The Cost of Decarbonization and Energy Upgrade Retrofits for US Homes

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CBE Brown Bag | 11th of October 2021

BUILDING TECHNOLOGY & URBAN SYSTEMS DIVISION
Energy Technologies Area

Building America
U.S. Department of Energy

What's The Issue?

HOMES USE A LOT OF ENERGY

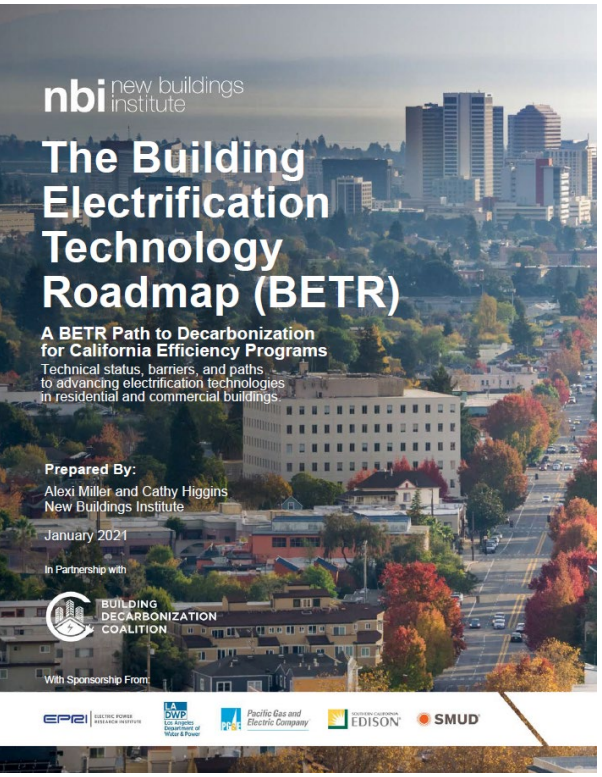
- **New residential homes** are pretty good and are only about 1% of homes in any given year
- **Existing residential homes** use (almost) all the energy

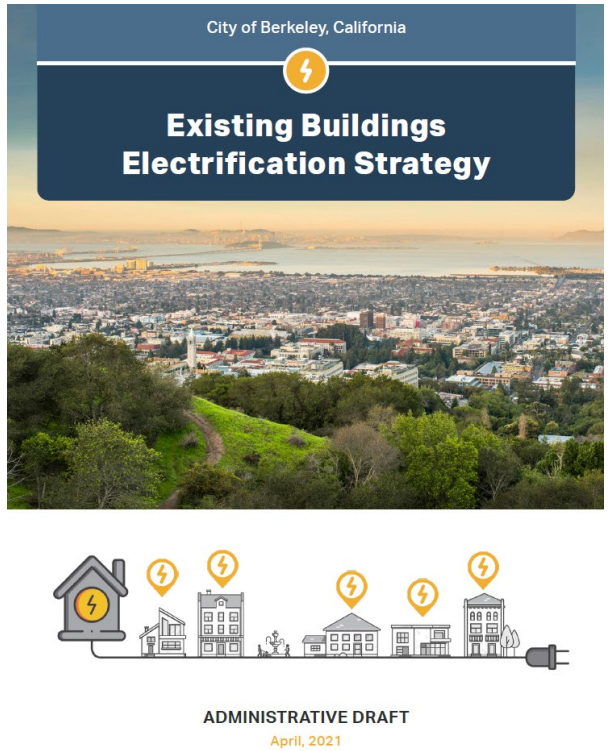
WE NEED TO FIX EXISTING HOMES

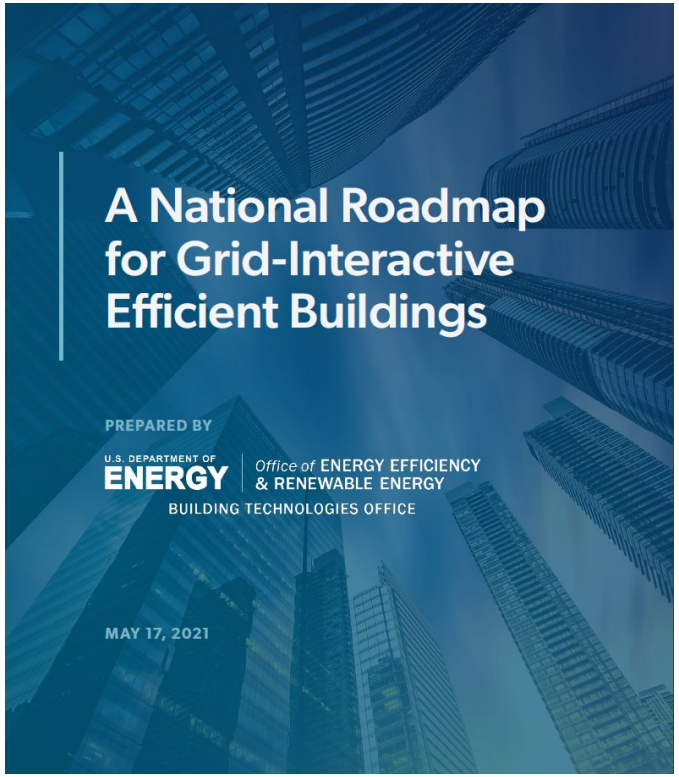
- Why aren't all homes upgraded?
- What are the barriers to scaling upgrades?
- Can we make upgrade costs more manageable?

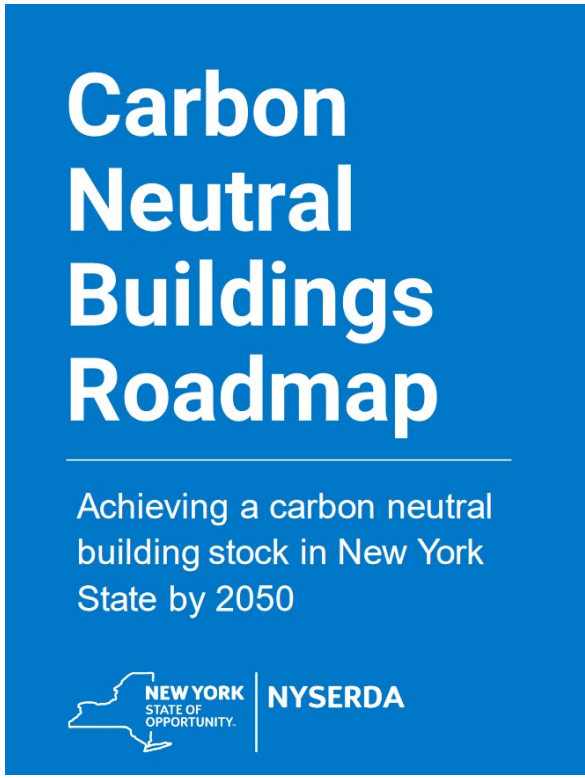
Switching from **Energy Efficiency** to **Low Carbon:**
We can't efficiency our way to zero carbon homes

Emerging Changes in Residential Construction

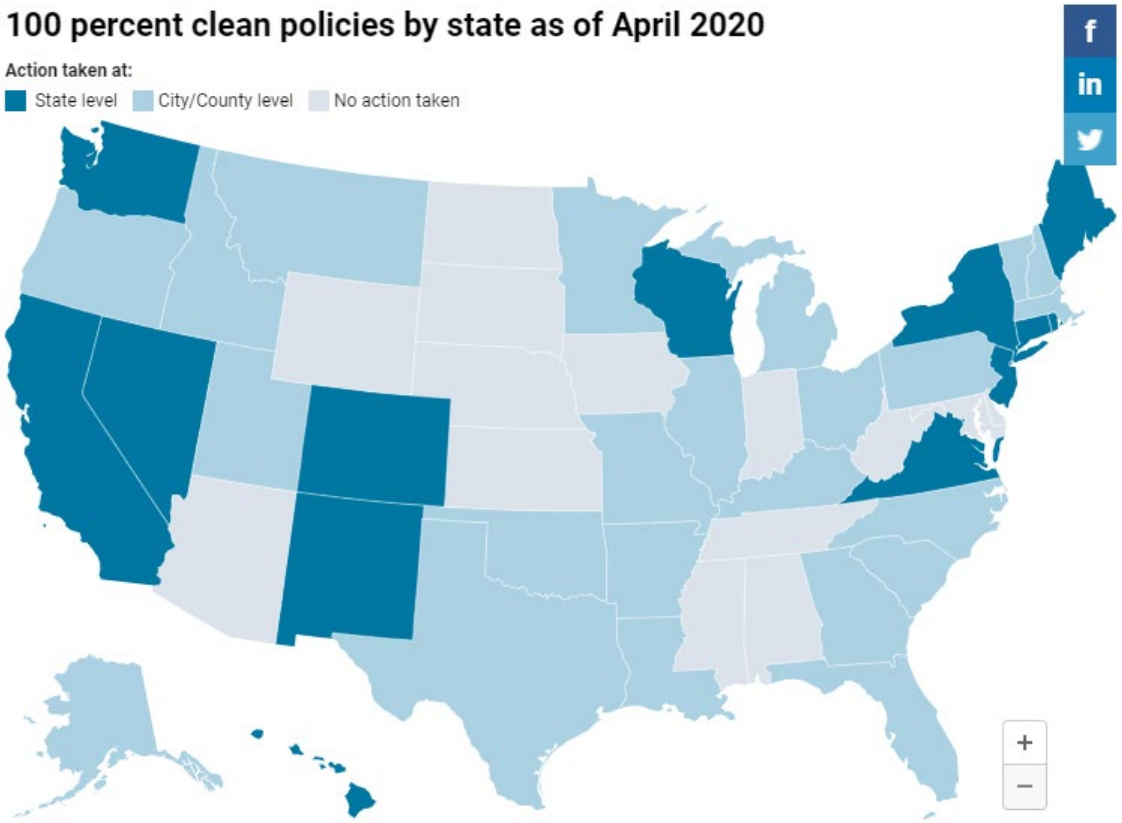

nbi new buildings institute
The Building Electrification Technology Roadmap (BETR)
A BETR Path to Decarbonization for California Efficiency Programs
Technical status, barriers, and paths to advancing electrification technologies in residential and commercial buildings
Prepared By:
Alexi Miller and Cathy Higgins
New Buildings Institute
January 2021
In Partnership with
BUILDING DECARBONIZATION COALITION
With Sponsorship From
EPRI
LA DWP
Pacific Gas and Electric Company
EDISON
SMUD


City of Berkeley, California
Existing Buildings Electrification Strategy
ADMINISTRATIVE DRAFT
April, 2021


A National Roadmap for Grid-Interactive Efficient Buildings
PREPARED BY
U.S. DEPARTMENT OF ENERGY
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY
BUILDING TECHNOLOGIES OFFICE
MAY 17, 2021


Carbon Neutral Buildings Roadmap
Achieving a carbon neutral building stock in New York State by 2050
NEW YORK STATE OF OPPORTUNITY.
NYSERDA

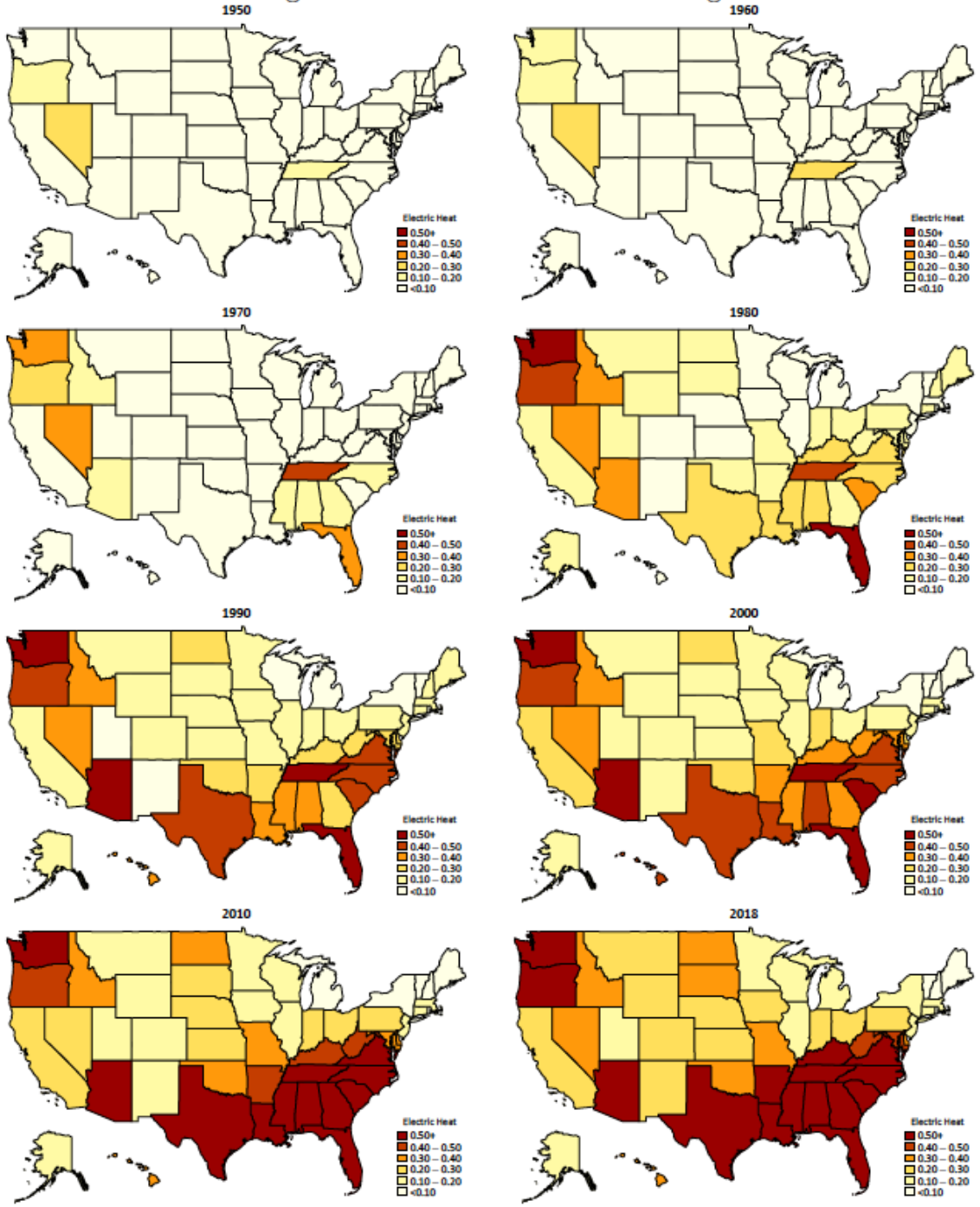
Policies



*Hover or click on states for more information.

Map: Center for American Progress • Source: Author's review of relevant state policies, updated from: Center for American Progress, "State Fact Sheet: 100 Percent Clean Future," October 16, 2019, available at https://www.americanprogress.org/issues/green/reports/2019/10/16/475863/state-fact-sheet-100-percent-clean-future/; Source: Sierra Club, "Ready for 100" https://www.sierraclub.org/ready-for-100/commitments..

