



Home Decarbonization Seminar Series

LBNL 2021/2022



BUILDING TECHNOLOGY & URBAN SYSTEMS DIVISION
Energy Technologies Area

Seminar Series Summary

Wednesdays at noon from now through early January

Six sessions (possibly more to come)

Focus on sharing practical experiences

Topics:

- Cost analyses
- Can you DIY home electrification?
- How to Electrify Your Home Without Panel Upgrades
- Planning, Designing and Installing Home Electrification
- Rapid Electrification of Existing Buildings: Problems and Opportunities
- Trials and Tribulations of Home Electrification

LBNL Staff



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Practitioners



Sean Armstrong



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Chris Stratton



Josie Gaillard



Jonathan Wooley



The Cost of Decarbonization and Energy Upgrade Retrofits for US Homes

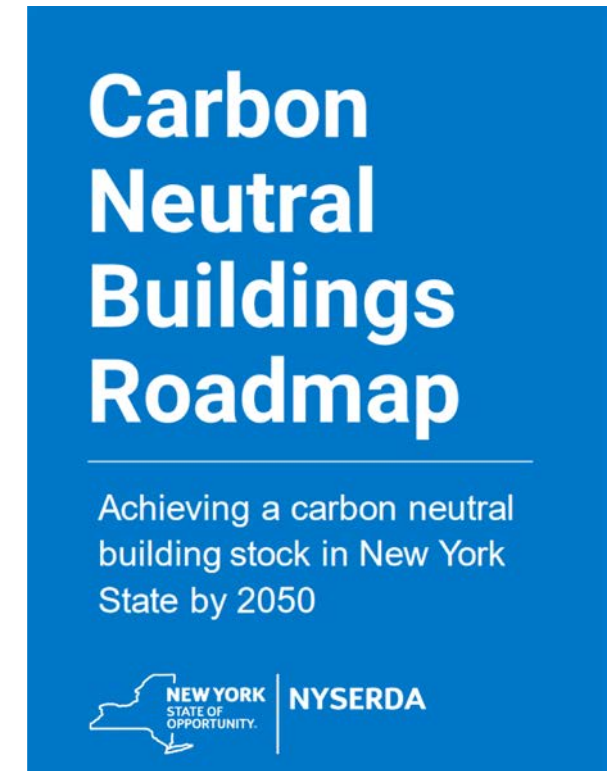
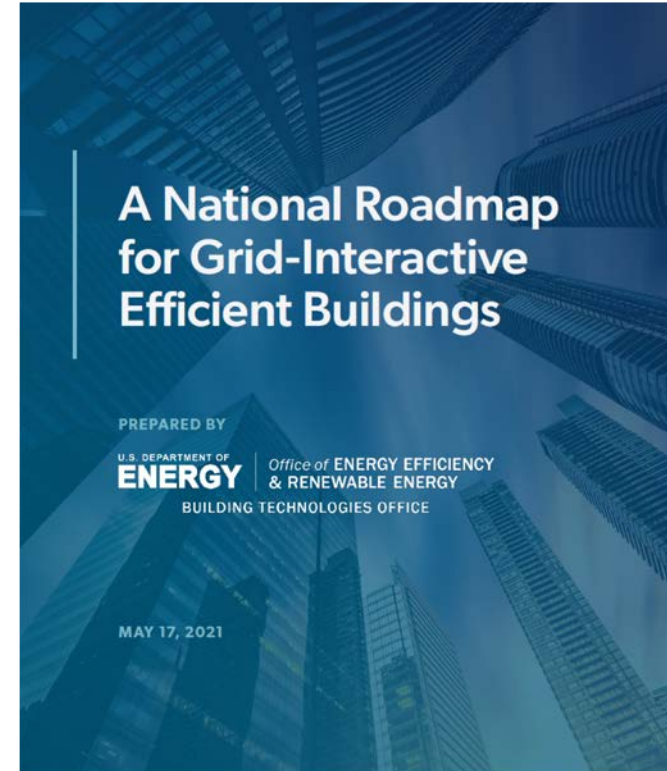
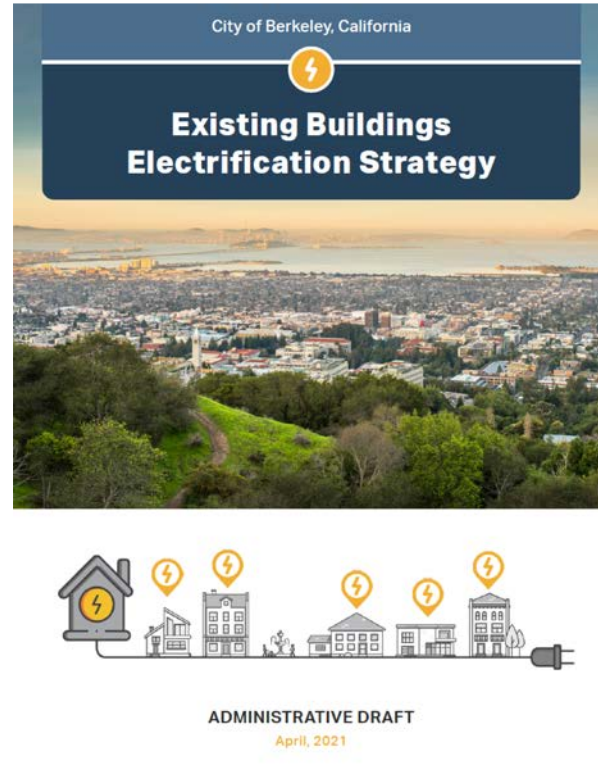
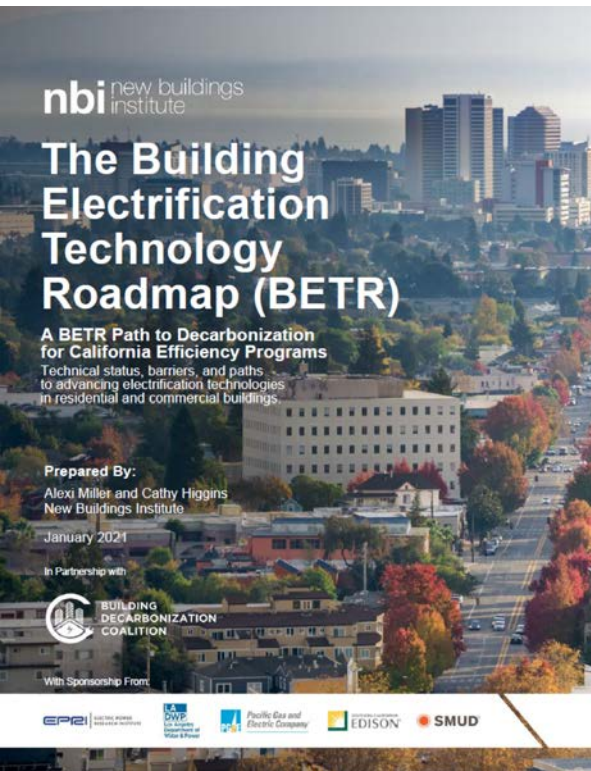
Brennan D. Less, Iain S. Walker, Núria Casquero Modrego

2021-11-17



BUILDING TECHNOLOGY & URBAN SYSTEMS DIVISION
Energy Technologies Area

Emerging Changes in Residential Construction



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

New Policies

100 percent clean policies by state as of April 2020

Action taken at:

- State level
- City/County level
- No action taken

The map displays the following distribution of actions:

- State level (Dark Blue):** Washington, California, Nevada, New Mexico, Wisconsin, New York, Vermont, Connecticut, Rhode Island, Massachusetts, New Jersey, Delaware, Maryland, Virginia, Kentucky, Tennessee, Alabama, Georgia, South Carolina, North Carolina, Florida, Louisiana, Texas, Oklahoma, Kansas, Nebraska, Minnesota, Iowa, Missouri, Arkansas, Mississippi, West Virginia, Pennsylvania, Ohio, Michigan, Indiana, Illinois, Wisconsin, Minnesota, North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Texas, New Mexico, Arizona, Utah, Idaho, Montana, Wyoming, Colorado, New Mexico, Arizona, Utah, Idaho, Montana, Wyoming, Colorado, New Mexico.
- City/County level (Light Blue):** Oregon, Idaho, Utah, Arizona, New Mexico, Texas, Oklahoma, Kansas, Nebraska, Minnesota, Iowa, Missouri, Arkansas, Mississippi, West Virginia, Pennsylvania, Ohio, Michigan, Indiana, Illinois, Wisconsin, Minnesota, North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Texas, New Mexico, Arizona, Utah, Idaho, Montana, Wyoming, Colorado, New Mexico.
- No action taken (Gray):** Montana, Wyoming, Colorado, New Mexico, Arizona, Utah, Idaho, Montana, Wyoming, Colorado, New Mexico.

Legend:

- State level
- City/County level
- No action taken

Map controls: + -

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>



Three Principles for Home Decarbonization

Principle #1: We can't efficiency our way to zero emissions

Principle #2: Homes will have to be electrified

Principle #3: Solutions need to be affordable

Customer Motivations

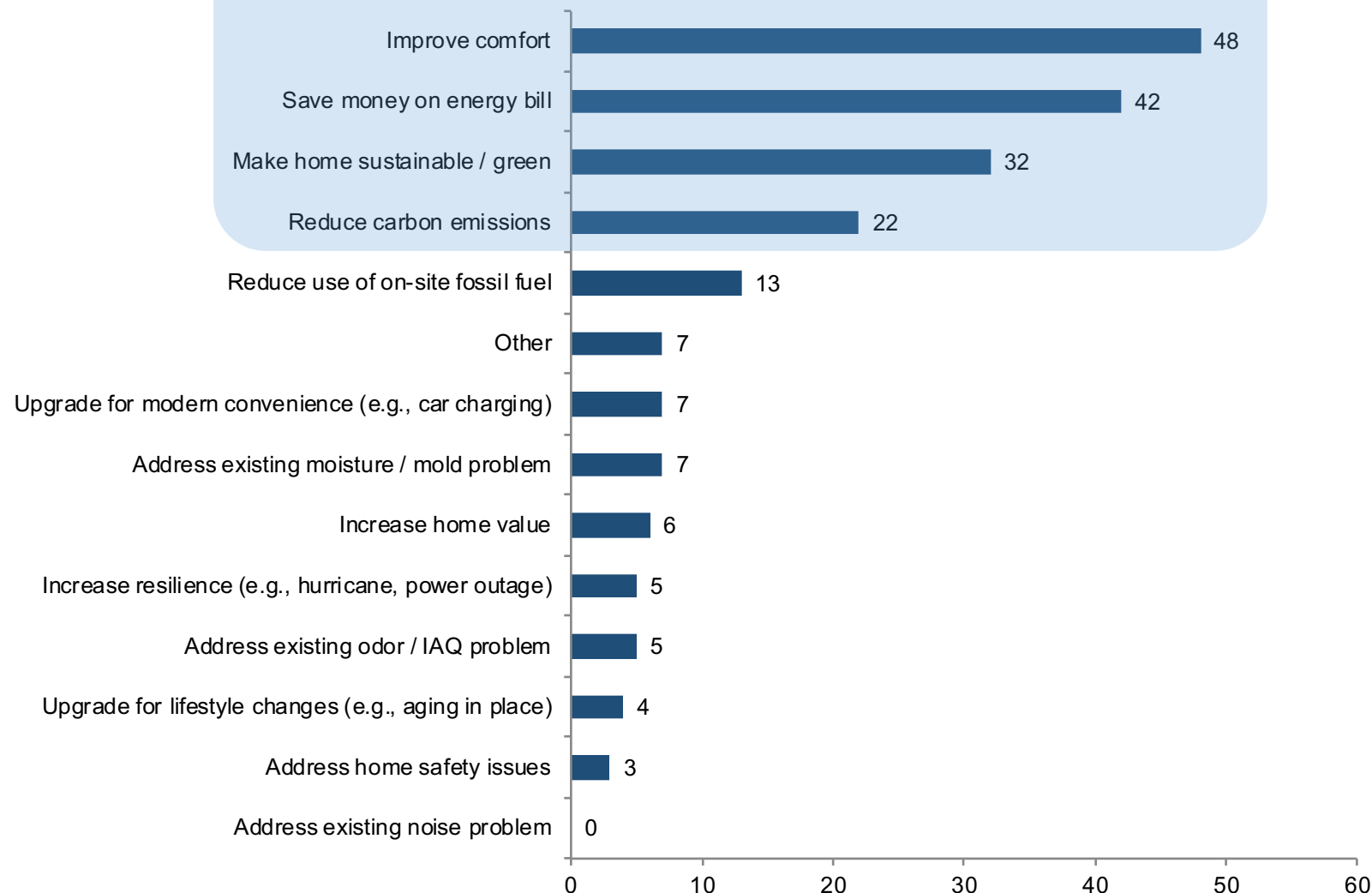
Residential <> Commercial

Profit is not the motive

ROI, payback and other traditional investment metrics are misleading and the wrong ones to use

