Building Electrification 101

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Office of Indian Energy, Webinar Series
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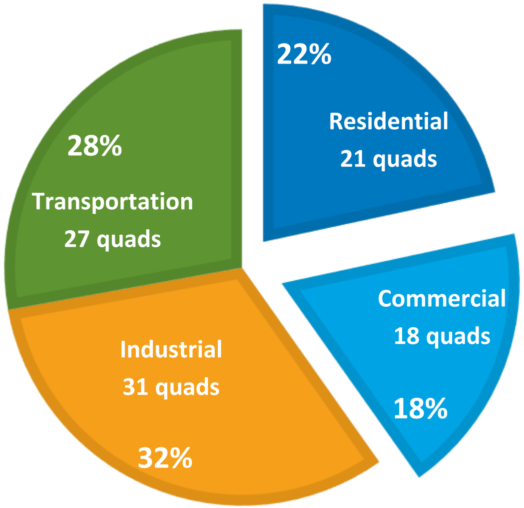
Outline

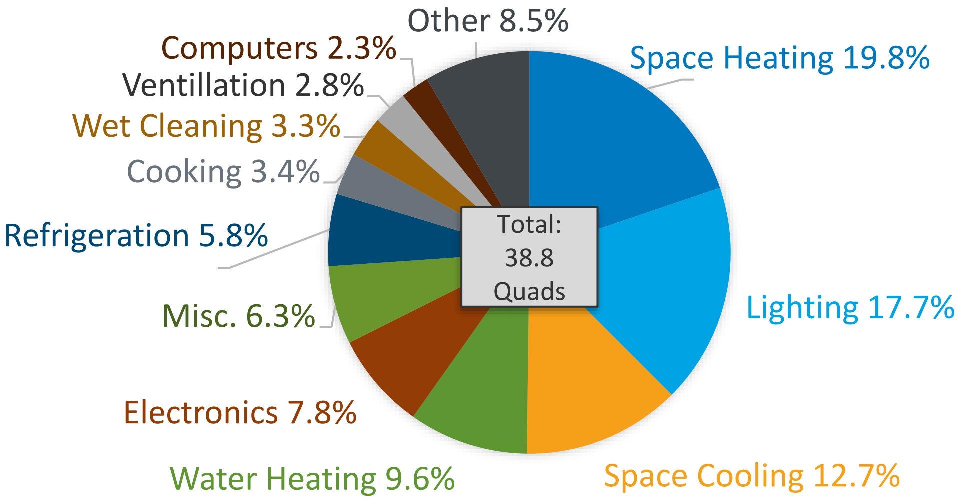
- Energy Use in US Buildings
- Introduction to Electrification
- Challenges and Opportunities
- Electrification Technologies
- Example modeling

U.S. Energy and Electricity Consumption by Sector

Energy Use



Building Energy Use



Buildings Energy Use: 40% of U.S. total

Buildings GHG: 38% of U.S. total

Chart sources: US EIA, VARIOUS SOURCES

Building Energy Services

COMFORT AND HEALTH

PROTECTION FROM ELEMENTS

EMPLOYMENT

INFORMATION ACCESS

FOOD PREPARATION & STORAGE

CLEANING

EDUCATION

RECREATION & ENTERTAINMENT

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How can we provide access to the necessary energy services in a building with the lowest human and environmental health impacts?

Energy Use – Human and Environmental Costs

- Outdoor Air Quality – fossil fuel combustion for electricity
- Indoor Air Quality – fossil fuel combustion in buildings
- Range of pollutants, e.g., $PM_{2.5}$, VOCs, NO_x, SO_x
- Can lead to serious impacts on human health:
  - Asthma, cardiac events, respiratory problems, miscarriage
  - ESPECIALLY in vulnerable populations (e.g., children, elderly)

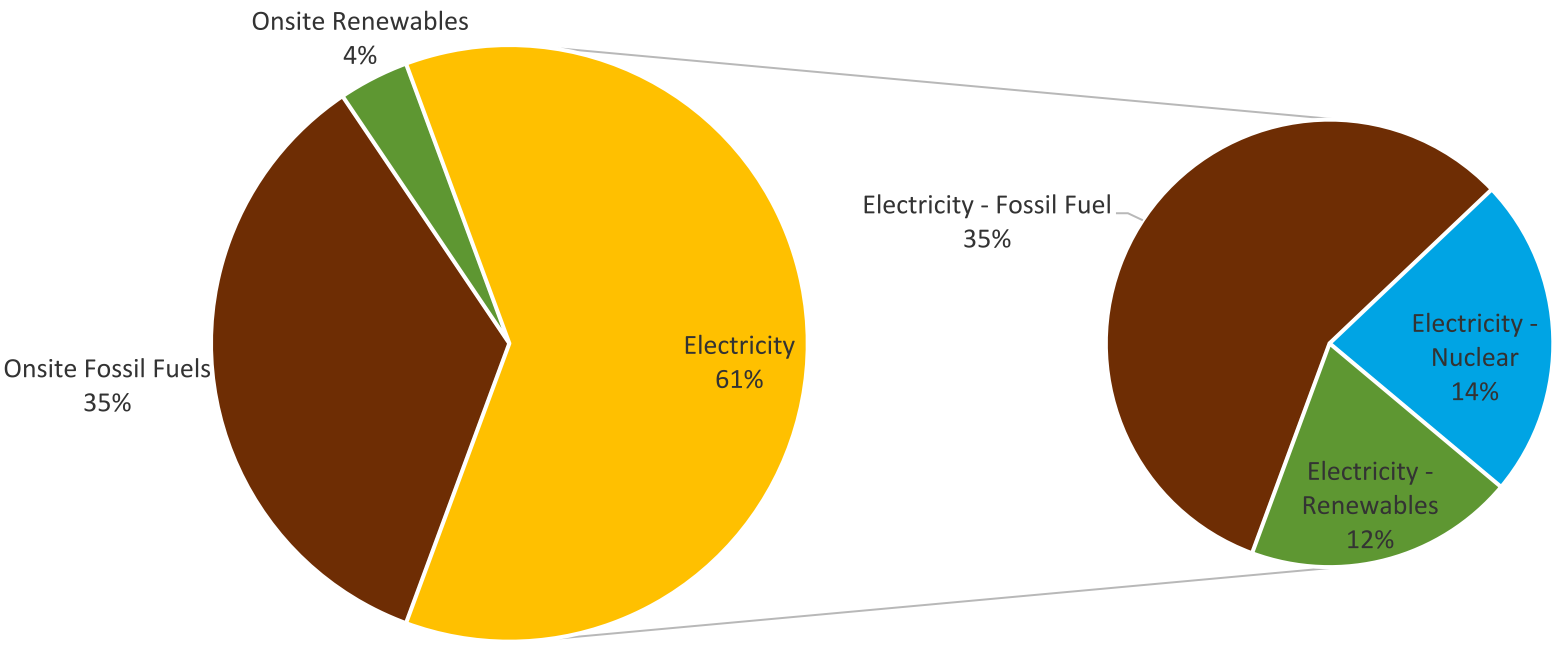
Electrification can improve indoor air quality and health by removing indoor pollutants from fossil fuel combustion

Buildings and Climate Change

FACT: We cannot achieve low or zero-carbon buildings while still burning fossil fuels on-site in homes or businesses