Products

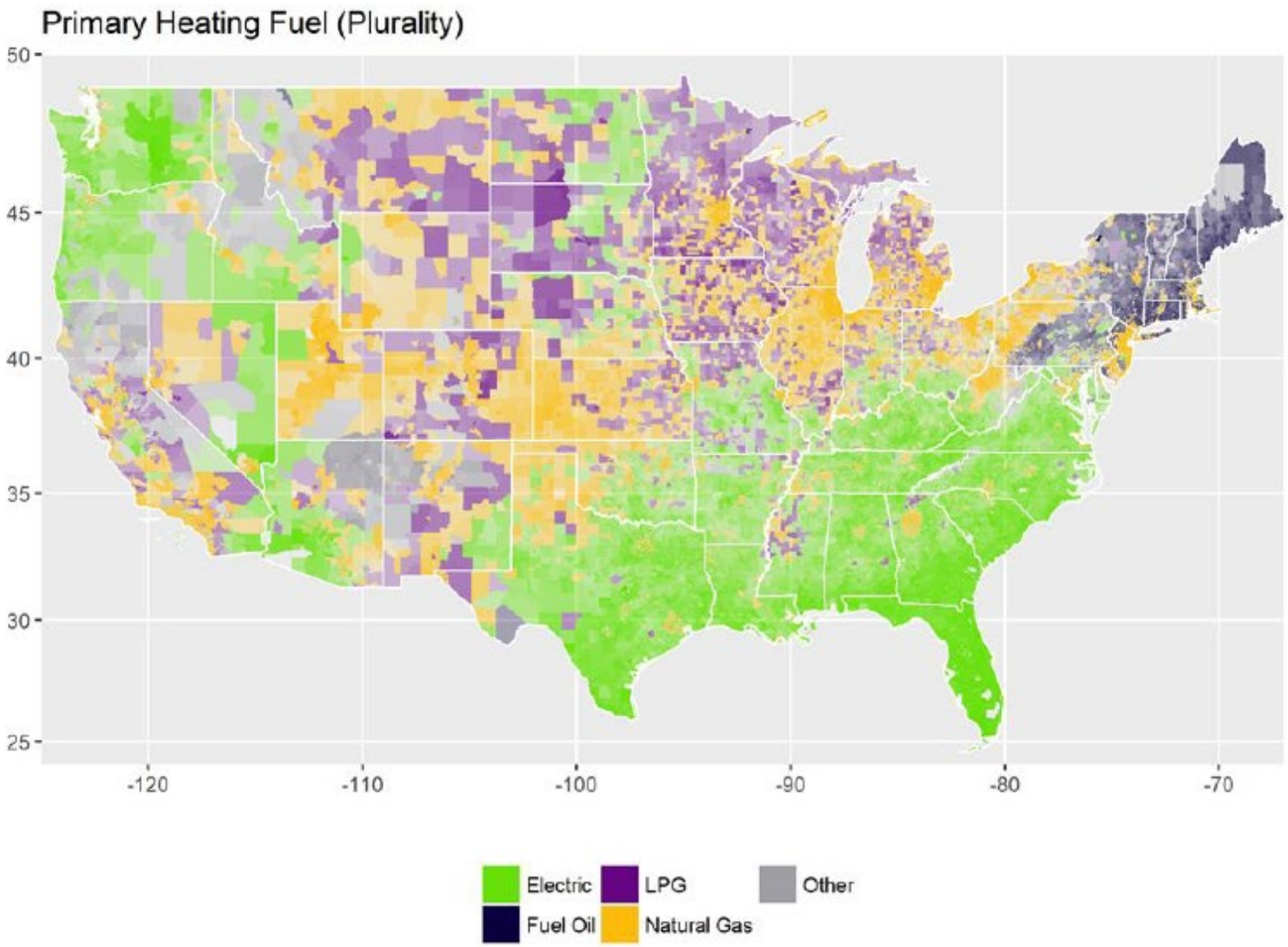


Growth in Electric Heating

- 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.

Heating Fuel



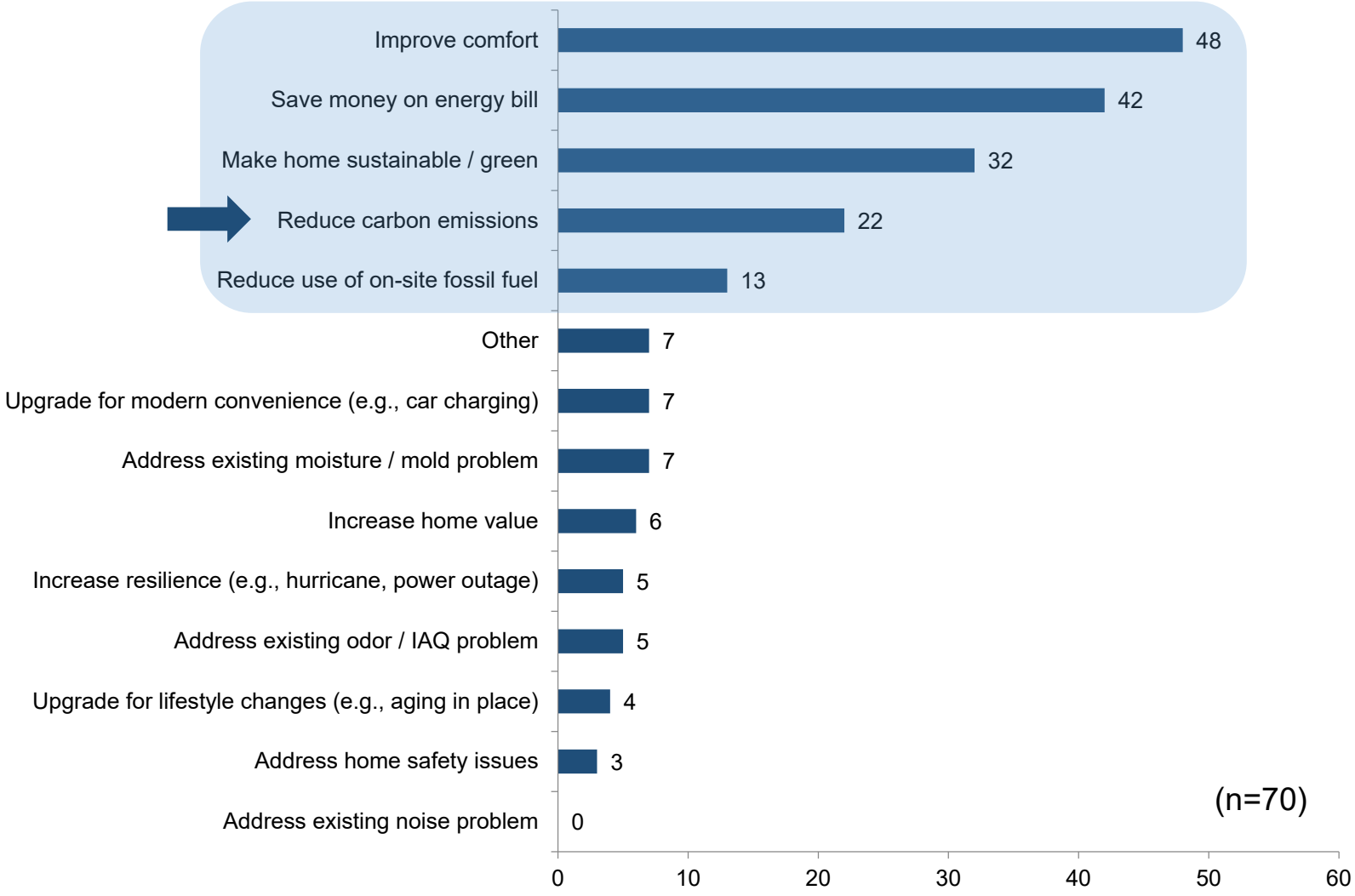
Data from the American Community Survey (2016).

Distribution of Electric Heating

- >25% of homes are already all-electric.
- 40% of homes have electric primary heating.

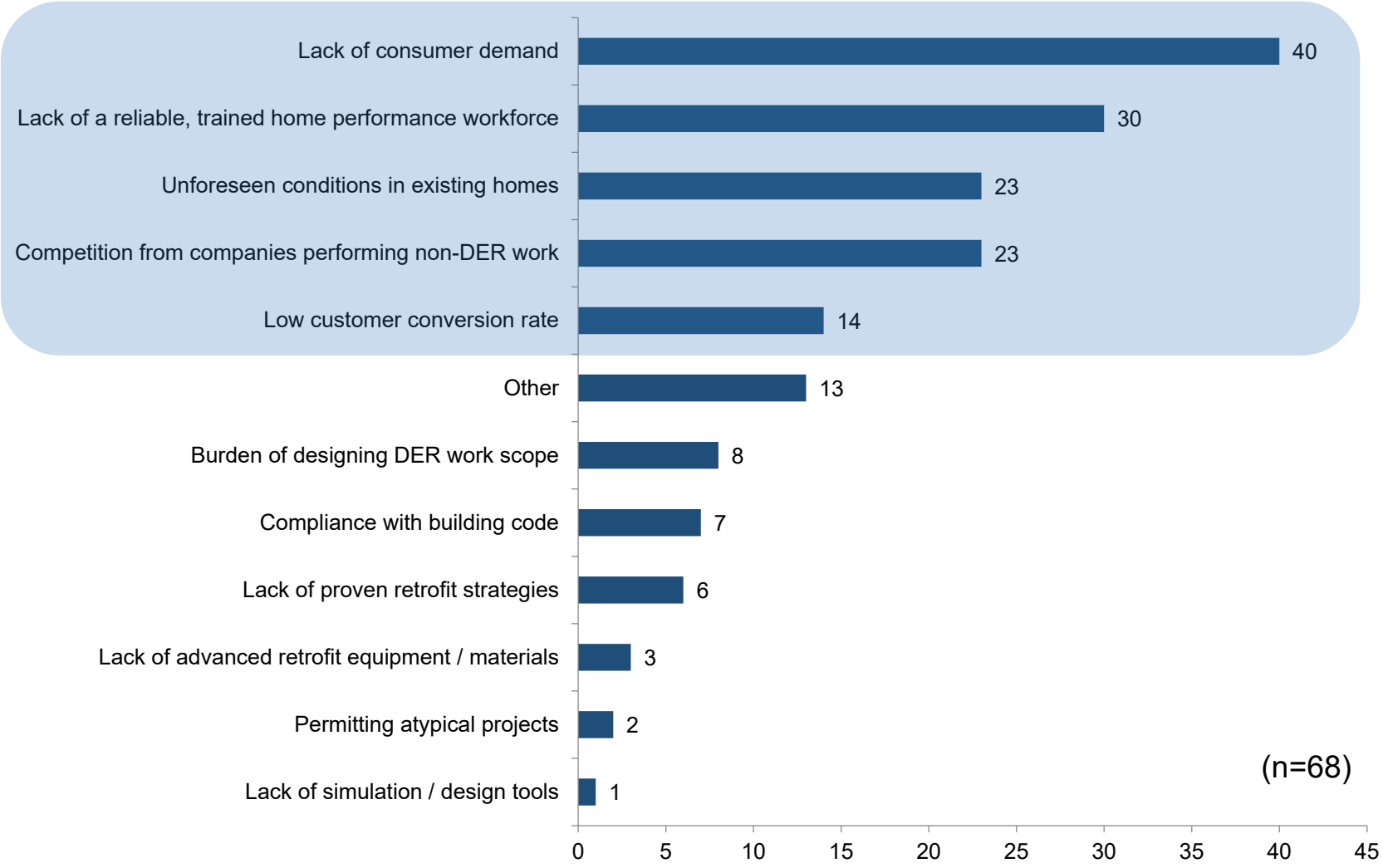
Customer Motivations

What are the main motivations of homeowners / building owners when seeking to perform a energy upgrade project?



Industry Perspective

Aside from costs, what are the biggest barriers when performing DER projects?



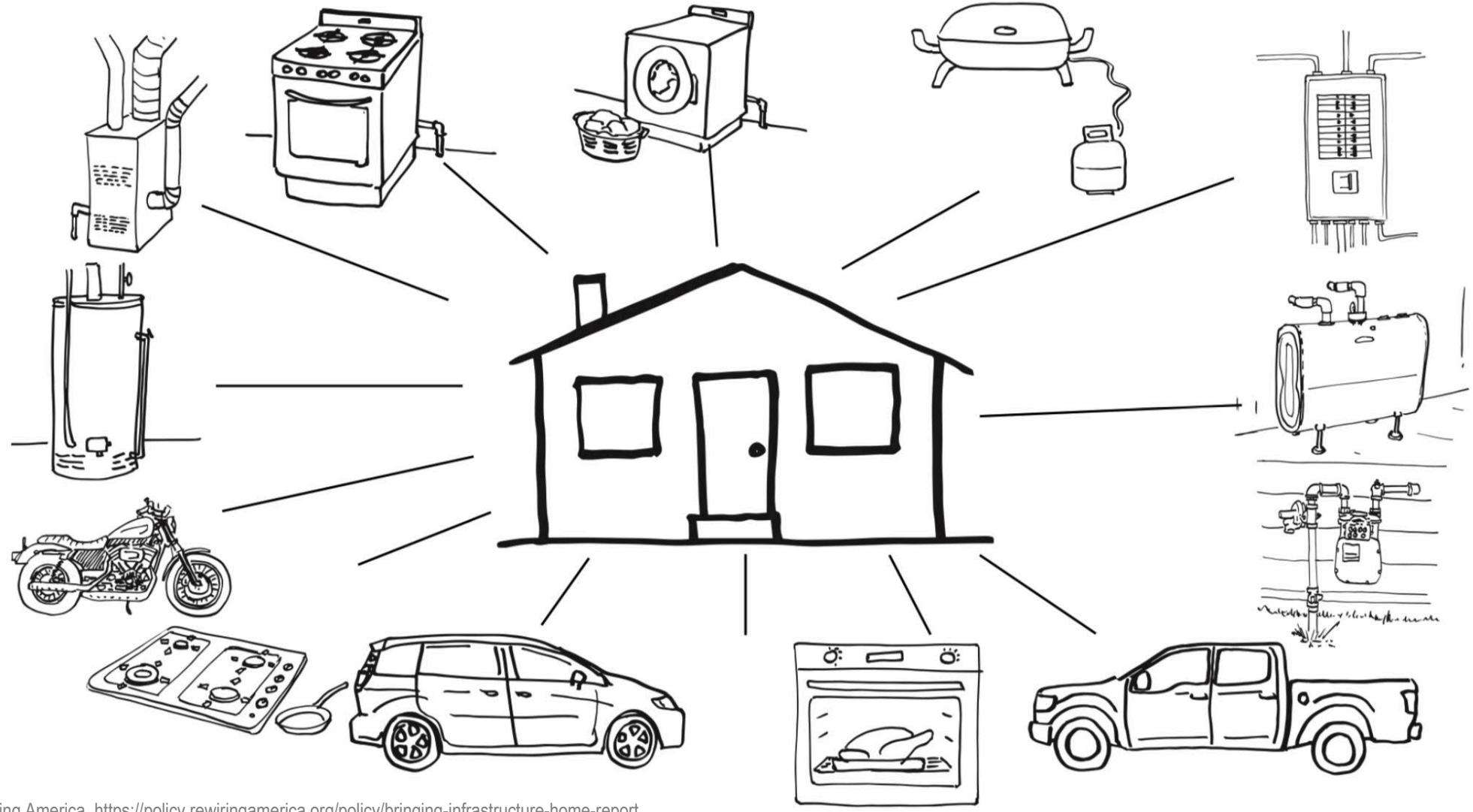
Advanced Technologies and Approaches

What contractors say will increase deep energy retrofits of homes

Ratings =	1	2	3	4	5	Total Responses
"One-stop shop" with energy audit, work scope, financing, permits, construction, testing	2	2	10	21	28	63
Energy plus healthy home retrofit	1	5	23	22	13	64
Standard weatherization combined with heat pump and PV	4	13	18	19	12	66
Over-time DER aligned with equipment replacement / upgrade	6	7	20	16	15	64
Home electrification retrofit	10	8	18	18	10	64
Exterior retrofit with minimal disturbance inside home	9	20	14	14	5	62
Pre-fabricated panelized envelope retrofits (e.g., EnergieSprong)	16	23	11	9	4	63

Why Electrification…?

What is Home Electrification…? Replacing fossil fuels with electricity



Credit: Rewiring America, https://policy.rewiringamerica.org/policy/bringing-infrastructure-home-report

Why Electrification…?

Need to STOP emitting CO_2

Need Low/Zero CO_2 energy – **ELECTRICITY** the only viable option.

