Electrification of Residential Buildings:

Draft Results of Energy and Emissions Savings Analysis

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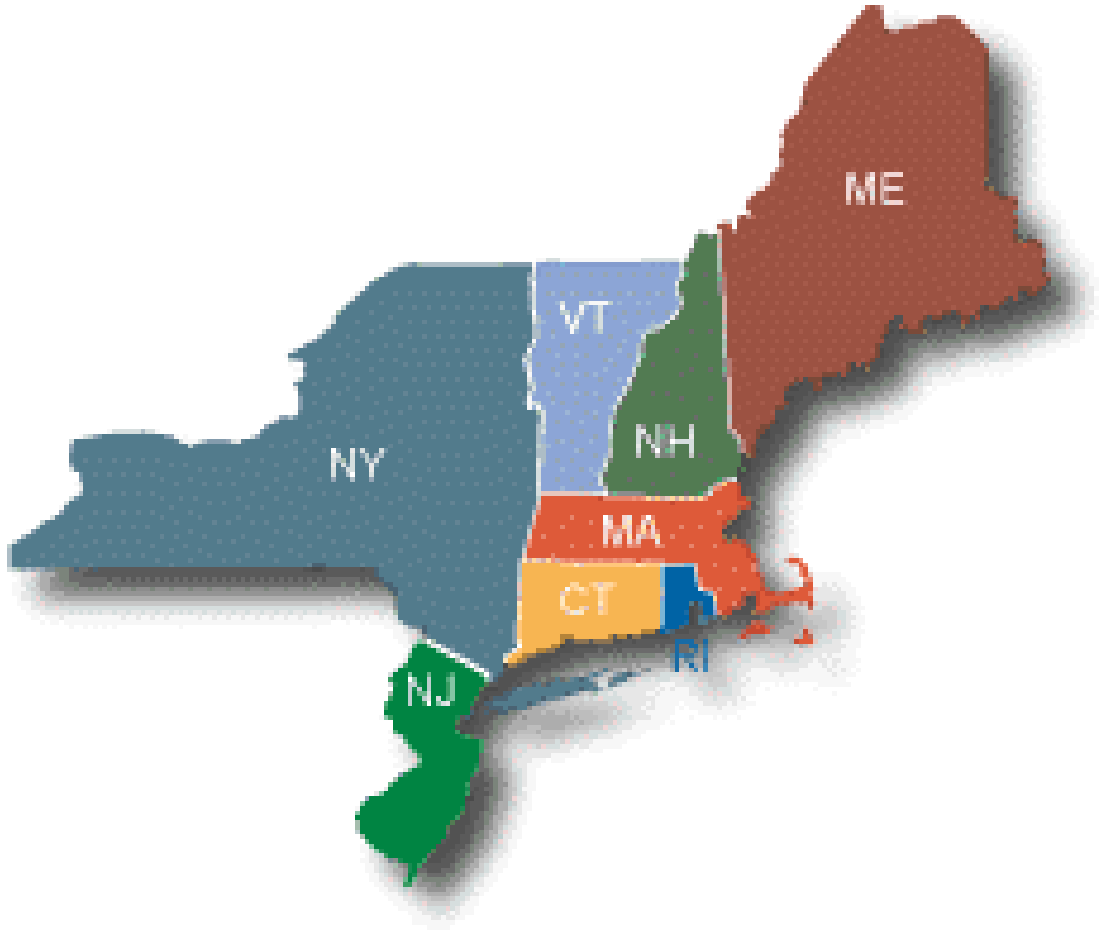
Northeast States for Coordinated Air Use Management (NESCAUM)

- NESCAUM is the regional nonprofit association of state air quality agencies in the Northeast.
- Our purpose is to provide scientific, technical, analytical, and policy support to our member states.



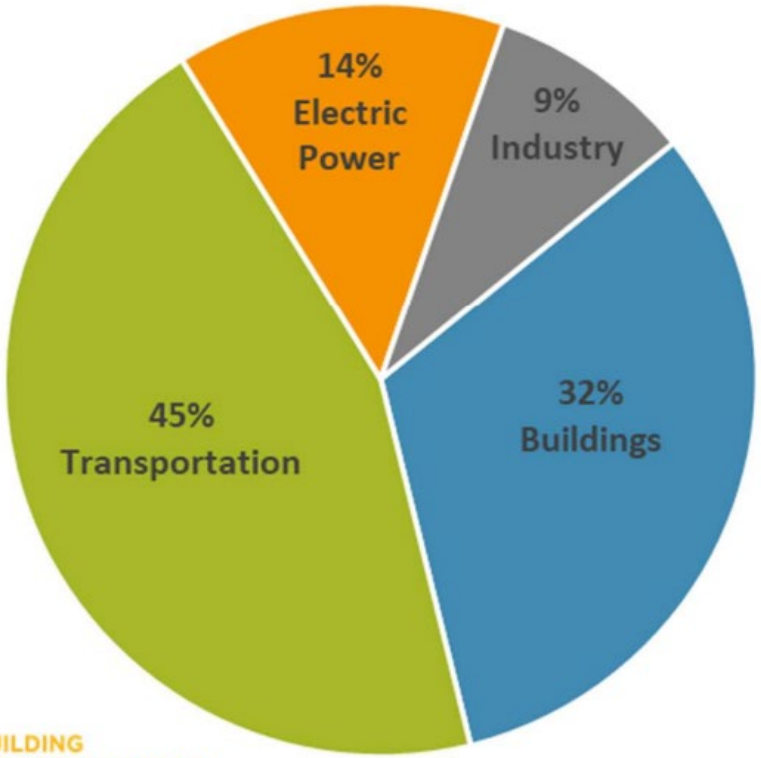
Presentation Overview

- Goals of the study
- Background
- Method
- Findings
- Conclusions and Next Steps

