Size up or size down? National analysis of heat pump sizing and impacts

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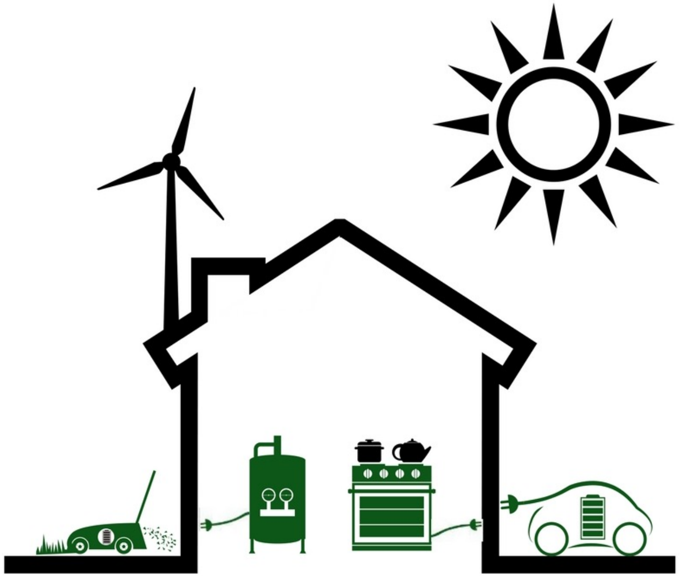
2023 Hot Water Forum & Hot Air Forum
March 7-9, 2023

Contents

Introduction

- Building electrification- a key component for achieving greenhouse gas emission targets
- Air-source heat pumps- an efficient method of decarbonizing buildings [1]
- Major factor for heat pump adoption: upfront installation cost and heat pump size
- Objective: National analysis of factors impacting heat pump sizing
- Methodology: Simulation of 550,000 representative dwelling units using ResStock^{TM} considering various performance levels with and without envelope upgrades



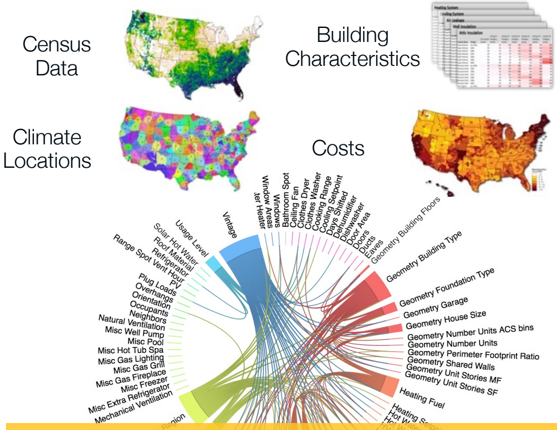
Source: https://www.eesi.org/electrification/be

[1] IEA, Installation of about 600 million heat pumps covering 20% of buildings heating needs required by 2030, Tech. rep.,1225 IEA (2022). Online: https://www.iea.org/reports/installation-of-about-600-million-heat-pumps-covering-20-of-buildings-heating-needs-required-by-2030

Background-ResStock

- ResStock: Highly granular residential building analysis tools for national, regional, and local housing stocks
- Analysis included all residential dwelling units in contiguous U.S.

Large public and private datasets



6000 probability distributions for 100 parameters structured in a dependency tree

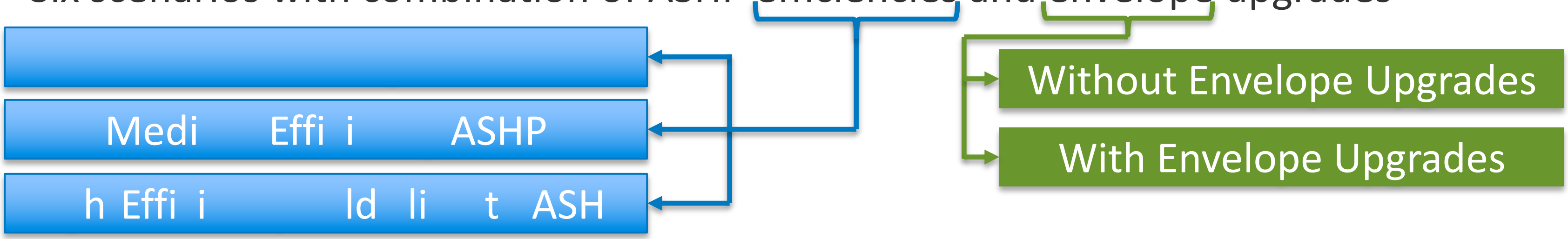
Housing stock characteristics database + Physics-based computer modeling + High-performance computing