“Affordability” and financing are key

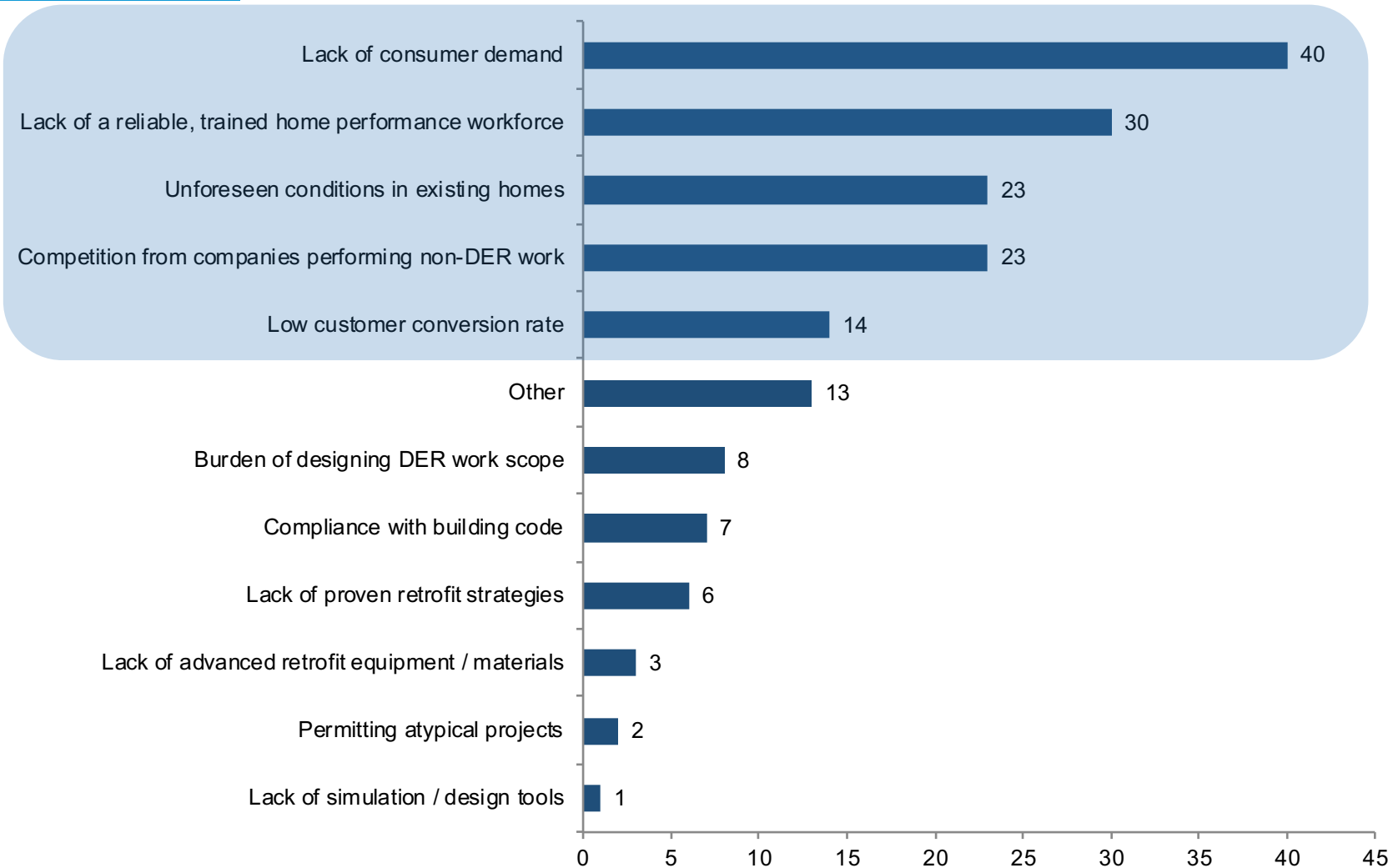
What are the main motivations of homeowners / building owners when seeking to perform a energy upgrade project?



Industry Perspective

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

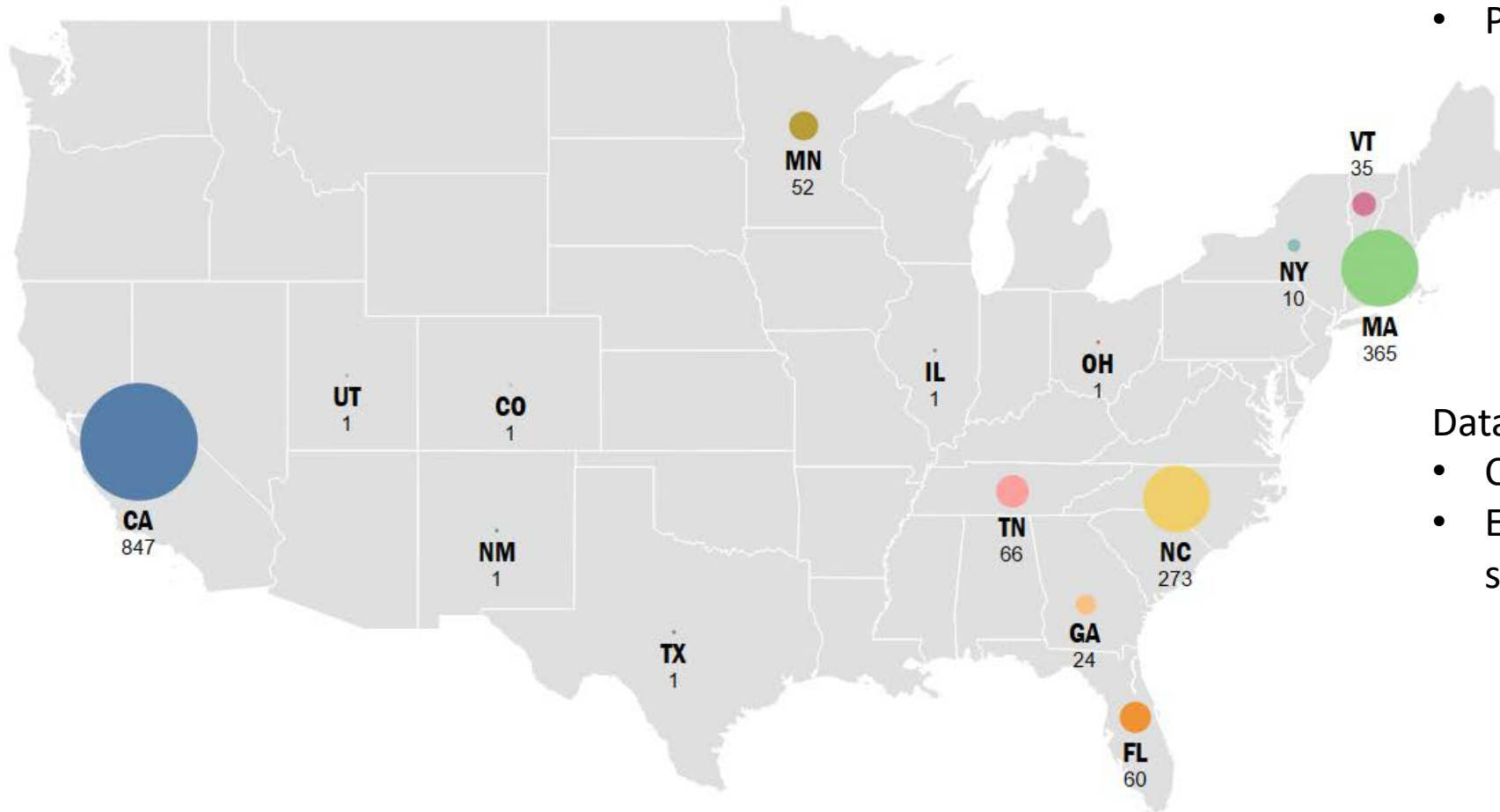
While we focus on costs today important to note other important factors to get to scale



Deep Retrofit Database Summary

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 CO₂) savings

12 Programs

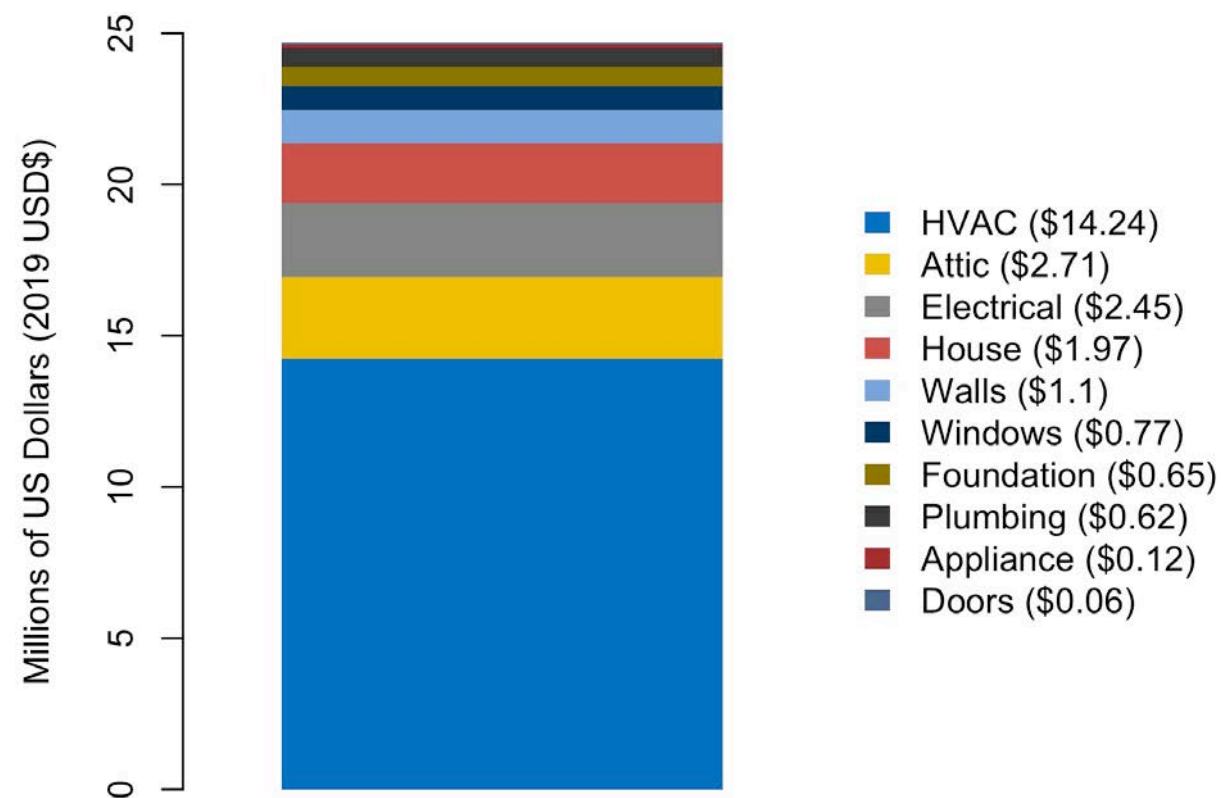
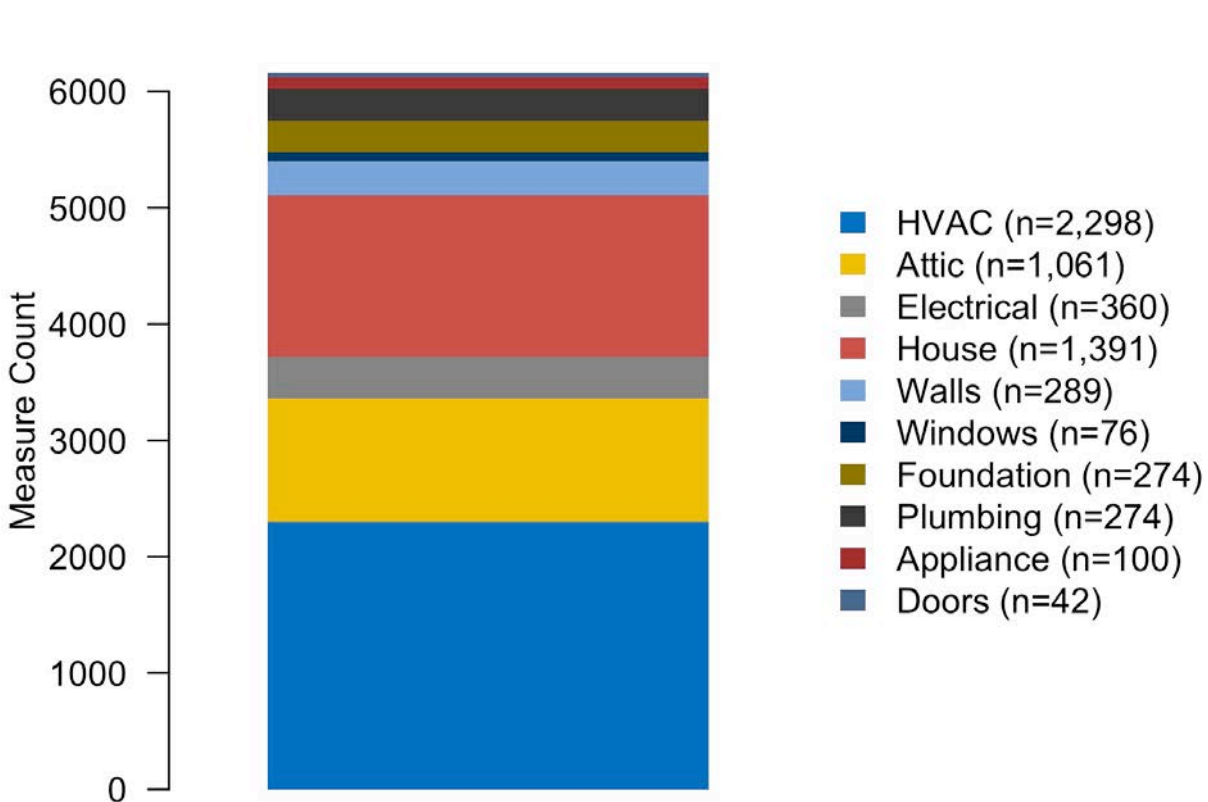
1,739 Projects