Goals of the Analysis

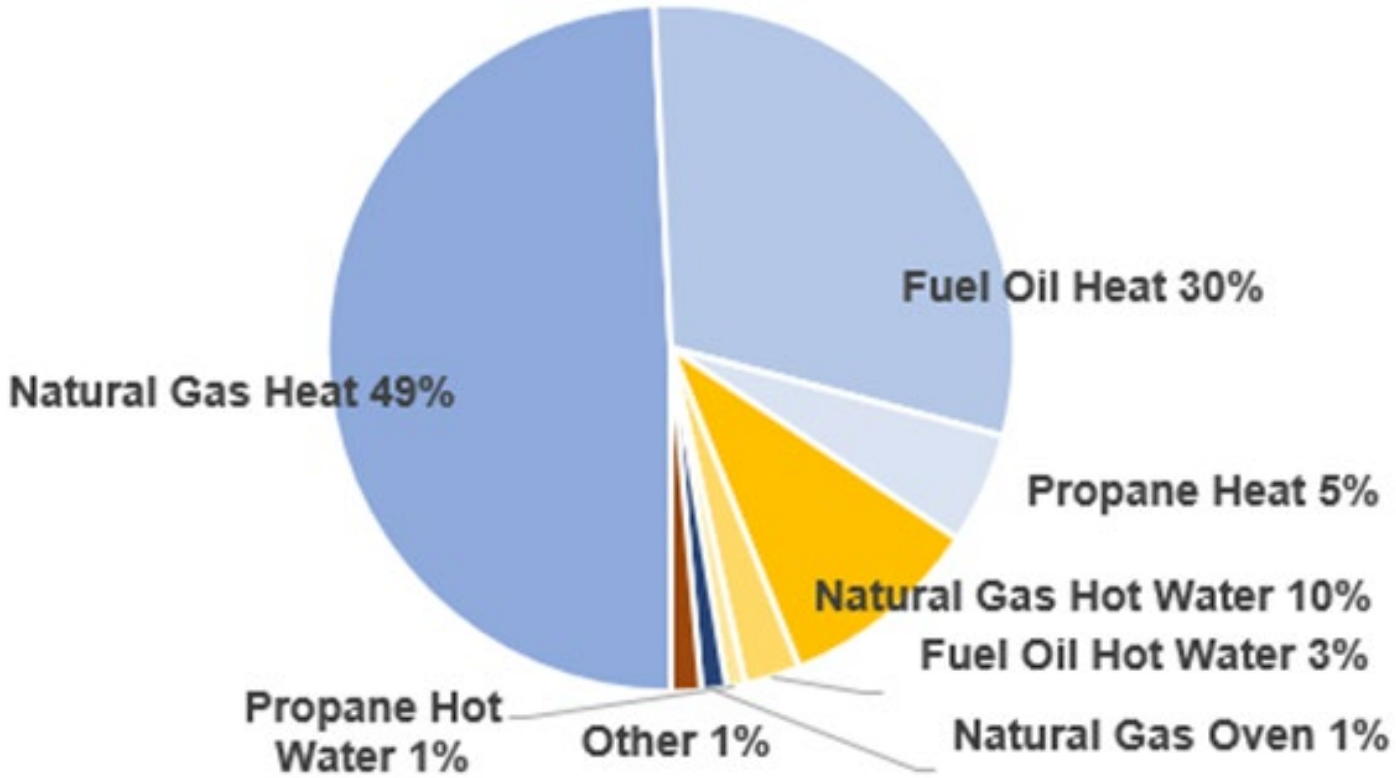
- Estimate the potential criteria and GHG emissions savings of:
  - Switching residential space heating from fossil fuels to heat pumps;
  - Switching residential electric resistance heat to heat pumps;
  - Switching residential fossil fuel and resistance heat powered hot water heaters to heat pumps; and
  - Switching residential clothes dryers and stoves to heat pump/induction stoves from fossil fuels.
- Expand on an analysis conducted last year for one state (CT) using the Department of Energy/National Renewable Energy Laboratory (NREL) ResStock analysis tool.

