Memorandum

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DATE: MARCH 29, 2021

RE: NEW YORK HEAT PUMP TRAJECTORY ANALYSIS

Executive Summary

Synapse modeled three different trajectories to reach a carbon-free building sector in the state of New York by 2050. New York's existing 2020–2025 heat pump energy savings targets are quite conservative and put the state on track for a back-loaded surge of early replacements of functioning fossil fuel heating systems in the 2040s. The scenario requiring early replacements comes at a high cost, as gas furnaces and other fossil-fuel based heating systems purchased in the next few years will need to be replaced well before the end of their useful economic lives. Such early replacements are also logistically challenging and back-loading heat pump adoption pushes back urgently needed carbon emissions reductions. We model two additional scenarios with accelerated heat pump adoption that demonstrate how New York can move toward a cleaner energy future faster and more cost-effectively. These two scenarios suggest the state should aim to achieve the following by 2030:

- 95–100 percent residential heat pump sales share
- 2.1–2.5 million households primarily heated by heat pumps
- 28–33 percent of residential thermal load served by heat pumps
- 19–25 percent of commercial thermal load served by heat pumps
- 190–240 trillion BTU thermal energy savings in the residential and commercial sectors

Charting a path that achieves these metrics will ensure that New York puts itself on track to eliminate building sector carbon emissions in an expedient, efficient, and lower-cost manner.

Introduction

NRDC tasked Synapse with developing intermediate and long-term benchmarks for heating electrification to ensure that the State of New York meets its greenhouse gas reduction targets. For this assessment, Synapse used its Building Decarbonization Calculator (BDC) and evaluated three separate trajectories to reach New York's goal of net zero emissions by 2050. The BDC models turnover of residential and commercial space and water heating systems across the state and calculates the emissions impacts of these heating system changes. This memo summarizes methods and assumptions we employed for each scenario and the results for each scenario.

Methods and Assumptions

Synapse modeled three different trajectories to reach a carbon-free building sector in 2050.

1. **Back-loaded Heat Pump Adoption.** This pathway demonstrates a trajectory that keeps the current installation rate of heat pumps constant for 2020 through 2025. After 2025, the residential heat pump market share trajectory increases at a moderate pace, reaching approximately 50 percent of sales in the early 2030s and nearly 100 percent of sales by 2040. Keeping sales constant through 2025 surpasses the amount of heat pumps required to meet the annual energy savings targets set by the New York Public Service Commission (PSC) for 2020 through 2025 (as shown in Table 1).[1] In order to reach the 2050 carbon-free goal, substantial numbers of early replacement heat pump installations are needed in the late 2040s.

Table 1: New York PSC Savings Targets vs. Modeled Savings (Gross MMBTU)

	2020	2021	2022	2023	2024	2025	Total
Annual Energy Savings Targets	239,482	424,448	547,045	672,345	787,186	896,085	3,566,591
Modeled Energy Savings with Constant Heat Pump Sales	2,179,699	2,102,086	2,067,826	2,033,388	2,000,172	1,965,749	12,348,920

2. **Moderate Heat Pump Adoption.** This pathway demonstrates a trajectory in between the back-loaded and accelerated heat pump adoption cases. It ramps heat pump adoption more quickly than current installation rates but still requires some early replacement of systems in the 2040s. This scenario achieves near 100 percent heat pump market share by 2031 for residential buildings and by 2033 for commercial buildings.

3. **Accelerated Heat Pump Adoption.** This pathway demonstrates a trajectory that rapidly accelerates heat pump adoption to take advantage of the full period between now and 2050 to electrify the state's buildings. The scenario achieves near 100 percent heat pump market share for new installations in residential buildings by 2028 and in commercial buildings by 2030. Smoothing out the heat pump adoption over the next three decades allows the state to focus on

[1] New York Public Service Commission. *In the Matter of a Comprehensive Energy Efficiency Initiative*, Case 18-M-0084, Order Authorizing Utility Energy Efficiency and Building Electrification Portfolios Through 2025 (January 16, 2020). We note that the statewide savings goal is inclusive of all customer sectors, building vintages, and new construction. It also applies to all heat pump systems designed to provide domestic hot water heating and/or space heating and cooling.

more cost-effective replacements at end of system life, rather than investing money into fossil fuel heating systems that will need to be replaced relatively soon after installation.

Assumptions

The BDC uses state-specific data on existing buildings from the U.S. Census Bureau's American Community Survey along with U.S. Energy Information Administration's Residential and Commercial Buildings Energy Consumption Surveys (RECS and CBECS) to develop estimates for the characteristics of New York's building heating system stock. To determine the current heat pump market share of new installations we relied on multiple sources. These included both D+R International's HVAC database[2] and recent annual increases in the number of homes heated primarily with electricity as reported by the American Community Survey. For example, the D+R International database shows 10,000 ducted heat pump installations and 51,000 ductless heat pump installations in 2017. Assuming an average of 2.5 ductless heat pumps are installed per household, this data suggests annual heat pump installations in approximately 30,000 households. Similarly, the American Community Survey shows an average annual increase in the number of homes heated primarily with electricity of about 26,000 between 2015 and 2019. Note that the D+R International data includes small commercial heat pumps as well, so we expect a small difference between the two sources.