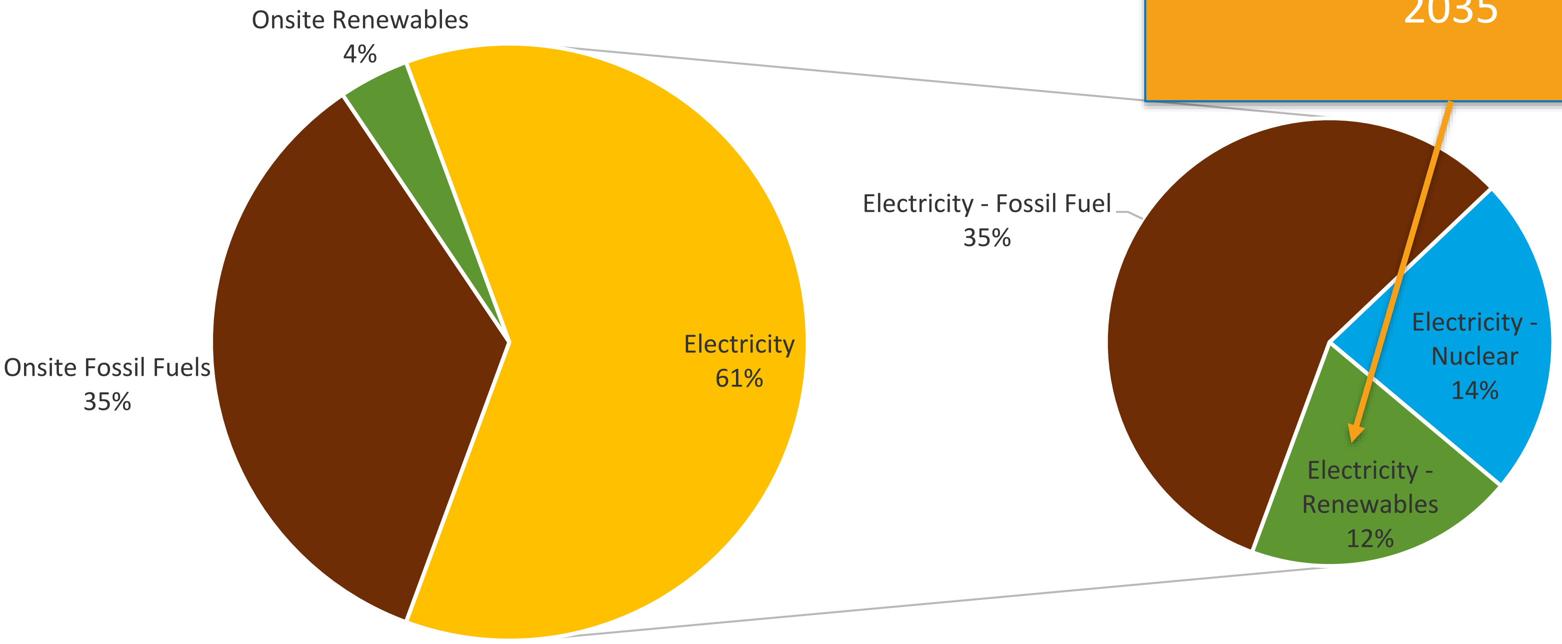
- Building sector strategy for climate change:
  - Switch all energy to electricity
  - Decarbonize the electric grid
  - Increase efficiency of equipment to reduce costs and energy need

Building Site Energy Consumption by Source



Building Site Energy Consumption by Source

Biden Administration Goal of 100% Renewable Energy by 2035



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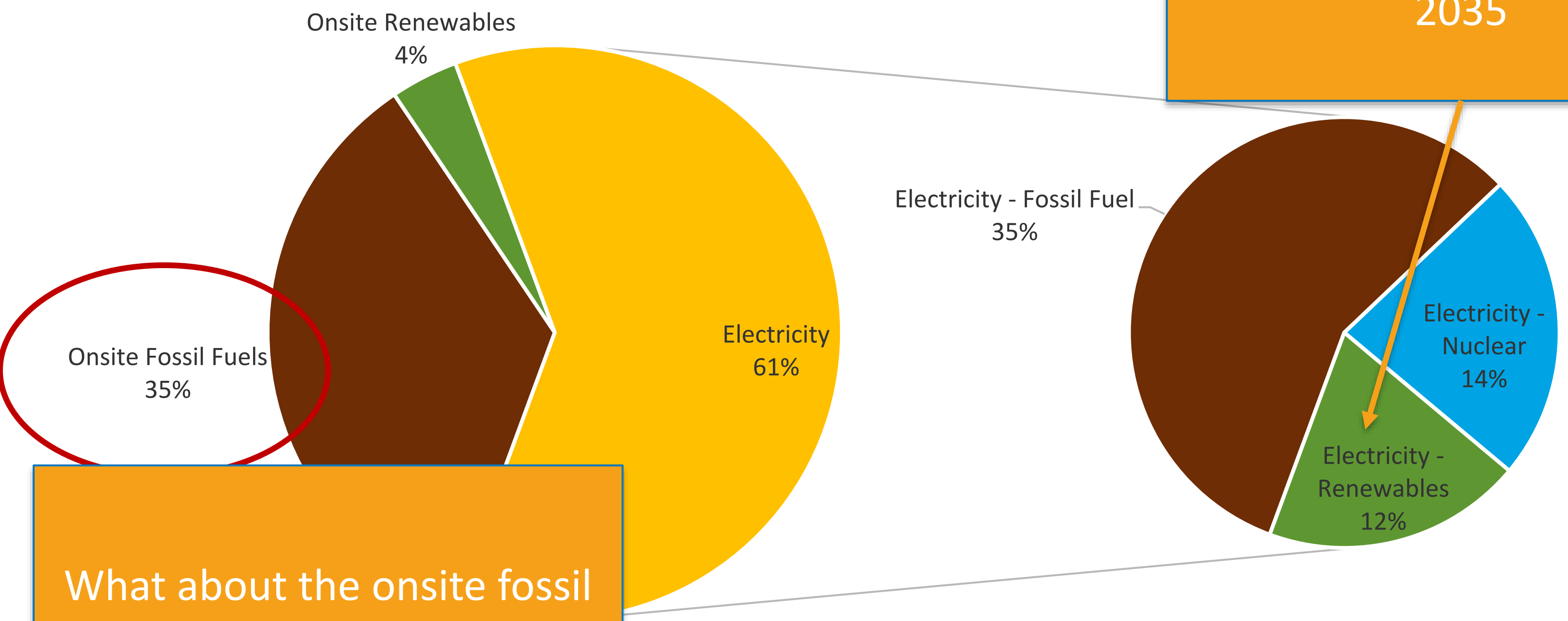
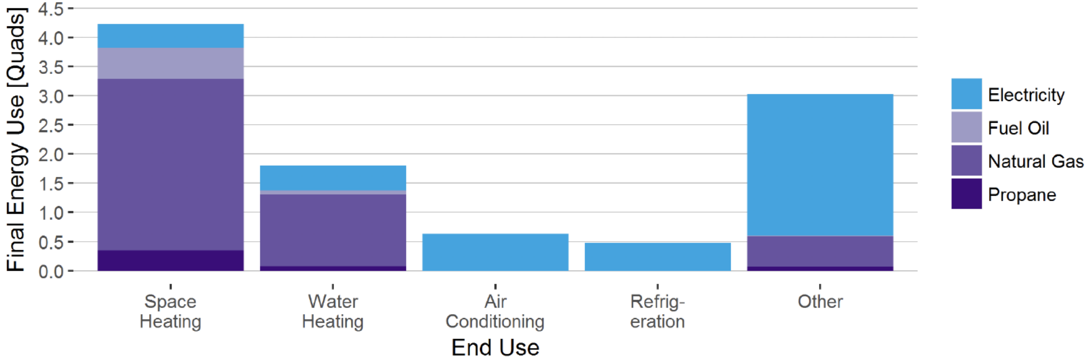


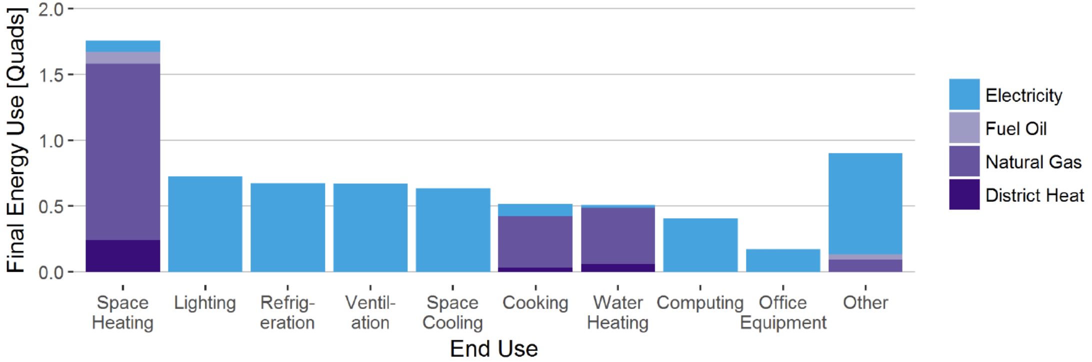
What about the onsite fossil fuels?

