2023 CONFERENCE
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RESIDENTIAL ENERGY SERVICES NETWORK
SAN DIEGO, CA
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Home Decarbonization and Electrification

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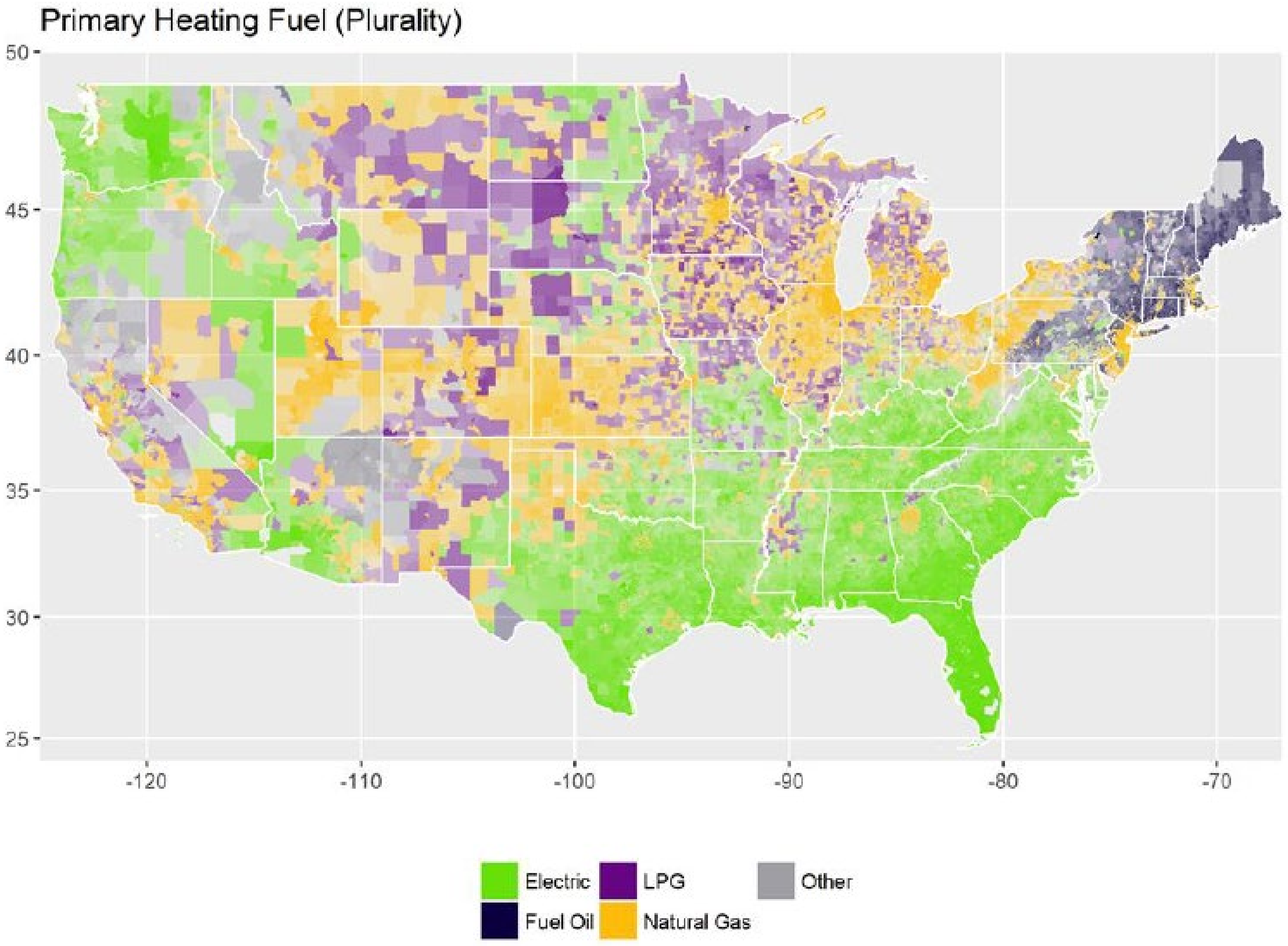
Background

Current Heating Fuel Use in the US



Data from the American Community Survey (2016).

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

Electric Heating

- 51% of MF units
- 27% of SF units

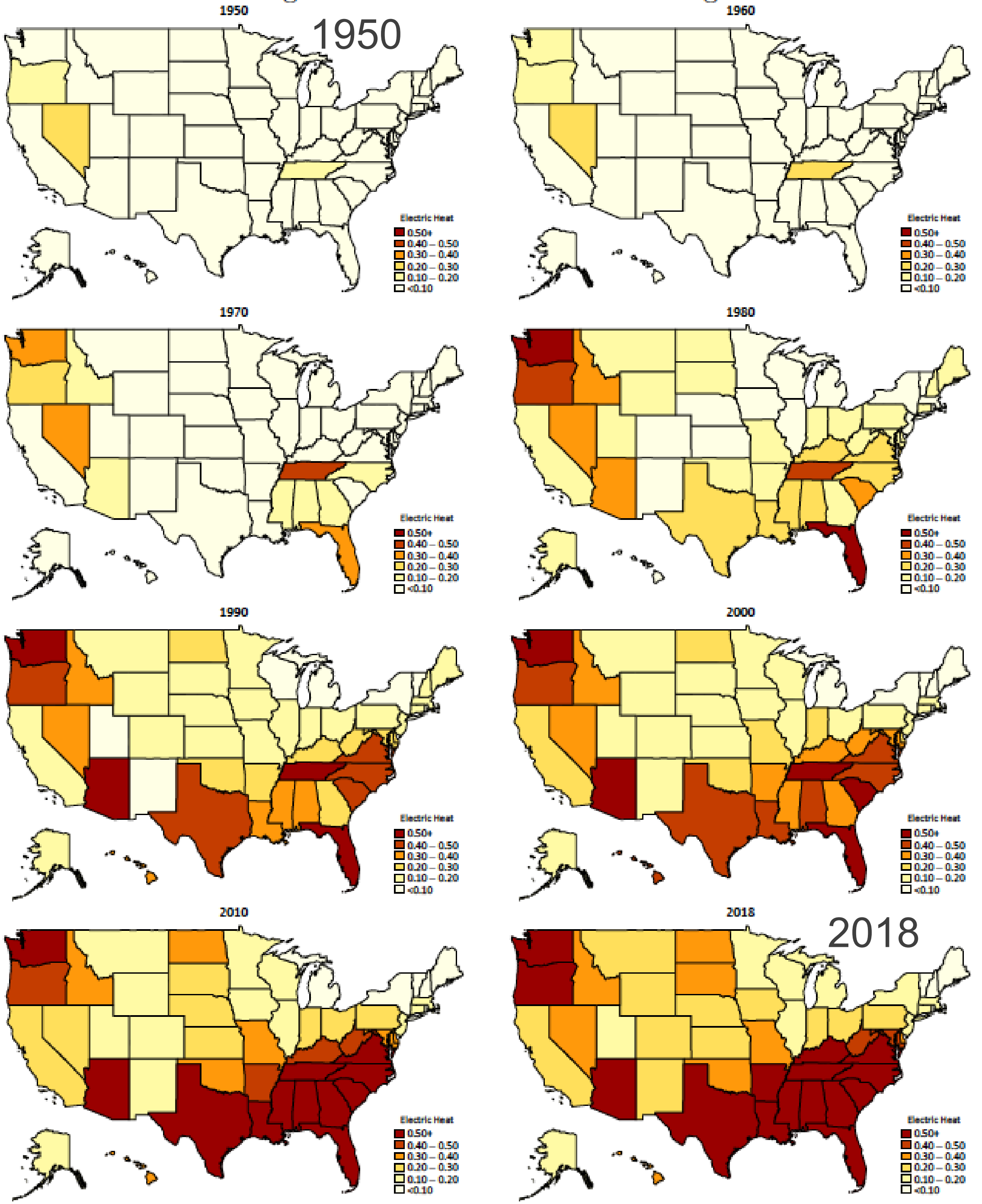
Electric DHW

- 55% of MF units
- 41% of SF units

Electric Cookers

- 67% of MF units
- 56% of SF units

*Residential Energy Consumption Survey (EIA) 2020

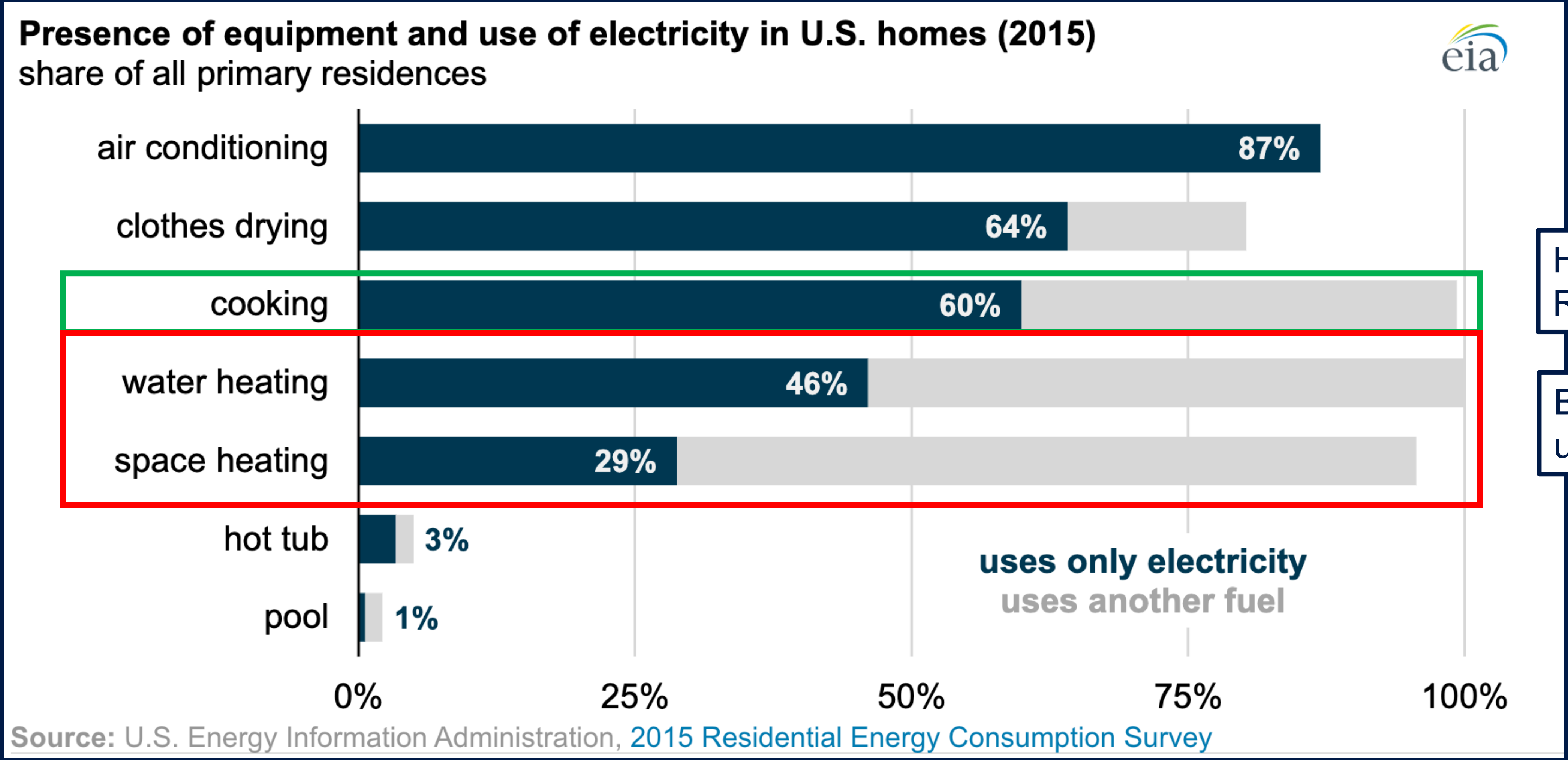


Growth in Electric Heating

- Electrification of largest end-use has been increasing for years.
- We are just going to accelerate this trend.
- Most new-home growth in areas where homes are electrified for heating/cooling.

Figure from Davis, L. 2020. What Matters for Electrification? Evidence from 70 years of US Home Heating Choices. Energy Institute at Haas, WP 309.

Current Electric Appliances in the US

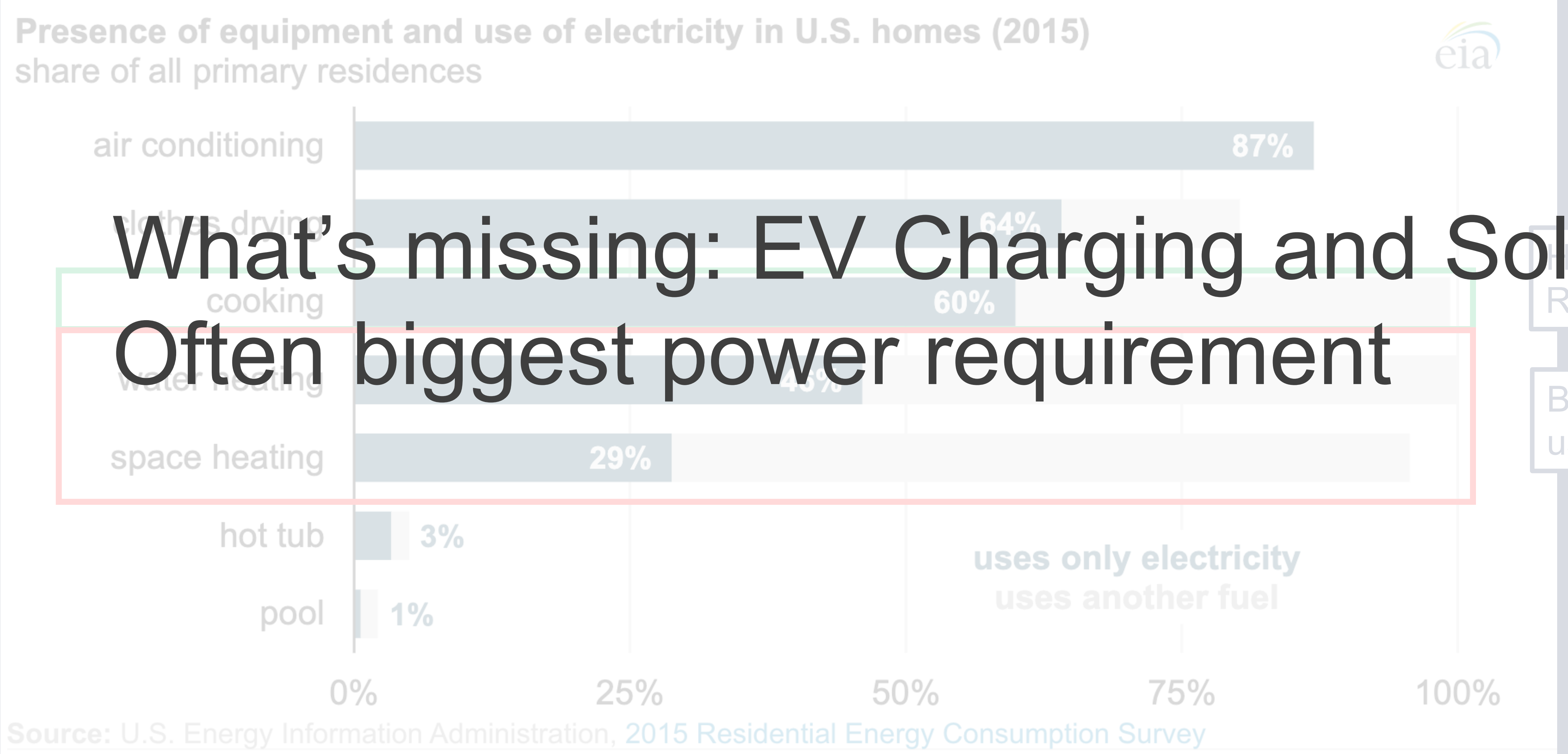


Highest Power Requirement?

