Who's on First? Methods and Results from Observations and Remote Measurements of Various Residential Hybrid Heating Systems Aimed at Increasing Resiliency and Decarbonization While Decreasing Costs

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ABSTRACT

The health and environmental benefits of urgently decarbonizing our economy are numerous but the high upfront and operating costs of doing so present real challenges to energy affordability and grid reliability. Heat pumps are a proven technology for reducing emissions from home heating, but installing all electric systems with resistance back up heating can incur costly electric panel upgrades, be expensive for customers to operate, and generate winter-peak demands that test grid resiliency. Hybrid heat pumps that use gas-fired (auxiliary) back up heating sources present opportunities to avoid high upfront and operating costs by using the heat pump when it performs best and then relying on the resiliency of the gas-fired systems when the economics favor doing so.

The focus of the paper is an evaluation of residential hybrid heating measures incentivized by an investor-owned gas utility in the Northeast region. In this case, the hybrid heating measures involve heat pump systems that work with a variety of existing or new gas-fired sources such as furnaces or hydronic boiler systems, providing partial displacement of natural gas usage. This represents the first evaluation of a residential decarbonization program by a gas distribution company in support of the states 2050 Energy Master Plan.

The paper reviews the application of an impact evaluation methodology that uses onsite inspections and an internet-connected submetering suite specifically designed to assess the partial displacement operation of hybrid systems. Research results will include heating season energy loads by fuel, influence of controls settings, carbon impacts, and customer bill impacts.

Introduction

The New Jersey Natural Gas (NJNG) Hybrid Heat Program was launched in 2025 under the SAVEGREEN® program cycle--the largest energy-efficiency investment in the company's history at $385.6 million--approved by the New Jersey Board of Public Utilities for January 2025 through June 2027. The Hybrid Heat program aims to advance New Jersey's clean energy and decarbonization goals by integrating high-efficiency electric heat pumps with efficient gas heating systems, offering customers flexibility, reliability, and cost savings while reducing carbon emissions. Hybrid heat is an NJNG name primarily, Building Decarbonization is the name used statewide by the utilities to refer to hybrid and other fuel switching programs.

The primary objective is to reduce carbon emissions from residential heating by integrating high-efficiency electric heat pumps with new or existing gas heating systems. This dual-fuel approach intends to decrease fossil fuel consumption while ensuring reliable heating during the cold weather. In addition to carbon reduction, the program aims to smooth peak demand on the gas system, provide customers with fuel flexibility and protect homes from energy market volatility.

Under a contract with NJNG to evaluate their energy efficiency portfolio, DNV conducted an impact evaluation of the Hybrid Heat Program over the course of the first full heating season for the first-year participants. The goals of the impact evaluation were to verify installation of the hybrid heating systems, collect and assess controls integration and settings key to hybrid function, measure heating loads and determine input energy to calculate energy savings, assess emissions impacts, and determine operating costs.

Hybrid Heat Measures

A hybrid heating system combines two technologies — a high-efficiency electric heat pump and a natural gas furnace or boiler — to deliver reliable, energy-efficient and cost-effective heating. These systems look and operate much like conventional forced-air furnaces or split-system air conditioners, using ductwork to distribute warm air throughout the home. What makes them different is their ability to switch between the heat pump and the gas backup system depending on outdoor conditions.

The changeover point for switching between the two heat sources is based on a predefined compressor lockout temperature. When properly calculated and implemented, this can be set to the outdoor temperature at which heating with the heat pump costs the same as heating with the gas furnace or boiler. Above this temperature, the heat pump is more economical and provides greater efficiency and carbon reduction benefits. Below it, the gas system is cheaper to run. Setting this balance point correctly is critical. To help contractors set this switchover temperature accurately, NJNG developed a spreadsheet-based calculator that factors in the heat pump and furnace system efficiencies, capacities, and the current electricity and gas prices.

The program presents a tiered incentive structure for existing residential customers with gas furnaces to install high-efficiency electric air-source heat pumps that operate alongside their existing or new gas heating systems. The program offers stacked rebates of up to $2,000 to $4,000 (depending on single or two-zone systems) and 0% APR On-Bill Repayment (OBRP) financing of up to $25,000 to enhance the financial attractiveness of dual-fuel upgrades. Additionally, low-income qualified customers can receive additional incentives.

To ensure optimal comfort and efficiency, NJNG requires each project to include an ACCA Manual J load calculation, appropriate Manual S equipment sizing, and the use of integrated thermostat controls that automatically switch between the heat pump and gas heating at the predetermined economic balance point temperature.

This program does not incentivize new standalone gas furnaces, but customers can get a rebate through the other HVAC program NJNG offers; customers interested in full electrification are referred to their electric utility.