10,512 Measures

3,294,946 ft²

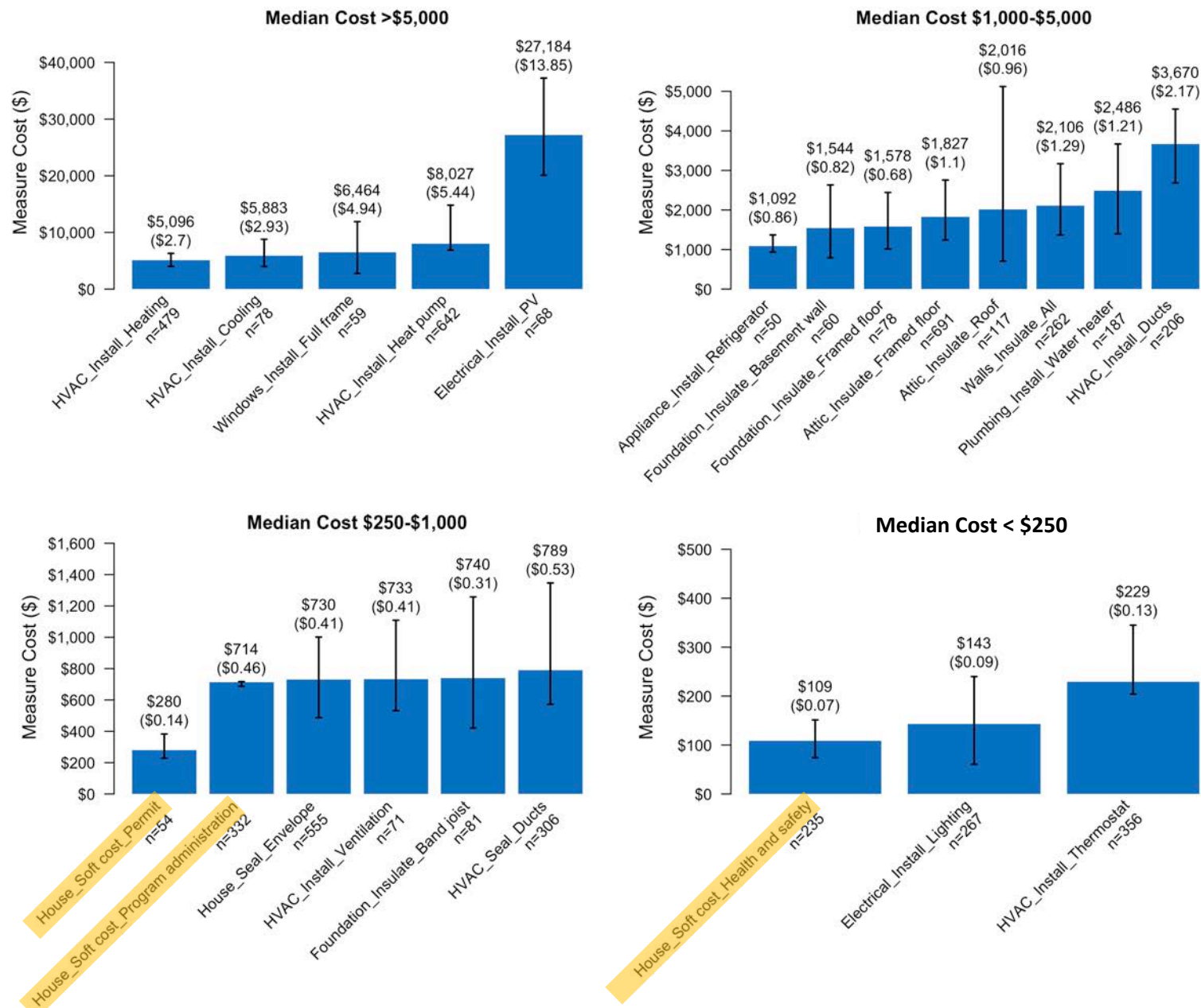
\$24,689,213

Measure Breakdown



Costs of Most Frequent Upgrade Measures

Median Total Cost (\$ per ft²)

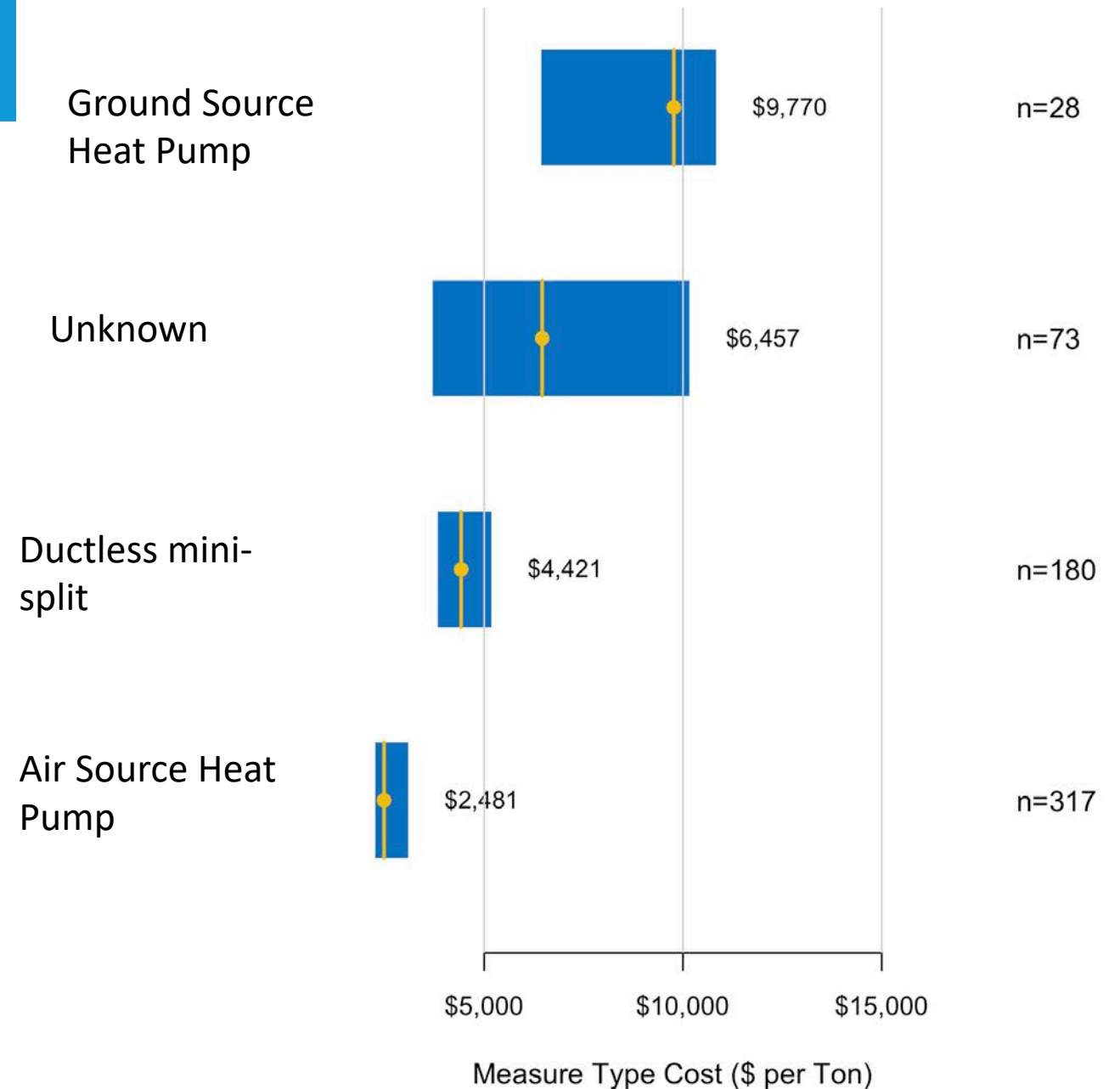


Heat Pump Costs

Some measures broken down by size, for example, heat pump costs per ton

This allows tradeoffs e.g., Balance cost of envelope load reduction with reduced heat pump cost

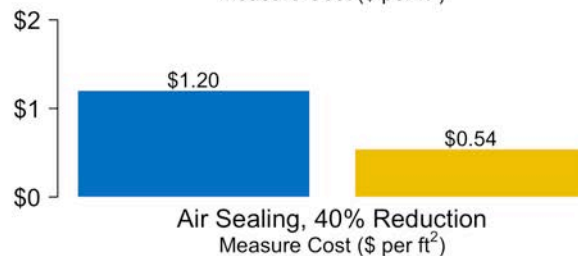
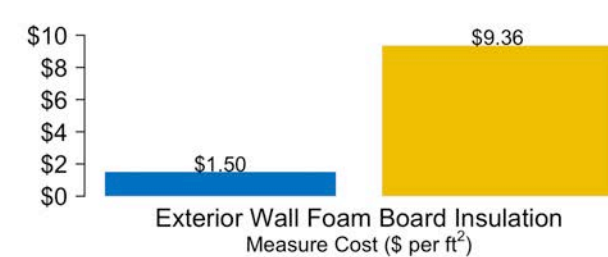
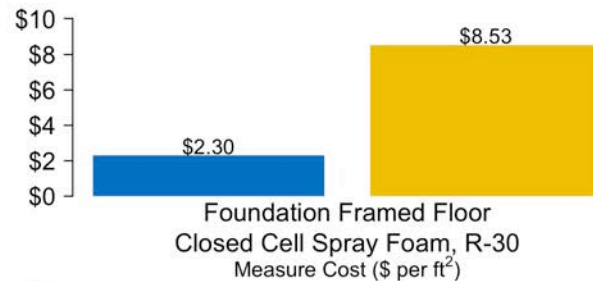
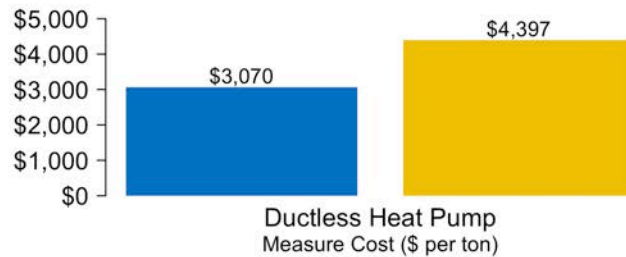
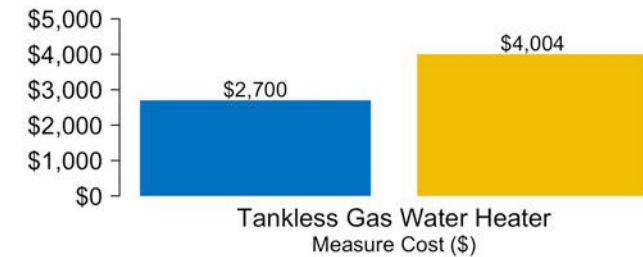
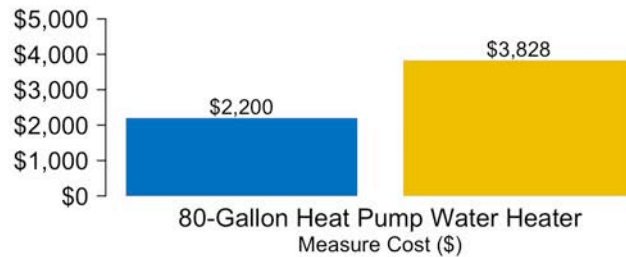
Heat Pump installation costs per ton



Comparing Median Measure Costs Against NREL EMDb

Most reported costs
higher than NREL
database

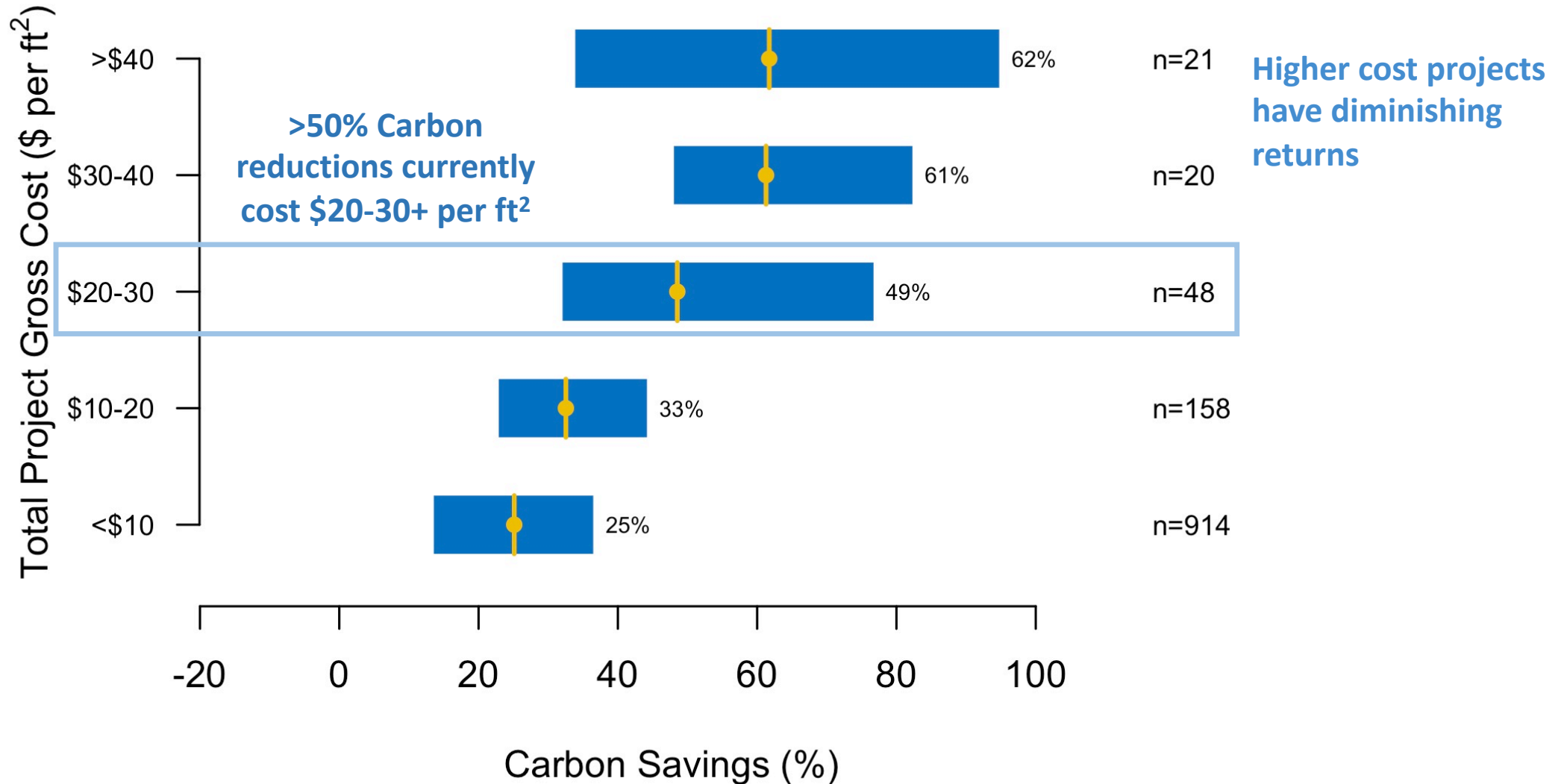
LBNL & NREL
collaborating to
update NREL
database