Biggest energy users

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

Current Electric Appliances in the US



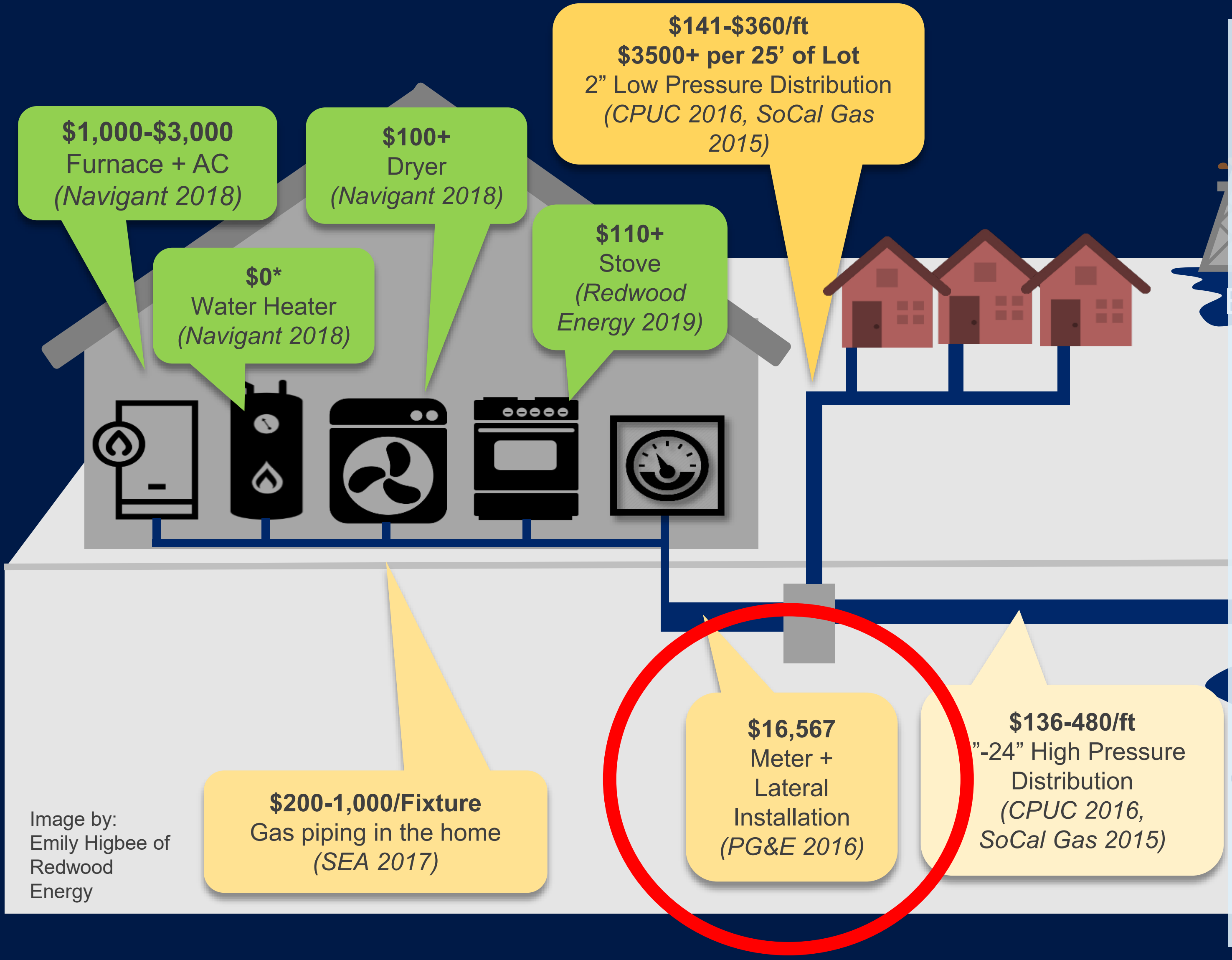
Requirement?

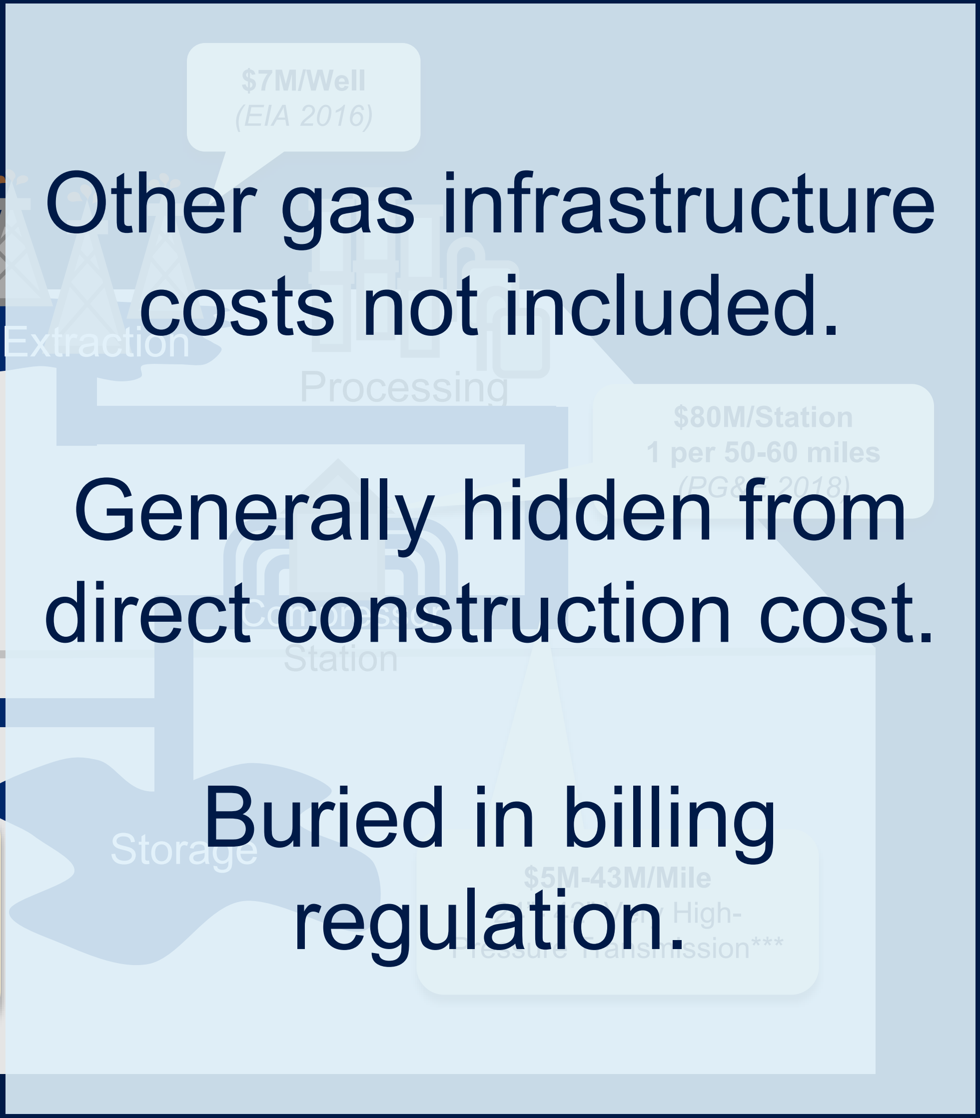
Biggest energy users

What’s missing: EV Charging and Solar PV
Often biggest power requirement

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

New Construction Costs:
→ $25,000 less to build all-electric homes





Other gas infrastructure costs not included.

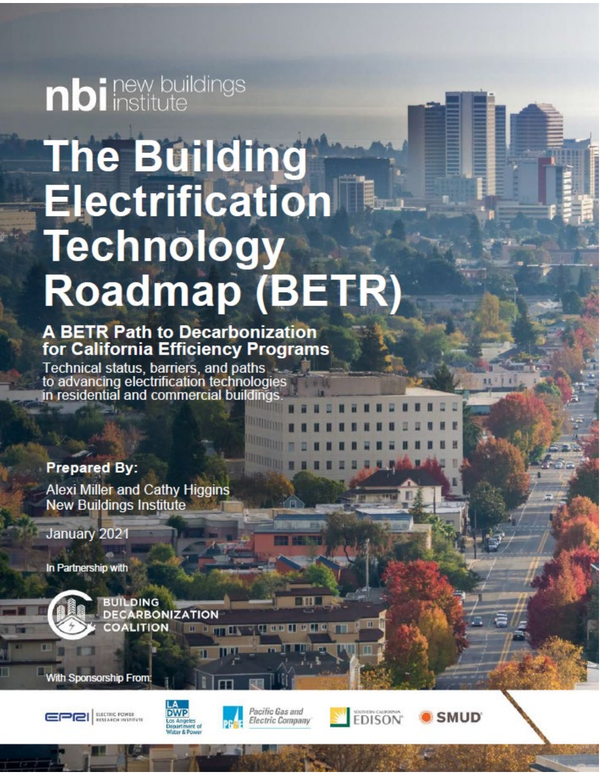
Generally hidden from direct construction cost.

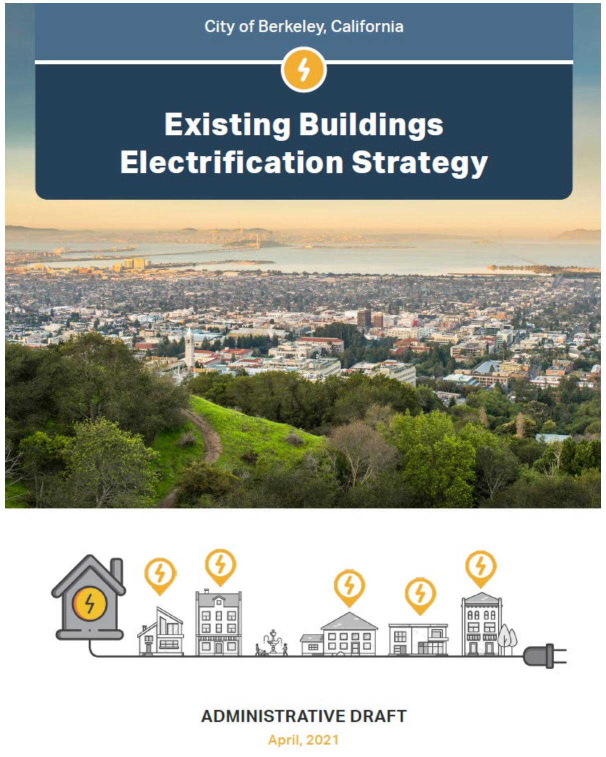
Buried in billing regulation.

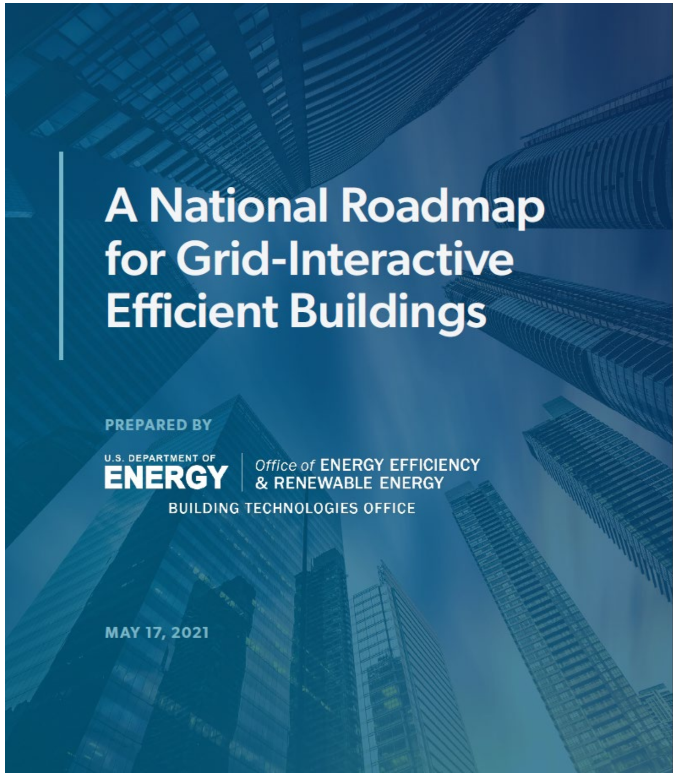
Graphic courtesy of Redwood Energy

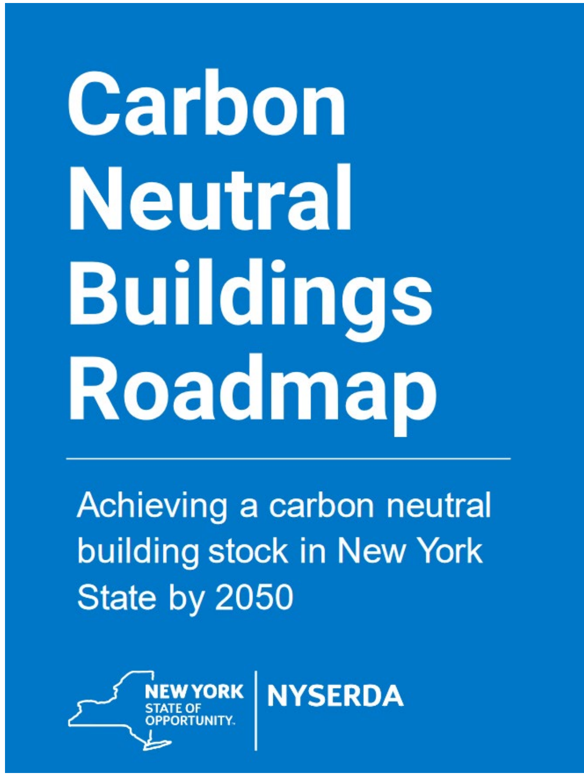
Graphic courtesy of Sean Armstrong, Redwood Energy

Emerging Changes in Construction





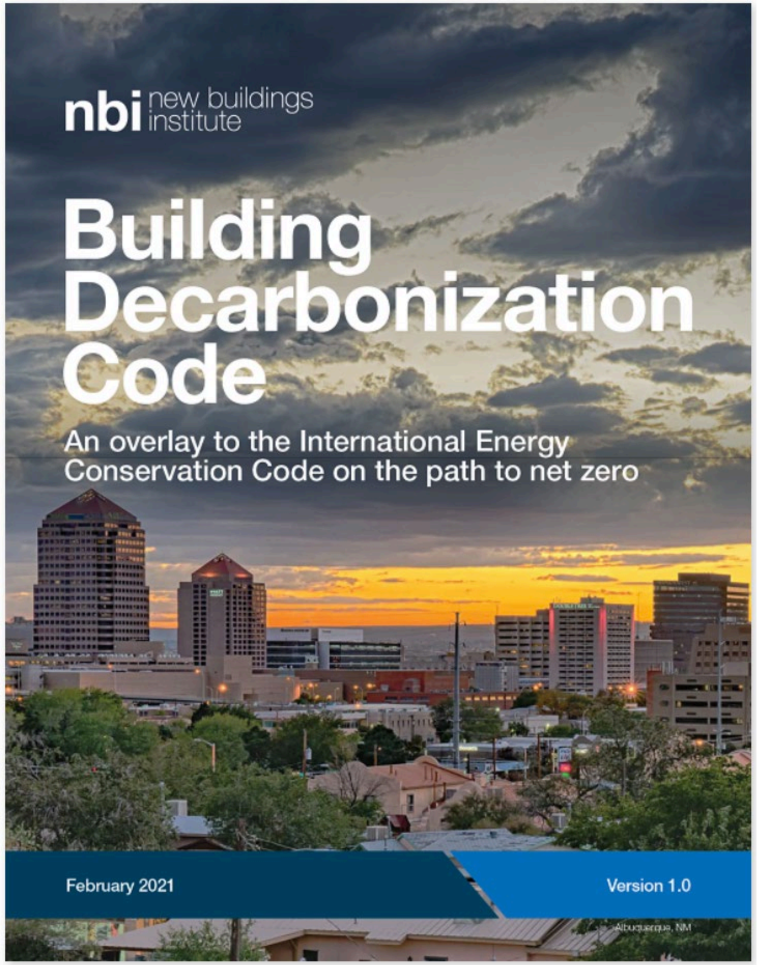




Think about it as the completion of the electrification program begun in the US 100 years ago

Codes and Ratings

California ELECTRIC HOMES



ZERO
ENERGY READY HOME
U.S. DEPARTMENT OF ENERGY

National Electric Code

Helpful guidance: Watt Diet Calculator

1. **Simplified approaches by electricians:**
    - Not using existing paths in the National Electric Code
2. **NEC unclear and not developed with home electrification in mind**
3. **Local code authorities unprepared**
    - Some will not allow circuit sharing or smart panel controls
4. **Updates proposed to simplify electric home compliance pathways**