In our modeling, the number of residential households heating with heat pumps increases by about 23,000 households in 2020, which we calibrated to be in line with the two sources. This level of annual increase results from a market share value of approximately 5 percent for the replacement of retiring natural gas systems and 10 percent for the replacement of retiring oil systems. In all three scenarios, we started the residential heat pump adoption curves at these market share values in 2020, and then escalated the percentage over time depending on the scenario. Given that existing commercial buildings would have a harder time switching to heat pumps due to the complexity of their HVAC system configurations, we assumed initial commercial market shares equal to half of the historical residential sales rate. Figure 1 and Figure 2 show the market share adoption trajectories for heating systems replacing residential and commercial natural gas space heating systems at the end of their useful lives. In 2020, most of these systems are replaced by new natural gas systems, but heat pumps gain greater market share in later years.

Throughout our analysis, we categorized all households in New York as being in the residential sector, even though large multifamily residential buildings may require different types of heat pump systems than single family homes. We measure the sizes of heat pump systems by the number of households they serve. For example, one large heat pump system serving 100 apartments is modeled as 100 individual heat pump systems.

[2] D+R International. 2018. *2017 HVAC Market Report.* Prepared for New York State Energy Research and Development Authority.

Figure 1: Residential natural gas to heat pump market share

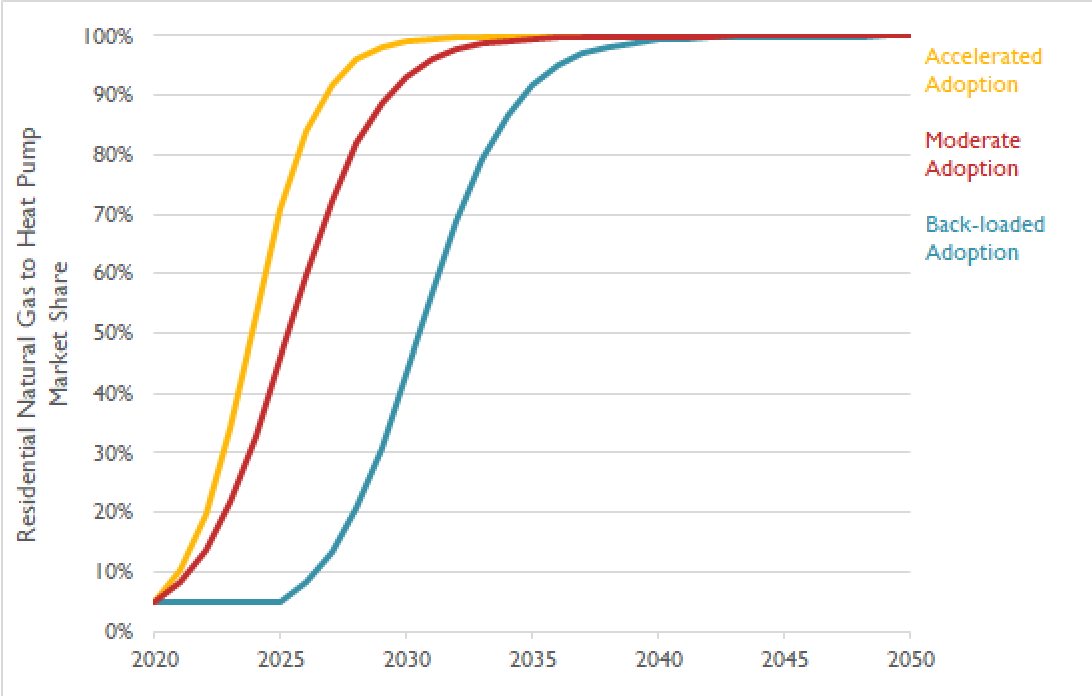
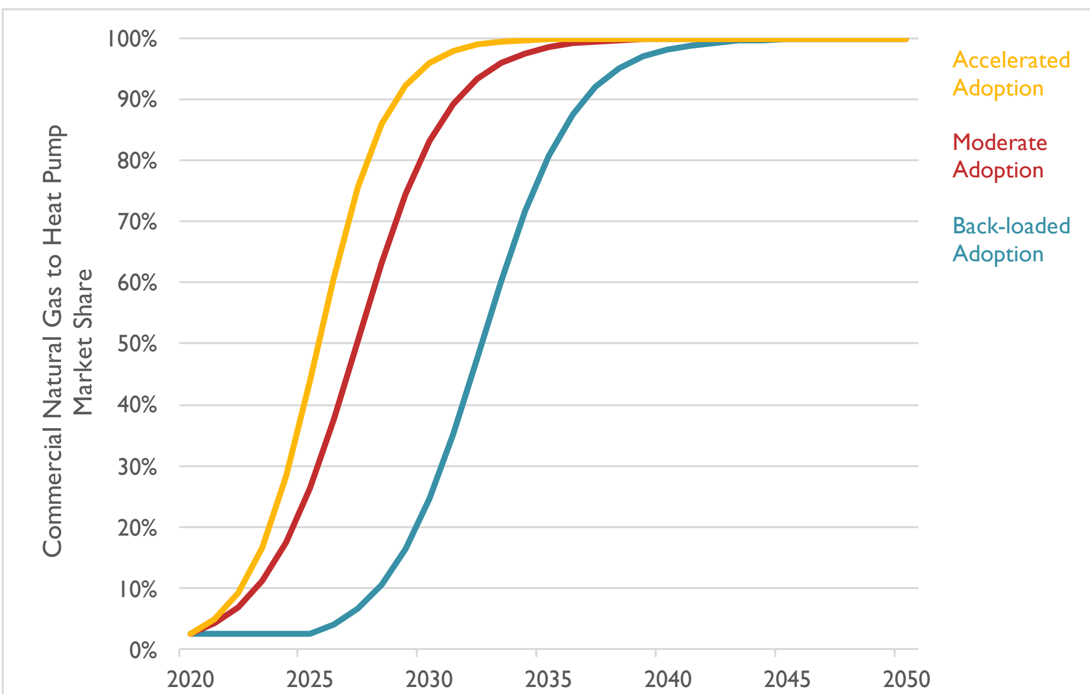


