Modeling Managed Building Electrification in New York State

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Integration Analysis Context

For the latest IA modeling inputs and outputs, see:

- https://www.nyserda.ny.gov/About/Publications/Energy-Analysis-Reports-and-Studies/Greenhouse-Gas-Emissions
- IA Annex 1 Inputs and Assumptions 2022 revised [xlsx]
- IA Annex 2 Key Drivers and Outputs 2022 revised [xlsx]

> The Integration Analysis (IA) is NYSERDA’s economywide decarbonization pathways model used to illustrate how New York State can achieve the greenhouse gas emission limits of the Climate Act.

> The model was developed to support deliberations of the NYS Climate Action Council for the Scoping Plan (Dec 2022). Assumptions are informed by feedback from sectoral Advisory Panels, input from the independent Technical Advisory Group, and related analytic work.

> NYSERDA continues to improve the IA modeling methods and assumptions.

Focus Today: IA Scenario 2 (updated Sept. 2023)

IA scenarios that meet the Climate Act emissions limits and achieve carbon neutrality by midcentury share foundational themes across <u>all</u> GHG mitigation scenarios:

- Zero emission power sector by 2040
- More rapid and widespread end-use electrification & efficiency
- Enhancement and expansion of transit & vehicle miles traveled reduction
- Higher methane mitigation in agriculture and waste
- End-use electric load flexibility reflective of high customer engagement and advanced techs

IA Scenario 2: Strategic Use of Low-Carbon Fuels

- Includes the use of bioenergy derived from biogenic waste, agriculture & forest residues, and limited purpose grown biomass, as well as green hydrogen, for difficult to electrify applications.
- An updated version of this scenario was recently proposed to support two related processes: (1) NYISO's System & Resource Outlook and (2) the Coordinated Grid Planning Process established by the NYS PSC.

Modeling Updates

As part of ongoing modeling work, updates were made to the Integration Analysis that was published in New York's Scoping Plan (Dec. 2022), including:

- Improved representation of annual and peak space heating load
- Higher Planning Reserve Margin (up to 18% by 2050, compared to 10%)
- Higher flexibility of Light Duty Electric Vehicle (LDV) charging
- Updated Expected Load Carrying Capability (ELCC) assumptions

The updates did not have a significant impact on key topline cost and benefit metrics. Some relevant metrics are slightly different as compared to the 2022 Scoping Plan:

- Annual loads decrease marginally, with 2050 annual loads 4 TWh (1%) lower.
- Peak loads are moderately lower in the near-term, but trend higher from 2035 onward; the updated 2050 peak is ~2 GW (5%) higher.
- Higher peak load and planning reserve margin needs drive higher zero-carbon firm capacity build (<2 GW). This increase is mitigated by the increased ELCC contribution of storage + renewables.

Available at: https://www.nyserda.ny.gov/About/Publications/Energy-Analysis-Reports-and-Studies/Greenhouse-Gas-Emissions

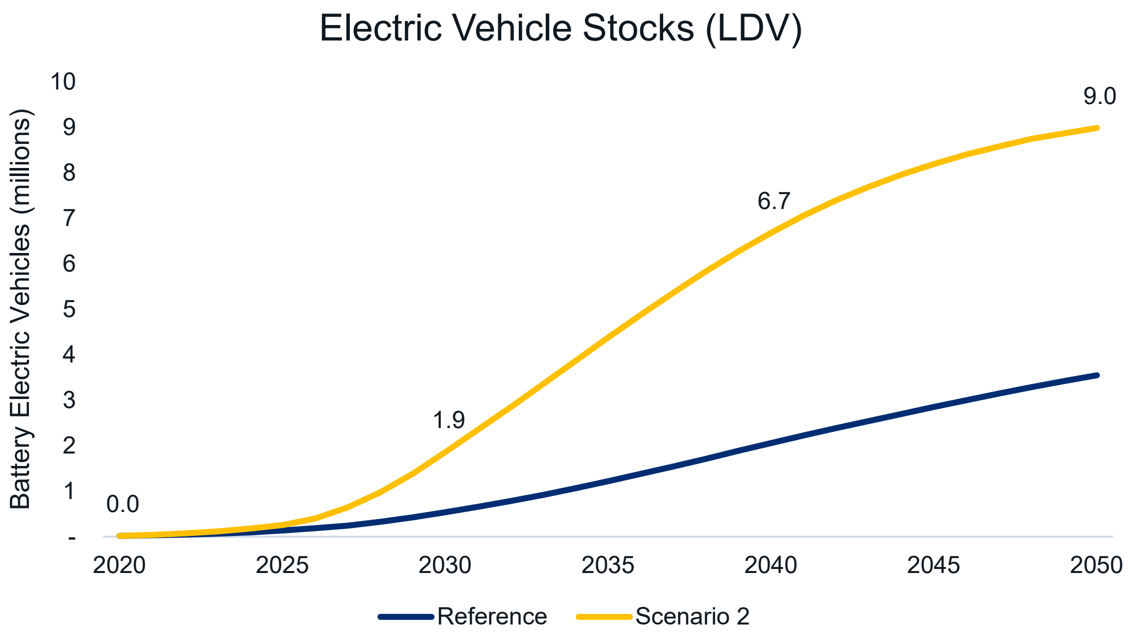
Load Drivers – Transportation

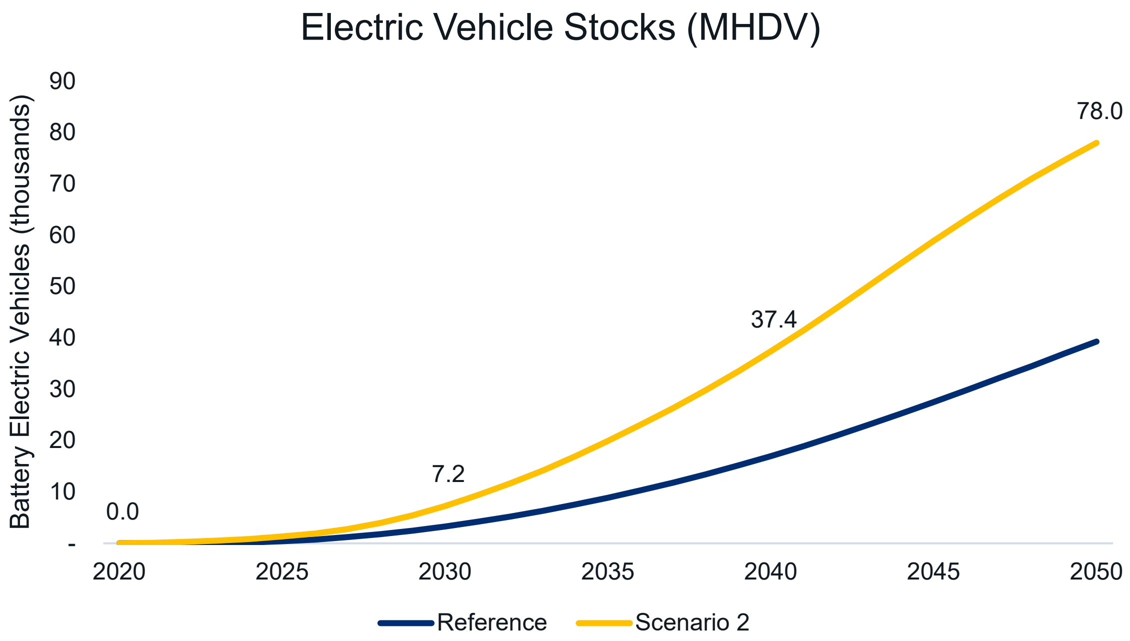
(Integration Analysis, Sept. 2023)