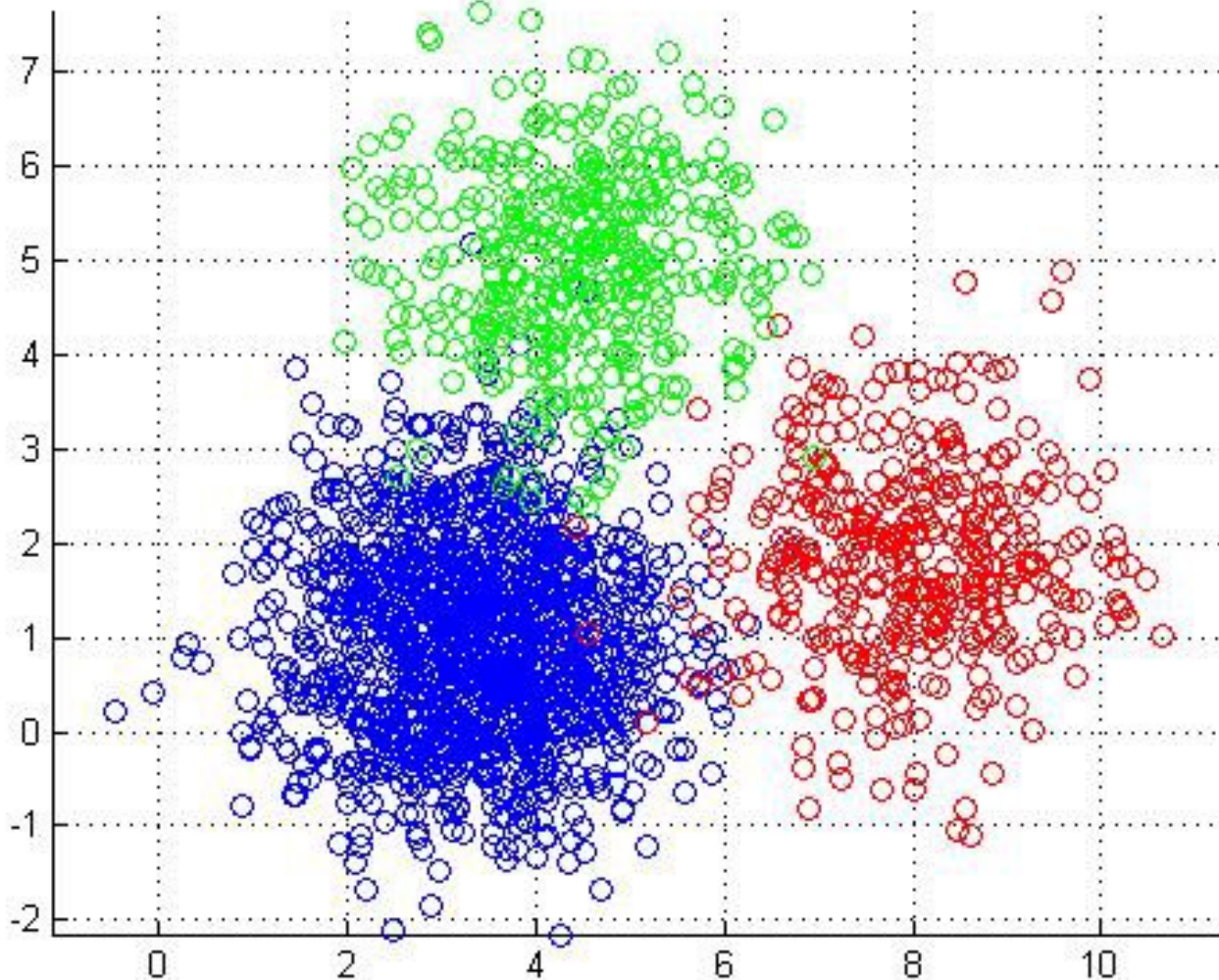
■ NREL Measure Database
■ LBNL Database

Project Cost vs. Carbon Savings

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



Clustering Project Types

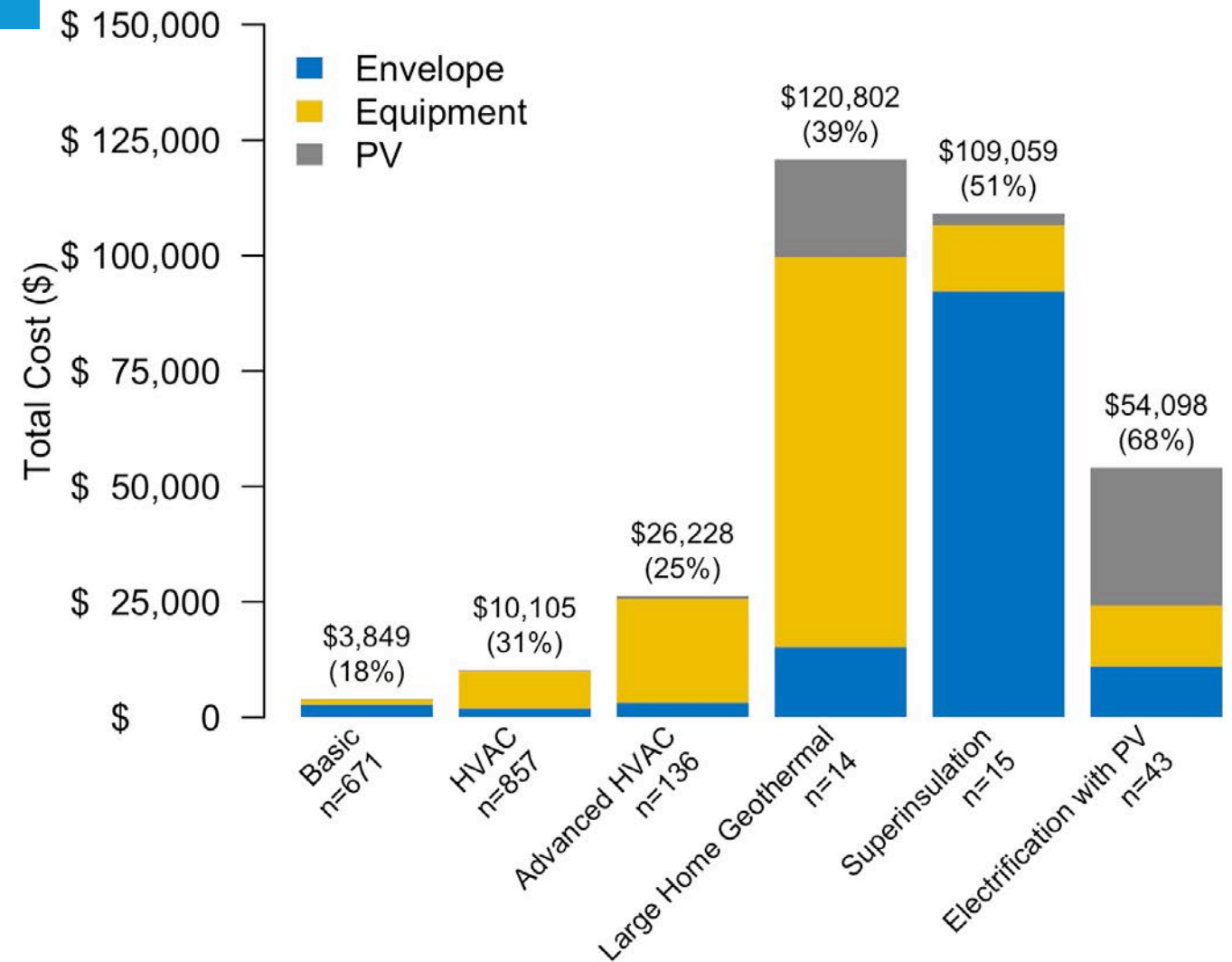


Unsupervised **Machine Learning** approach that groups similar objects such that the objects in the same group are more similar to each other than to objects in the other groups.

Upgrade projects were clustered based on total project costs.

Clustered Project Cost Stacks

\$ - Total Cost
(% - CO₂e reduction)