Building-Related CO2 Emissions



BUILDING DECARBONIZATION COALITION

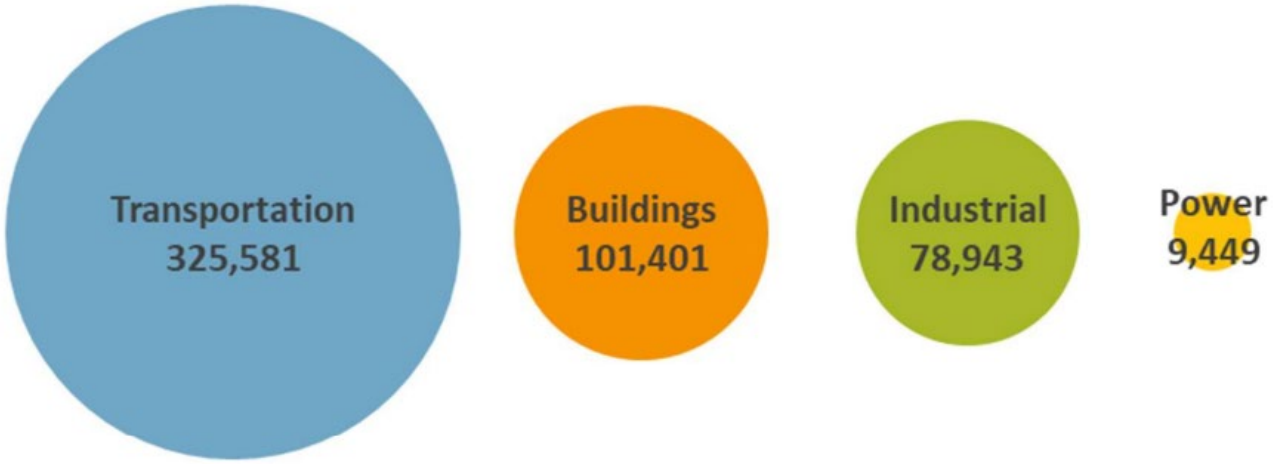
Source: EPA State Inventory Too

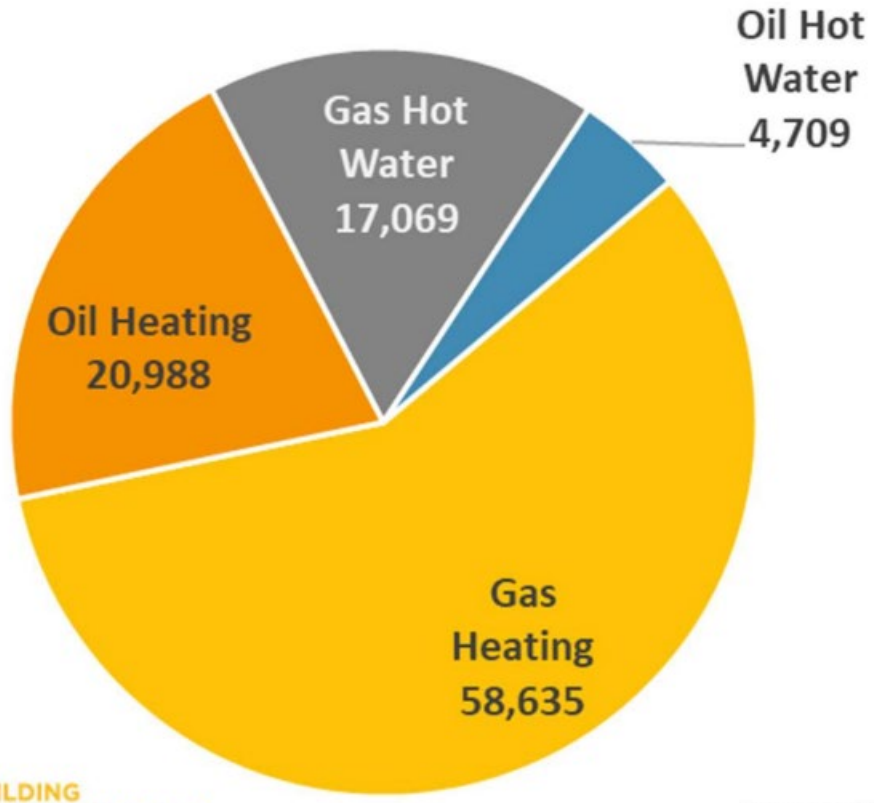


Source: ResStock Baseline Scenario

The above chart is for the eight NESCAUM member states

NOx Emissions from On-Site fossil fuel Combustion in Residential Buildings





- Data shown only for the NESCAUM region
- Data excludes emissions associated with electricity generation

BUILDING DECARBONIZATION COALITION

Source: RECS, CBECS, AP42

Source: Building Decarbonization Coalition – EIA State Energy System Data (SEDS), AP42.

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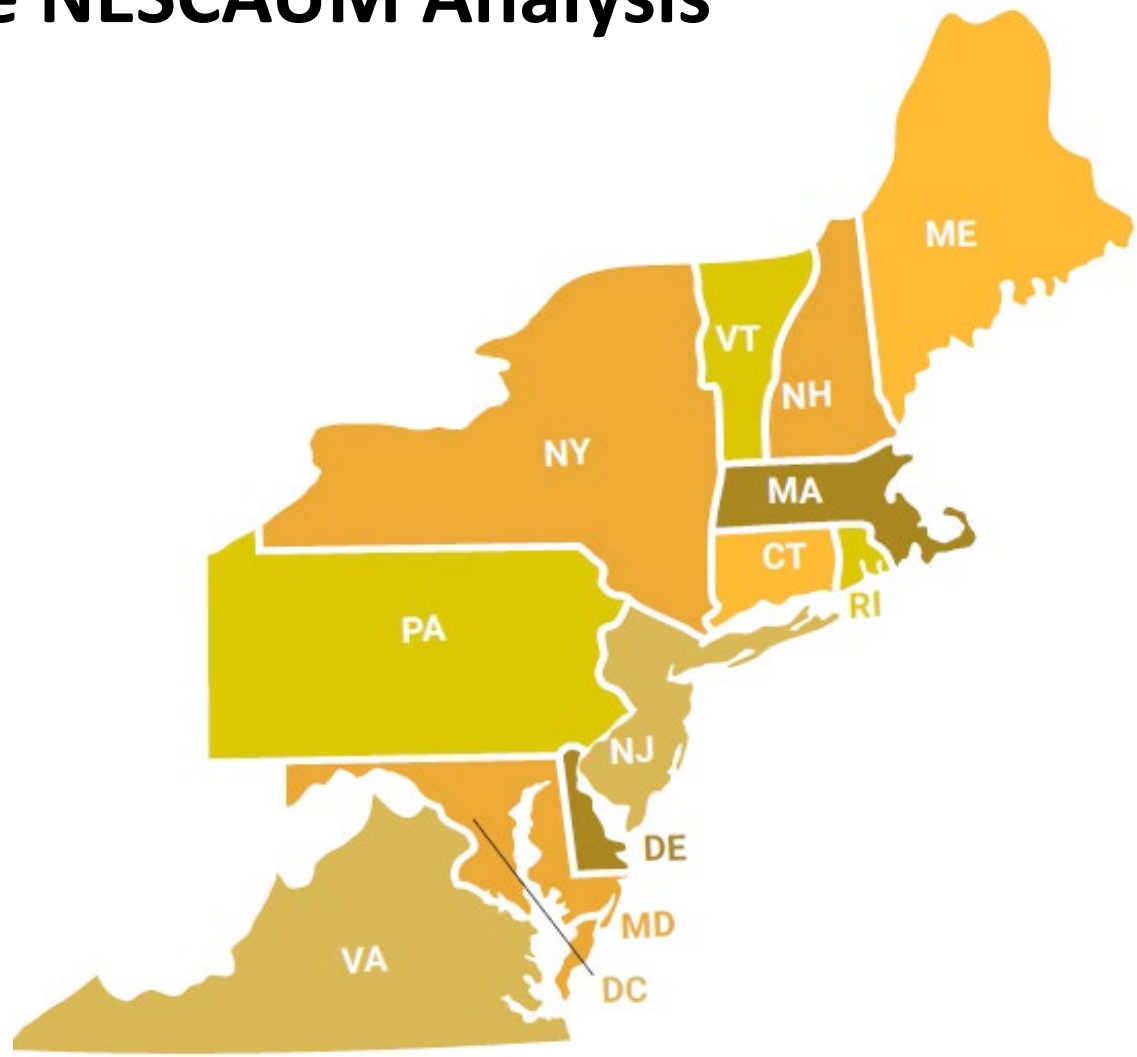
Geographic Area of the NESCAUM Analysis

- 13 states/jurisdictions in the Northeast and mid-Atlantic.
- Results are provided for the 13 jurisdictions combined.
- Final results will also be available for individual states and the District of Columbia.
- The analysis expands on a 2021 study that estimated emission reductions from building electrification in Connecticut.