Significant growth in EV sales, and resulting EV stock, is needed to achieve Climate Act emission limits. Economics and policy targets (e.g. ZEV MOU, Advanced Clean Cars, and Advanced Clean Trucks) will contribute to deployment:

LDV: 100% 2035 zero-emission vehicles sales

MHDV: 100% 2045 zero-emission vehicle sales

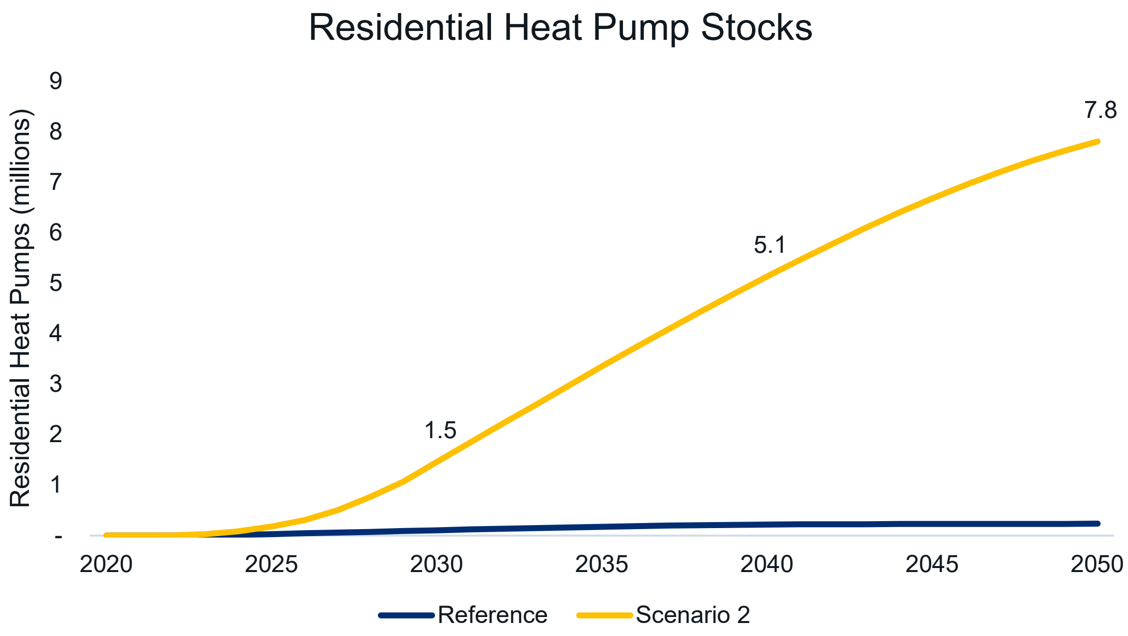


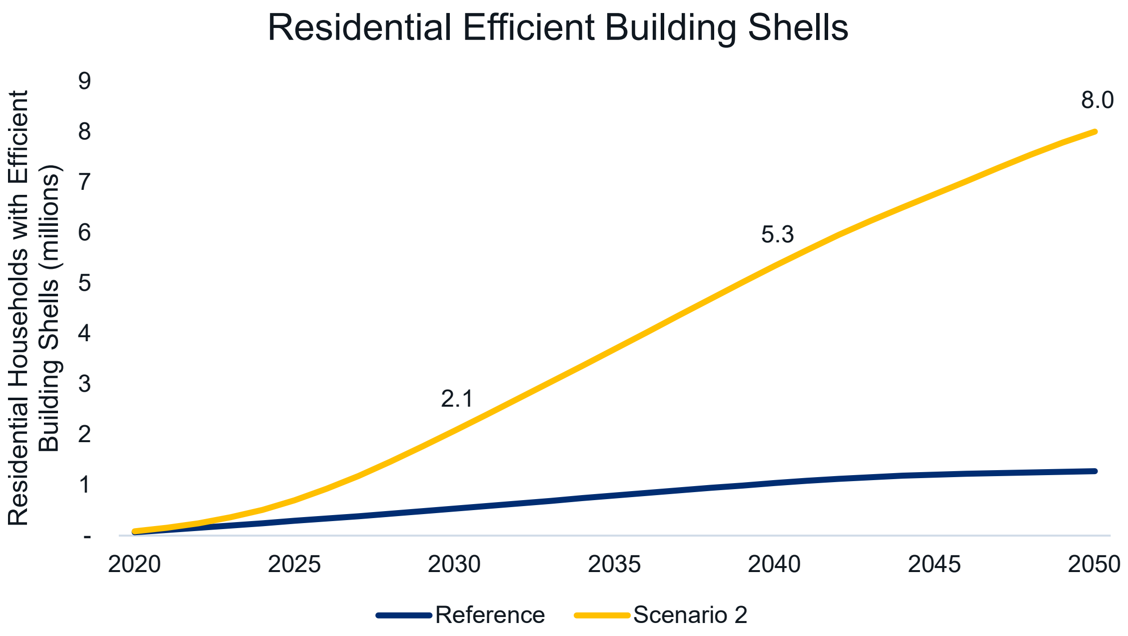


Load Drivers – Buildings

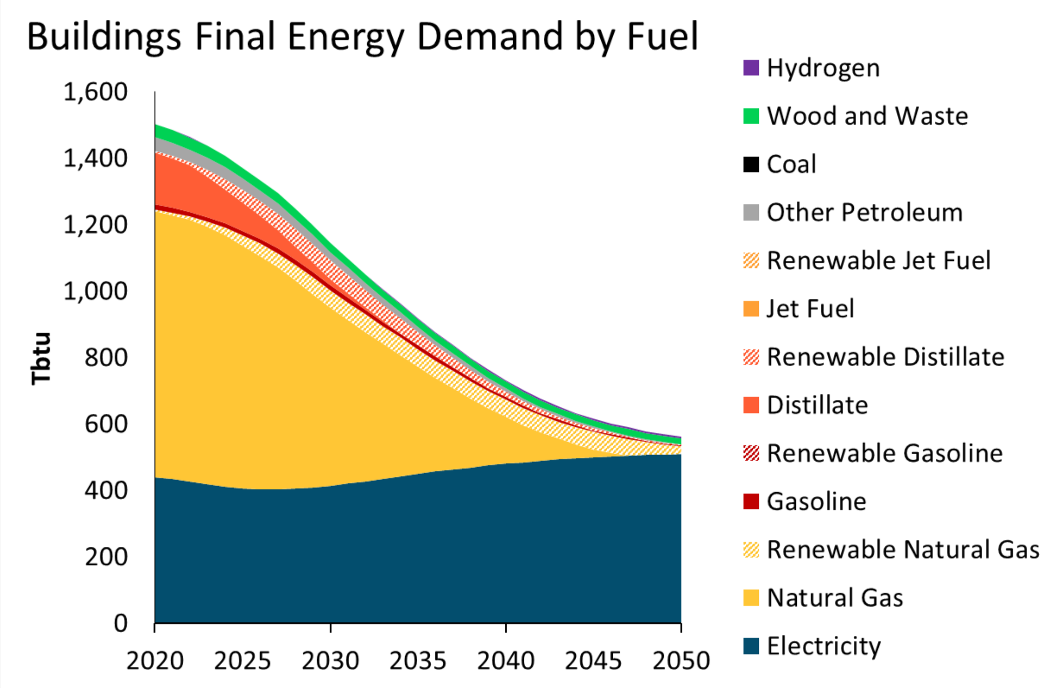
(Integration Analysis, Sept. 2023)