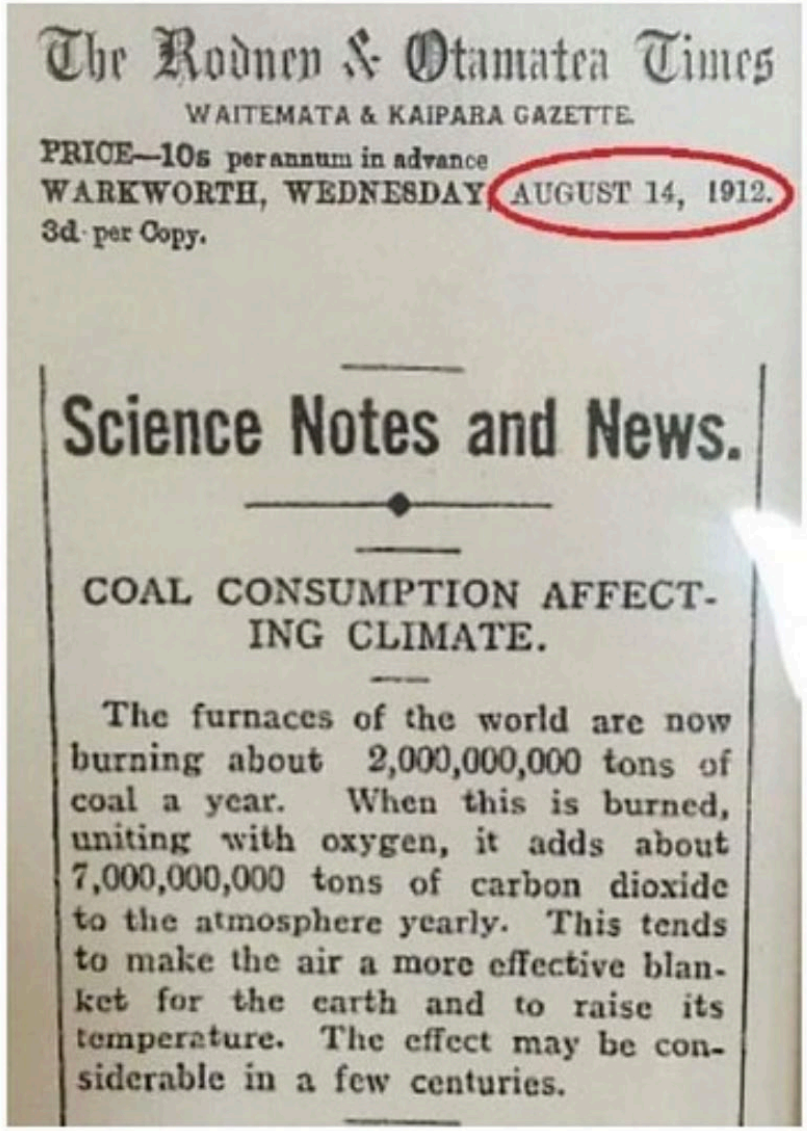
- Allows use of Low/Zero carbon renewable energy

"We can't efficiency our way to zero carbon emissions"

- Very limited efficiency gains remain for fossil-fuel heating and DHW

Gas leaks typically about 2-3% but higher GWP makes this a 20-30% increase in greenhouse gas emissions

- 0.5% leakage inside homes



The Rodney & Otamatea Times

WAITEMATA & KAIPARA GAZETTE.

PRICE—10s per annum in advance
WARKWORTH, WEDNESDAY, AUGUST 14, 1912.
3d per Copy.

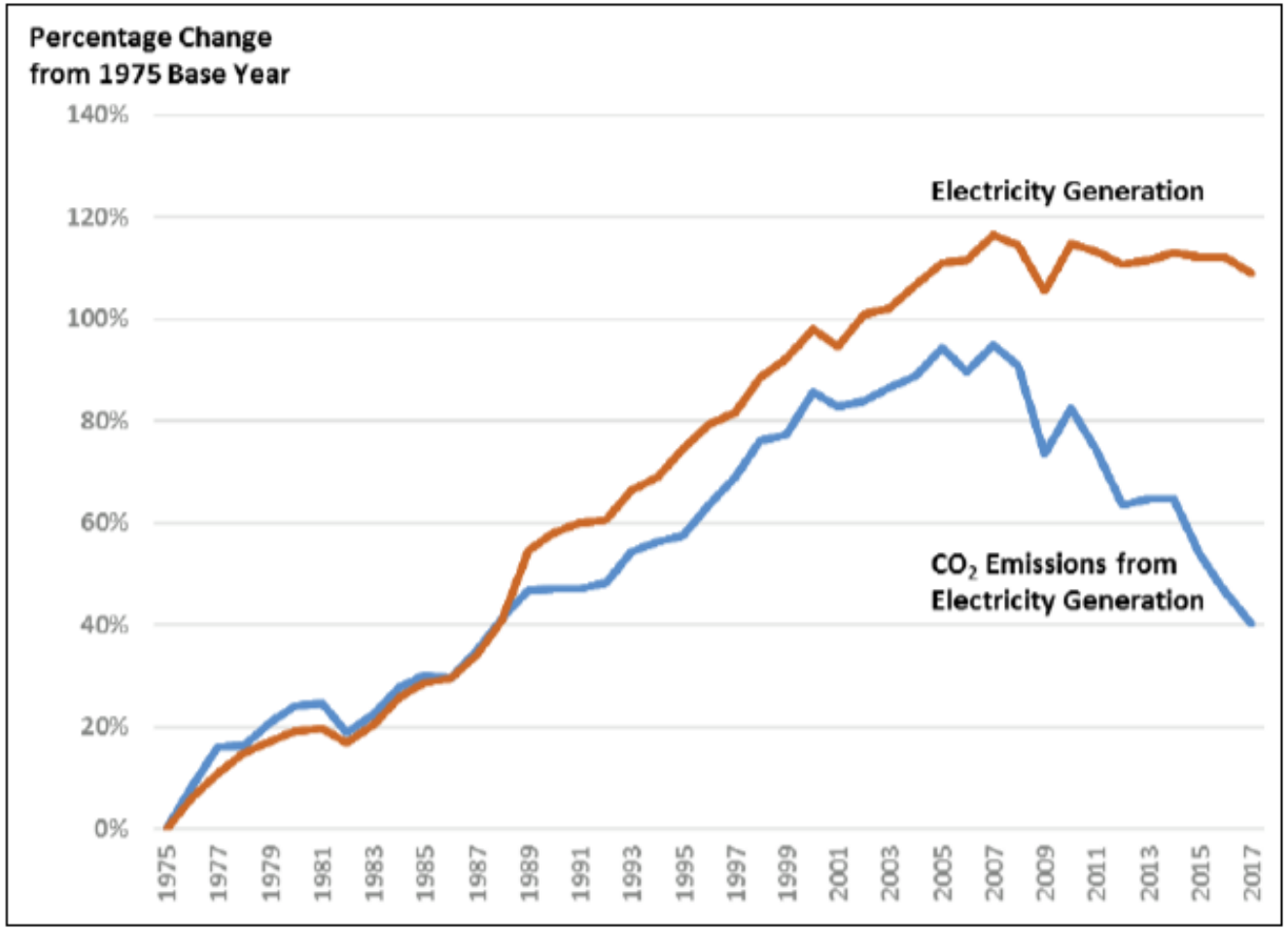
Science Notes and News.

COAL CONSUMPTION AFFECTING CLIMATE.

The furnaces of the world are now burning about 2,000,000,000 tons of coal a year. When this is burned, uniting with oxygen, it adds about 7,000,000,000 tons of carbon dioxide to the atmosphere yearly. This tends to make the air a more effective blanket for the earth and to raise its temperature. The effect may be considerable in a few centuries.

Why Electrification…?

1975 - 2017



Source: Prepared by CRS; data from EIA, *Monthly Energy Review*, net electricity generation from Table 7.2 and emissions from Table 12.6, http://www.eia.gov/totalenergy/data/monthly/.

Figure from : US Carbon Dioxide Emissions in the Electricity Sector: Factors, Trends and Projections, 2019. Congressional Research Service.

Electricity is rapidly lowering its CO_2 content

Why Electrification…?

Energy Impacts

- Significant site savings using Heat Pumps – typically factors of 3-4 compared to fossil fueled appliances and electric resistance heat and DHW.

- Primary or source energy less clear due to electric distribution system losses. Minimize primary energy by:
    - **On-site generation:** Mainly PV but could include solar hot water
    - **On-site storage:** Limits peak power, allows shifting energy use to time of greatest renewable generation

- (Utilities willing) Electrification allows homes to operate at minimum power using their own generation/storage – big increase in resiliency.

- Not just electrification: energy efficiency will help the transition and keep costs down.

Why Electrification…?

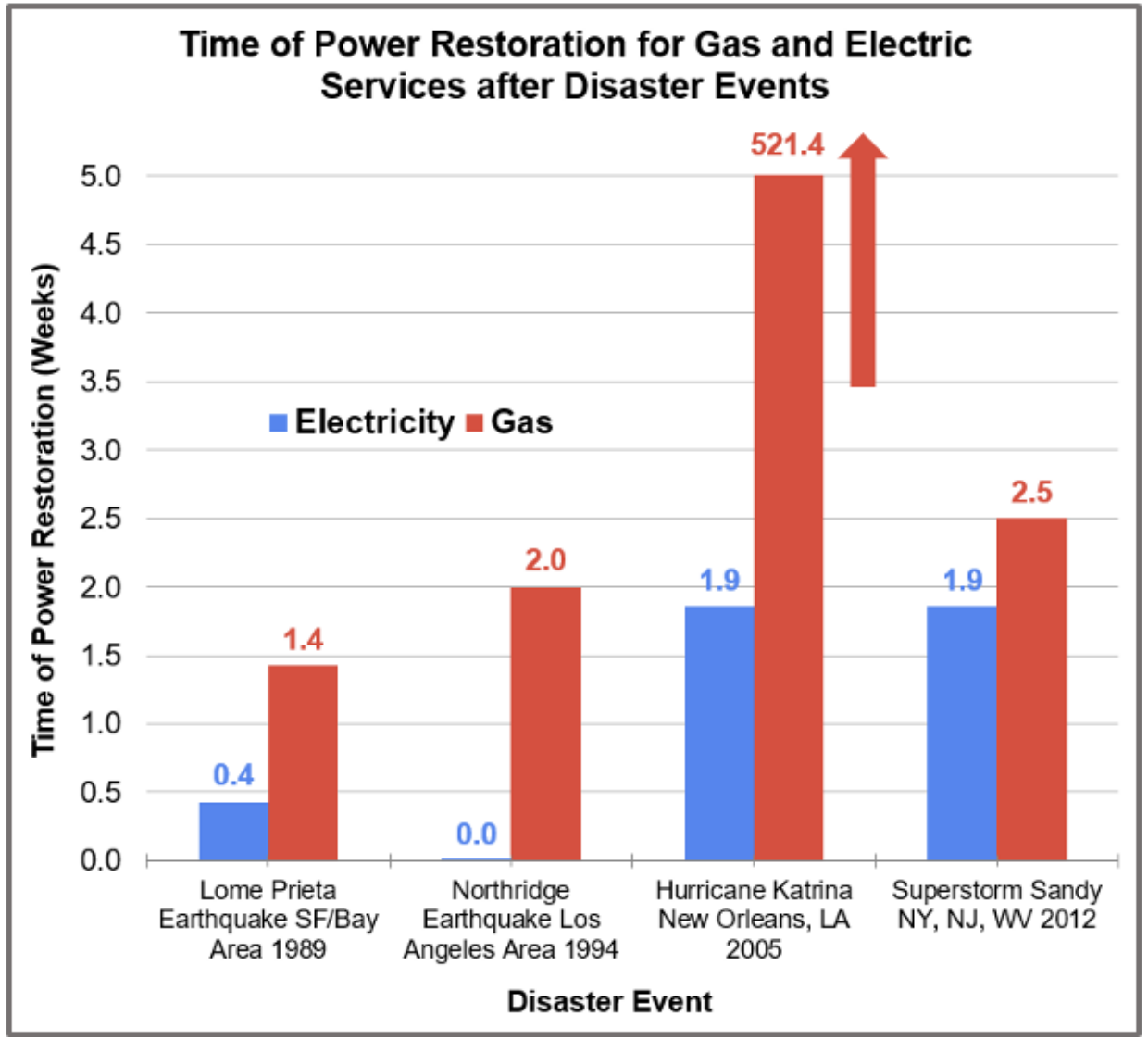
We have to fix all the homes in the country and electrification is easier than other **retrofit** approaches:

- Less home disturbance
- Better cost control
- Easier financing
- Easier work for contractors c/w envelope/window upgrades
- **Easier to sell – give people what they want**

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

Resiliency

- On-site **storage and generation** allows basic home operation during emergencies.
- About half of **natural gas** processing is along the gulf coast and highly vulnerable to *hurricanes and storm* surges.



Transportation

EV-Ready Homes

- Current poor public charging infrastructure:
  - Need to be able to charge at home
- All new homes should have a circuit ready for a charger install
- Trickier in existing home – need a space circuit or new panel/rewiring
- EV is easily be the biggest home load: 7.2 kW up to 50 kW
- Car battery may become the house battery

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:**
  - Field studies show key health-related contaminants related to bring fossil fuels: cooking and poor appliance venting
  - Electrification removes need for combustion safety testing, CO alarms
  - EPRI study: Electrification results in more than 12,000 avoided deaths and a monetized health benefit of $108B per year…. *Just for California plus additional benefits from cleaner outdoor air*

- **Outside air:** PM2.5 & NO_2
  - Environmental Justice Issue – often worse in disadvantaged communities

Safer Homes

Key safety issues are:

- **Carbon monoxide** – No concerns if home is all-electric
- **Fire safety** – No naked flames
- **Kitchen safety** - No naked flames
  (Induction cooking inherently safer – cooler surfaces for induction cooktops, no flames)
- **No gas explosions**
  A key risk factor for utilities – see, for example, PG&E's bad reputation from occasional home explosions
- **Earthquake safety**
  Post-earthquake fires usually a bigger hazard than the earthquake itself

Health and Environmental Justice

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

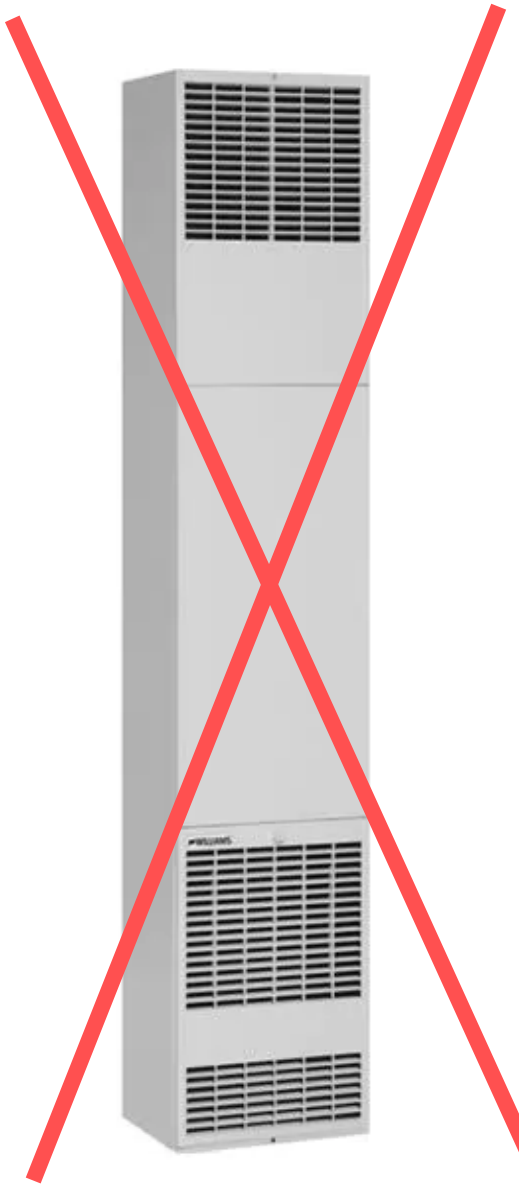
Their low capacity serving small spaces makes them ideal candidates for low-cost replacement with a Heat Pump – possibly even a 120V Heat Pump