OpenStudio EnergyPlus

Further information:
Overview: https://resstock.nrel.gov/
Calibration/validation documentation: https://www.nrel.gov/docs/fy22osti/80889.pdf
Source code: https://github.com/NREL/resstock

Scenario Description

- Six scenarios with combination of ASHP efficiencies and envelope upgrades



Scenario name	Upgrade details			Applicability criteria	Capacity retention @ 5 °F (-15 °C)	Minimum temp. for heat pump operation
	Heat pump type	Cooling efficiency (SEER)	Heating efficiency (HSPF)			
Min. Efficiency ASHP	Central single-speed	15	9	with ducts (79%)	47%	0 °F (-17.8 °C)
	Ductless var.-speed	14.5	8.2	without ducts (21%)		None
Medium Efficiency ASHP	Central var.-speed	22	10	with ducts (79%)	49%	0 °F (-17.8 °C)
	Ductless var.-speed	17	9.5	without ducts (21%)		None
High-Efficiency Cold Climate ASHP	Central var.-speed	24	13	with ducts (79%)	85%	None
	Ductless var.-speed	29.3	14	without ducts (21%)		

- All scenarios include duct insulation upgrade to 10% leakage and R-8 insulation

Envelope upgrade

- Three scenarios include heat pumps with envelope upgrades

Attic Insulation | R-6.5 Wall Insulation |

Envelope upgrades	Upgrade details	Applicability criteria
Attic floor air-sealing and insulation	R-values follow 2021 IECC	Homes with vented attic and attic R-value less than 2021 IECC
R-6.5 (RSI-1.1) wall insulation with re-siding	R-6.5 (RSI-1.1) of continuous wall insulation, e.g., 1" of rigid polyisocyanurate board installed under new siding	Homes older than 1990 with less than R-19 (RSI-3.3) wall insulation
Low-e storm windows	Exterior low-e storm windows	Homes with single and double-pane windows

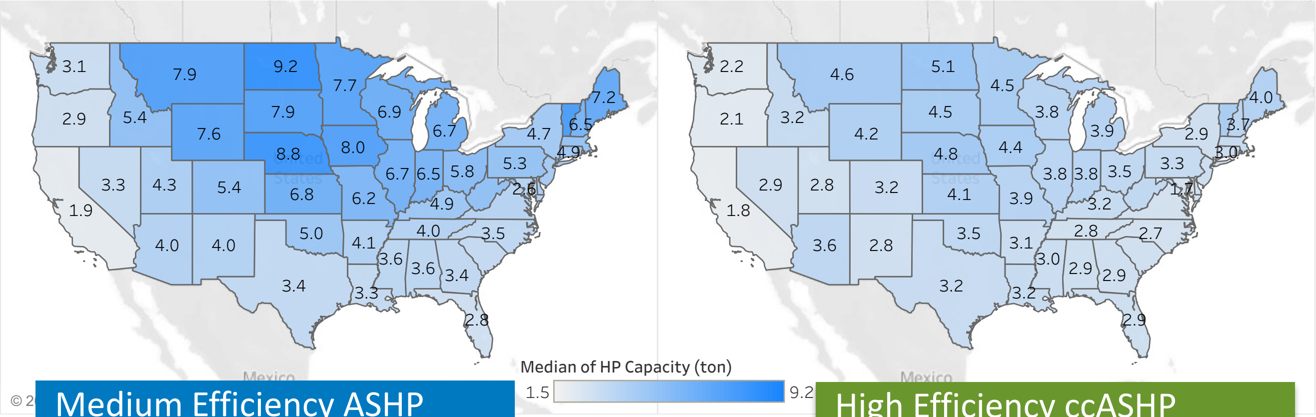
- Modeling limitation: Ductwork airflow constraints on heat pump sizing
  - Heat pump size based on a) design cooling and heating loads / b) design cooling loads
  - In reality, existing duct system may force under sizing of heat pumps and use electric resistance backup