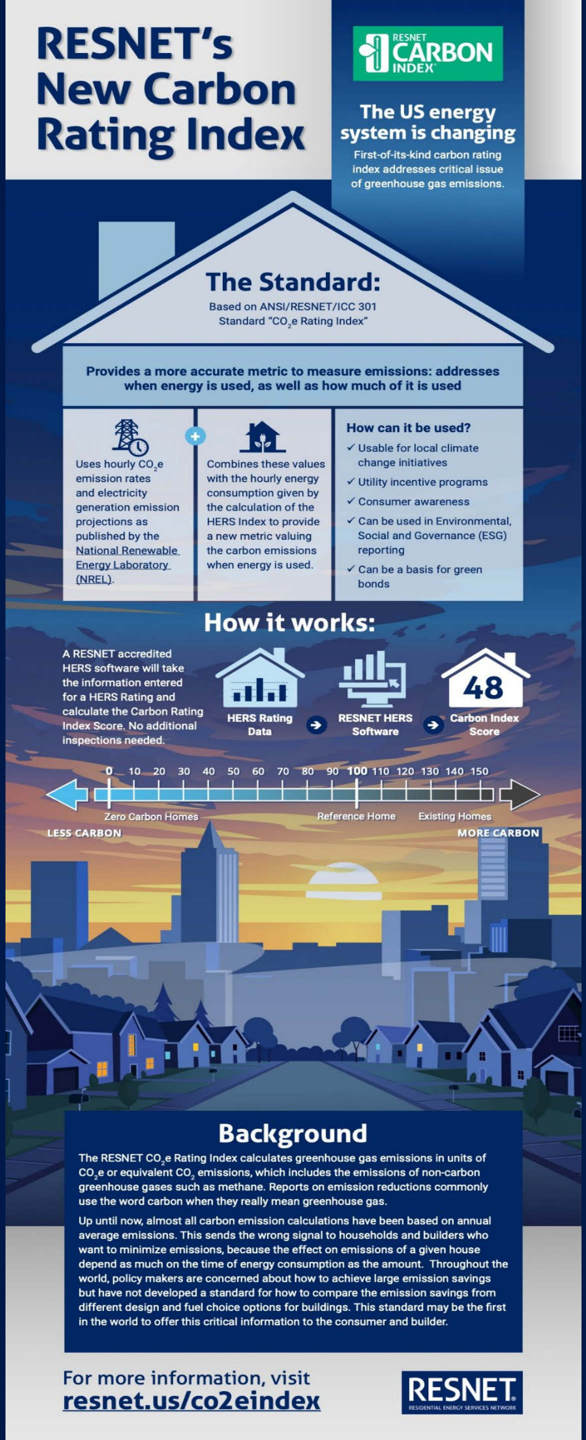
Redwood Energy & Tom Kabat+

RESNET Ratings

RESNET 301 Addendum B: CO_2 rating index

- **Uses HOURLY emissions not annual averages**

$$CO_2\text{index} = \frac{CO_2\text{rated home}}{CO_2\text{reference home}}$$



Challenges of Decarbonizing the Residential Building Stock

Common Barriers with Single Family Homes

Today's biggest barriers for decarbonizing homes

- **Cost and affordability**
- **Lack of workforce**
  - All contractors are busy
  - Anecdotally: 6-12 months lead time
- **Lack of equipment**
  - Supply chain issues (COVID, Economic crisis, etc.)
  - Poor US Manufacturing base
- **Lack of easily available financing**
- **Minimize grid impacts**
- **Current practice**
  - Like-for like equipment replacement
- **Existing buildings**
  - Emit all the carbon and are hardest to fix.
- **Lack of real estate market valuation**

New Challenges

Transportation

► Current poor public charging infrastructure:

- Need to be able to charge at home
- Who pays for infrastructure? Only EV owners?
- How to share charging spaces and charging bills?
- Should we restrict home chargers to Level 2?

Resilience

► Electrical outages are much more frequent than natural gas outages

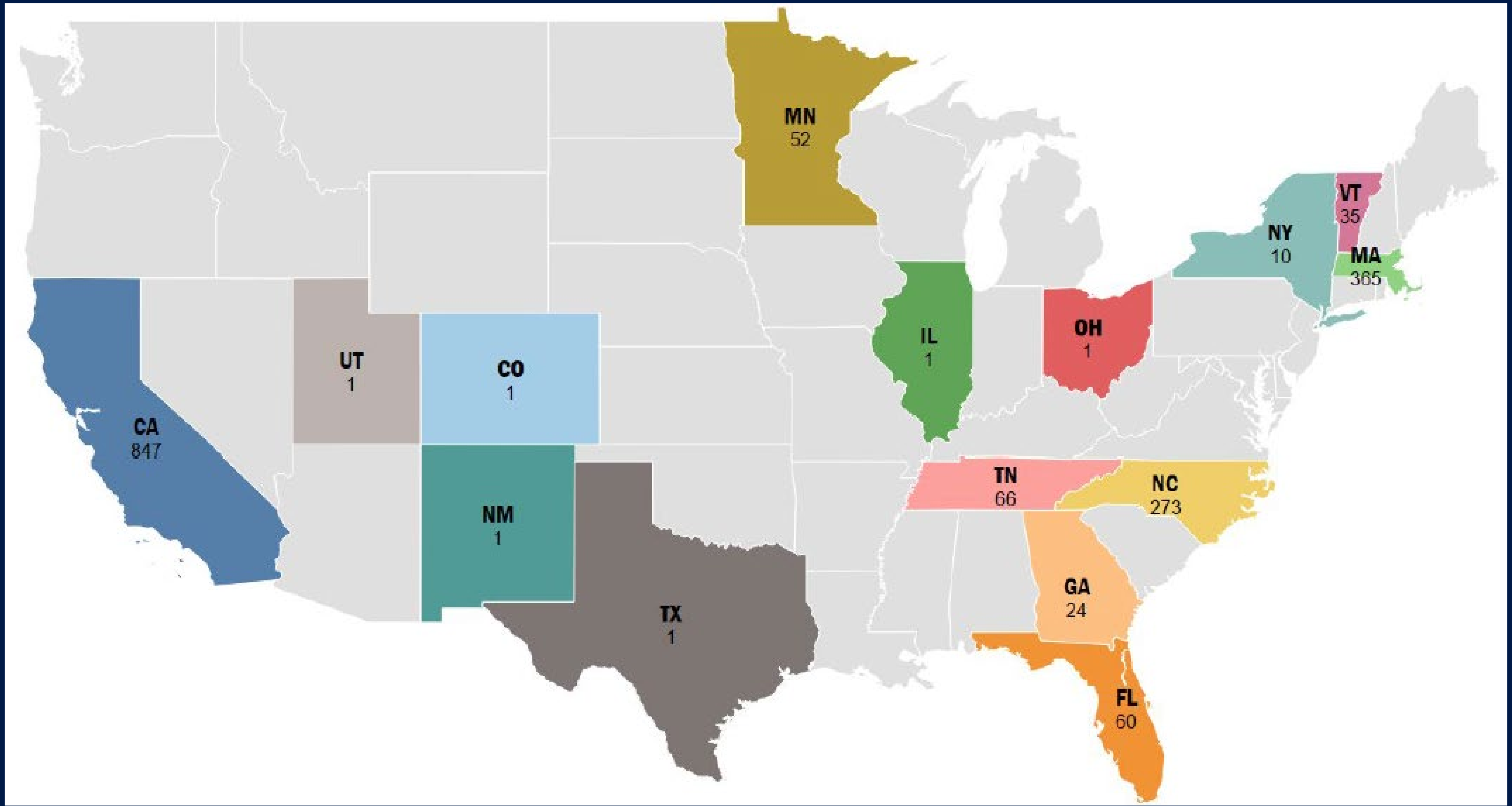
- Most outages are short (Typically <24h)
- After disasters, gas infrastructure remains offline for much longer than electrical.
- On-site storage and generation allows basic home operation during emergencies.

Peak Power

► We need ways for homes to respond to this and minimize cost impacts - On-site storage – batteries or thermal

Assessing the Cost of Decarbonization / Electrification

Single Family - Cost Database



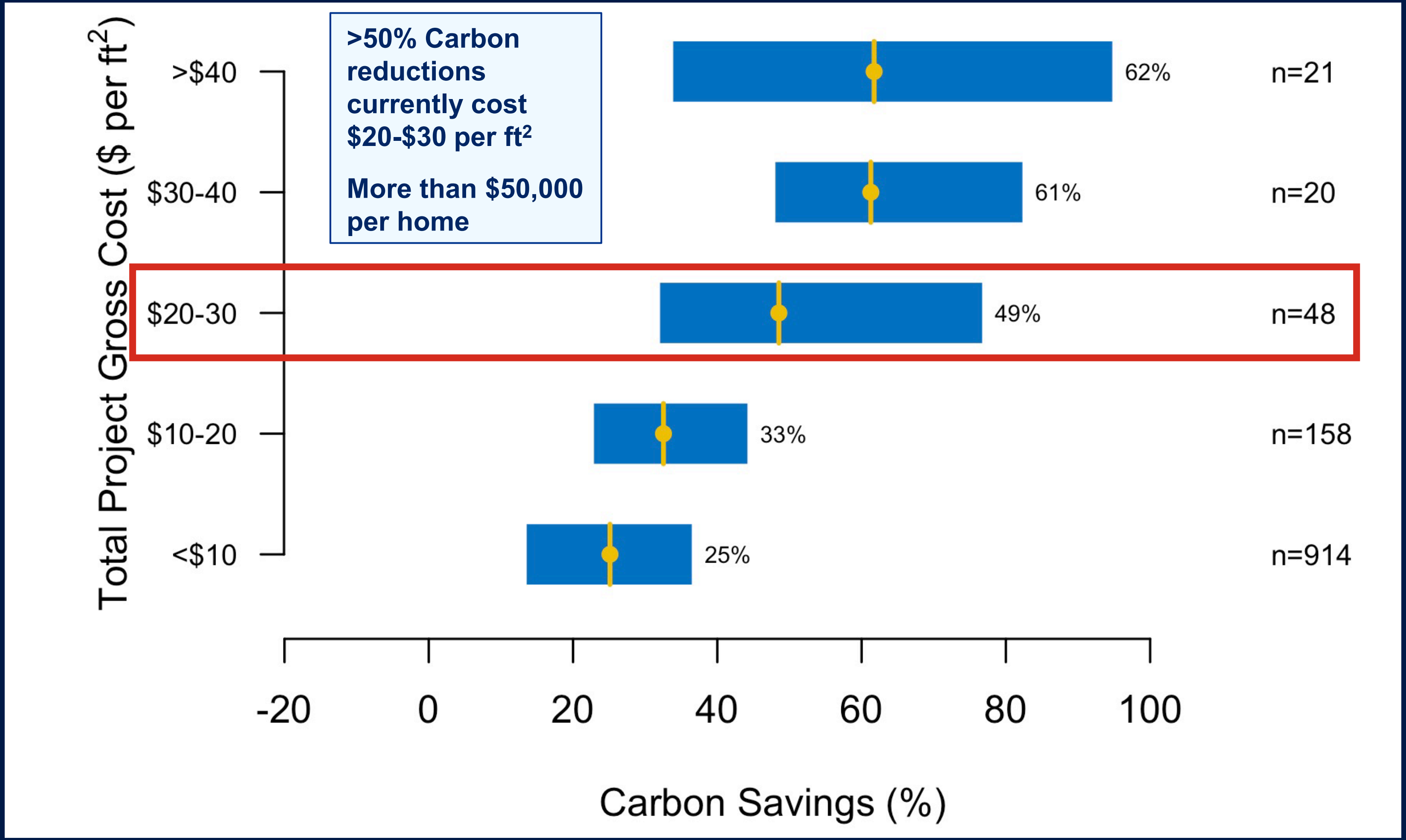
Sample of convenience:
- Most data voluntarily provided by energy programs
- Paid contributions for 475 homes

Data included:
- Costs - Broken down by measure
- Energy (and calculated CO_2) savings
- All costs in $2019 and nationally averaged

12 Programs 1,739 Projects 10,512 Measures 3,294,946 ft^2 $24,689,213

Project Cost vs. Carbon Savings

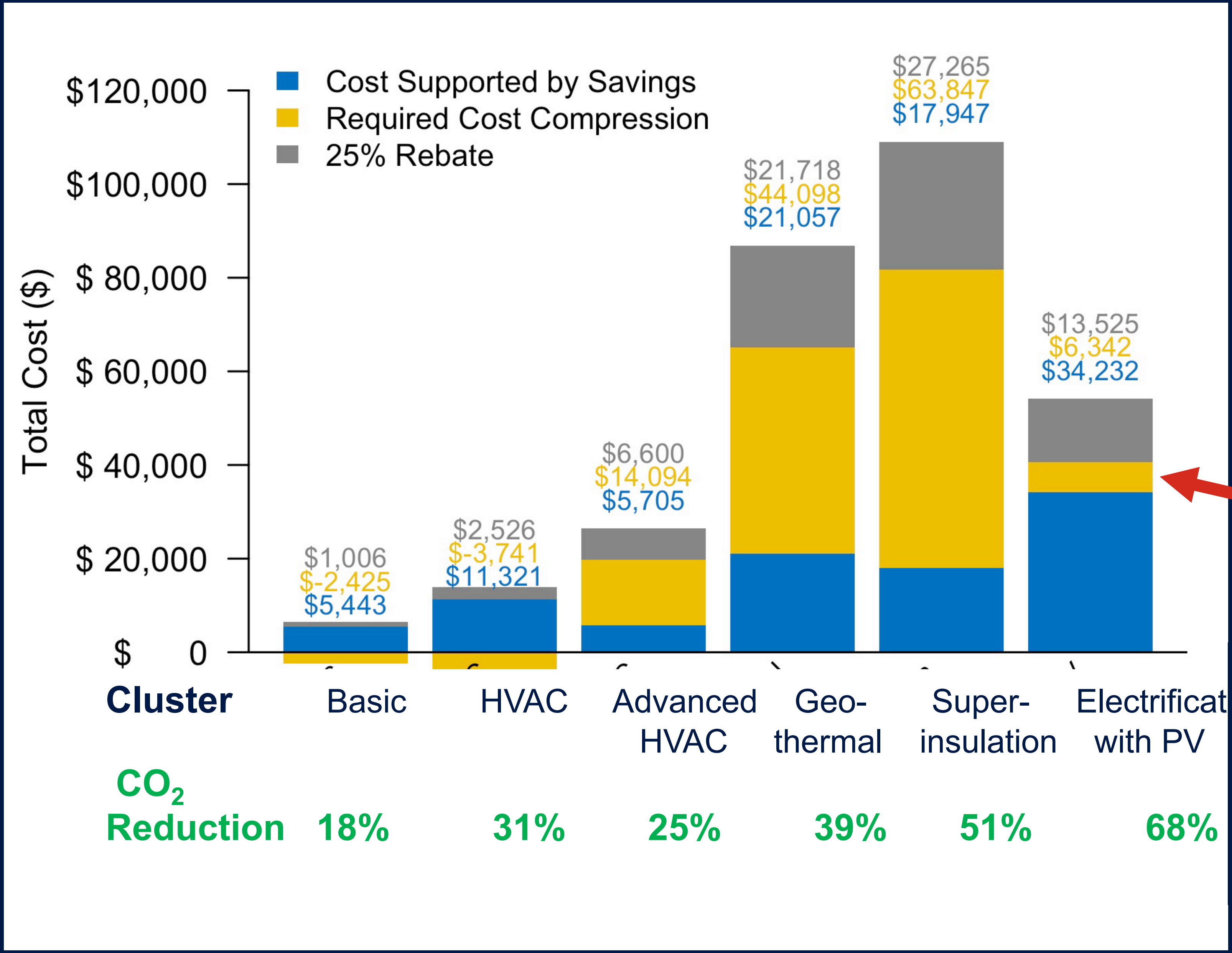
How much does it cost to get to 50% savings?



- These costs do not include rebates
- Not enough carbon emission reduction
- Costs too much for adoption at scale

Higher cost projects have diminishing returns

Cost Compression – Rebates (not tax credits!)