ReStock Analysis Tool

- Models energy consumption/savings & avoided CO_2 emissions in 48 states.
- Meteorology from three calendar years was taken into account to determine heating and cooling requirements.
- 550,000 representative dwelling units for each run:
  - One for every 240 residential units that exist in the U.S.
- 100+ home characteristics based on data from EIA Residential Energy Consumption Survey and US Census American Household Survey and American Community Survey (e.g., climate zone, building type, vintage, occupants, floor area, heating/cooling, appliances, insulation, windows).
- 10 measure packages (basic & enhanced enclosure, min- & high-efficiency heat pumps w/wo electric backup, heat pump water heaters, min- & high-efficiency whole home electrification w/wo enhanced enclosure).

ReStock Analysis Tool (Continued)

- Energy savings calculated for states by comparing energy consumption for three ResStock scenarios with baseline consumption:
  - High Efficiency Heat Pumps with Electric Backup (space heating)
  - Heat Pump Water Heaters (water heating)
  - Whole Home High Efficiency Electrification, no enhanced enclosures (whole home)
- NESCAUM calculated on-site emissions using AP-42 emissions factors for fuel oil, natural gas, and propane furnaces.
- Upstream emissions were calculated by multiplying change in electricity (mWh) by emission factors from New England ISO and eGrid

Electricity-Related Emission Factors Used in the Analysis

State	NOx (lb/MWh)	SO2 (lb/MWh)	CO2 (lb/MWh)
NE ISO	0.11	0.02	706
CT	0.11	0.02	706
MA	0.11	0.02	706
ME	0.11	0.02	706
NH	0.11	0.02	706
RI	0.11	0.02	706
VT	0.11	0.02	706
DC	3.2	0.04	797
DE	0.32	0.35	695
MD	0.26	0.29	735
NJ	0.24	0.06	543
NY	0.2	0.04	377
PA	0.4	0.5	755
VA	0.3	0.1	633

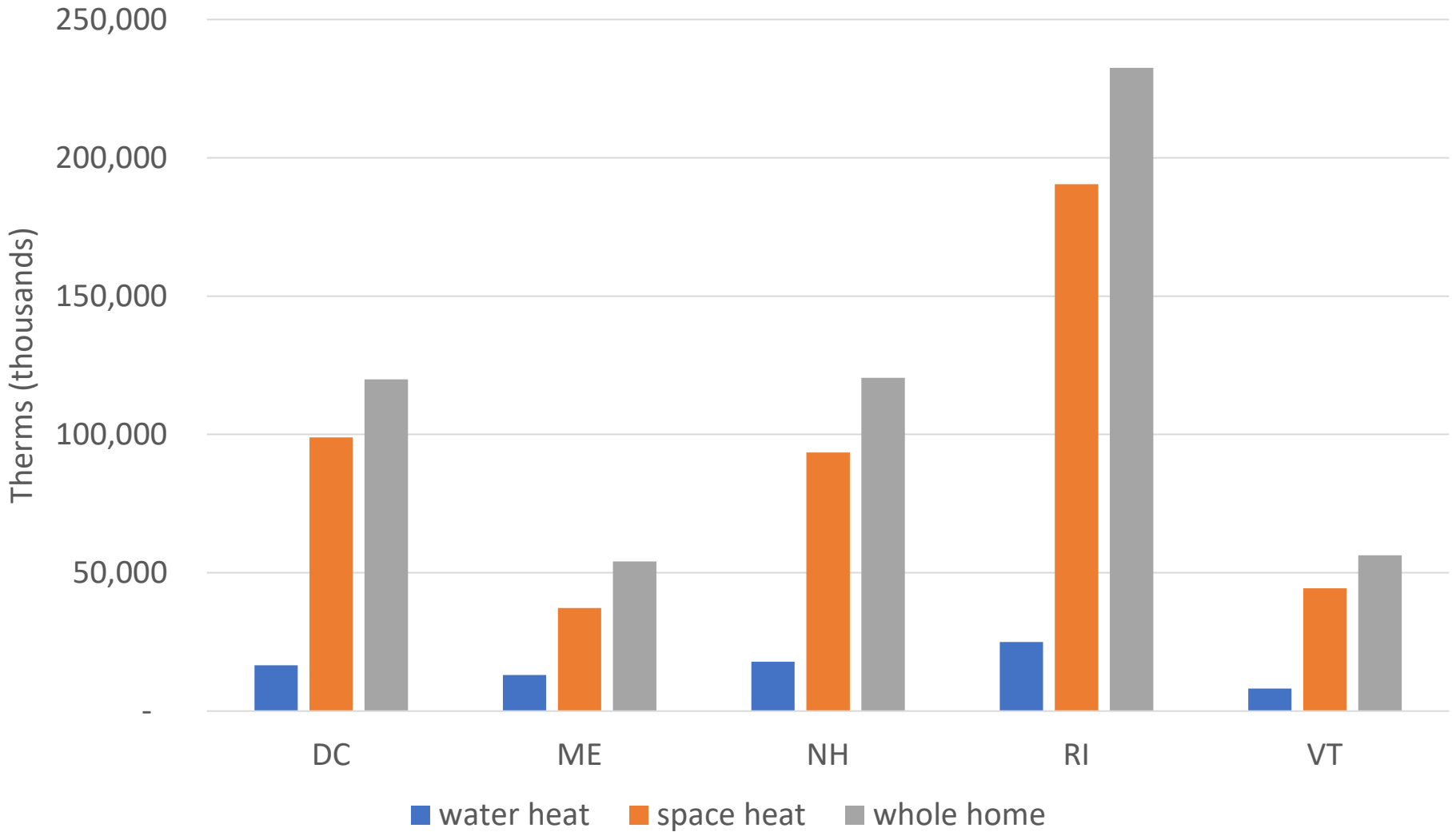
Source: ISO New England 2022 and EPA eGRID 2020