Factors impacting ASHP sizes

Capacity Retention

- Higher capacity retention in high-efficiency heat pump reduces equipment size, particularly in the cold-climate region
- Median size for high efficiency heat pump reduced by 42% compared to medium efficiency heat pump for cold-climate

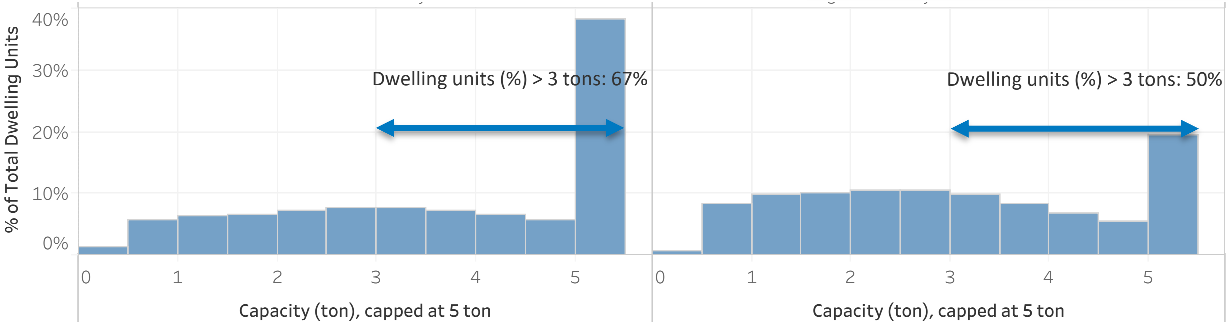
Median HP Size



Medium Efficiency ASHP
~10 HSPF1
50% capacity at 5°F

High Efficiency ccASHP
~13 HSPF1
85% capacity at 5°F

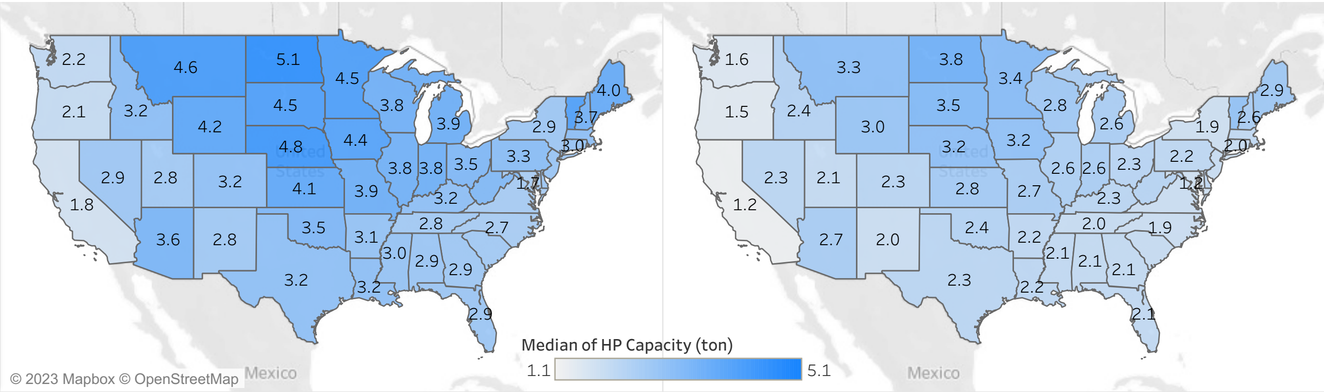
HP Size Distribution



Envelope Upgrades

- Lower heating and cooling demand with increased envelope efficiency decreases heat pump size
- Average heat pump size for high-efficiency heat pumps reduced by 1.4 tons with envelope upgrade, reducing installation cost by $2500