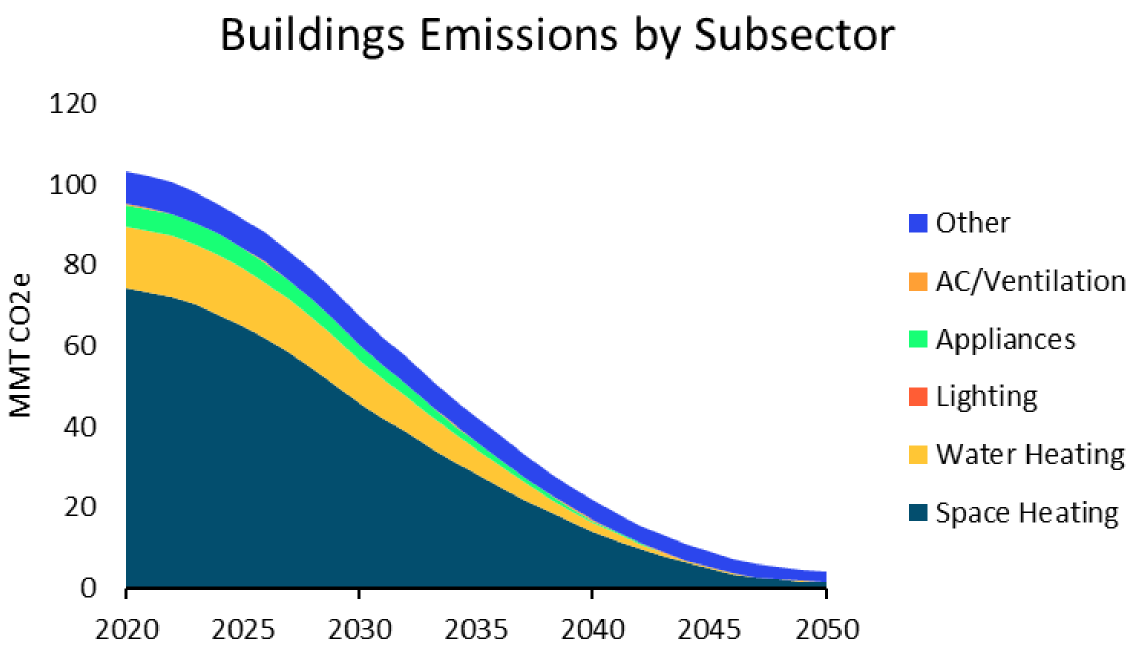
Building emissions reductions are driven by rapid electrification with high efficiency heat pumps, increased energy efficiency, and improved building shells, in line with New York's Scoping Plan strategies for achieving by 2035 in residential and commercial buildings 100% sales shares for zero-emission heating, hot water, cooking, and clothes drying equipment.





Buildings – Energy Demand & Emissions
(Integration Analysis, Sept. 2023)



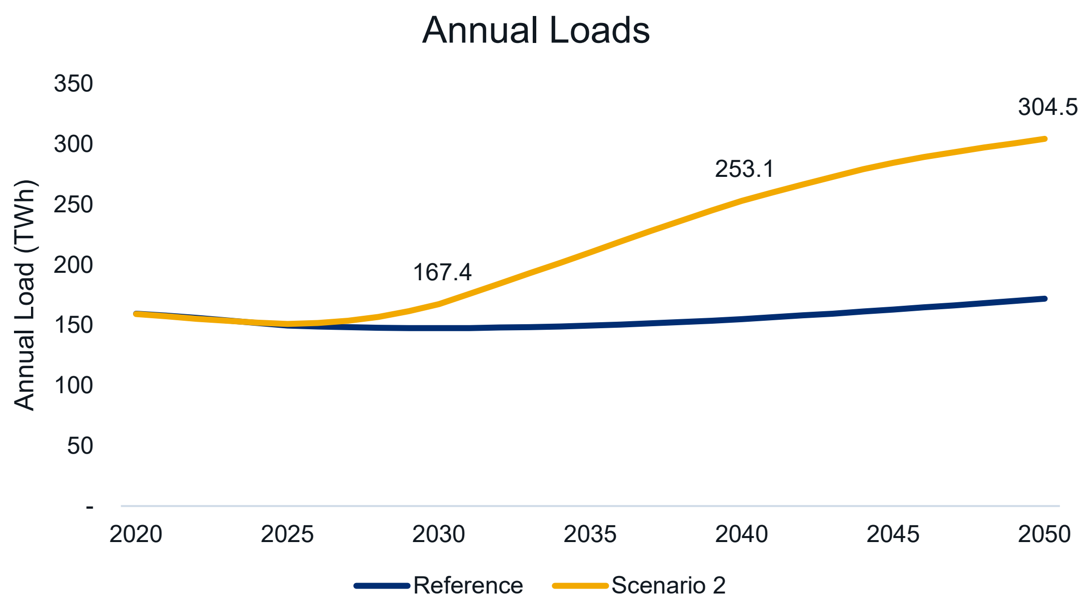


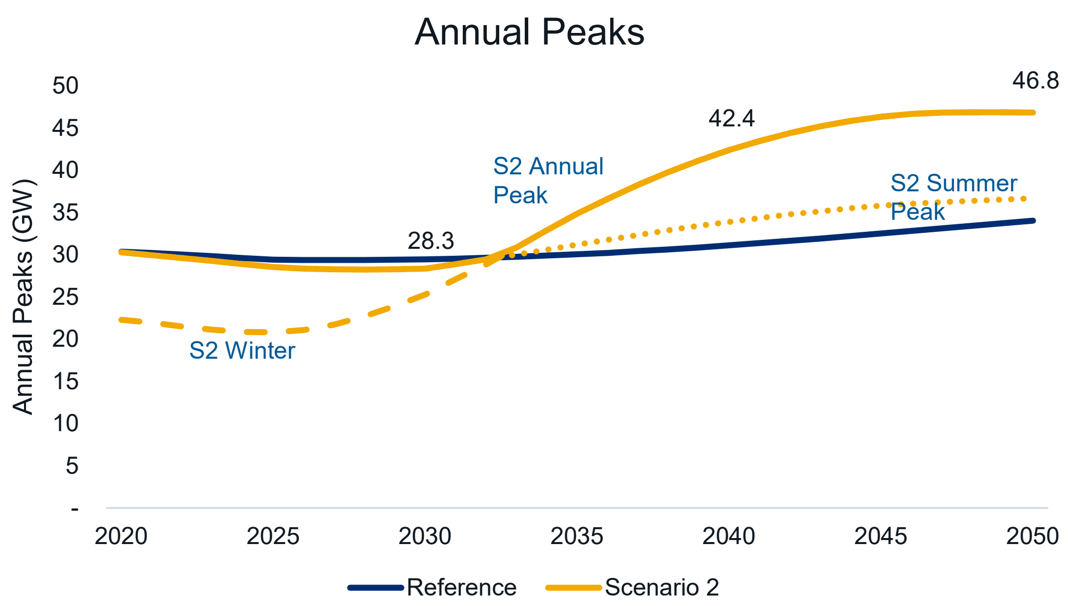
Scenario 2, 2020 is a modelled year, reflecting historical trends

Resultant Loads and Peaks, NYS Electric System
(Integration Analysis, Sept. 2023)

Loads and peaks are driven by significant economywide electrification, but mitigated by significant energy efficiency (e.g., building shell investments, flexible EV charging) in mitigation cases.

