NATIONAL HOME PERFORMANCE
VIRTUAL CONFERENCE APRIL 12-16,2021

Emerging Trends in Deep Energy Retrofits: Insights from >1,000 US Projects

Presented By

Brennan Less, Iain Walker & Núria Casquero

Building AMERICA
U.S. Department of Energy

BERKELEY LAB
BUILDING TECHNOLOGY & URBAN SYSTEMS DIVISION
Energy Technologies Area

PRESENTERS

Brennan Less

Scientific Engineering Associate

LBNL

Núria Casquero

Post-Doctoral Scholar

LBNL

Iain Walker

Staff Scientist

LBNL

SESSION OBJECTIVES

At the conclusion of this session, participants will be able to:

- ❑ Identify what measures and measure packages are most common in US retrofits.
- ❑ Understand how the strategies driving the design of whole home retrofits are evolving in the context of climate change, electrification and rapidly changing costs.
- ❑ Improved understanding of the factors that affect the costs and performance of deep retrofit projects.

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

How to Address Those Questions

STATE-OF-THE-ART REVIEW

- Recent documented developments for Energy Efficient / Low Carbon homes
- Past experiences and programs in the US and Europe
- What has been successful
- What has not been successful

PROJECT COST SOLICITATION

- Learn from people currently doing this work about costs
- Breakdown costs by category (e.g. “sunshot” program for solar PV) to get “cost stacks”

MARKET SURVEY

- Understand what motivates and deters DER projects in today’s market
- Identify promising approaches and technologies from the industry perspective
- Learn from people doing this work about barriers, what works, possible future strategies to get to scale

State-of-the-art Review

Emerging Pathways to Upgrade the US Housing Stock: A Review of the Home Energy Upgrade Literature (2021)

https://eta.lbl.gov/publications/emerging-pathways-upgrade-us-housing

State-of-the-art Review

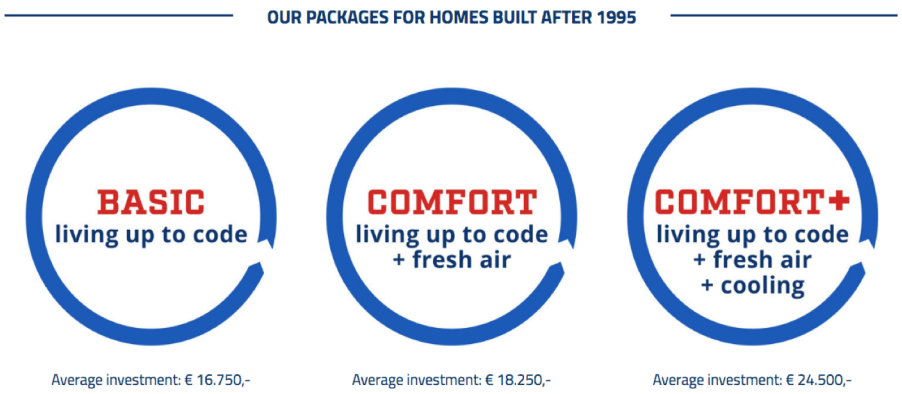
- **Focus on recent efforts**
  161 scientific papers and technical reports from the *past ten years*
- **Integrated Approaches at Large Scale**
- **Summary of 14 Deep Energy Upgrade Programs**
  Large range in costs, scope and savings
- **Getting to scale**
  - Key barriers to scaling up Deep Energy Retrofits (DERs)
  - Identifying ways to scale and overcome challenges
- **Emerging program changes**
  - Recent changes to Deep Energy Retrofit (DER) project design
  - Emerging program innovations
  - New metrics
- **Emerging Technologies**
  - Increased interest in electrification
  - Smart Ventilation
- **Health and Indoor Air Quality (IAQ)**

Integrated Approaches at Large Scale

The Netherlands

Climate Mission The Netherlands

- "One Stop Shop" packaged approaches including: financing, planning, design, installation
- Makes it simple and easy for home owners.



www.climatemission.eu

EnergieSprong

- More than 5,000 homes.
- Simplified panelized retrofits pre-fab in factory.
- Best for simple homes.

https://energiesprong.org

Summary of 14 Deep Energy Upgrade Programs

Program Name	Number of Homes	Average Cost ($)	Average Site Energy Savings	Notes
Energy Upgrade California - CA	20,000	$6,300	274 kWh, 16 Therms	Actual bill savings. Predicted savings were typically much higher.
Zero Energy Now - VT	24	$54,500	39% delivered site energy savings; 64% fossil fuel and grid energy savings; 60% energy cost savings	Weather normalized savings from utility bills and fuel delivery invoices. Most projects electrified, including insulation, heat pumps and PV.
Home MVP – MA: Deep	66	$49,126	48%	Predicted energy savings
Home MVP – MA: All	341	$21,675	33%	Half were electrified
Extreme Energy Makeovers - TN	3,420	$9,000	35% (4,900 kWh)	Deemed energy savings; affordable housing
National Grid Deep Energy Retrofit Pilot Community - MA and RI	60	$34.59 /ft^2	55%; 43% source energy savings	For 29 comprehensive projects
FSEC DERs - FL	10	$14,323	38%	DER increment was $7,074; affordable housing
FSEC DERs - FL	70	$16,424	30%	DER increment was $3,854; affordable housing
EnergyFIT Philly - PA	67	$14,257	36% gas, 22% electric	Affordable housing
EnergySmart Ohio - OH	11	$30,173		Cost data from Redwood Energy Guide
Home Intel by Home Energy Analytics - CA	1,400	Effectively zero	10%	CA's first pay-for-performance utility program; Includes automated energy end-use feedback and customized coaching
Home Intel by Home Energy Analytics - CA	16	Effectively zero	42% electric, 17% gas	Higher performing subset
Sealed - NY	338	$10,000	20% heating, 5% electricity	

Summary of 14 Deep Energy Upgrade Programs

IS THIS ENOUGH?

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Summary of 14 Deep Energy Upgrade Programs

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INDUSTRY NEEDS BIG CHANGES

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Scale - NY	338	$10,000	20% heating, 5% electricity	

Getting to Scale

KEY BARRIERS TO SCALING UP DEEP ENERGY RETROFITS

- Projects focused solely on energy savings are not appealing to enough people.
- Market interest and acceptance is low amongst homeowners.
- Costs are too high.
- Economic justifications are challenging and possibly inadequate. Low electricity and natural gas prices make financial payback arguments challenging.
- Lack of trained workforce with the necessary skills.
- Lack of real estate market valuation of DERs/home upgrades.

Getting to Scale

Financing

- Weak credit limits loan market access.
- Financing projects with relatively low investment returns.
- Owners are risk-averse and would seek borrowing costs that are below the Energy Efficiency rate of return. Uncertainty in the distribution of project returns necessitates even lower risk and loan costs.
- Large number of transaction costs, including time/expense to find and monitor contractors and to secure financing. Loan costs also must be low enough to offset these transactional, soft costs.
- Programs need to Include financing as a core element:
    - Pay As You Save (On-Bill)
    - PACE
    - pay-for-performance
    - Financing from the program using local networks of lenders.

Emerging Program Changes

- Make DERs Appeal to Home Owners

Energy Programs – NEED TO

- Provide information. Programs must sell something people want, e.g., affordable, tangible solutions.
- Use the right language – use words with positive associations.
- Improve energy modeling outcomes through better access to energy use data, model calibration, and adoption of standardized home performance data protocols.
- Include rebates, financing and other incentives.
- Partner with trusted messengers.
  - Work with community organizations to engage homeowners, particularly for low income/disadvantaged communities.
  - Neighborhood or street-level recruitment.
- Make it easy, make it fast.
- Invest in a well-qualified workforce that homeowners trust and use contractors as program ambassadors.

Emerging Program Changes

NEW METRICS

- CO_2 (and other Green House Gas) emissions.
- Peak demand and the ability of a home or technology to time-shift to optimize use of renewables, respond to variable energy costs, and support electric grid reliability.
- Assessments of health, safety and IAQ associated with home energy upgrades including fire risk, CO, particles, wildfire and pandemic resistance
- New ways to assess the cost of energy upgrades. These include:
  - **Monthly net cost of ownership:** i.e., a cash-flow approach more akin to traditional home mortgages.
  - **Affordability:** Like selling a car, the home upgrade industry needs to do better at sales and closing deals by selling retrofits in the same way as leasing and financing of automobiles.

Emerging Technologies

- Develop a standardized set of strategies that apply to the many building typologies that have broad consumer appeal

The strategies should focus on:

- Decarbonization and electrification.
- Demand-responsive and resilience-focused technologies including electric batteries and thermal storage.
- Heat pump technologies.
- Grid connectivity.
- Smart technology and web-connectivity.
- Resilience to natural and manmade disasters: wildfires, infrastructure failures.
- Health and safety.

Emerging Technologies

INCREASED INTEREST IN ELECTRIFICATION

- We cannot “efficiency our way to zero carbon emissions”: Electrification is a core strategy to achieving deep carbon reductions in buildings (and vehicles).
- There is existing consumer demand for PV and electrification.
- Solar generation and storage is becoming more affordable.
- Improvements in Heat Pump Systems, particularly for cold climates and water heating.
- Reduced health and safety concerns (reducing risks from CO, NO_2, particles, etc. from fossil fueled appliances): This can make homes more safe for occupants, while also reducing program costs that no longer require combustion gas leak detection or combustion safety testing.

Emerging Technologies

INNOVATION 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)

Lumin[xl]
Smart Panel

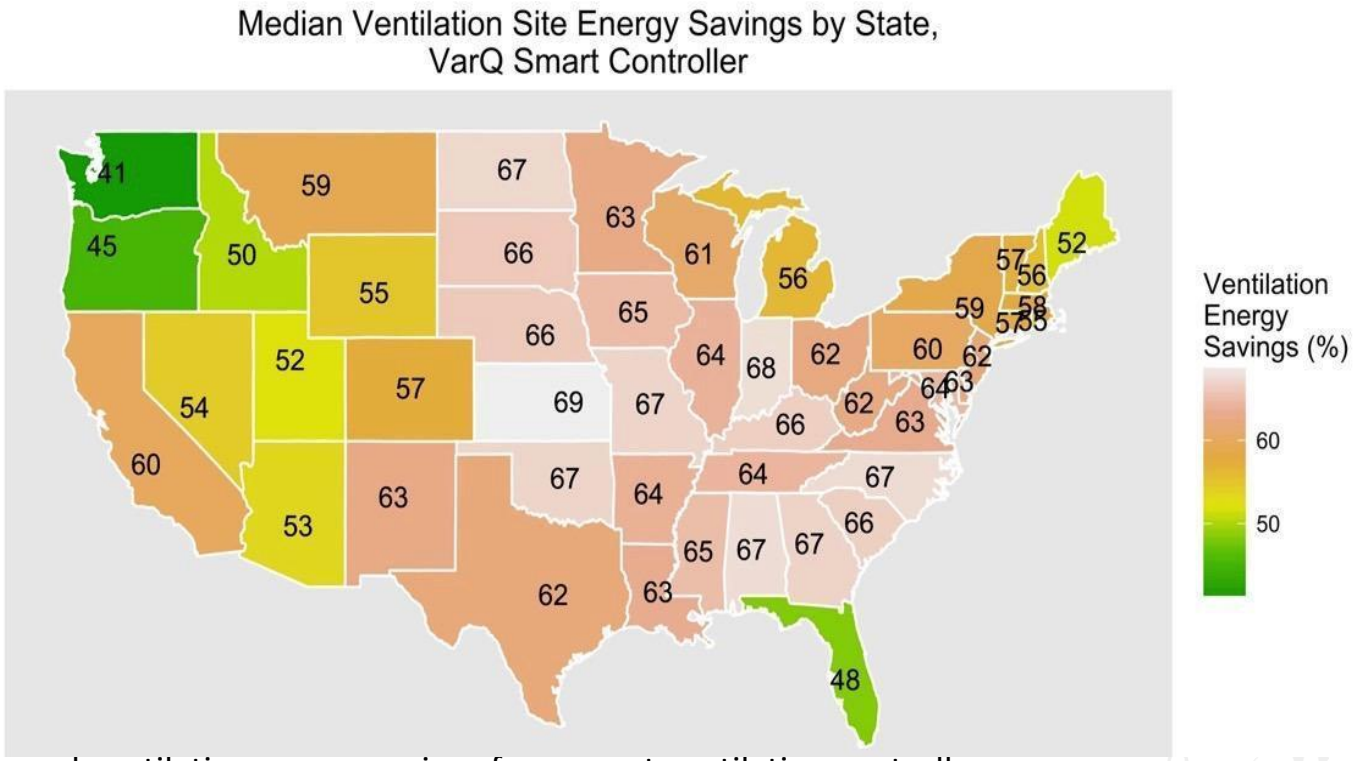
Power-efficient Appliances (120V)

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
		

Source - Sean Armstrong, Redwood Energy (2020)

Emerging Technologies

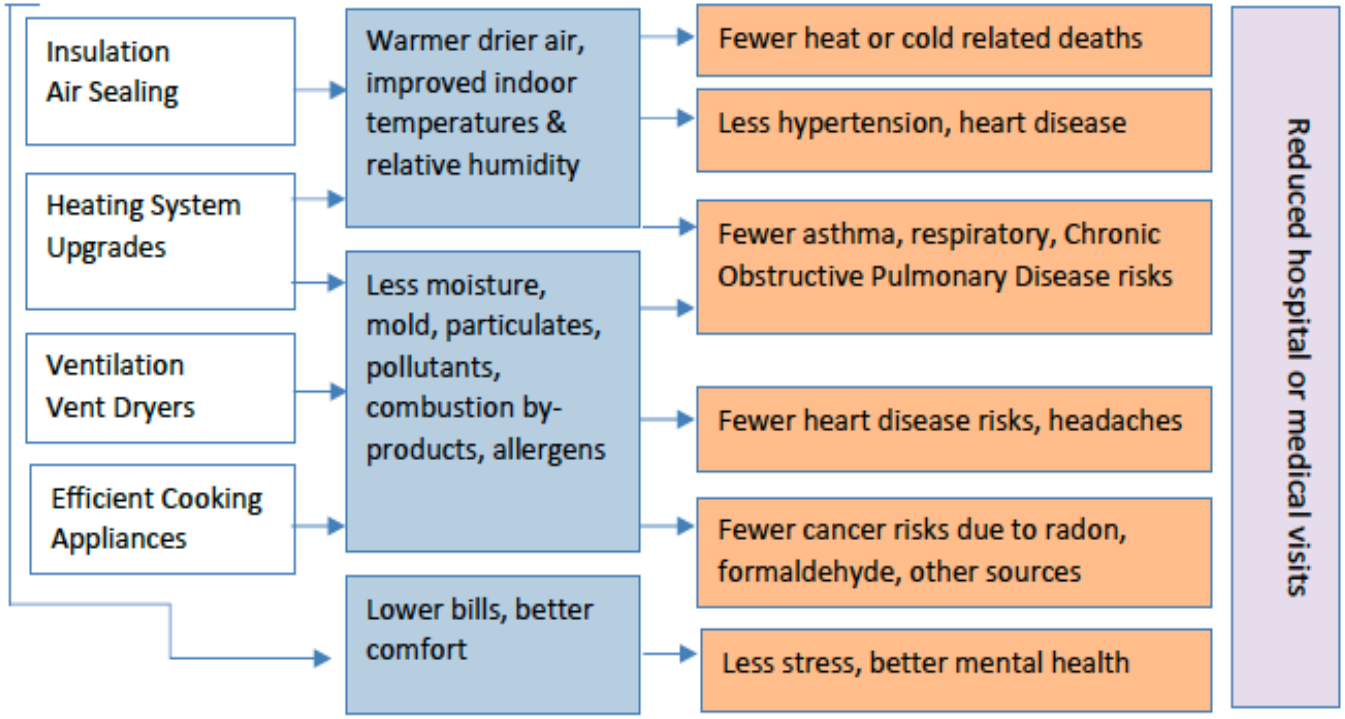
SMART VENTILATION



Annual ventilation energy savings for a smart ventilation controller.