Assumptions

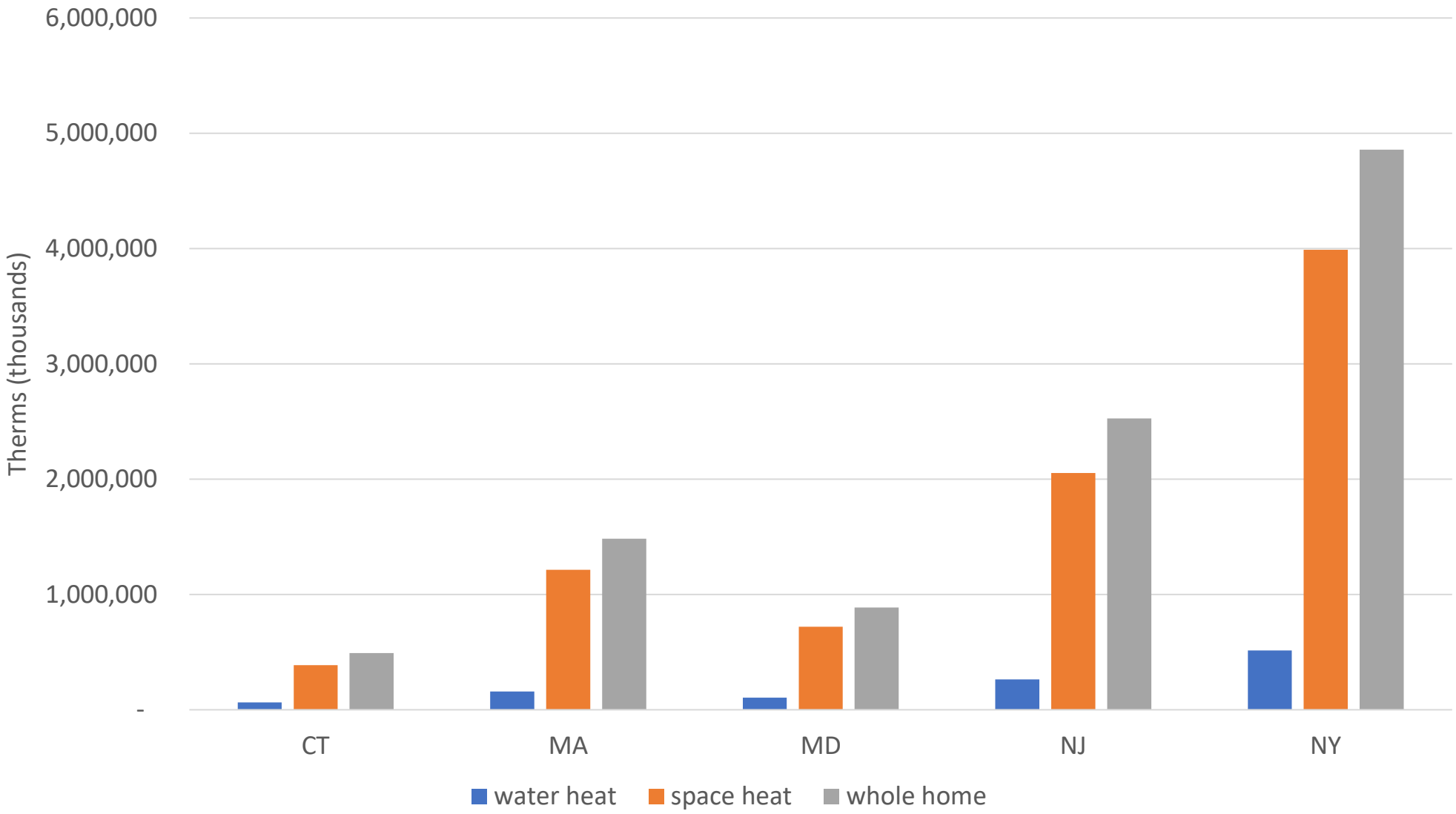
- The analysis assumes all technically feasible appliance conversions in the 13-jurisdiction area.
- Technologies are applied by the model without regard to cost:
  - Economic barriers may reduce introduction of technologies as seen in the earlier NESCAUM analysis with ResStock.
- There is no phasing in of electrification in the analysis, only a complete conversion occurring from today's baseline. This is designed to illustrate the maximum potential we can expect in terms of emissions reductions with residential building electrification.
- We have not estimated any change in electricity-related emissions due to electricity sector decarbonization efforts.
- No additional improvements were assumed to building envelopes.
- 95% - 100% of residences assumed to have appliance conversions in the 13-jurisdiction region.

Results

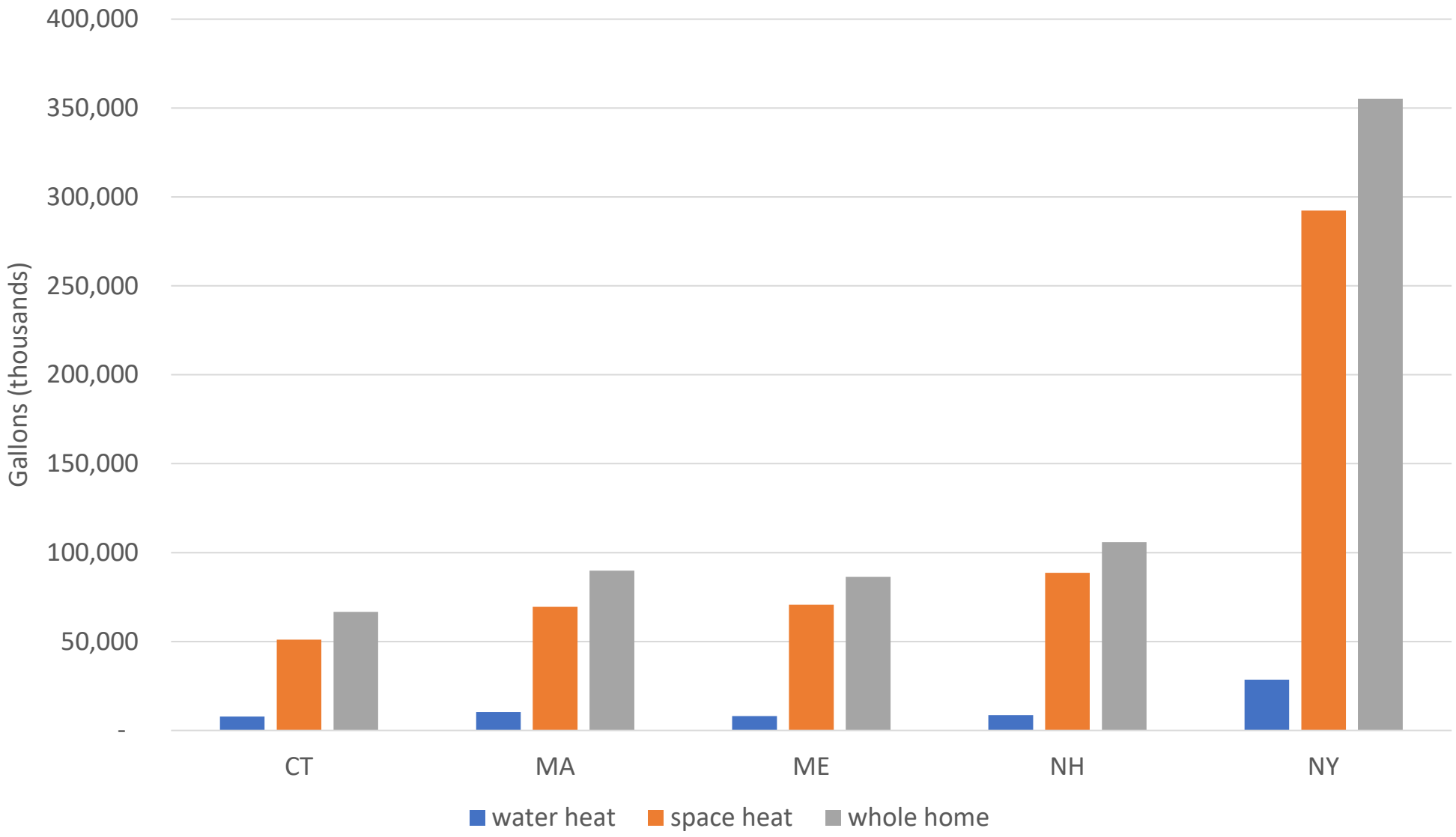
Estimated Therms of Natural Gas Saved Smaller States/Jurisdictions