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

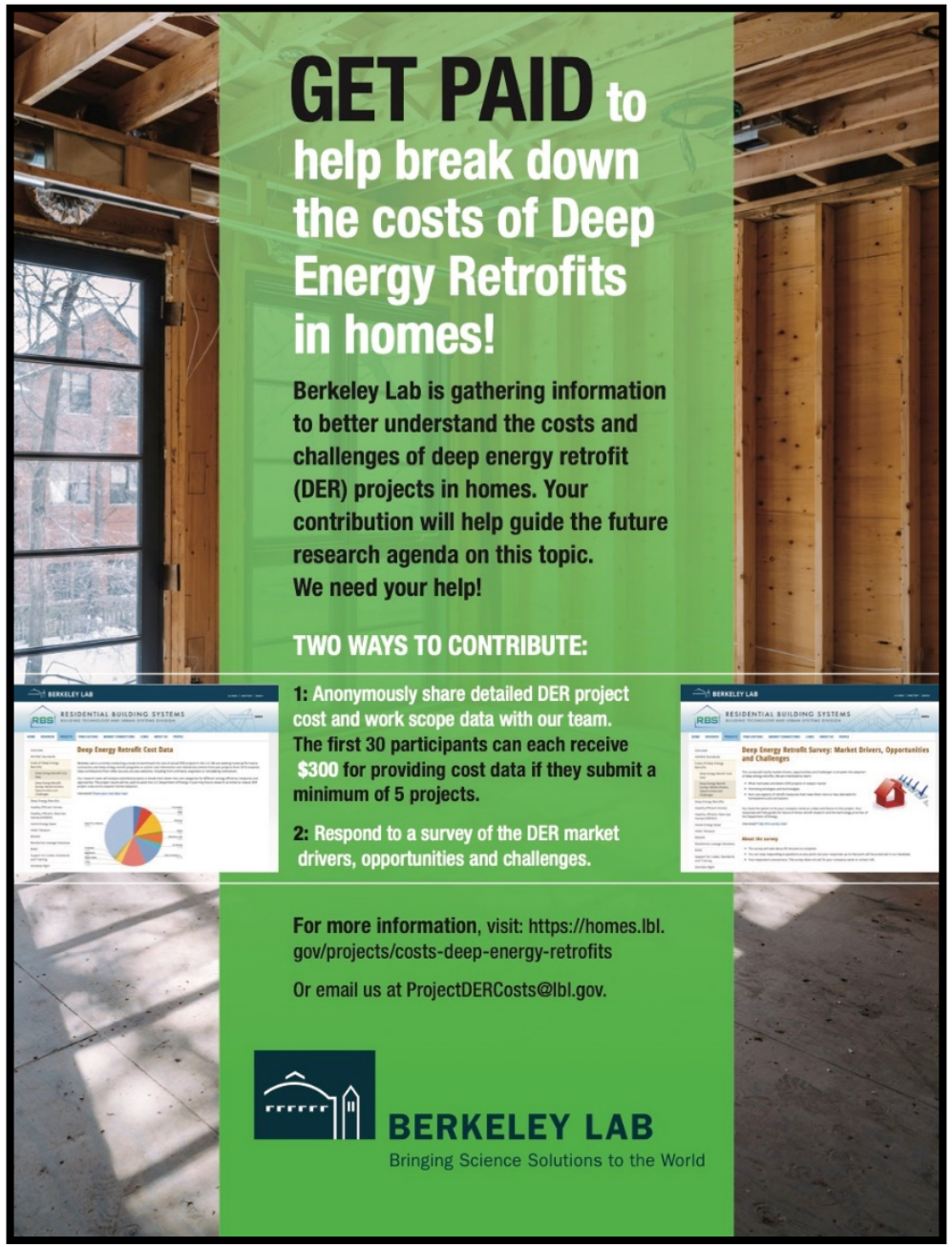
Eliminate use of GAS cooking appliances as supplemental heat

- Need to provide good low operating cost options for low income households

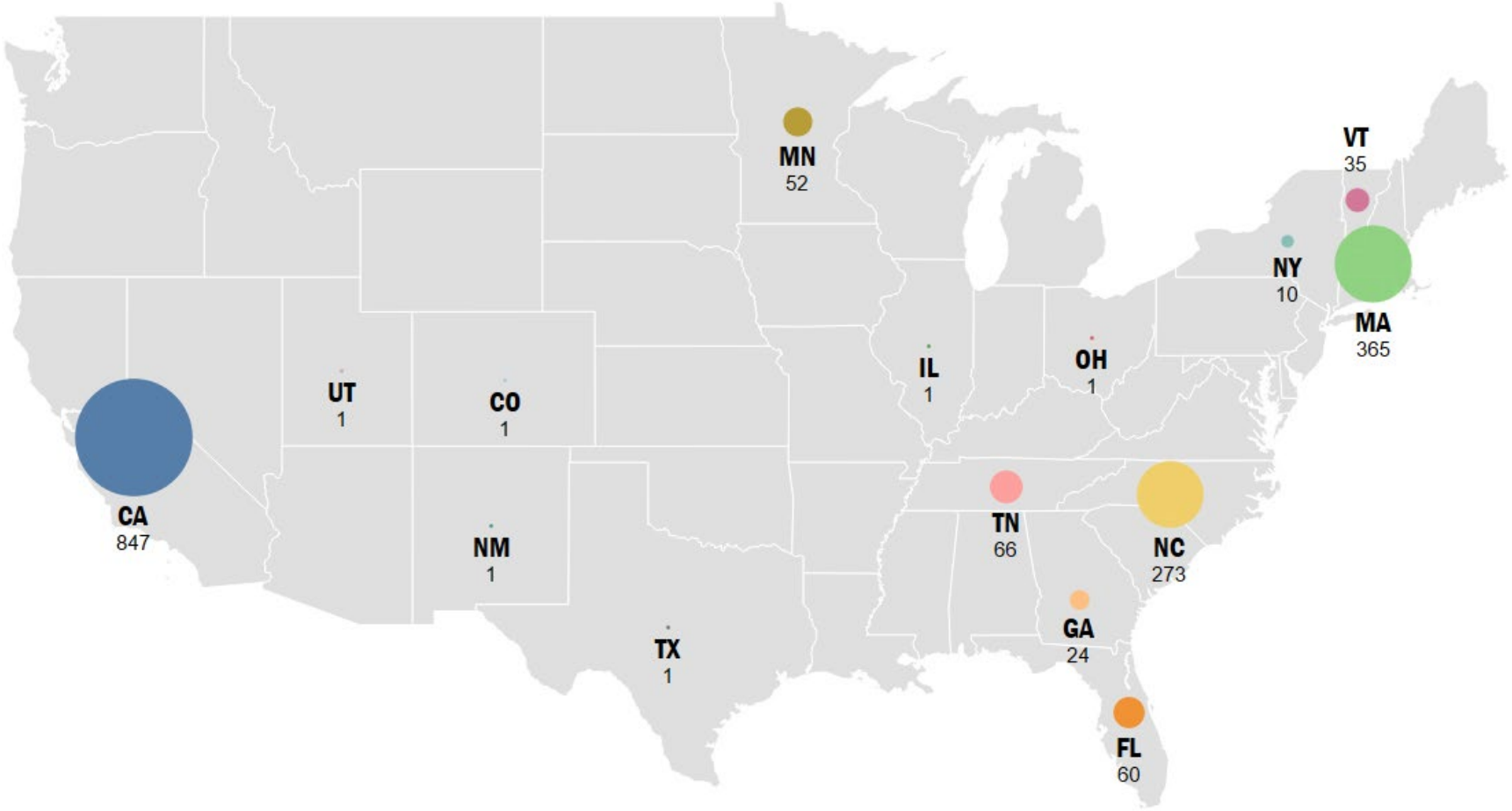


Reducing the Cost of Decarbonization / Electrification

Data Solicitation

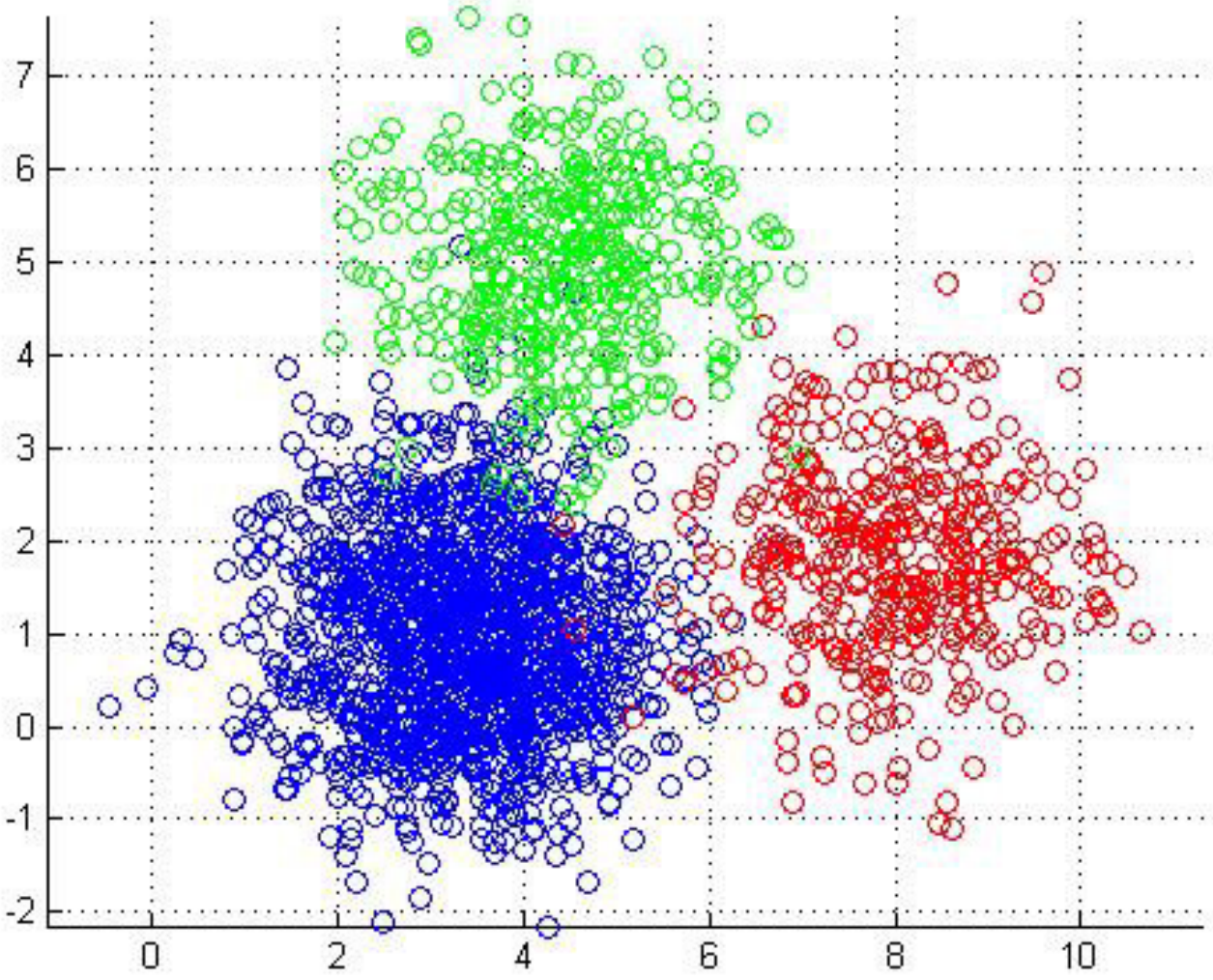


Database Summary



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

Clustering Project Types

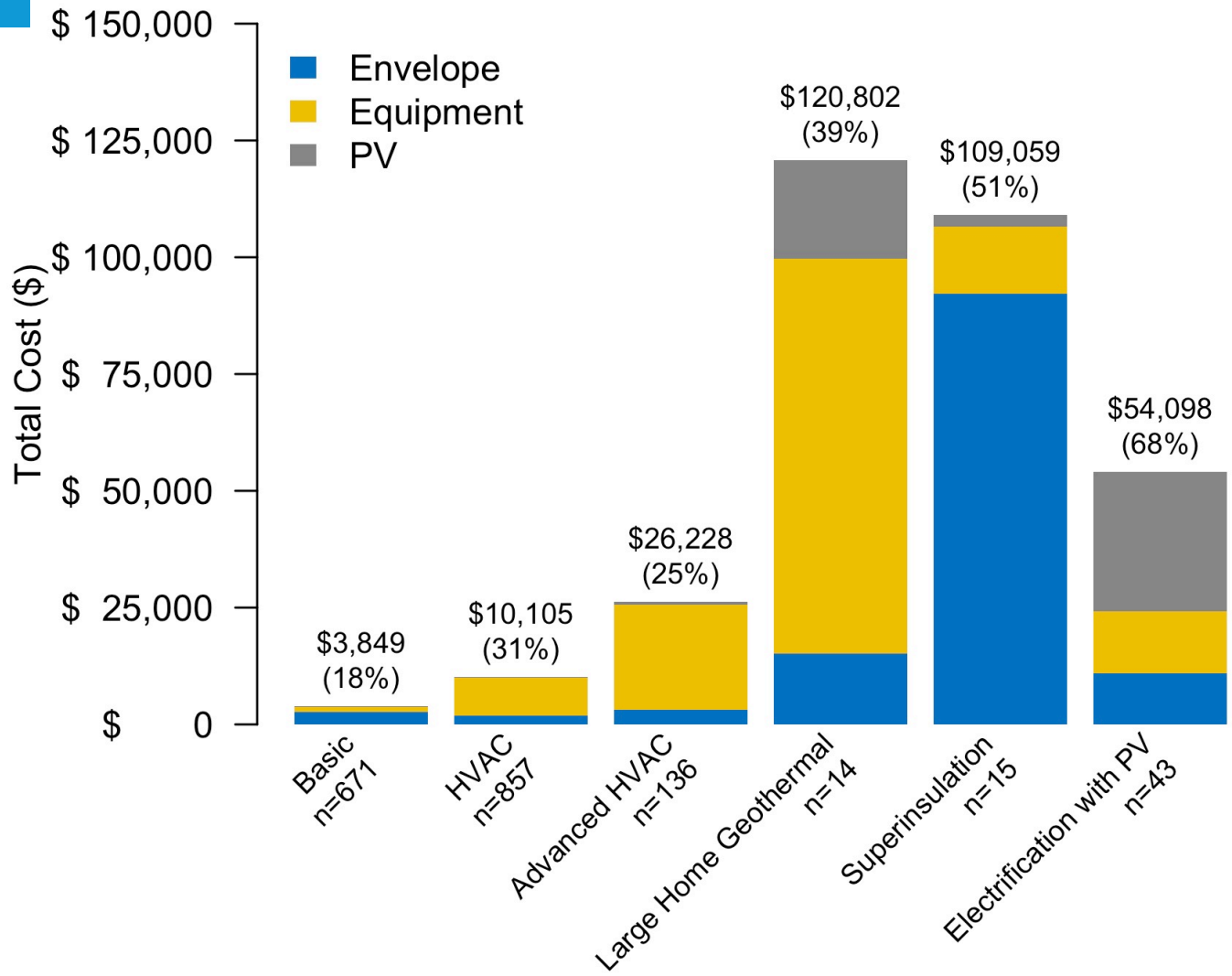


Unsupervised **Machine Learning** approach that groups similar objects such that the objects in the same group are more similar to each other than to objects in the other groups.