Current State of Electrification in Buildings

Residential – RECS 2009; Electricity is 43% of final energy



Commercial – CBECS 2012 – Electricity is 61% of final energy



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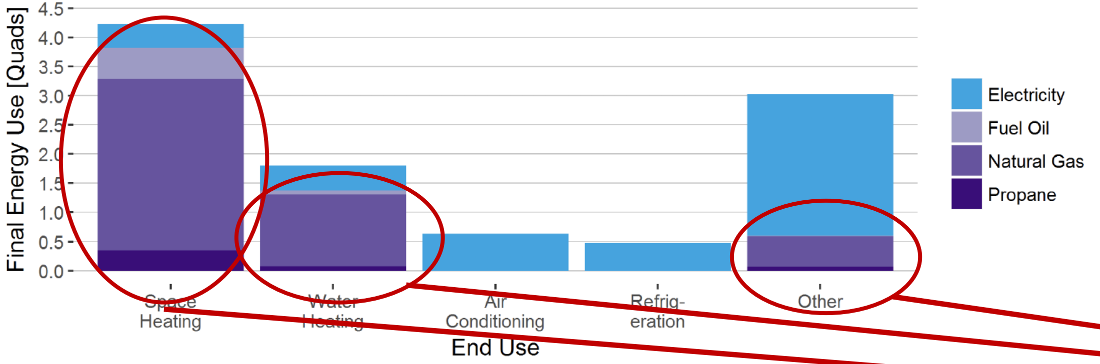

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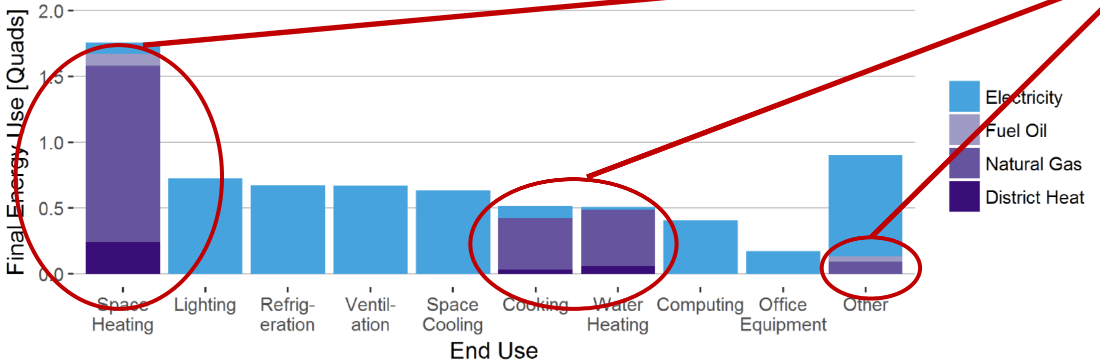

Major fossil-fuel energy uses:

- Space heating
- Water heating
- Cooking
- Clothes Drying

Electrification - Benefits

- Reduced CO_2 emissions*
- Improved indoor air quality
- Can power homes with renewable energy sources

*Sometimes, not always

Electrification - Benefits

- Reduced CO_2 emissions*
- Improved indoor air quality
- Can power homes with renewable energy sources
- Supports national decarbonization strategy

*Sometimes, not always

If electrification has so many health and environmental benefits, why aren’t we doing it more?

Electrification - Concerns

- Cost – to building owners, occupants, and operators
  - Utility bills: electricity is generally more expensive than natural gas
  - Purchase cost: electric equipment is often more expensive
  - Brute-force electrification could lead to serious equity concerns
- Reliability – when you lose electricity, you lose electric services
  - ERCOT (Texas) outage led to deaths and property damage
  - Onsite backup is an option to mitigation – but this could be expensive
- Electric grid capacity – electrification would dramatically change our demand for electricity
- Electrical readiness – can the home/business electrical panel support more electric appliances (leading to more cost to upgrade)

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How can we mitigate some of these concerns to achieve health and climate goals? Are there "smarter" ways to electrify?

Major Technology Options for Electrification

- Space heating
  - Electric resistance
  - Heat pumps
- Water heating
  - Electric resistance
  - Heat pump
- Cooking
  - Electric
  - Induction
- Clothes Drying
  - Heat Pump
  - Electric
  - (Ultrasonic)*

*Still in research development. Minimum 5-10 years from commercialization

Major Technology Options

Heat Pumps

- Moves heat from air (or ground)
- Can remove heat even from very cold air

Resistance Heating

- Create heat by running electricity through a material
- MUCH less efficient (and therefore much more expensive to use)

Induction Cooking

- Uses magnetic fields to directly heat cookware instead of heating stovetop
- Heats much more quickly than electric resistance (or natural gas) stoves

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Potentially key technology for beneficial electrification

Heat Pumps

- Extract heat from air or ground and move it into a building
- Can operate a low temperatures, BUT efficiency reduces
- Need backup heat source at lowest temperatures
- Commonly available, but not always familiar to HVAC installers
- High upfront cost, but low energy usage (and energy bills) during operation

Chicago Residential Retrofits Case Study

Project Goals

- 50% energy reduction across all homes in Chicago
- Keep from increasing occupant energy bills
- Prioritize decarbonization
- Evaluate the role of heat pumps in deep energy retrofits and electrification
- Equity – how does this impact disadvantaged households in Chicago?

Project Overview

1. Calibrate Chicago ResStock
2. Model Deep Energy Retrofit Packages
3. City and Neighborhood-Scale Analysis
4. Field Validation of Selected Packages
5. Case Studies and Findings Synthesis

ResStock

- Detailed national model of residential energy use in the U.S. with high temporal (15 minute) and spatial (County / PUMA) resolution
- Can also model the impacts of technology changes to the building stock (e.g., installing heat pumps)

- For this project, we calibrated ResStock for the Chicago area

resstock.nrel.gov

Metrics

- Annual post-retrofit utility cost: by fuel and total
- Utility bill savings: by fuel and total
- CO_2e savings (different factors)
- Energy savings by fuel and total
- Site energy intensity
- % change in site energy intensity
- Modeled upgrade cost
- Simple Payback