By 2050, loads increase by 90+% and peaks increase by 55+% relative to starting year values. By 2035, the Mitigation scenario shifts from summer to winter-peaking.





IA Scenario 2: Other Key Assumptions

- **Dispatchable, emissions-free resources** are modeled as thermal resources using green hydrogen.
- **Trading with neighboring regions**: Under mitigation scenarios, NYISO is modeled as having zero net imports by 2040 on an annual basis, to be consistent with zero-emissions power sector requirement. Clean energy policies of neighboring zones were included at a high level.
- **Tier 4 treatment**: Both CHPE and CPNY are included in Mitigation scenarios
  - CHPE is modeled as injecting 1,250 MW of firm capacity into NYISO Zone J, with 95% capacity factor
    - Generation from CHPE is modeled as incremental to the 70% by 2030 requirement
  - CPNY is modeled as adding 1,300 MW of bi-directional transfer capacity between Zone A-E and J
    - CPNY upstate renewable generation is modeled as contributing to the 70% by 2030 requirement
- **ELCCs** are developed for renewables and storage using E3’s Loss of Load Probability model.

High Efficiency Heat Pump Performance Considerations

Heat Pump Performance

Heating coefficient of performance (COP) measures how much thermal energy a heating system produces for every unit of energy input (= energy out / energy in).

Several variables impact heat pump performance and space conditioning loads:

> Building shell (envelope) efficiency
> Equipment specs and quality
> Proper design and installation
> For air source heat pumps (ASHP), the temperature difference between indoors and outdoors

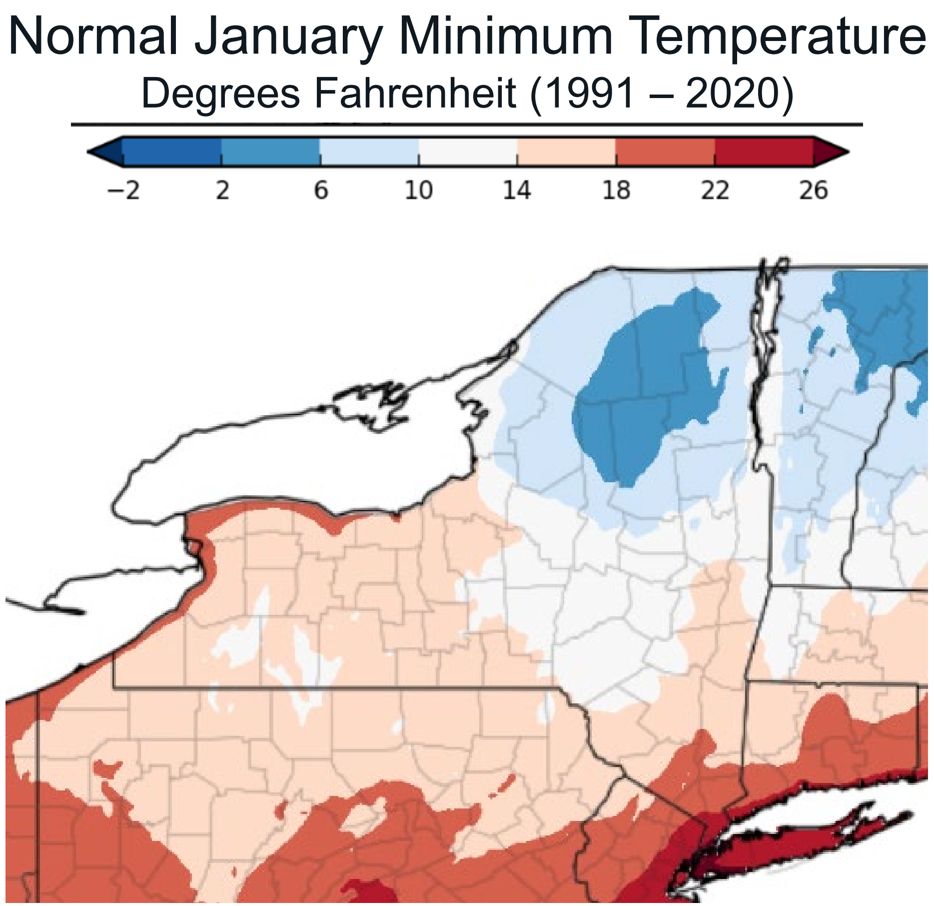
> Cold climate ASHPs work well in New York’s climate, though in very cold outdoor conditions their heating capacity (output) and efficiency (coefficient of performance or COP) drop.

> Ground source heat pumps (GSHP) perform well in extreme temperatures since heat is exchanged between the building and stable ground temperatures via an underground piping system.

NYS Regional Differences in Climate

NYS Winter Temperature Patterns

- Temperature extremes are critical in considering how well cold climate ASHPs will serve each region in NYS.
- Northeast Energy Efficiency Partnerships (NEEP), Consortium for Energy Efficiency (CEE), and ENERGY STAR maintain cold climate ASHP specifications that require qualified residential-sized products to meet a COP ≥1.75 at 5°F.
- Coastal (ocean or lake) and southern regions of NYS tend to have winters with minimum temperatures above 5 °F, while in colder mountainous and northern regions temperatures fall below 5°F.

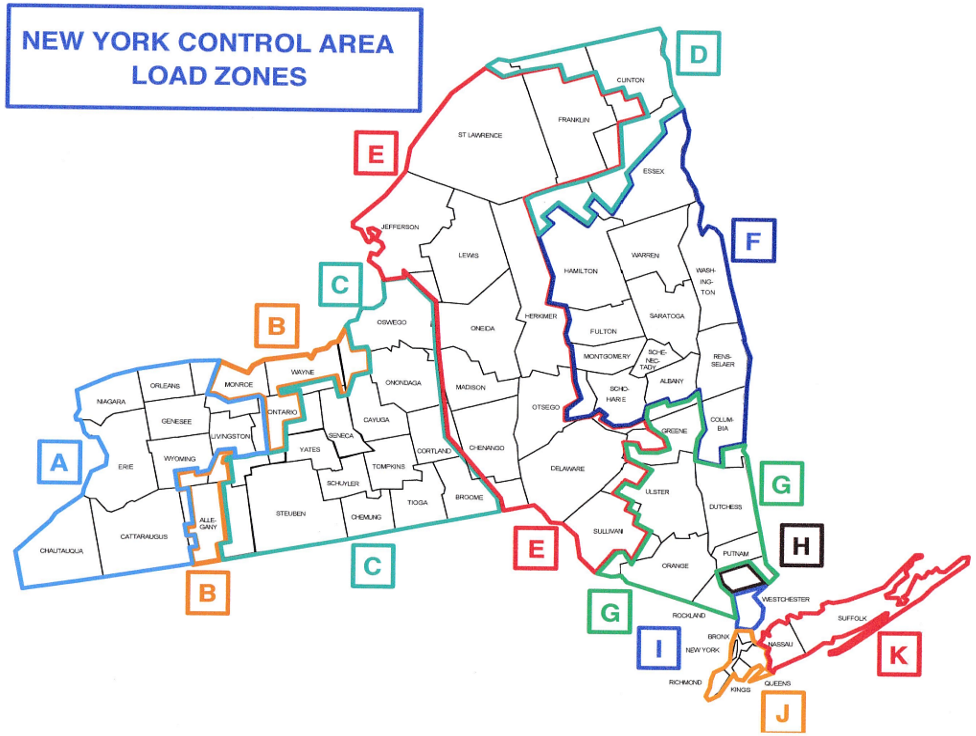


Source: Northeast Regional Climate Center at Cornell University
(http://www.nrcc.cornell.edu/regional/climatenorms/climatenorms.html)