Clustering Project Types

Clustering Project Types

$ - Total Cost
% - CO_2e reduction



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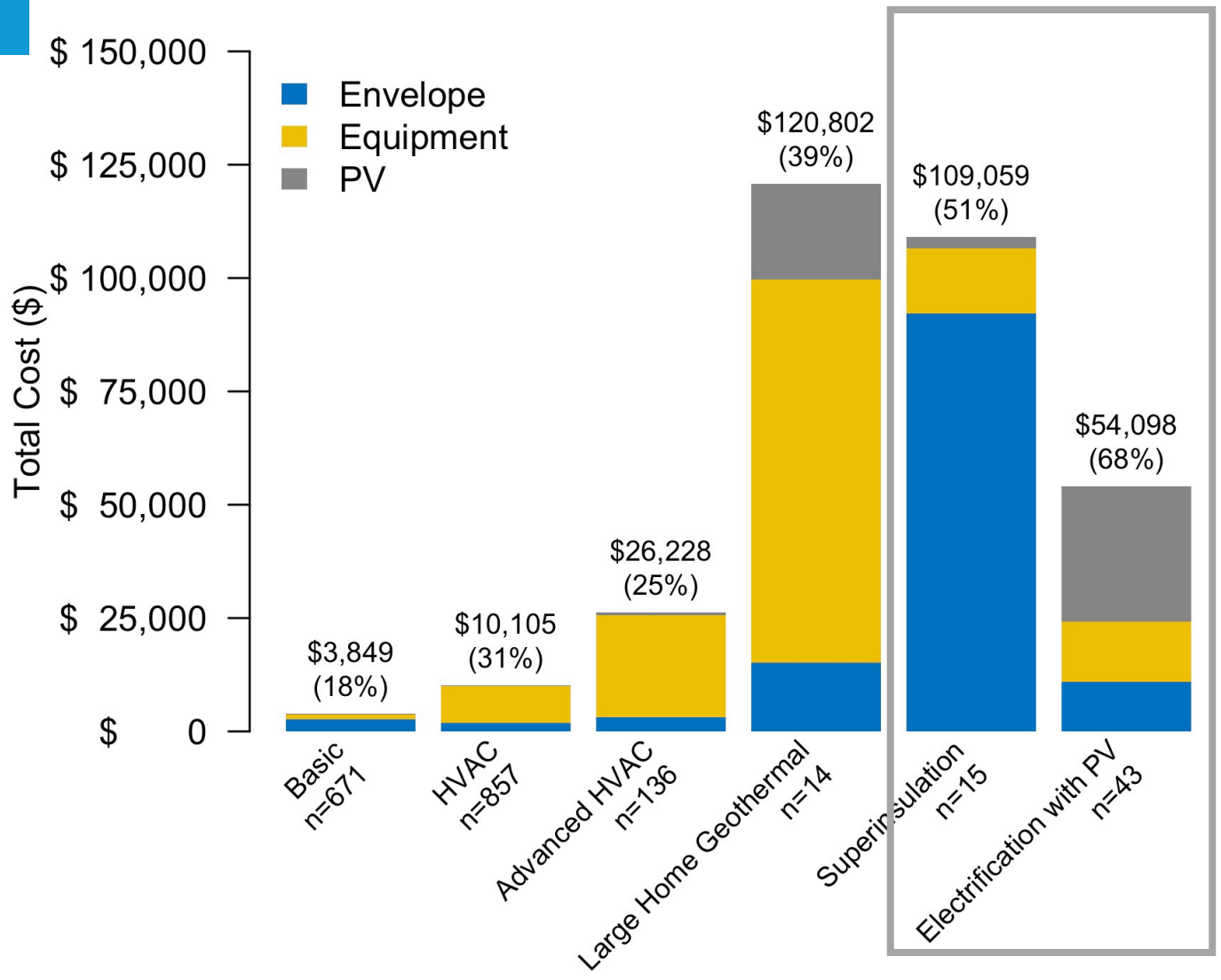

Affordability and Cost Compression

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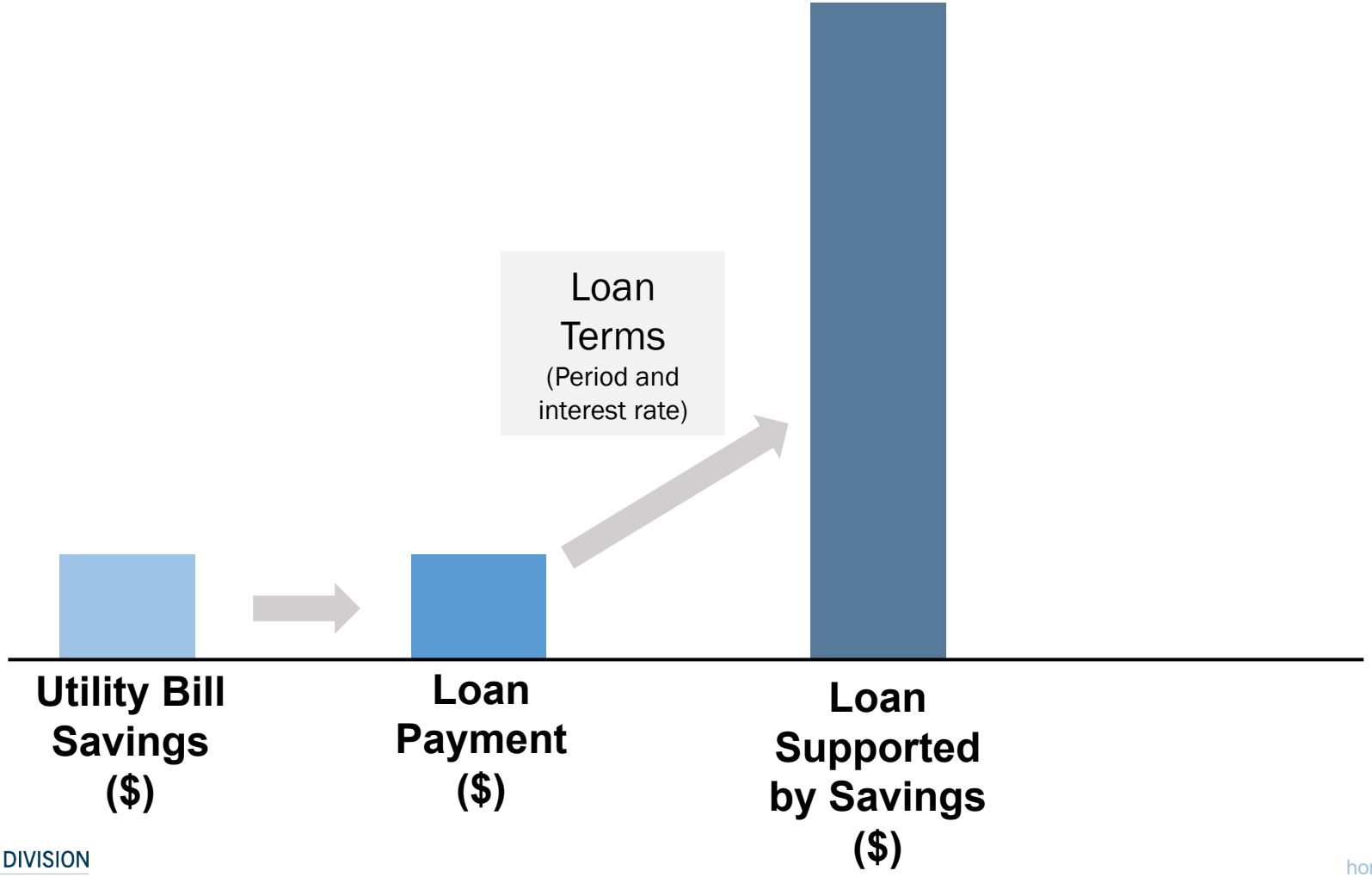

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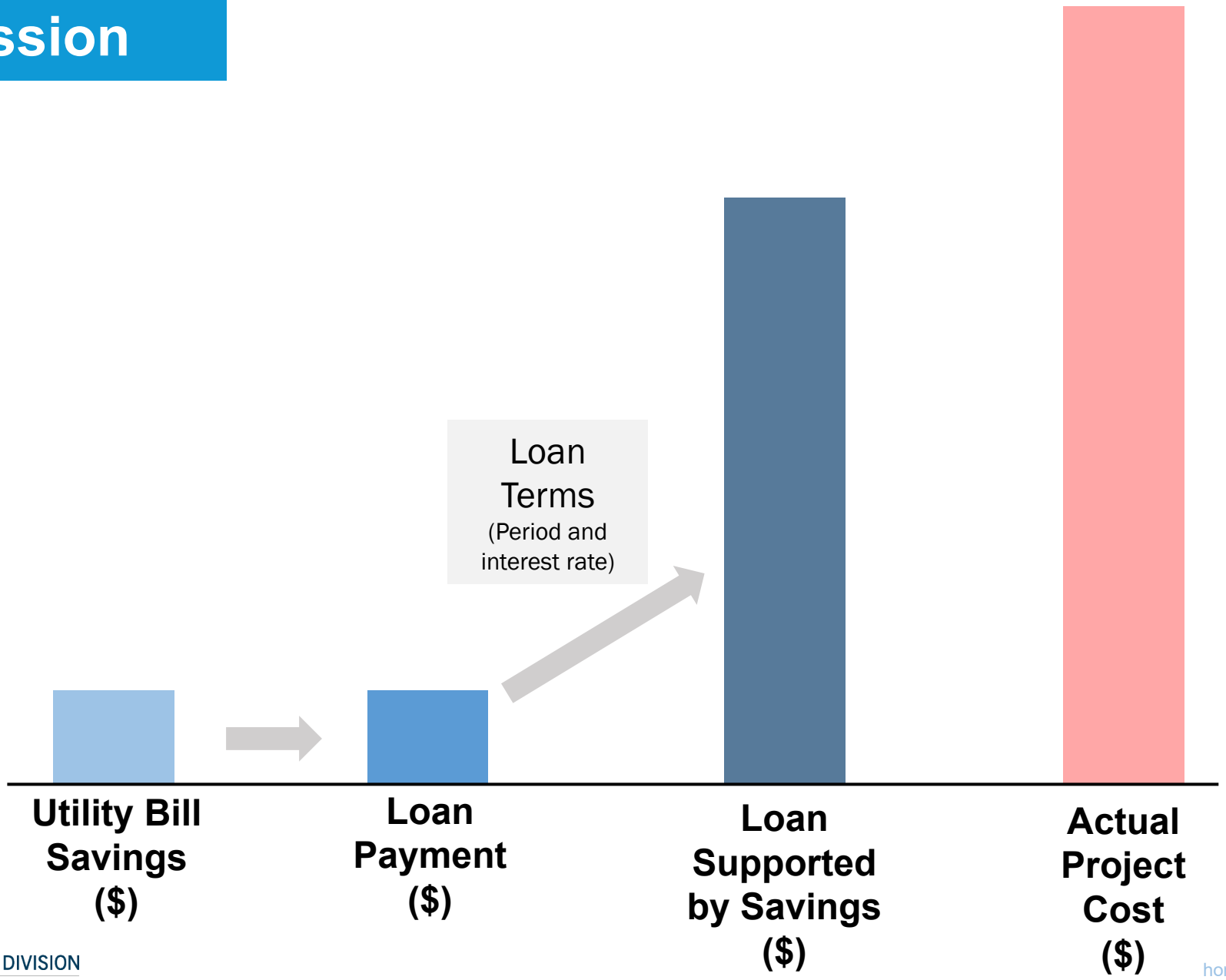

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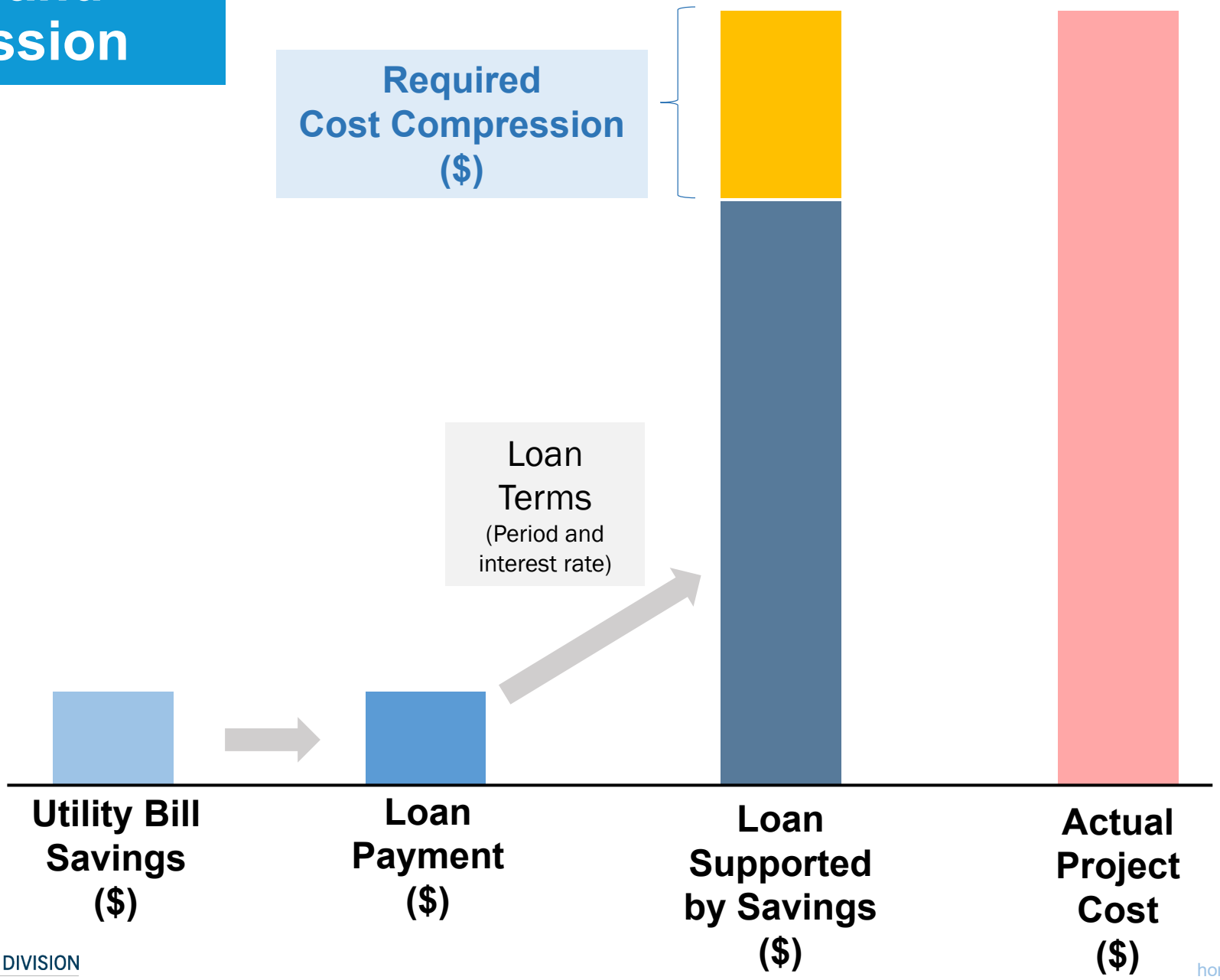
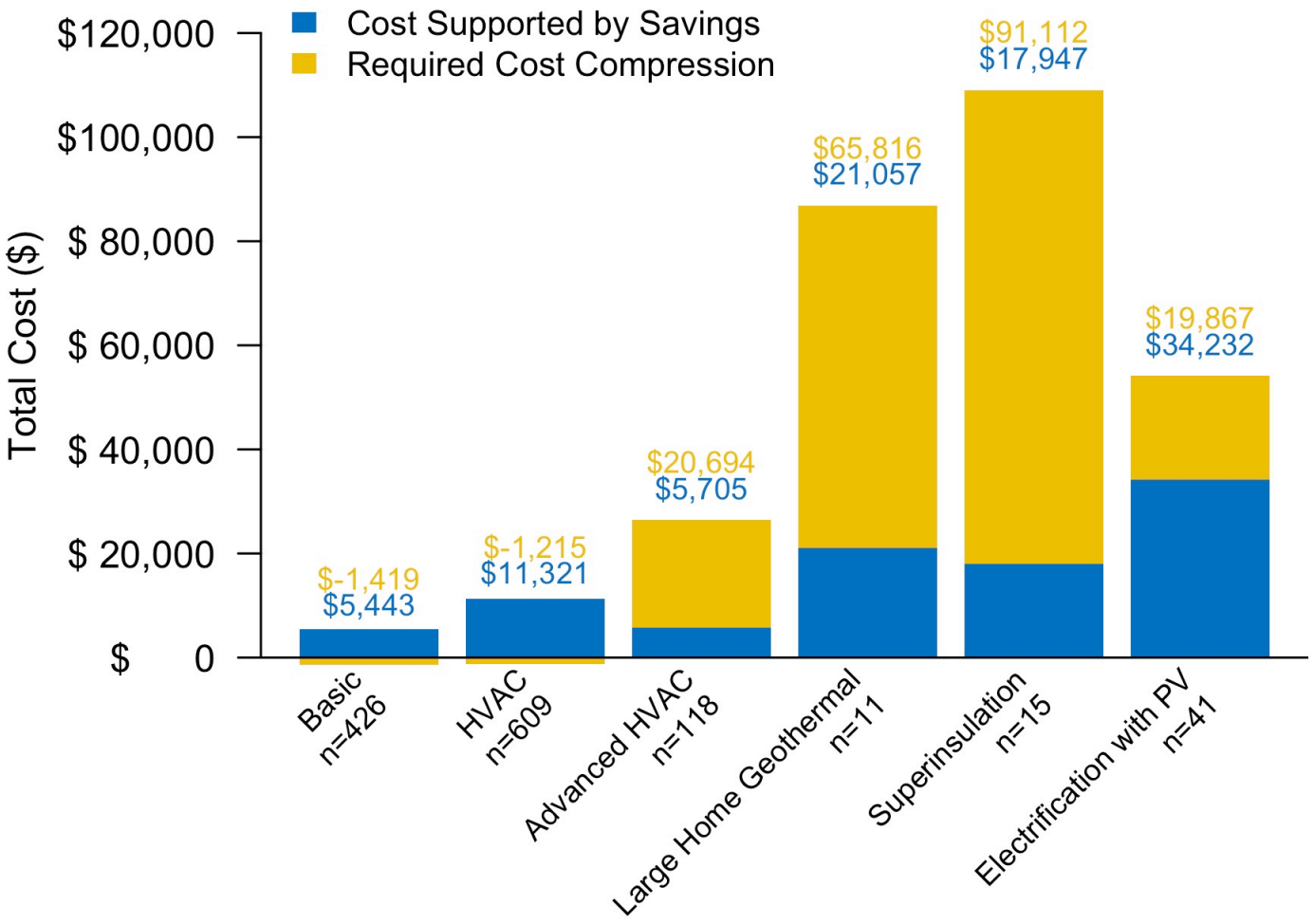
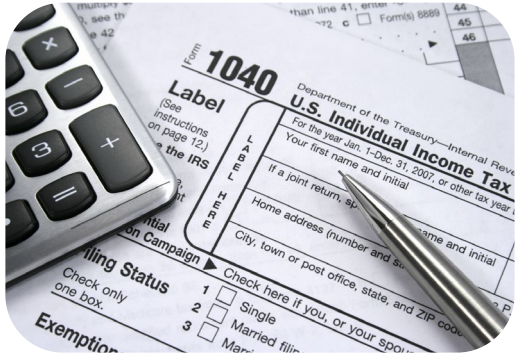