Figure 2: Commercial natural gas to heat pump market share



New York is unique because of the extensive district steam system in New York City. In this analysis, we assume that buildings with these systems do not transition over to heat pumps like the other fossil fuel heating systems. Additional research will be required to determine the best way to ensure that homes relying on district steam will be emissions-free by 2050. Because the Climate Leadership and Community Protection Act mandates that the electric sector reaches 100 percent carbon-free power by 2040, it is also possible that the fuel source used to generate steam for district heating will become emissions-free. Currently, district steam systems are responsible for less than 5 percent of total building sector emissions.[3] For these reasons, we currently exclude district steam from our analysis.

Results

For each of the three scenarios and each year between 2020 and 2050, we modeled the new space and water heating system installations, the total stock of operating space and water heating systems, and the resulting on-site greenhouse gas emissions. We discuss some of these results in the paragraphs below. Detailed results for the following metrics are presented in the Appendix:

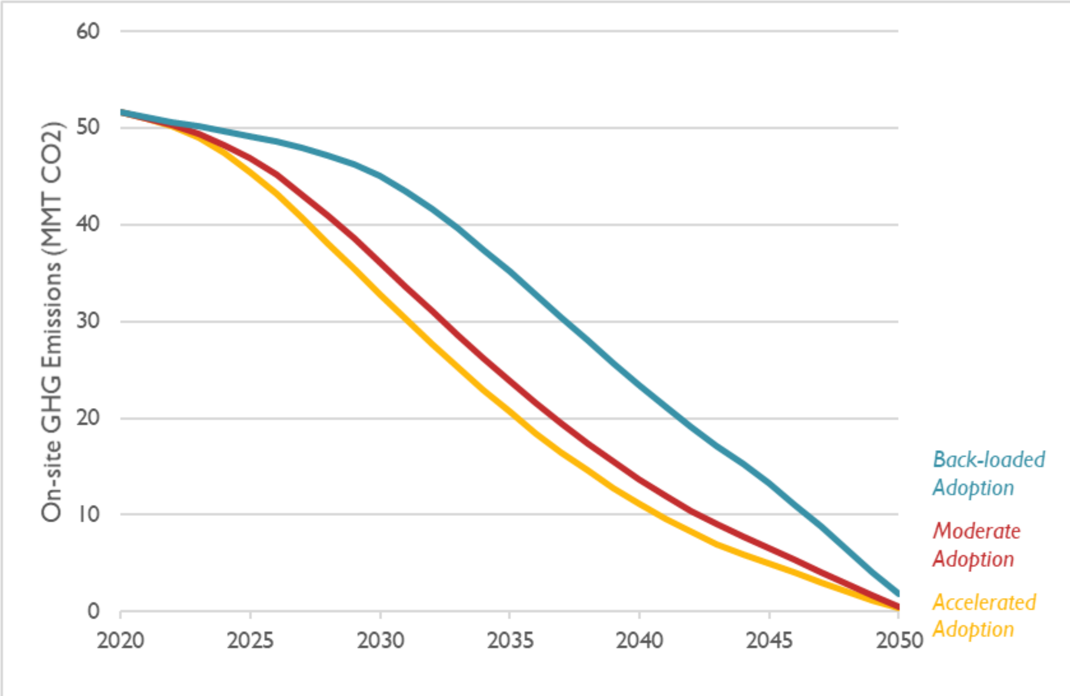
- Residential and Commercial Natural Gas Replacement Sales Share
- Total Residential Households Primarily Heated with Heat Pumps
- Total Commercial Square Footage Heated with Heat Pumps
- Total GHG Emissions

Emissions

Figure 3 shows the total space and water heating emissions in each scenario. Note that we have not quantified off-site greenhouse gas emissions, such as those resulting from the generation of electricity or the upstream methane emissions leaks associated with natural gas production, distribution, and transmission. While increasing electricity consumption to power heat pumps will lead to some increase in electric generation emissions, this impact will be mitigated if New York achieves its ambitious clean electricity goals, including a target of zero emissions from electric generation by 2040. Expanded demand side management and demand response can also help mitigate the impact of increased building electrification on load and emissions.