NYS Regions Modeled in the Integration Analysis

The IA models energy demand at 5 load zones

Load Zone	Housing Units	Climate Zones	99% Heating Design Temps
Upstate NY A-E	2,276,257	5A (64%) & 6A	St. Lawrence: -9F Buffalo: 7F
Upstate NY F	586,720	5A (77%) & 6A	Essex: -11F Albany: 1F
Hudson Valley (G,H,I)	895,845	5A (49%), 4A (42%), 6A	Kingston: 2F Rockland: 15F
Long Island (K)	1,046,997	4A	Suffolk: 10F Nassau: 17F
NYC (J)	3,472,354	4A	Central Park:13F Queens: 17F
Statewide	8,278,173	4A (59%); 5A (28%); 6A (13%)	



Sources: Census American Community Survey 2018; NYS Energy Code Manual for Design Professionals; Manual J (8th Ed.)/ASHRAE (2013) 99% Heating Design Temperatures.

Energy efficient building shell upgrades reduce space conditioning loads and improve comfort

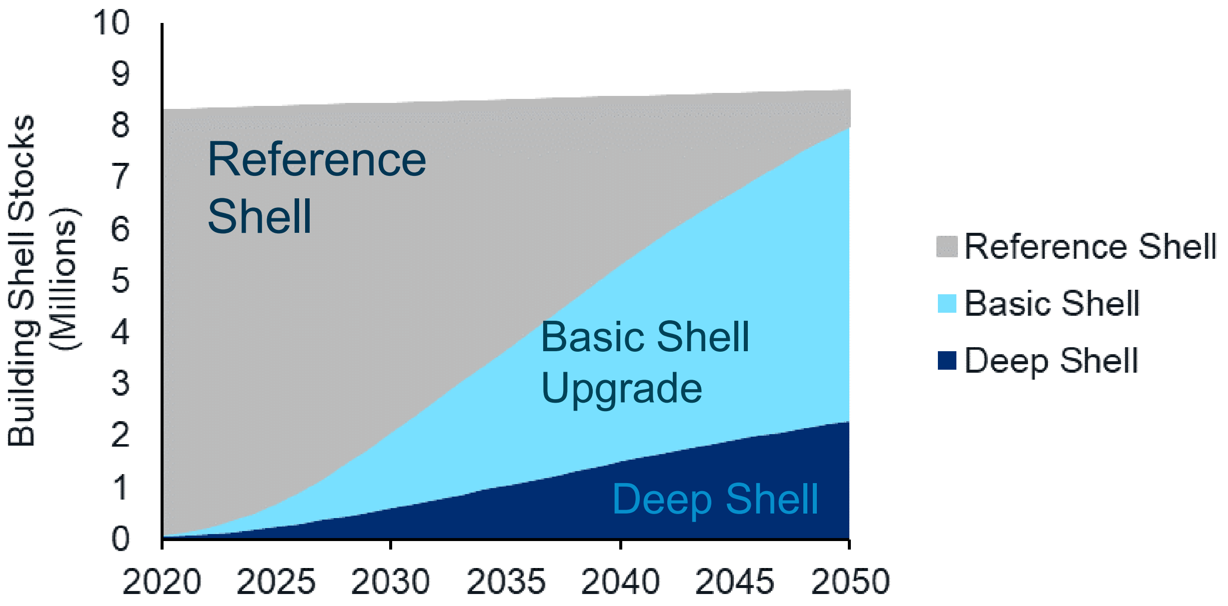
IA Basic Shell Definition: **27% (single family) to 44% (large multifamily) reduction in building space heating** and 14% (single family) to 27% (large multifamily) reduction in A/C demands.

- For single family, aligns with NYSERDA's Comfort Home "Better" Load Reduction Package: seal and insulate attic and rim joist and insulate walls and floors.
- For large multifamily, per modeling for *New York's Carbon Neutral Buildings Roadmap* (Dec 2022), upgrade includes air sealing, double-pane windows, and code compliant insulation for roof and walls.

IA Deep Shell Definition: **57% (single family) to 87% (large multifamily) reduction in building space heating** and 57% (single family) to 9% (large multifamily) reduction in A/C demands.

- For single family, aligns with modern Energy Code.
- For large multifamily, represents best in class tech.

IA Scenario 2 (Sept. 2023): Residential Building Shell Stocks



2020 is a modelled year

➢ **Priority for future analysis:**

- Load reduction packages in larger buildings that reflect more incremental, yet impactful, upgrades. E.g., air sealing + roof insulation in multifamily; envelope repair + control optimization in commercial.

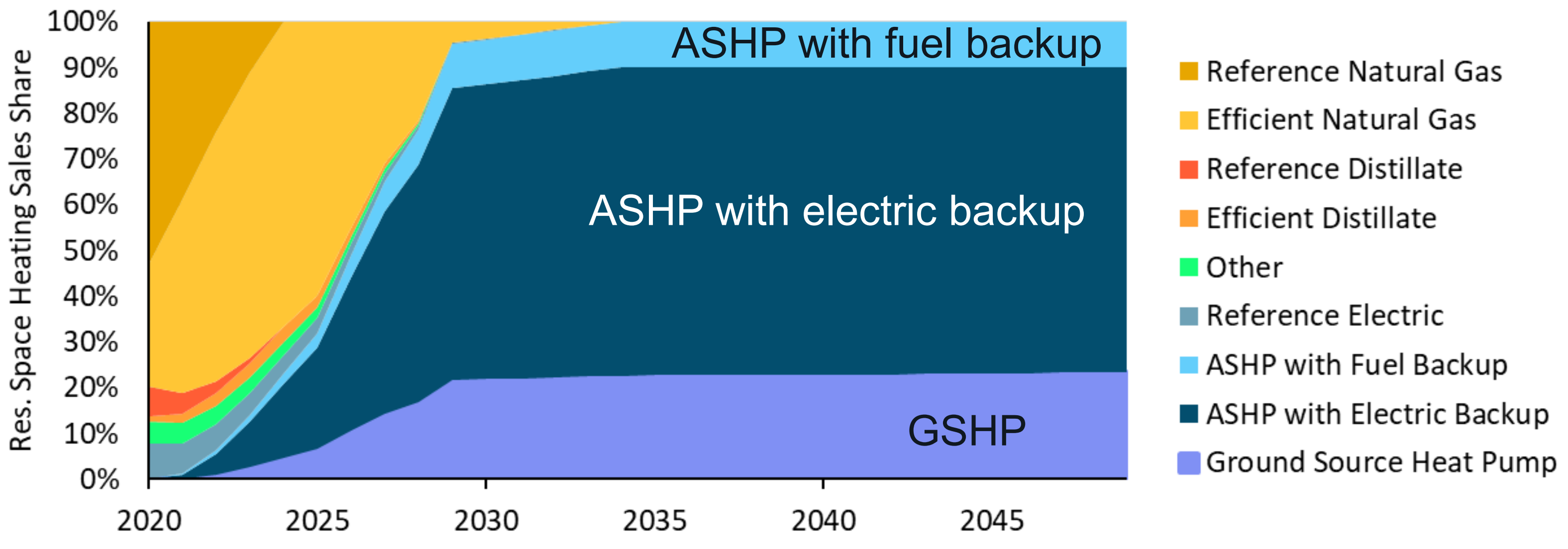
IA Scenario 2 (Sept. 2023): Residential Space Heating Sales Share and Stocks