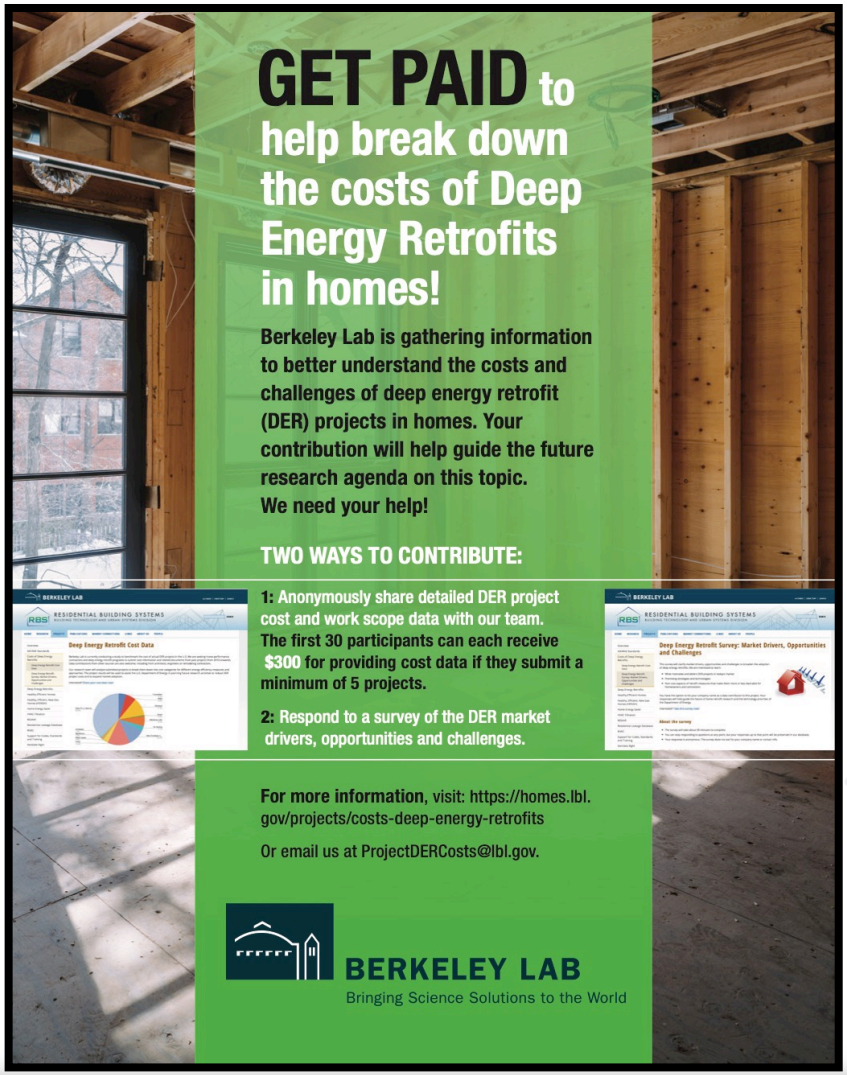
Health and Indoor Air Quality (IAQ)

Occupant Health and Indoor Environmental Benefits of Residential Energy Efficiency

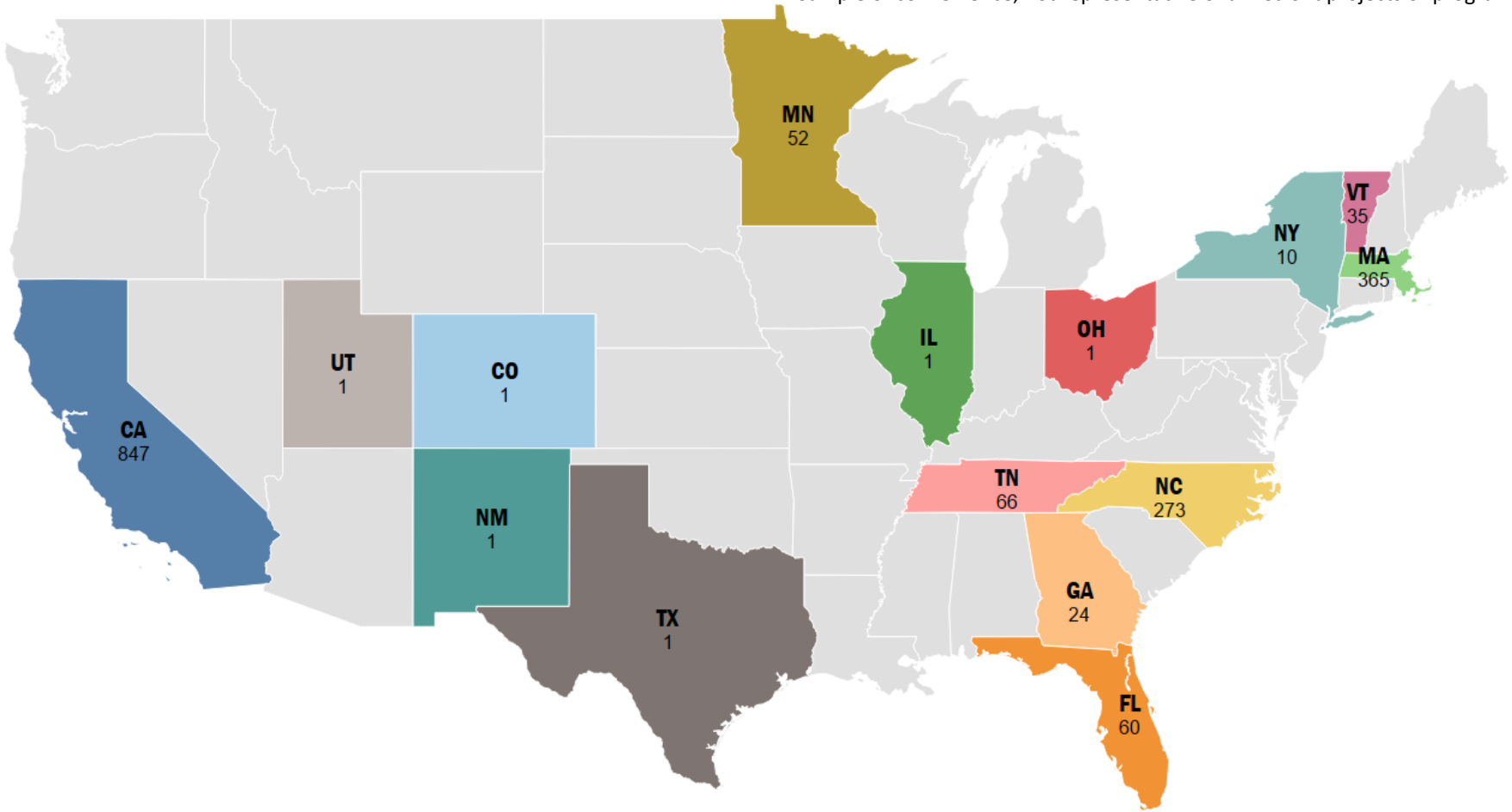


Source - E4TheFuture (2016)

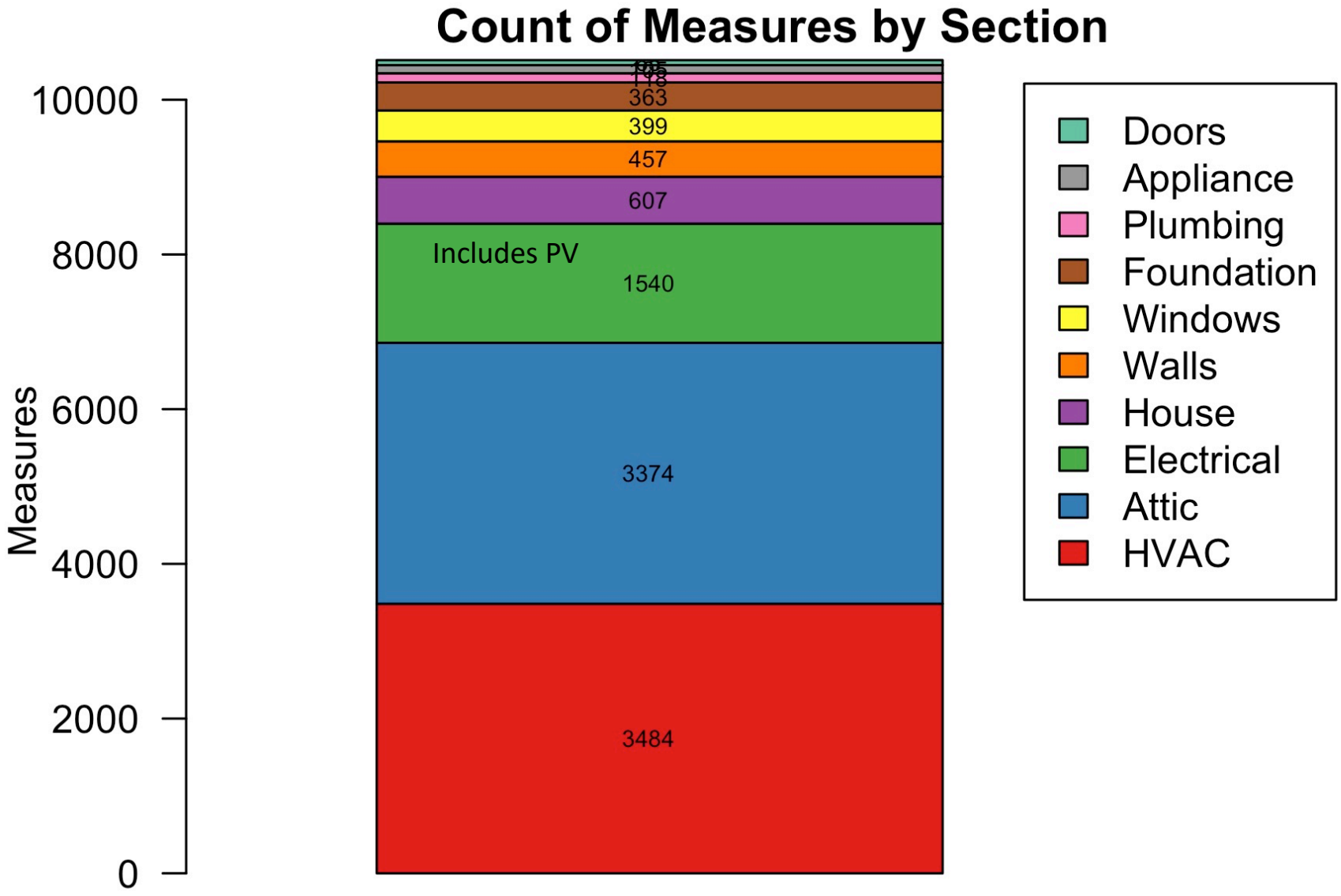
Project Cost Solicitation

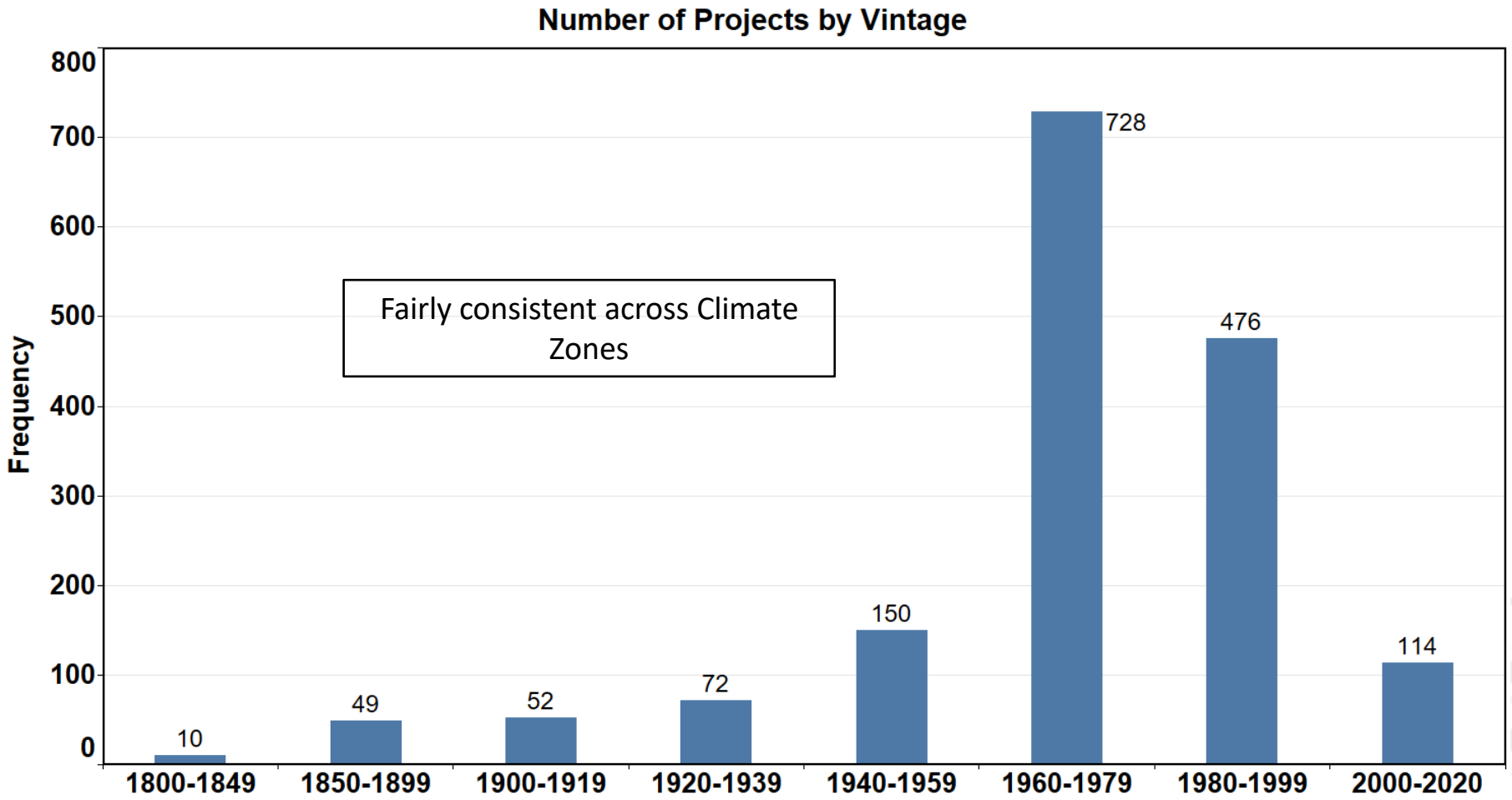

GET PAID to help break down the costs of Deep Energy Retrofits in homes!
Berkeley Lab is gathering information to better understand the costs and challenges of deep energy retrofit (DER) projects in homes. Your contribution will help guide the future research agenda on this topic.
We need your help!
TWO WAYS TO CONTRIBUTE:
1: Anonymously share detailed DER project cost and work scope data with our team. The first 30 participants can each receive $300 for providing cost data if they submit a minimum of 5 projects.
2: Respond to a survey of the DER market drivers, opportunities and challenges.
For more information, visit: https://homes.lbl.gov/projects/costs-deep-energy-retrofits
Or email us at ProjectDERCosts@lbl.gov.
BERKELEY LAB
Bringing Science Solutions to the World

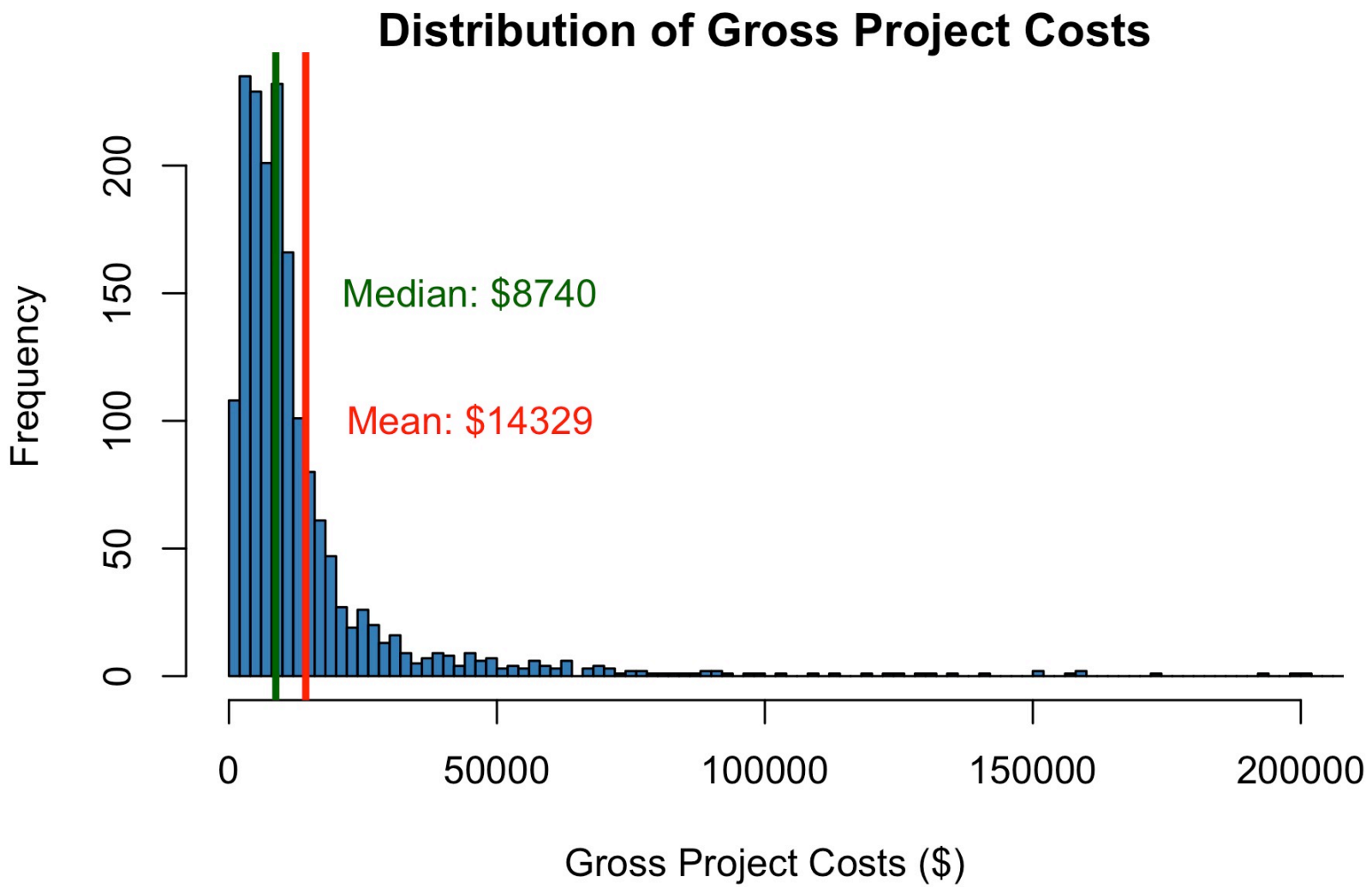
Sample of convenience, not representative of all retrofit projects or program activity