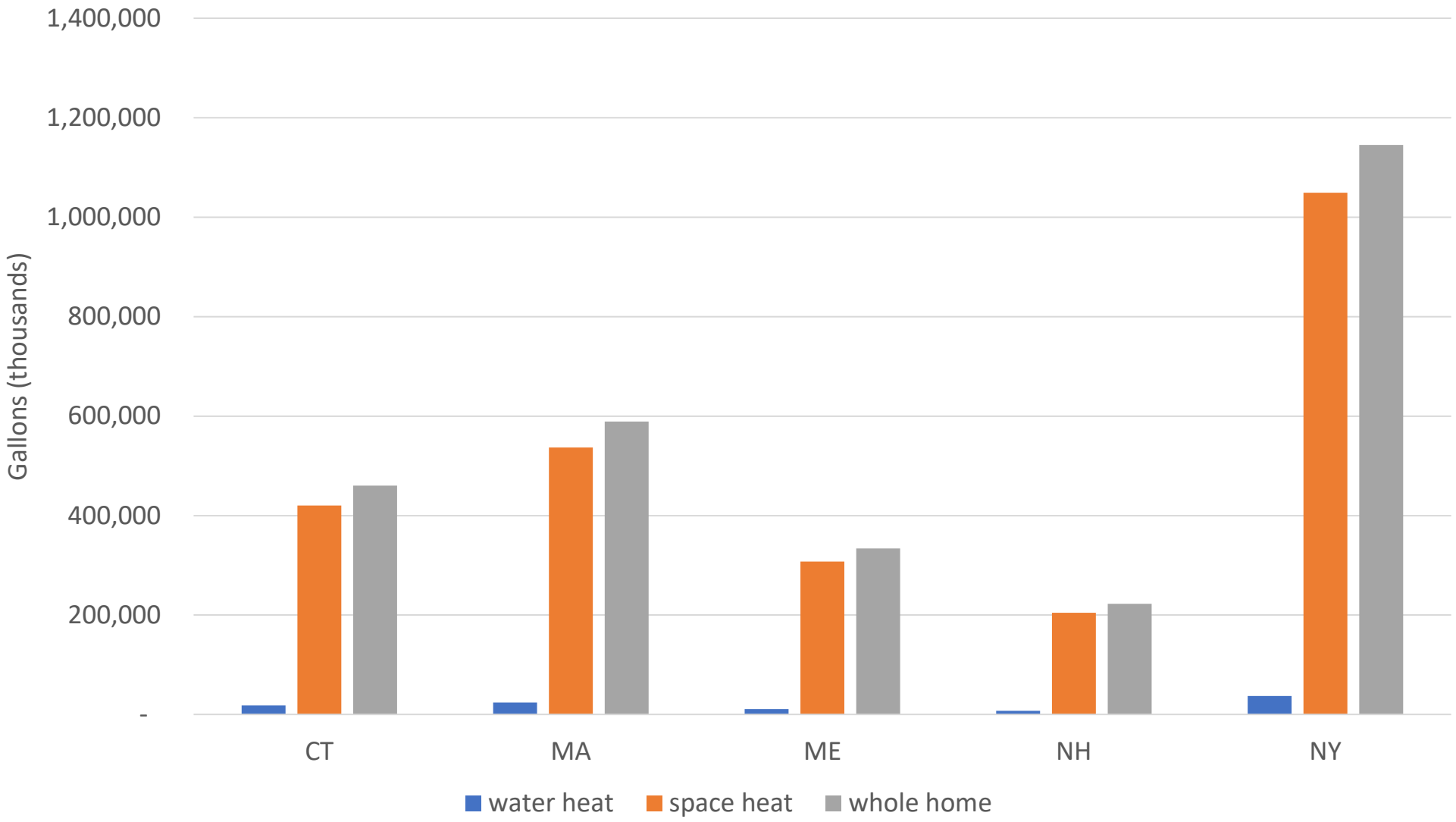
Estimated Therms of Natural Gas Saved (larger states)