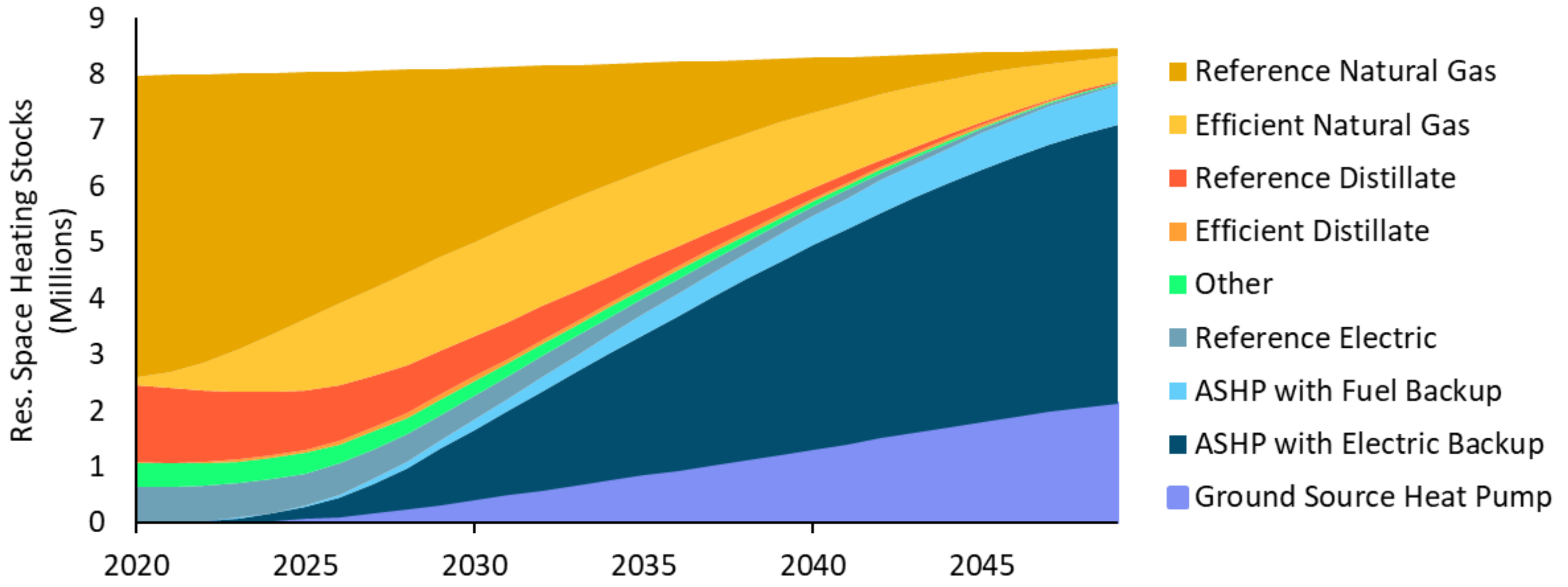
For high efficiency heat pumps, performance over average seasonal conditions and during short-term peak cold temperatures are both important considerations

IA models a mix of high efficiency heat pumps, including backup heat and GSHP to maintain reliability in critical buildings and to mitigate electric sector peak impacts:

~ 80% share of cold climate air source heat pumps (ASHP), including 10% ASHP with fuel backup

~ 20% share of ground source heat pumps (GSHP), with greater GSHP share upstate





Heat pump annual (seasonal) efficiency is modeled to improve over time, with 2020 values based on measured performance in NYS field studies

Heat Pump Annual Heating COP Integration Analysis Assumptions (Sept. 2023)				
Building Type	**Technology**	**2020**	**2030**	**2040**
Single Family	cold climate ASHP	2.4	3.3	3.6
Large Multifamily		2.5	3.5	3.8
Commercial		2.6	3.1	3.1
Single Family	GSHP	3.44	4.0	4.2
Large Multifamily		3.66	4.3	4.5
Commercial		3.44	4.0	4.2

Annual coefficient of performance (COP) values reported for new heat pumps sold in the stated year.

Sources: 2020 annual heating COP values reflect weighted average statewide values for heat pump technologies in NYSERDA's Building Efficiency and Electrification Model (BEEM), based on a series of white papers and analyses prepared by NYSERDA contractors using field test and pilot program data. See also the *Methodology Appendix* (Section 3.3.5) for the *Assessment of Energy Efficiency and Electrification Potential in New York State Residential and Commercial Buildings* (Cadmus, April 2022).

ASHP annual COP improvement based on NREL (2021) *Electrification Futures Study* Moderate Advancement scenario.
GSHP annual COP improvement based on EIA (2023) *Updated Building Sector Appliance and Equipment Costs and Efficiencies*.

Heat pump performance at peak cold temperatures also is modeled to improve over time – while assuming all ASHPs use a backup heating source

Residential Heat Pump Peak Heating COP Integration Analysis Assumptions (Sept. 2023)				
Load Zone	**Technology**	**2020**	**2030**	**2040**
Upstate NY F	cold climate ASHP with electric resistance backup	1.3	1.8	2.0
Upstate NY A-E & Hudson Valley (G,H,I)		1.4	1.9	2.1
Long Island (K)		1.5	2.1	2.3
NYC (J)		1.6	2.2	2.4
Statewide Average	ASHP w/ fuel backup	N/A, fuel used during peak cold periods		
Statewide Average	GSHP	3.5	4.1	4.3

Peak COP values are reported for new heat pumps sold in the stated year.

Source: Values derived based on annual heating COP assumptions and building simulation modeling for multiple NYS climate conditions and building/housing types.

➢ **Priority for future analysis:**

- To date, IA makes a simplifying (and conservative) assumption that backup heat is used with ASHP systems statewide.
- An area of active research is when backup or supplemental heat is advisable based on regional differences in design temperatures, shell efficiency performance, and building type.

Recent residential ccASHP study in NYS and MA

Metered data from 43 residential sites found overall average cold climate ASHP system seasonal heating COP of 2.34, in line with comparable studies.