[3]City of New York, Mayor's Office of Sustainability. 2016. *One City Built to Last.*

Figure 3. On-site space and water heating GHG emissions by scenario



Space Heating Stock and Sales

In this section we present charts that show the total stock and annual sales of space heating equipment, which is responsible for the majority of on-site emissions from buildings. Space heating emissions in 2020 represent 86 percent of total space and water heating emissions. (Additional on-site emissions result from cooking, clothes drying, and other end-uses that were not included in our modeling here. According to RECS, these other end-uses account for 7 percent of residential natural gas consumption, less than 1 percent of residential fuel oil consumption, and 15 percent of residential propane consumption in the Mid-Atlantic census division, which includes New York.[4]) Water heating equipment similarly transitions toward heat pump technologies in our analysis but is not separately shown here for simplicity. Note that the sales charts show a slight decrease in new installations between 2030 and 2031, which is a result of slower expected population growth (and consequently new housing construction) after 2030.[5]

Back-loaded heat pump adoption

For the back-loaded adoption scenario, we find that keeping the current rate of heat pump sales constant through 2025 will surpass the state's 3.6 trillion BTU target. However, the market must then

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[4] U.S. Energy Information Administration. 2018. *Residential Energy Consumption Survey*. Available at: https://www.eia.gov/consumption/residential/.

[5] Weldon Cooper Center for Public Service. 2018. "Observed and Total Population for the U.S. and the States, 2010-2040." *Demographics Research Group.* Available at: https://demographics.coopercenter.org/national-population-projections

rapidly increase after 2025 in order to achieve nearly 100 percent heat pumps by 2050. In this scenario, more than 1.5 million residential households in New York still depend on fossil fuel-based heating systems in the late 2040s and are forced to do early replacements (i.e., replace their working heating systems with heat pumps).