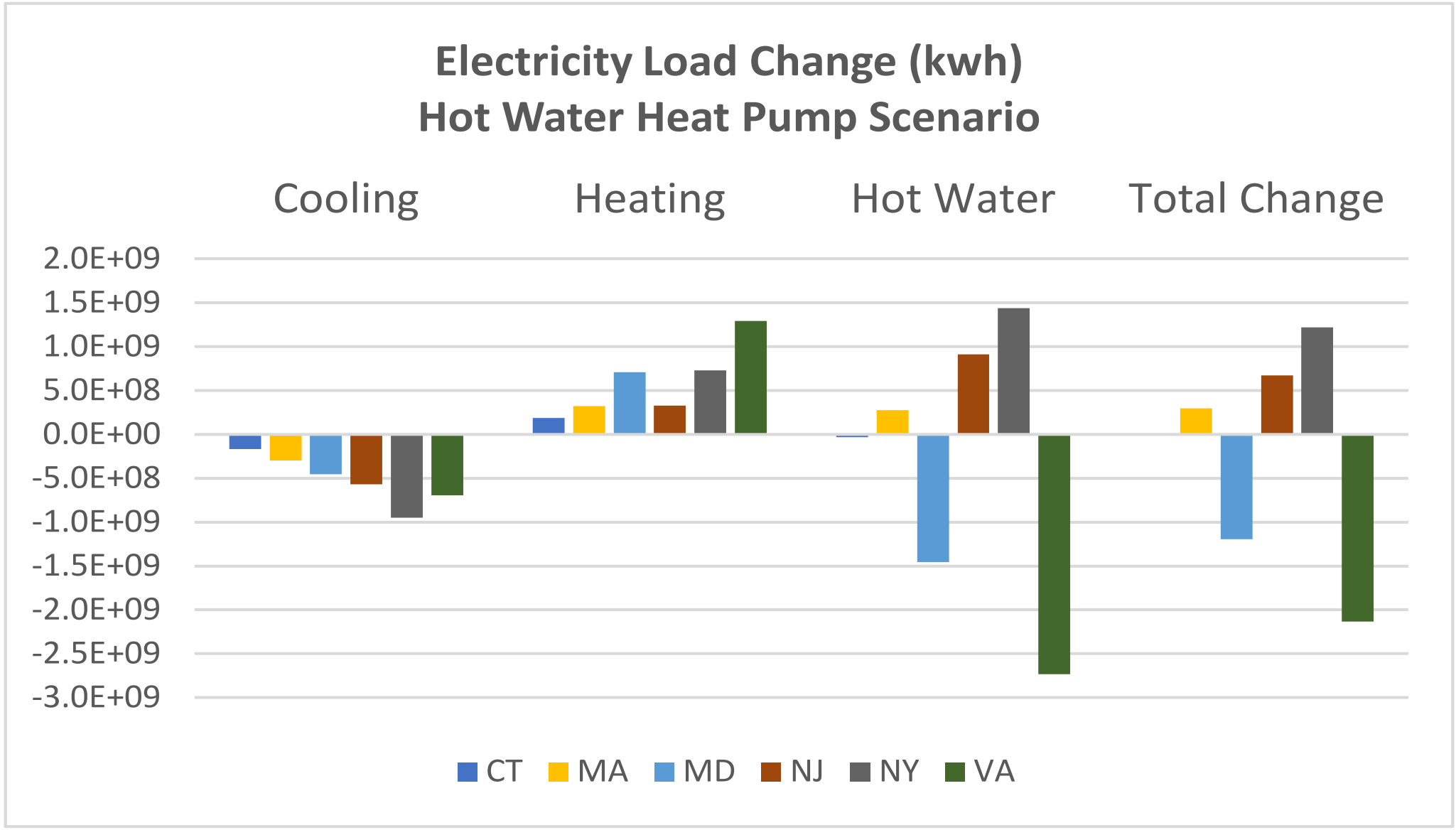


Estimated Gallons of Propane Saved (Selected States)



Estimated Gallons of #2 Fuel Oil Saved (Selected States)




Electricity Load Change (kwh)
Hot Water Heat Pump Scenario
Cooling
Heating
Hot Water
Total Change
2.0E+09
1.5E+09
1.0E+09
5.0E+08
0.0E+00
-5.0E+08
-1.0E+09
-1.5E+09
-2.0E+09
-2.5E+09
-3.0E+09
CT
MA
MD
NJ
NY
VA

Potential Emissions Reduced in the Northeast and Mid-Atlantic

Scenario	CO_2 Reduction (annual tons)*	NOx Reduction (annual tons)*	PM2.5 Reduction (annual tons)
Hot water heater conversion	12,708,728	9,819	637
Space heating conversion	103,432,766	86,406	5,222
Whole home conversion	127,530,194	104,578	6,308

*includes upstream emissions associated with electric generating units

Source: NESCAUM and OTC draft analysis using NREL ResStock outputs

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Hot Water Heater Conversions: Potential Emissions Reduced by State

	On-site + Upstream	
	NOx	CO_2
CT	492	640,539
DC	178	108,233
DE	108	165,134
MA	981	1,181,133
MD	638	1,038,847
ME	205	279,109
NH	206	263,365
NJ	1,240	1,511,630
NY	2,739	3,412,063
PA	1,854	2,381,448
RI	159	191,032
VA	912	1,408,415
VT	107	127,781
Sum	9,819	12,708,728

- Annual regional reduction in CO_2 equivalent to 1.4 billion avoided gallons of gasoline combusted
- 3 million cars taken off the road for one year

Emissions equivalencies source: EPA GHG equivalency calculator (https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator#results)

Whole Home Conversion: Potential Emissions Reduced by State

	On-site + Upstream	
	NOx	CO_2
CT	5,980	6,992,219
DC	1,291	899,871
DE	1,195	1,598,145
MA	11,350	12,261,208
MD	6,455	9,679,517
ME	3,101	2,760,924
NH	2,826	2,740,073
NJ	12,629	15,397,822
NY	30,499	38,006,797
PA	18,308	22,576,156
RI	1,824	1,919,383
VA	7,651	11,590,890
VT	1,470	1,107,189
Sum	104,578	127,530,194

- Annual regional in CO_2 equivalent to 14 billion avoided gallons of gasoline combusted
- 27 million cars taken off the road for one year

Emissions equivalencies source: EPA GHG equivalency calculator (https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator#results)

Conclusions: Energy Consumption

- More natural gas is reduced than any other fuel type in all scenarios.
- 4 billion gallons of fuel oil and 14 billion therms of natural gas, and 1 billion gallons of propane could be reduced through whole home electrification.
- With whole home conversion, ResStock estimates a net increase in 54,000 gWh of electricity in the 13-jurisdictions annually will occur.
- In three jurisdictions (DC, DE, and MD) electricity consumption is projected to be reduced with whole home electrification:
  - This is due to relatively inefficient air conditioning systems in the baseline
  - Also due to resistance heat in the baseline
- In all three scenarios (hot water, space heating, and whole home) total energy consumption decreases significantly.

