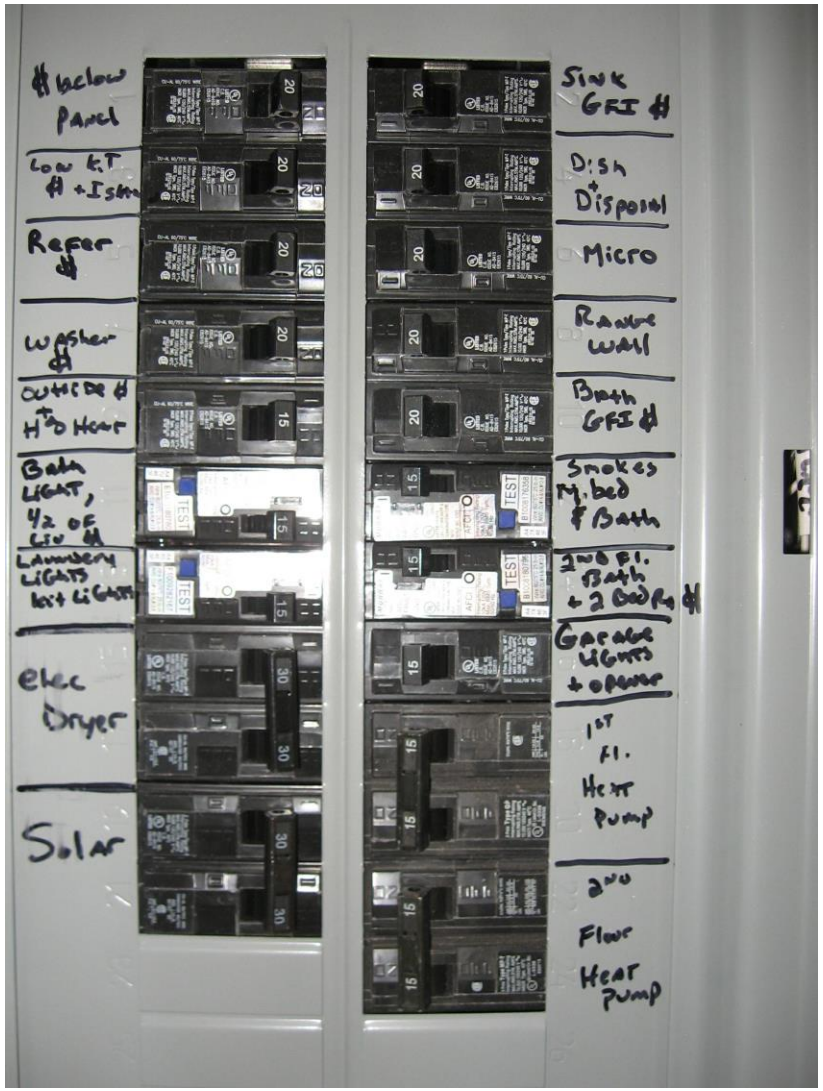


N=64

California Status (need to add other hot dry climates)

- 8% (1.1 m) CA homes all electric as of 2020
- 14 m homes in CA
- 6 million built before 1968 (when 100A became standard – its now 200A)
- Upgrading 6 million homes is about $25-$40 billion
- Cost range in CA $3,000-$25,000 to homeowner + similar amount for utility
- 3-6 months wait

- ALSO…. Current rebates encourage panel upgrade they do not pay for low power or power efficient appliances/systems



Avoiding redecorating – many thousands of $

Photo – Eric Morill

What Drives Panel Upgrades?

1. Over-simplified approaches by electricians
   - Don’t use available compliance paths in National Electric Code (NEC)
   - We will talk about how to best use the current NEC
2. NEC not developed for electrification retrofits
   - Likely too conservative
   - We will talk about data-driven potential NEC changes
3. Local code authorities are not prepared
   - Some will not allow circuit sharing/smart panels
4. Current driver is adding PV and EV
   - Future drivers: cooking, heat pumps, clothes drying, pools/hot tubs

Sometimes an update is needed

Old, unsafe or damaged panels

Fuse Boxes

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

Utilizing the NEC - 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

100 Amp Panel

Device Volts	Device Amps					Device Amps	Device Volts
120	8	Lights/Plug	15	15	Lights/Plug	8	120
120	8	Lights/Plug	15	15	Lights/Plug	8	120
120	8	Lights/Plug	15	15	Lights/Plug	8	120
120	10	Garbage Disposal	20	20	Kitchen Outlets	13	120
120	7	Refrigerator	20	20	Kitchen Outlets	13	120
120	0	Spare	15	20	Dishwasher	12	120
120	0	Furnace (removed)	15	20	Clothes Washer	13	120
240	20	Heat Pump Centrally Ducted	30	20	Hybrid Heat Pump Dryer	14	240
240	20	EV Charger	25	50	Range (cooktop +oven)	40	240
240	16	Solar Input	20	20	Heat Pump Water Heater	12	240

House square footage = 2000 Total Counted Panel Amps = 96.7

Source - Tom Kabat & Sean Armstrong

Power saving devices

Smart Circuit Splitters and Sharing

EV-PowerShare[xliii]
EV-PS Smart

SimpleSwitch[xliv]
240V / EV Circuit Switch

BSA Electronics[xli]
Dryer Buddy

Neo Charge[xlii]
Smart Splitter

Programmable Subpanels

Eaton[xxxix]
Energy Management
Circuit Breaker (EMCB)

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

Battery Integrated Stoves

Meter Collars

Load Sharing and circuit splitting

Smart circuit splitters allow two devices to share a single circuit, which can help avoid an electrical panel upgrade

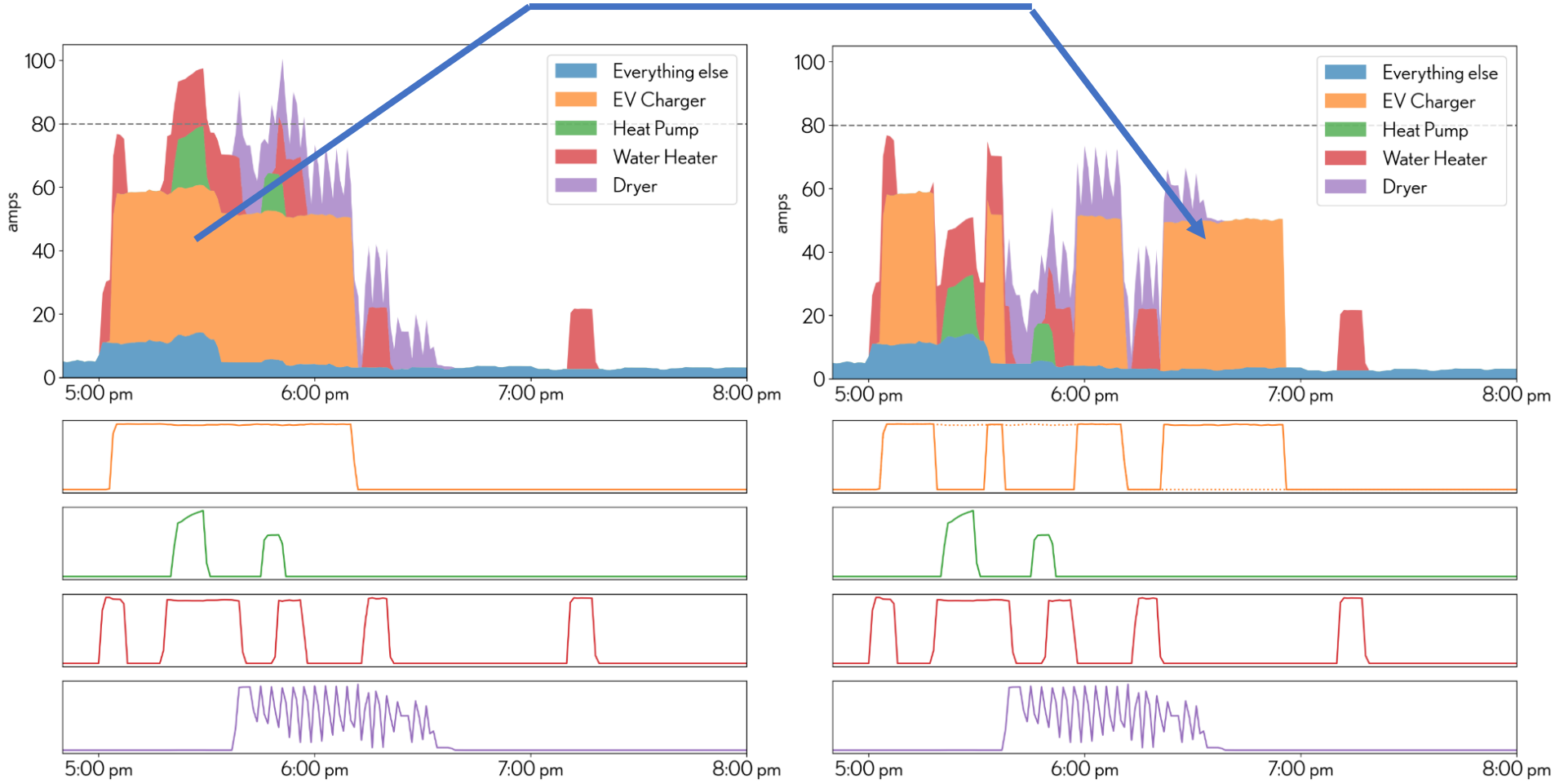
Most common sharing between an EV charger and an electric clothes dryer.

	Neo Charge[116] Smart Splitter	**BSA Electronics**[117] Dryer Buddy	**SimpleSwitch**[118] 240V Circuit Switch	**Splitvolt**[119] Splitter Switch	**Thermolec**[120] DCC	**Evduty**[121] Smart Current Sensor
Cost ($)	$500 (Appliance) $550 (Dual Car)	$200 – 365 (several outlet versions)	$550 (240V) $650 (EV) $550 (120V)	$319	$1,050 (DCC-9), $945 (DCC-10)	$500
Switch On/Off Between Two Devices	Yes	Yes	Yes	Yes	NA	NA
Continuous Power to Two Devices	Yes	Yes	No	No	NA	Yes, *shares power between appliance circuit and EV circuit*
Monitors Whole House Loads	No	No	No	No	Yes, *if total panel exceeds 80% rated load, turns off EV charging. Reconnects automatically*	Yes, *monitors a unit/home's current draw, left over current will be used to charge EV*

Load Sharing and circuit splitting

Classic peak case: come home from work and plug in car, turn up heat, start laundry

Smart device shifts EV charging later avoiding big peak



Sam Calisch, Rewiring America, Data from SPAN.io

Load Sharing and circuit splitting challenges

Codes and Regulations

Does the NEC correctly account for these devices – or include them at all?