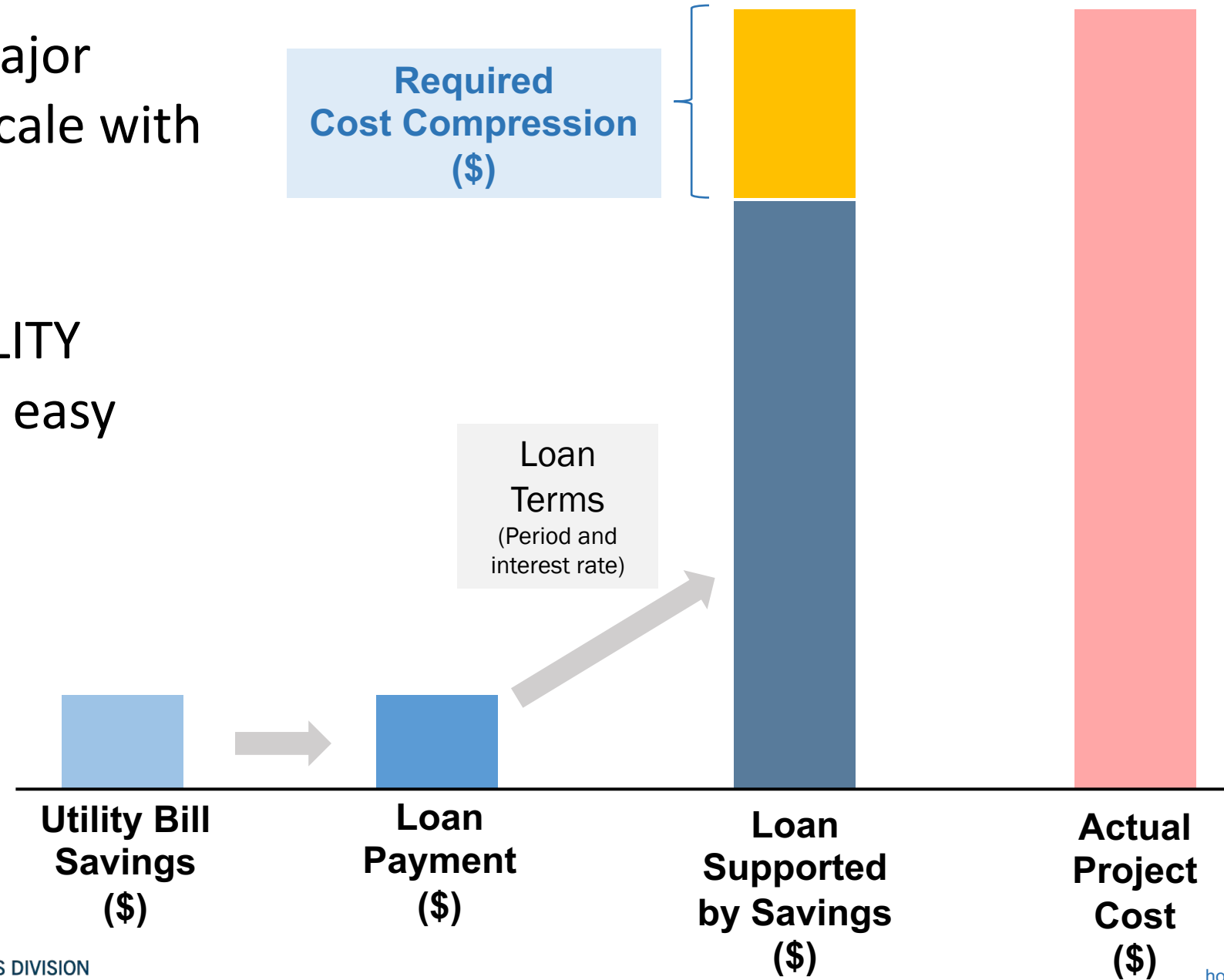


Affordability, Cash Flow and Cost Compression – Schematic

Upfront costs are a major barrier to getting to scale with decarbonization

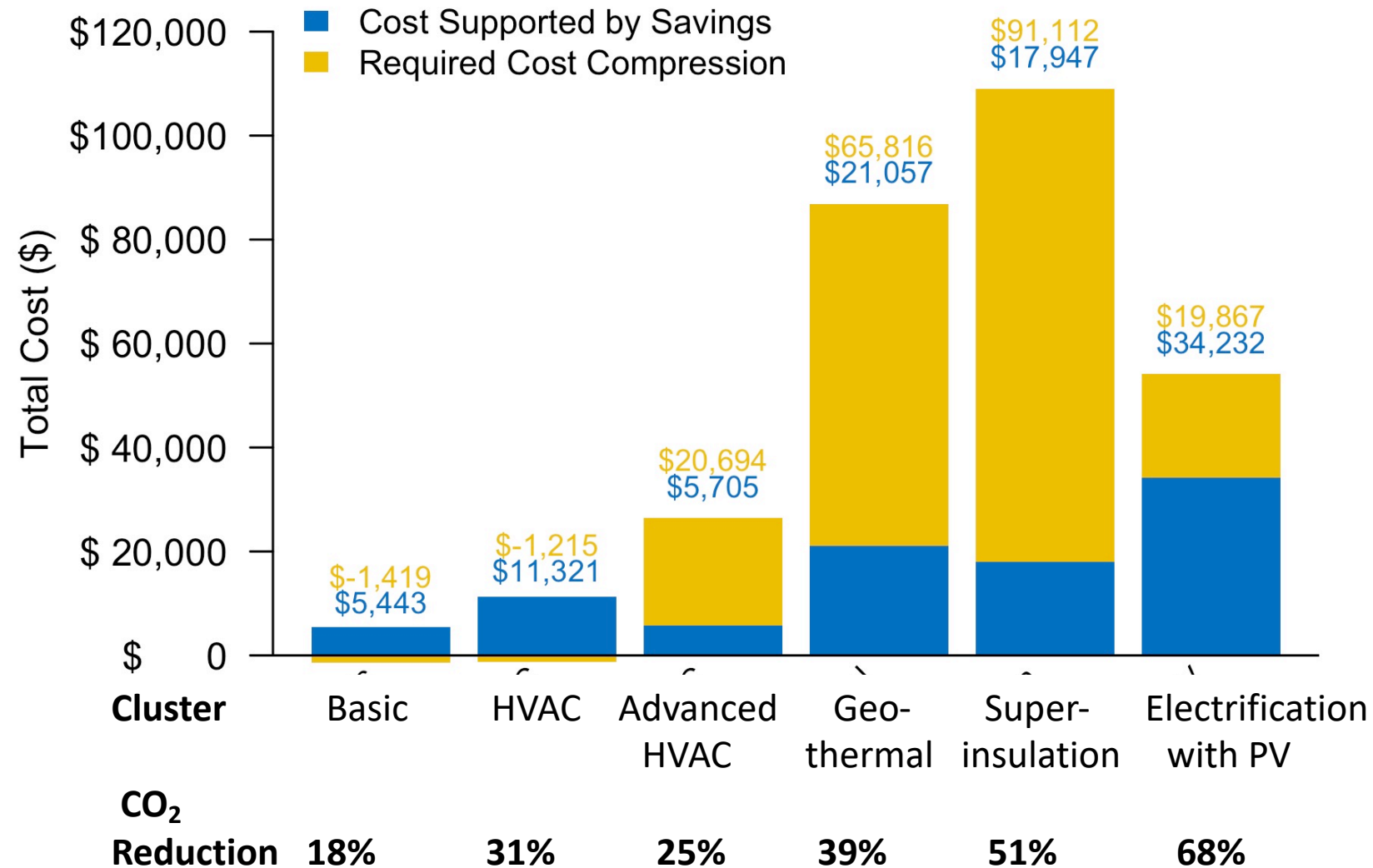
Focus on AFFORDABILITY

- Requires access to easy financing

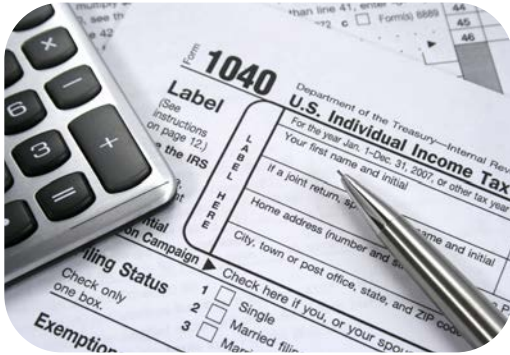


Clustered Projects: Required Cost Compression

Terms: 30-year, 3% interest



Cost Compression - Pathways



Rebates and
Incentives



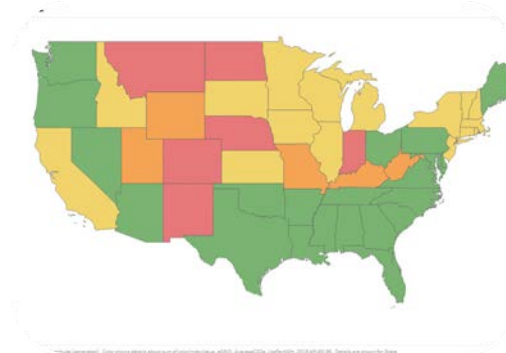
Upgrade Package
Optimization



Technology
Innovation



Soft Cost
Reductions

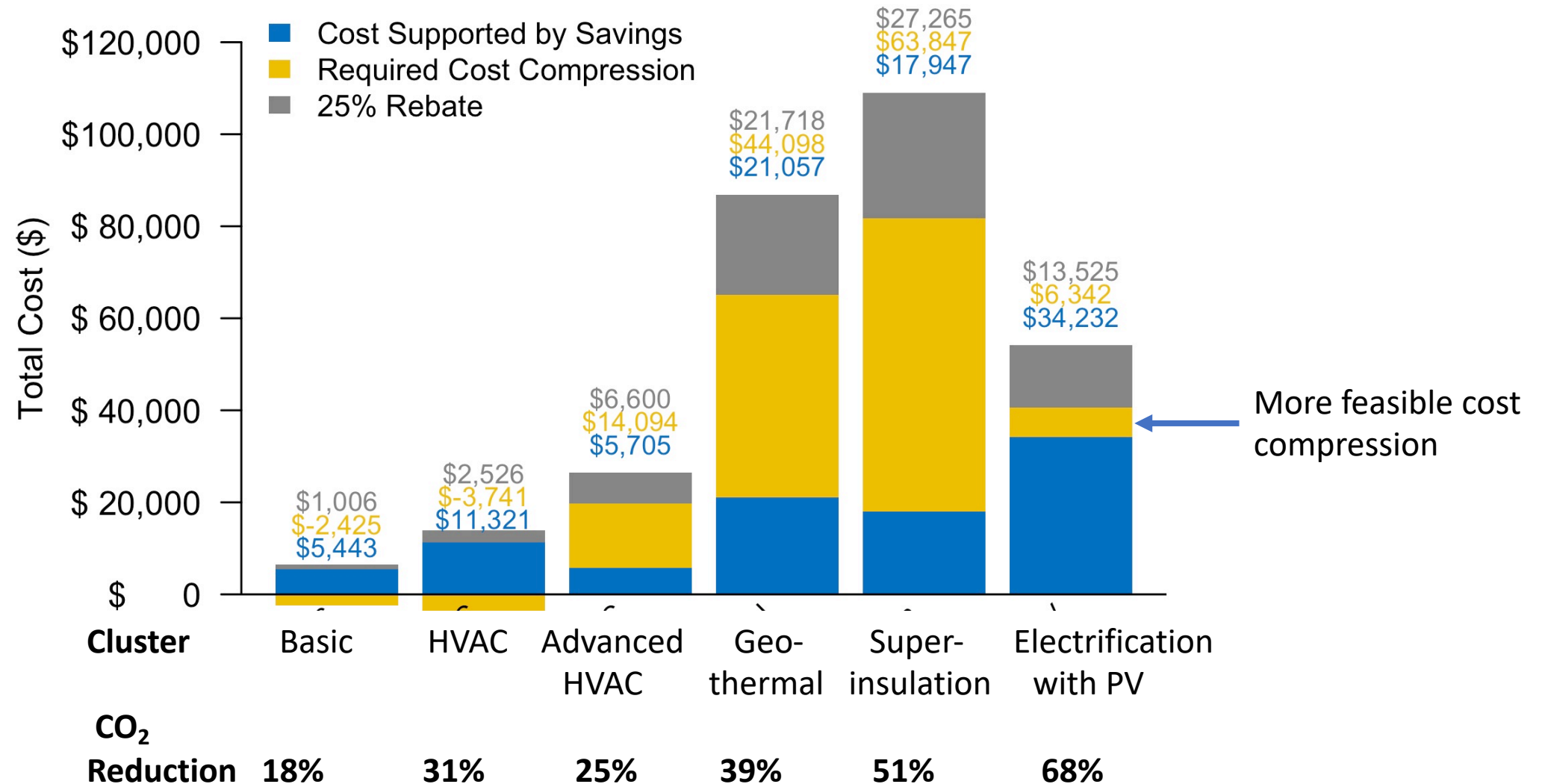


New Metrics



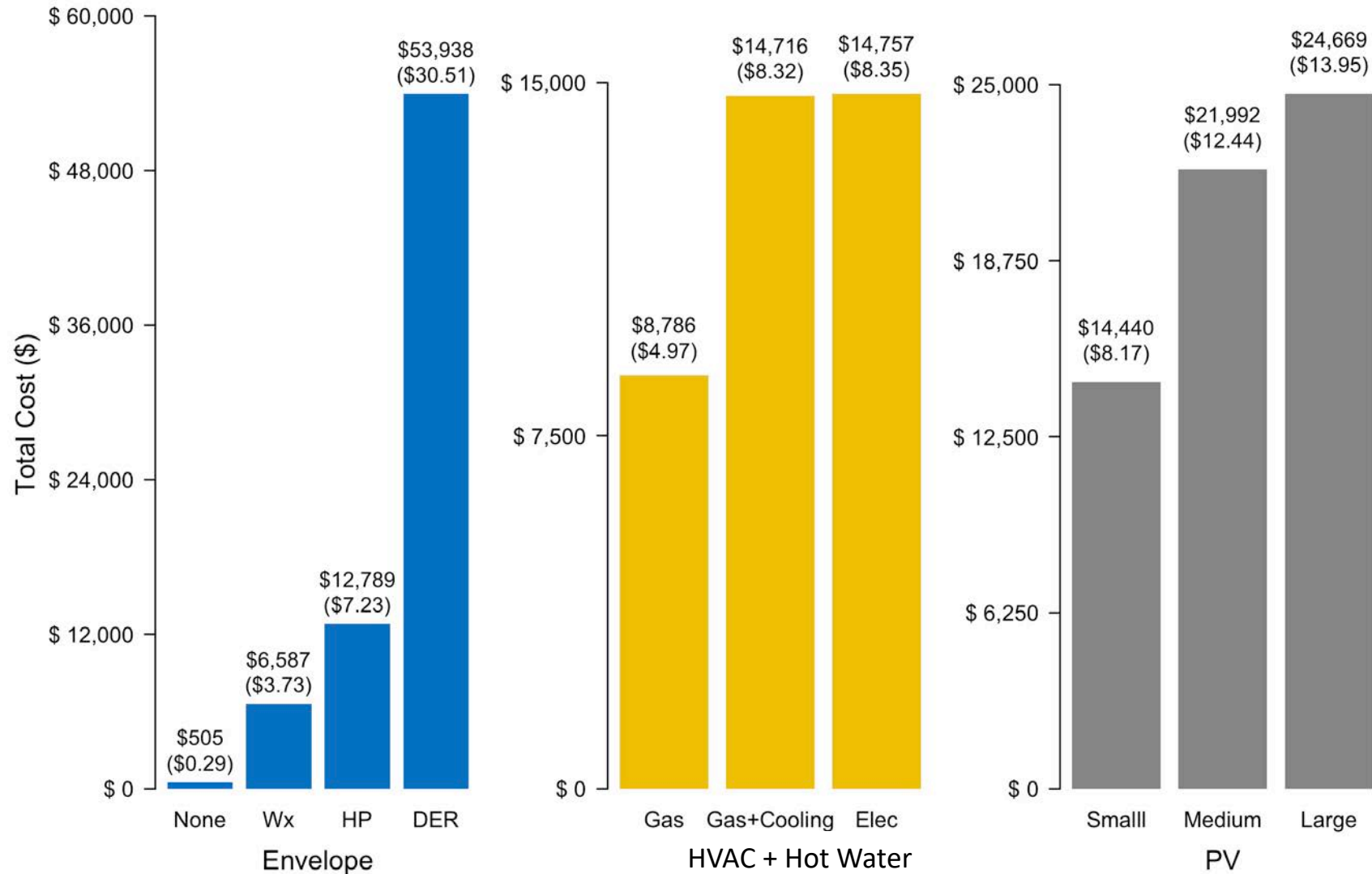
No- and Low-Cost
Methods

Cost Compression - Rebates



Cost Compression – Package Optimization

Archetypal Upgrade Packages



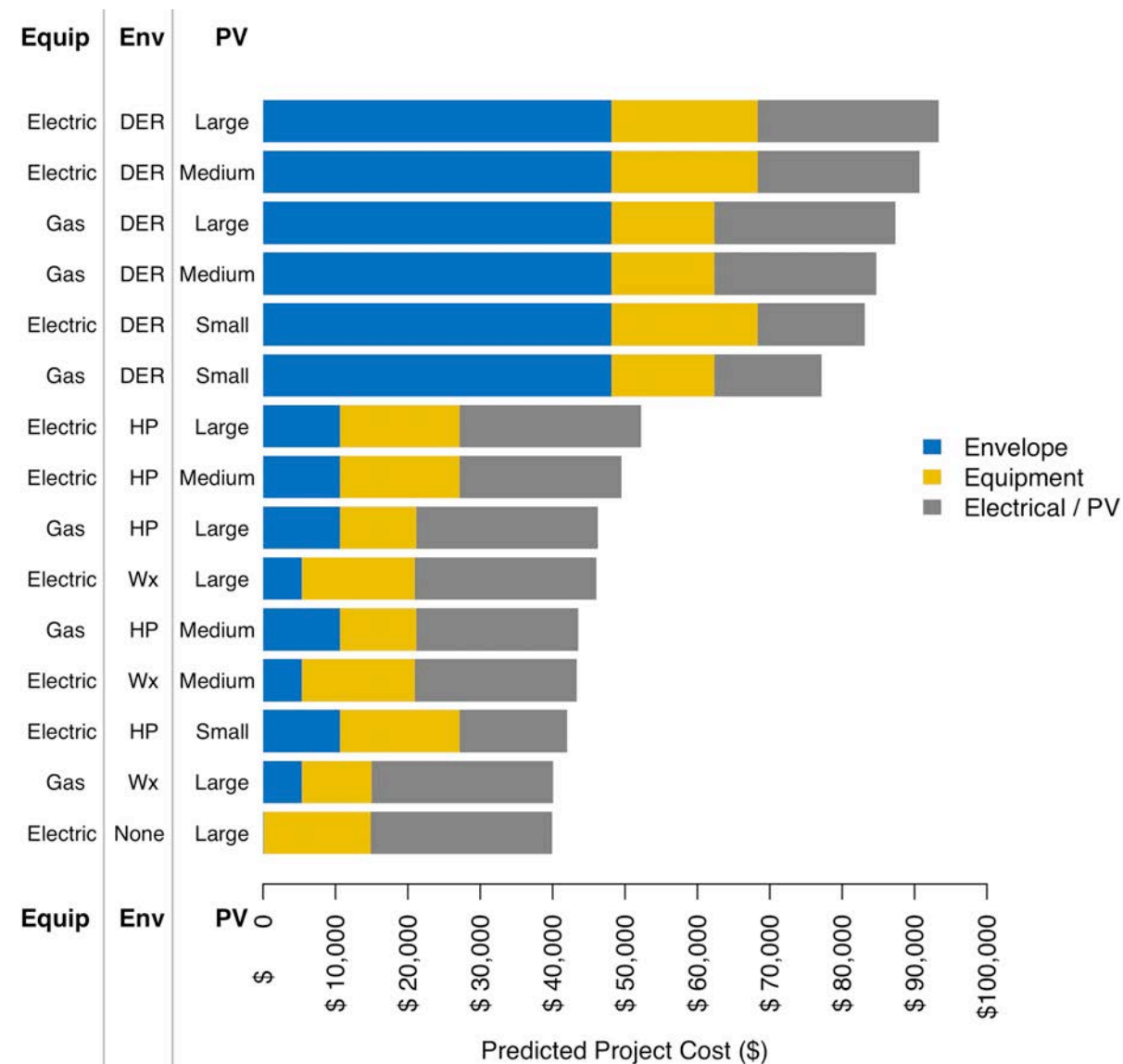
Archetypes Created from 4 envelope, 3 HVAC & DHW and 3 PV options