Conclusions: Emission Reductions

- With a switch of all housing units in the region to heat pumps for space heating, water heating, clothes drying, and cooking, 104,000 tons of NOx, 6,000 tons of $PM_{2.5}$, and 127 million tons of CO_2 could be reduced annually (with upstream emissions factored in).
- A conversion of fossil fuel and electric resistance heat hot water heaters to fuel pumps could reduce over 12 million tons of CO_2 and 9,000 tons of NOx annually.
- Electricity-related emissions cause an increase of 4,000 tons of NOx and 13 million tons per year of CO_2, with current grid emissions assumed. Net emissions reductions still far exceed these tons.
- Significant reductions in electricity-related emissions are realized from conversion from conventional A/C and resistance heating systems to heat pumps.
    - Although this reduction will shrink as jurisdictions move to lower carbon electricity sources

Next Steps:

- Consider evaluation of health benefits using EPA's COBRA model.
- Finalize draft report summarizing the study and distribute to states for review.
- Present findings to NESCAUM and/or Ozone Transport Commission Air Directors.
- Make publicly available when finalized.

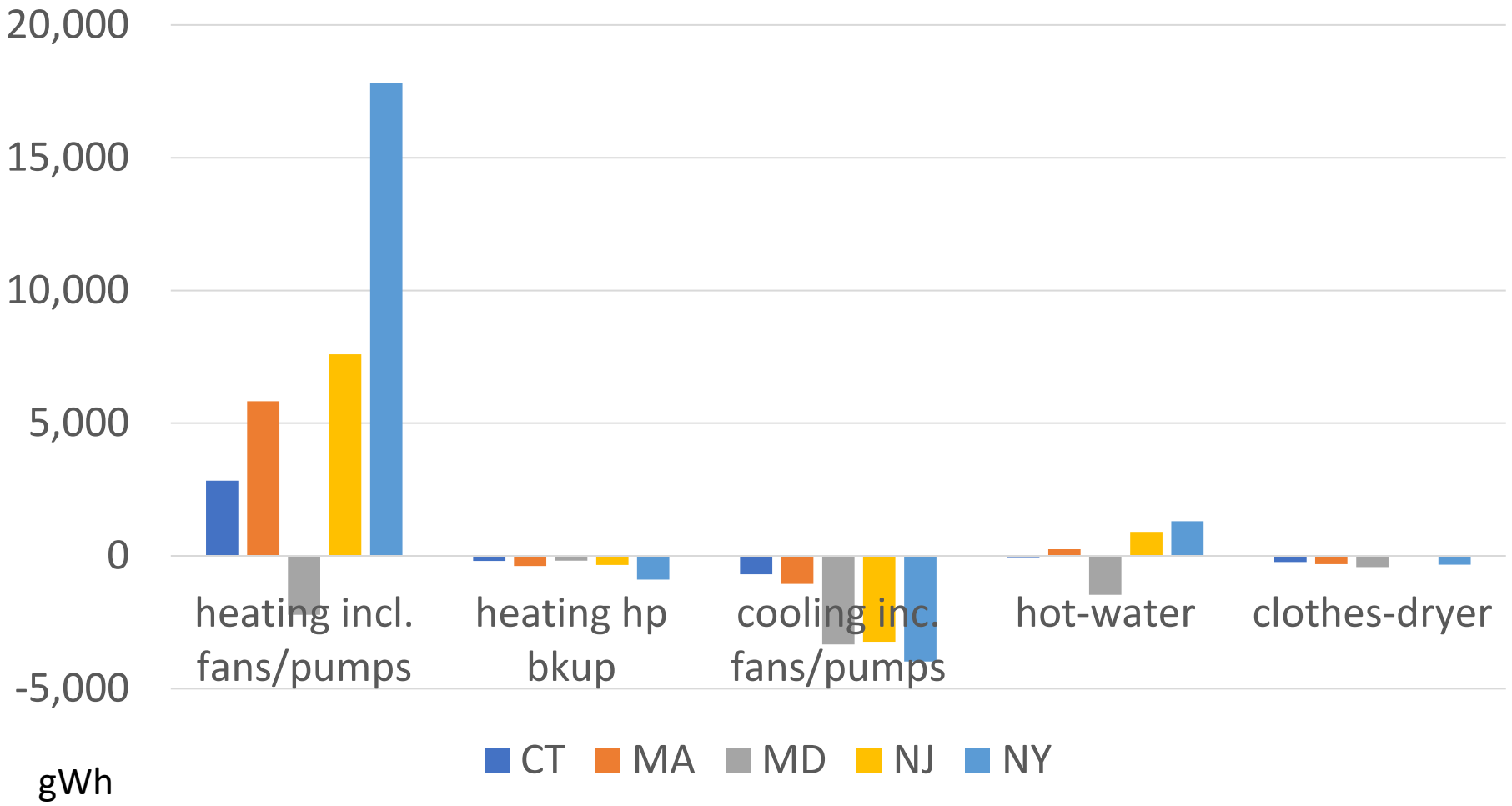
Thanks to:

State staff who provided input on the 2021 analysis

The NREL ResStock team

Additional Slides

Estimated Change in Electricity Consumption – Selected States



Source: NREL ResStock outputs

Package #4 Description – Heat Pump High Efficiency

- Centrally ducted heat pump, variable-speed mini-split, SEER 24, 13 HSPF
  - Apply to dwelling units with ducts and no heat pump or a less efficient heat pump (SEERs < 24; HSPFs < 13)
  - Sized to ACCA Manual S
  - Backup heat provided by electric resistance, active when the heat pump can't meet the load
- Ductless variable-speed mini-split heat pump SEER 29.3 14 HSPF 7
  - Apply to dwelling units without ducts and no heat pump or a less-efficient heat pump (MSHP SEER 14.5, 8.2 HSPF or MSHP SEER 29.3, 14 HSPF not sized to max load)
  - Sized to max load
  - Backup heat provided by electric resistance, active when the heat pump can't meet the load

Package #6 Description – Heat Pump Water Heaters

- 50 gallon, 3.45 UEF heat pump
  - For dwelling units with 1-3 bedrooms and an existing water heater other than an electric tankless water heater
- 66 gallon, 3.35 UEF
  - For dwelling units with 4 bedrooms and an existing water heater other than an electric tankless water heater
- 80, 3.45 UEF
  - For dwelling units with more than 4 bedrooms and an existing water heater other than an electric tankless water heater

Package #8 Description – Whole Home Electrification

- No enclosure measures
- High-efficiency heat pump (Measure Package 4) for all dwelling units with non-electric heating or less-efficient electric heating
- Heat pump water heater for all dwelling units with non-electric heating or less-efficient electric water heating
- Ventless heat pump dryer (CEF=5.2) for all dwelling units with non-electric dryers or less-efficient electric dryers
- Electric oven and induction range for all dwelling units