Does you local authority allow their use?

Home Infrastructure

If you don’t have an existing electric dryer circuit to share with an EV you still need to add that circuit

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			

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**

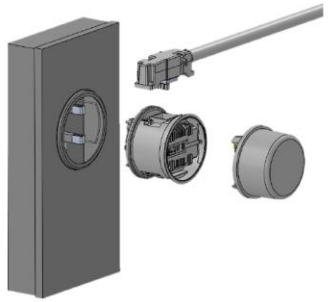
Meter Collars bypass internal busbar current limit

EXISTING PRODUCT - SOLAR

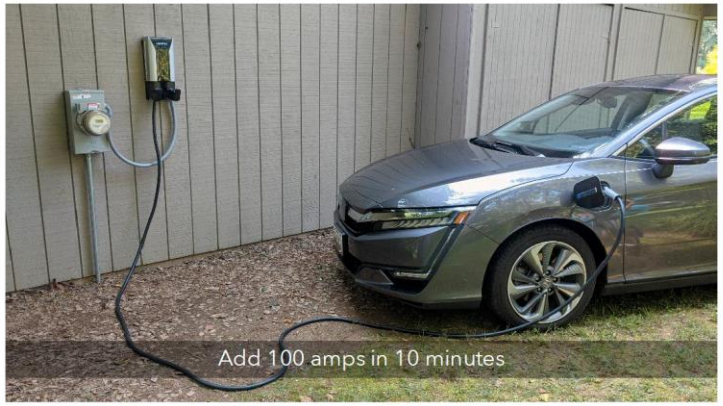
- Solar Adapter
  - UL Listed (414 - Meter Sockets)
  - 5 mins to install, 30 mins to interconnect
  - 200A continuous rating, utility power
  - 80A continuous rating, PV input (15kW)
  - Integrated PV breaker
  - Optional smart module – RGM and cellular comms
  - Approved in 20 states
  - 15,000 units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



Integrating transportation

- Current poor public charging infrastructure:
  - Need to be able to charge at home
- EV could easily be the biggest home load: up to 50 A
  - Need to restrict power requirement to 7.2kW
  - 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

Challenge Overview

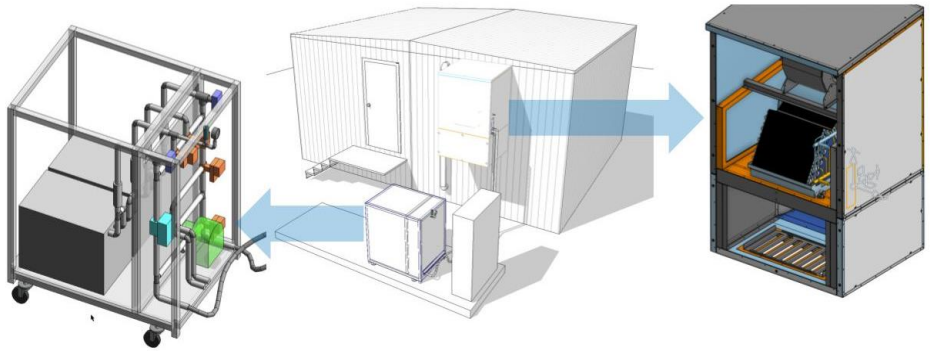
The Equitable and Affordable Solutions to Electrification (EAS-E) Home Electrification Prize provides up to $2.4 million in prizes for innovative solutions that advance electrification retrofits of residential homes across all building types and geographies.

Leave a Message

New Ideas?

- Battery-integrated appliances: Battery-integrated stove never draws more than 1500W, compared to several kW for traditional stove

- Using thermal storage to boost capacity so lower power lower capacity heat pumps can be used = grid responsive HVAC



- Cold Climate heat pumps (avoiding high power electric resistance backup)

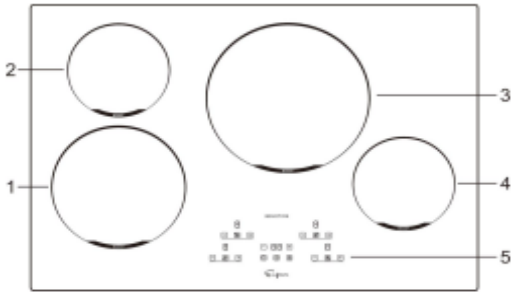
U.S. DEPARTMENT OF ENERGY
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Residential Cold-Climate Heat Pump Technology Challenge

New Ideas?

20A Induction Range Design Test
CalFlexHub Project

- Develop a fully functional 20A range
  - Normally requires 40A circuit
  - Use power sharing

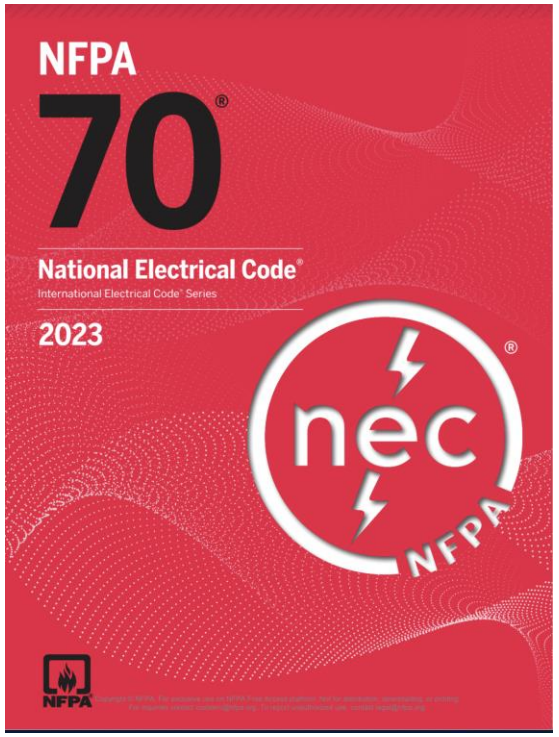


EMPV-30EC02

1. max. 1800/2100W zone
2. max. 1200/1500W zone
3. max. 2300/3700W zone
4. max. 1200/1500W zone
5. Control panel

New Ideas – updating NEC for electrification retrofits

- Updating NEC to better accommodate home electrification
  - What are actual coincident loads?
  - How close are most homes to panel capacity and ability to add loads?
  - Allow load reductions/load control
    - Power Efficient Appliances
    - Circuit Sharing
    - Energy storage



NEC Options

NEC 220.87

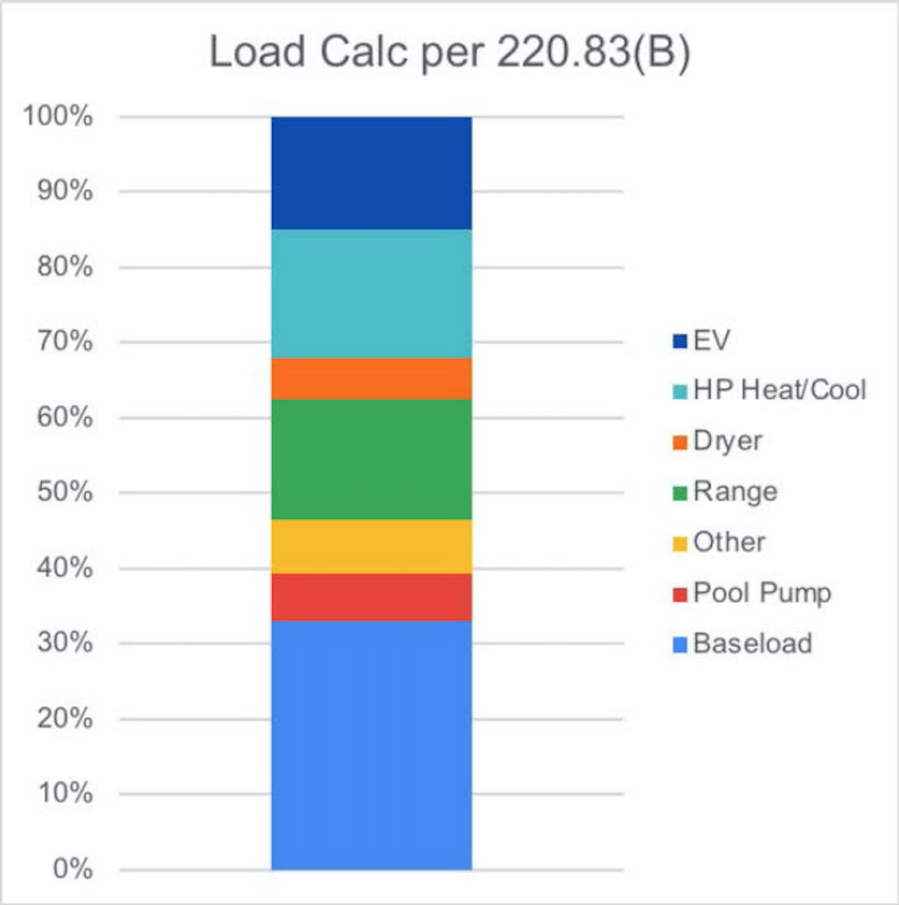
- Existing loads based on metering data (15 minute)
- Total load = (Metered Load) x 1.25 + New Load