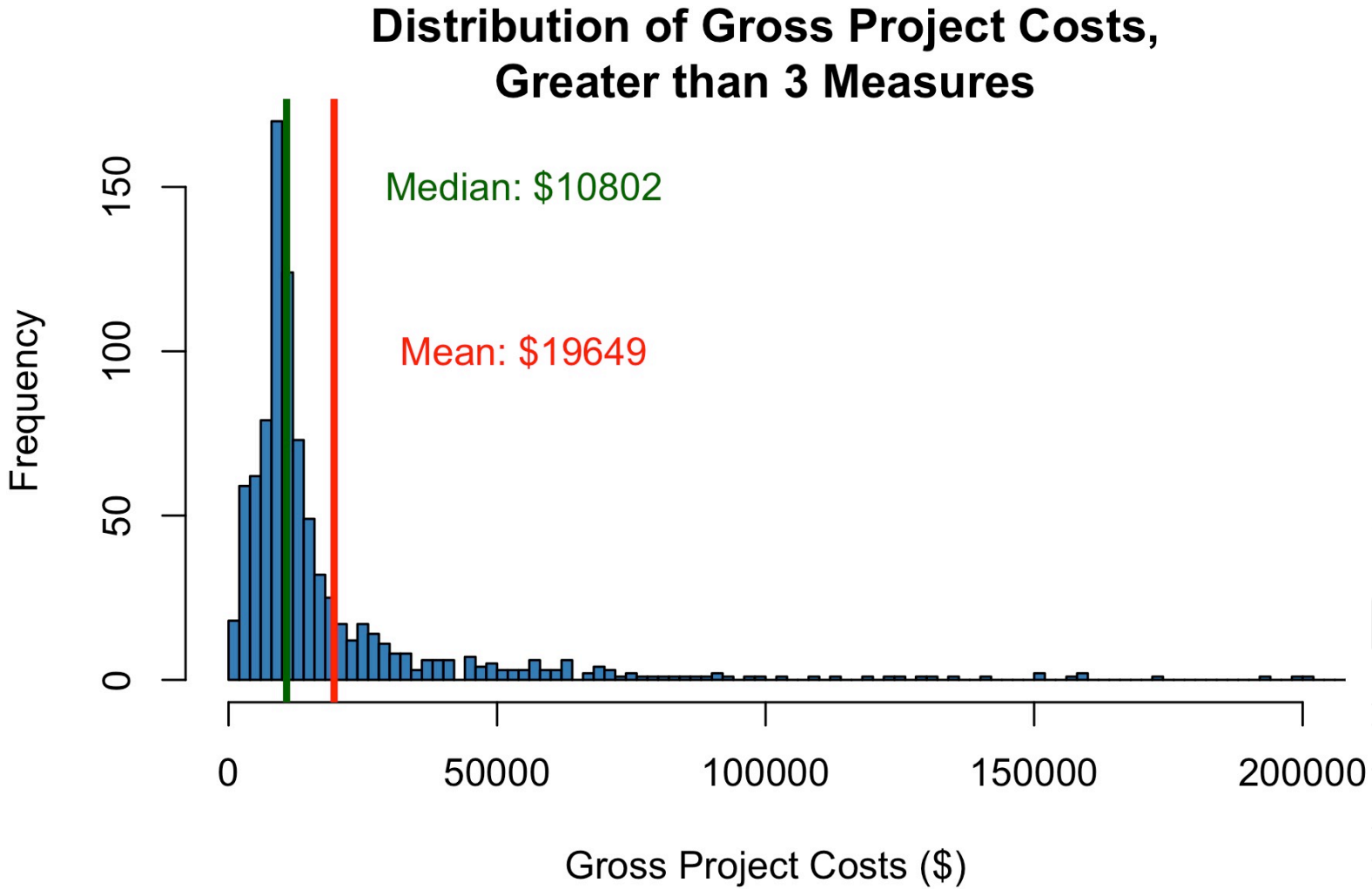


14 Programs | 1,739 Projects | 10,512 Measures | 3,294,946 ft² | $24,689,213

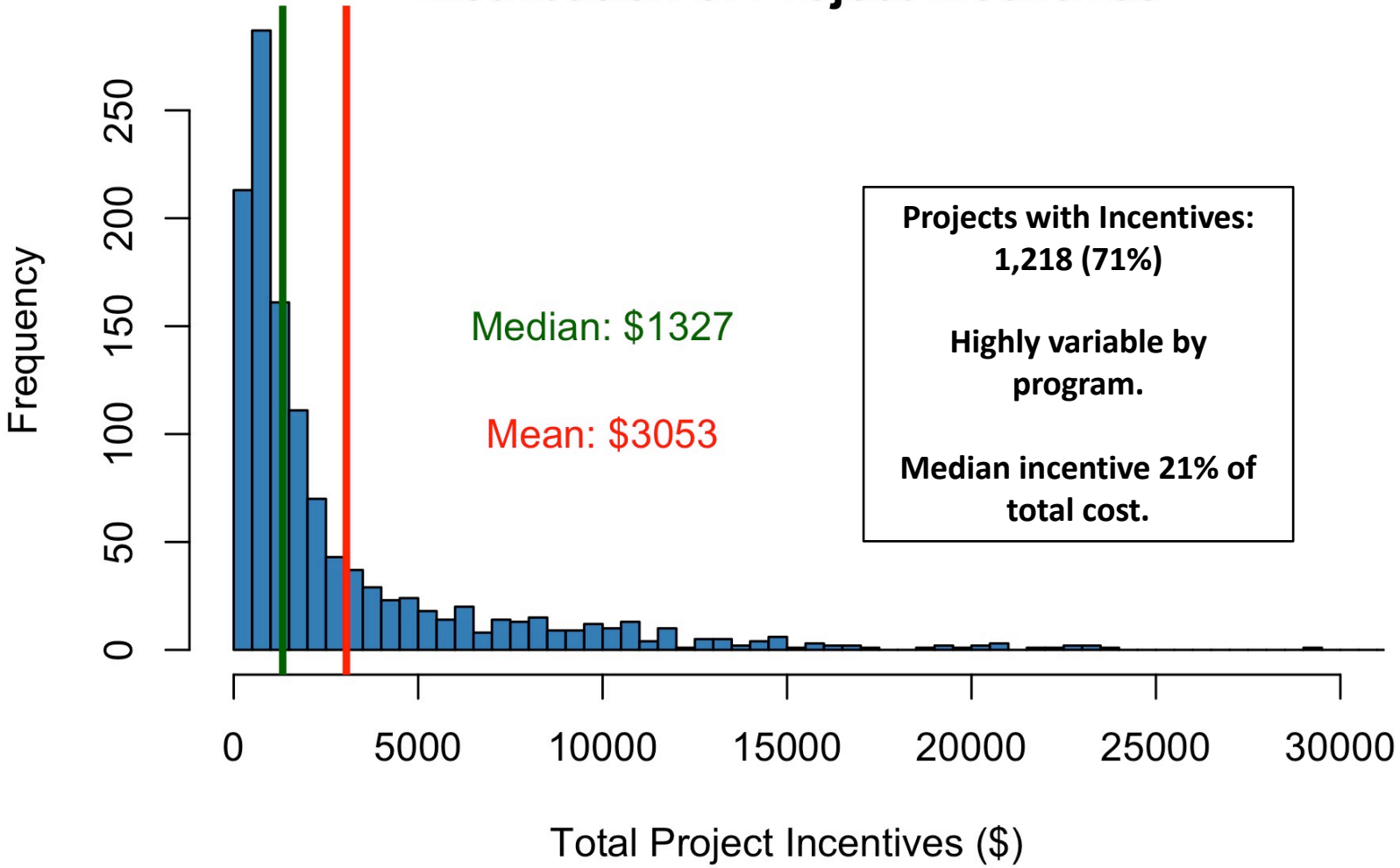

Count of Measures by Section
Measures
10000
8000
6000
4000
2000
0
363
399
457
607
Includes PV
1540
3374
3484
Doors
Appliance
Plumbing
Foundation
Windows
Walls
House
Electrical
Attic
HVAC


Number of Projects by Vintage
Frequency
800
700
600
500
400
300
200
100
0
10
49
52
72
150
728
476
114
1800-1849
1850-1899
1900-1919
1920-1939
1940-1959
1960-1979
1980-1999
2000-2020
Fairly consistent across Climate Zones


Distribution of Gross Project Costs
Frequency
0
50
100
150
200
Median: $8740
Mean: $14329
0
50000
100000
150000
200000
Gross Project Costs ($)


Distribution of Gross Project Costs,
Greater than 3 Measures
Median: $10802
Mean: $19649
Frequency
0
50
100
150
0
50000
100000
150000
200000
Gross Project Costs ($)

Distribution of Project Incentives

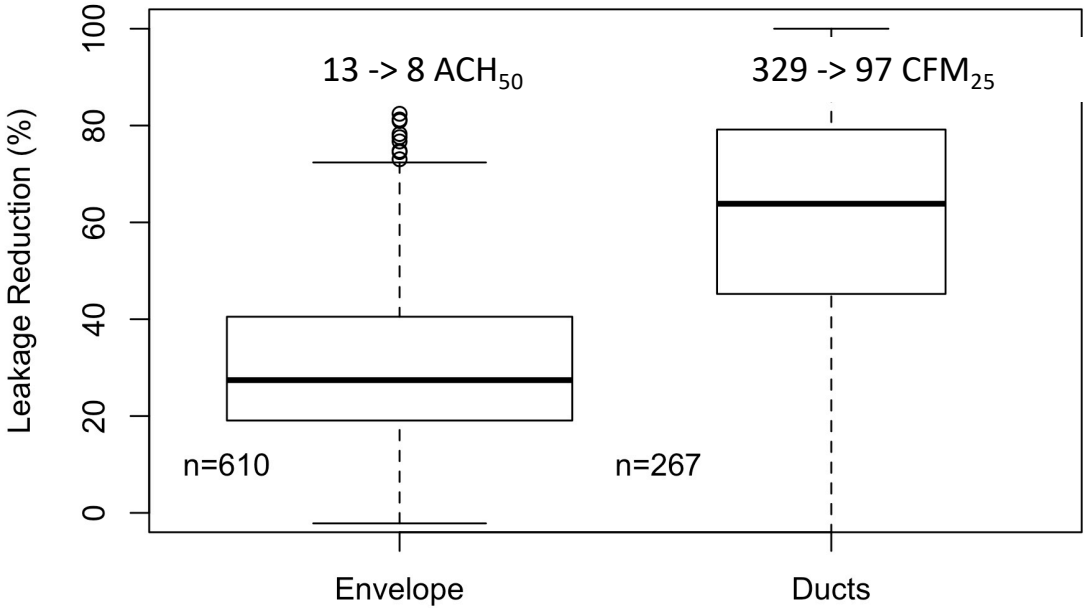


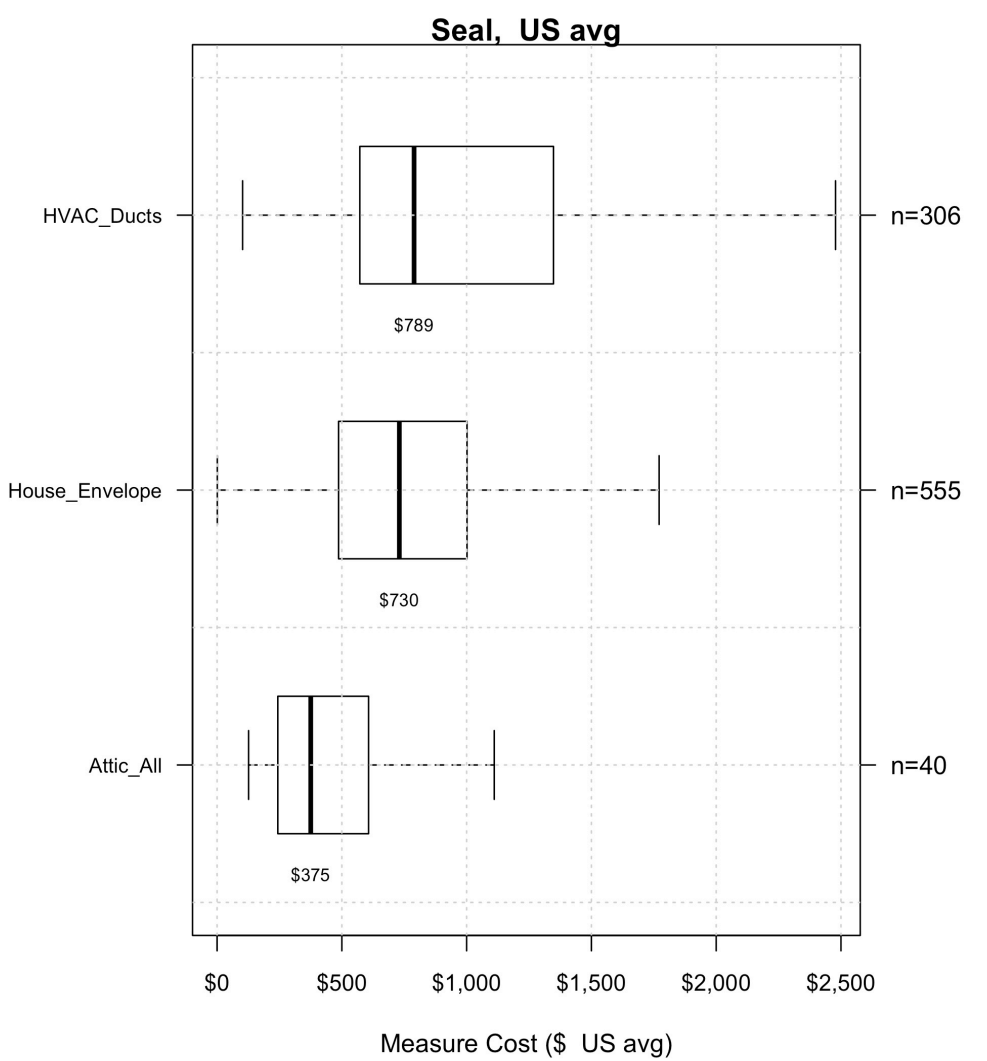
Projects with Incentives: 1,218 (71%)

Highly variable by program.

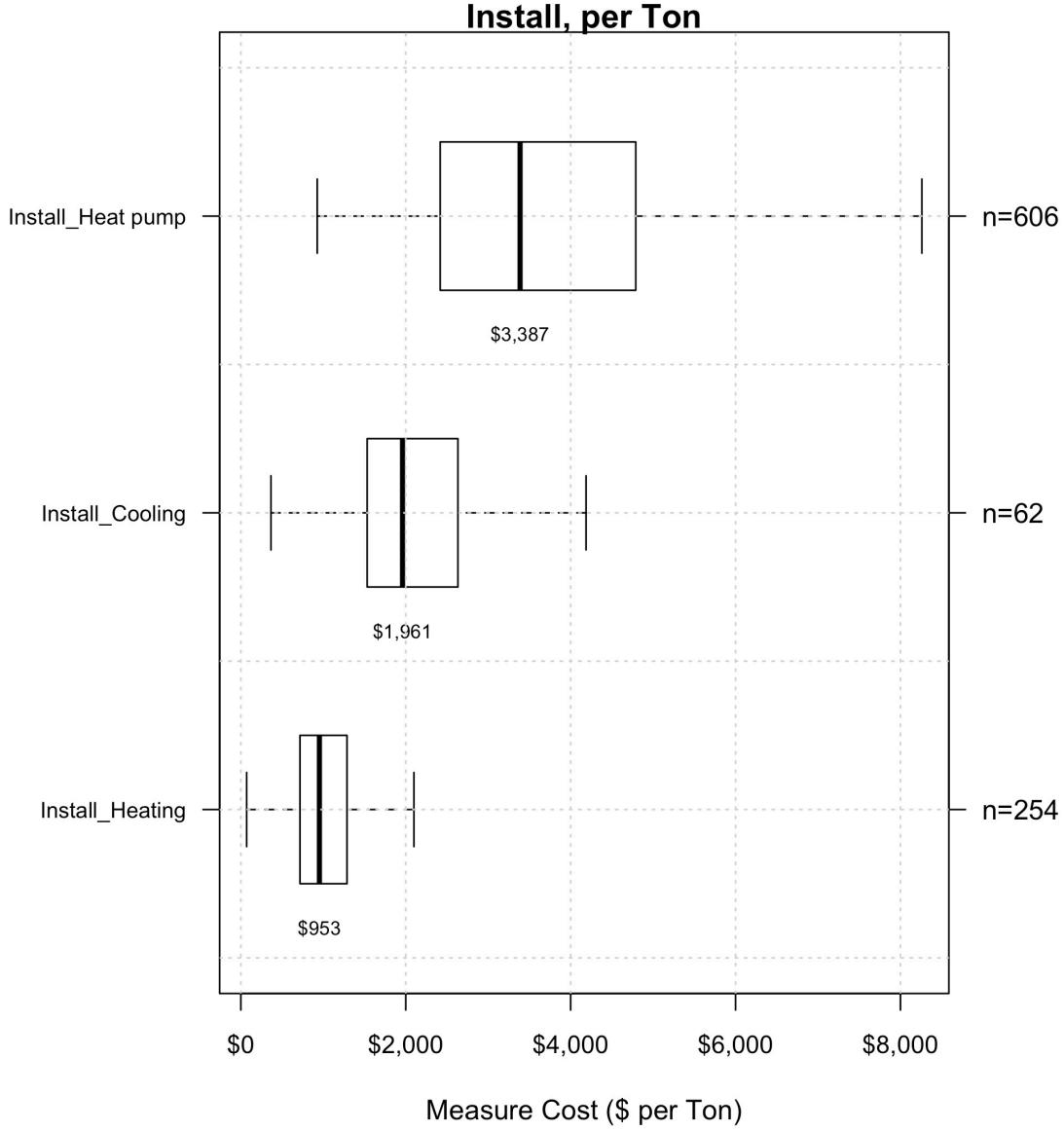
Median incentive 21% of total cost.