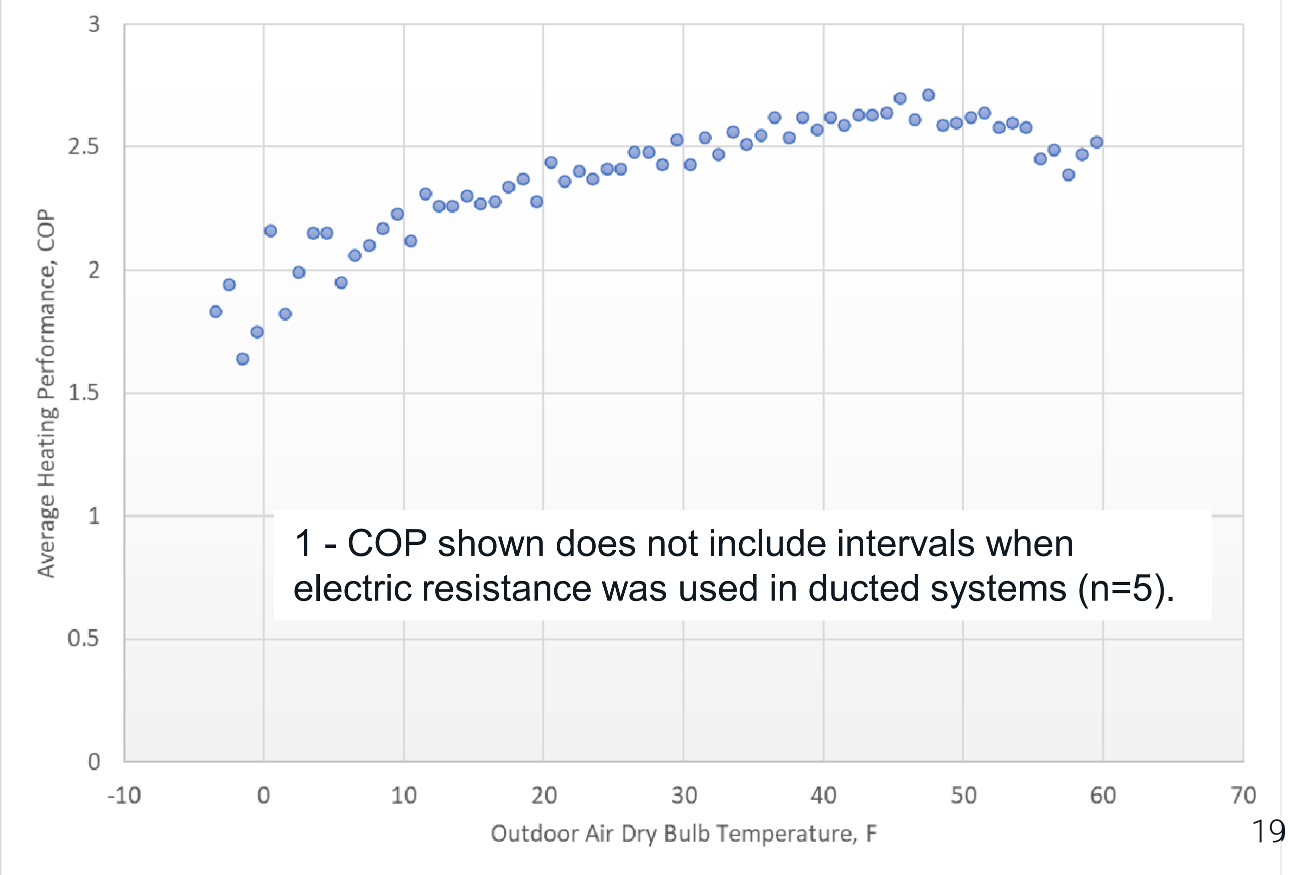
- NYS ASHP systems had a noticeable peak load compared to the daily average. New York could expand education to "set-it-and-forget-it" (remove overnight setbacks).
- **Caveat:** small sample, indicative findings.

Surveys (n=628) found customers were highly satisfied with their ASHP's heating (8.5/10) and cooling (9.0/10) performance and very likely to recommend an ASHP.

See: Cadmus (April 2022), *Residential ccASHP Building Electrification Study* and *NYSERDA-Specific Results* at https://www.nyserda.ny.gov/About/Publications/Evaluation-Reports/Clean-Heating-Cooling

Measured ccASHP Average Heating Performance[1] by Outdoor Air Temperature Bin

n=43 residential (1-4 unit) buildings in NYS and MA

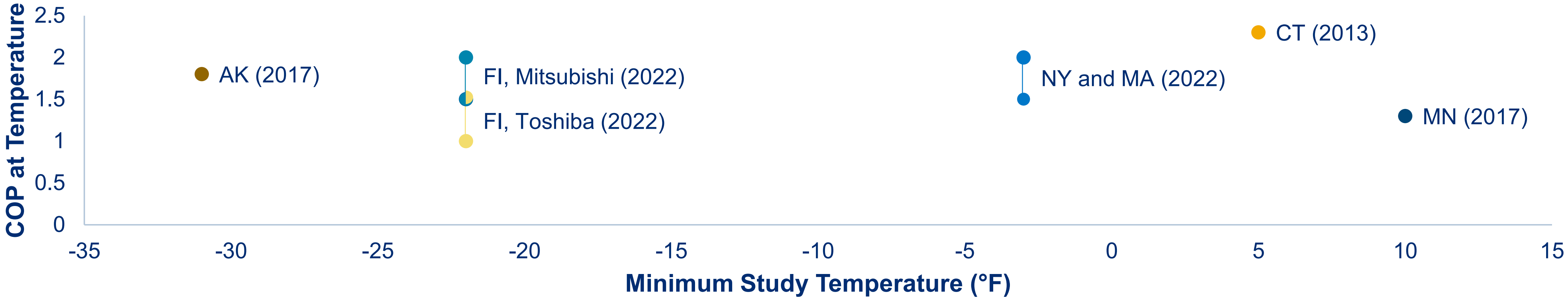


1 - COP shown does not include intervals when electric resistance was used in ducted systems (n=5).

Recent review of in-field performance data

A Sept. 2023 study that aggregated data from cold climate ASHP field studies found that the heat pumps performed efficiently and to standard in low temperatures. All studies found an average COP >2.4 between 14°F and 40°F. For field studies conducted in "extreme cold" (below 14°F) conditions across Finland and the US States of Alaska, Connecticut, New York, Massachusetts, and Minnesota, cold climate ASHPs achieved COPs between 1.0-1.5 at -22°F and 2.3 at 5°F.

cold climate ASHP Performance Efficiency found in Field Studies (Gibb et al., 2023)

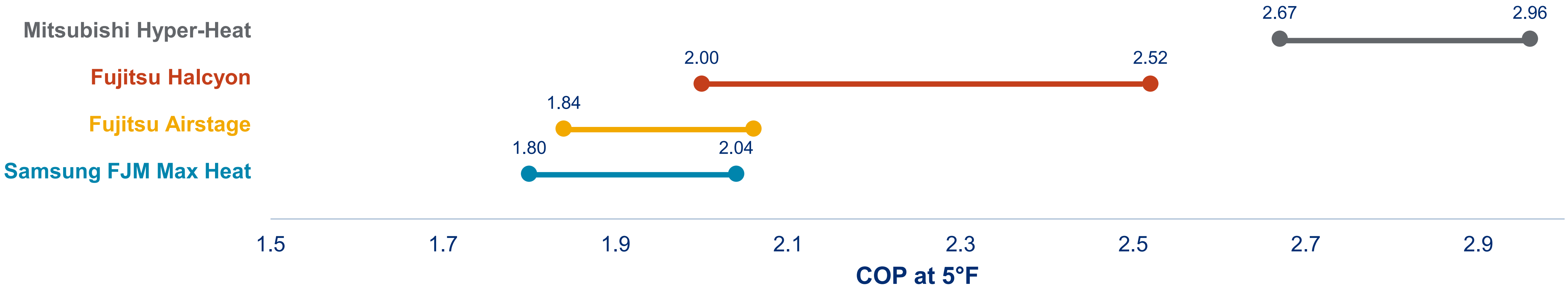


Sources: Gibb et al. (2023), *Coming in from the cold: Heat pump efficiency at low temperatures*, Joule, https://doi.org/10.1016/j.joule.2023.08.005
The Cadmus Group, (2022), *Residential ccASHP Building Electrification Study,* https://e4thefuture.org/deep-dive-research-heat-pump-building-electrification/

Indicators of technology advancement

Modern heat pump technology can perform at even greater COPs. Among the most-rebated cold climate ASHP models in Maine,[1] manufacturer-reported COP at 5°F reaches nearly 3 for certain ductless models. The [DOE's Residential Cold Climate Heat Pump Challenge](#) (currently in field testing) aims to commercialize by next year centrally ducted cold climate ASHPs that can operate at a minimum of 2.1 to 2.4 COP at 5°F and use lower GWP (global warming potential) refrigerant. While GSHPs typically provide a high and more constant COP, even higher efficiencies are possible through incorporating heat recovery and thermal energy networks.