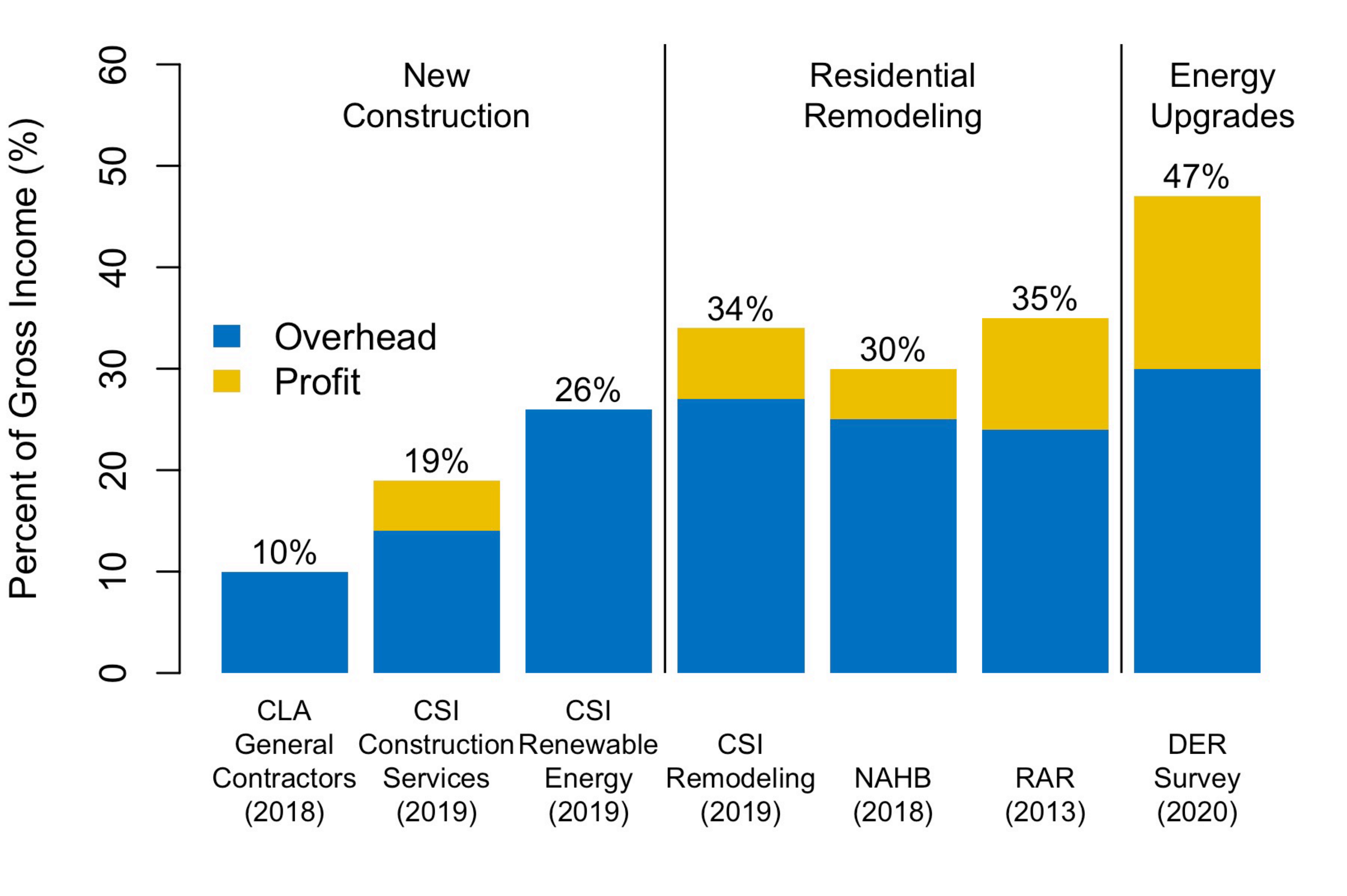
Helps reduce up-front costs

Increases affordability

Key marketing strategy – people like to get a “deal

More feasible cost compression

Cost Compression – Soft Costs



Need to reduce Soft Costs:

- Customer acquisition
- Testing
- Program participation
- Project design

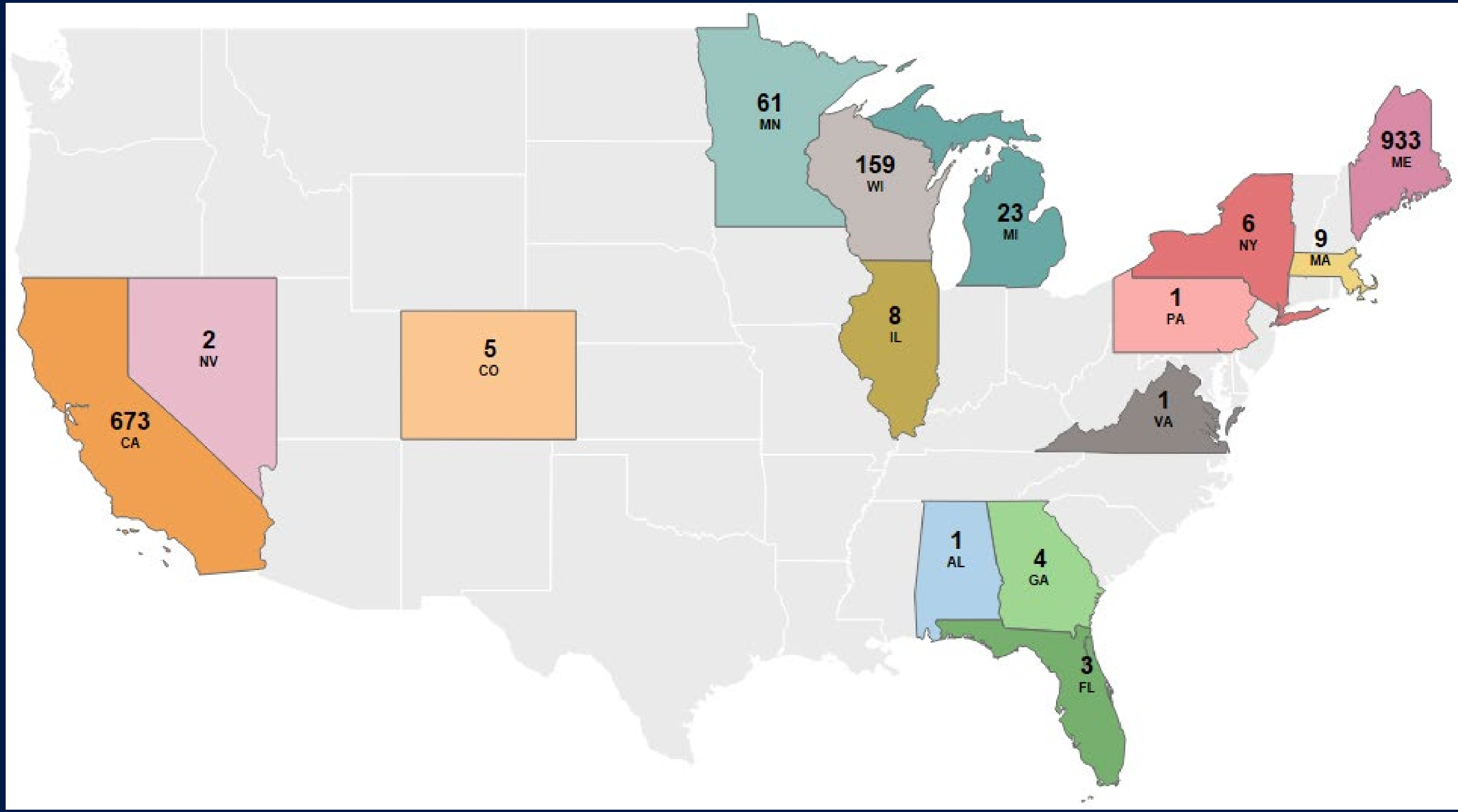
Added Complexity for Multifamily

Single-family vs Multifamily

- **Housing type:** Affordable; Market rate
- **Building typology:** Attached; semi-attached; isolated
- **Rise:** Low-; Mid-; High-Rise
- **Unit ownership:** Renter; owner
- **Historical building:** Yes; No
- **Elevator:** Yes; No
- **Original use of the building**
- **Unit type:** SRO; 1B; 2B; 3B; etc.
- **Heating, cooling and DHW configuration:** Units; Central
- **Occupied during retrofit:** Yes; No
- **Retrofit type:** Retrofit; Gut Rehabilitation
- **Non-residential space:** Lobby; Laundry; Corridors

Metric ► $/unit

Database Summary – Multifamily Buildings



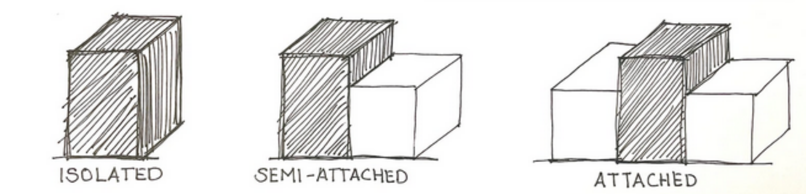
Total ► 1,889 Multifamily Projects (1,860 Detailed / 12 Non-Detailed / 17 Audits)
Total ► 1,636 Multifamily Projects (91% Low-rise / 7% Mid-rise / 2% High-rise)
Total ► 5,794 Measures 33,062,842.64 ft^2 (3.071.638 m^2) $493,839,973

Home Vintage	1850-1899	8
	1900-1959	73
	1960-1979	64
	1980-1999	39
	2000-2020	54
Project Year	2022	353
	2021	659
	2020	62
	2019	121
	2018	115
	2017	101
	2016	101
	2015	6
Project Duration	< 3 month	675
	<6 months	166
	<12 months	153
	<18 months	50
	<24 months	20
	<30 months	8
	<36 months	4
	>36 months	3
All projects - Electrification Focused		

Database Summary – Multifamily Buildings

Community	Urban	66%
	Suburban	34%

Building Typology	Attached	24%
	Semi attached	19%
	Isolated	57%



Stories Above Grade	Low Rise	91%
	Mid Rise	7%
	High Rise	2%

- **low-rise: 1-4 Floors**
- **mid-rise: 5-8 Floors**
- **high-rise: >8 Floors**

Historical Building	Historical	5%
	Non Historical	95%

Unit Ownership	Community property	3%
	Housing Authority	1%
	Non-profit	3%
	Property Management	1%
	Rental	91%

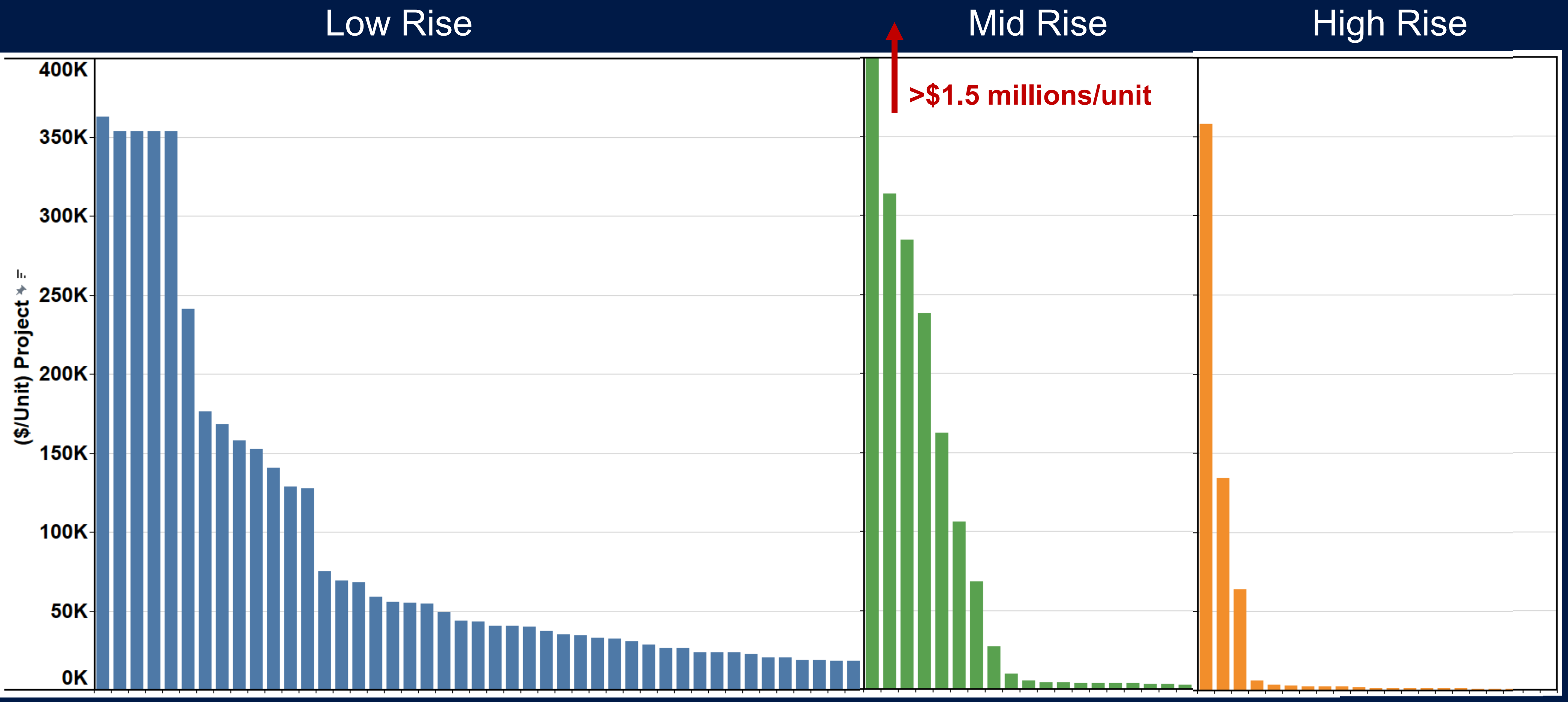
Housing Type	Affordable Housing	79%
	Luxury	1%
	Market Rate	19%
	Other	0%

Retrofit Type	Gust rehabilitation	2%
	Renovation	1%
	Retrofit	97%

Distribution of Gross Project Costs

- ► 5,794 retrofit measures
- ► Cost doesn't include incentives

- ► Median: $15,355/project
- ► Mean: $261,429/project



Low Rise
Total units: 39,594

Mid Rise
Total units: 10,992

High Rise
Total units: 7,077

Low Rise

- **Mean $ 9,385 /unit**
- Median $ 1,509/unit

Mid Rise

- **Mean $ 27,259 /unit**
- Median $ 993/unit

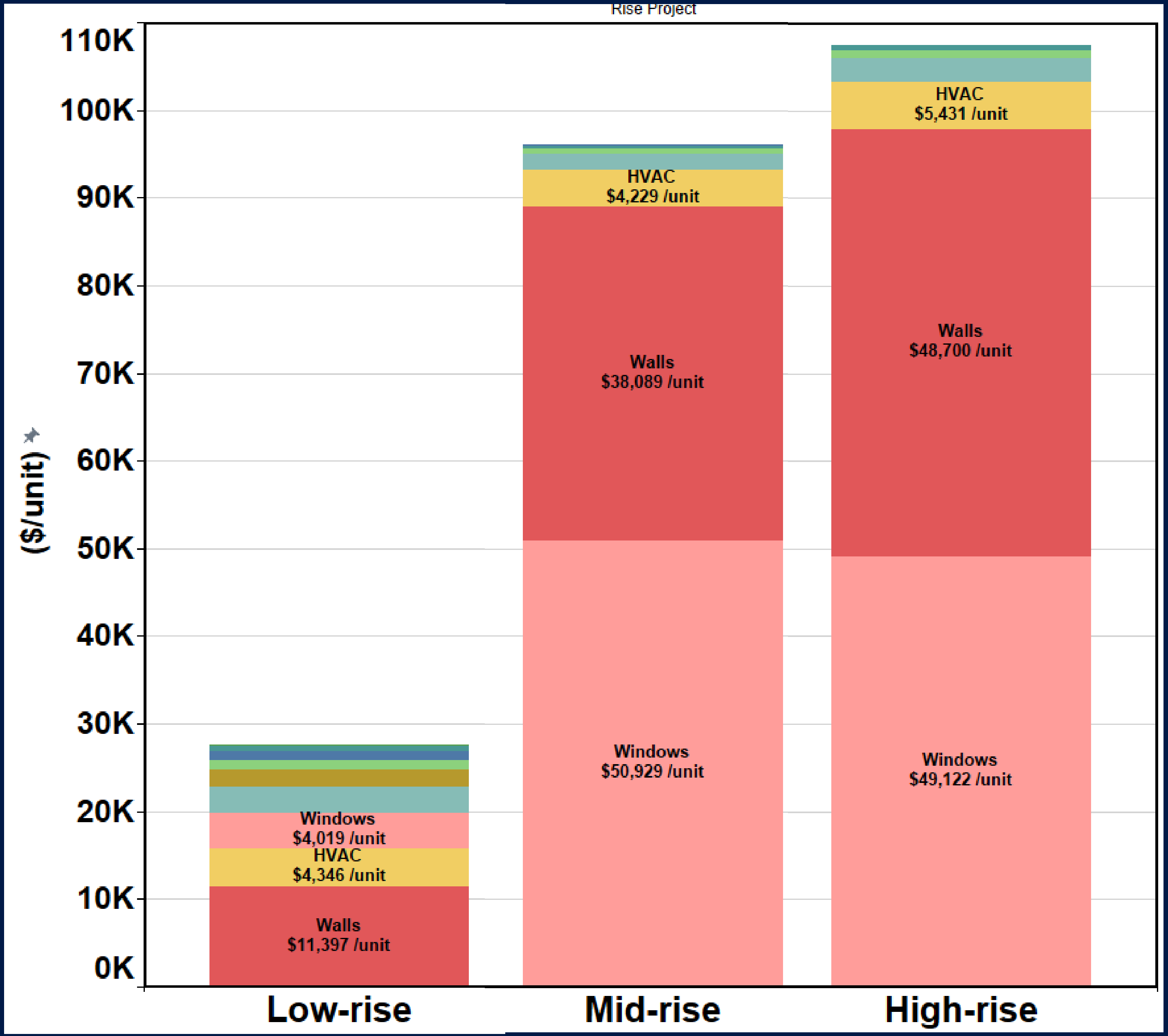
High Rise

- **Mean $ 15,115 /unit**
- Median $ 978/unit

NYSERDA Report: Construction cost is $40,000/unit.