Figure 4. Back-loaded adoption residential space heating stock

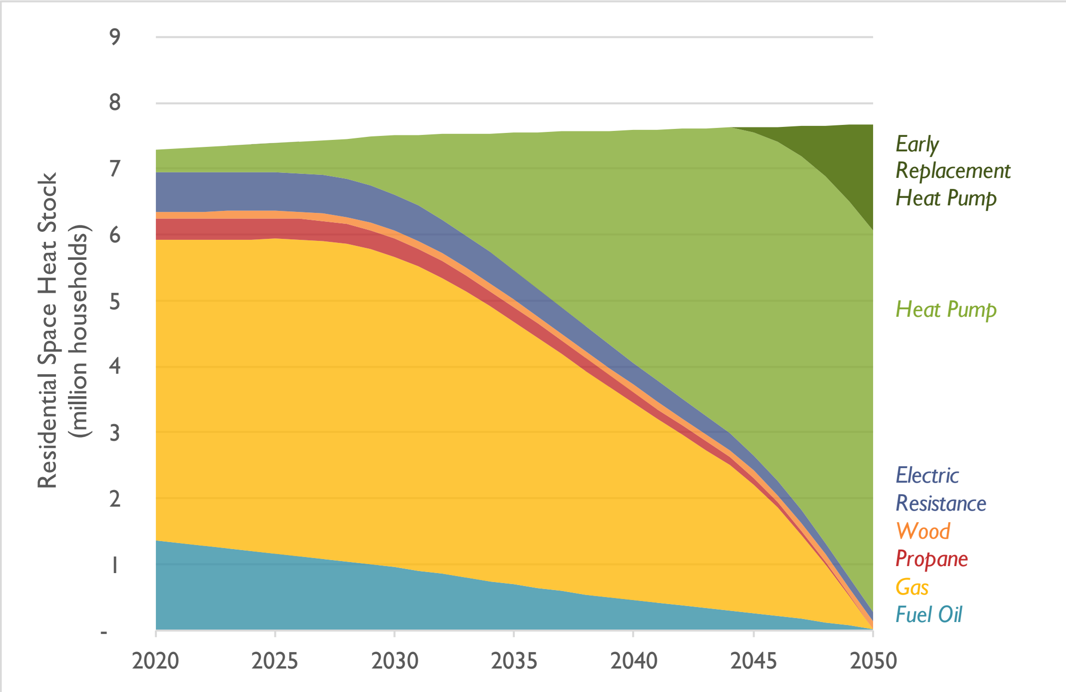


Figure 5. Back-loaded adoption residential space heating sales

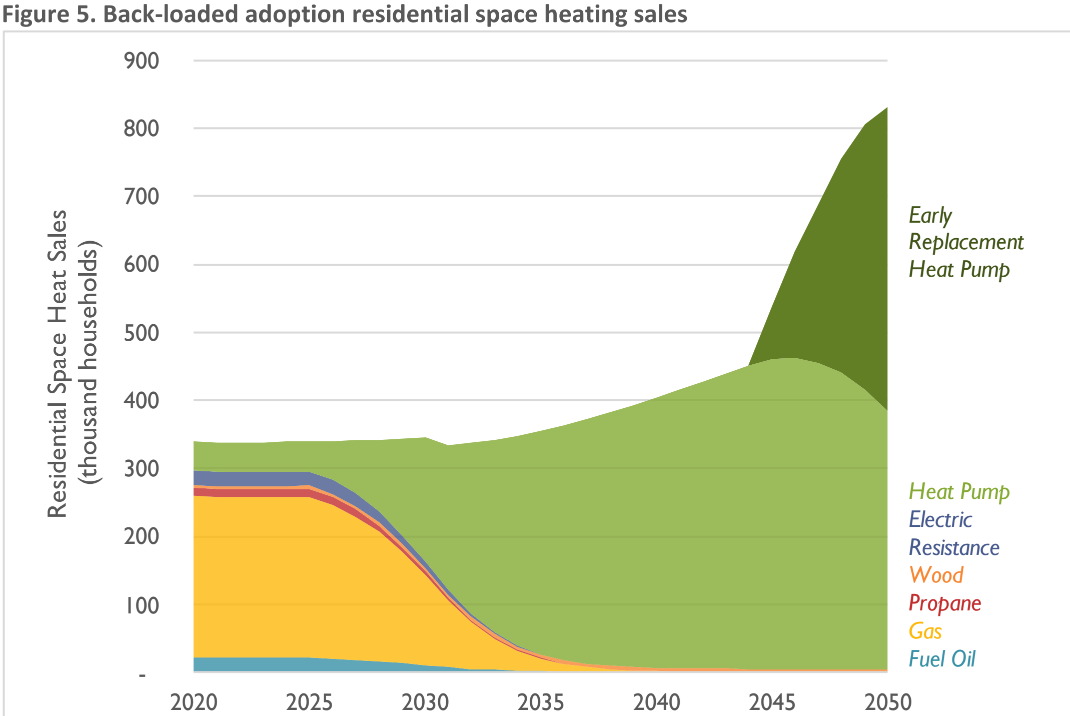
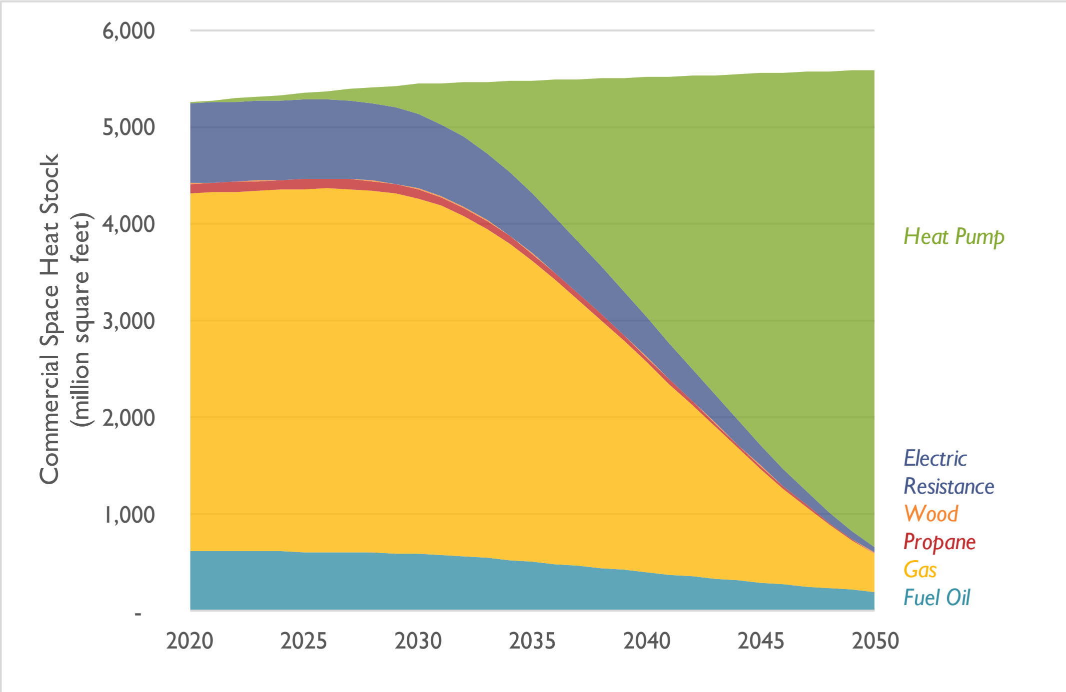


Figure 6. Back-loaded adoption commercial space heating stock



Moderate heat pump adoption

The moderate adoption case increases the rate of heat pump adoption beginning in the early 2020s but allows some sales of fossil fuel heating systems to continue into the early 2030s. In this scenario, about 750,000 heat pumps are installed to replace fossil fuel heating systems before the ends of their useful lives.