Costs and CO₂ reduction predicted using random forest regression models for each individual measure

Cost Compression – Package Optimization

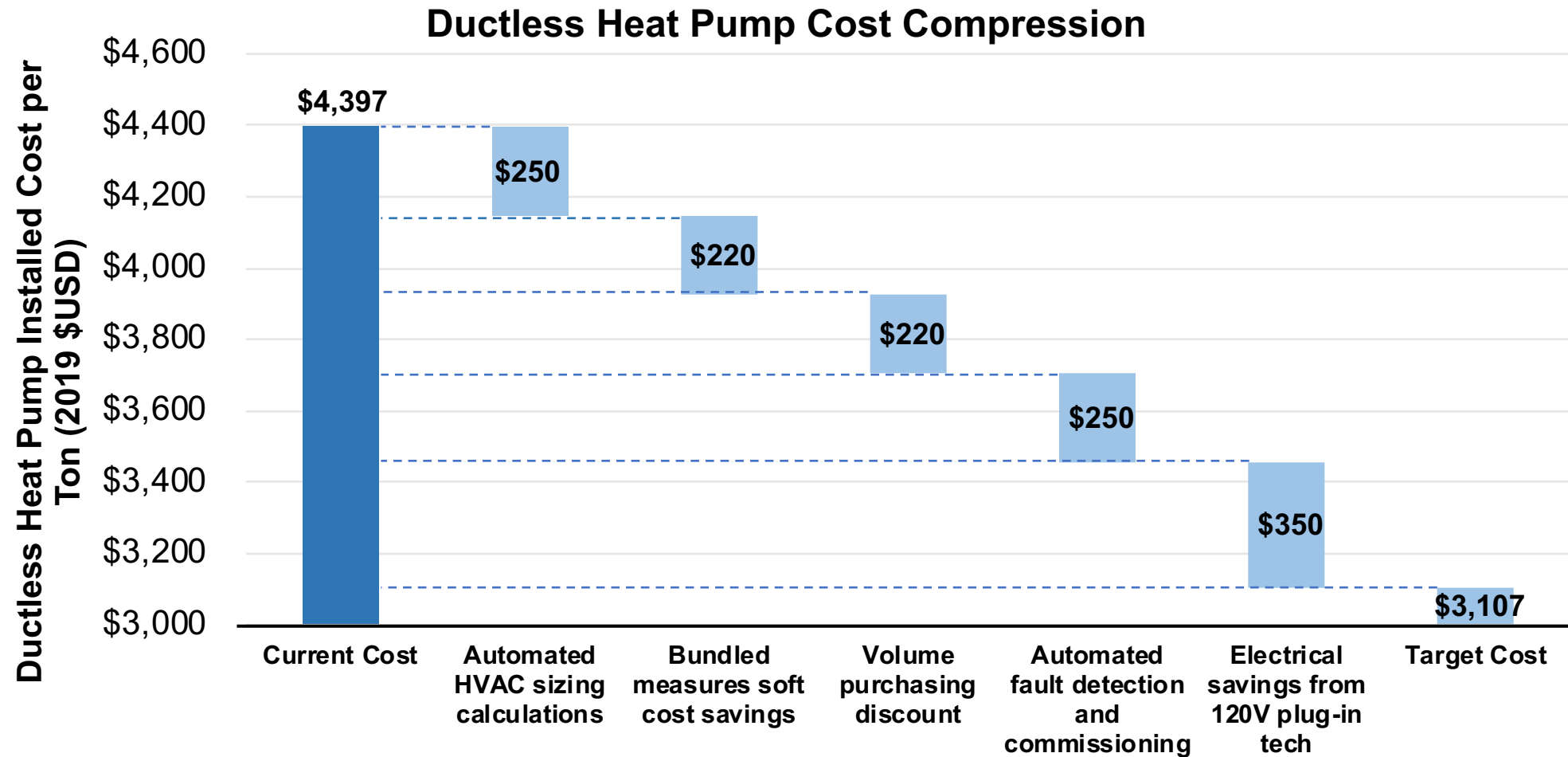
Archetypal Upgrade Packages

60-70% CO₂e Savings

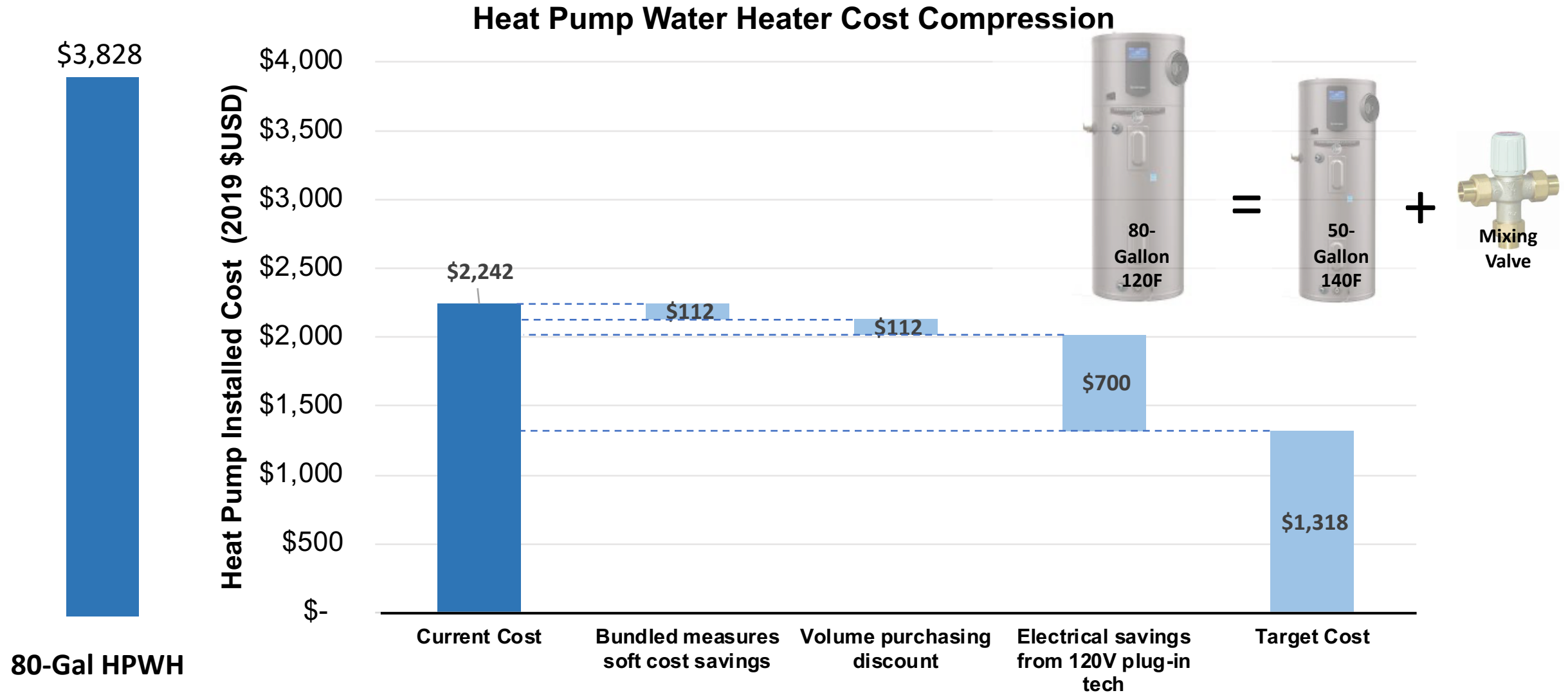


Mild Envelope upgrades +
PV gives good carbon
savings at least cost

Cost Compression – Ductless Heat Pumps



Cost Compression - Heat Pump Water Heater, 50-Gal



Cost Compression – Low Power Electrification

Avoiding Panel Upgrade Costs

Contractor's Pricing Guide:
Residential Repair & Remodeling Costs
with RSMeans data

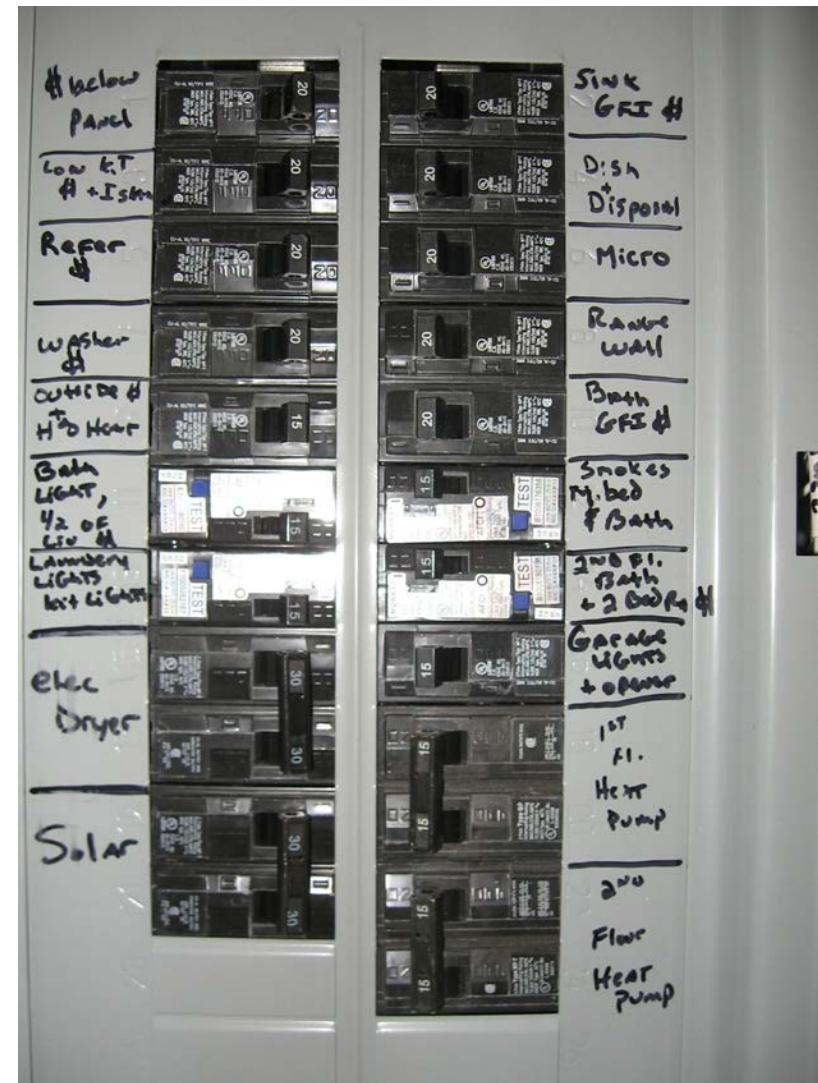
→ **\$1,954**

Average range: **\$1,500 - \$4,000**



(replace an existing panel with a new model with new housing)

<https://www.fixr.com/costs/install-electrical-circuit-panel-upgrade>



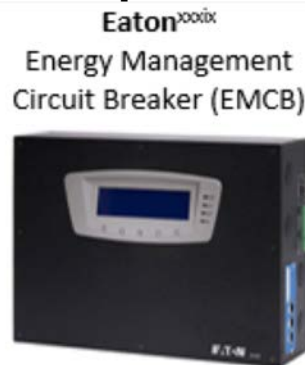
Cost Compression – Low Power Electrification