Construction period, which includes interior upgrades, was expected to be **14 months** for **21 units**.

Total Recorded Expenditures by Section



Total Energy-Related Costs

Low Rise
~$9,300 /unit

Mid Rise
~$27,200 /unit

High Rise
~$15,100 /unit

Another ~$8,000/unit on on-energy-related work

- Envelope costs are very high for mid/high rise
- HVAC (and other) costs very similar across all building types

Multifamily Case Studies

Affordable Housing

EDEN HOUSING

Switching from natural gas appliances to electric

- **Eden Housing** and the **East Palo Alto Community Alliance and Neighborhood Development Organization** (EPACANDO)
- Demolished 37 apartments, renovated 57 and is building 128 new apartments.
- One-third remodeled and two-thirds brand new, nine of which will offer supportive services for people who experience homelessness.

*https://www.kneedeeptimes.org/flipping-the-switch-on-all-electric-housing/

Successful decarbonization projects

Switching from natural gas appliances to electric ones

- New induction stove
- Heat pump that offers air conditioning
- 2 Electric water heaters per apartment (resilience)

- Battle with electric equipment, increases in tenant utility costs and energy use, and complex funding structure.

- Manufacturers and contractors are still getting up to speed on the new technology and how to install it.

- *"We used to know how big a gas water heater should be to heat enough hot water for a 50-unit apartment building. How many kilowatt hours do we have to come up with to heat the same amount of water for the same amount of people? We've never done that before… We're kind of on the bleeding edge,"*
  - **Tom White**, Eden Housing's associate director

*https://www.kneedeeptimes.org/flipping-the-switch-on-all-electric-housing/

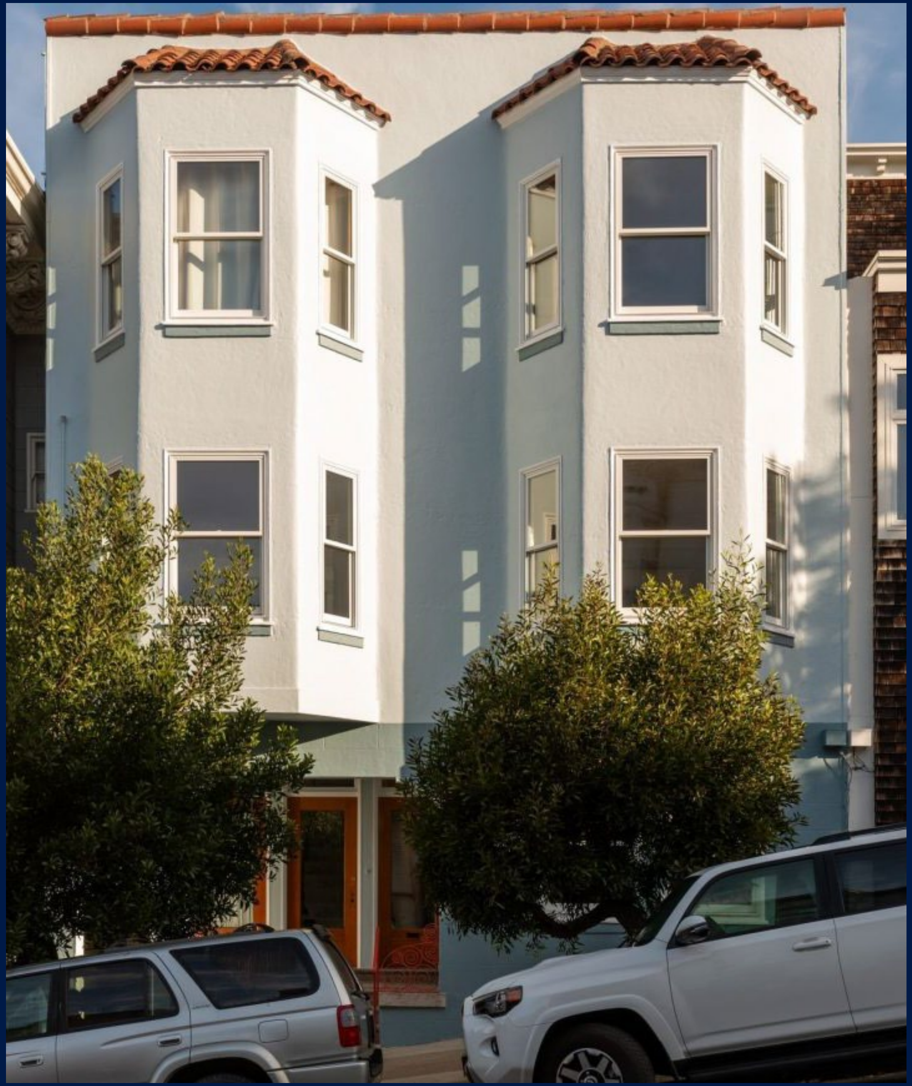
Market Rate Low-Rise

***Lessons learned and best practices**

- Transitioning the building from gas to all-electric has also yielded cost, safety, and health benefits, e.g., improved air quality and removed the risk of indoor fires and explosions.

- Unit utility bills $40-$90 per month— $150-$200 per month in previous winters .

- **EUI = 9.75 kBtu per square foot**, passes the **Architecture 2030 Challenge** target for new construction even without using solar panels.

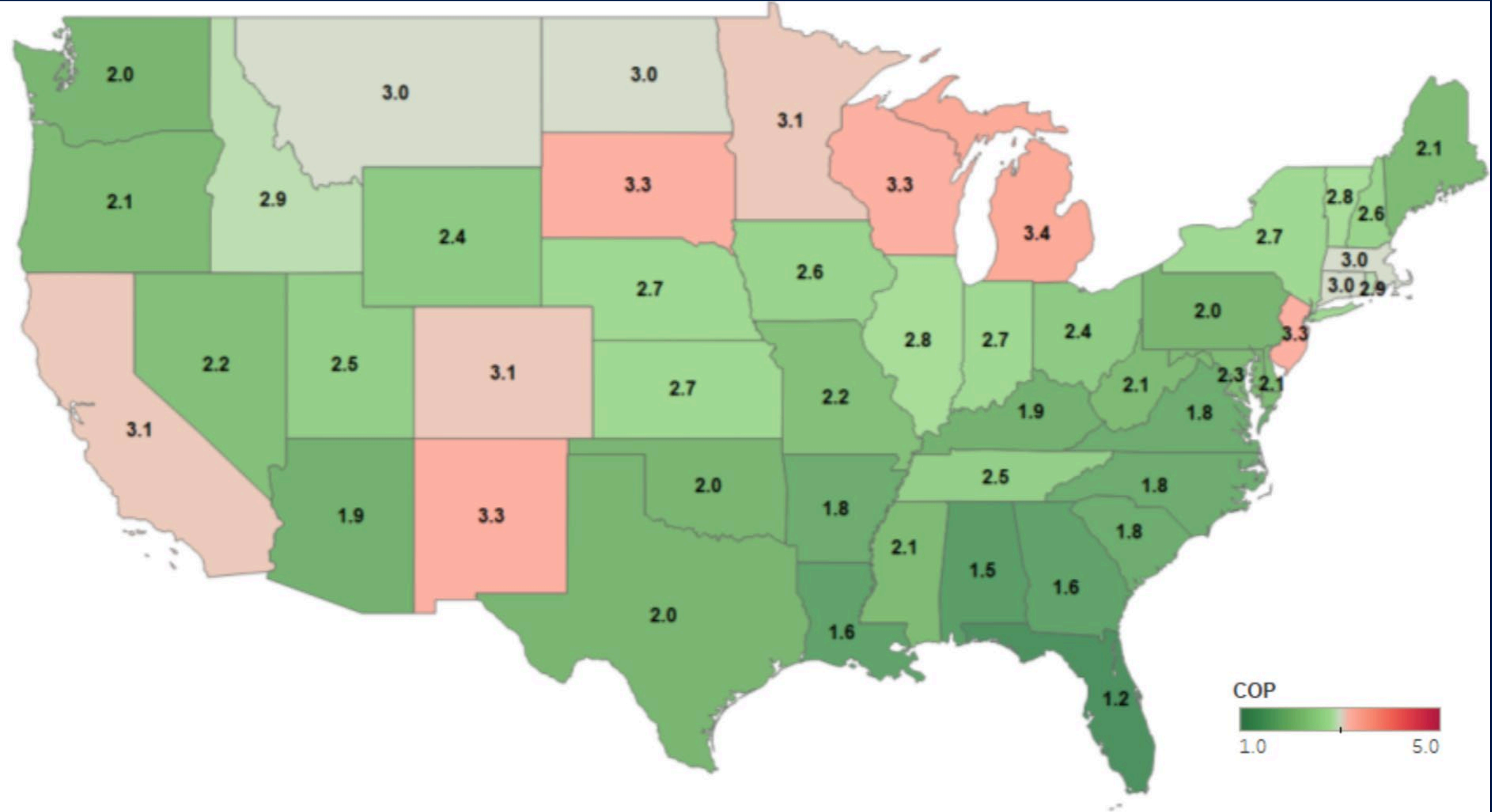


*https://www.builditgreen.org/blog/a-transition-from-gas-to-all-electric/

Operating Costs & Emissions

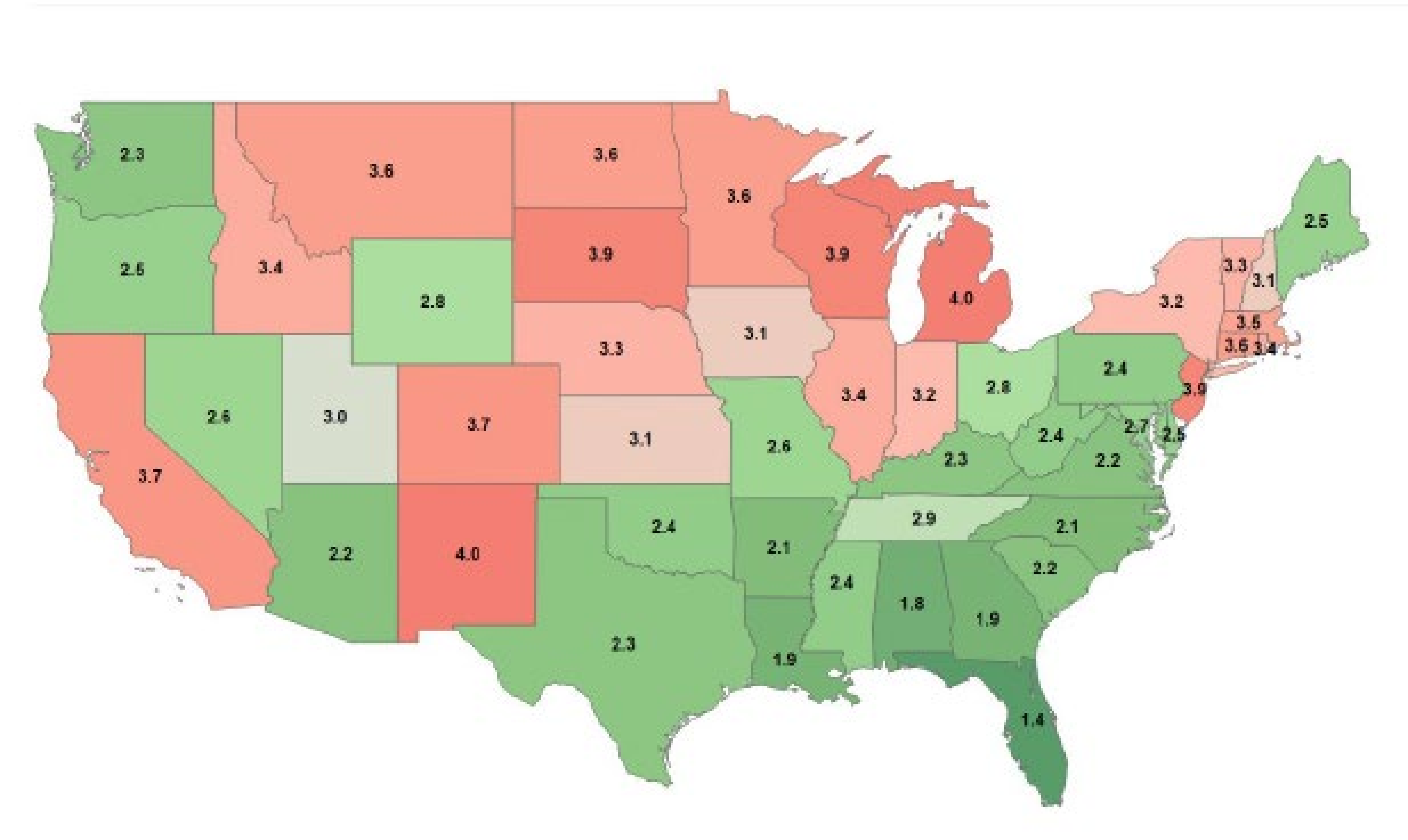
Operating Costs

Minimum COP required for break-even utility costs (2019)
Heat pumps vs. **80 AFUE** natural gas furnace