AIR SEALING COST AND PERFORMANCE



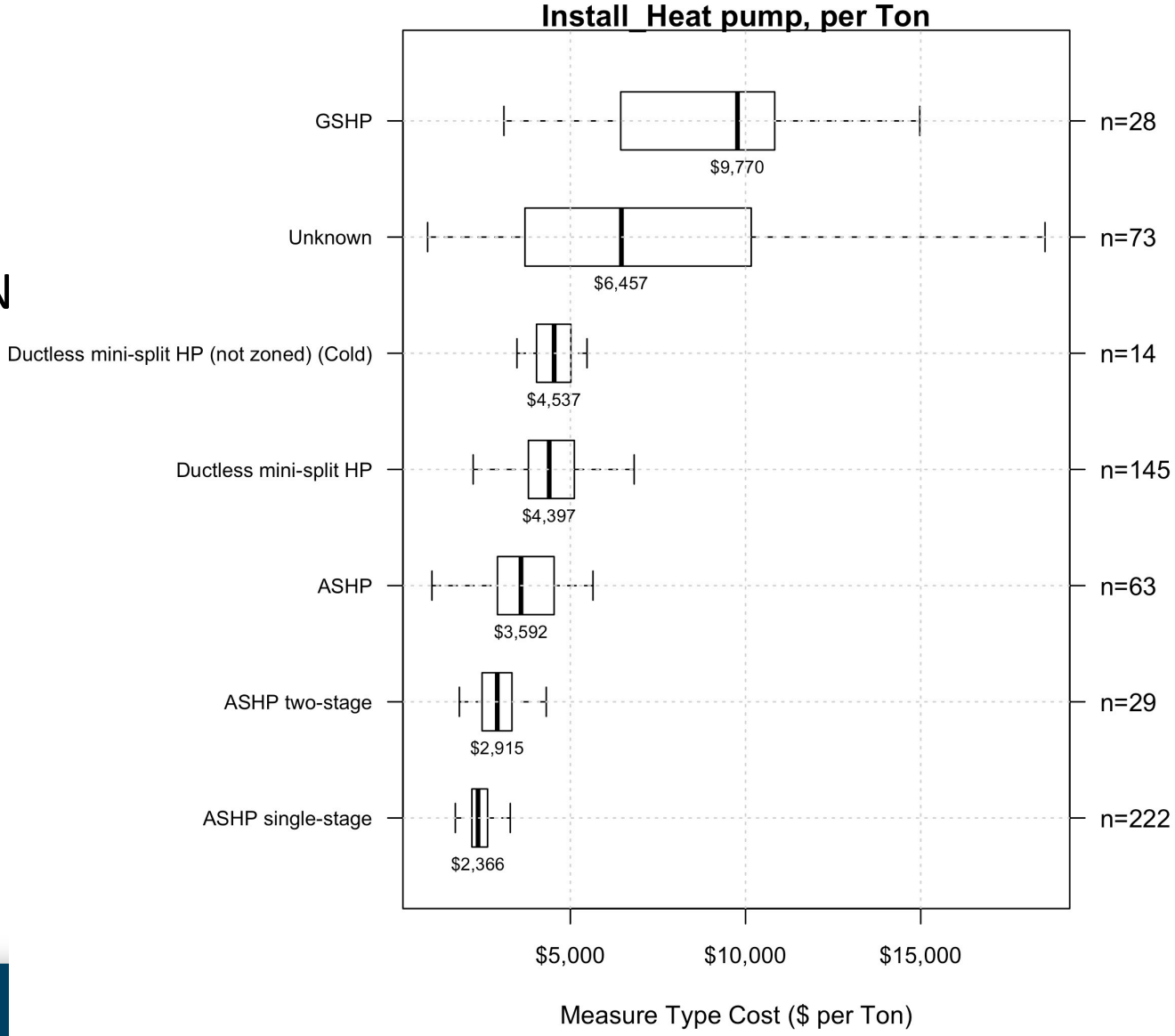


HVAC INSTALLATION COST PER TON



Much larger heating systems are typically installed, which levels out the total system costs

HEAT PUMP INSTALLATION COST PER TON

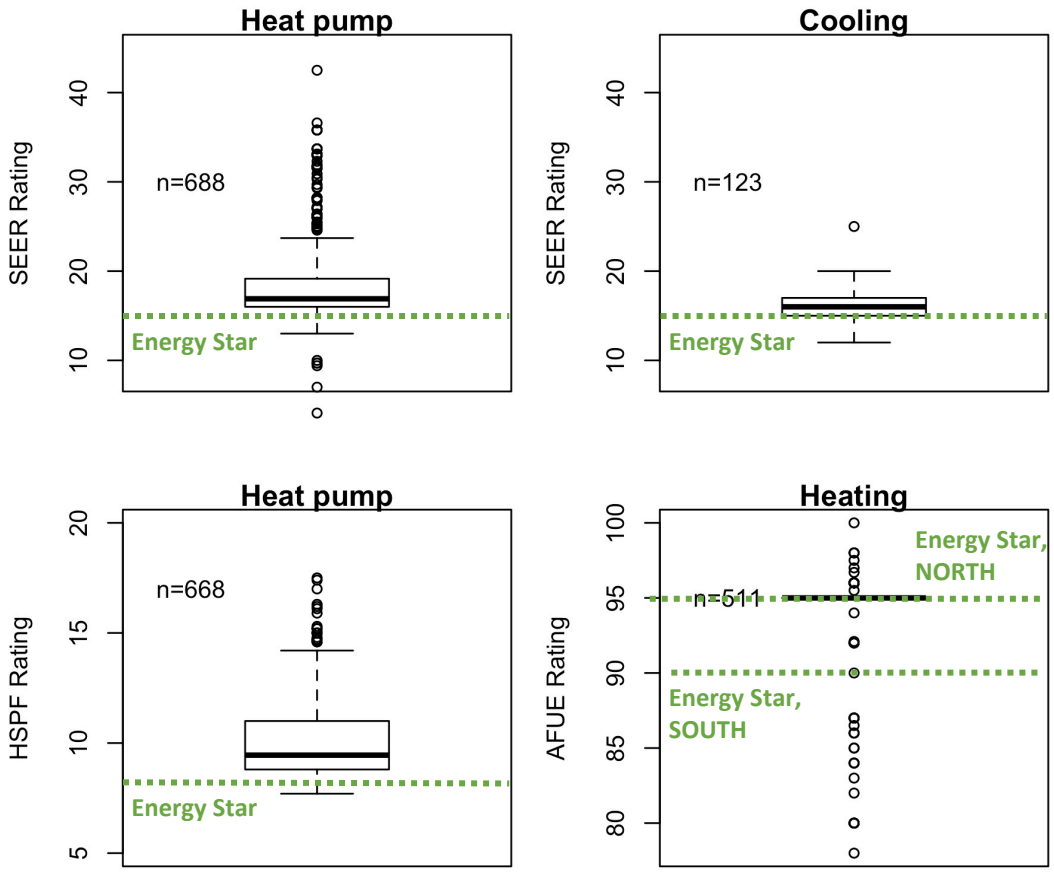


Ground source are 2x the price per ton

<$200 per ton cost premium for “cold” climate units?

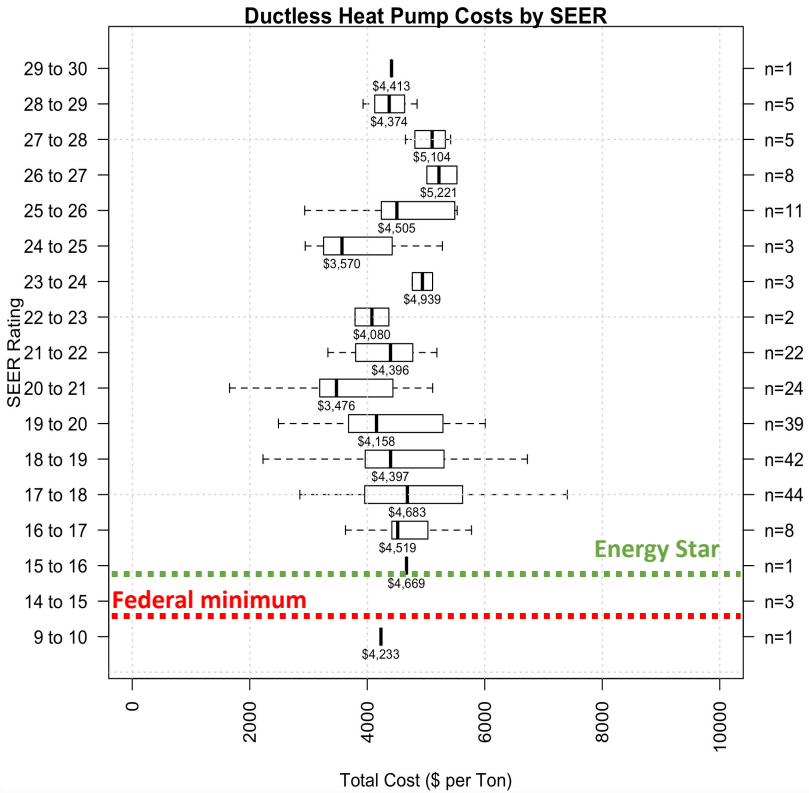
Dominated by lower SEER and HSPF units installed in NC

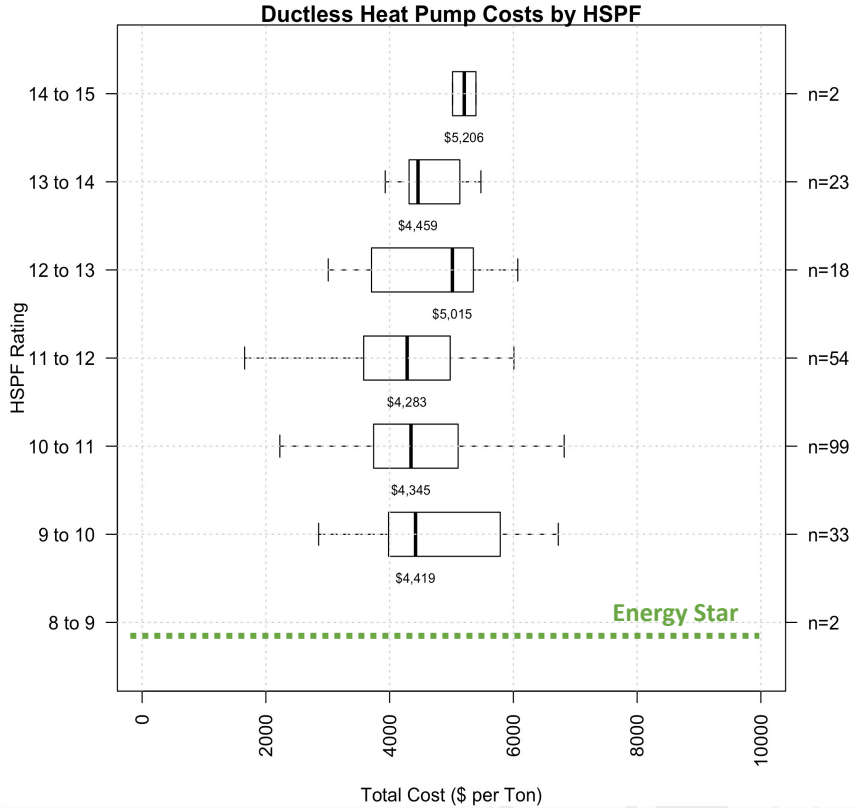
HVAC Equipment Efficiency



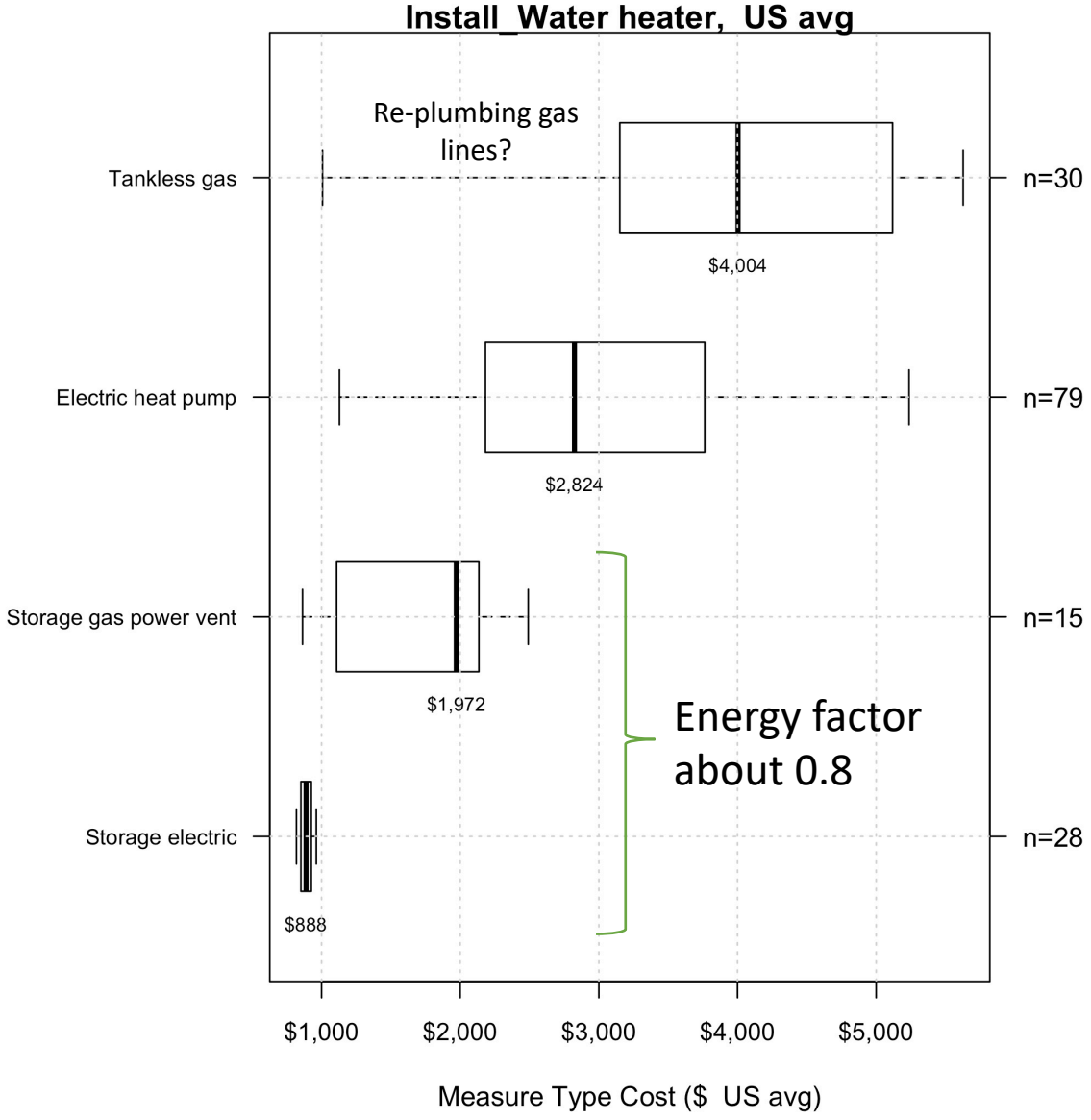
IS "BETTER" MORE EXPENSIVE?

Non-efficiency features dominate installed costs: brand, location, installer, site access, electrical requirements, etc.