		Utility Basic	HP HVAC with Basic Shell	HP HVAC with Premium Shell	Utility Plus	Utility Deep Efficiency	Electrification Basic	Electrification with HPs	Electrification with HPs and Deep Efficiency	Full Upgrades (no electrification)	Full Upgrades (Electrification)
Shell	Air sealing (25% reduction)	E, G	E, G	E, G	E, G	E, G	E, G	E, G	E, G	E, G	E, G
	Drill-and-Fill to R-13 for Frame Walls	E, G	E, G	E, G	E, G	E, G	E, G	E, G	E, G	E, G	E, G
	XPS R-20			E, G		[illegible]	[illegible]	[illegible]	[illegible]	E, G	E, G
	Attic insulation R-49	E, G	E, G	E, G	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
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	Low-E Double Pane Windows, High Gain			E, G		[illegible]	[illegible]	[illegible]	[illegible]	E, G	E, G
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Fuel-Based	ENERGY STAR 96% AFUE NG Furnace				G	[illegible]	[illegible]	[illegible]	[illegible]	G	
	ENERGY STAR NG Boiler				G	[illegible]	[illegible]	[illegible]	[illegible]	G	
	Electric Furnace, 100% AFUE					[illegible]	[illegible]	[illegible]	[illegible]		
	Electric Boiler, 100% AFUE						G				
	ASHP, High Eff (for ducted)		E, G	E, G				E, G	E, G	E	E, G
	MSHP (for non-ducted)		E, G	E, G				E, G	E, G	E	E, G
	Premium NG Water Heater				G	G				G	
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	Electric Cooking						G	G			
	Induction Cooking								E, G	E	E, G
Swap	ENERGY STAR Refrigerator, Most Eff					E, G			E, G	E, G	E, G
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Ten Upgrade Packages

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Envelope (insulation, windows, air sealing)

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Switching electric/natural gas equipment (space heating, water heating, cooking, clothes drying)

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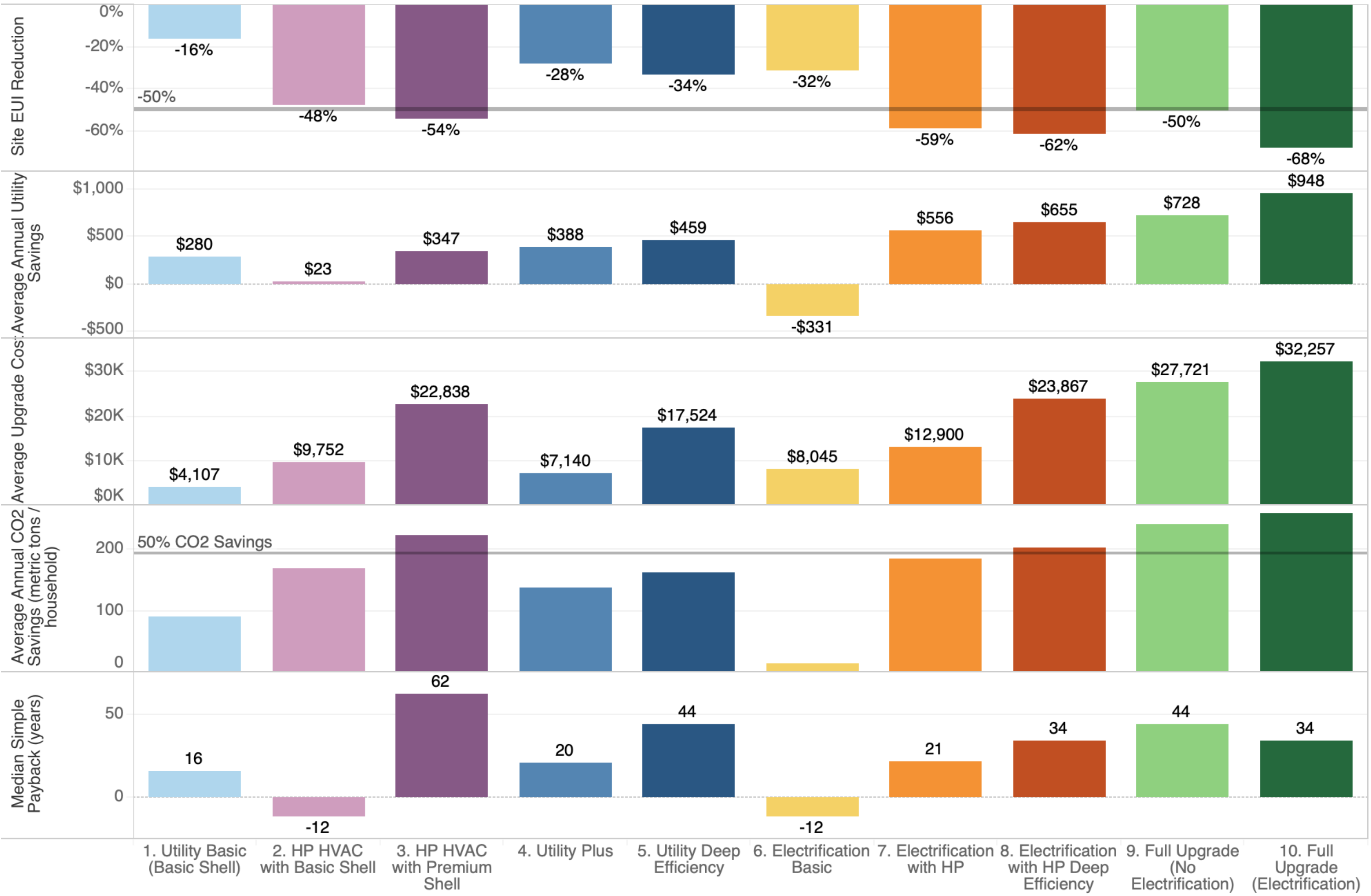
Efficient electric appliances (lighting, clothes washing, refrigerator)

Package Savings

Package Summary



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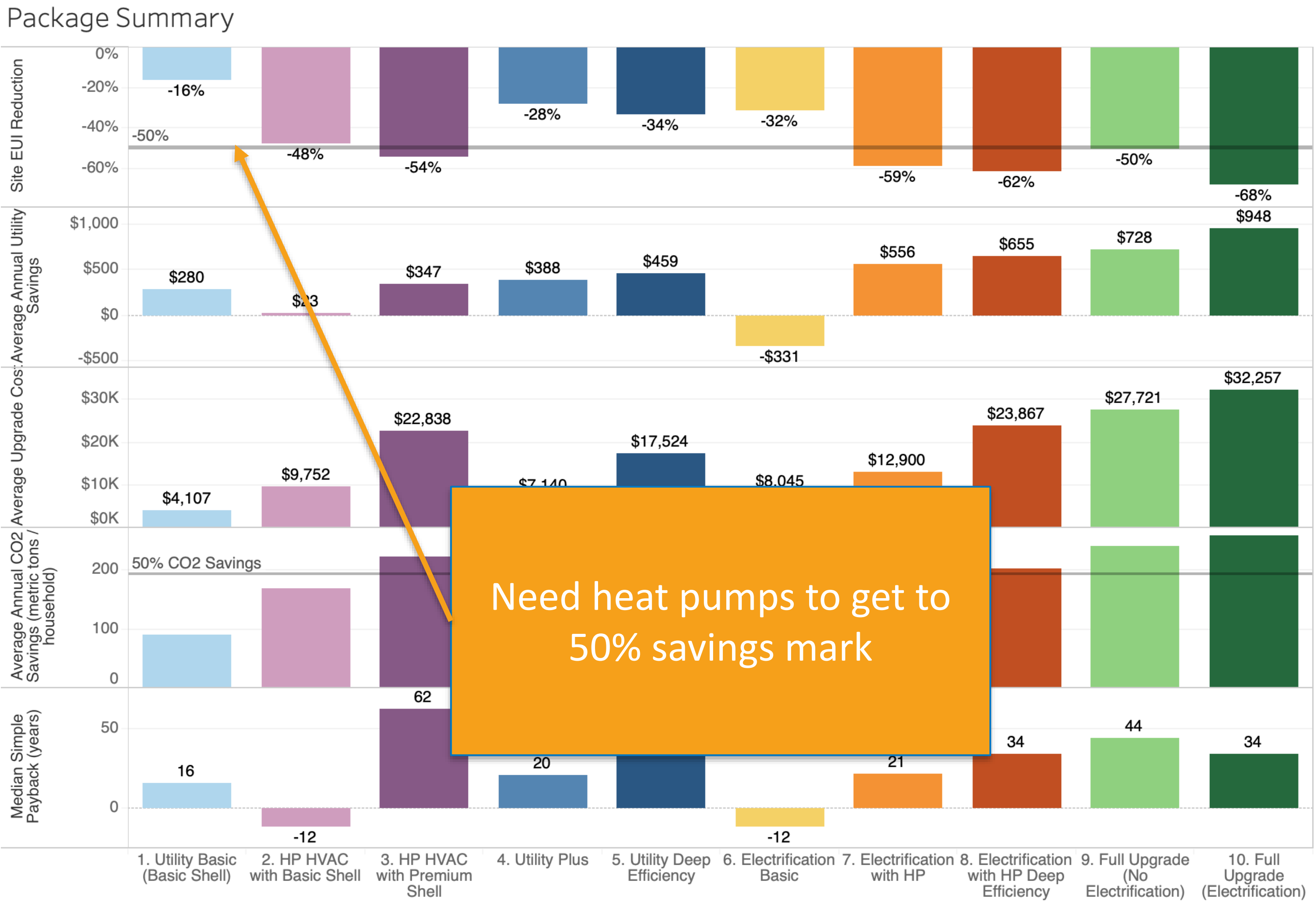