NEC 220.83

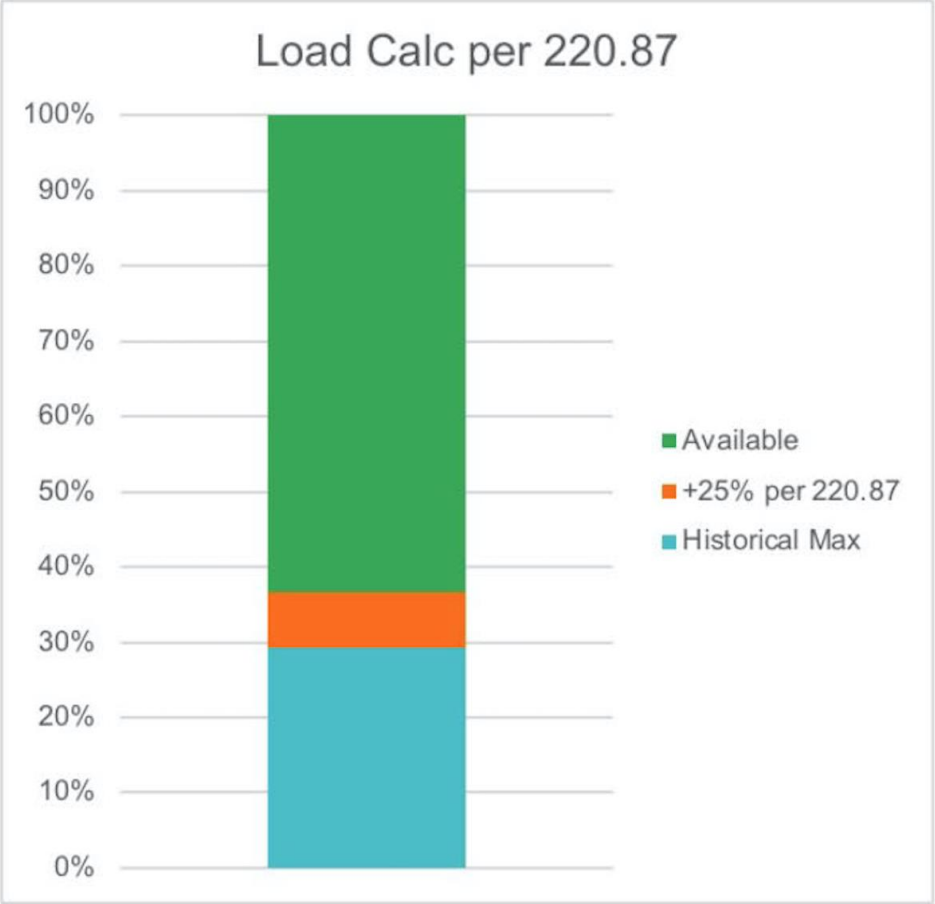
- Existing loads as a bottom-up summation of connected loads with different treatment when adding HVAC
- No New HVAC: 8,000 watts + 40% of remaining connected loads (including heating and cooling)
- New HVAC: 8,000 watts + 40% of remaining connected loads + max(heating, cooling)

Comparison of load calculation options

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



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



Per NEC 220.87: plenty of room for HPWH

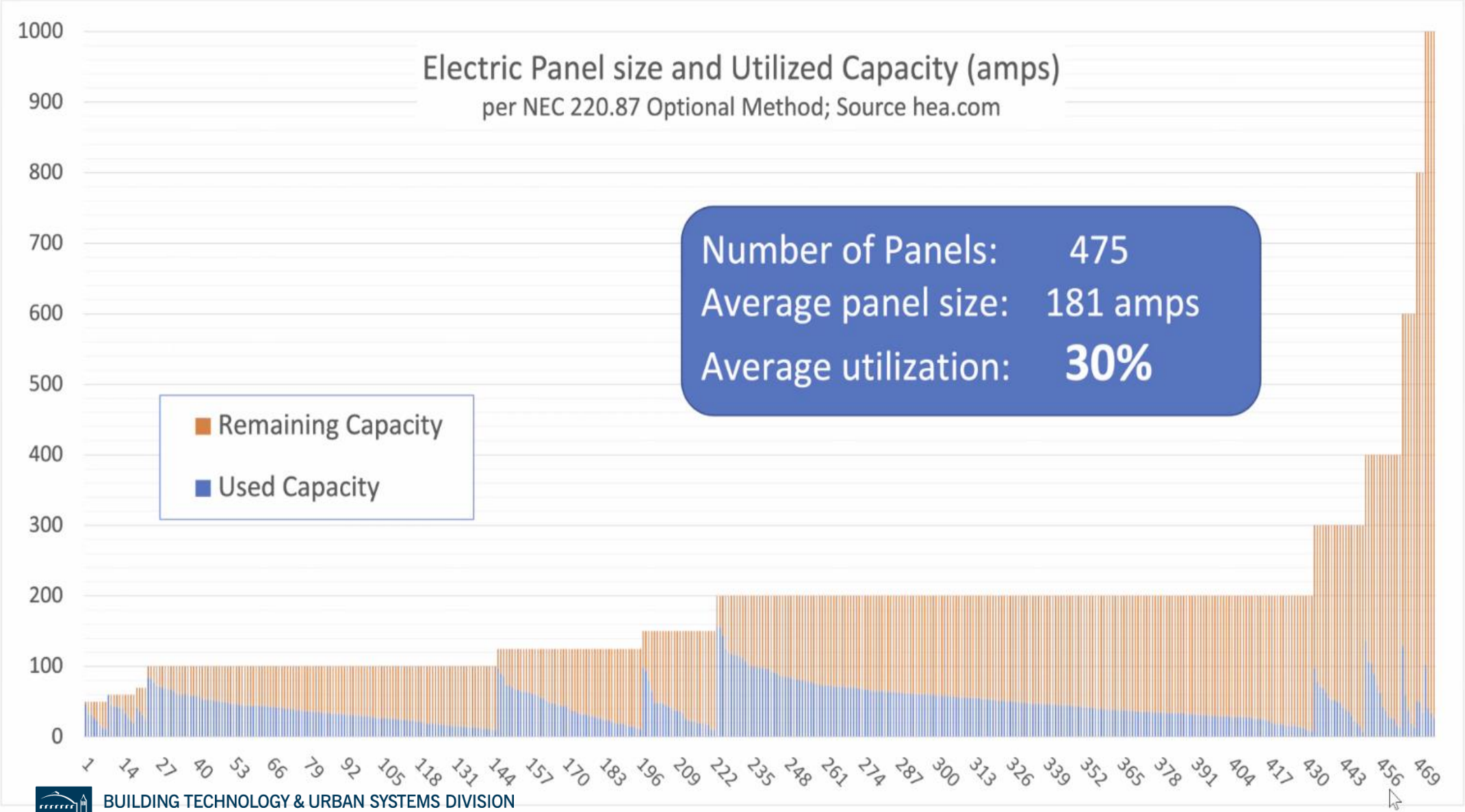
Images from from Josie Gaillard

120% rule for PV

PV Amps = Busbar Rating x 1.2 – Main Breaker rating
200A bus bar and 200A main breaker allows for 40A of PV

We can increase PV allowance by **decreasing** the main breaker rating
200A busbar and 175A main breaker allows for 65A of PV

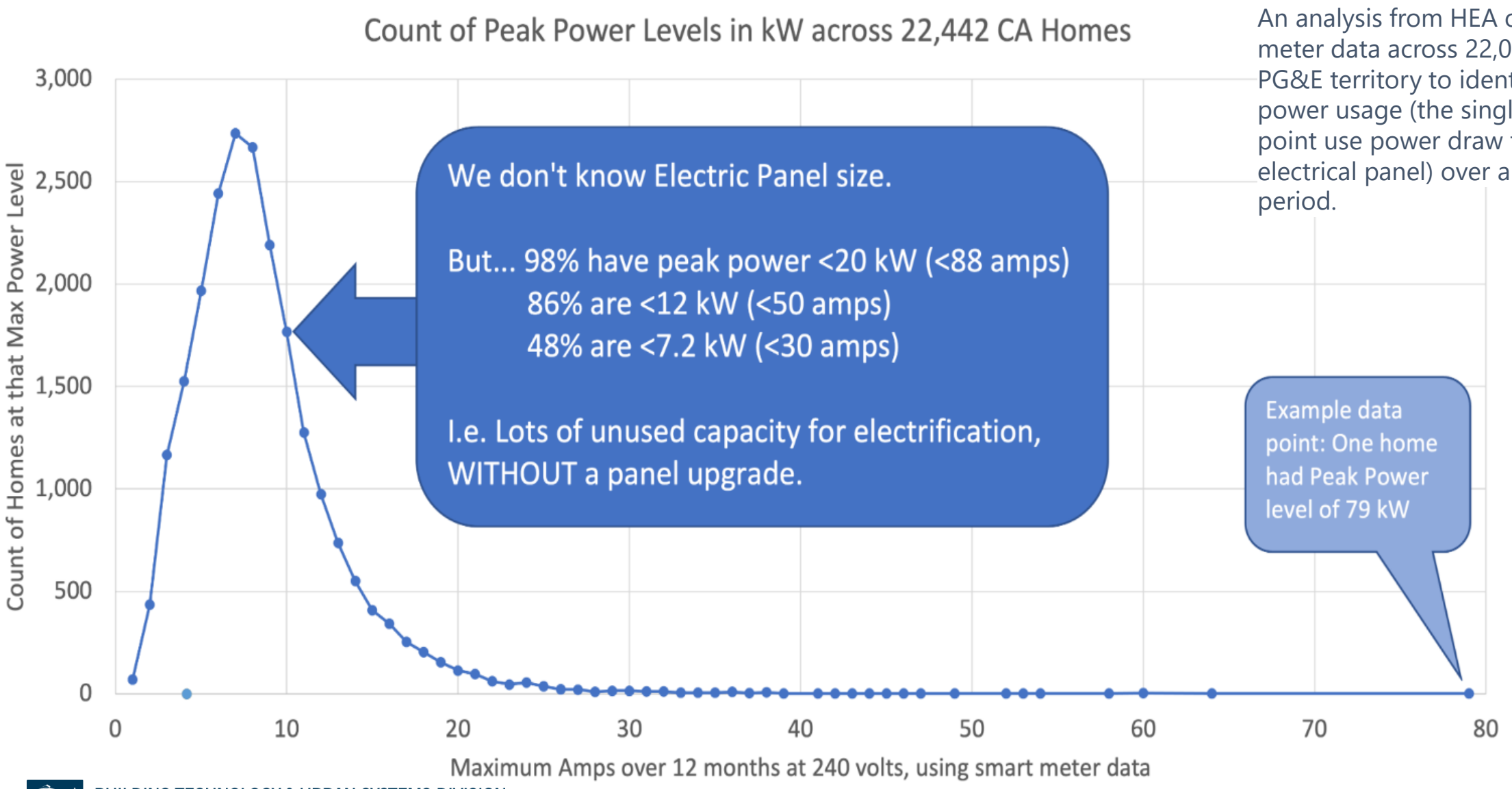
Available Capacity to Electrify



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

Source:
HEA, HomeIntel

Available Capacity to Electrify



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.