Figure 7. Moderate adoption residential space heating stock

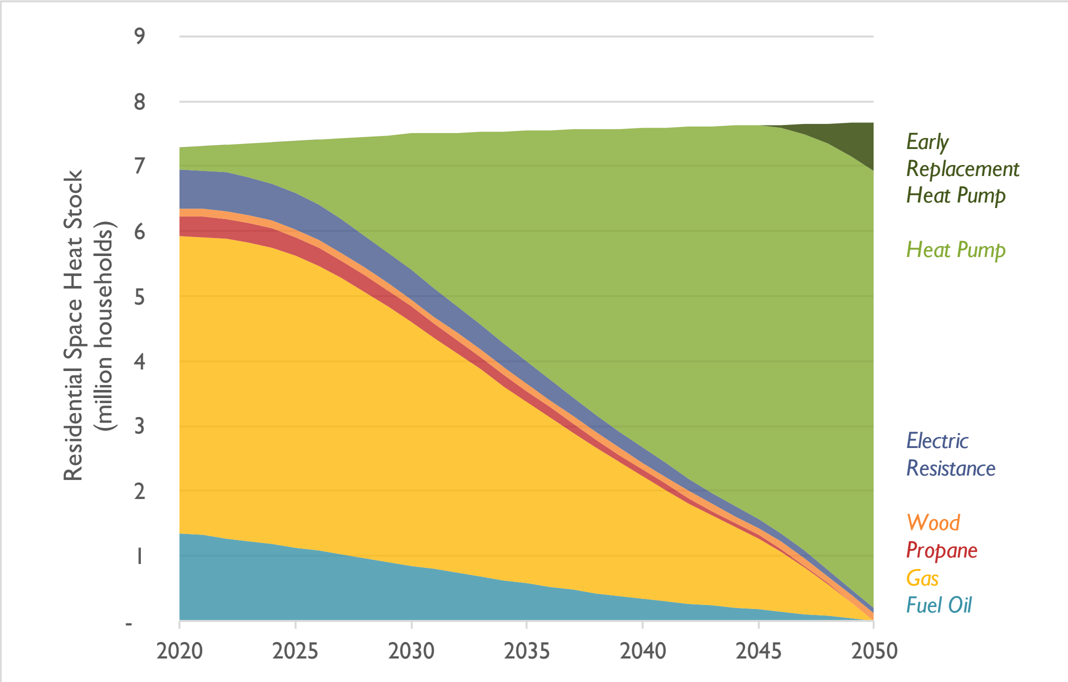


Figure 8. Moderate adoption residential space heating sales

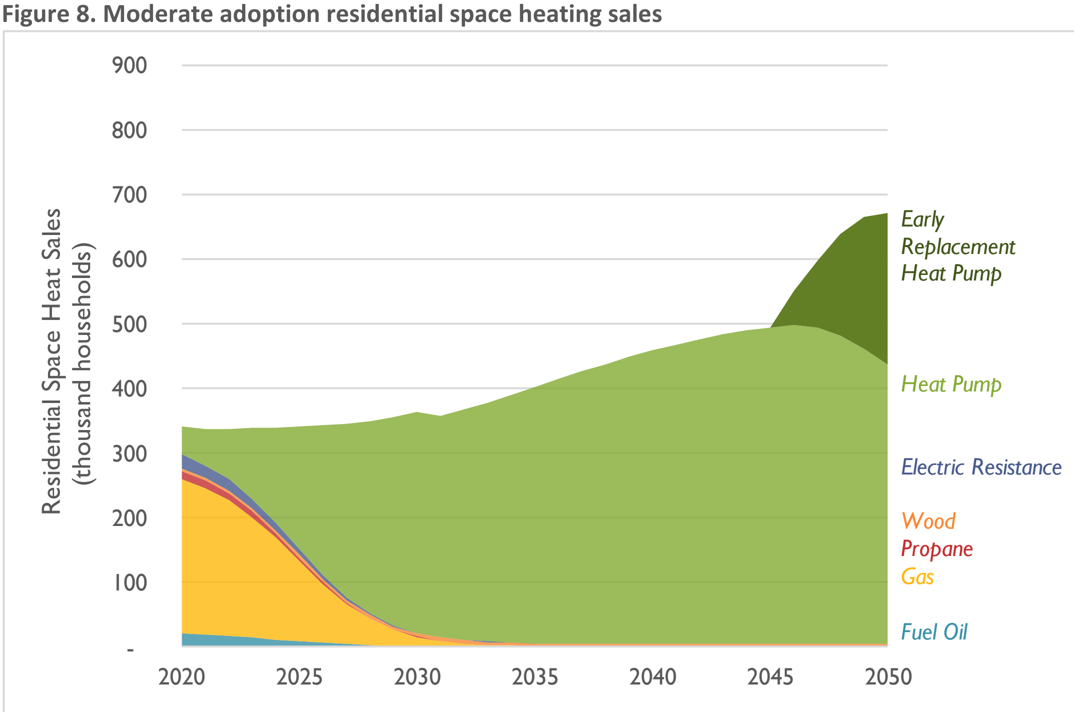
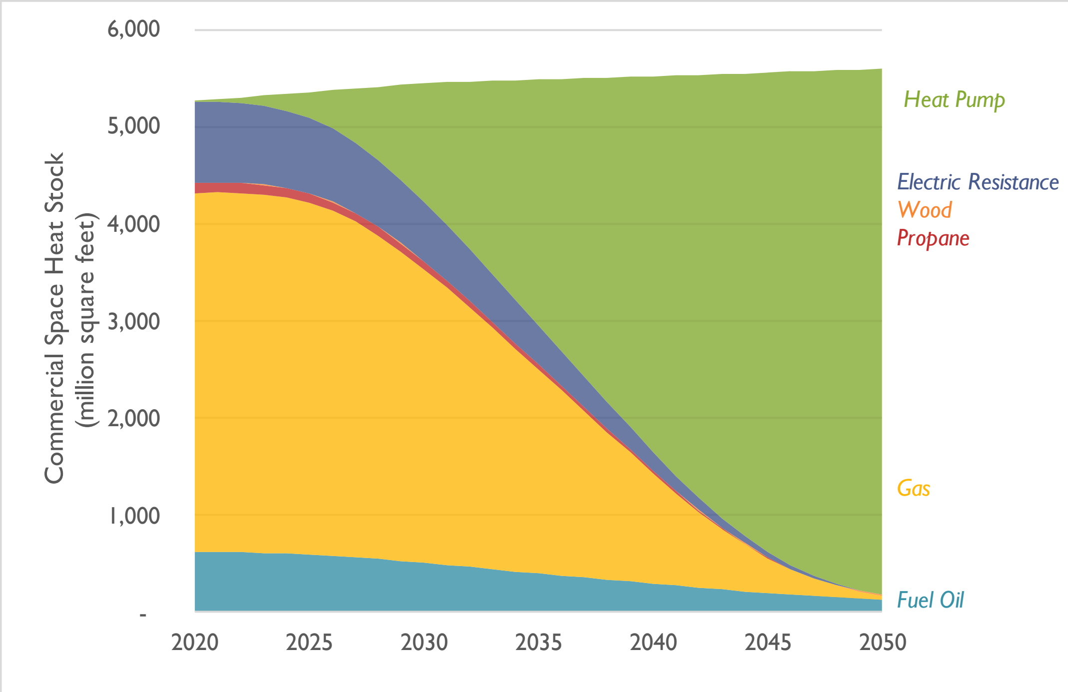