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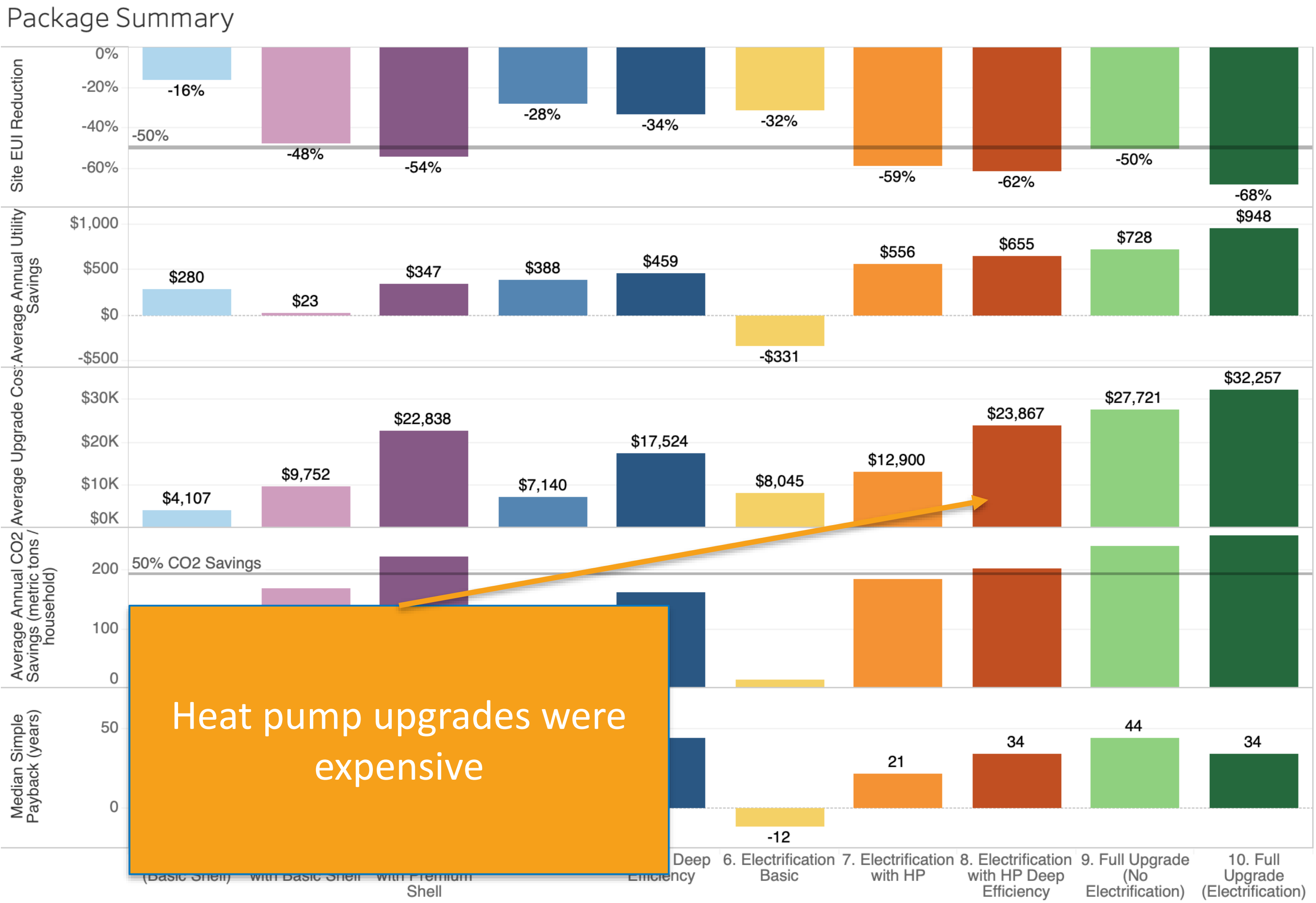
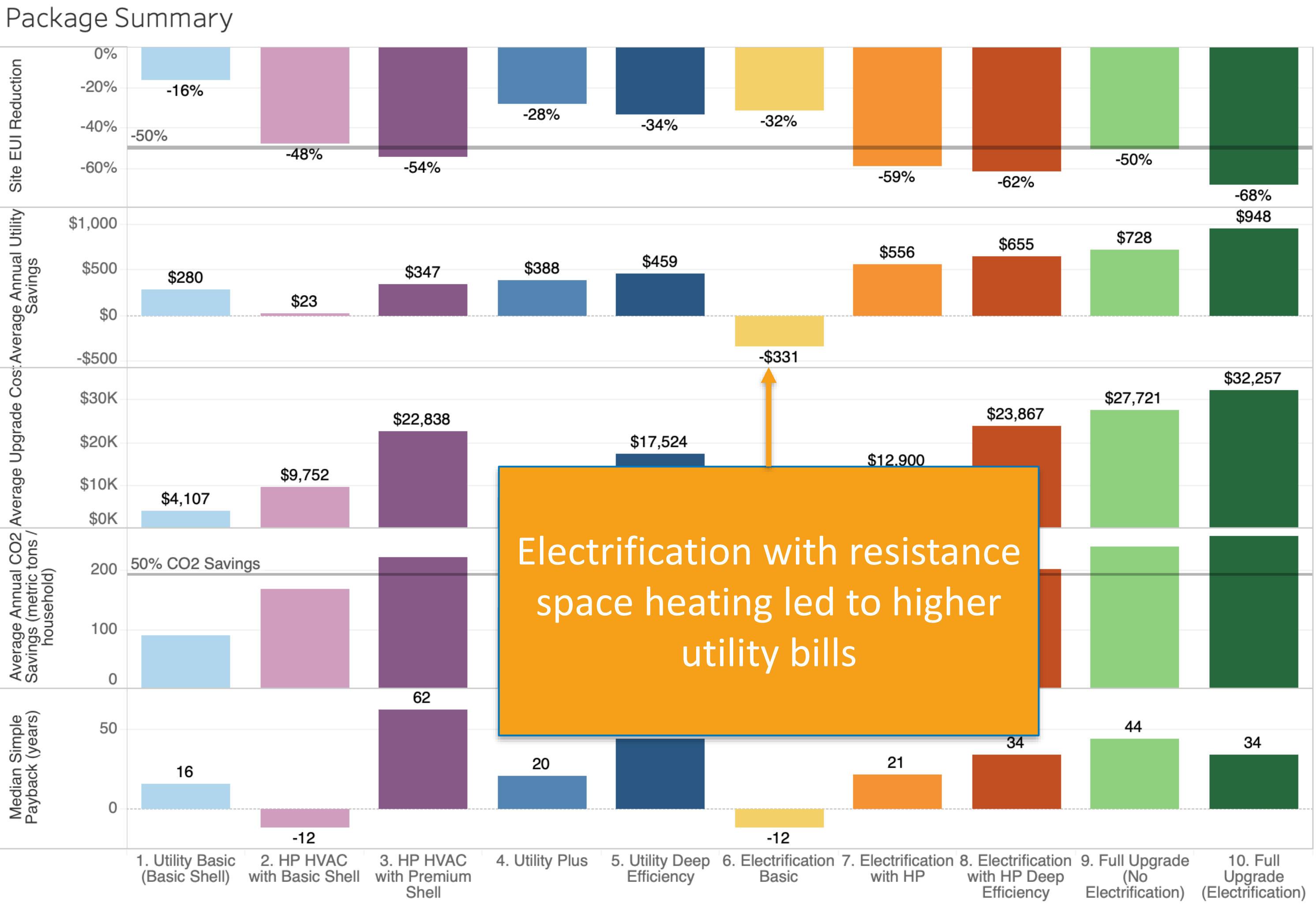