Avoiding Panel Upgrade Costs

Smart Circuit Splitters and Sharing



Programmable Subpanels



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
		

Watt Diet Calculator

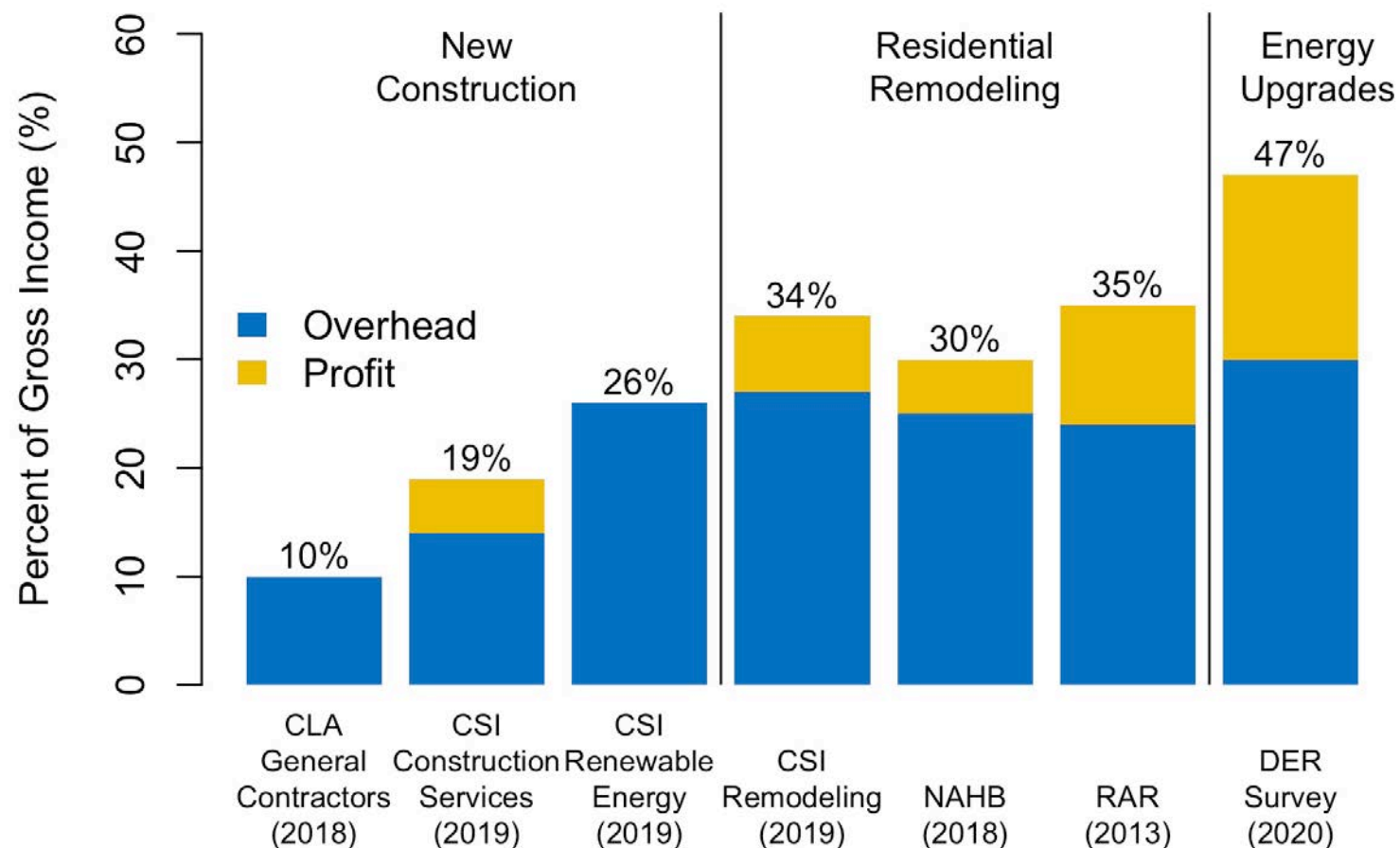
All Electric 100 Amp Home (2,000 square feet)
Ducted heat pump, medium power heat pump water heater, hybrid heat pump dryer

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

homes.lbl.gov

Cost Compression – Soft Costs



Need to reduce Soft Costs:

- Customer acquisition
- Testing
- Program participation
- 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 – Soft Costs – Real Life Examples DIY Solar PV and Heat Pump

- Eliminate overhead with online experience
- Flat pricing across the US
- DIY or full-service options

**Want to DIY? You put
up the panels, we do the rest.**



**Transparent Pricing
Lowest Guaranteed**

OPTIONAL ADD ONS		
Equipment + Permits & DIY Support \$0.90-\$1.20 /watt GET STARTED WITH EQUIPMENT	+	<div><div>Ground Mount + Installation \$0.30* /watt GET STARTED WITH GROUND MOUNT</div><div>OR</div><div>Full Service Install + Warranty \$0.37* /watt GET STARTED WITH FULL SERVICE</div></div>

*Pricing reflected as after incentive pricing.

- Custom design
- Pre-insulated line sets
- Simplified fittings
- Strong advertising

MRCOOL
COMFORT MADE SIMPLE

HOME THE STORY PRODUCTS WHERE TO BUY SUPPORT REE

Never Stop *Dreaming*
MRCOOL
Innovative Heating & Air for Your
Family

watch the video

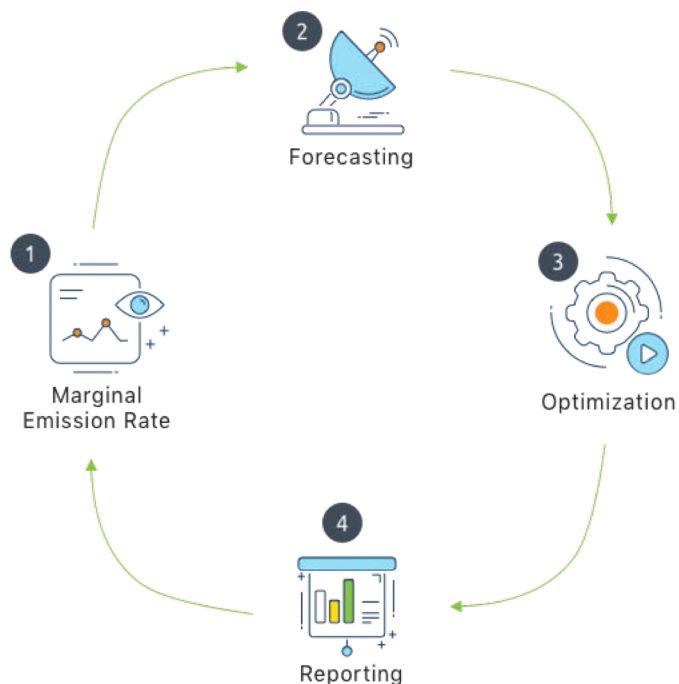
Cost Compression – No- and Low-Cost

Automated emission reductions



HOMEintel

Small – but easy and low cost
Should be part of every project



"We cut our bill in half and are on track to save over \$2,000 after the changes we made with HomeIntel's help."

HomeIntel customer

Their story: This couple has lived in their 3,000sqft home in Stanford, CA for 30 years.

Despite completing HVAC upgrades, they still had high energy use.

Their results: Saving \$220 per month and over \$2,500 annually.



The customer above found **4 Energy Hogs** using HomeIntel.



(1) Old **baseboard heaters** costing \$100 per month



(2) Continuous hot water **recirculation pump** costing \$50 per month



(3) 20 year old **wine cellar** (cooler pictured) costing \$120 per month



(4) Instant **hot water dispenser** under the sink costing \$30 per month



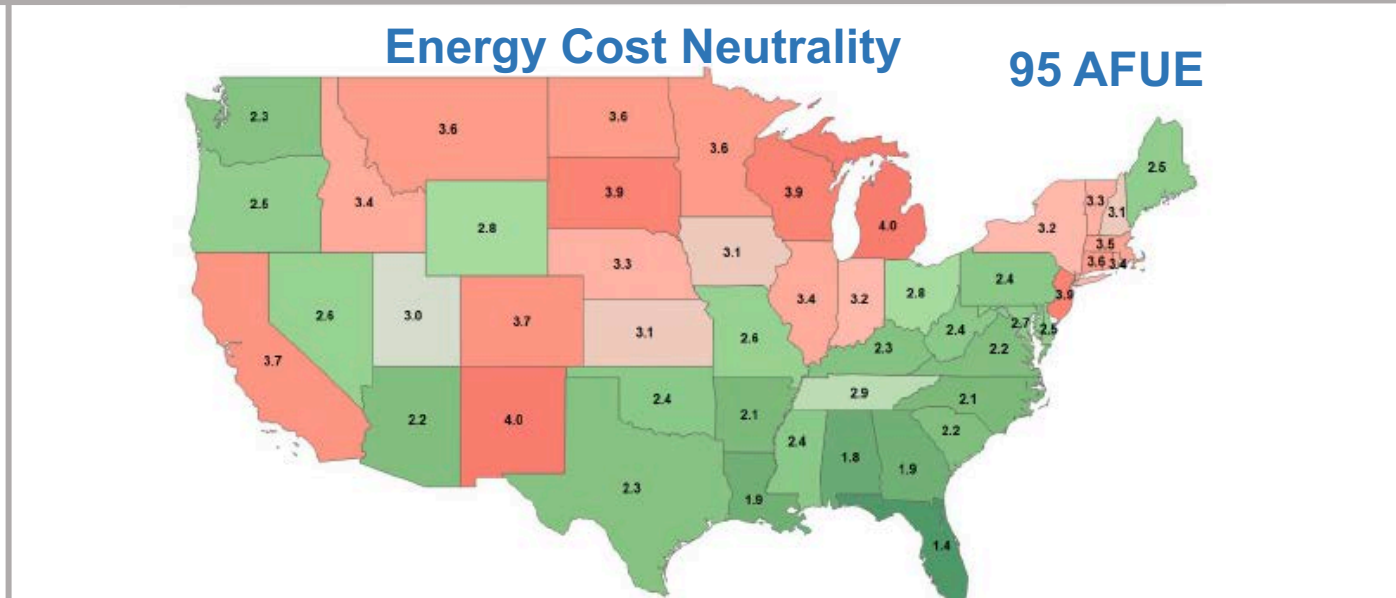
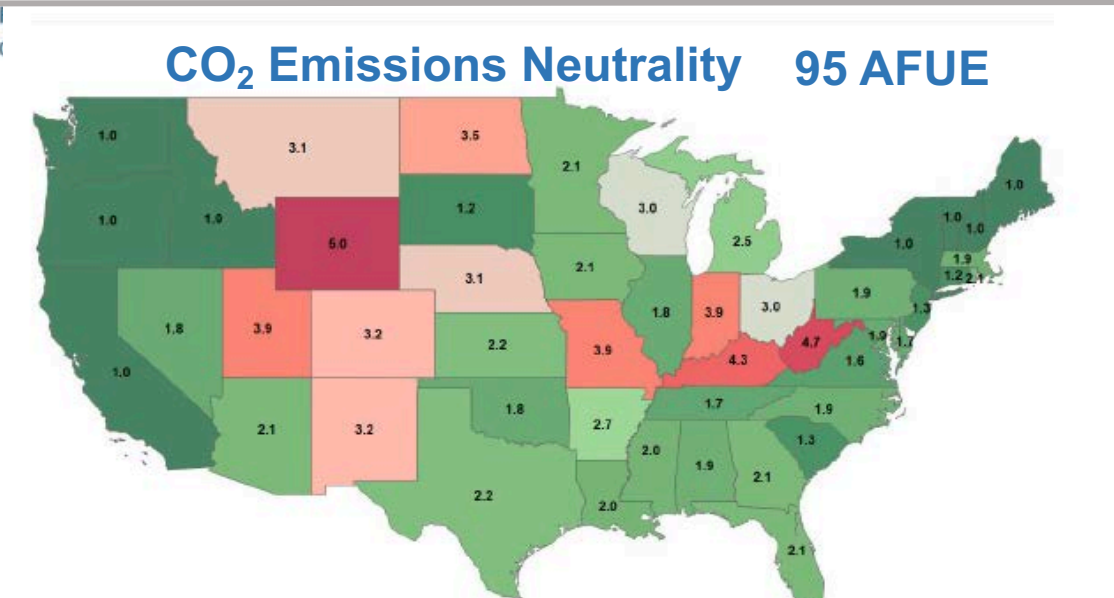
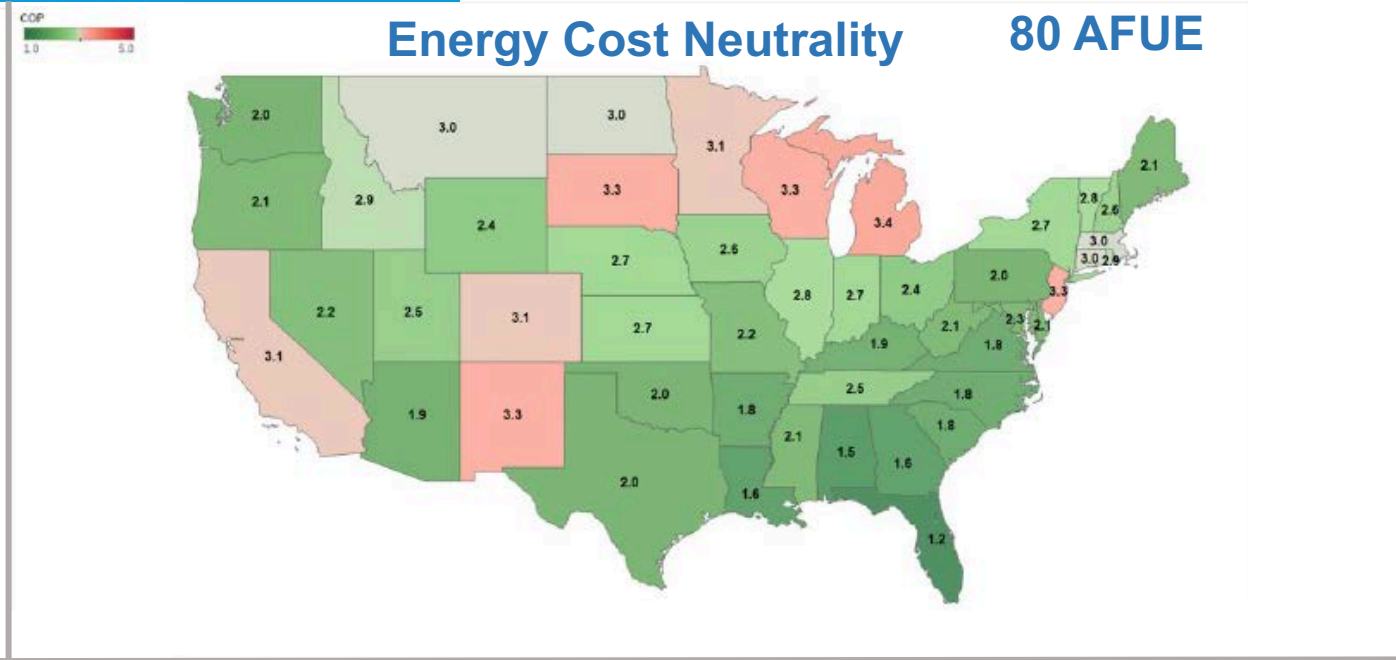
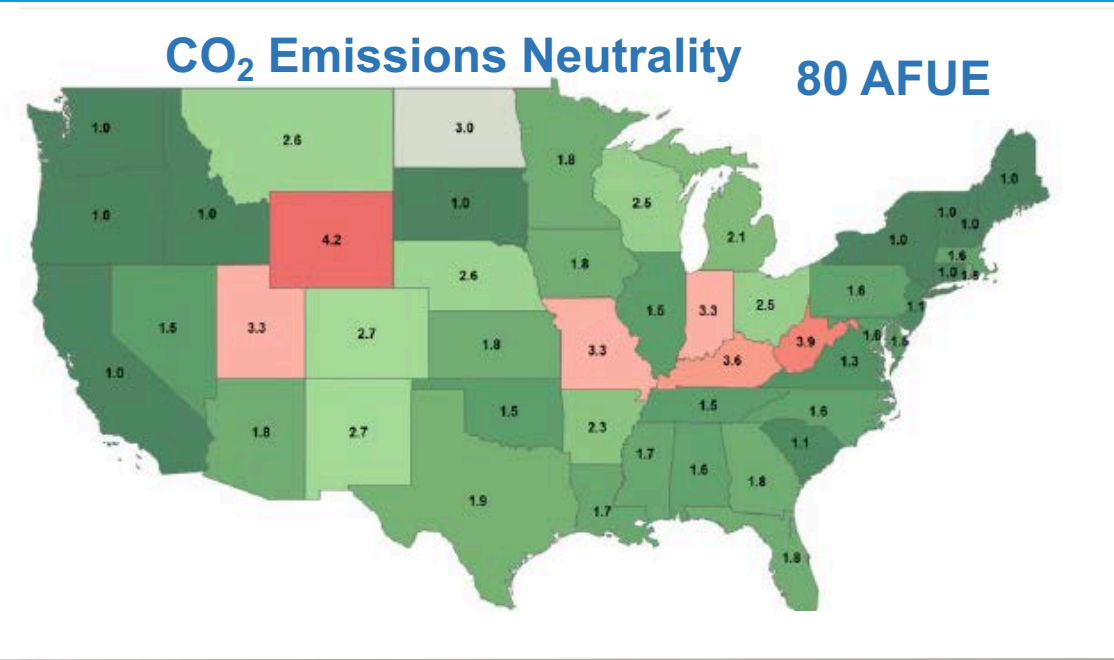
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Energy Technologies Area