Terms: 30-year, 3% interest

Clustered Projects Cost Compression



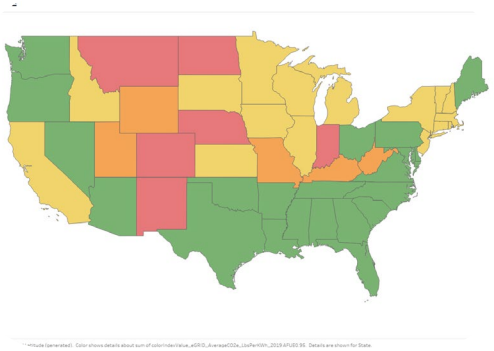
Cost Compression - Pathways



Rebates and Incentives

Technology Innovation

Soft Cost Reductions



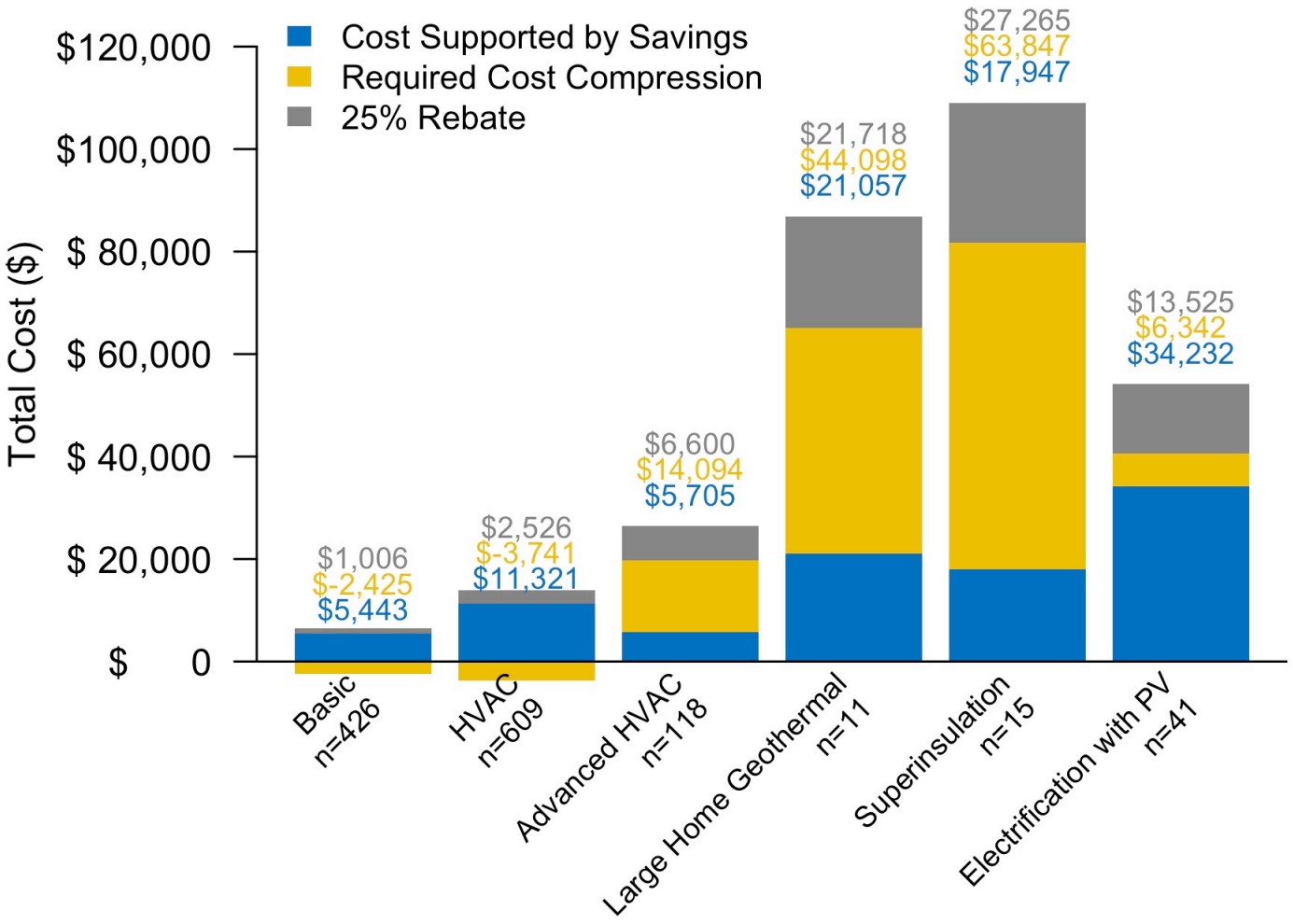
New Metrics

No- and Low-Cost Methods

Cost Compression - Rebates

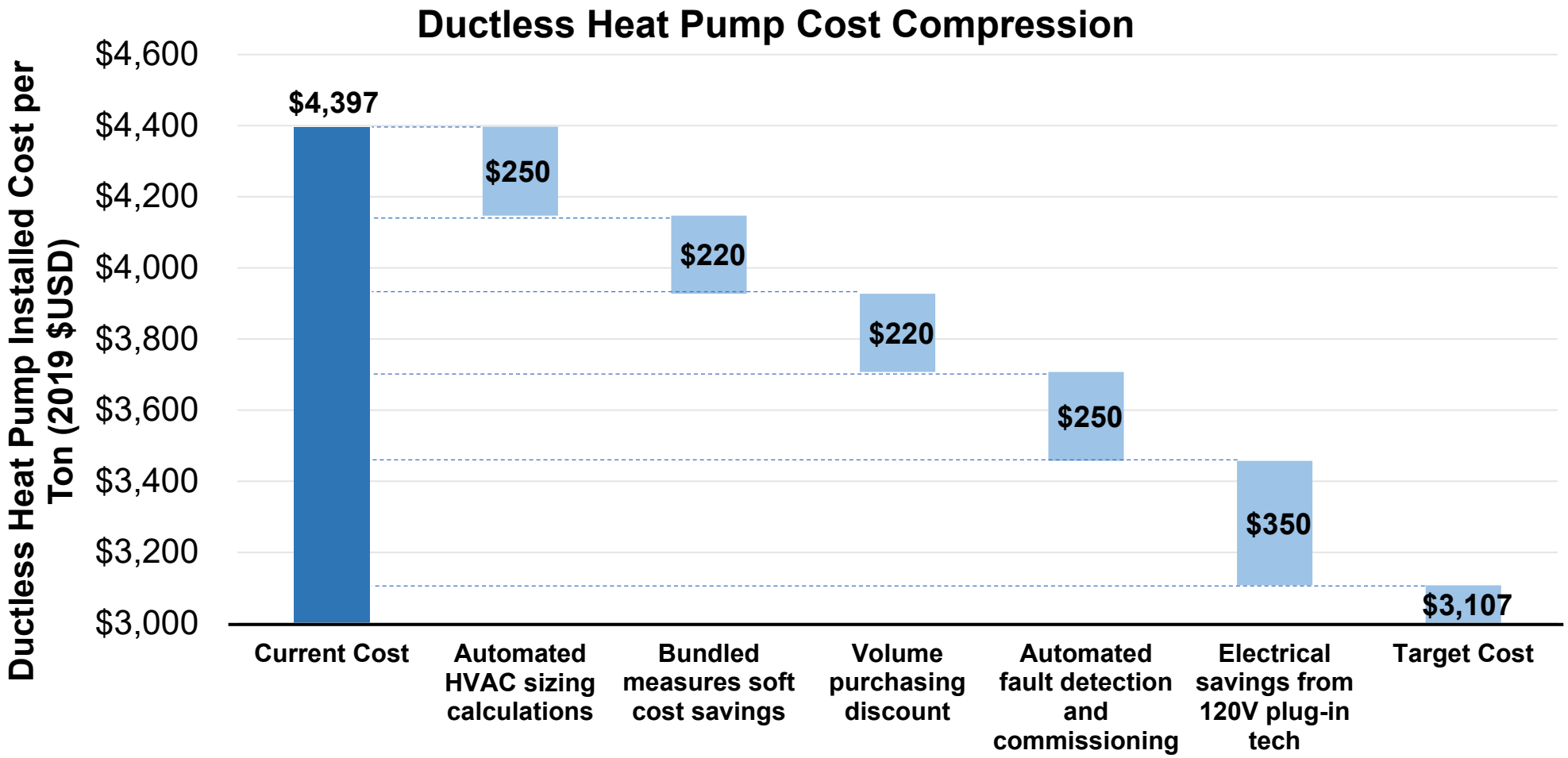
Terms: 30-year, 3% interest

Cost Compression - Rebates

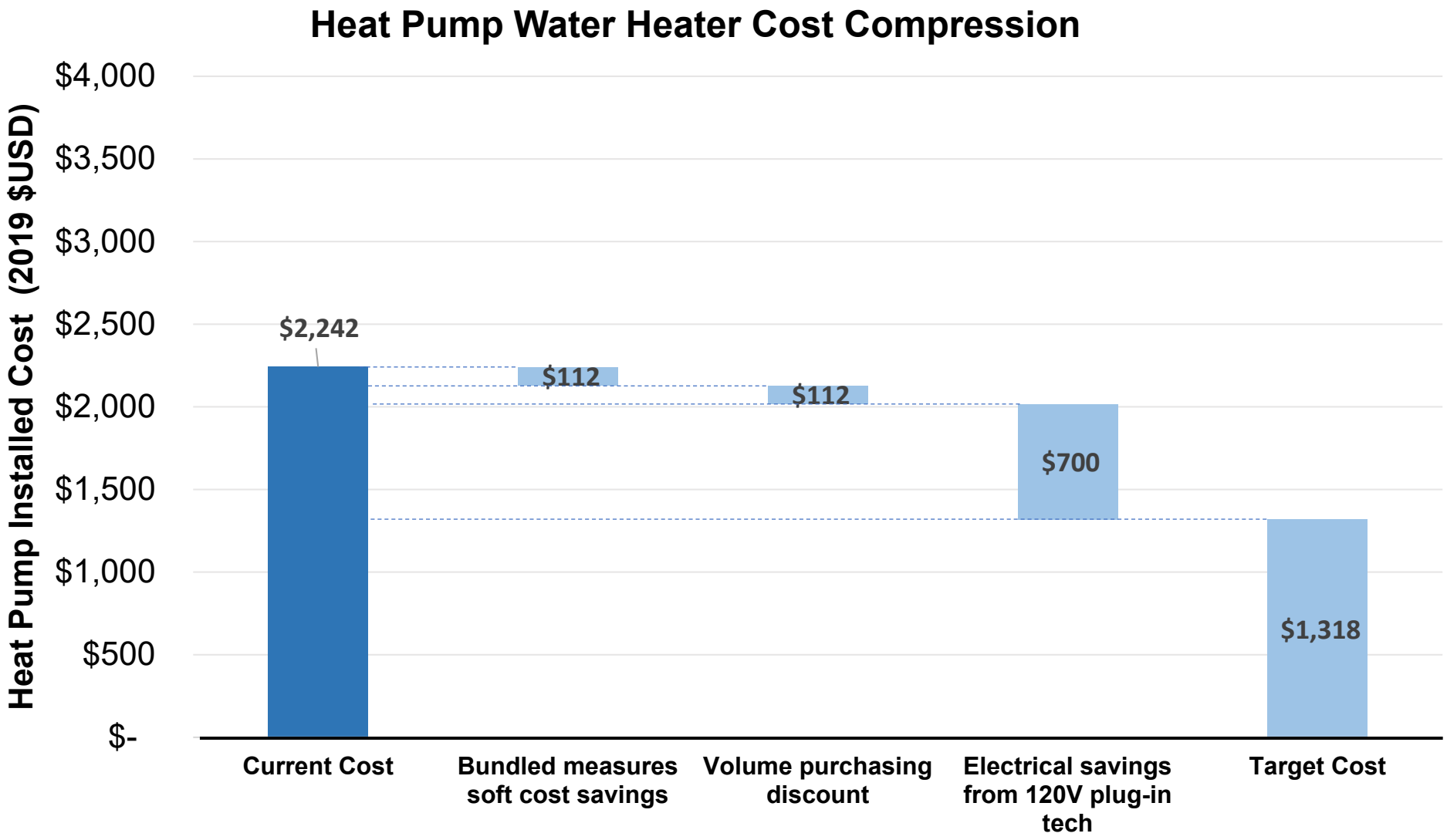


Cost Compression – Technology Innovations

Cost Compression – Ductless Heat Pumps

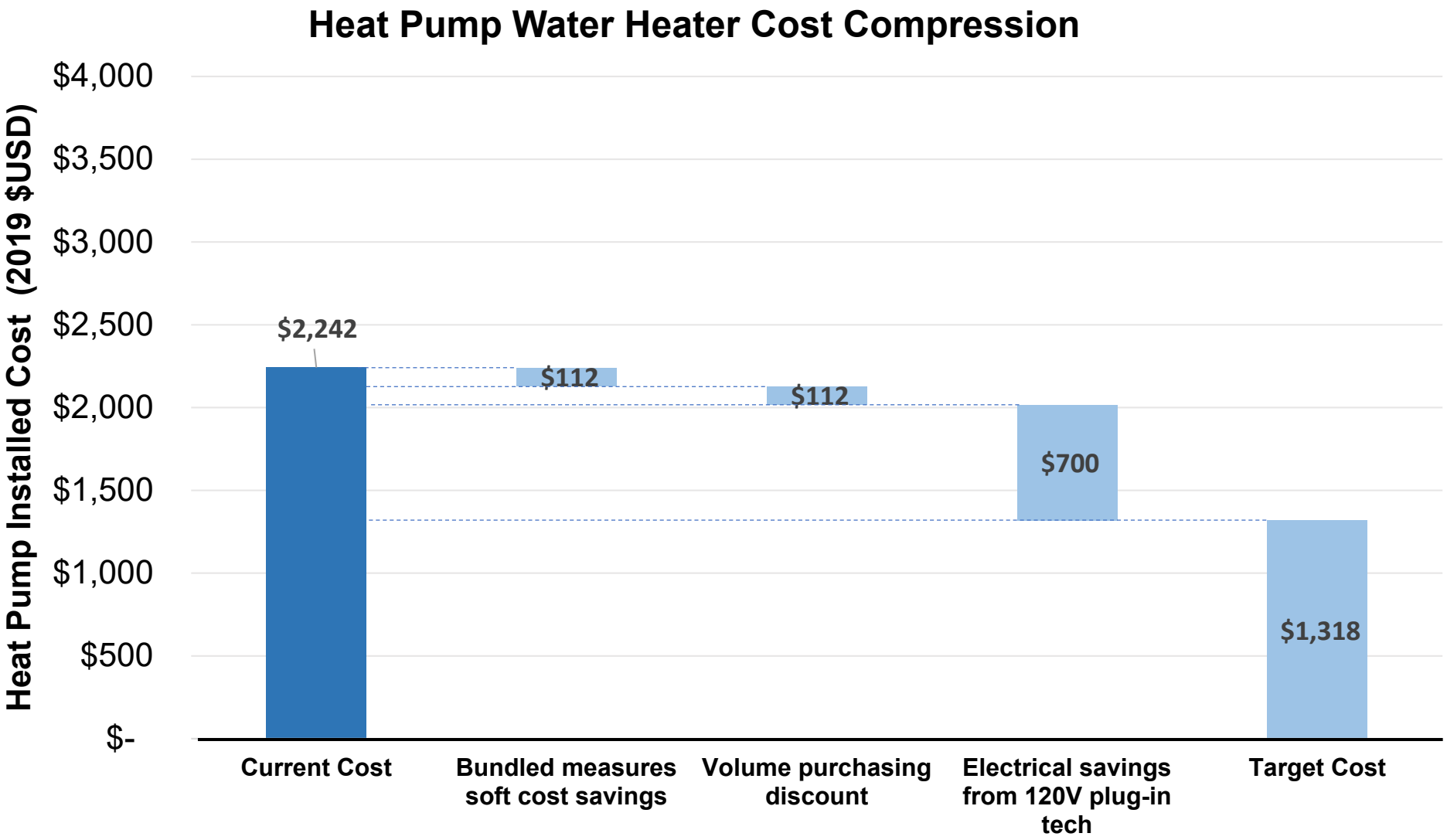


Cost Compression - Heat Pump Water Heater, 50-Gal



Cost Compression - Heat Pump Water Heater, 50-Gal

80-Gal HPWH



Cost Compression - Heat Pump Water Heater, 50-Gal

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Cost Compression – Low Power Electrification

Source - Sean Armstrong, Redwood Energy (2020)

Cost Compression – Low Power Electrification

INNOVATIONS FOR EASIER HOME ELECTRIFICATION

Avoiding panel upgrade/new service/home rewiring costs

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 Volts	Device Amps					Device Amps	Device Volts