Heat pump upgrades were expensive

Package Savings



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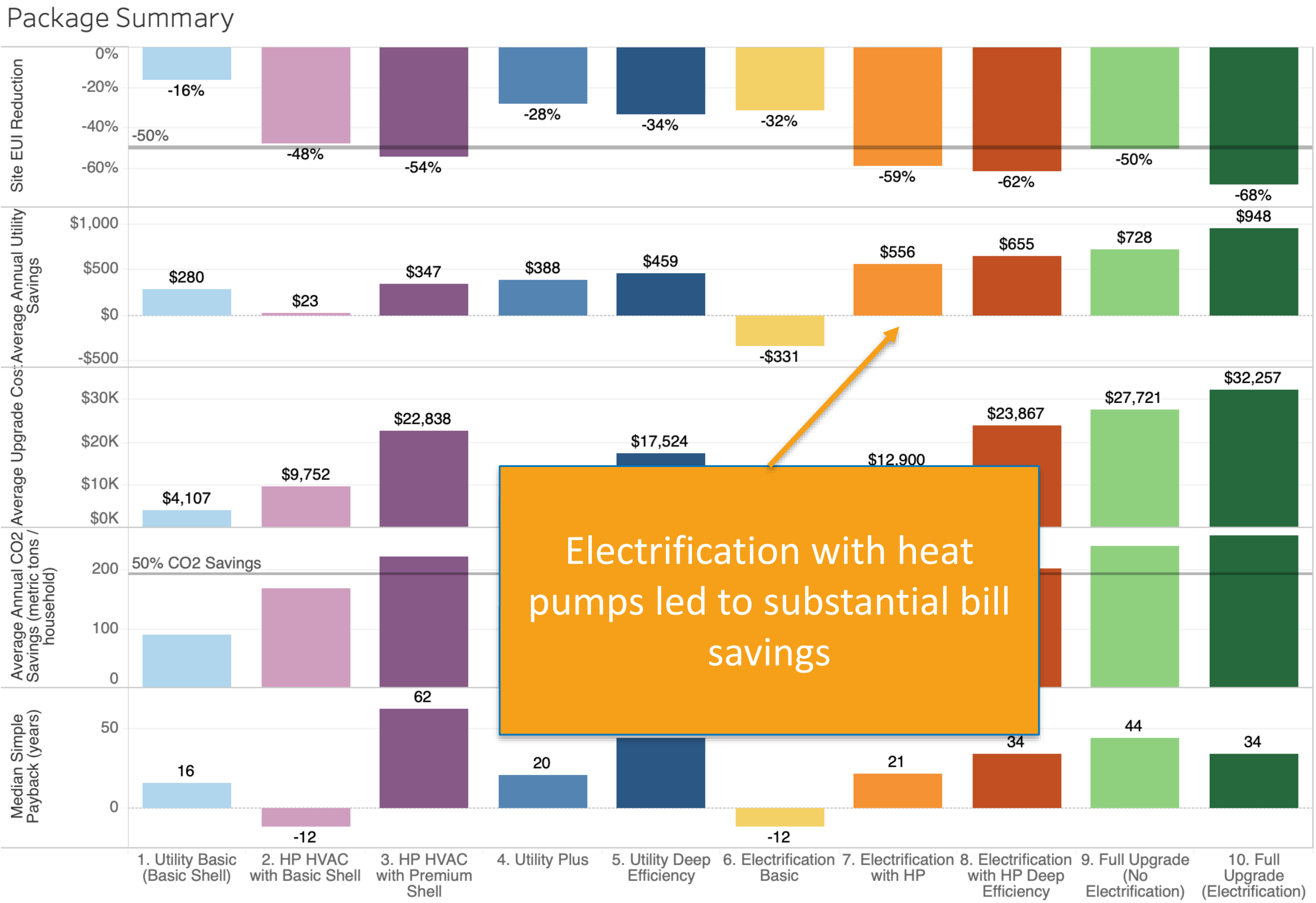