Source:
HEA, HomeIntel

220.87 Determining Existing Loads. The calculation of a feeder or service load for existing installations shall be permitted to use actual maximum demand to determine the existing load under all of the following conditions:

(1) The maximum demand data is available for a 1-year period.

Exception: If the maximum demand data for a 1-year period is not available, the calculated load shall be permitted to be based on the maximum demand (the highest average kilowatts reached and maintained for a 15-minute interval) continuously recorded over a minimum 30-day period using a recording ammeter or power meter connected to the highest loaded phase of the feeder or service, based on the initial loading at the start of the recording. The recording shall reflect the maximum demand of the feeder or service by being taken when the building or space is occupied and shall include by measurement or calculation the larger of the heating or cooling equipment load, and other loads that might be periodic in nature due to seasonal or similar conditions. This exception shall not be permitted if the feeder or service has a renewable energy system (i.e., solar photovoltaic or wind electric) or employs any form of peak load shaving.

(2) The maximum demand at 125 percent plus the new load does not exceed the ampacity of the feeder or rating of the service.

(3) The feeder has overcurrent protection in accordance with 240.4, and the service has overload protection in accordance with 230.90.

Determining Existing Loads

- Overall, improve clarity and usability
- Update language to explicitly allow smart meter data
- Lack of clarity on 60- vs. 15-min data
- Add adjustment from 60- to 15-min
- Clarify calculation procedures when <1-year of data is available
- Add method for solar PV based on peak output of inverter or real-time estimates of output
- Question whether 125% assumption of Continuous Loads is appropriate
- Currently lacks clear discussion of how to account for new loads (explicitly link with 220.83)

220.83 Existing Dwelling Unit. This section shall be permitted to be used to determine if the existing service or feeder is of sufficient capacity to serve additional loads. Where the dwelling unit is served by a 120/240-volt or 208Y/120-volt, 3-wire service or feeder, calculating the total load in accordance with 220.83(A) or (B) shall be permitted.

(A) Where Additional Air-Conditioning Equipment or Electric Space-Heating Equipment Is Not to Be Installed. The percentages listed in Table 220.83(A) shall be used for existing and additional new loads.

Load calculations shall include the following:

(1) General lighting and general-use receptacles at 33 volt-amperes/m^2 or 3 volt-amperes/ft^2 as determined by 220.42
(2) 1500 volt-amperes for each 2-wire, 20-ampere small-appliance branch circuit and each laundry branch circuit covered in 210.11(C)(1) and (C)(2)
(3) The nameplate rating of the following:
   a. All appliances that are fastened in place, permanently connected, or located to be on a specific circuit
   b. Ranges, wall-mounted ovens, counter-mounted cooking units
   c. Clothes dryers that are not connected to the laundry branch circuit specified in item (2)
   d. Water heaters

(B) Where Additional Air-Conditioning Equipment or Electric Space-Heating Equipment Is to Be Installed. The percentages listed in Table 220.83(B) shall be used for existing and additional new loads. The larger connected load of air conditioning or space heating, but not both, shall be used.

Other loads shall include the following:

(1) General lighting and general-use receptacles at 33 volt-amperes/m^2 or 3 volt-amperes/ft^2 as determined by 220.42
(2) 1500 volt-amperes for each 2-wire, 20-ampere small-appliance branch circuit and each laundry branch circuit covered in 210.11(C)(1) and (C)(2)
(3) The nameplate rating of the following:
   a. All appliances that are fastened in place, permanently connected, or located to be on a specific circuit
   b. Ranges, wall-mounted ovens, counter-mounted cooking units
   c. Clothes dryers that are not connected to the laundry branch circuit specified in item (2)
   d. Water heaters

Table 220.83(A) Without Additional Air-Conditioning or Electric Space-Heating Equipment

Load (kVA)	Percent of Load
First 8 kVA of load at	100
Remainder of load at	40

Table 220.83(B) With Additional Air-Conditioning or Electric Space-Heating Equipment

Load	Percent of Load
Air-conditioning equipment	100
Central electric space heating	100
Less than four separately controlled space-heating units	100
First 8 kVA of all other loads	100
Remainder of all other loads	40

220.83 Existing Dwelling Unit. This section shall be permitted to be used to determine if the existing service or feeder is of sufficient capacity to serve additional loads. Where the dwelling unit is served by a 120/240-volt or 208Y/120-volt, 3-wire service or feeder, calculating the total load in accordance with 220.83(A) or (B) shall be permitted.

(A) Where Additional Air-Conditioning Equipment or Electric Space-Heating Equipment Is Not to Be Installed. The percentages listed in Table 220.83(A) shall be used for existing and additional new loads.

No new A/C or electric heating

Load calculations shall include the following:

(1) General lighting and general-use receptacles at 33 volt-amperes/m^2 or 3 volt-amperes/ft^2 as determined by 220.42

(2) 1500 volt-amperes for each 2-wire, 20-ampere small-appliance branch circuit and each laundry branch circuit covered in 210.11(C)(1) and (C)(2)

(3) The nameplate rating of the following:

a. All appliances that are fastened in place, permanently connected, or located to be on a specific circuit
b. Ranges, wall-mounted ovens, counter-mounted cooking units
c. Clothes dryers that are not connected to the laundry branch circuit specified in item (2)
d. Water heaters

(B) Where Additional Air-Conditioning Equipment or Electric Space-Heating Equipment Is to Be Installed. The percentages listed in Table 220.83(B) shall be used for existing and additional new loads. The larger connected load of air conditioning or space heating, but not both, shall be used.

New A/C or electric heating
(always treated at 100% of nameplate rating)

Other loads shall include the following:

(1) General lighting and general-use receptacles at 33 volt-amperes/m^2 or 3 volt-amperes/ft^2 as determined by 220.42

(2) 1500 volt-amperes for each 2-wire, 20-ampere small-appliance branch circuit and each laundry branch circuit covered in 210.11(C)(1) and (C)(2)

(3) The nameplate rating of the following:

a. All appliances that are fastened in place, permanently connected, or located to be on a specific circuit
b. Ranges, wall-mounted ovens, counter-mounted cooking units
c. Clothes dryers that are not connected to the laundry branch circuit specified in item (2)
d. Water heaters

Table 220.83(A) Without Additional Air-Conditioning or Electric Space-Heating Equipment

Load (kVA)	Percent of Load
First 8 kVA of load at	100
Remainder of load at	40

Table 220.83(B) With Additional Air-Conditioning or Electric Space-Heating Equipment

Load	Percent of Load
Air-conditioning equipment	100
Central electric space heating	100
Less than four separately controlled space-heating units	100
First 8 kVA of all other loads	100
Remainder of all other loads	40

220.83 Existing Dwelling Unit. This section shall be permitted to be used to determine if the existing service or feeder is of sufficient capacity to serve additional loads. Where the dwelling unit is served by a 120/240-volt or 208Y/120-volt, 3-wire service or feeder, calculating the total load in accordance with 220.83(A) or (B) shall be permitted.

(A) Where Additional Air-Conditioning Equipment or Electric Space-Heating Equipment Is Not to Be Installed. The percentages listed in Table 220.83(A) shall be used for existing and additional new loads.

Load calculations shall include the following:

(1) General lighting and general-use receptacles at 33 volt-amperes/m² or 3 volt-amperes/ft² as determined by 220.42
(2) 1500 volt-amperes for each 2-wire, 20-ampere small-appliance branch circuit and each laundry branch circuit covered in 210.11(C)(1) and (C)(2)
(3) The nameplate rating of the following:
   a. All appliances that are fastened in place, permanently connected, or located to be on a specific circuit
   b. Ranges, wall-mounted ovens, counter-mounted cooking units
   c. Clothes dryers that are not connected to the laundry branch circuit specified in item (2)
   d. Water heaters

(B) Where Additional Air-Conditioning Equipment or Electric Space-Heating Equipment Is to Be Installed. The percentages listed in Table 220.83(B) shall be used for existing and additional new loads. The larger connected load of air conditioning or space heating, but not both, shall be used.

Other loads shall include the following:

(1) General lighting and general-use receptacles at 33 volt-amperes/m² or 3 volt-amperes/ft² as determined by 220.42
(2) 1500 volt-amperes for each 2-wire, 20-ampere small-appliance branch circuit and each laundry branch circuit covered in 210.11(C)(1) and (C)(2)
(3) The nameplate rating of the following:
   a. All appliances that are fastened in place, permanently connected, or located to be on a specific circuit
   b. Ranges, wall-mounted ovens, counter-mounted cooking units
   c. Clothes dryers that are not connected to the laundry branch circuit specified in item (2)
   d. Water heaters

Table 220.83(A) Without Additional Air-Conditioning or Electric Space-Heating Equipment

Load (kVA)	Percent of Load
First 8 kVA of load at	100
Remainder of load at	40

Table 220.83(B) With Additional Air-Conditioning or Electric Space-Heating Equipment

Load	Percent of Load
Air-conditioning equipment	100
Central electric space heating	100
Less than four separately controlled space-heating units	100
First 8 kVA of all other loads	100
Remainder of all other loads	40

3 watts/ft² for general lighting and plugs. For comparison, Table 220.42(A) lists assumptions for other building types. ALL <2.2 and most 1-1.5 watts/ft².

220.83 Existing Dwelling Unit. This section shall be permitted to be used to determine if the existing service or feeder is of sufficient capacity to serve additional loads. Where the dwelling unit is served by a 120/240-volt or 208Y/120-volt, 3-wire service or feeder, calculating the total load in accordance with 220.83(A) or (B) shall be permitted.