Figure 9. Moderate adoption commercial space heating stock



Accelerated heat pump adoption

This scenario envisions the most ambitious heat pump adoption trajectory in the 2020s and 2030s, which leads to the successful conversion of almost all heating systems to heat pumps as they naturally reach the end of their useful lives. Approximately 560,000 heating systems are retired early in the 2040s in this scenario to achieve nearly 100 percent heat pump market share.

Figure 10. Accelerated adoption residential space heating stock

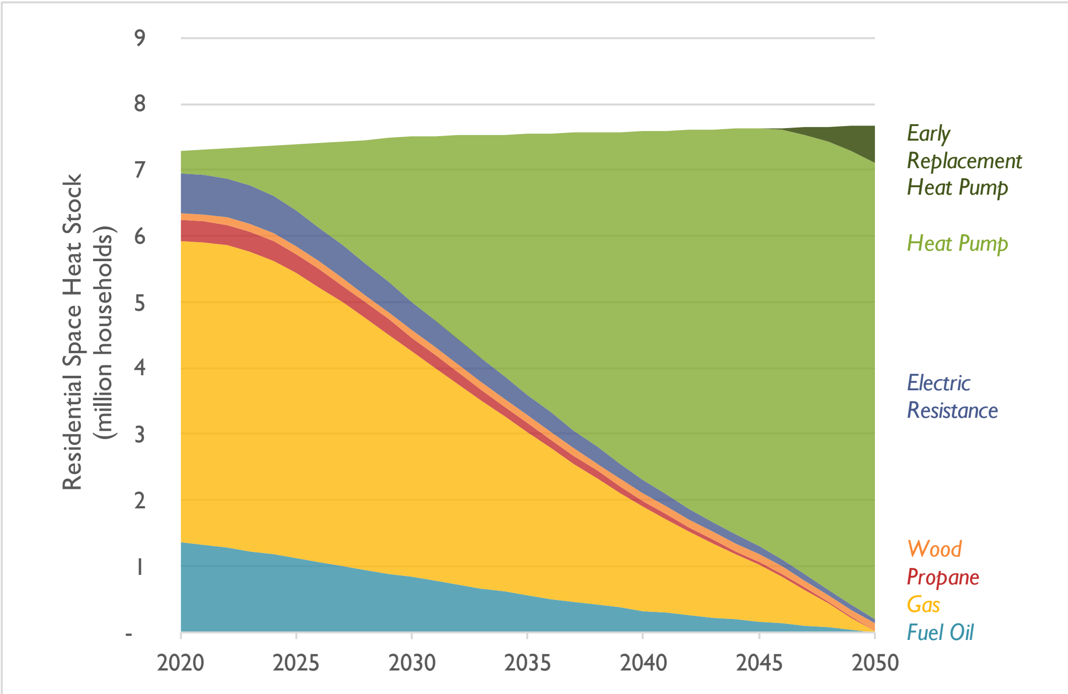


Figure 11. Accelerated adoption residential space heating sales

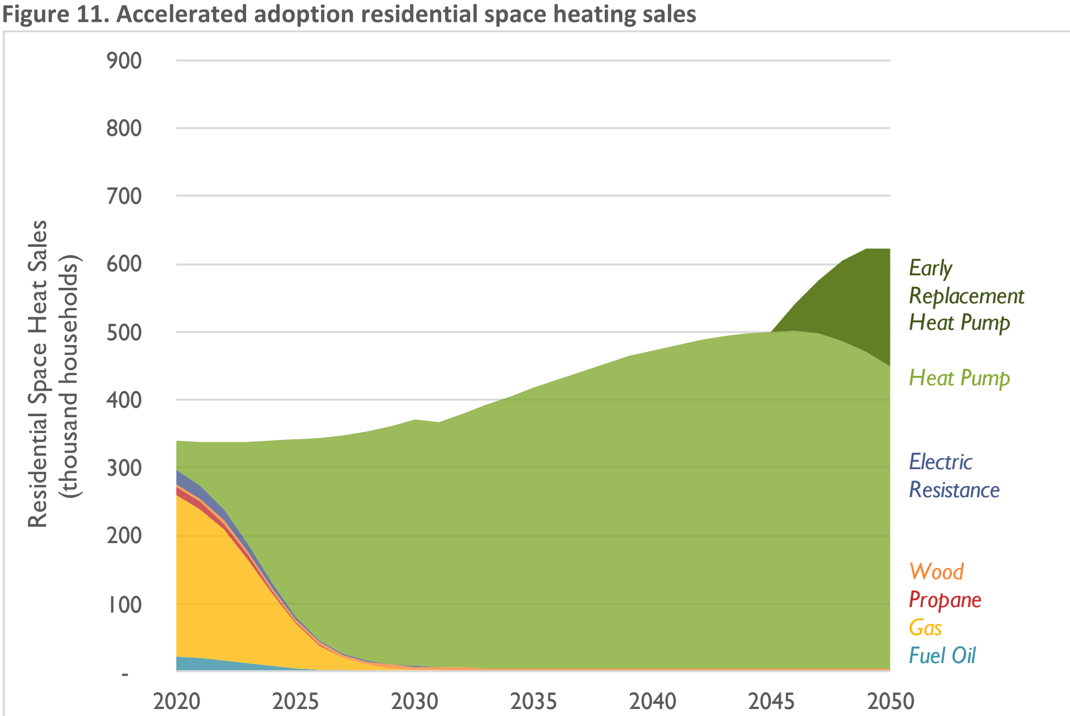
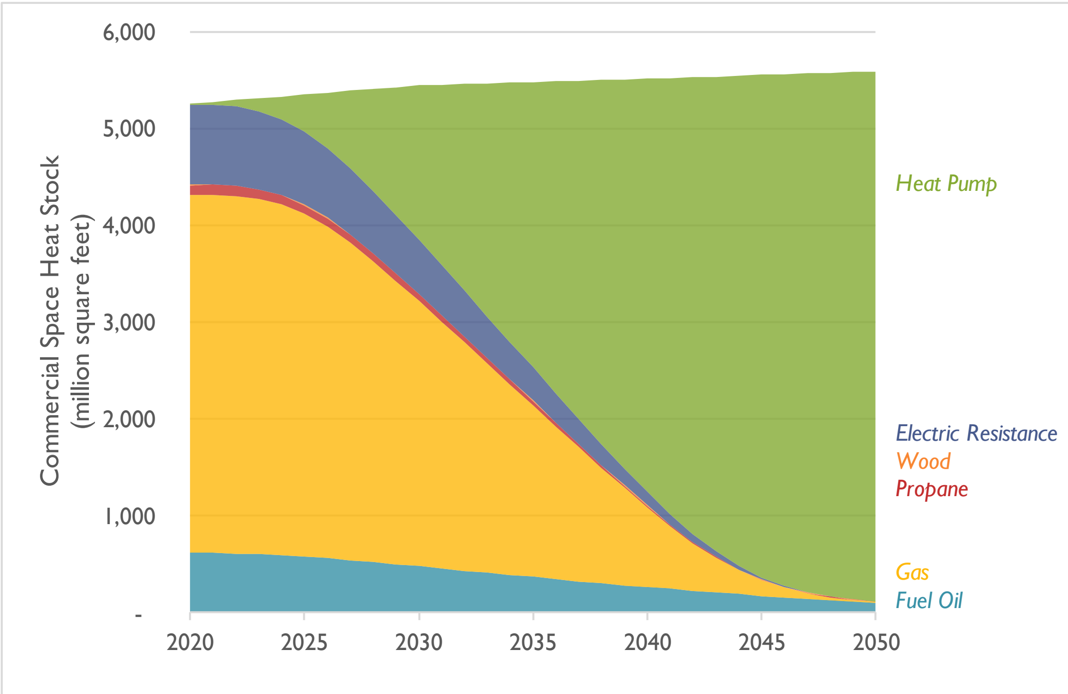


Figure 12. Accelerated adoption commercial space heating stock



Appendix

Appendix Table 1. Sales, stock, and emissions by scenario

			2020	2025	2030	2040	2050