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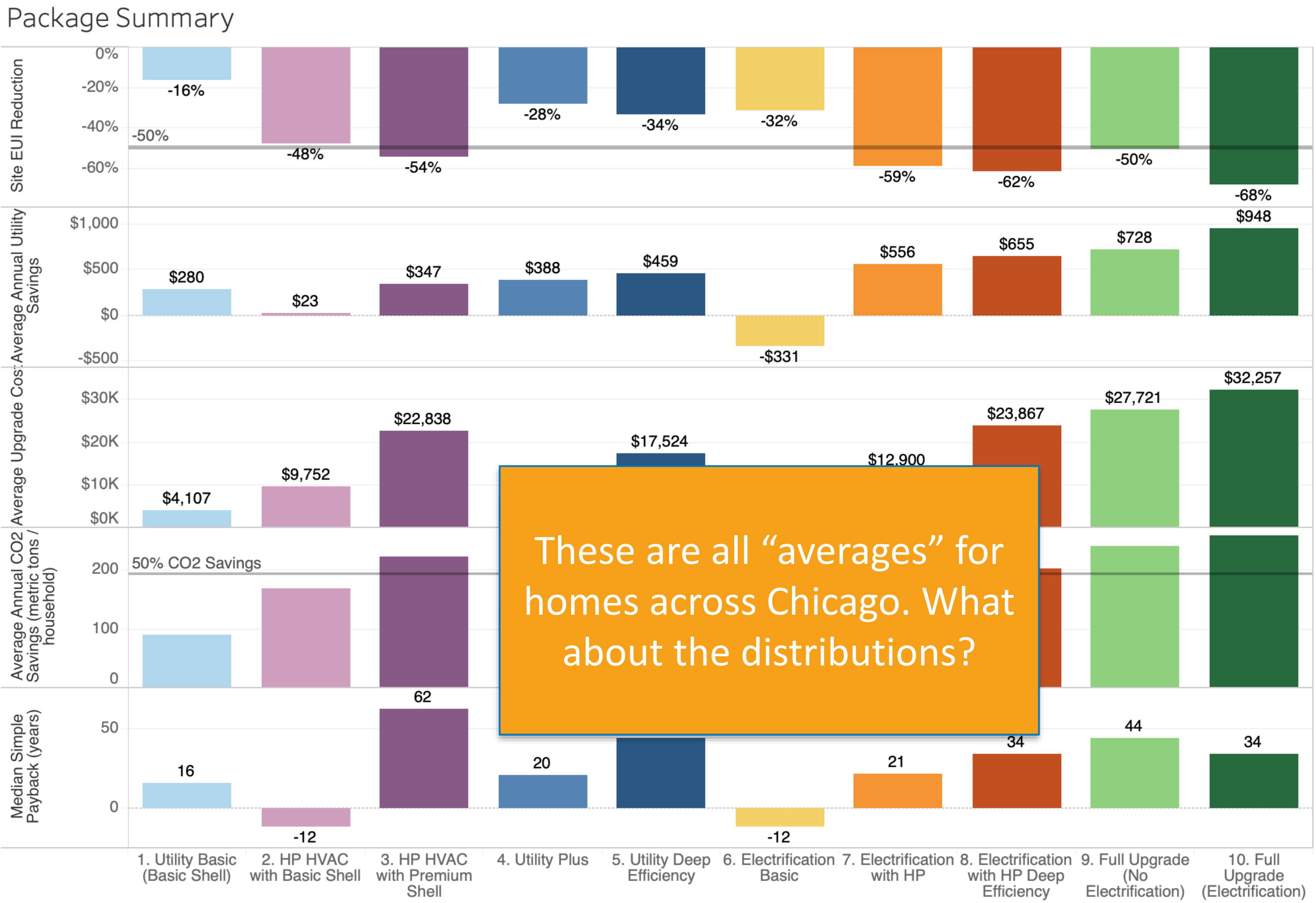
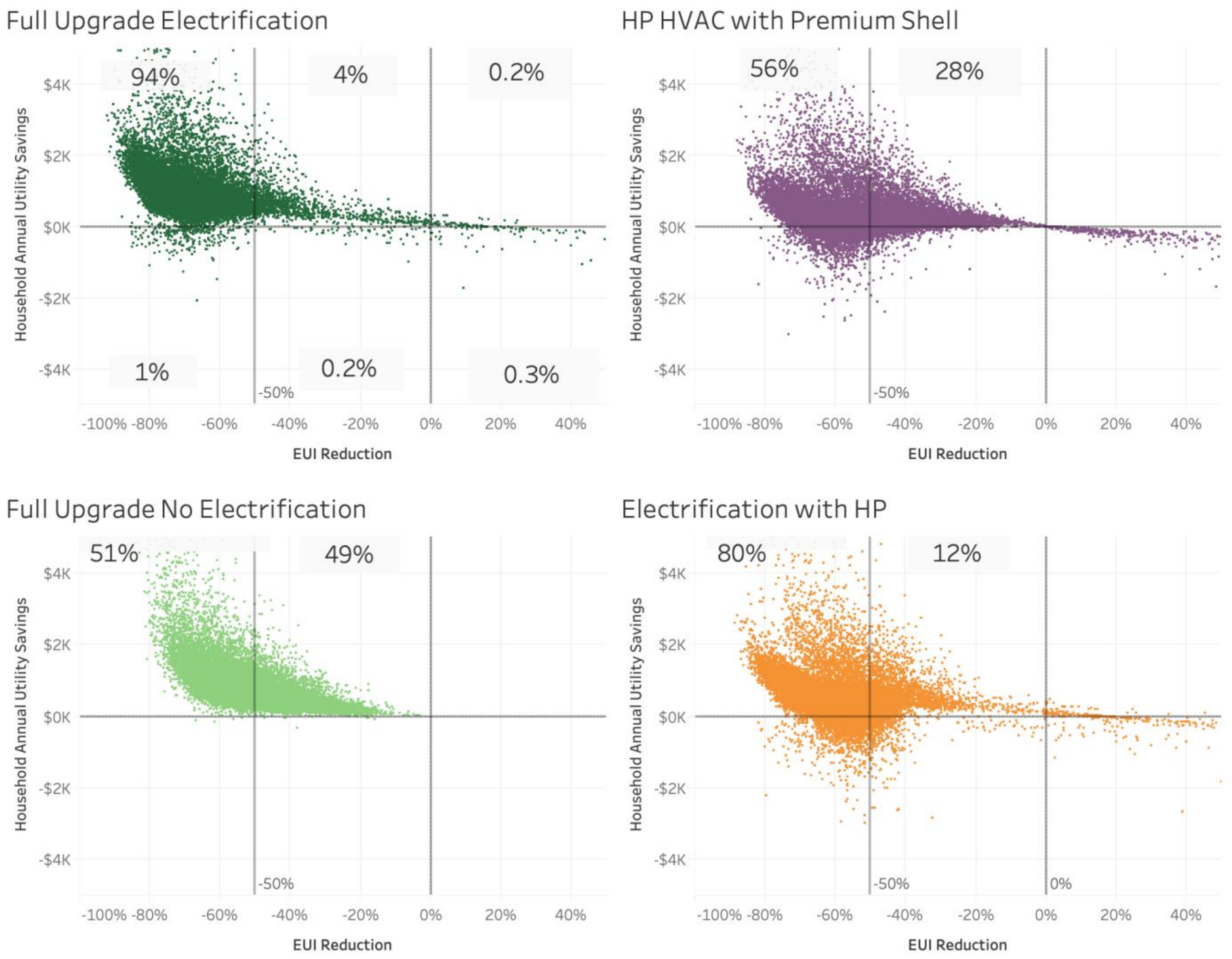


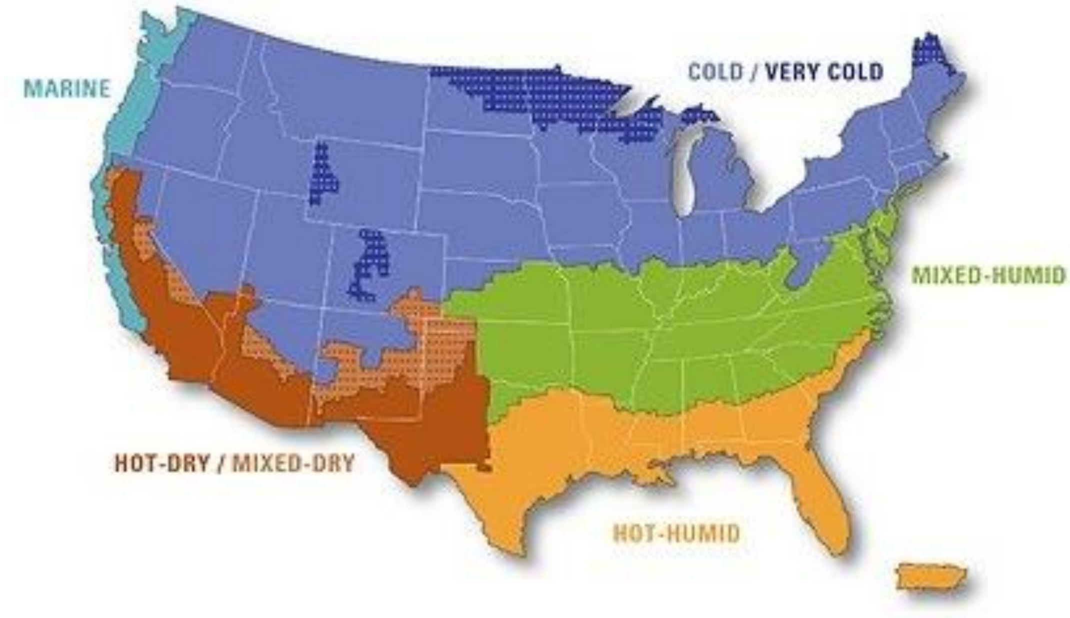

Full Upgrade Electrification
94%
4%
0.2%
1%
0.2%
0.3%
-50%
$4K
$2K
$0K
-$2K
-$4K
Household Annual Utility Savings
-100% -80% -60% -40% -20% 0% 20% 40%
EUI Reduction
HP HVAC with Premium Shell
56%
28%
-50%
Full Upgrade No Electrification
51%
49%
-50%
Electrification with HP
80%
12%
-50%
0%