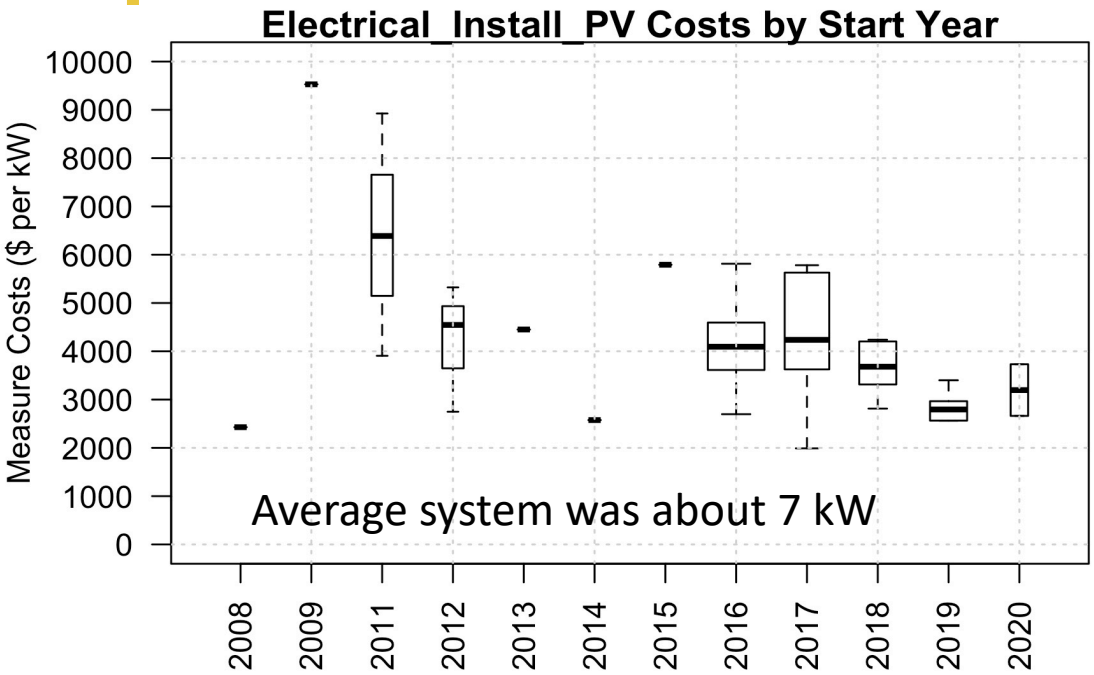
WATER HEATER INSTALLATION COST

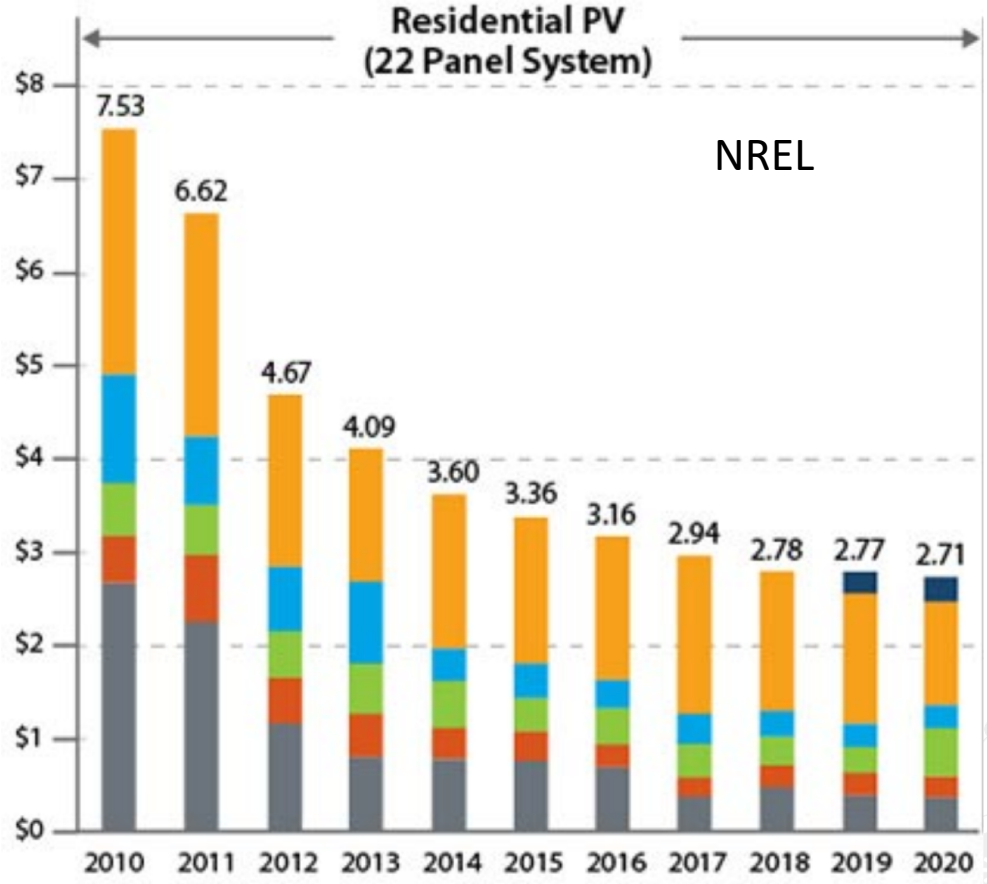


Energy factor about 0.8

Energy factor about 3.2

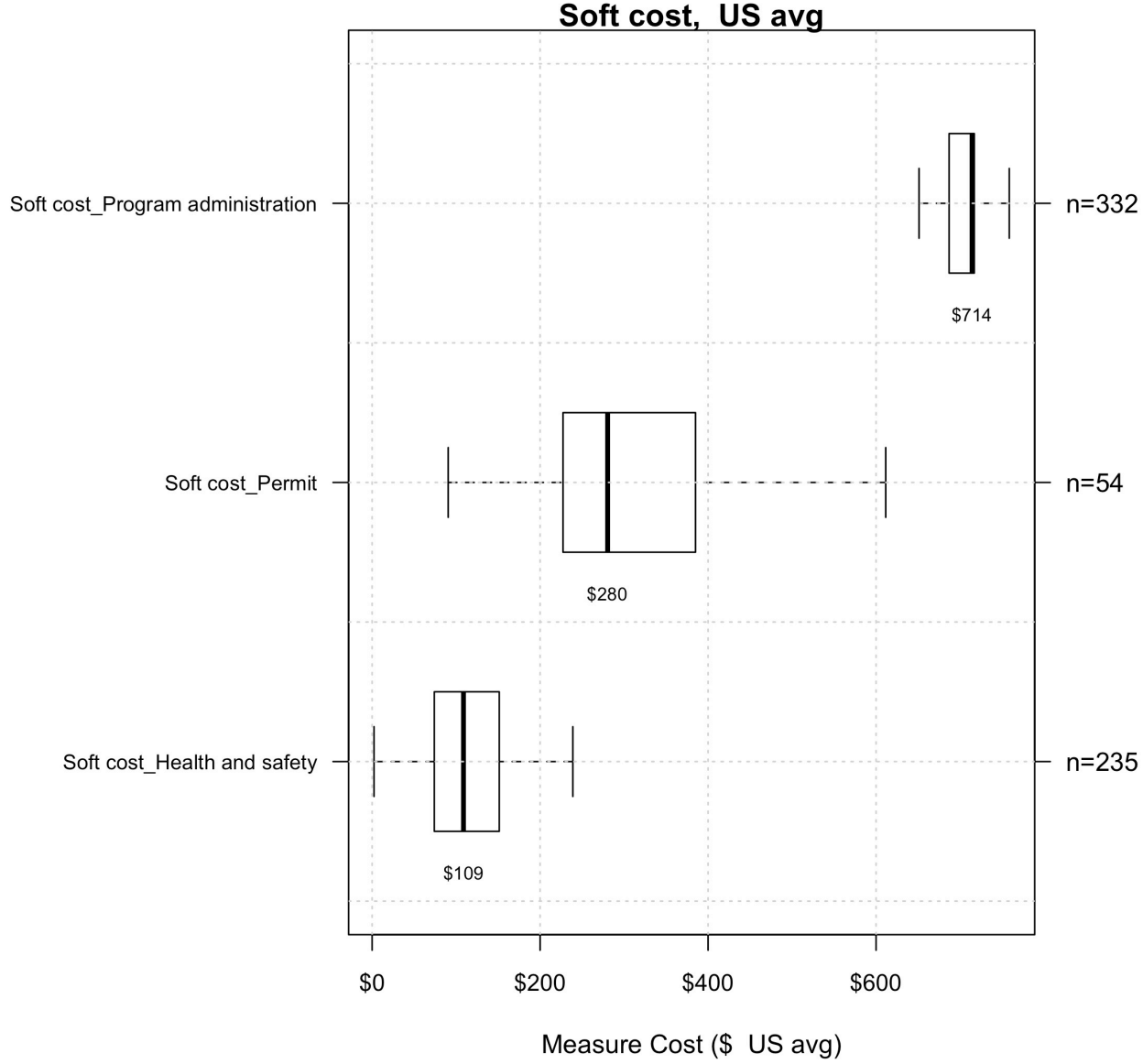
PV Cost Over-Time



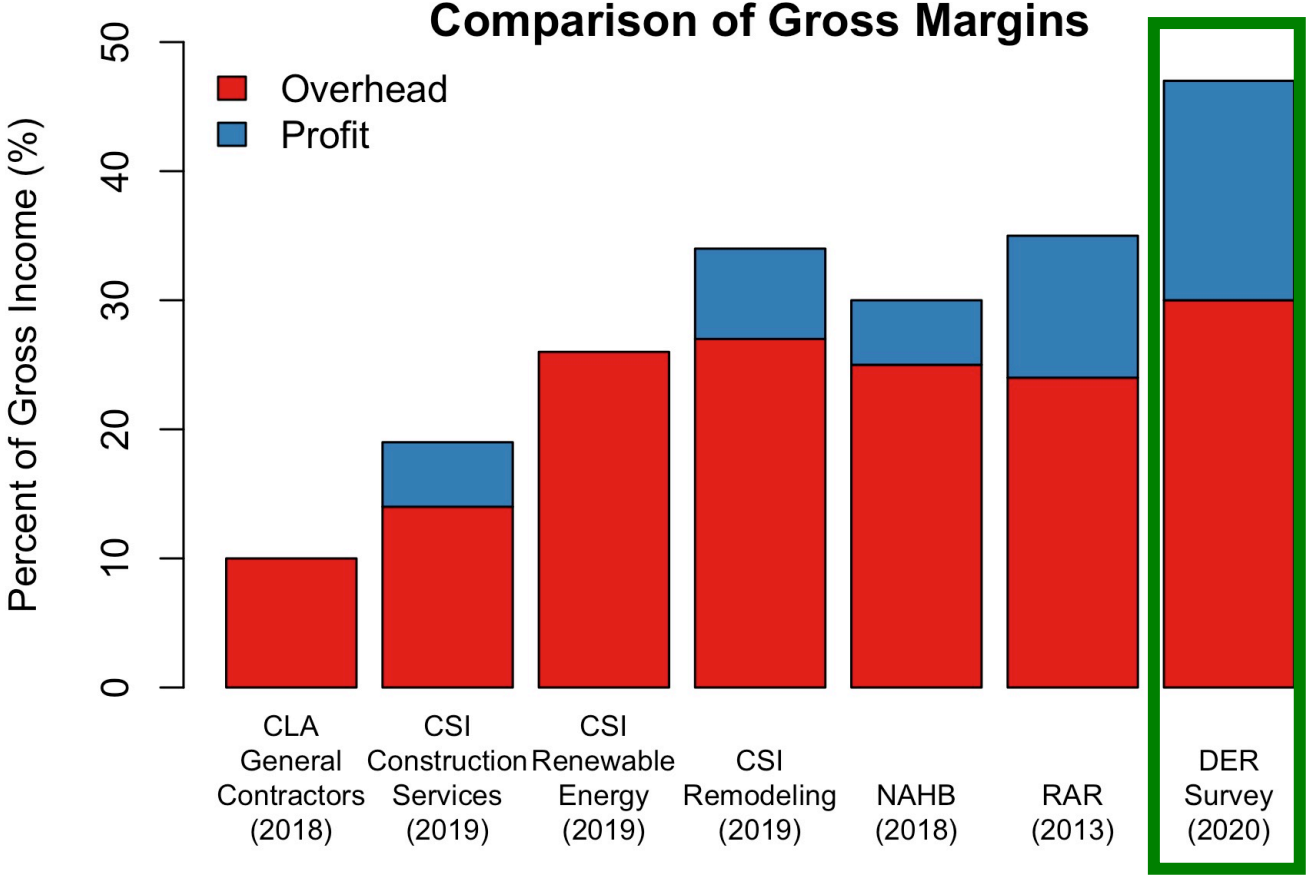


https://www.nrel.gov/solar/solar-installed-system-cost.html

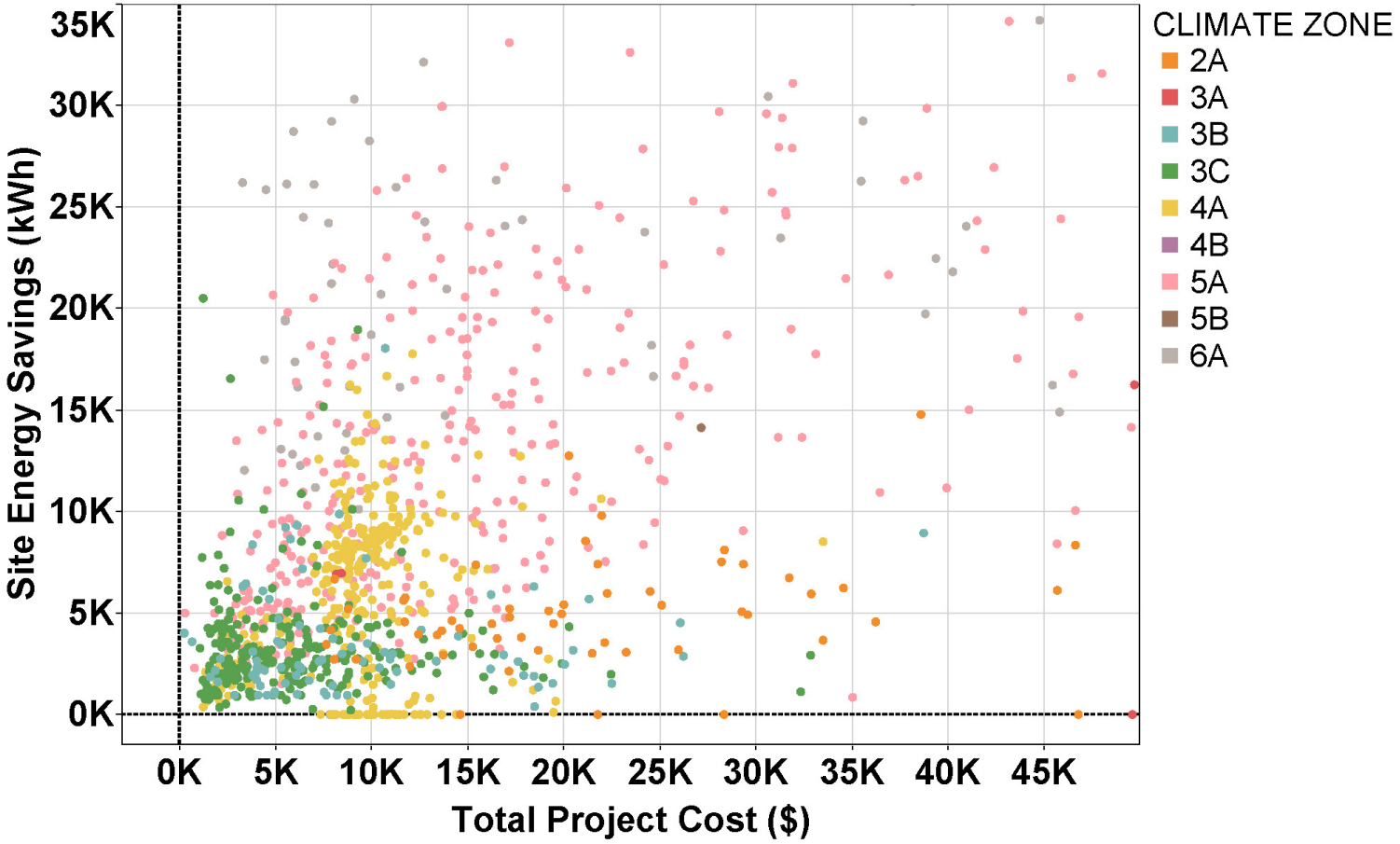
SOFT COST PER PROJECT



Soft Costs (State-of-the-art Review)



DOES MORE COST = MORE ENERGY SAVINGS?

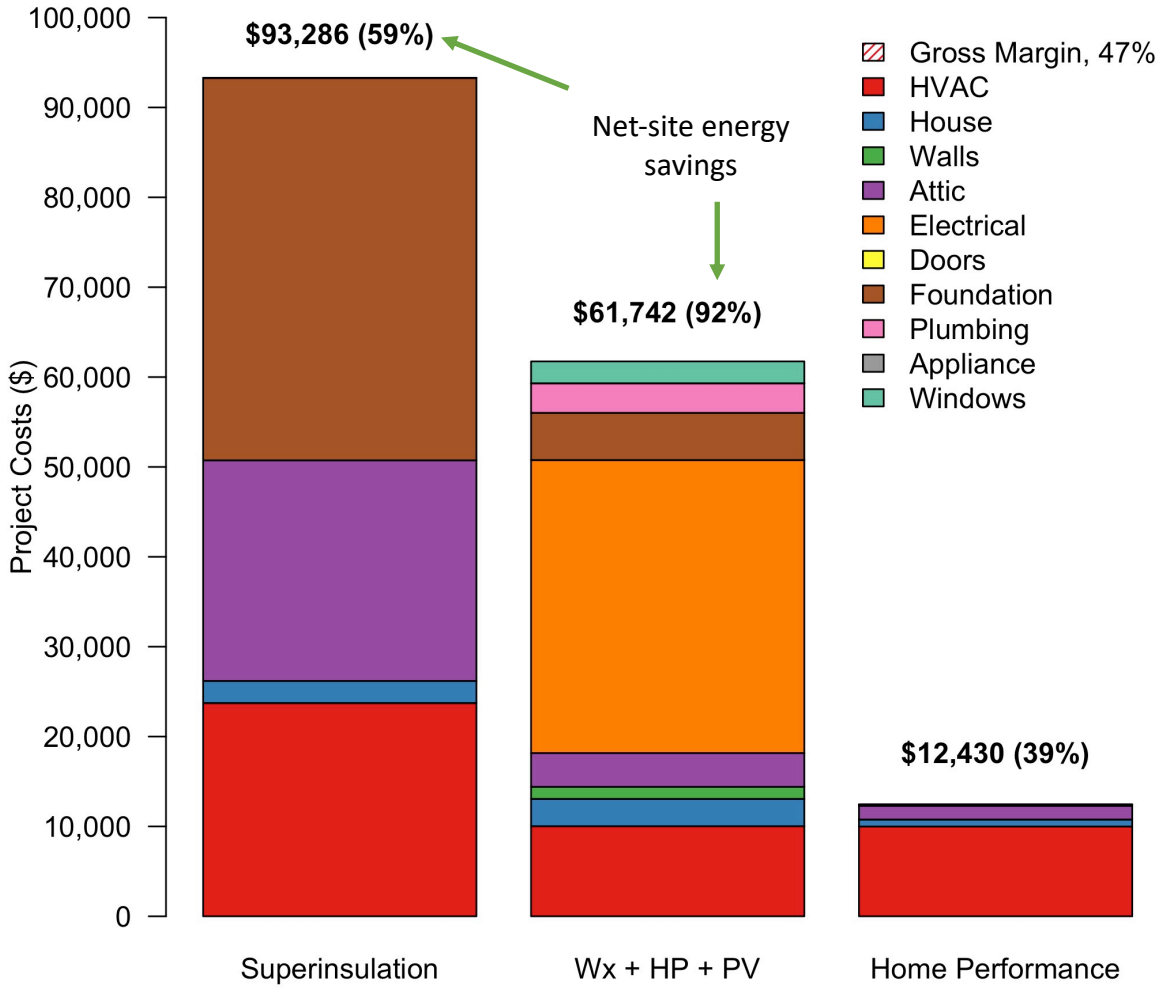


Typical Retrofit Packages

Example Archetypal Projects

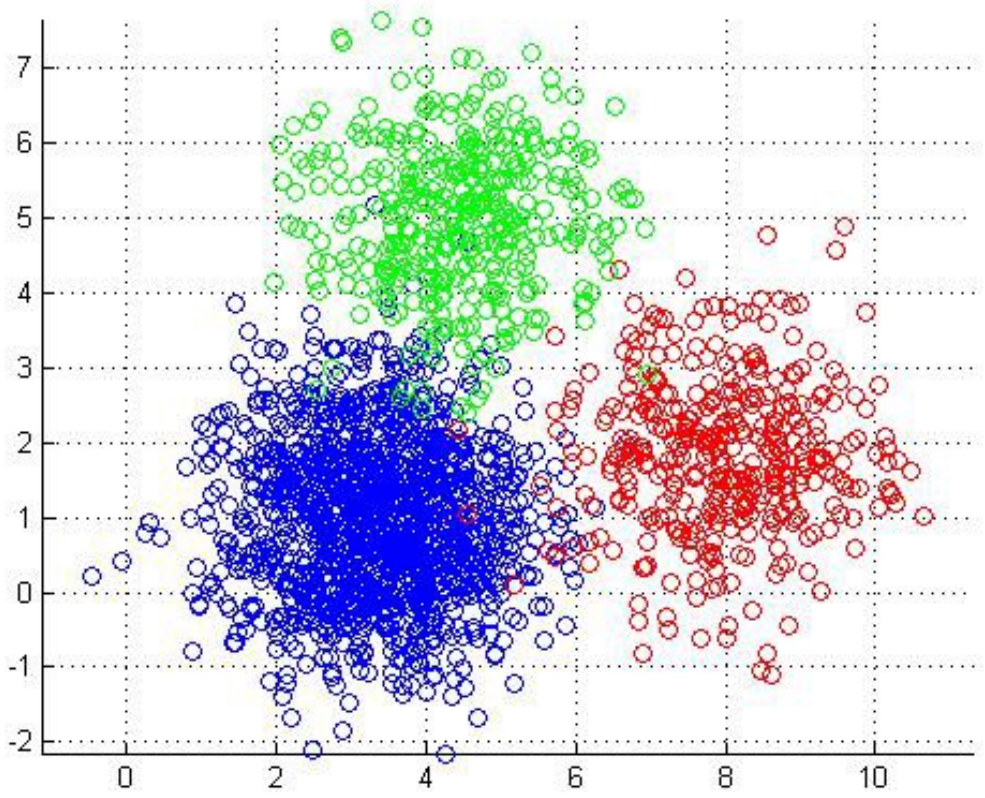
Three archetypal retrofits – these are specific projects NOT averages