Decarbonization Costs – New Metrics

Using Electric Heat Pumps Instead Of Gas Furnaces

Heat Pump COP required to break even with a gas furnace



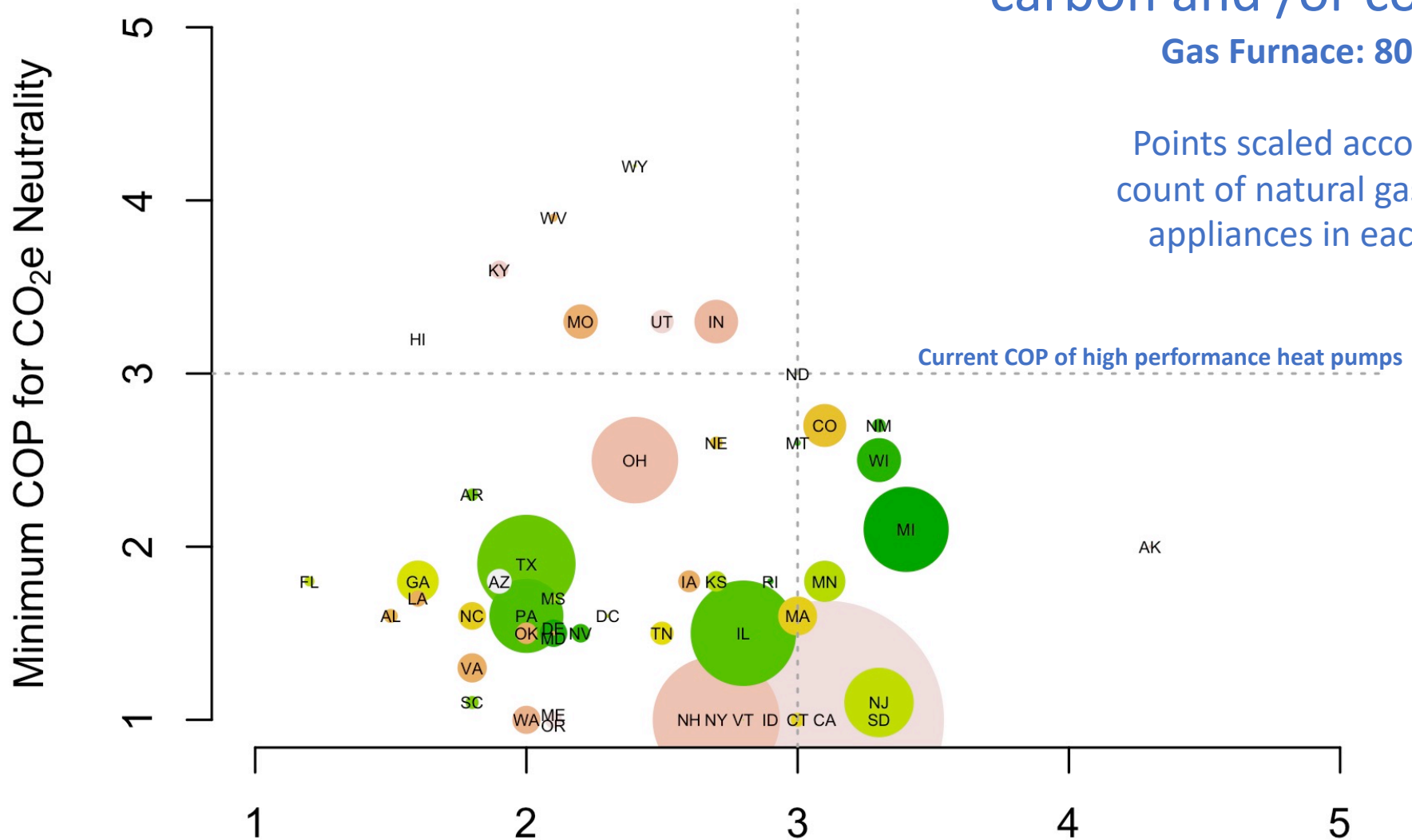
Decarbonization Costs— New Metrics

Using Electric Heat Pumps Instead Of Gas Furnaces

What Heat Pump performance is required to be carbon and /or cost neutral?

Gas Furnace: 80 AFUE

Points scaled according to count of natural gas heating appliances in each state



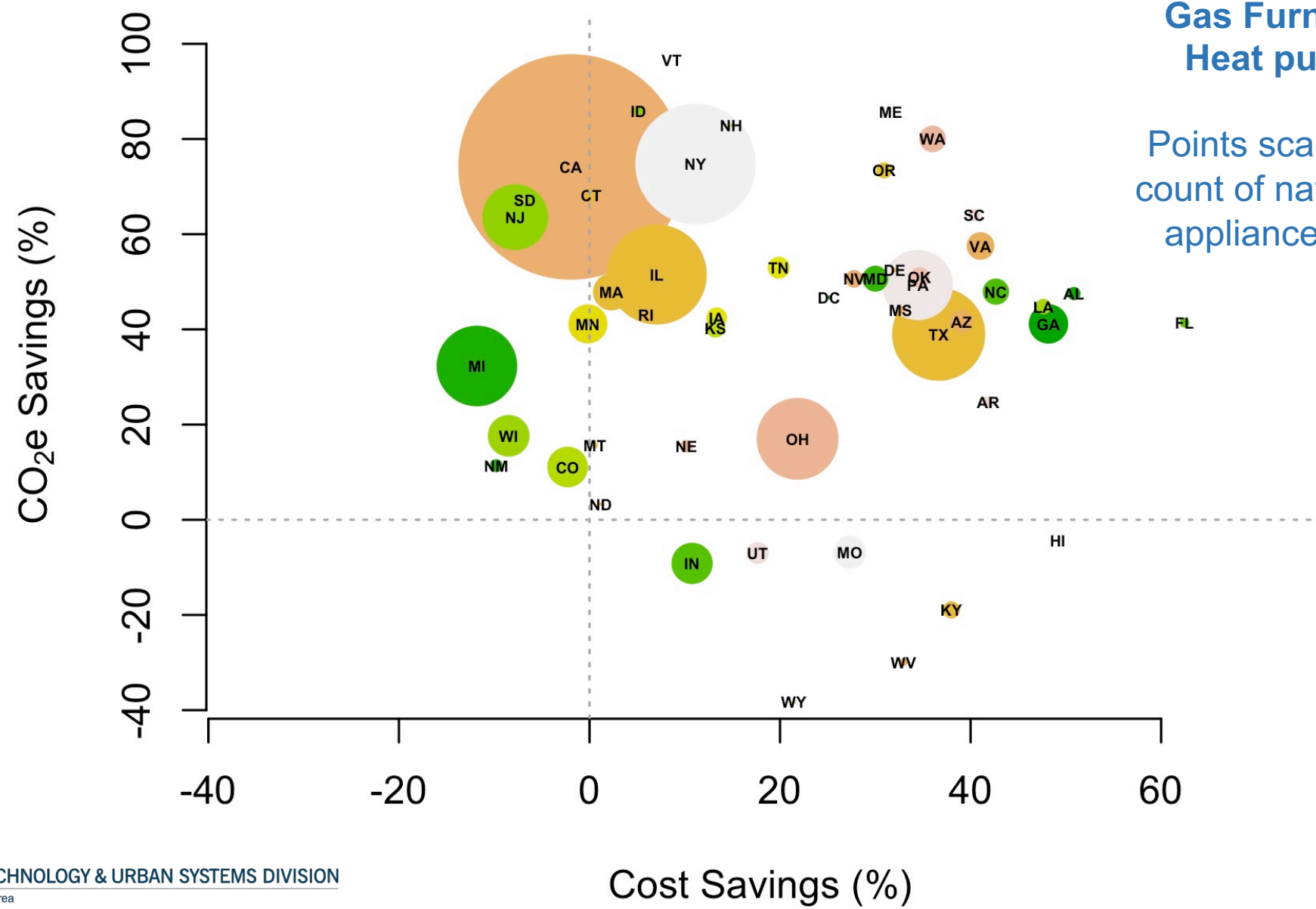
Cost Compression – New Metrics

Using Electric Heat Pumps Instead Of Gas Furnaces

What are the carbon and cost savings?

Gas Furnace: 80 AFUE
Heat pump: 3.0 COP

Points scaled according to count of natural gas heating appliances in each state



What's Next: Transportation

- Current poor public charging infrastructure:
 - Need to be able to charge at home
- Need a spare circuit or new panel/wiring
- EV could easily be the biggest home load: up to 50 kW
 - Need to restrict power requirement to 7.2kW (or less?)
 - Use timers/smart circuit sharing
- How to make this affordable for everyone?



What's Next: 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

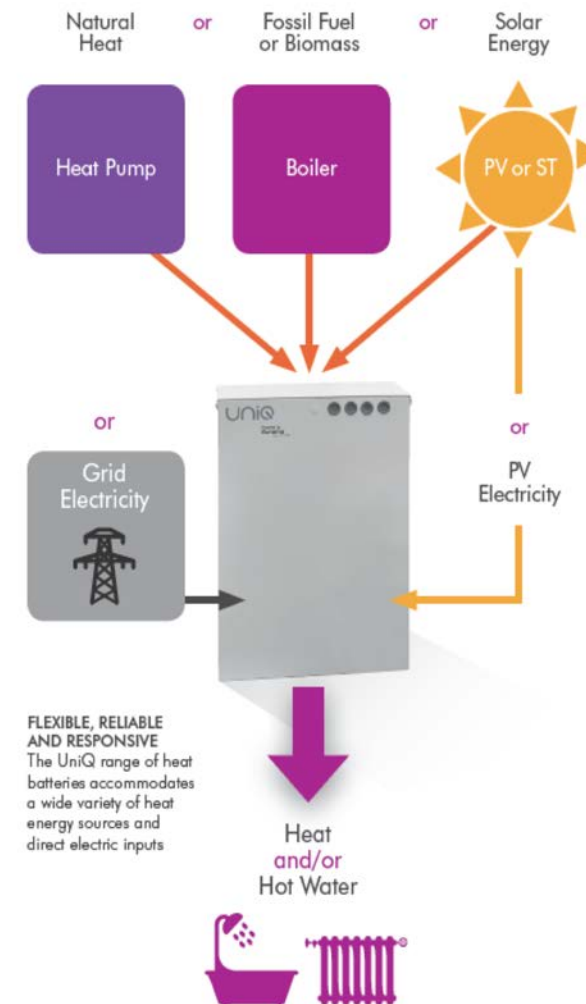
Offset cost with downsized heat pump

Electric Battery

- 3 to 5 kWh in every home

Thermal Storage

- Safe, common, phase change materials
- 10.5 kWh in same space as 50 gallon tank
- How to make this affordable for everyone?



What's Next?

- Data gathering and analysis for multifamily and manufactured homes
- R&D directed at cost compression – both soft and hard costs
- R&D supporting financing mechanisms for affordability and decarbonization program development
- Develop guidance for industry on most effective approaches
- Stakeholder meetings and other industry engagement

Next Seminar

December 1st

Can you DIY Home Electrification?

Howdy Goudey
Spencer Dutton
Jonathan Wooley
Bruce Nordman