Chicago Conclusions

- This is a single case study, but initial results are promising that heat pumps could be deployed without increasing bills even in a very cold climate
- Field validation work is ongoing to verify these findings
- Cost of heat pumps still a substantial barrier

National Characterization Study

Climate Zones Differences in Heating Fuel



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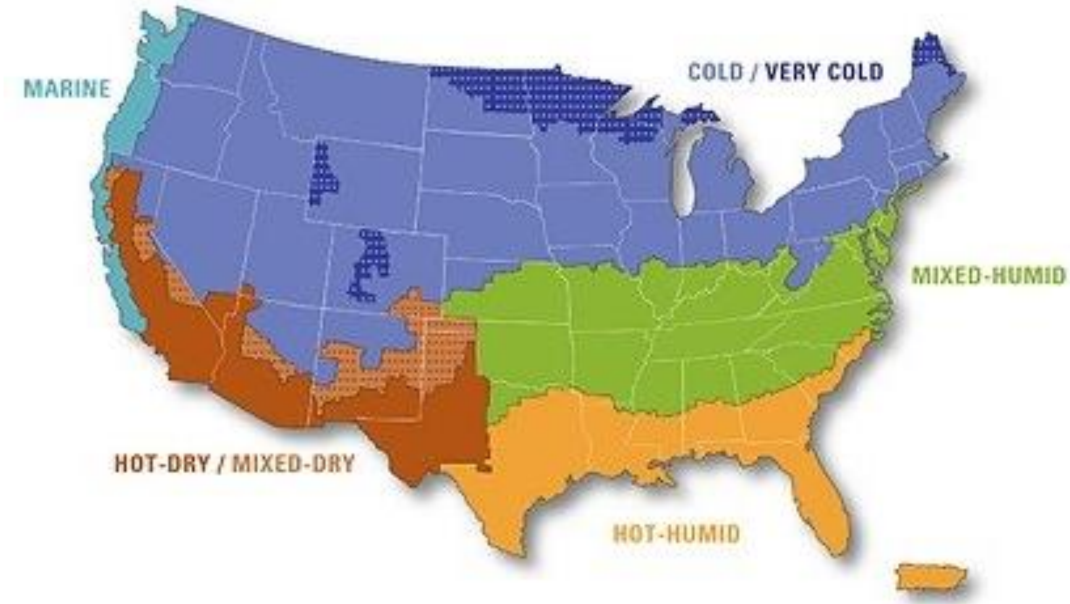

Building America Climat..	RECS Building Type (with height)	Primary heating fuel: Natural Gas	Electricity	Propane	Fuel Oil	None	Other Fuel
Cold & Very Cold	Single-Family Detached	67%	13%	9%	12%	0%	
	Mobile Home	45%	20%	19%	15%	0%	
	Single-Family Attached	79%	15%	1%	5%	0%	0%
	Multi-Family with 2 - 4	69%	23%	1%	7%	0%	0%
	Multi-Family with 5+ Unit..	48%	48%	1%	2%	1%	0%
	Multi-Family with 5+ Unit..	52%	42%	1%	3%	1%	1%
Hot-Dry & Mixed-Dry	Single-Family Detached	67%	28%	3%	0%	1%	
	Mobile Home	52%	36%	11%	0%	1%	
	Single-Family Attached	64%	34%	0%		2%	
	Multi-Family with 2 - 4	55%	42%	0%		3%	
	Multi-Family with 5+ Unit..	40%	55%	0%	0%	4%	
	Multi-Family with 5+ Unit..	41%	54%	0%		5%	0%
Hot-Humid	Single-Family Detached	28%	69%	3%	0%	0%	
	Mobile Home	3%	91%	6%	0%	0%	
	Single-Family Attached	8%	91%	0%		0%	
	Multi-Family with 2 - 4	8%	91%	0%		0%	
	Multi-Family with 5+ Unit..	4%	95%	0%	0%	1%	
	Multi-Family with 5+ Unit..	5%	94%	0%	0%	2%	
Marine	Single-Family Detached	65%	29%	4%	2%	0%	
	Mobile Home	27%	68%	4%	0%	0%	
	Single-Family Attached	63%	36%	0%		0%	
	Multi-Family with 2 - 4	44%	54%	0%	0%	1%	0%
	Multi-Family with 5+ Unit..	26%	71%	0%	0%	2%	0%
	Multi-Family with 5+ Unit..	30%	66%	0%	0%	3%	0%
Mixed-Humid	Single-Family Detached	50%	37%	7%	6%	0%	
	Mobile Home	9%	76%	12%	3%	0%	
	Single-Family Attached	63%	34%	0%	3%	0%	
	Multi-Family with 2 - 4	54%	41%	0%	5%	0%	0%
	Multi-Family with 5+ Unit..	32%	61%	1%	6%	1%	0%
	Multi-Family with 5+ Unit..	42%	40%	1%	16%	1%	1%

Climate Zones Differences in Heating Fuel

Building America Climat..	RECS Building Type (with height)	Primary heating fuel: Natural Gas	Electricity	Propane	Fuel Oil	None	Other Fuel
Cold & Very Cold	Single-Family Detached	67%	13%	9%	12%	0%	
	Mobile Home	45%	20%	19%	15%	0%	
	Single-Family Attached	79%	15%	1%	5%	0%	0%
	Multi-Family with 2 - 4	69%	23%	1%	7%	0%	0%
	Multi-Family with 5+ Unit..	48%	48%	1%	2%	1%	0%
	Multi-Family with 5+ Unit..	52%	42%	1%	3%	1%	1%
Hot-Dry & Mixed-Dry	Single-Family Detached	67%	28%	3%	0%	1%	
	Mobile Home	52%	36%	11%	0%	1%	
	Single-Family Attached	64%	34%	0%		2%	
	Multi-Family with 2 - 4	55%	42%	0%		3%	
	Multi-Family with 5+ Unit..	40%	55%	0%	0%	4%	
	Multi-Family with 5+ Unit..	41%	54%	0%		5%	0%
Hot-Humid	Single-Family Detached	28%	69%	3%	0%	0%	
	Mobile Home	3%	91%	6%	0%	0%	
	Single-Family Attached	8%	91%	0%		0%	
	Multi-Family with 2 - 4	8%	91%	0%		0%	
	Multi-Family with 5+ Unit..	4%	95%	0%	0%	1%	
	Multi-Family with 5+ Unit..	5%	94%	0%	0%	2%	
Marine	Single-Family Detached	65%	29%	4%	2%	0%	
	Mobile Home	27%	68%	4%	0%	0%	
	Single-Family Attached	63%	36%	0%		0%	
	Multi-Family with 2 - 4	44%	54%	0%	0%	1%	0%
	Multi-Family with 5+ Unit..	26%	71%	0%	0%	2%	0%
	Multi-Family with 5+ Unit..	30%	66%	0%	0%	3%	0%
Mixed-Humid	Single-Family Detached	50%	37%	7%	6%	0%	
	Mobile Home	9%	76%	12%	3%	0%	
	Single-Family Attached	63%	34%	0%	3%	0%	
	Multi-Family with 2 - 4	54%	41%	0%	5%	0%	0%
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Climate Zones Differences in Heating Fuel

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US National Characterization Study

- Forthcoming report discussing energy use, fuel type, decarbonization, building type breakdown, and description of US building stock by region
- Will also include interactive web viewer down to the County level

U.S. Building Stock Characterization Study.
A National Typology of Buildings

Janet Reyna, Eric Wilson, Aven Satre-Meloy, Amy Egerter, Carlo Bianchi, Marlena Praprost, Andrew Speake, Lixi Liu, Andrew Parker, Ry Horsey, and Stacey Rothgeb

Questions?

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