Traditional super-insulation is outperformed by emerging Heat pumps + Wx + PV



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 - Descriptions

Label	Description	Total Project Cost ($)	Number of Projects	Number of Measures	Project Length (months)
Low Cost Weatherization	Low-cost, basic retrofit (insulation with some HVAC)	$3,849	671	2	1
Medium Cost Weatherization	Medium cost, basic retrofit (HVAC with some insulation)	$10,105	857	3	1
Medium Cost HVAC Focused	Medium cost, HVAC-focused retrofit (HVAC with some insulation)	$26,228	136	2.5	1
High Cost Large HVAC Focused	High cost, HVAC-focused retrofit of large homes (HVAC, insulation, DHW, some lighting and PV)	$120,802	14	9	3
High Cost Envelope Focused	High cost, classic comprehensive deep retrofit (HVAC, Insulation, some DHW, and Windows)	$109,059	15	16	15
Medium Cost HP/PV Focused	Medium cost, heat pump and PV-focused retrofit (PV, HVAC, insulation, and some DHW)	$54,098	43	10	4

Clustering Project Types - Performance

Cluster	Site Energy Savings (%)	Site Energy Savings (kWh/sqft)	Energy Cost Savings ($/sqft)	Project Cost ($/sqft)	Cost of Saved Energy ($/kWh)	Simple Payback (years)
Low Cost Weatherization	20%	2.3	$0.15	$2	$0.08	15
Medium Cost Weatherization	33%	4.2	$0.38	$6	$0.12	16
Medium Cost HVAC Focused	40%	6.8	$0.14	$11	$0.16	60
High Cost Large HVAC Focused	56%	9.0	$0.25	$23	$0.24	82
High Cost Envelope Focused	64%	14.0	$0.61	$57	$0.40	120
Medium Cost HP/PV Focused	72%	14.5	$0.89	$28	$0.18	31

Typical CO_2e savings were roughly 70 vs. 50% for the highlighted clusters.

Regression Modeled Archetypes

Upgrade equipment with electrical heat pumps, focused insulation/sealing and medium PV system.

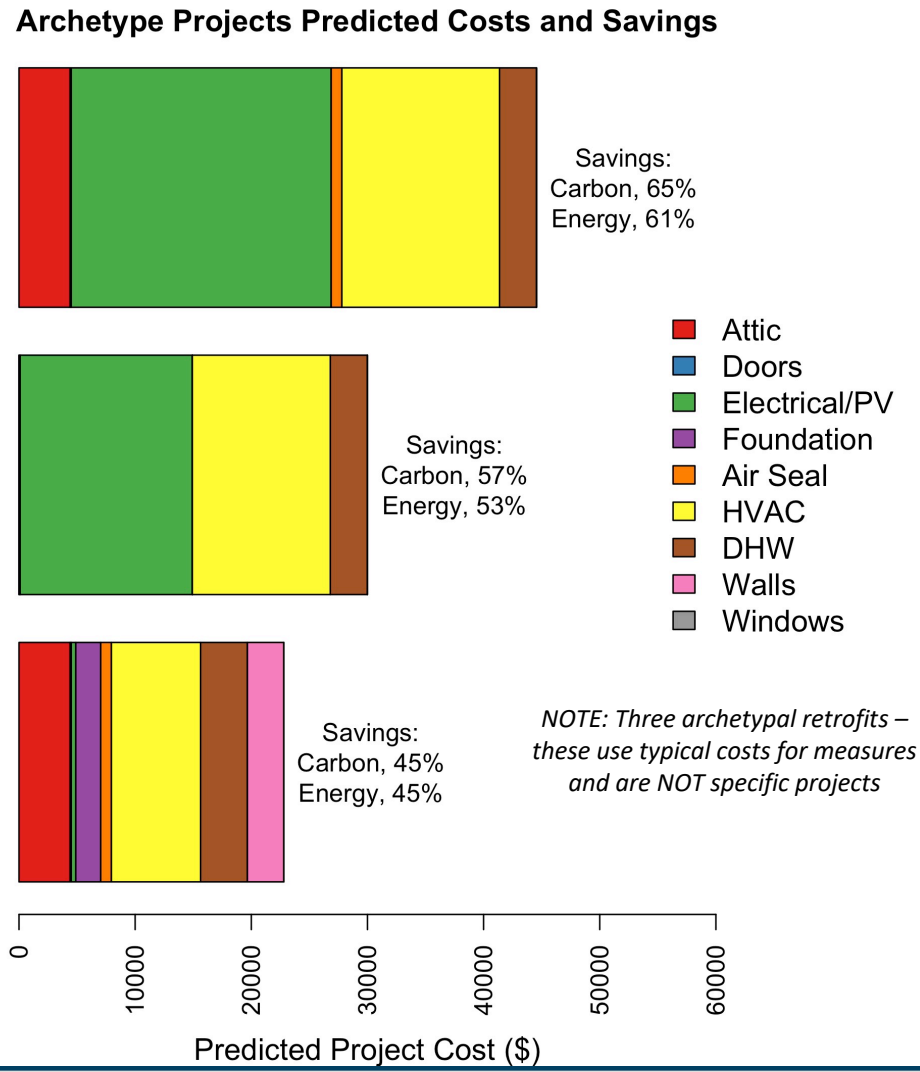
Equipment - Electric
Envelope - Wx
PV - Medium

Equipment-only upgrade with electrical heat pumps and small PV system.

Equipment - Electric
Envelope - None
PV - Small

Traditional, aggressive home performance upgrade without fuel switching and no PV.

Equipment - Gas
Envelope - HP
PV - None



NOTE: Three archetypal retrofits – these use typical costs for measures and are NOT specific projects

Project Cost Solicitation

OTHER REMARKS

- Not many window replacements – very costly and not much energy savings
- Some key upgrades missing but will become more critical in the future: installing ventilation/air cleaning – much more awareness now of this issue. Only 58 homes had MV installed
- It is possible to have very high (>70%) energy savings with readily available off the shelf insulation, lighting, appliance, DHW and HVAC solutions. We recommend using these existing technologies because they are easy to find, and will be easier to maintain and have proven reliability.
- Simple load reduction with PV and electrification is a very attractive approach. The energy savings and carbon reductions are very high, the approach is affordable, uses readily available technology and already has a workforce and infrastructure in place familiar with these exiting technologies. Furthermore, it is appealing to homeowners and easier to sell – which is significant if we want to get to scale. It is also flexible in that I can be used in may climates and house types because it is not dependent of climate-specific solutions
- Costs for individual measures vary a lot from house to house. This has implications for business and homeowner risk acceptability. Measures that have better controlled costs (i.e., less variability) are likely to be more attractive due to reduced uncertainty (like PV).

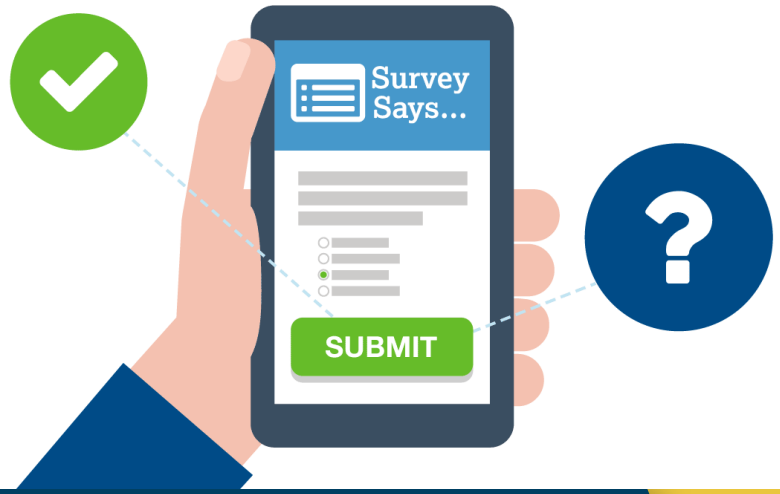
Market Survey

DOE Deep Energy Retrofit Cost Survey (2020)

https://eta.lbl.gov/publications/doe-deep-energy-retrofit-cost-survey

Market Survey

- Qualtrics survey platform
- 20-minute online survey to gather information from building energy professionals on their DER experiences and opinions
  - What motivates and deters DER projects in today's market?
  - Promising strategies and technologies
  - Non-cost aspects of retrofit measures
- 73 survey participants
  - Home performance contractor (25%)
  - Consultant (15%)
  - Program manager (14%)
  - Researcher (12%)
  - General contractor (11%)
  - Other (23%), e.g., engineer, architect, energy rater



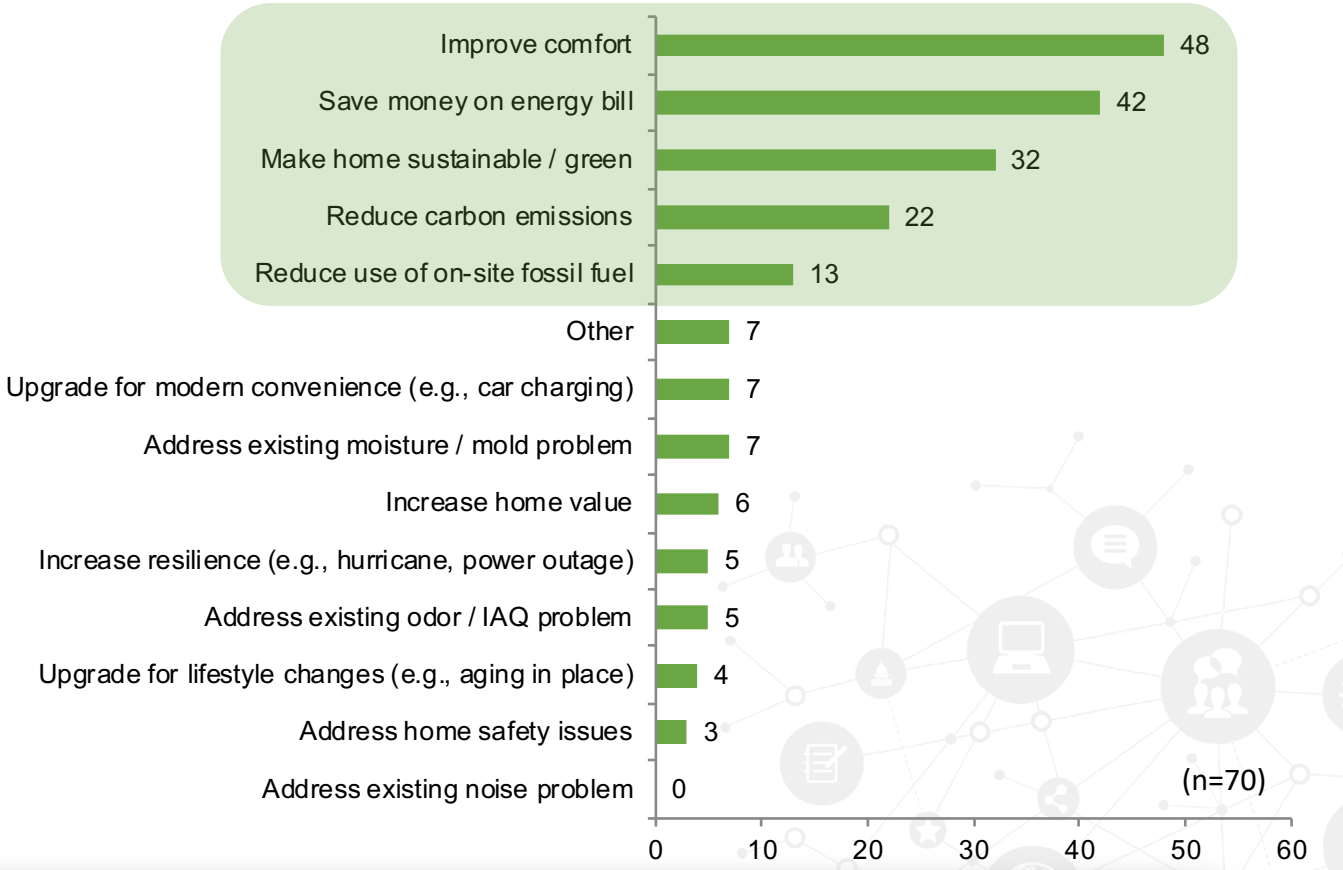
Market Survey

Survey questions organized by main sections of topic:

- Background information about past DER experiences of the respondent.
- Consumer perspective on DER projects
- Home performance contractor perspective on DER challenges
- Promising technologies and approaches to advance DER
- Work scope and approaches to DER from past experiences
- Project costs for performing DER

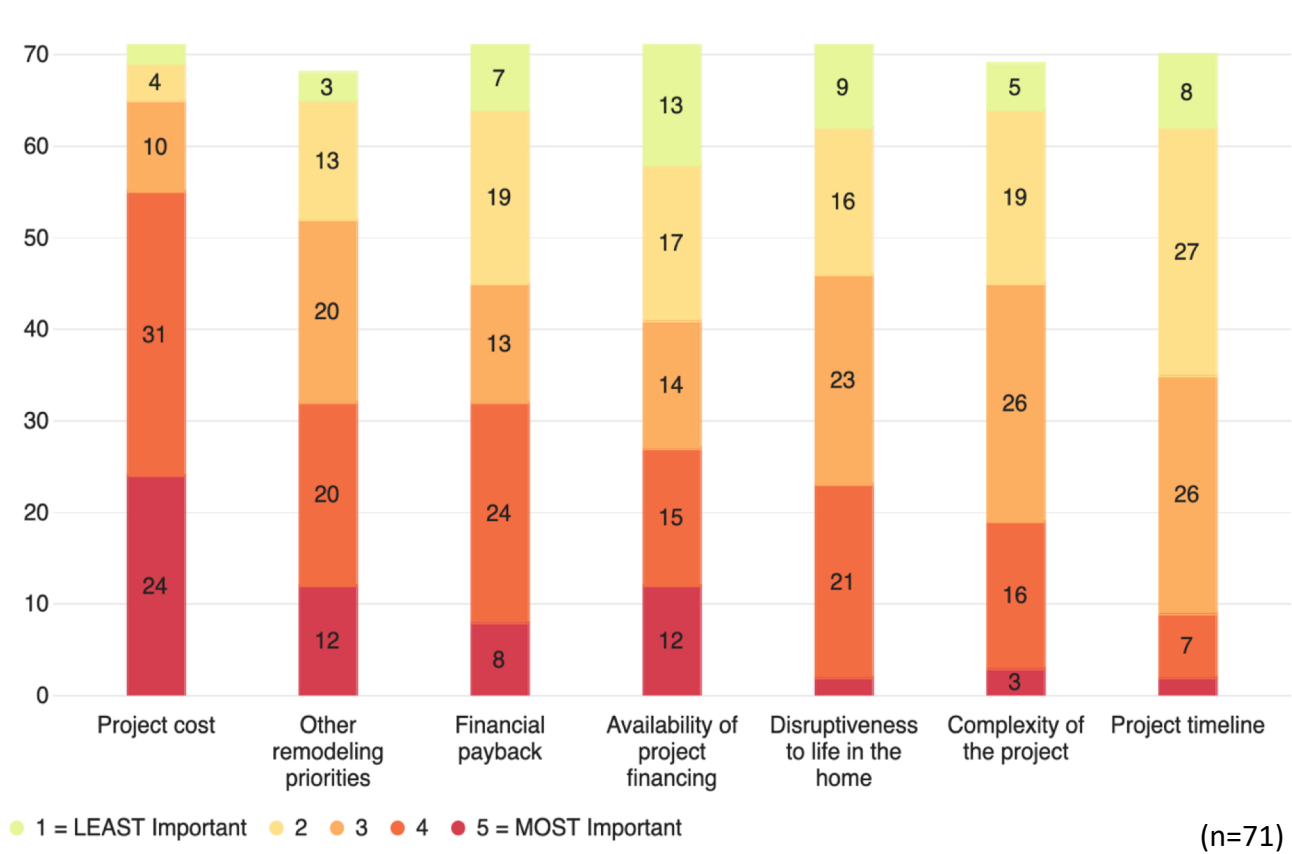
Customer Perspective

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



Customer Perspective

Importance of factors when homeowners decide whether or not to proceed with a DER project