Median HP Size

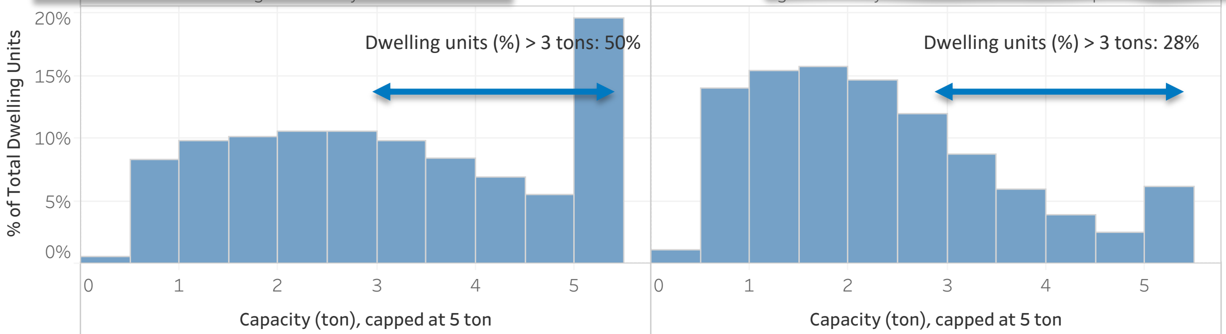


High Efficiency ccASHP (~13 HSPF1)

Both sized for max. of Manual J heating or cooling

High Efficiency ccASHP (~13 HSPF1) + Envelope

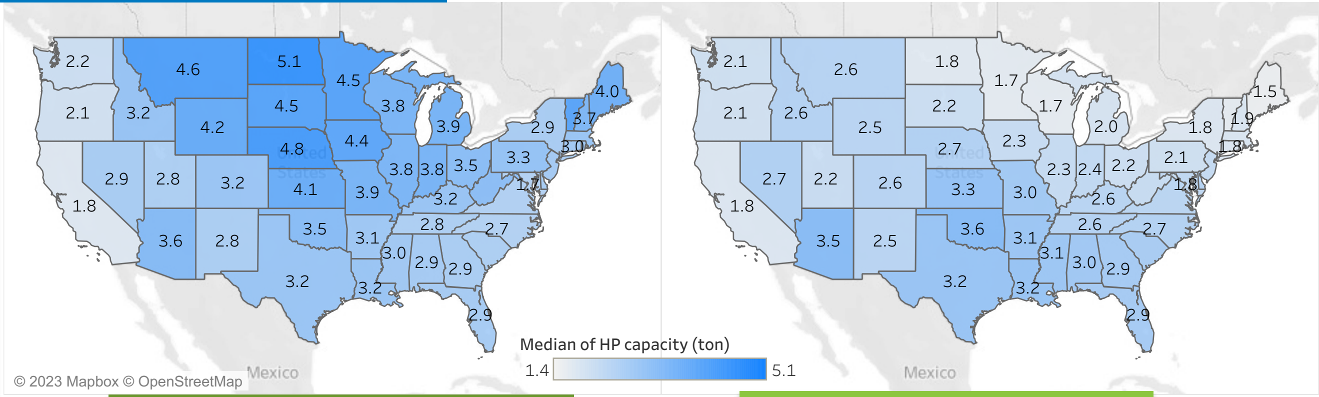
HP Size Distribution



Sizing Methodology

- Heat pump sizing based on **maximum** heating and cooling load is higher than heat pump sizing with **cooling load** priority for heating dominant region