(A) Where Additional Air-Conditioning Equipment or Electric Space-Heating Equipment Is Not to Be Installed. The percentages listed in Table 220.83(A) shall be used for existing and additional new loads.

Load calculations shall include the following:

(1) General lighting and general-use receptacles at 33 volt-amperes/m^2 or 3 volt-amperes/ft^2 as determined by 220.42
(2) 1500 volt-amperes for each 2-wire, 20-ampere small-appliance branch circuit and each laundry branch circuit covered in 210.11(C)(1) and (C)(2)
(3) The nameplate rating of the following:
   a. All appliances that are fastened in place, permanently connected, or located to be on a specific circuit
   b. Ranges, wall-mounted ovens, counter-mounted cooking units
   c. Clothes dryers that are not connected to the laundry branch circuit specified in item (2)
   d. Water heaters

(B) Where Additional Air-Conditioning Equipment or Electric Space-Heating Equipment Is to Be Installed. The percentages listed in Table 220.83(B) shall be used for existing and additional new loads. The larger connected load of air conditioning or space heating, but not both, shall be used.

Other loads shall include the following:

(1) General lighting and general-use receptacles at 33 volt-amperes/m^2 or 3 volt-amperes/ft^2 as determined by 220.42
(2) 1500 volt-amperes for each 2-wire, 20-ampere small-appliance branch circuit and each laundry branch circuit covered in 210.11(C)(1) and (C)(2)
(3) The nameplate rating of the following:
   a. All appliances that are fastened in place, permanently connected, or located to be on a specific circuit
   b. Ranges, wall-mounted ovens, counter-mounted cooking units
   c. Clothes dryers that are not connected to the laundry branch circuit specified in item (2)
   d. Water heaters

1,500 watts for each small appliance and laundry branch circuit

Table 220.83(A) Without Additional Air-Conditioning or Electric Space-Heating Equipment

Load (kVA)	Percent of Load
First 8 kVA of load at	100
Remainder of load at	40

Table 220.83(B) With Additional Air-Conditioning or Electric Space-Heating Equipment

Load	Percent of Load
Air-conditioning equipment	100
Central electric space heating	100
Less than four separately controlled space-heating units	100
First 8 kVA of all other loads	100
Remainder of all other loads	40

220.83 Existing Dwelling Unit. This section shall be permitted to be used to determine if the existing service or feeder is of sufficient capacity to serve additional loads. Where the dwelling unit is served by a 120/240-volt or 208Y/120-volt, 3-wire service or feeder, calculating the total load in accordance with 220.83(A) or (B) shall be permitted.

(A) Where Additional Air-Conditioning Equipment or Electric Space-Heating Equipment Is Not to Be Installed. The percentages listed in Table 220.83(A) shall be used for existing and additional new loads.

Load calculations shall include the following:

(1) General lighting and general-use receptacles at 33 volt-amperes/m^2 or 3 volt-amperes/ft^2 as determined by 220.42
(2) 1500 volt-amperes for each 2-wire, 20-ampere small-appliance branch circuit and each laundry branch circuit covered in 210.11(C)(1) and (C)(2)
(3) The nameplate rating of the following:
   a. All appliances that are fastened in place, permanently connected, or located to be on a specific circuit
   b. Ranges, wall-mounted ovens, counter-mounted cooking units
   c. Clothes dryers that are not connected to the laundry branch circuit specified in item (2)
   d. Water heaters

(B) Where Additional Air-Conditioning Equipment or Electric Space-Heating Equipment Is to Be Installed. The percentages listed in Table 220.83(B) shall be used for existing and additional new loads. The larger connected load of air conditioning or space heating, but not both, shall be used.

Other loads shall include the following:

(1) General lighting and general-use receptacles at 33 volt-amperes/m^2 or 3 volt-amperes/ft^2 as determined by 220.42
(2) 1500 volt-amperes for each 2-wire, 20-ampere small-appliance branch circuit and each laundry branch circuit covered in 210.11(C)(1) and (C)(2)
(3) The nameplate rating of the following:
   a. All appliances that are fastened in place, permanently connected, or located to be on a specific circuit
   b. Ranges, wall-mounted ovens, counter-mounted cooking units
   c. Clothes dryers that are not connected to the laundry branch circuit specified in item (2)
   d. Water heaters

Table 220.83(A) Without Additional Air-Conditioning or Electric Space-Heating Equipment

Load (kVA)	Percent of Load
First 8 kVA of load at	100
Remainder of load at	40

Table 220.83(B) With Additional Air-Conditioning or Electric Space-Heating Equipment

Load	Percent of Load
Air-conditioning equipment	100
Central electric space heating	100
Less than four separately controlled space-heating units	100
First 8 kVA of all other loads	100
Remainder of all other loads	40

Do we need explicit language addressing EV, stationary batteries, etc.?

Energy Management Systems

From Article 750

(1) Current Setpoint. A single value equal to the maximum ampere setpoint of the EMS shall be permitted for one or more of the following:

(1) For calculating the connected load per 220.70
(2) For the maximum source current permitted by EMS control

From Article 220

220.70 Energy Management Systems (EMSs). If an energy management system (EMS) is used to limit the current to a feeder or service in accordance with 750.30, a single value equal to the maximum ampere setpoint of the EMS shall be permitted to be used in load calculations for the feeder or service.

The setpoint value of the EMS shall be considered a continuous load for the purposes of load calculations.

Energy Management Systems

From Article 750

(1) Current Setpoint. A single value equal to the maximum ampere setpoint of the EMS shall be permitted for one or more of the following:

(1) For calculating the connected load per 220.70
(2) For the maximum source current permitted by EMS control

Does a single value really suffice?

From Article 220

220.70 Energy Management Systems (EMSs). If an energy management system (EMS) is used to limit the current to a feeder or service in accordance with 750.30, a single value equal to the maximum ampere setpoint of the EMS shall be permitted to be used in load calculations for the feeder or service.

The setpoint value of the EMS shall be considered a continuous load for the purposes of load calculations.

How do we account for tech that controls only certain loads (e.g., EV and DHW) based on the whole dwelling real-time demand?

Want to Be Involved?

- Share data (panel amperage, peak data, end-uses)
- Review draft code language prior to sharing with NFPA (before April 2023)
- Local adoption of code provisions:
  - Advocate with the California Building Standards Commission
  - Convene national code stakeholders group to support local adoption of low-power provisions prior to 2026 code launch

What About Different Load Types Adding Differently?

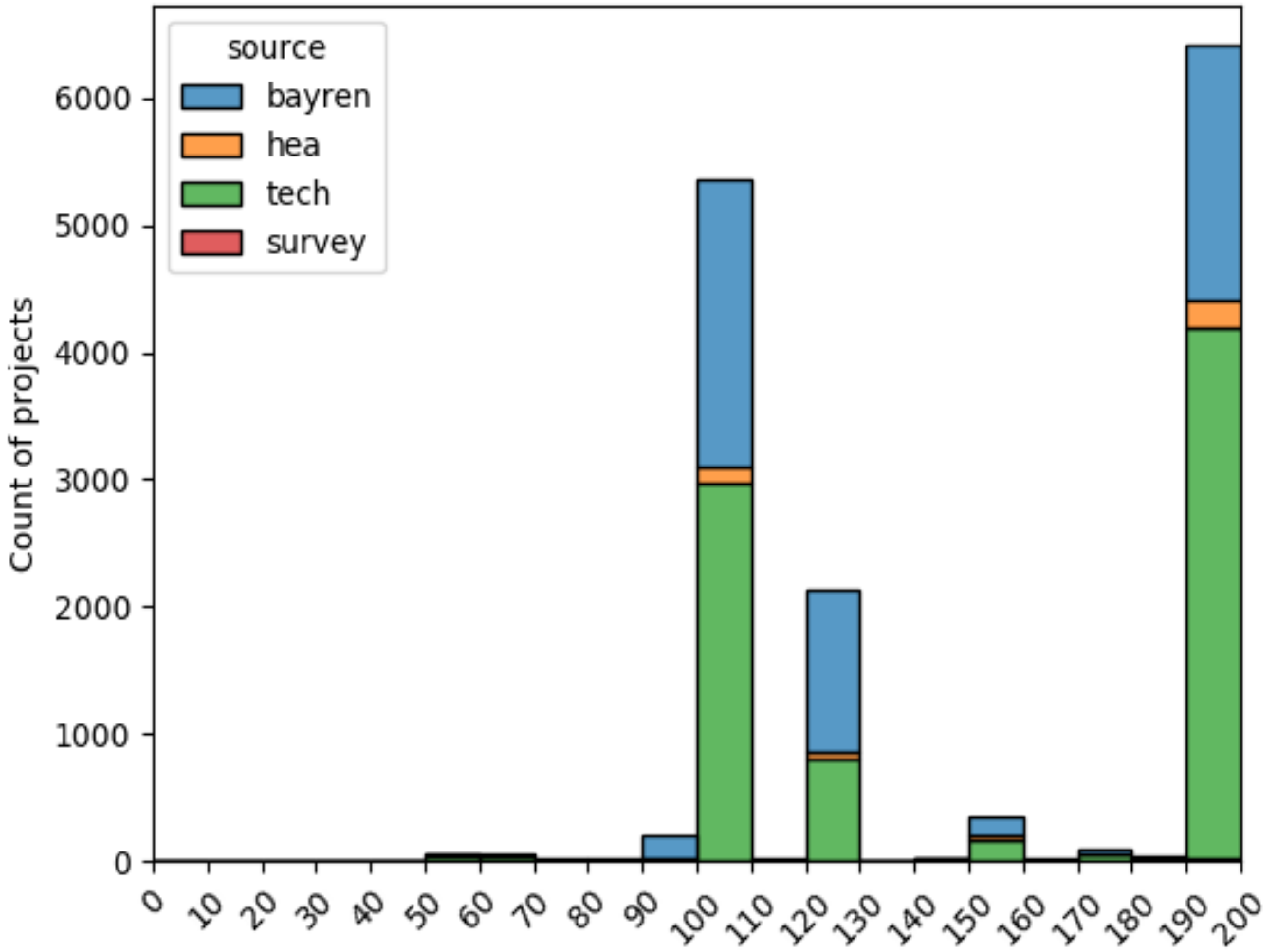
- HVAC, EV, DHW, Laundry and Cooking might add very differently.
- Currently the code recognizes HVAC as being different and treats it with a 100% multiplier.
- We could derive distinct slope/multiplier values for different load types, if this is justified in the data.
  - New Peak = Intercept + 0.8 x HVAC + 0.5 x DHW + 0.95 x EV + 0.2 x All Others
  - This increases complexity and makes analysis more difficult.