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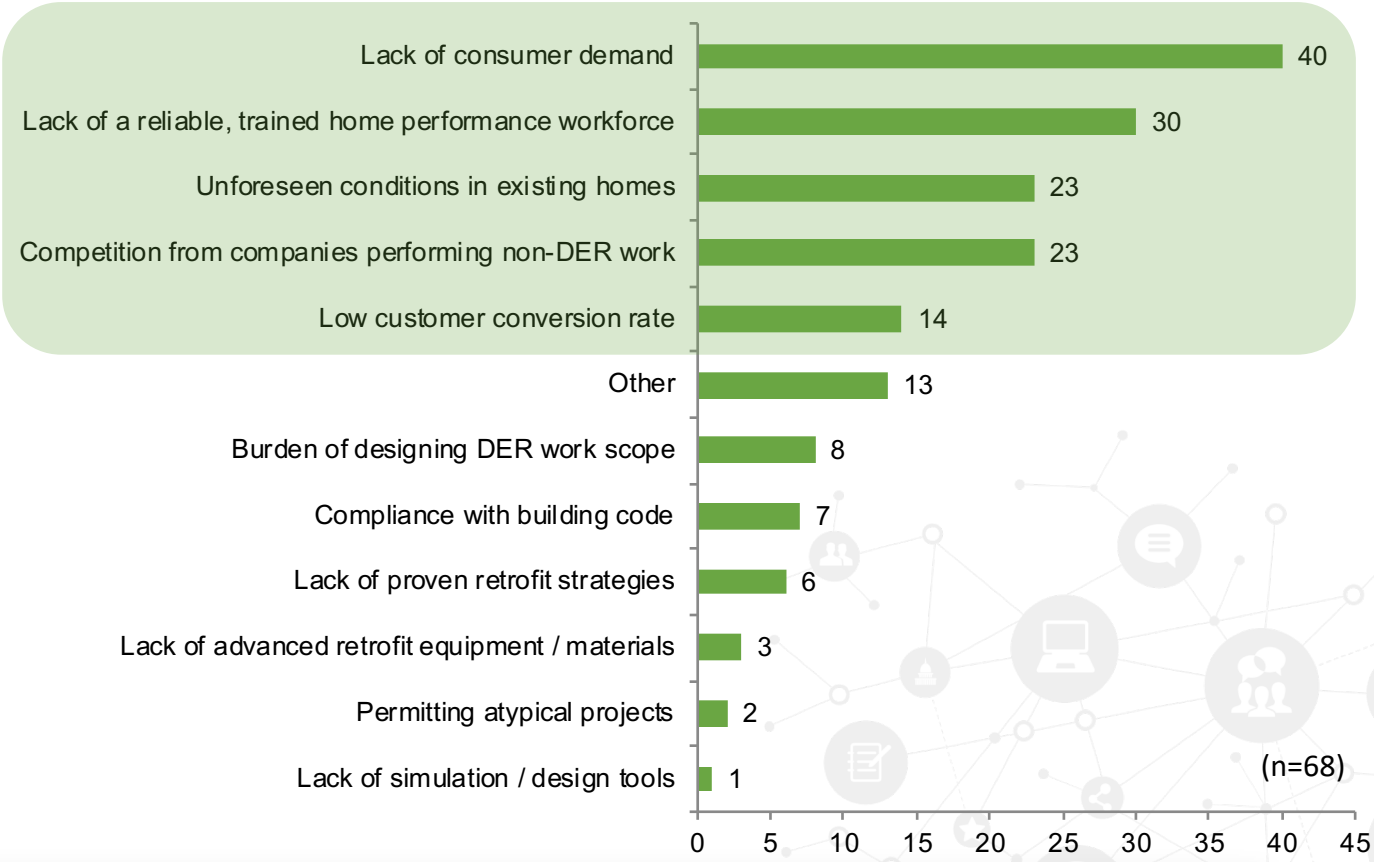
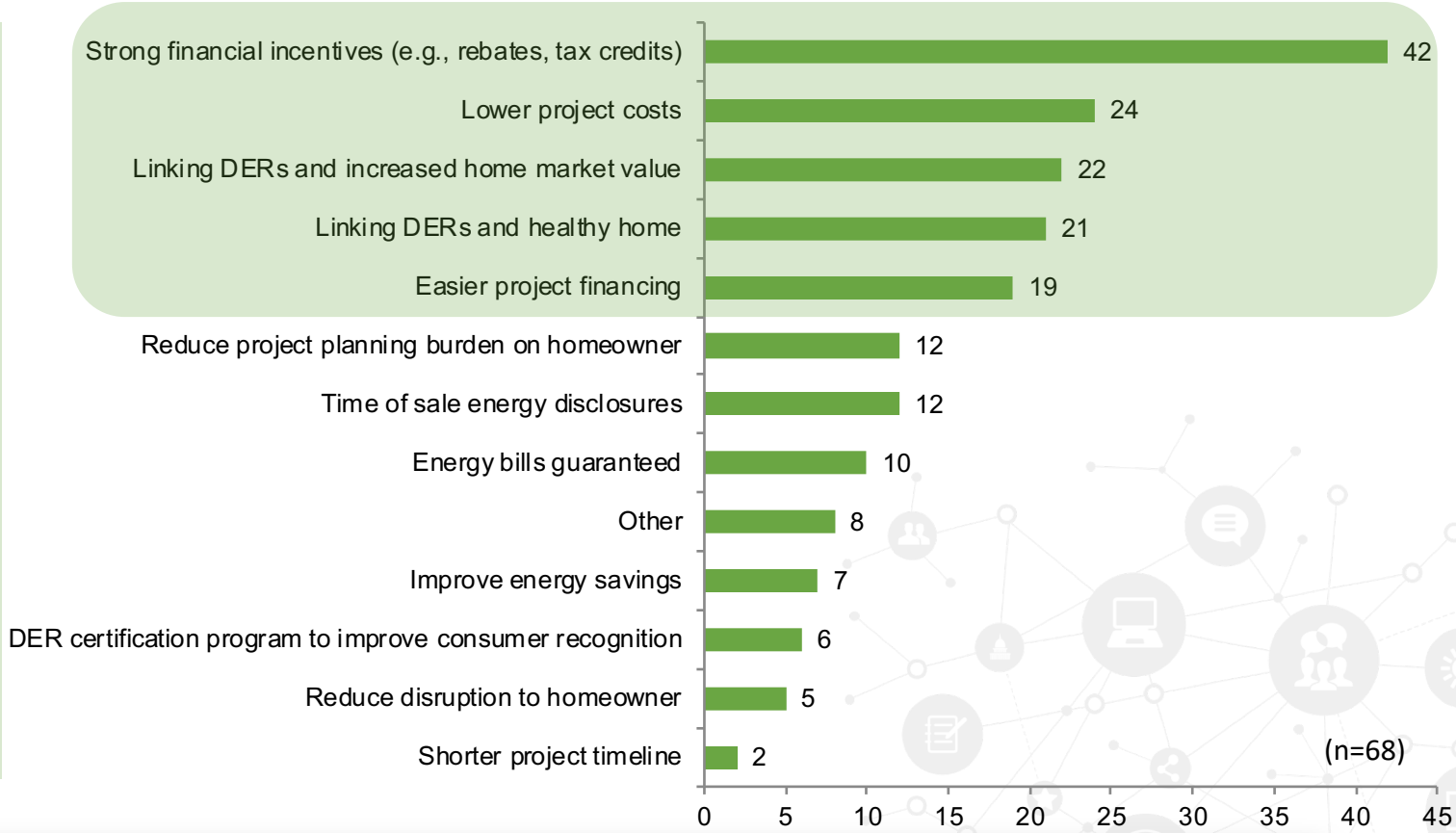
Industry Perspective

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



Industry Perspective

What are the most effective ways to increase customer demand for DER projects?



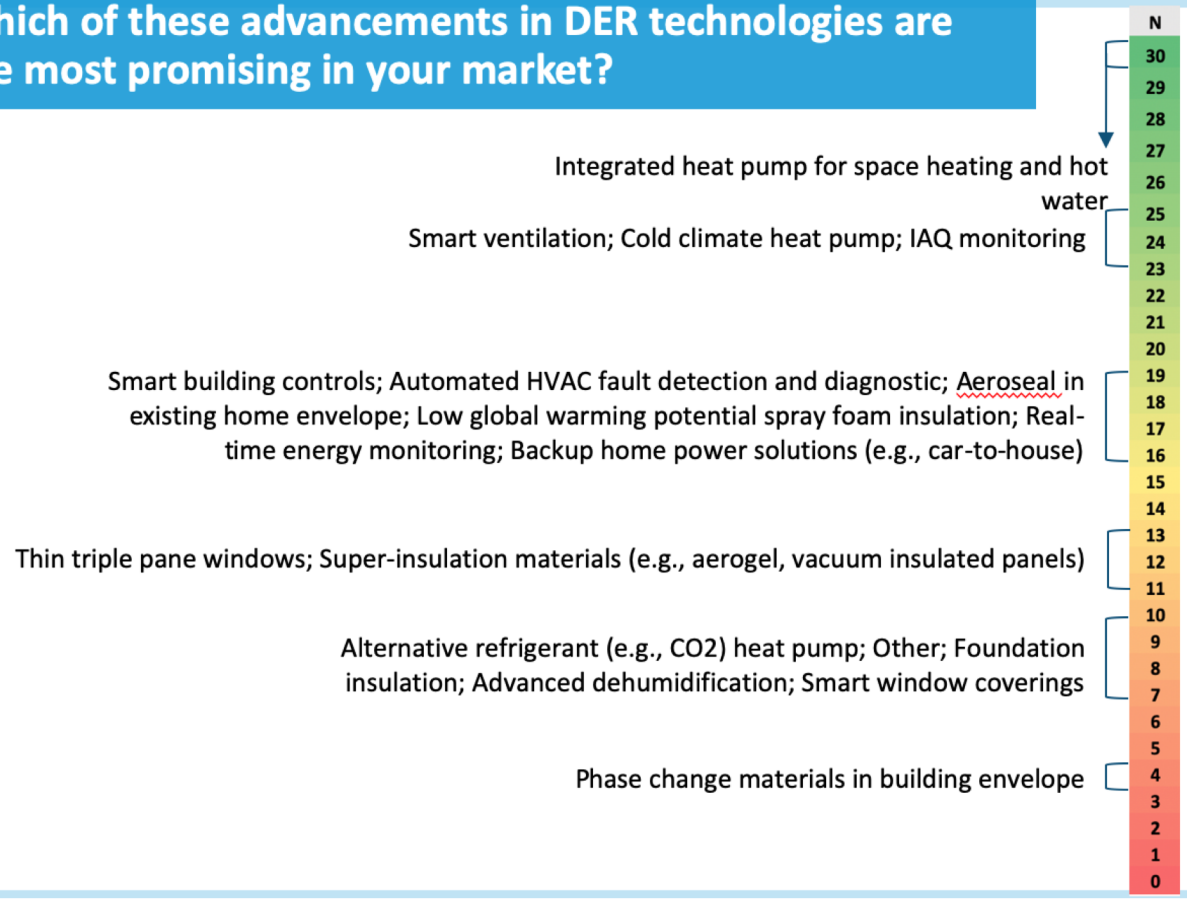
Advanced Technologies and Approaches

Rating of approaches for performing DER in your market.

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

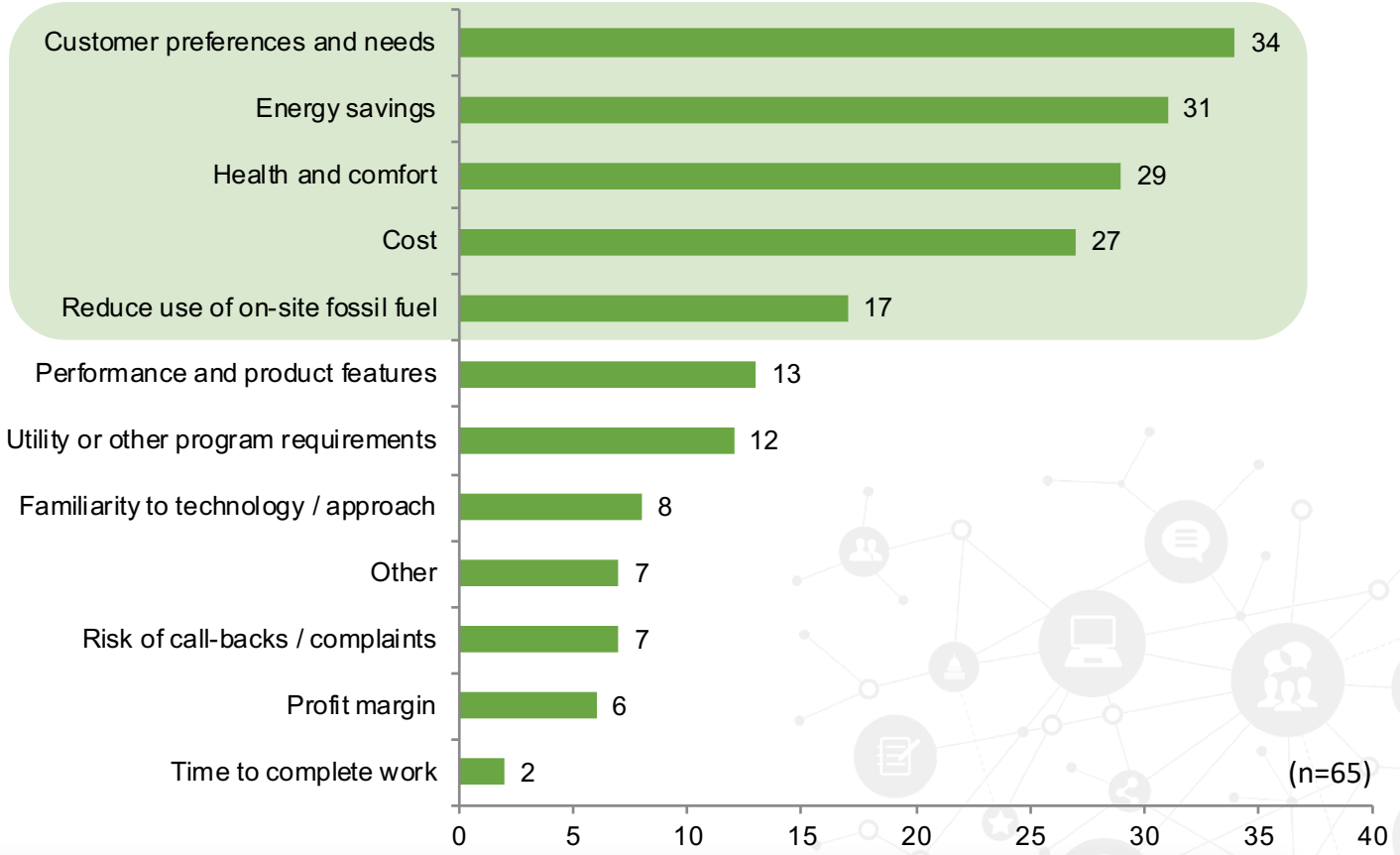
Advanced Technologies and Approaches

Which of these advancements in DER technologies are the most promising in your market?



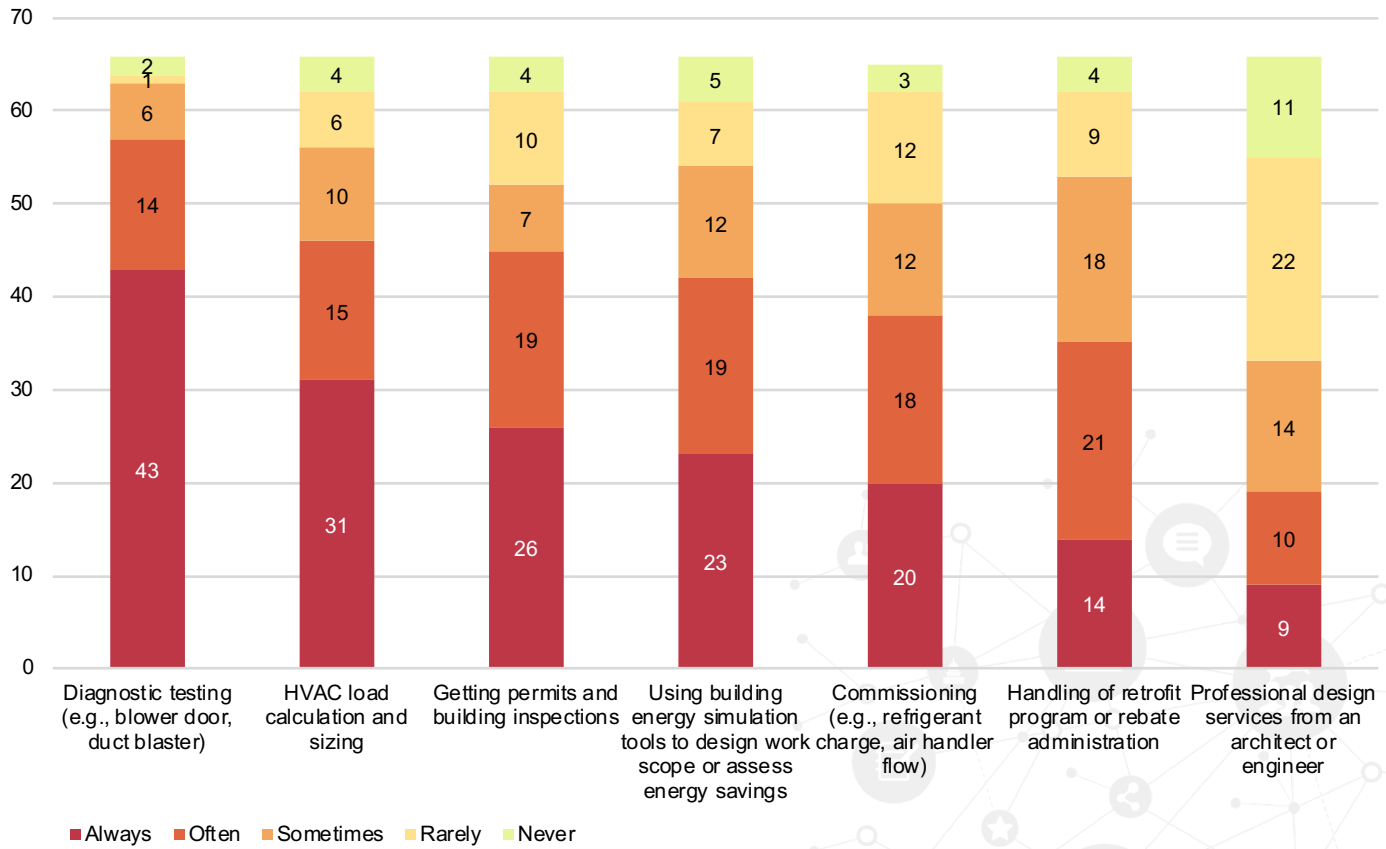
Work Scope and Approaches

When choosing between different retrofit options for the DER projects that you are involved in, what are the leading factors that drive your decision?