		100	Amp Panel				
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 - Sean Armstrong, Redwood Energy (2020)

Cost Compression – Low Power Electrification

INNOVATIONS FOR EASIER HOME ELECTRIFICATION

Avoiding panel upgrade/new service/home rewiring costs

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
		

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Cost Compression – Soft Costs

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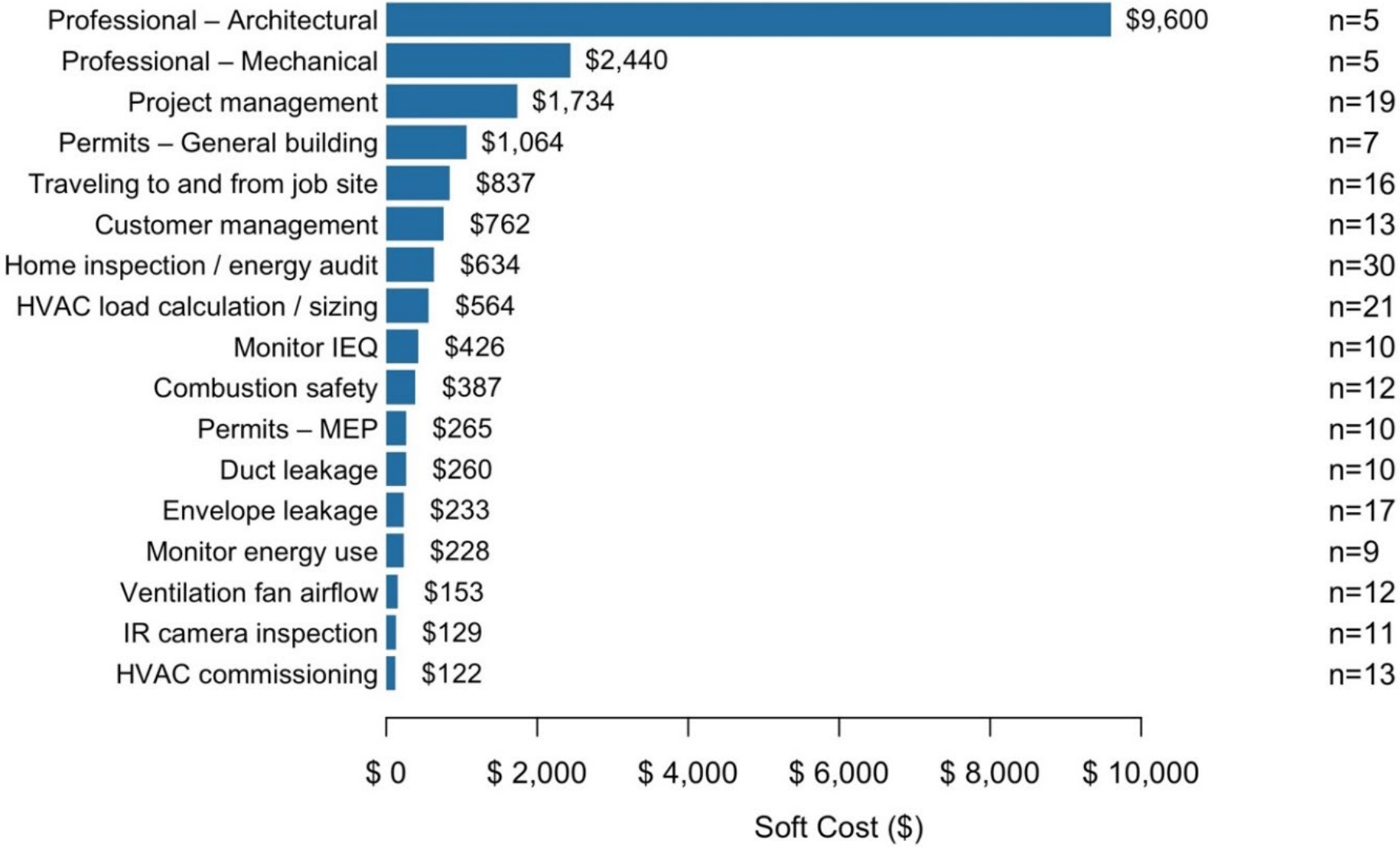
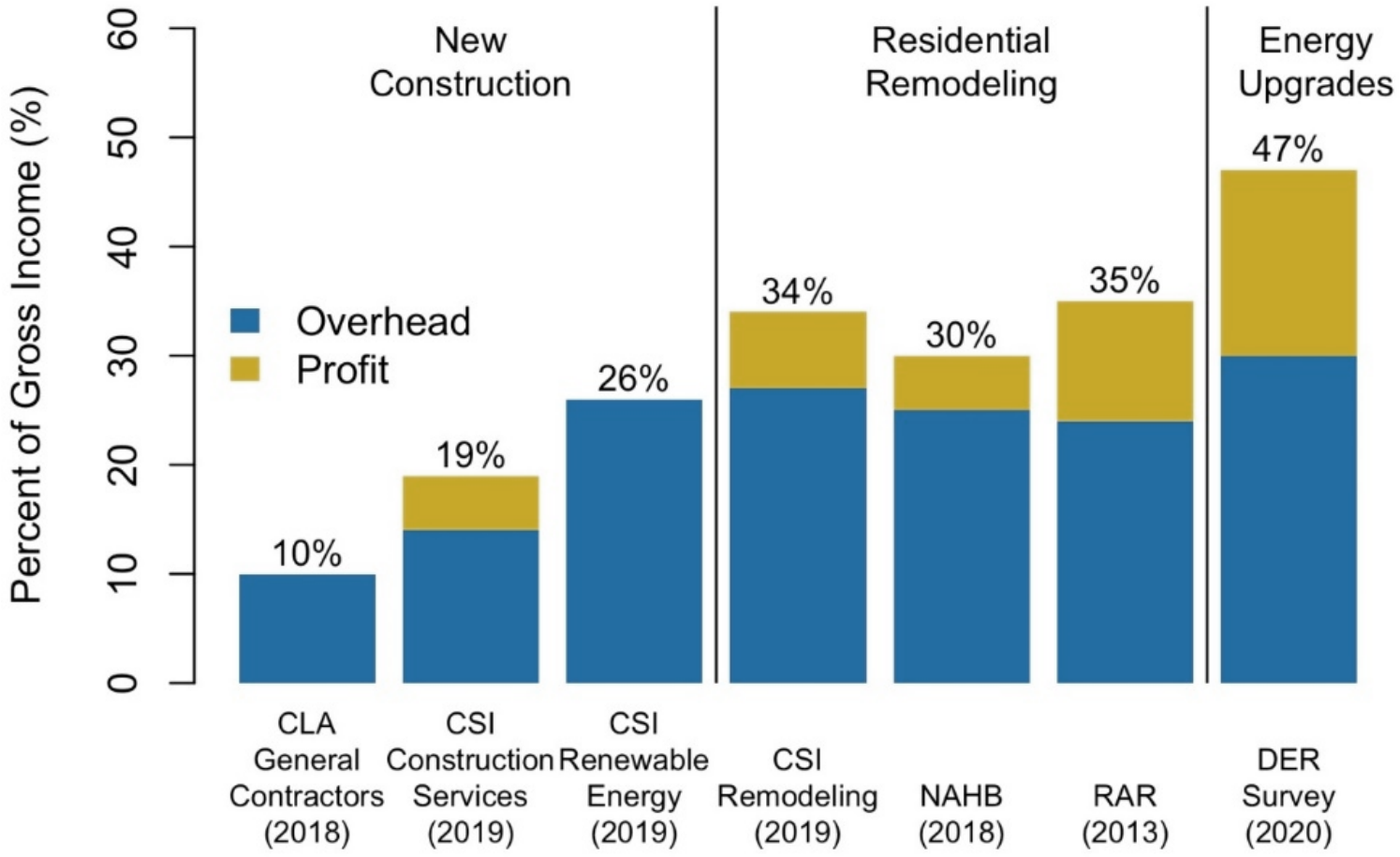


Cost Compression – Soft Costs



Need to reduce Soft Costs:

- Customer acquisition
- Testing
- Program participation
- Load calculations
- Project design

Cost Compression – Soft Costs

	Outsource customer acquisition to programs with marketing and sales expertise	Reduce diagnostic testing and commissioning	Remote approaches to customer acquisition, management and sales	Automated, rapid HVAC equipment sizing
CURRENT	$1,000-2,500 per project	Combustion: $387	Remote audits: 40% cost savings for individual projects	$564
COMPRESSED	$700	$0	60% savings for executed projects	$100