NEC update: using Metered Data

15 minute data from 1300 homes from NEEA study

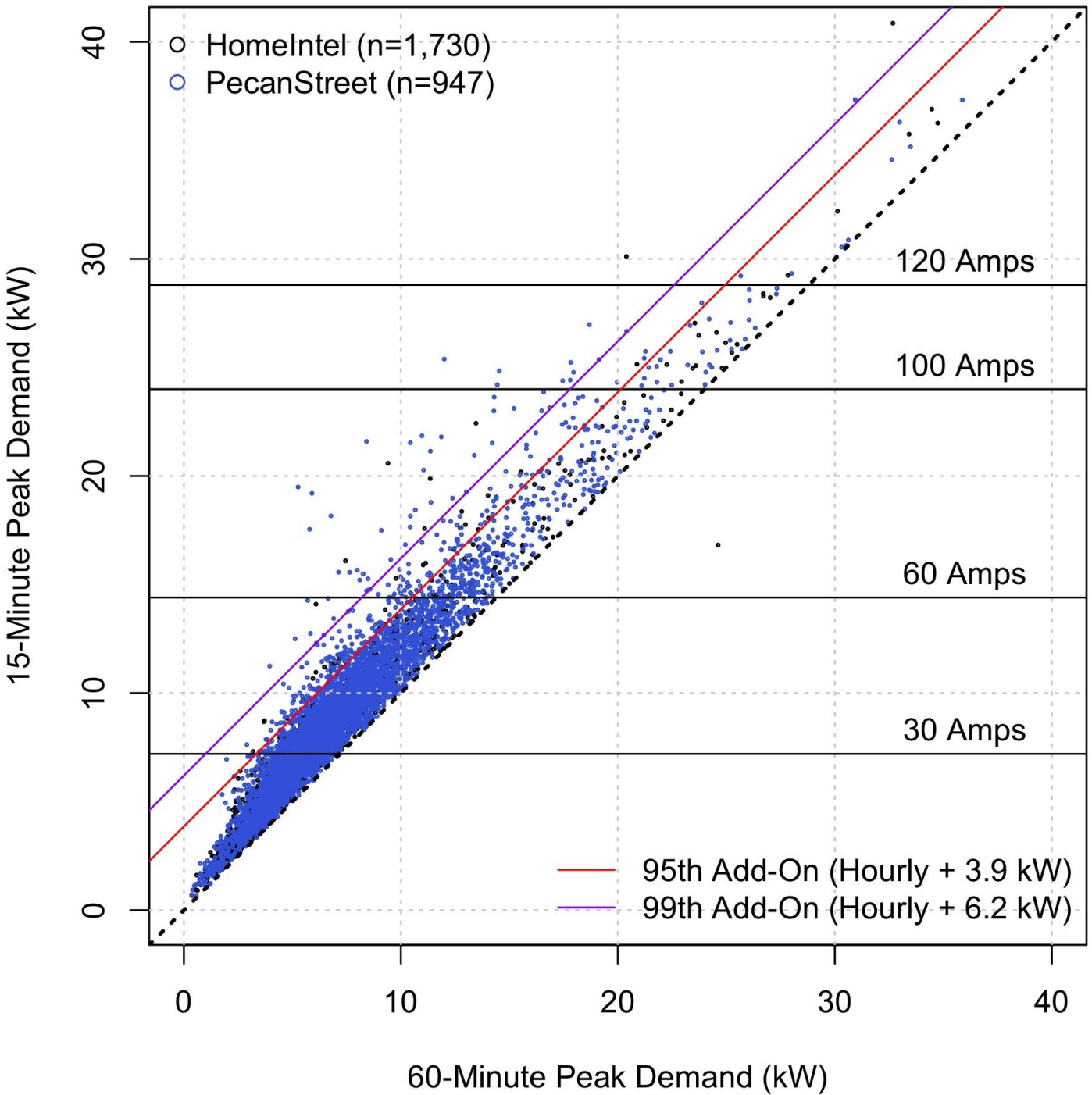
- How close do homes get to panel capacity
  - How much capacity is really available??
- If high power devices share a circuit how often would one have to be switched off?
  - When are devices coincident with peak load?
  - What end uses contribute most to peak load?