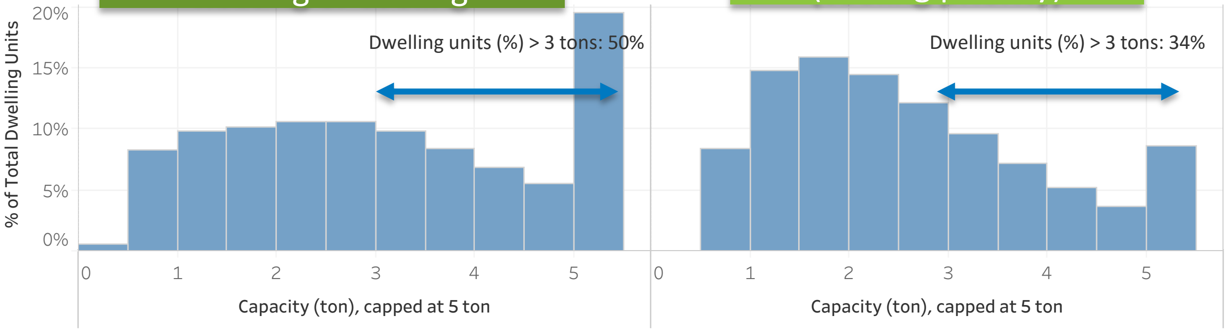
Median HP Size



High Efficiency ccASHP Sized for max. of Manual J heating or cooling

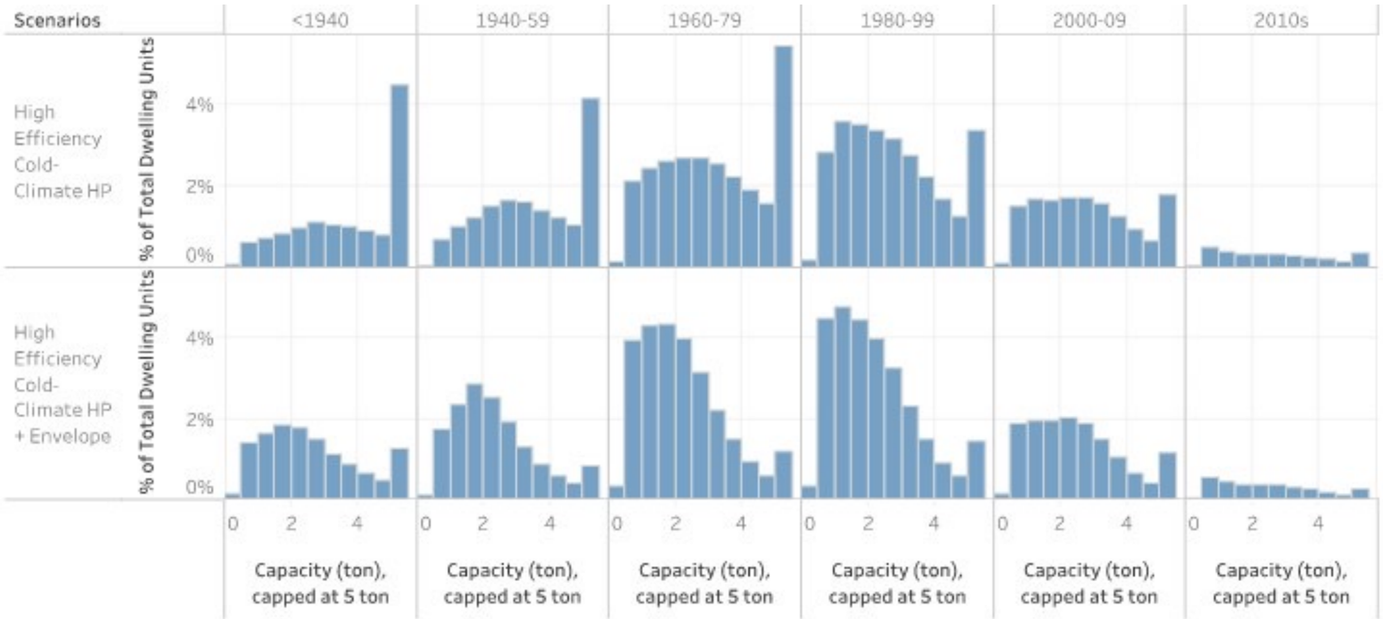
High Efficiency ccASHP Sized per Manual S (cooling priority)