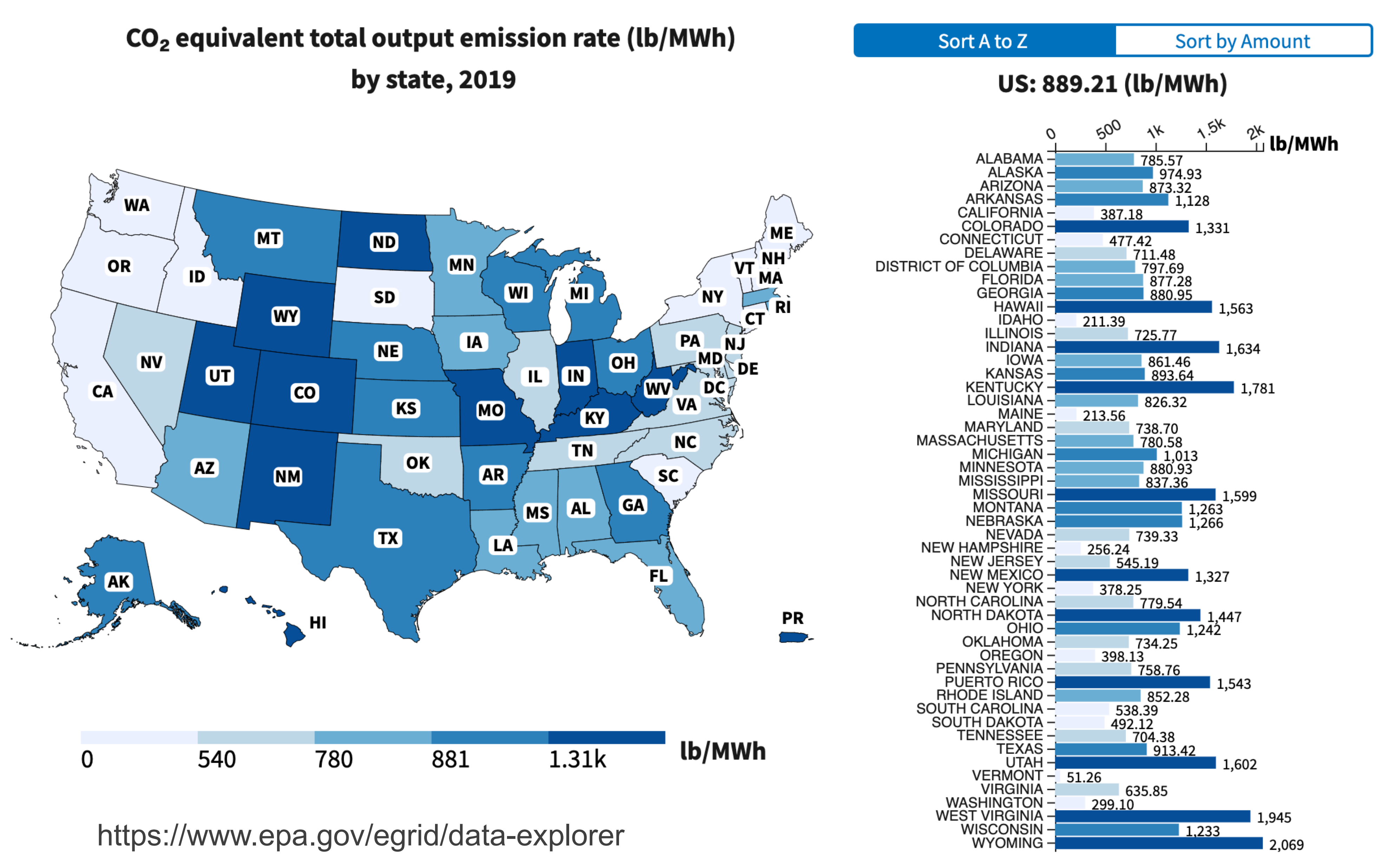


Operating Costs

Minimum COP required for break-even utility costs (2019)
Heat pumps vs. **95 AFUE** natural gas furnace



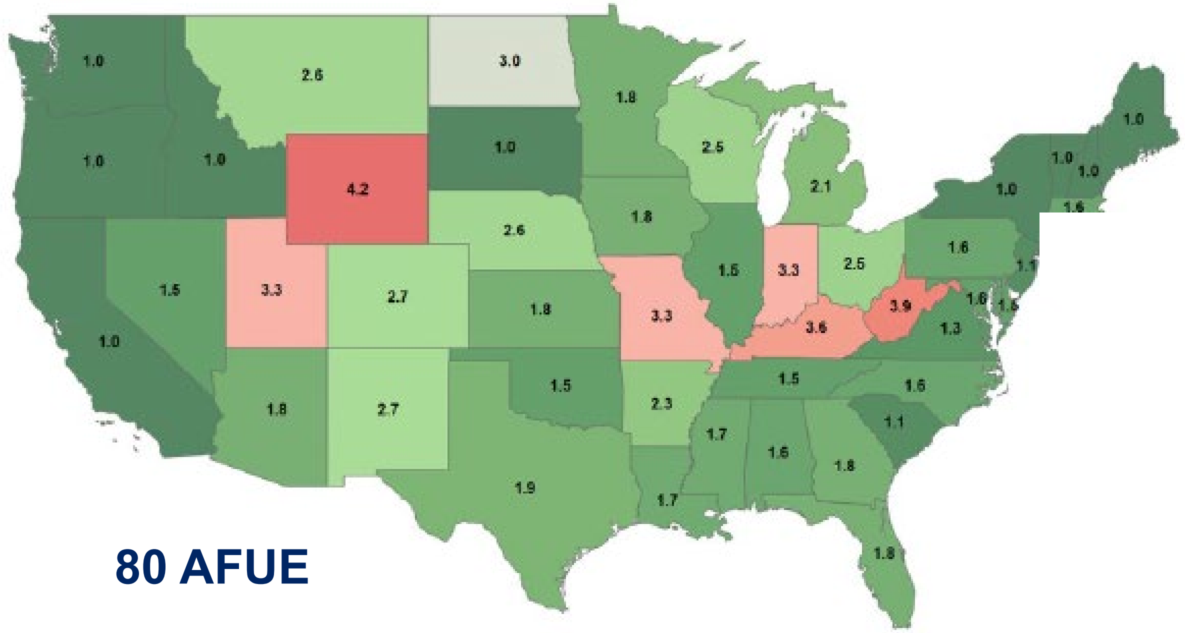
CO_2 in Electricity



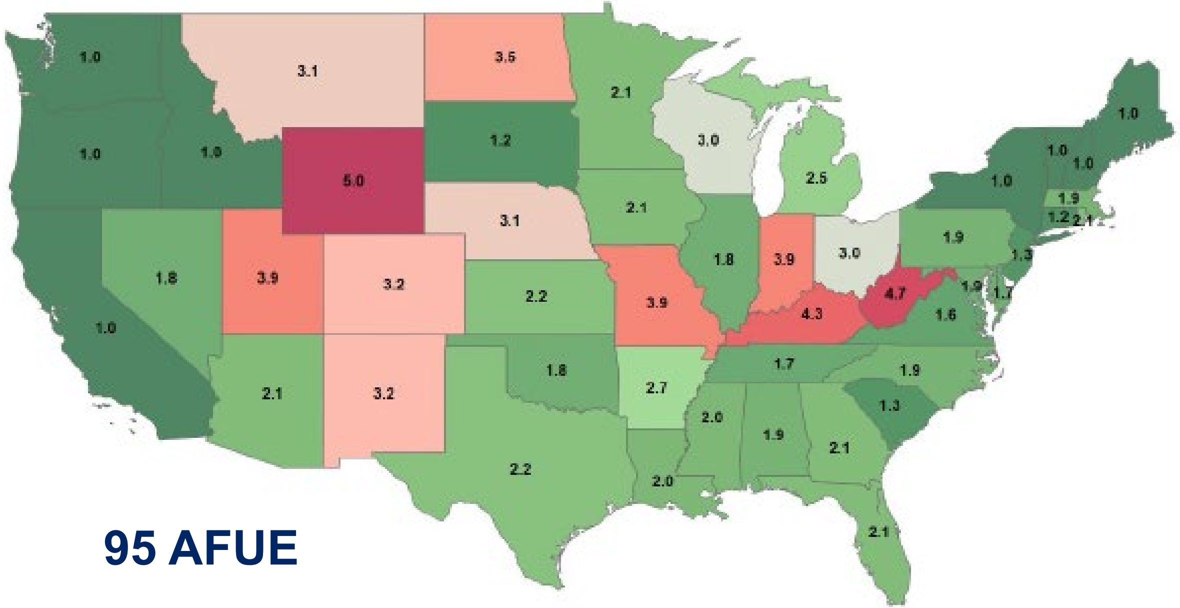
https://www.epa.gov/egrid/data-explorer

Heat Pump COP required to break even with a gas furnace

CO_2e Emissions Neutrality



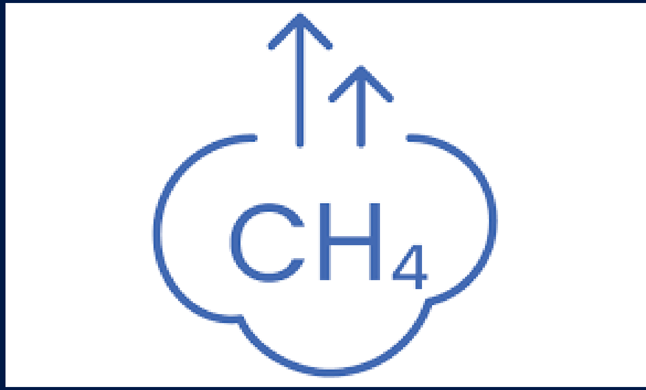
80 AFUE



95 AFUE

Not just CO_2 : Methane Leaks

- Not considered in most analyses.
- Methane is 80 times more potent Green House Gas (GHG) than CO_2 over a 20 year period and 25 times over a 100 year period.
- Even small leaks have a big impact on GHG emissions.
- The methane leaked inside homes adds about 15% additional GHG effect.
  - Much more if distribution is included (~4% leakage)
- This is why removing all gas infrastructure is important
  - A problem for “mixed fuel” approaches where existing gas heat is retained.

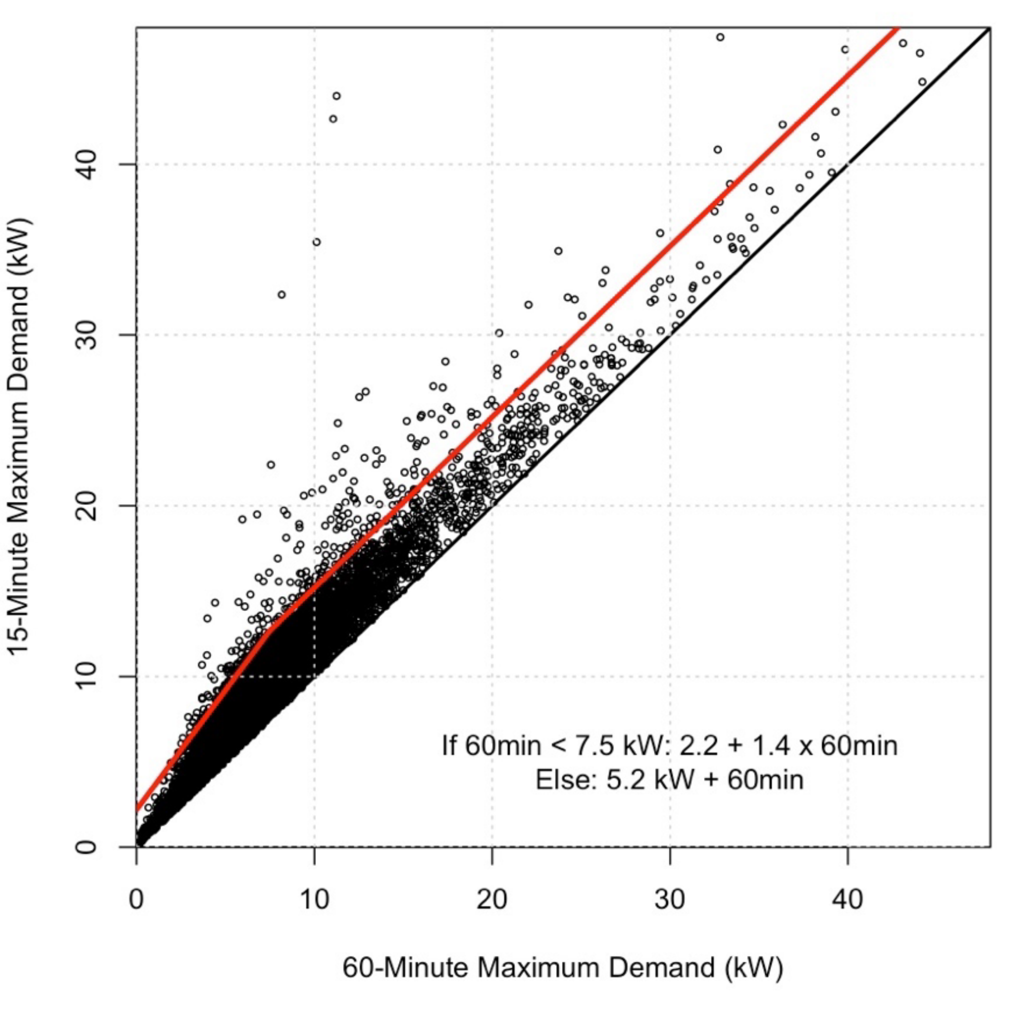


Home infrastructure

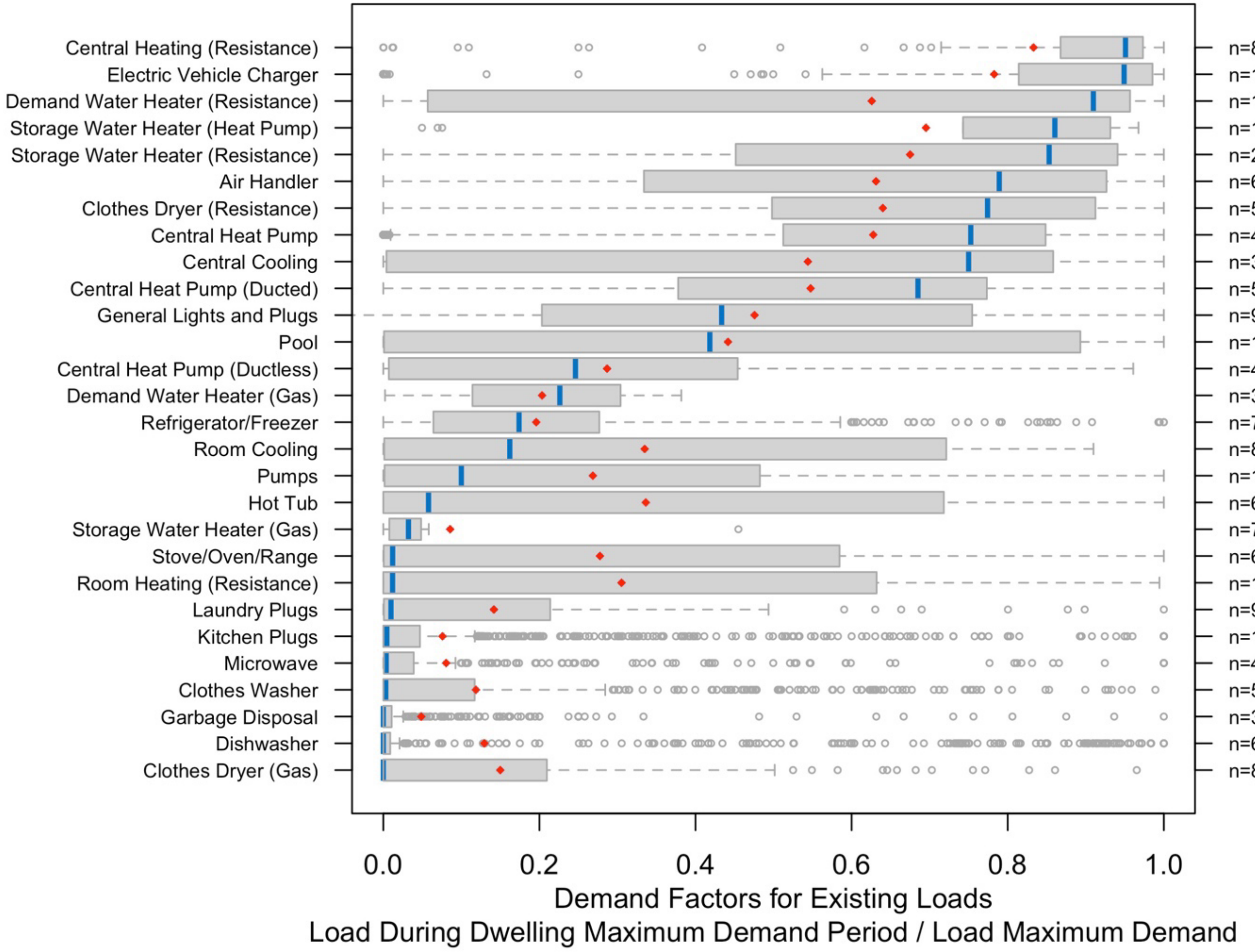
What drives panel replacement and service changes?