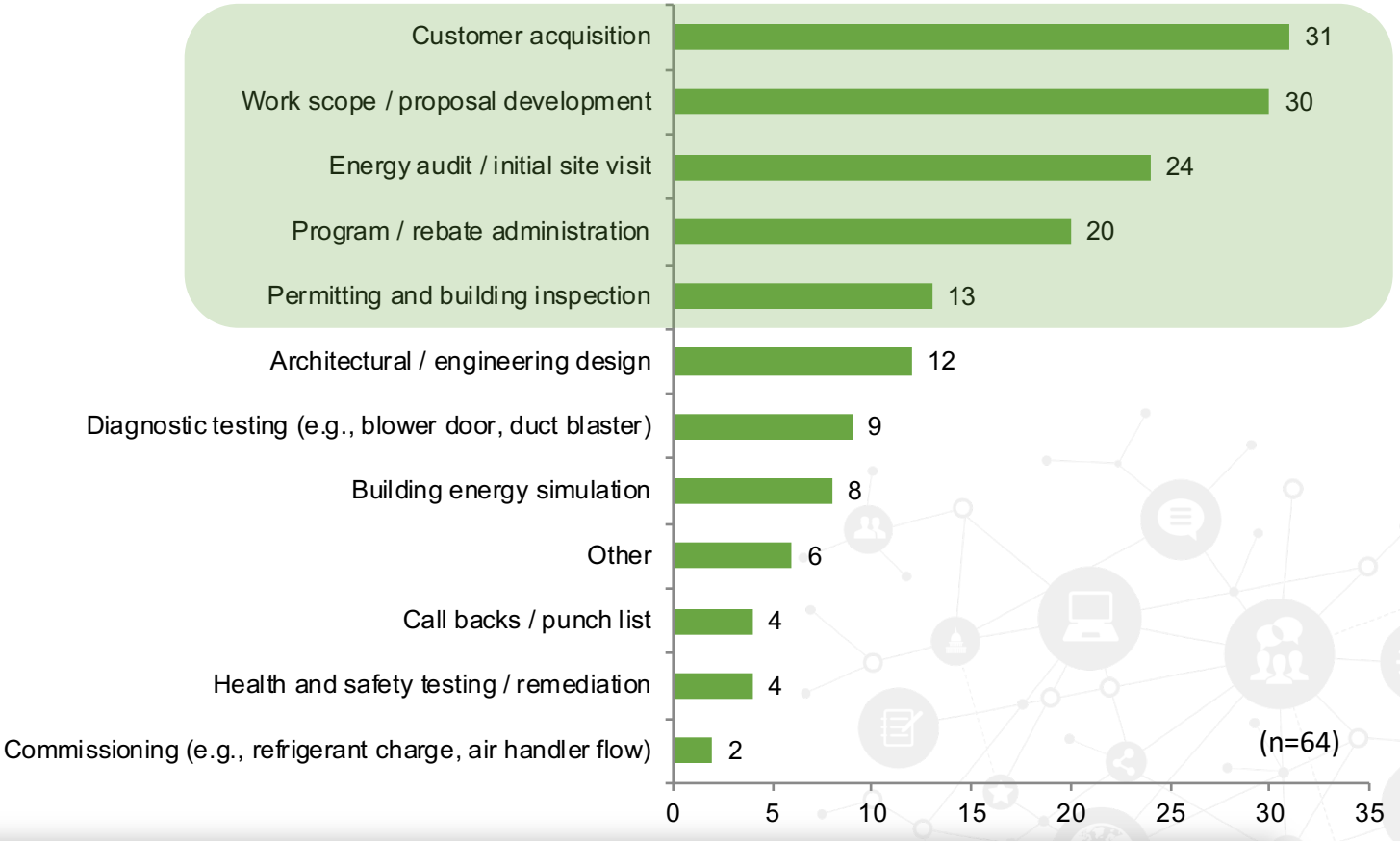
Work Scope and Approaches

Frequency of work elements that are included or involved in DER projects



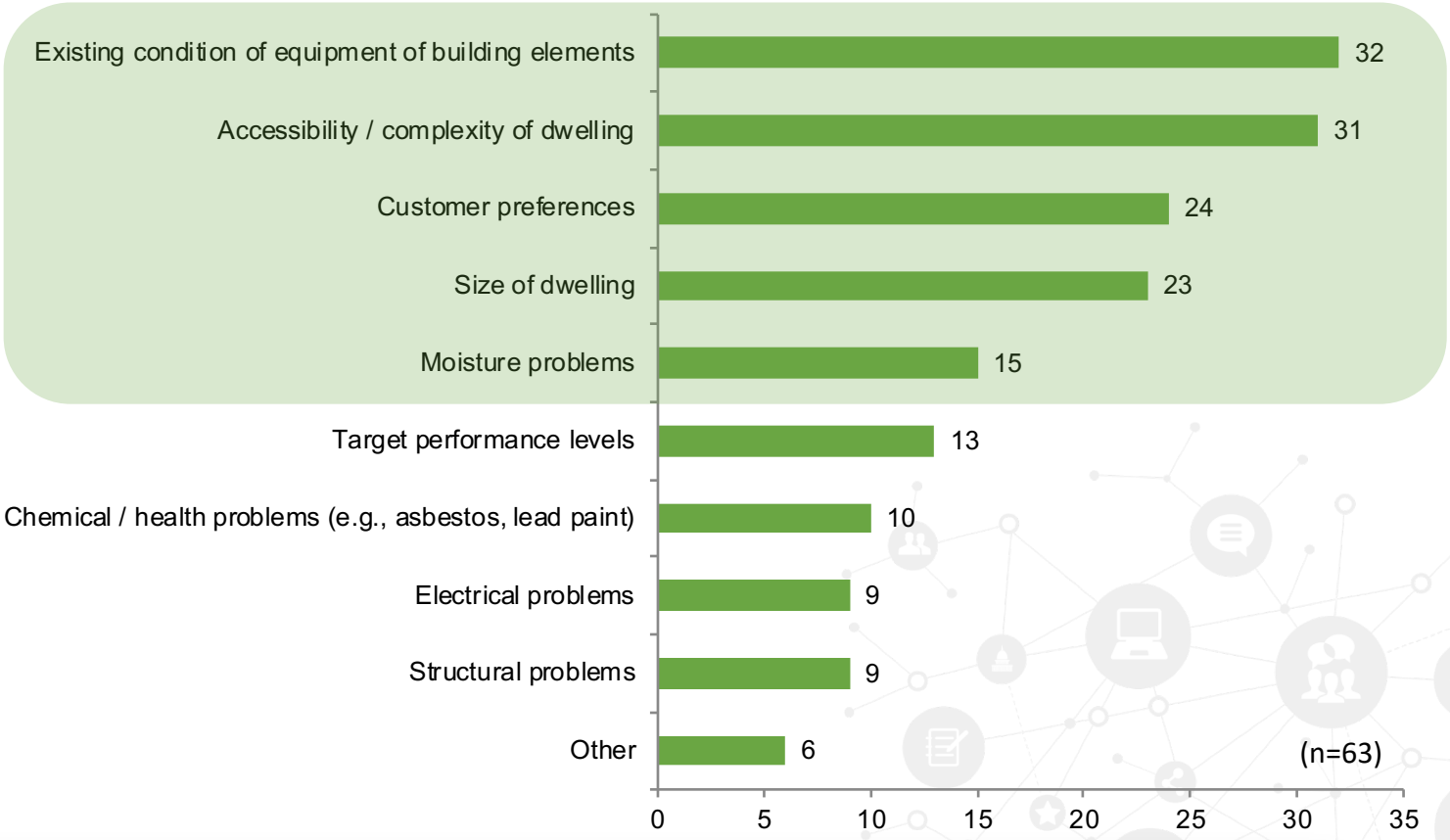
Work Scope and Approaches

Non-construction tasks that survey respondents found to be the most time consuming



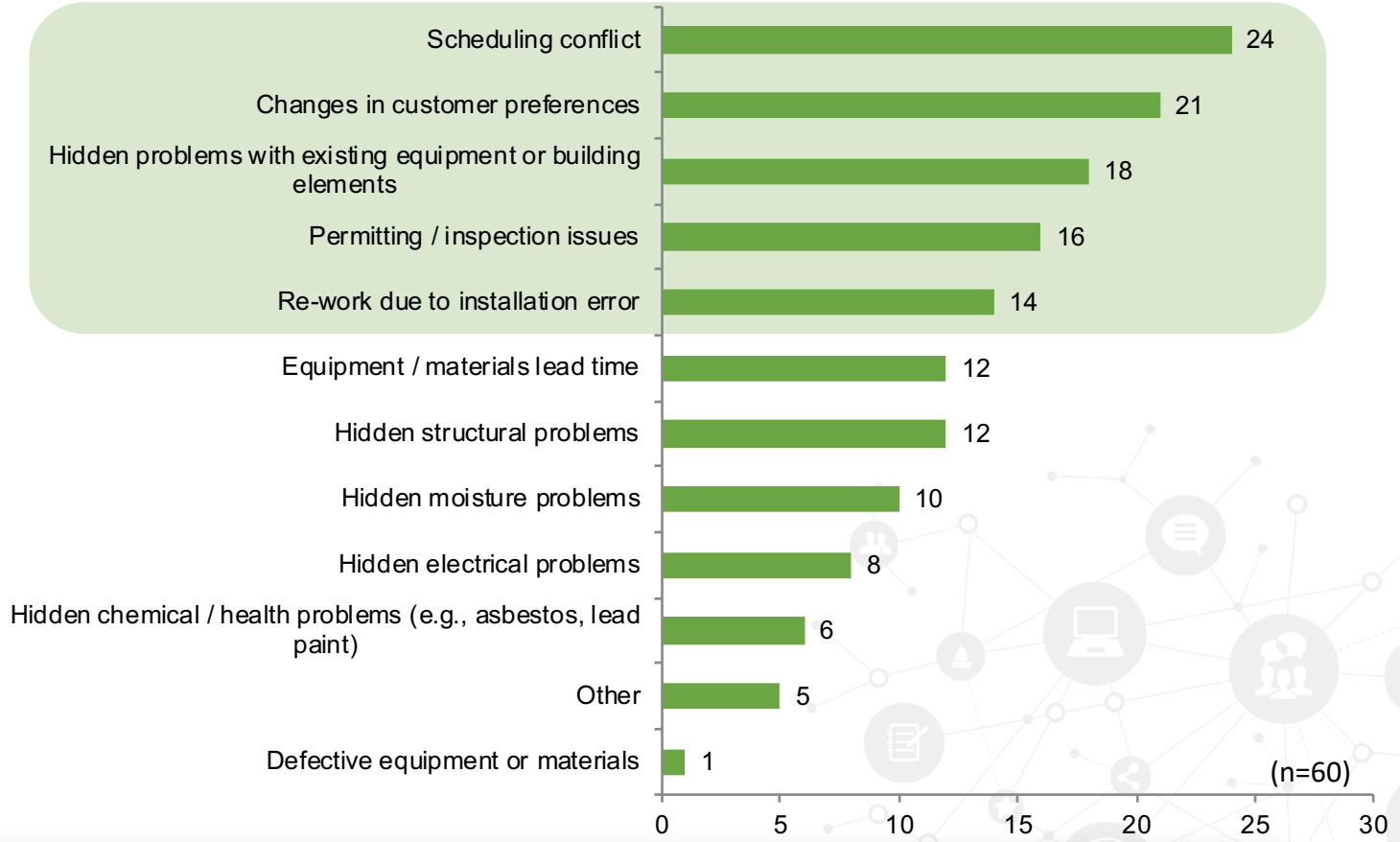
Project Cost Estimates

Important drivers of cost variability in DER projects



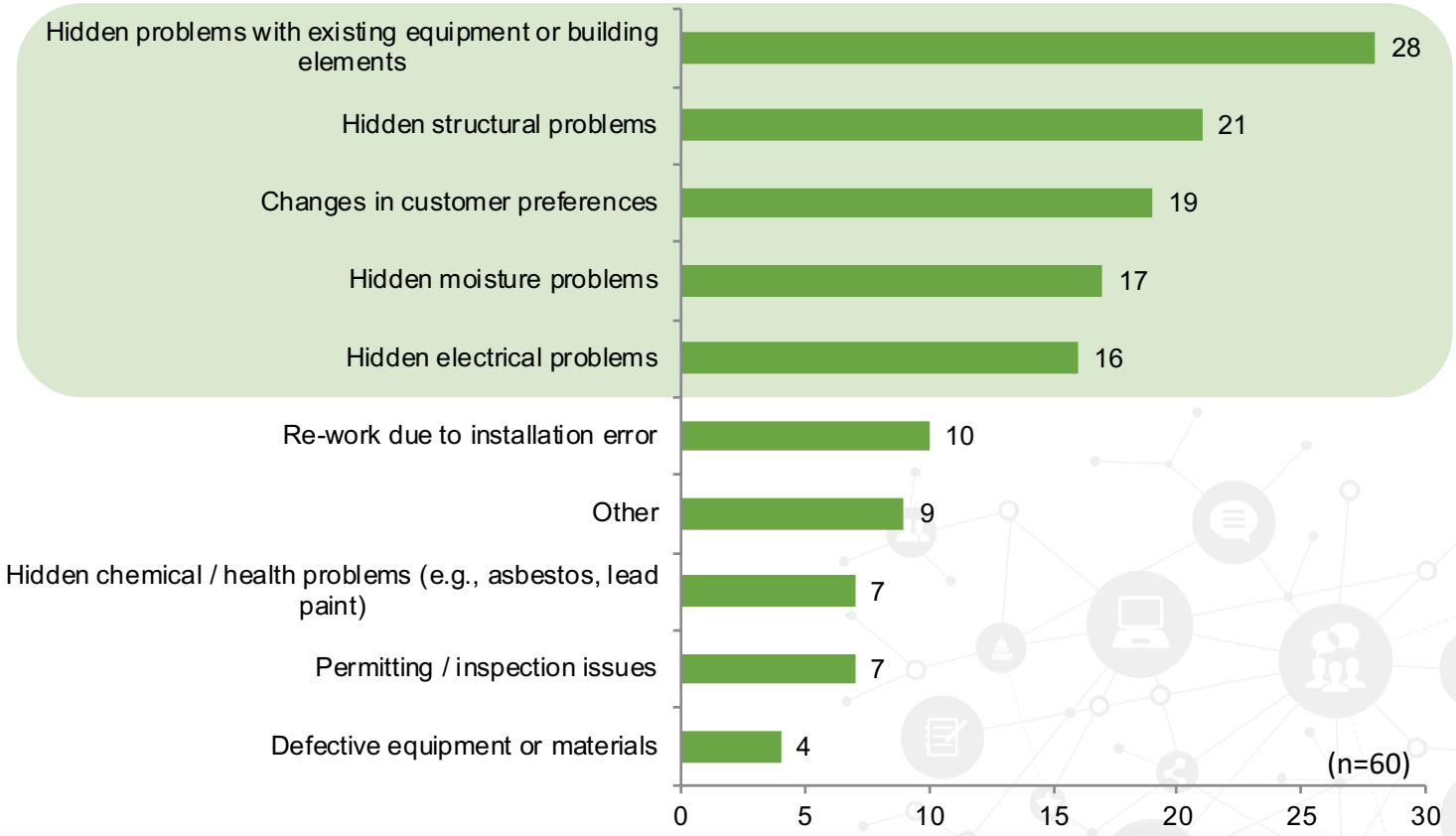
Project Cost Estimates

Common causes of DER project delays



Project Cost Estimates

Common causes of DER project cost increase.



Market Survey: Additional Suggestions from Contributors

DEEP ENERGY RETROFITS NEED TO

- Define its role in the Energy Efficiency market.
- Focus on carbon reduction over the life cycle of the home.
- Continue technology innovations.
- Enable contractors to make money and build partnership.
- Include disadvantaged communities.
- Rethink how to drive customer demands.
- Broaden work scope to include plug loads, inefficient plumbing.

THANK YOU

Brennan D. Less

Scientific Engineering Associate

BDLess@lbl.gov

Iain S. Walker

Staff Scientist

ISWalker@lbl.gov

Núria Casquero-Modrego

Post-Doctoral Scholar

NuriaCM@lbl.gov