COP Range at 5°F of Most-Rebated Product Lines in Maine (Efficiency Maine, 2023)



Note 1: Includes heat pump models that are still in production and for which COP data is available from AHRI.

Appendix Slides

Discussion

And to continue the discussion:
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ccASHP Specifications

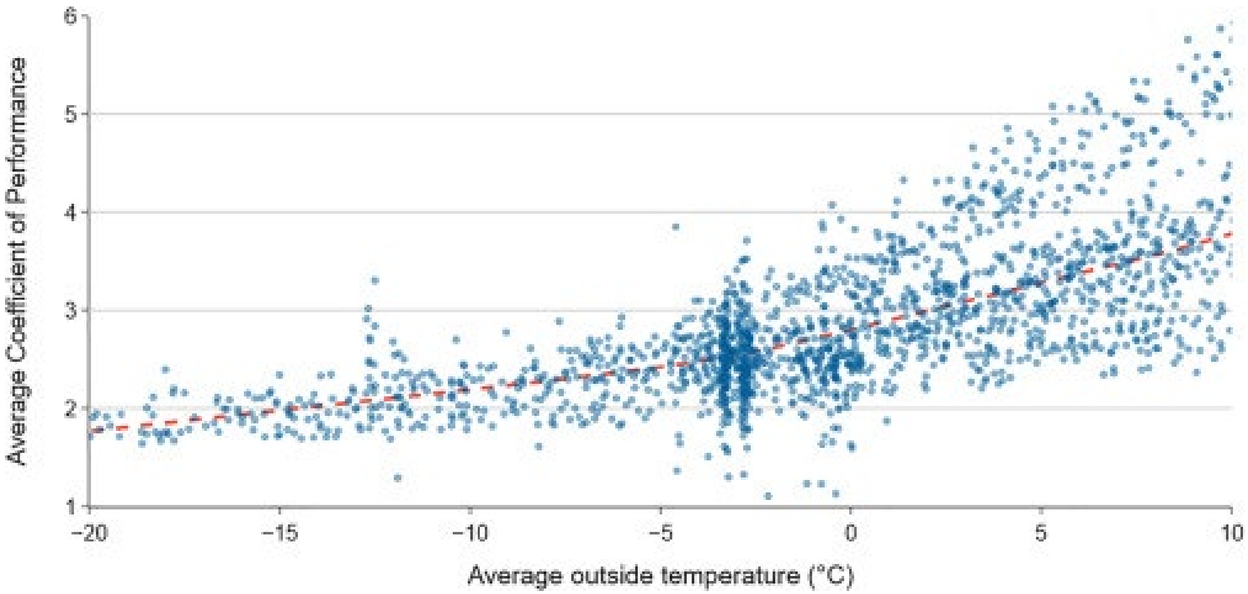
A cold climate air-source heat pump (ccASHP) is a heat pump specifically engineered for and deployed in cold climates. The Northeast Energy Efficiency Partnerships (NEEP), Consortium for Energy Efficiency (CEE), and ENERGY STAR all maintain ccASHP specifications.

Issuer	Specification	Released	COP Standard
NEEP	Cold Climate Air Source Heat Pump Specification	January 2023	• **COP ≥1.75 at 5°F** for ducted and non-ducted ASHP. • **COP between 1.45-1.55 at 5°F** (depending on capacity) for variable refrigerant flow multi-split heat pumps, packaged terminal, and single package vertical heat pumps.
CEE[1]	CEE[SM] Residential Heating and Cooling Systems Initiative, Electric Equipment Specifications	January 2023	• **COP ≥1.75 at 5°F** for ducted, non-ducted, and packaged air source heat pumps in Northern US states and Canada.
ENERGY STAR	Central Air Conditioner and Heat Pump Specification	January 2022 (new version under development)	• **COP ≥1.75 at 5°F.**

[1] The non-advanced tiers of CEE standards for Northern US states and Canada serve as the Inflation Reduction Act of 2022's (IRA) standard for 25C tax credits in the air source heat pump and hot pump water heater residential product categories.

ccASHP Performance Efficiency Found in Field Studies
(Gibb et al., 2023)

ccASHP average COP in "mild cold" (14 to 41°F) conditions from Canada, China, Germany, Switzerland, the US (incl. NYS), and the UK



-10°C = 14°F

ccASHP COP in "extreme cold" (below 14°F)

ccASHP Study Location	Year	Min. Temp (°F)	COP at Min. Temp.
US – NYS and Massachusetts	2022	-3	1.5-2.0
US - Connecticut	2013	5	2.3
Finland - Mitsubishi model	2022	-22	1.5-2.0
Finland – Toshiba model	2022	-22	1.0-1.5
US - Minnesota	2017	10	1.3
US - Alaska	2017	-31	1.8

Source: Gibb et al. (2023), *Coming in from the cold: Heat pump efficiency at low temperatures*, Joule. https://doi.org/10.1016/j.joule.2023.08.005

Performance Efficiency at 5°F of Commonly Rebated Residential Heat Pumps in Maine (Efficiency Maine, 2022-2023)

Manufacturer	Model Numbers	AHRI Reference Numbers	Number of Indoor Units	Ducting Configuration	Heating COP at 5°F as Calculated by M1
Mitsubishi Electric	MUZ-FS12NA-U1	209832203	Single	Non-Ducted	2.96
Mitsubishi Electric	MUZ-FS06NA-U1	209832199	Single	Non-Ducted	2.90
Mitsubishi Electric	MUZ-FS09NA-U1	209832201	Single	Non-Ducted	2.85
Mitsubishi Electric	MUZ-FS18NA-U1	205975735 / 209832207	Single	Non-Ducted	2.79 / 2.81
Mitsubishi Electric	MUZ-FS15NA-U1	205975734 / 209832205	Single	Non-Ducted	2.67 / 2.68
Fujitsu Halcyon	AOUG15LZAS1	204740070 / 206597212	Single	Non-Ducted	2.52
Fujitsu Halcyon	AOUG15LZAH1	204740071 / 206597213	Single	Non-Ducted	2.34
Fujitsu Halcyon	AOUG12LZAS1	204740068 / 206597210	Single	Non-Ducted	2.32
Fujitsu Halcyon	AOUG12LZAH1	204740069 / 206597211	Single	Non-Ducted	2.16
Fujitsu Halcyon	AOUG09LZAS1	204740066 / 206597208	Single	Non-Ducted	2.14
Fujitsu Airstage	AOU24RLXFZH	8033586 / 8033742 / 8063925	Multiple	Non-Ducted	2.06
Samsung	AJ036BXS4CH	207349920	Multiple	Non-Ducted	2.04
Fujitsu Airstage	AOU36RLXFZH	8908615 / 8908616 / 8912450	Multiple	Non-Ducted	2.02
Fujitsu Halcyon	AOUG09LZAH1	204740067 / 206597209	Single	Non-Ducted	2.00
Fujitsu Airstage	AOUH18LMAS1	206913027	Single	Non-Ducted	2.00
Fujitsu Airstage	AOU18RLXFZH	8033584 / 8033585 / 8063924	Multiple	Non-Ducted	1.84
Samsung	AJ030BXS4CH	207349919	Multiple	Non-Ducted	1.80

Includes heat pump models that are still in production; COP data from AHRI.