Residential Natural Gas Replacement Sales Share	%	**Back-loaded**	5%	5%	43%	99%	100%
		Moderate	5%	46%	93%	100%	100%
		Accelerated	5%	71%	99%	100%	100%
Total Households Heating with Heat Pumps	***# of households***	**Back-loaded**	330,185	443,868	891,642	3,529,082	7,382,850
		Moderate	330,185	808,345	2,105,972	4,921,036	7,479,446
		Accelerated	330,185	1,011,963	2,499,280	5,279,362	7,490,225
Commercial Natural Gas Replacement Sales Share	%	**Back-loaded**	2.5%	2.5%	25%	98%	100%
		Moderate	2.5%	26%	83%	100%	100%
		Accelerated	2.5%	44%	96%	100%	100%
Total Commercial Square Footage Heating with Heat Pumps	***thousand square feet***	**Back-loaded**	12,331	72,235	310,336	2,482,065	4,928,145
		Moderate	12,331	265,637	1,221,946	3,872,067	5,412,156
		Accelerated	12,331	380,905	1,593,615	4,274,383	5,476,400
Total GHG Emissions	***MMT CO2***	**Back-loaded**	51.6	49.2	45.0	23.4	1.8
		Moderate	51.6	46.9	36.1	13.7	0.5
		Accelerated	51.6	45.5	32.8	11.1	0.4