Using Metered Data



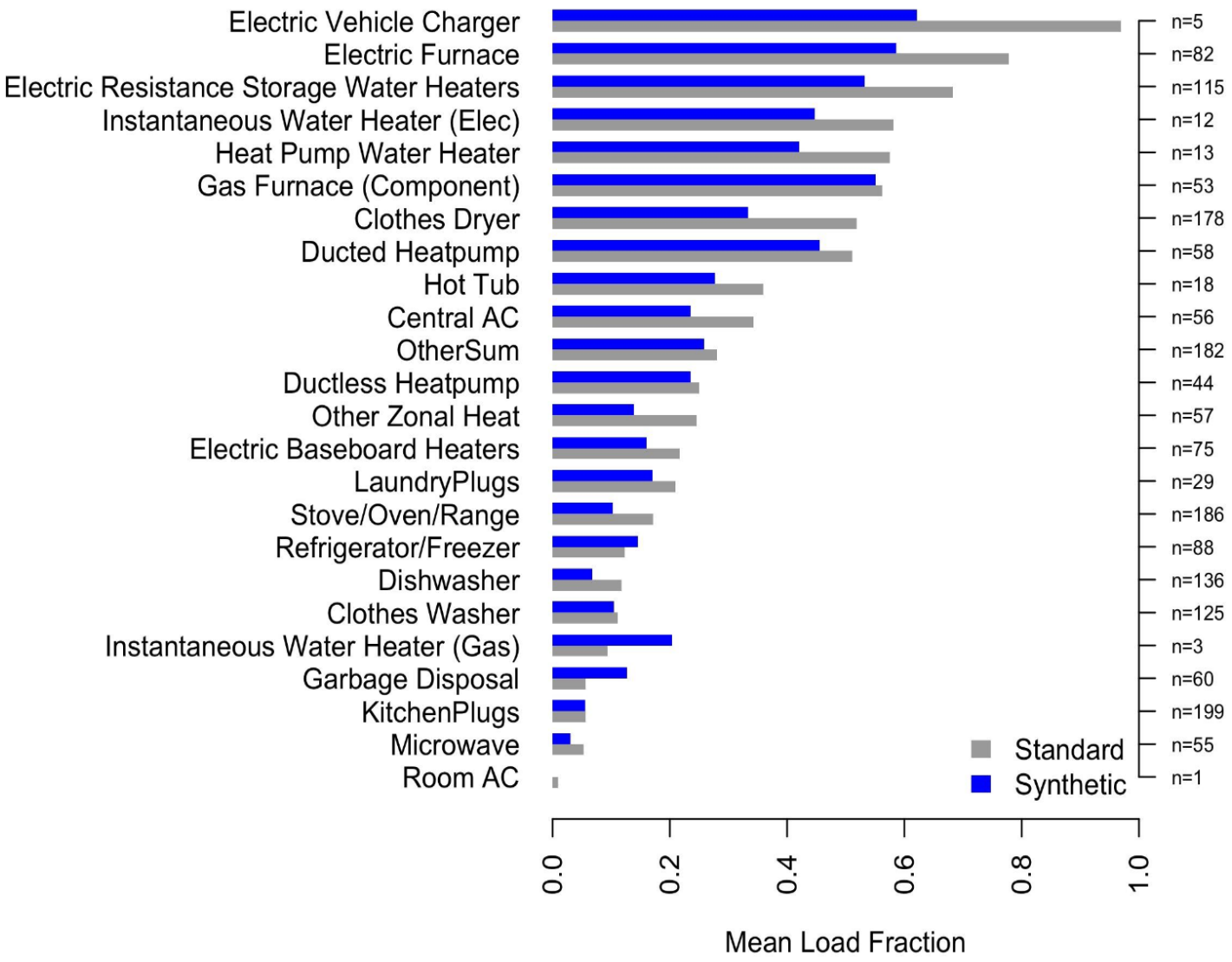
Using Metered Data

Predicting 15-minute from 60-minute peak demand data



Using Metered Data

Load Fractions by End-Use Type



Initial Thoughts on End-Use Load Fractions

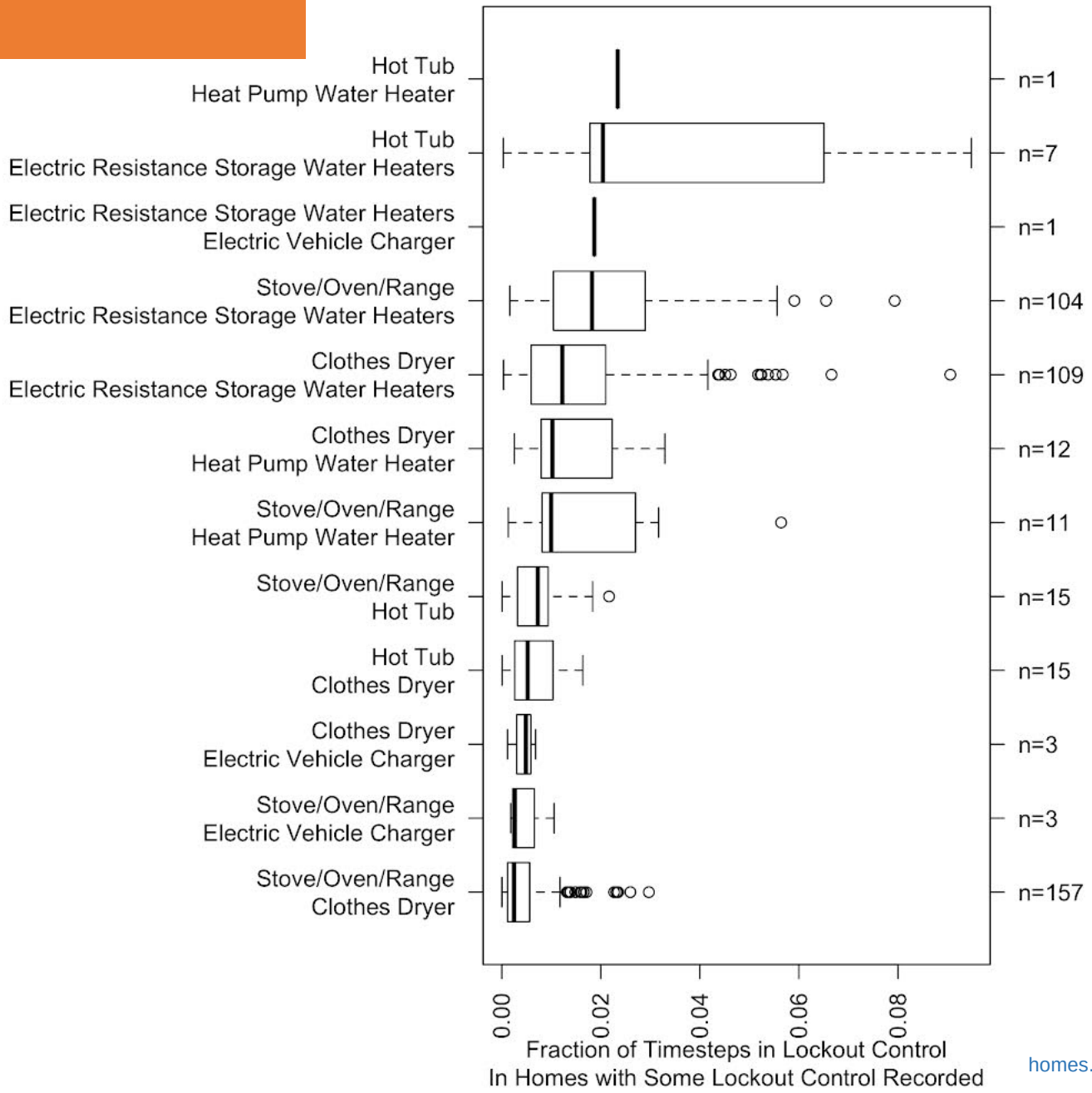
- Three categories to include in NEC calculations:
  - Household appliances that are human-operated: **<20%**
  - Thermostat-controlled devices (e.g., water heating and HVAC): **40-60%**
  - Electric vehicle charging: **100%**
- Other data sources will be analyzed and merged with the EULR data using standardized end-use categories

https://neea.org/data/nw-end-use-load-research-project/energy-metering-study-data

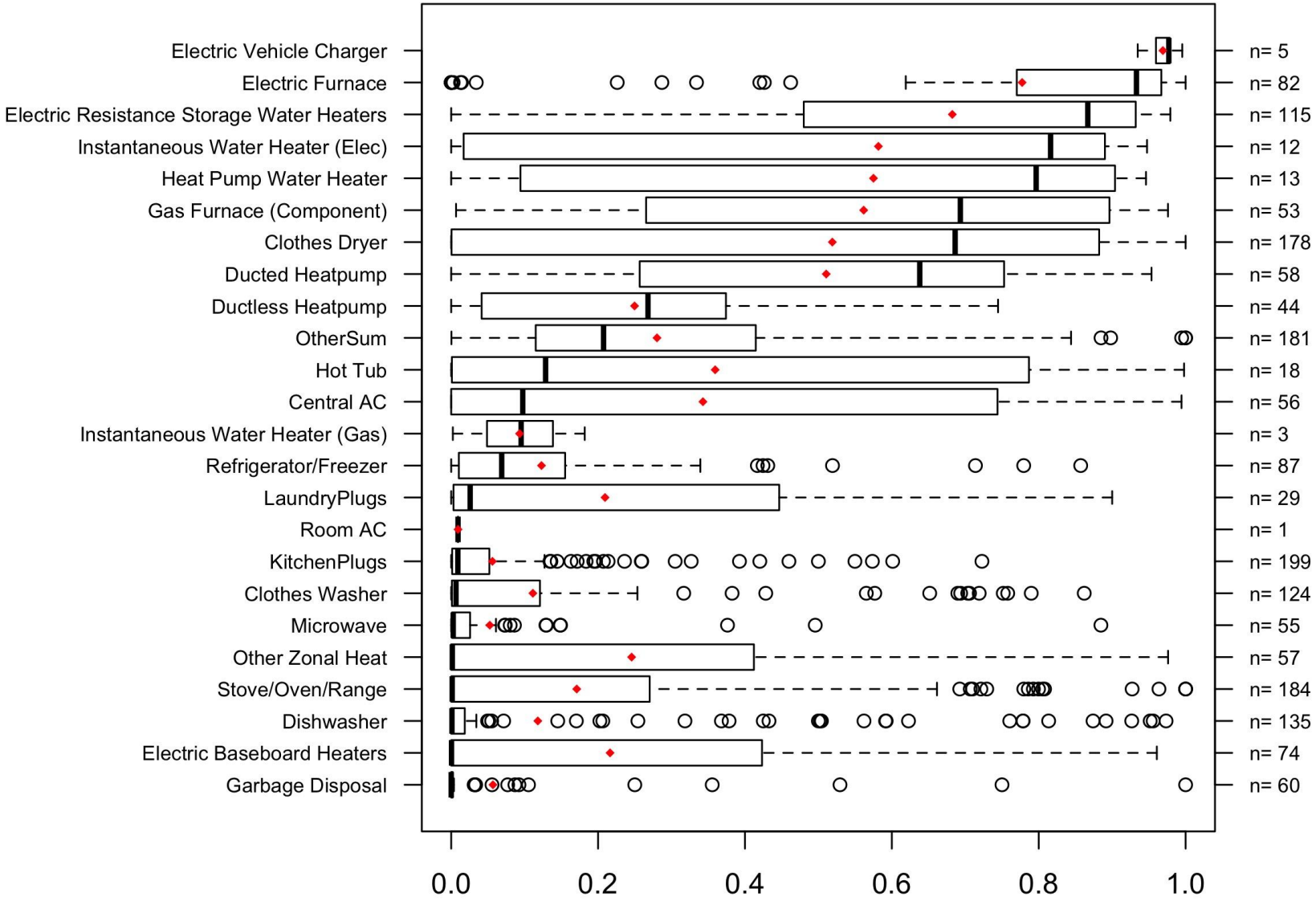
Circuit Sharing Potential

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?



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

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

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

- We need rebates for ***avoiding*** panel replacement
  - 120V HPWH
  - Small split HP systems
  - 120V cooking
  - Battery and energy storage systems (whole home or in appliances)
  - EV pausers
  - Meter collars
  - Reduces grid stress in the future as we electrify

Summary

- Use existing NEC options (with guidance available online)
- Use power efficient equipment – preferably 120V
- Use circuit sharing – particularly for EVs (most “pauseable” load)
  - Consider lower power EV charging
- Meter collars allow quick addition of big loads
- Traditional load reduction helps (lower capacity heating/cooling equipment)

In the (near) future

- Storage technologies at whole house and individual appliance level
- Updated NEC to allow new technologies & improve existing calculations
- More resources to guide contractors and homeowners becoming available
- More power efficient options

Resources

- For electrification big picture: **Rewiring America** and **Rewiring Communities**
- For power-restricted homes: **Redwood Energy Pocket Guide**

Rewiring Communities:

A Plan to Accelerate Climate Action and Environmental Justice By Investing in Household Electrification at the Local Level

[1] Adam Zurofsky,[2] Jeffrey Schub,[3] John Rhodes,[4] Tony Curnes,[5] and Sam Calisch[6]

REWIRING AMERICA

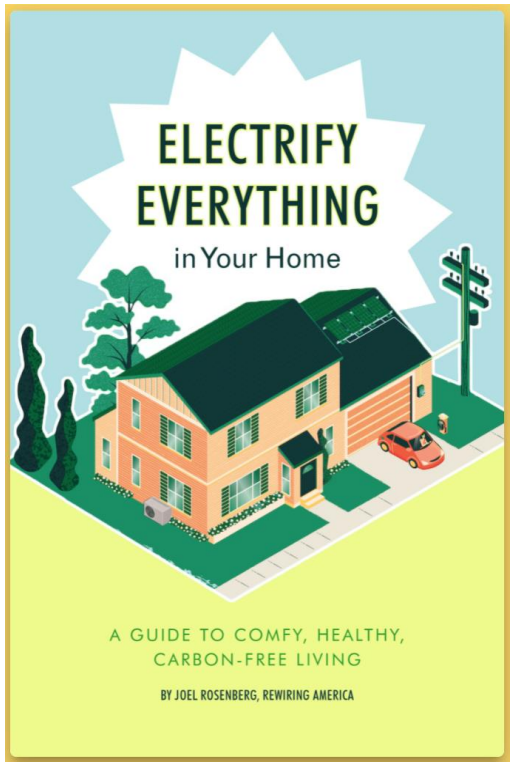
Coalition for Green Capital

Resources

https://www.natethehousewhisperer.com/electrify-everything-course.html

THE SWITCH IS ON

https://www.switchison.org/



https://www.rewiringamerica.org/electrify-home-guide

Most Efficient 2022
ENERGY STAR
www.energystar.gov

BUILDING DECARBONIZATION COALITION

Questions?