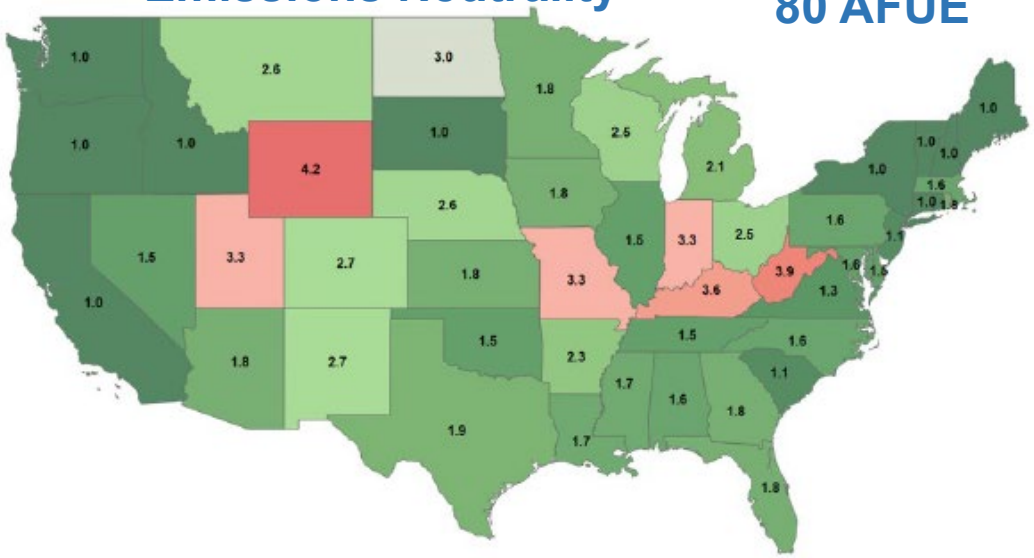
Cost Compression – New Metrics

Using Electric Heat Pumps Instead Of Gas Furnaces

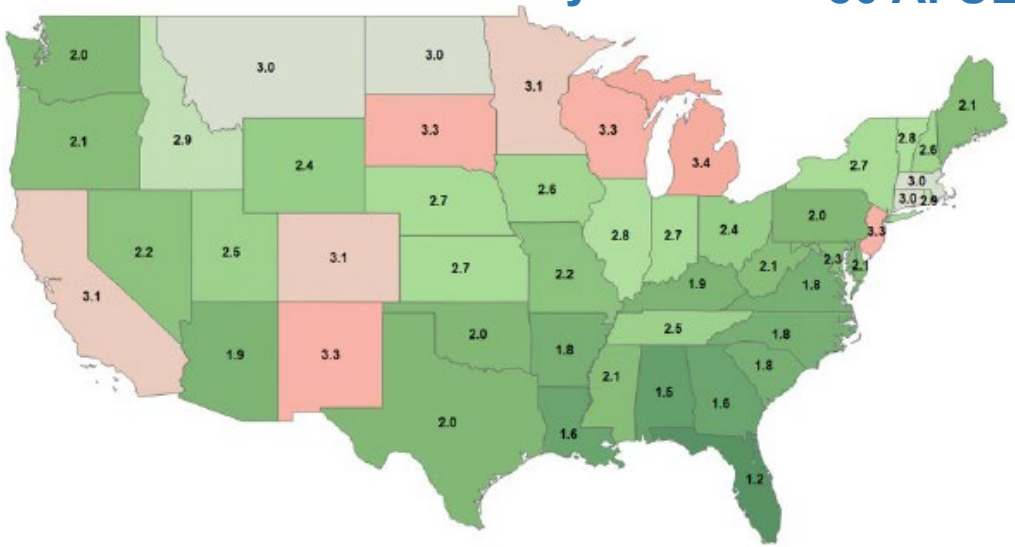
Cost Compression – New Metrics

Using Electric Heat Pumps Instead Of Gas Furnaces

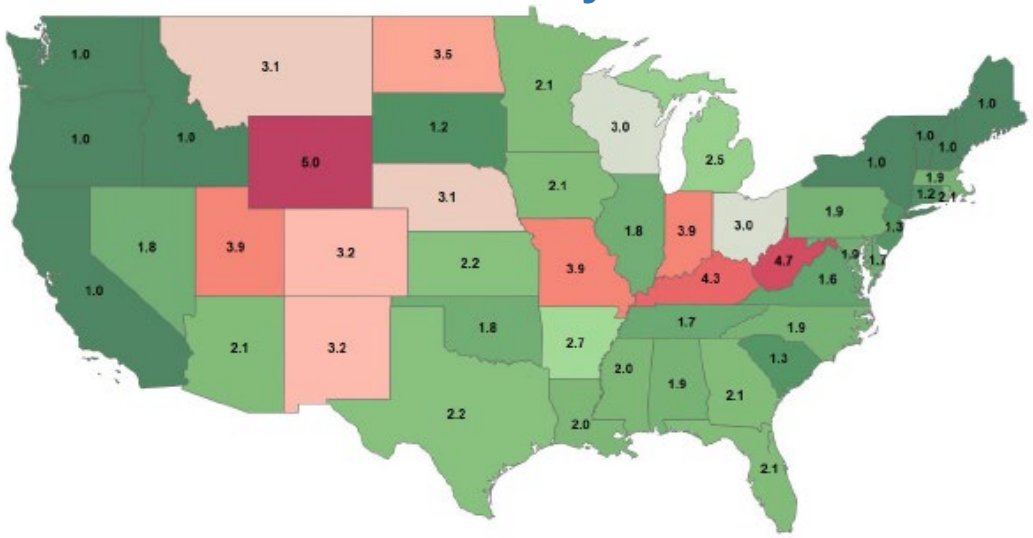
Emissions Neutrality — 80 AFUE



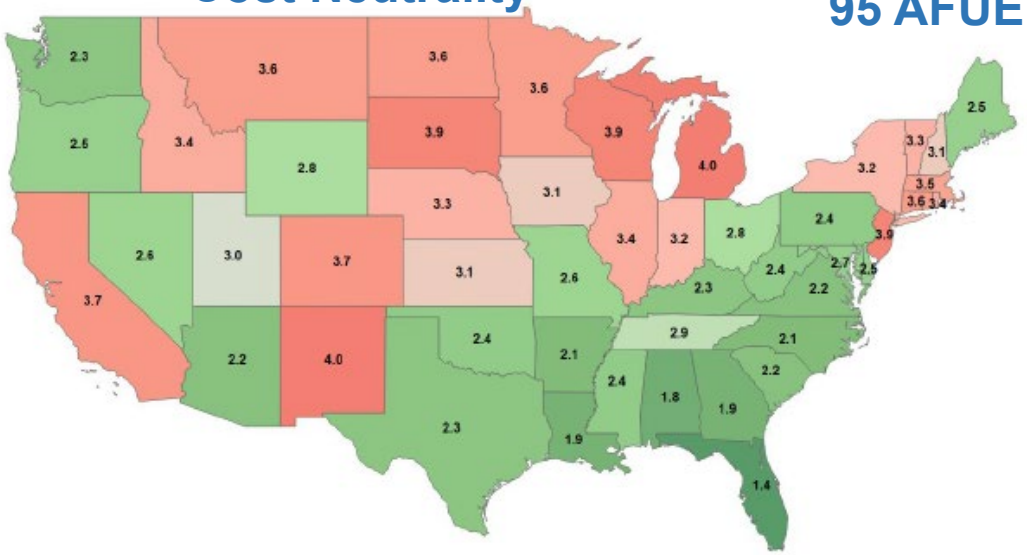
Cost Neutrality — 80 AFUE



Emissions Neutrality — 95 AFUE

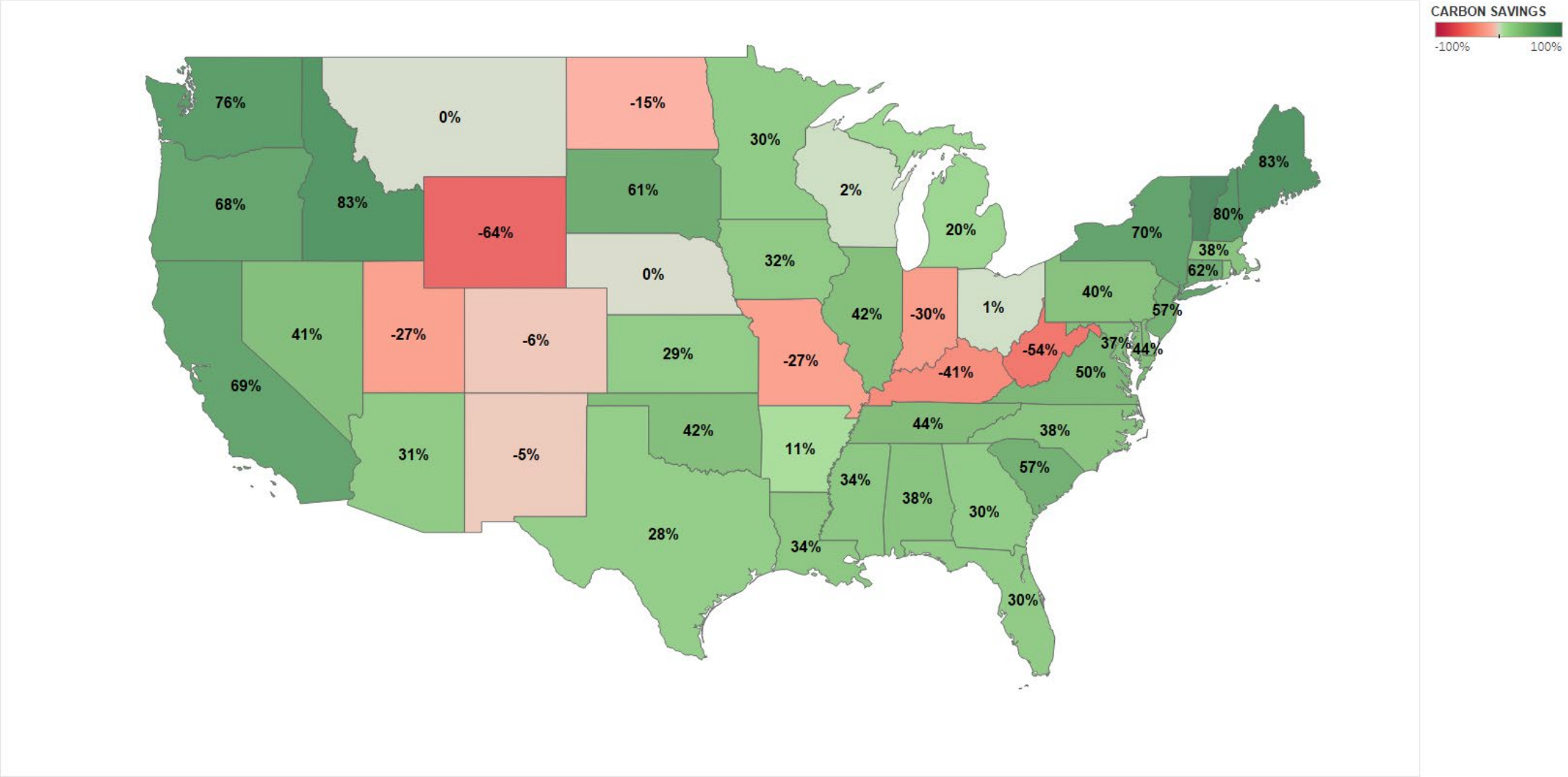


Cost Neutrality — 95 AFUE



Cost Compression – New Metrics
Using Electric Heat Pumps Instead Of Gas Furnaces

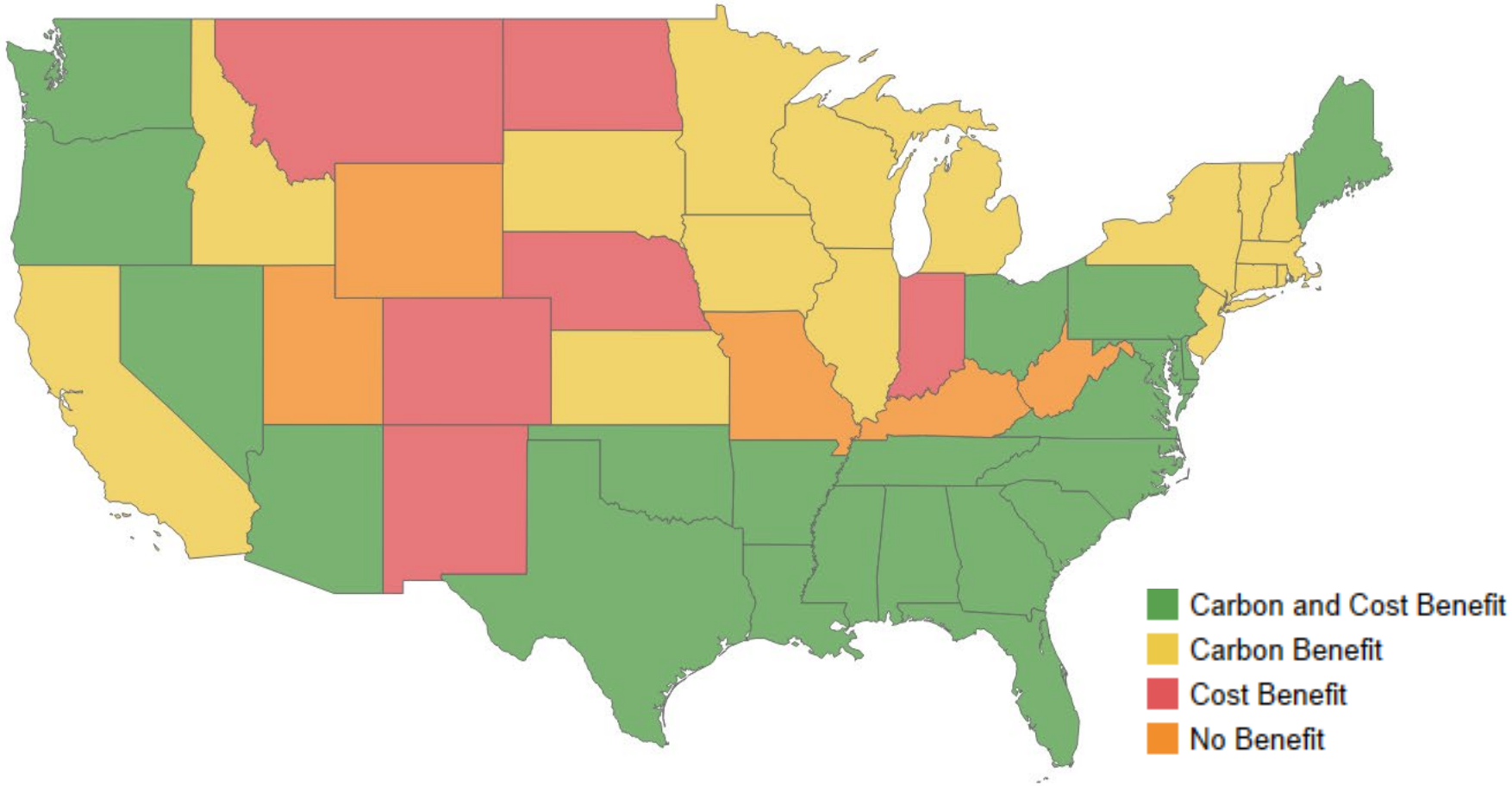
Carbon Savings COP3 with a 95 AFUE



Map based on Longitude (generated) and Latitude (generated). Color shows sum of carbonSavingsCOP3_eGRID_AverageCO2e_LbsPerKWh_2019 AFUE0.95. The marks are labeled by sum of carbonSavingsCOP3_eGRID_AverageCO2e_LbsPerKWh_2019 AFUE0.95. Details are shown for State.

Cost Compression – New Metrics
Using Electric Heat Pumps Instead Of Gas Furnaces

Colour Index 95 AFUE



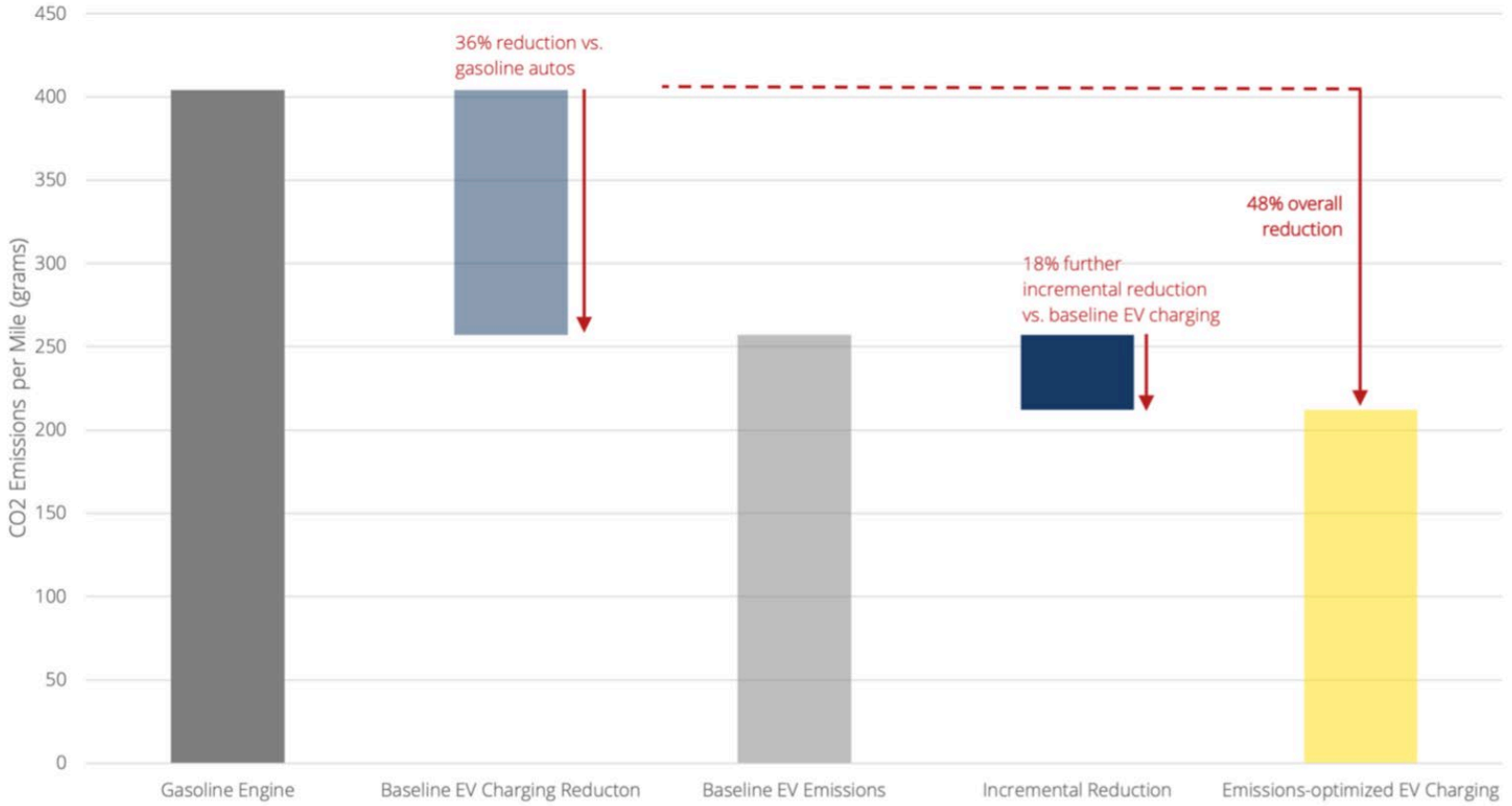
Map based on Longitude (generated) and Latitude (generated). Color shows details about sum of colorIndexValue_eGRID_AverageCO2e_LbsPerKWh_2019 AFUE0.95. Details are shown for State.

Cost Compression – No- and Low-Cost

Automated emission reductions

Cost Compression – No- and Low-Cost
Automated emission reductions

FIGURE ES1
Emissions-optimized EV Charging Waterfall
Average Mileage Scenario - SPP Night



https://www.watttime.org/downloads/how-emissions-optimized-ev-charging-enables-cleaner-electric-vehicles/

What's Next?

- Cost Compression
  - Technology, Soft Costs, Behavior, New Metrics
  - Streamlining/Reducing code and permitting requirements
- Standardized packages of upgrades to simplify decision-making process
- Electrification for Low-Income households
  - Drop-in/Plug-in/DIY approaches
  - Transportable technologies
- Over-come market fears about heat pump performance, higher energy costs, induction cooking
- Document health and IAQ outcomes of electrification
- How to overcome emergency equipment replacement
- Homeowner electrification ambassador programs
- Contractor networks

Resources

- For electrification big picture: **Rewiring America** and **Rewiring Communities**
- For power-restricted homes: **Redwood Energy Pocket Guide**
- Check with your contractor or utility for rebates

Thank You…!

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