HP Size Distribution



Building Characteristics

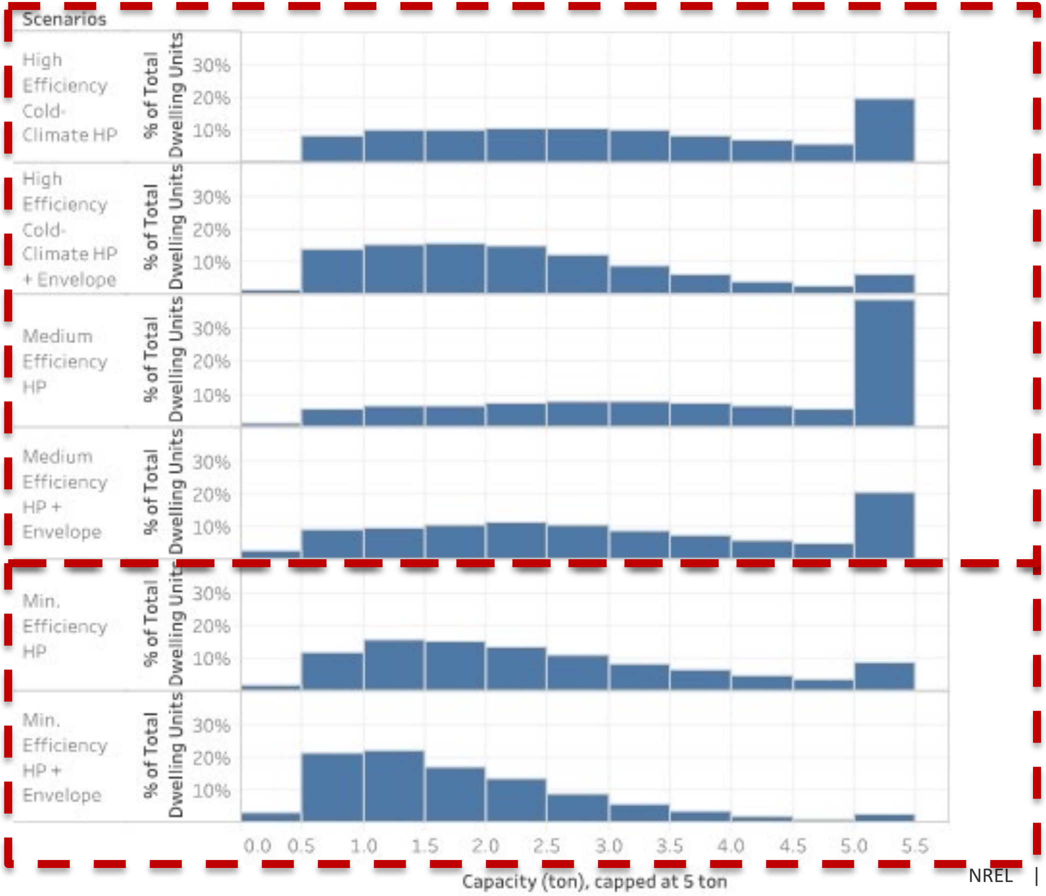
- Older vintage buildings require higher heat pump sizes due to higher heating and cooling load
- Envelope upgrades in older vintage buildings have significant impact on HP size compared to newer vintage buildings



Performance level comparison- Overall distribution

- Minimum efficiency heat pump sized based on cooling load only resulting in smaller-sized units
    - High-efficiency and medium-efficiency heat pumps sized based on maximum heating and cooling load

- High-efficiency HP + envelope has the lowest heat pump size among high and medium-efficiency HP scenario



Summary

- Major influencing factors for heat pump size
  - ❑ Climate region
  - ❑ Heat pump capacity retention
  - ❑ Envelope upgrades
  - ❑ Sizing method
  - ❑ Vintage
- High-efficiency HP with envelope upgrade scenario results in lowest HP size among high and medium-efficiency scenarios
  - However, high-efficiency HP + envelope has the highest initial cost
- Upcoming paper will present detailed analysis of heat pump electrification impacts on
  - ❖ Bill savings
  - ❖ Carbon emission
  - ❖ Upgrade cost
  - ❖ Net present value (NPV)
  - ❖ Sensitivity to incentives and fuel price volatility

Thank you

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NREL/PR-5500-85347

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, under Contract No. DE-AC36-08GO28308, and by The Regents of the University of California under contract no. DE-AC02-05CH11231, for the U.S. Department of Energy (DOE). Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Building Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government.

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