Extra slides

Breaker curve

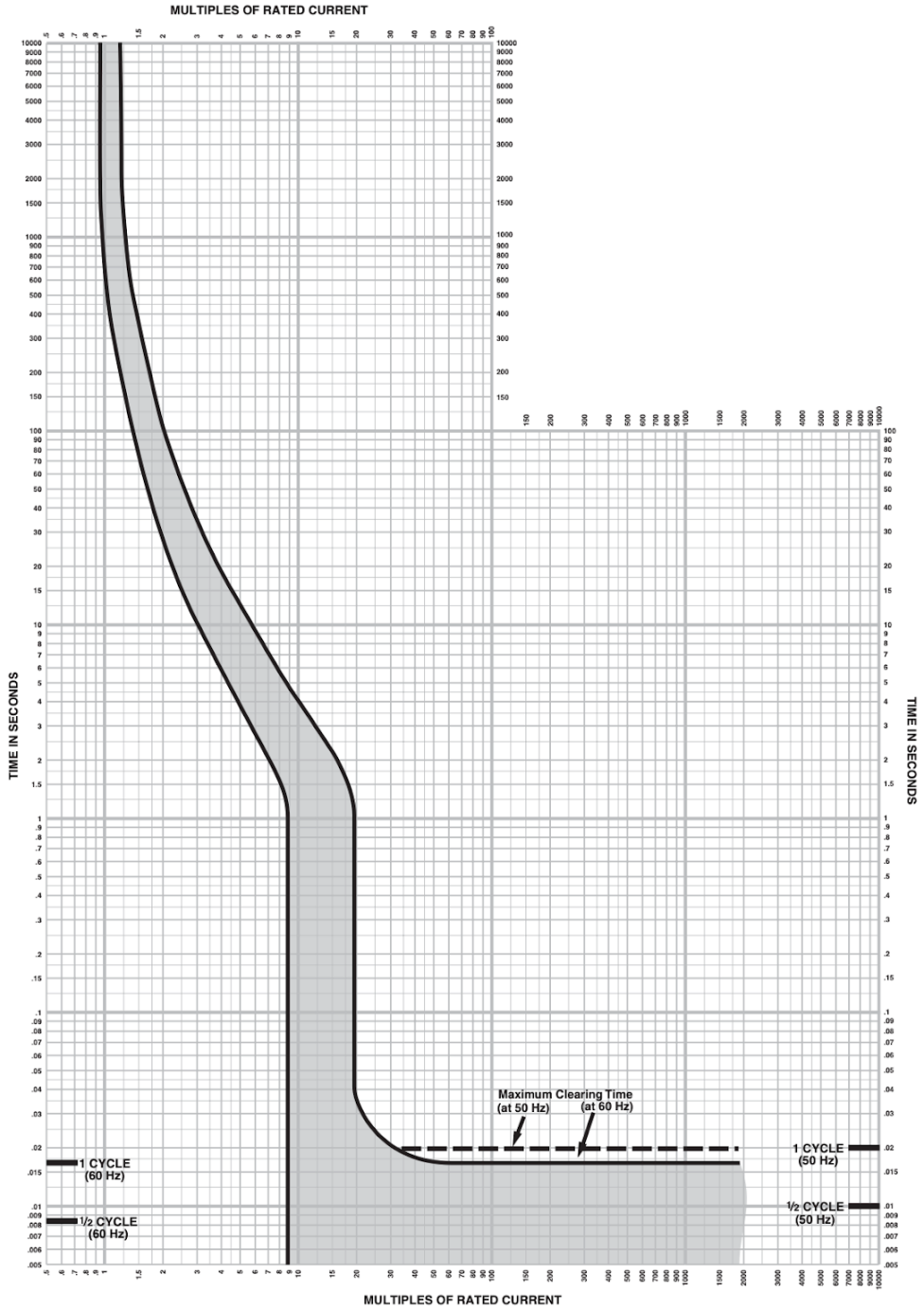


Figure 1: Thermal-magnetic Time/Current Characteristic Curve

Tips for avoiding an expensive electric panel upgrade:

- Consider sharing existing 240V circuits between two devices using a "smart splitter" like those from NeoCharge, SplitVolt and DryerBuddy.
- To free up old 240V circuits, upgrade to more efficient appliances, such as a combined 120V washer dryer, a kitchen range that combines an induction cooktop with an oven on a single circuit, or replacing a 240 volt oven with a plug in air fryer, instapot, or other combined device.
- Consider a load monitoring device to "throttle" EV chargers to available household power, such as the SimpleSwitch or DCC-9 devices.
- Limit EV charging. Note that most EVs will gain over 40 miles of range after 10 hours of charging on a standard120V outlet. This satisfies most commutes, and longer trips can be handled via the growing network of public DCfast-charging stations.
- If you are considering a panel upgrade see this related report by PG&E and others.
- Plan in advance for future loads, like EV chargers, heat pumps, and induction cooktops. If panel capacity is limited, spend more for the most efficient versions of each appliance since it can avoid much more expensive panel upgrade costs.

Findings About Costs - Homeowner Side

"Homeowner Equipment Service Upgrade Fee" refers to the electrical panel and associated work behind the meter

Cost Description	Average cost	Transaction
Homeowner Equipment Service Upgrade Fee	$1,300 - $5,000	Homeowner → Contractor
Breaker Panel Upgrade	$1,300 - $5,000	Homeowner → Contractor
Upgrade/New Branch Circuits	$250 - $700 per circuit	Homeowner → Contractor
Permit Costs	**PG&E Territory**: $125 - $500 **Arcata, CA**: $129 **Humboldt County**: $132 **Other Northern Counties**: $125 - $140 **SDG&E Territory**: City $128, County $136	Homeowner → Contractor — OR — Homeowner → City/County
	Contractor "Bundled" Fee: $500 (All Permit + Labor Fees in one)	Homeowner → City/County
Trenching & Conduit	$5 - $15 per linear foot (Homeowner Property)	Homeowner → Contractor

Objective 2. Understand the costs incurred by all parties when upgrading electrical service to residential sites

Activity 1: Identify typical costs and Activity 2: Identify/explain factors that impact these costs

1 Customer-Owned Equipment Upgrades

$3,000 to $18,000+

Cost Description	Average cost	Transaction
Homeowner Equipment Service Upgrade Fee	$1,300 - $5,000	Homeowner → Contractor
Breaker Panel Upgrade	$1,300 - $5,000	Homeowner → Contractor
Upgrade/New Branch Circuits	$250 - $700 per circuit	Homeowner → Contractor
Permit Costs	**PG&E Territory**: $125 - $500 **Arcata, CA**: $129 **Humboldt County**: $132 **Other Northern Counties**: $125 - $140 **SDG&E Territory**: City $128, County $136	Homeowner → Contractor — OR — Homeowner → City/County
	Contractor "Bundled" Fee: $500 (All Permit + Labor Fees in one)	Homeowner → City/County
Trenching & Conduit	$5 - $15 per linear foot (Homeowner Property)	Homeowner → Contractor

Activity 1: Identify typical costs and Activity 2: Identify/explain factors that impact these costs

2 Contractor Bills Utility for Labor

$2,000 to $30,000+

Utility provides the materials

- Wire
- Conduit
- Pole changeouts
- Transformer upgrades

Cost Description	Average cost	Transaction
Transformer Upgrade	$6,000 - $8,000	Homeowner → Utility
Pole Replacement	$9,000 - $11,000	Homeowner → Utility
Total New or Upgraded Utility Equipment Service	$10,000 - $30,000	Utility → Contractor
Overhead line, service line only	$2,850 - $4,500 (Utility supplies materials)	Utility → Contractor
Overhead line with a new Utility pole	$11,000 - $13,000 (Utility supplies materials)	Utility → Contractor
Overhead to underground conversion	$13,000 - $18,000 (Utility supplies materials)	Utility → Contractor
Trenching for underground upgrades	$180 to $200 per llinear foot (Utility/Public Property)	Utility → Contractor

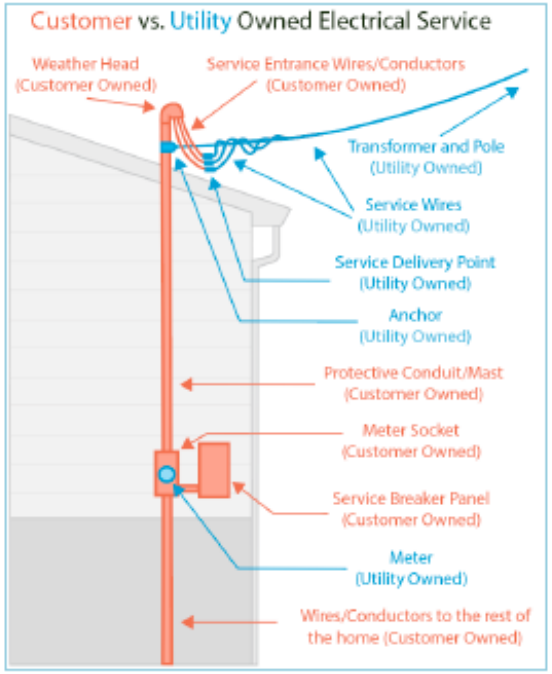
All costs that exceed the Rule 15 and 16 allowance are passed on to the customer for the service upgrade

Utility Equipment Costs that the Customer May Pay

Cost Description	Average cost	Transaction
Transformer Upgrade	$6,000 - $8,000	Homeowner → Utility
Pole Replacement	$9,000 - $11,000	Homeowner → Utility
Total New or Upgraded Utility Equipment Service	$10,000 - $30,000	Utility → Contractor
Overhead line, service line only	$2,850 - $4,500 (Utility supplies materials)	Utility → Contractor
Overhead line with a new Utility pole	$11,000 - $13,000 (Utility supplies materials)	Utility → Contractor
Overhead to underground conversion	$13,000 - $18,000 (Utility supplies materials)	Utility → Contractor
Trenching for underground upgrades	$180 to $200 per llinear foot (Utility/Public Property)	Utility → Contractor

Service Upgrades for Electrification Retrofits Study Final Report

May 27, 2022



Courtesy of Emily Higbee, Redwood Energy Research Director

The above image displays ownership of basic electrical service equipment that will be assessed by an electrification retrofit contractor to complete an overhead Service Upgrade. All the components depicted in the diagram are within the scope of an electrical Service Upgrade discussed in the report except for new wires to the rest of the home.

CALMAC STUDY ID: **PG&E0467.01**

CONTRIBUTORS

NV5 INC.
Shoshana Pena, Director of Program Services
Collin Smith, Program Manager
Greg Butsko, Vice President of Distribution Services
Rick Gardner, Director of Distribution Services

REDWOOD ENERGY
Sean Armstrong, Principal
Emily Higbee, Research Director
Dylan Anderson, Senior Staff Researcher
Rebecca Hueckel, Senior Staff Researcher

PROJECT SPONSORS
Pacific Gas and Electric Company: Robert Kasman, Victoria Culter, and Kati Pech
San Diego Gas and Electric Company: Kelvin Valenzuela and Dan Hudgins