1. Current main drivers are adding Solar PV and EV Charging
2. Big CO_2 emitters (heat/cool) add very little to peak if heat pumps are used
3. Simplified approaches by electricians
   - Not using existing paths in the National Electric Code, e.g., using metered data
   - Profitable work
   - Habit/comfort
4. NEC unclear and not developed with home electrification in mind: updating NEC
5. Local code authorities unprepared
   - Some will not allow circuit sharing or smart panel controls

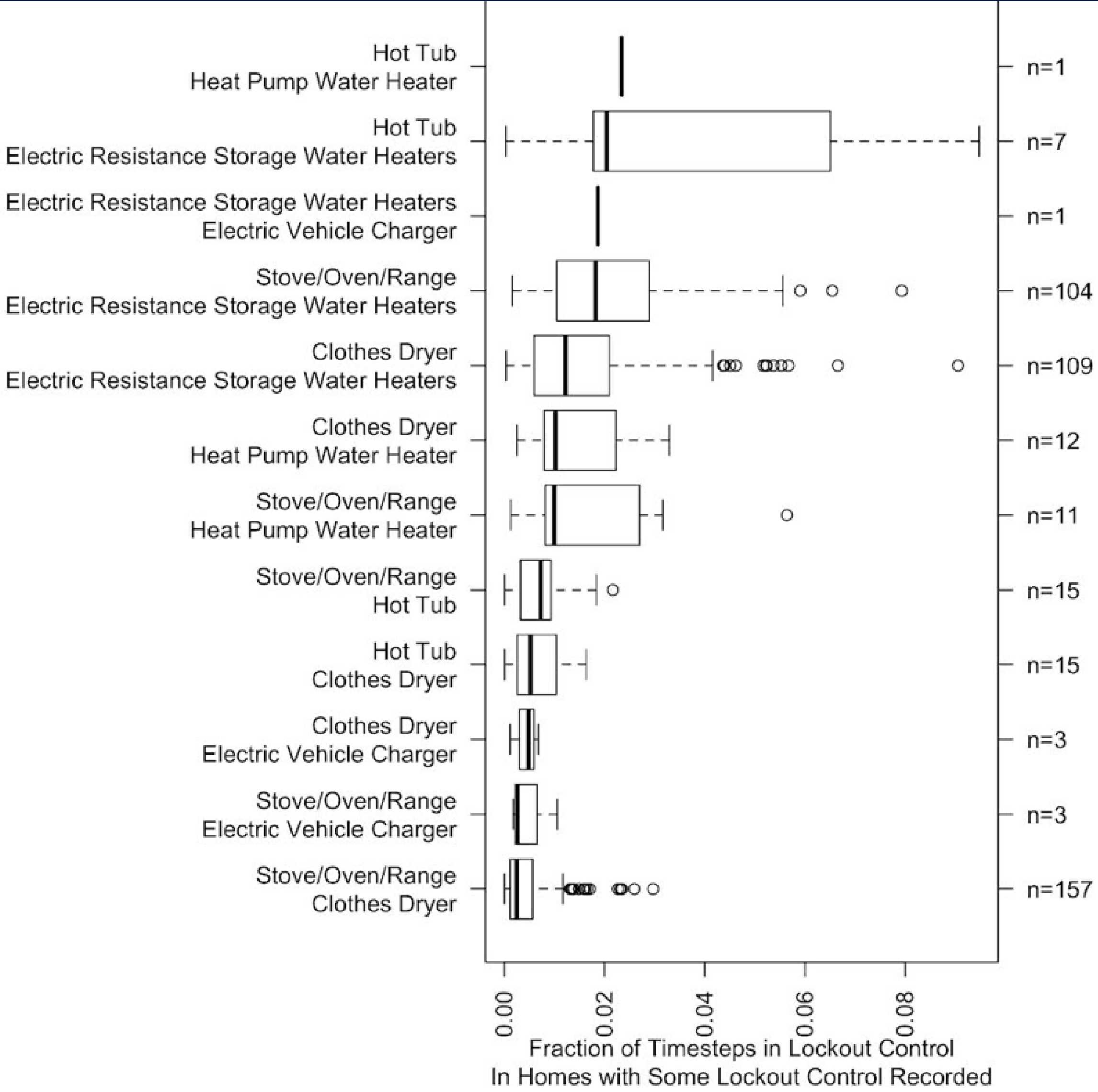
Proposed conversion from 60 minute smart meter data to 15 minute data for NEC calculations



What's ON at peak load?
EVs & resistance heat



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



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
Rewiring: Can trigger knob & tube replacement ~$10,000-20,000

Time delays

3-6 months project delays
>1-year lead time on transformers
Utility might reject your interconnection

Additional ratepayer costs for:

- Utility distribution system capacity increases
- New generation/storage

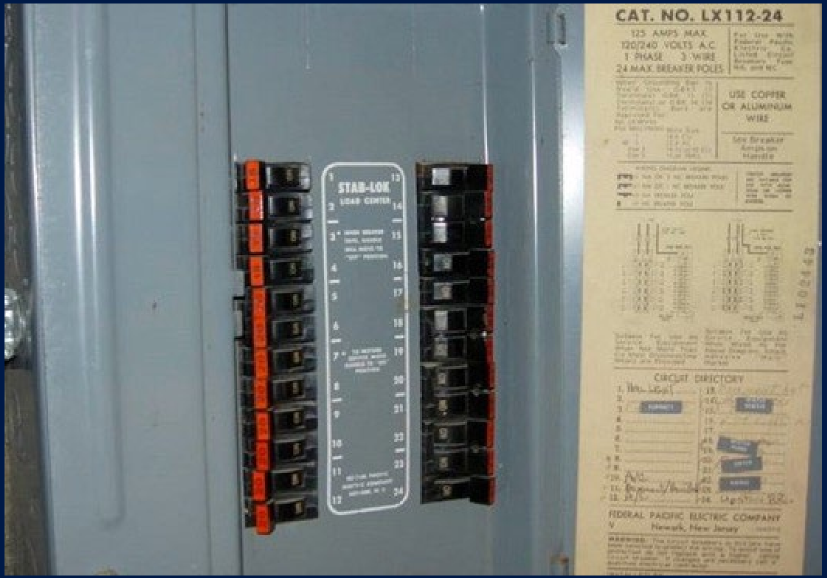
Image courtesy of All-electric California (Eric Morill)

Sometimes an update is needed

Old, unsafe or damaged panels

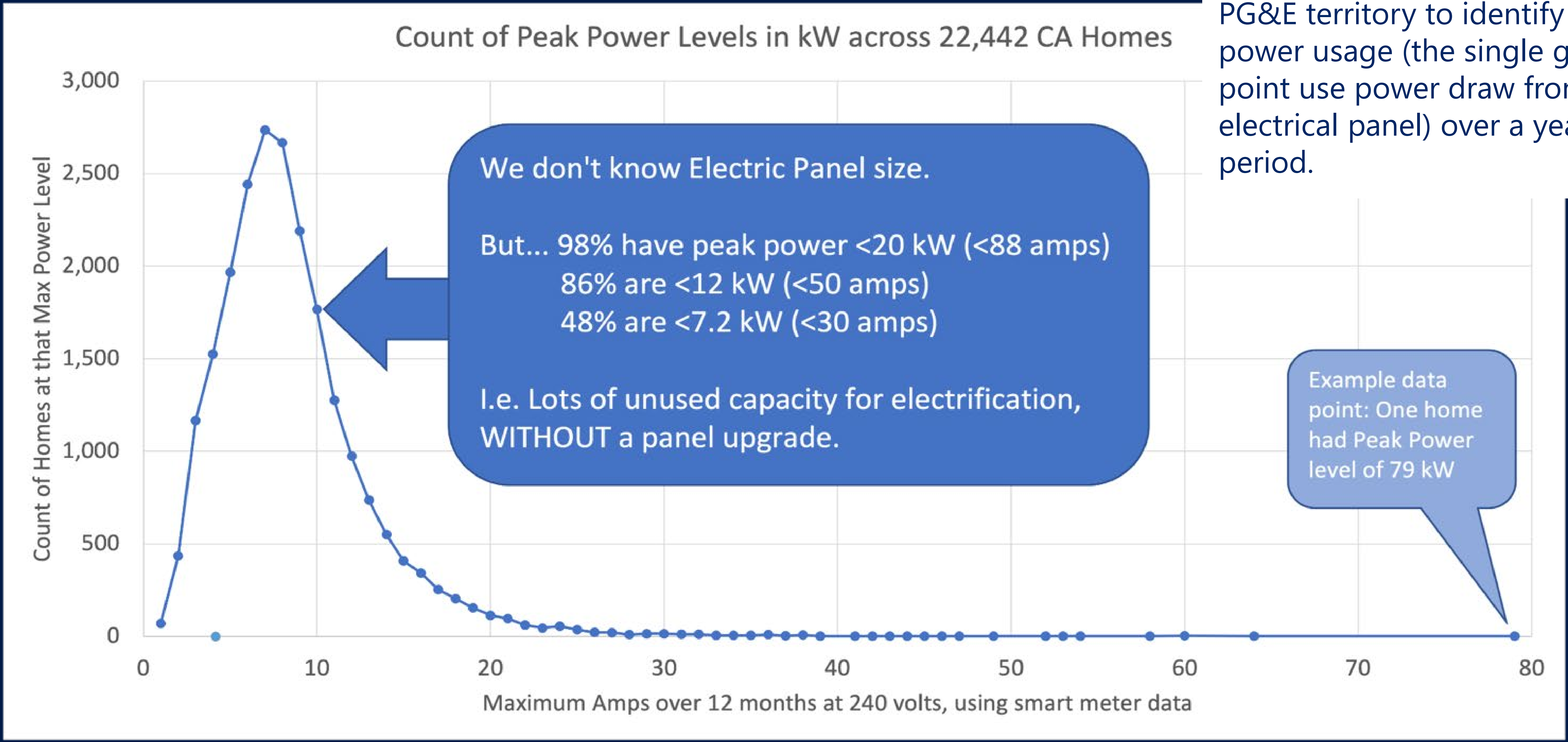
Fuse Boxes

Zinsco/GTE Sylvania and Federal Pacific panels are dangerous



Can we add new loads?

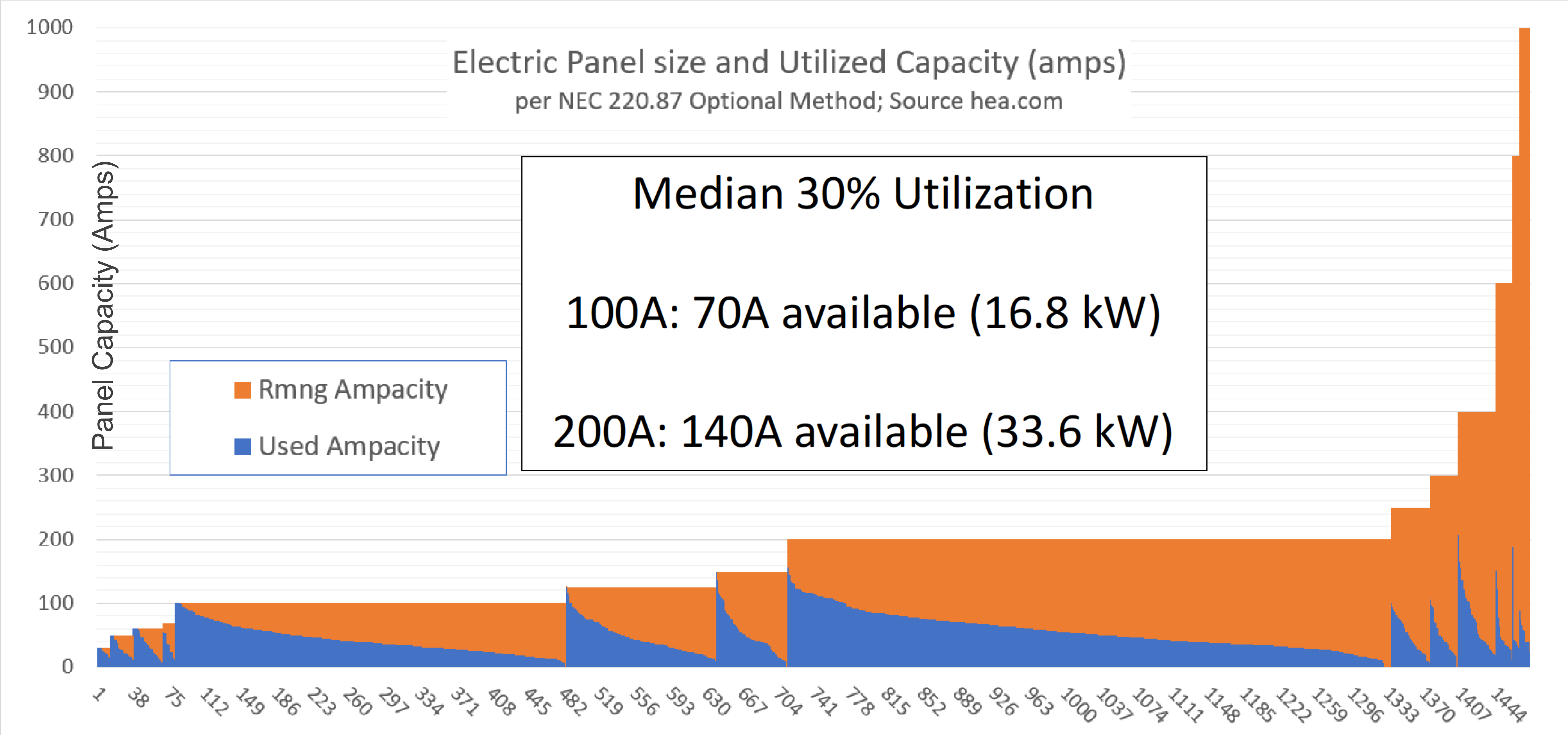
An analysis from HEA of smart meter data across 22,000 homes in PG&E territory to identify peak power usage (the single greatest point use power draw from their electrical panel) over a year-long period.



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

Source:
HEA, HomeIntel

Can we add new loads?

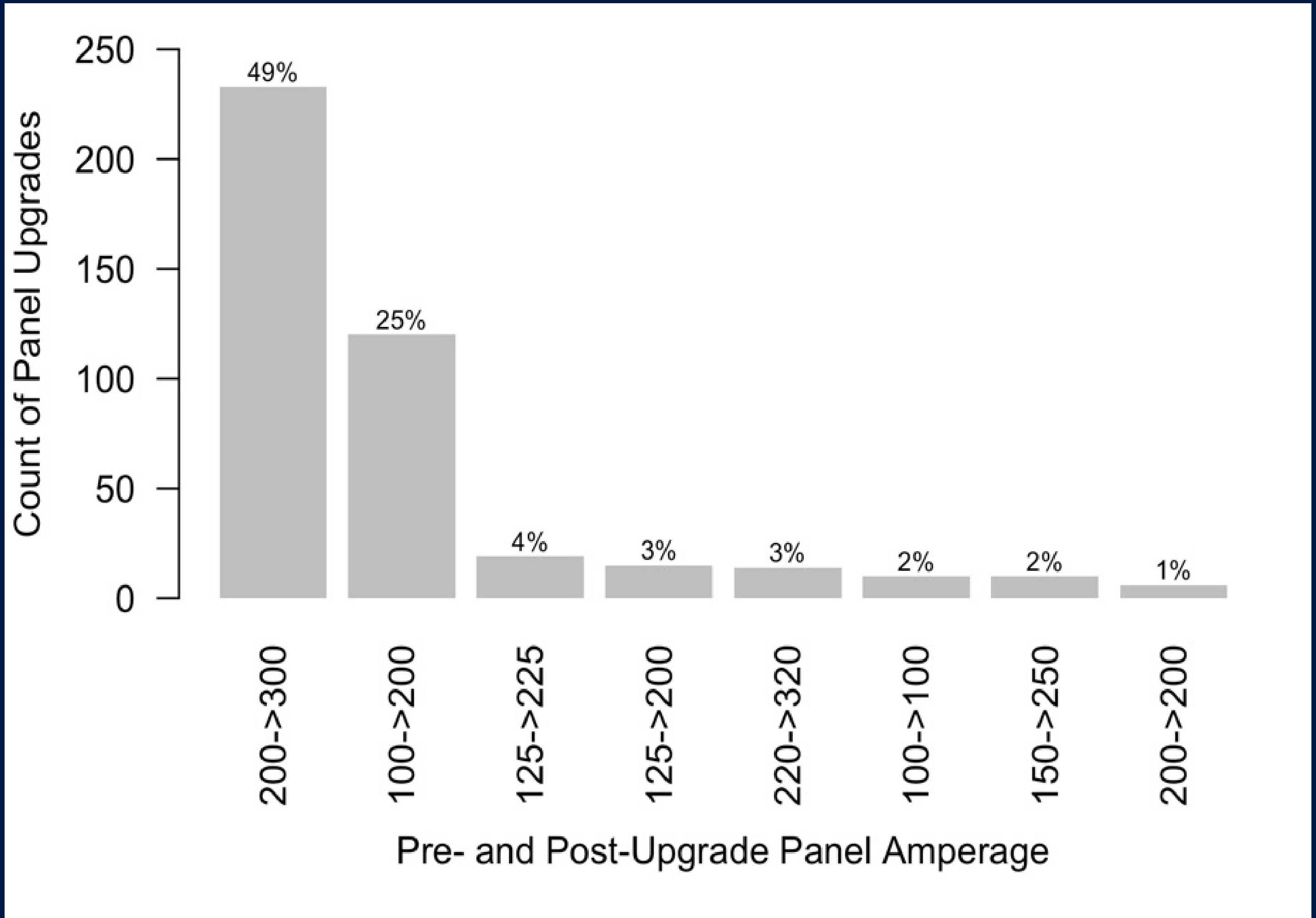


*Not a representative sample of all CA homes, and mix of all electric and electric + gas. Source: HEA, HomeIntel

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



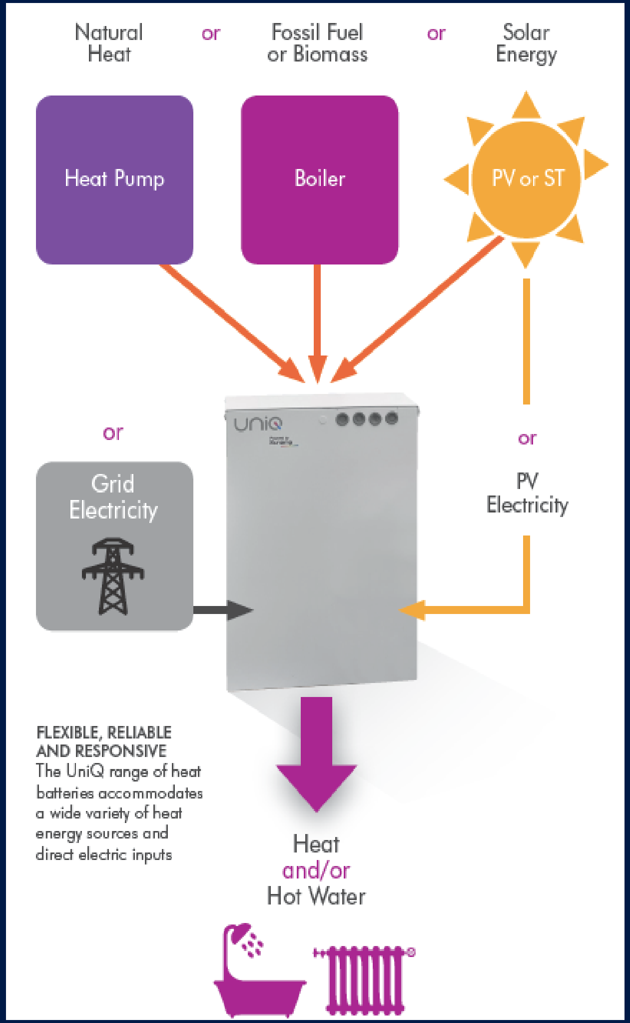
Grid Integration: Time Shifting Using Storage

Can be charged from onsite solar or low-cost mid-day grid power?

Good for disadvantaged / low-income communities: avoid peak pricing and demand charges

Electric Battery

- 3 to 5 KWh in every home – much less than 13.5 kWh ($13k) Tesla Powerwall



Thermal Storage

- Safe, common, cheap phase change materials
- 10.5 KWh in same space as 50 gallon tank

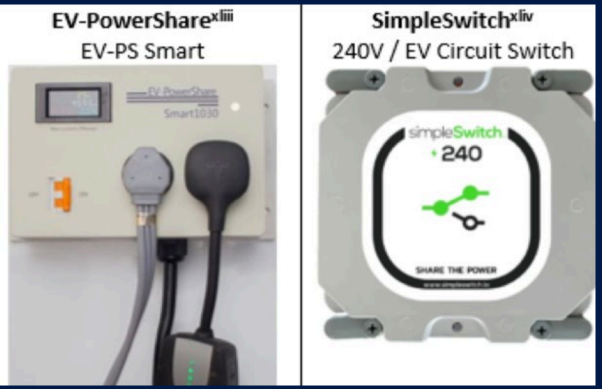
POWER-efficient electrification

Meter collars for PV and EVs

120V plug-in appliances

120V Battery-integrated appliances

Smart circuit breakers and sharers



120V Condensing and HP dryers

Non-Energy Benefits

Healthier Homes

Health Reasons to Eliminate Fossil Fuels

- **Burning fossil fuels:** emit several contaminants of concern:
  - $PM_{2.5}$, NO_2, CO, aldehydes and leaking unburned CH_4

- **In the home:**
  - Main sources are cooking, unvented heaters and poor appliance venting
  - This would serve Low-Income/Disadvantaged households the most
    - More likely to have poorly vented appliances
    - Smaller dwellings have higher contaminant concentrations
    - Low income dwellings less likely to have ventilation systems

- **Outside air:** $PM_{2.5}$ & NO_2
  - Environmental Justice Issue – often worse in disadvantaged communities

Safer Homes

Key safety issues are:

- **Carbon monoxide (CO)** → No concerns if home is all-electric
- **Fire safety** → No flames
- **Kitchen safety** → Induction cooking inherently safer – cooler surfaces
- **No gas explosions** → A key risk factor for utilities
- **Earthquake safety** → Post-earthquake fires usually a bigger hazard than the earthquake itself

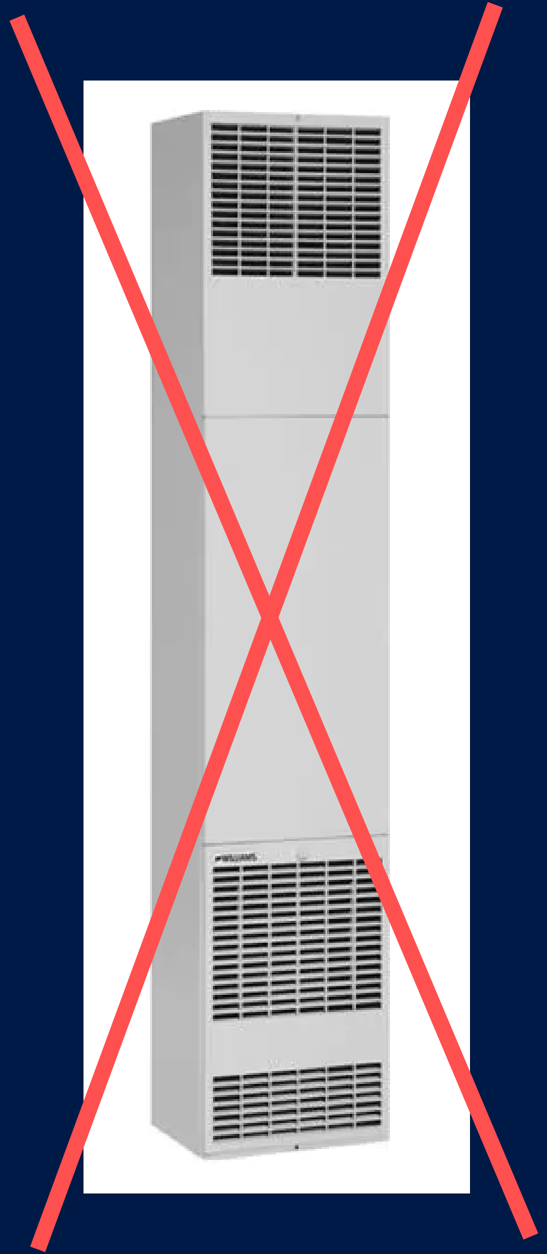
Removing Poor Appliances

- **Removing poor appliances:** e.g. Wall Furnaces
  - Wall furnaces are chronically poor at venting
  - Causes moisture problems and high levels of combustion contaminants
  - Even worse if kitchen of bath exhausts are used

Their low capacity serving small spaces makes them ideal candidates for low-cost replacement with a Heat Pump – possibly even a 120V Heat Pump

- **This would serve Low-Income households the most**
  - More likely to have wall furnaces
  - Smaller dwellings have higher contaminant concentrations
  - Low income dwellings less likely to have ventilation systems

- **Eliminate use of GAS cooking appliances as supplemental heat**
  - Need to provide good low operating cost options for low income households



Both Food and Heat Sources Generate Pollutants

Gas

Particles,

CO_2 & H_2O

NO_2 (and NO), CO

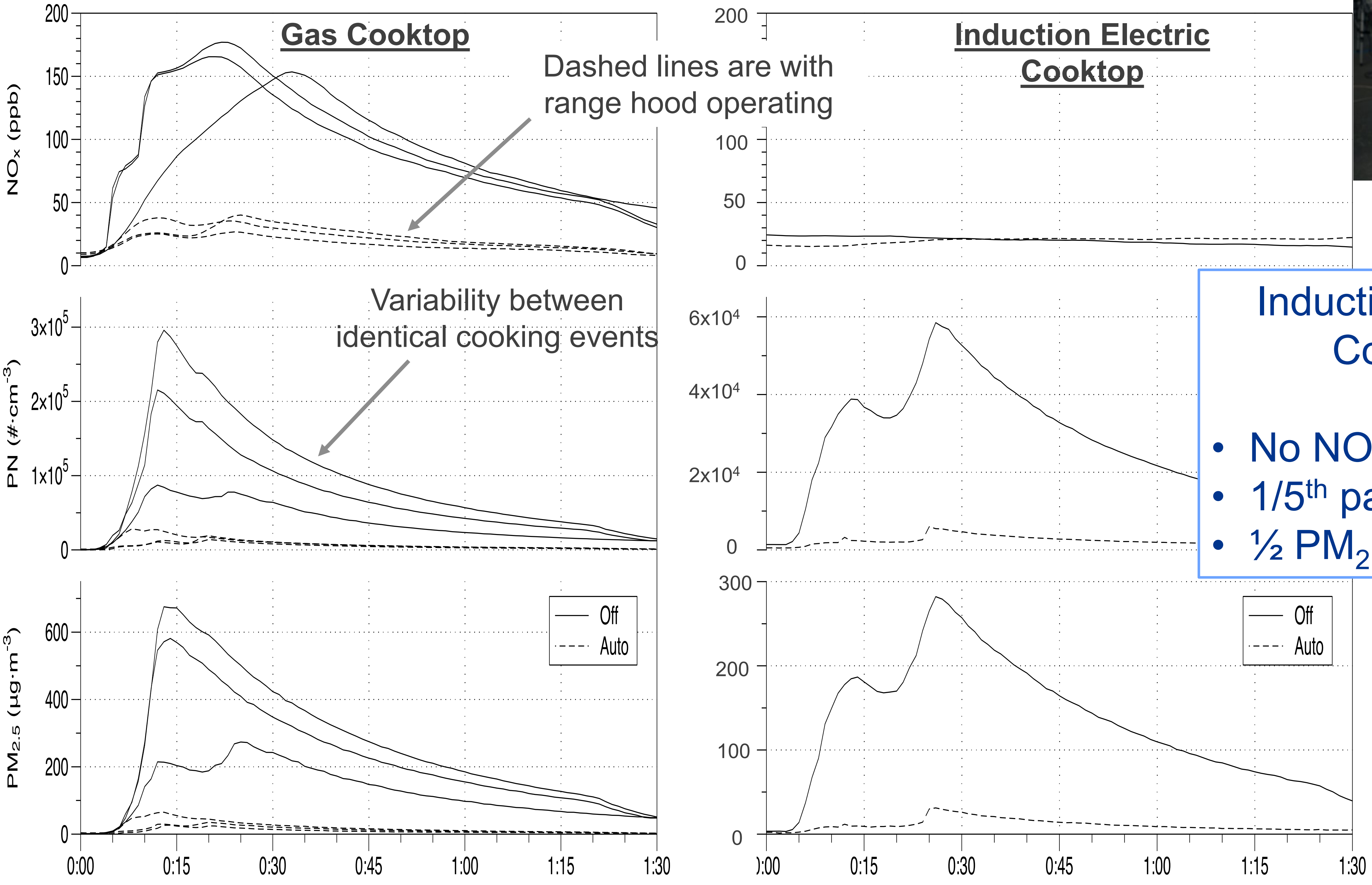
Food

Particles, Formaldehyde, Acetaldehyde, Acrolein, H2O, Odors

Electric

Fine and ultrafine particles
Less so from induction

Lab testing at LBNL using scripted meals



Induction vs. Gas Cooktop:

- No NO_x
- 1/5th particle count
- ½ $PM_{2.5}$ mass

New CA code requirements

- Key health contaminants are $PM_{2.5}$ (gas and electric cooking) and NO_2 (only from gas)
- To meet health guidelines better kitchen ventilation is required for NO_2, i.e., gas cooking

Floor Area (ft^2)	**Capture Efficiency**		**Airflow as installed (cfm)**	
	Gas	Electric	Gas	Electric
>1500 ft^2	0.70	0.50	180	110
1000 - 1500 ft^2	0.80	0.50	250	110
750 - 1000 ft^2	0.85	0.55	280	130
<750 ft^2	0.85	0.65	280	160

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

Summary of Topics for Raters

- RESNET CO_2 index
- New building codes for all-electric homes
- New equipment: batteries, thermal storage, smart panels, EV charging
- New equipment sizing paradigms
  - A small capacity unit with storage = same performance as a large capacity unit
- New Power-Efficient approaches: appliances and electric equipment
- Kitchen venting
- No combustion safety testing
- No appliances to relight after blower door air leakage test

Thank you…!

Questions…?

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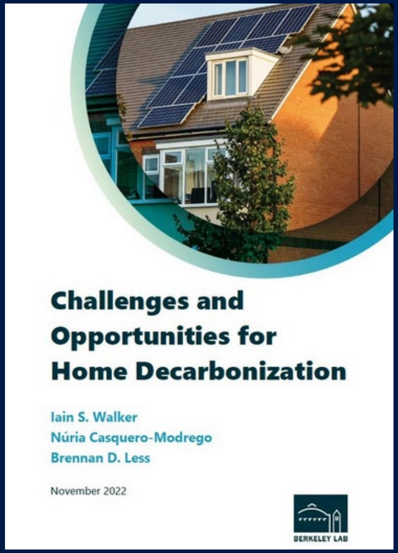

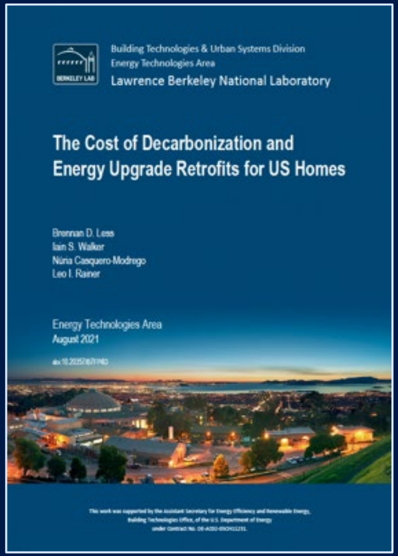

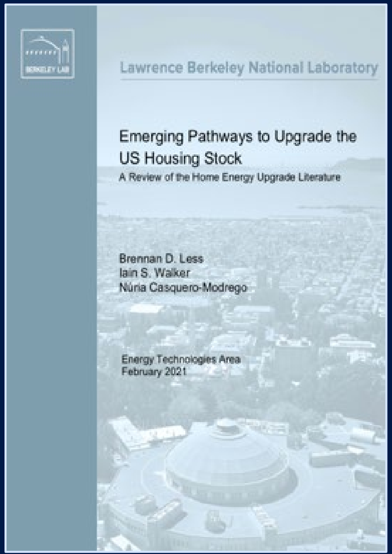

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