Evaluation Methodology

The evaluation conducted phone surveys with a sample of 25 participant customers, out of a population of 67 unique program participating customers, that verified the installation and current operation of hybrid heating systems during August and September 2025. For a subset of 16 customers from this sample, the evaluation conducted onsite inspections for more detailed installation verification and to collect system characteristics and controls that influence hybrid heating system operations. Information gathered during these inspections provided a means of assessing the extent of the integration of hybrid heat pump and gas-fired heating systems, as well as assessing system controls settings that influence when the systems provide heating via the heat pump or the natural gas heating source (gas furnace or hydronic gas boiler).

Out of the 16 customer sites that were inspected, ten had sub-metering hardware installed on their heating systems and multi-mode system airflow measurements performed. The sub-metering equipment was installed on the indoor air handler (furnace), outdoor heat pump equipment, and heating distribution piping (for systems with a hydronic boiler) to measure the following elements:

- Air handler total unit power and furnace/boiler combustion fan power
- Air handler air-side supply and return air temperatures
- Outdoor heat pump total unit power
- Outdoor heat pump condenser fan power
- Ambient outdoor air temperature
- Boiler space heating branch return and supply water temperature

Figure 1 below shows the submetering equipment installed on an outdoor heat pump unit and on the accompanying indoor furnace air handler unit.

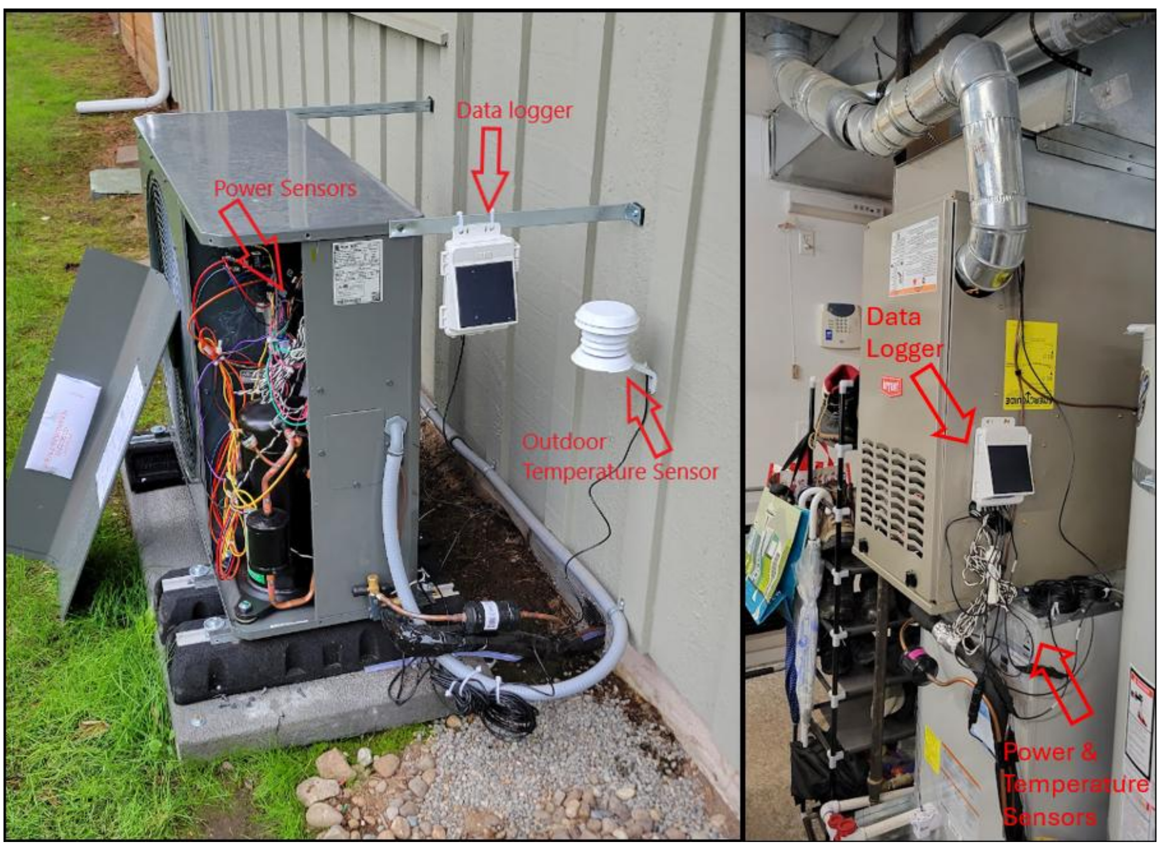

Figure 1. Photos of submetering equipment installed on outdoor heat pump and furnace air handler

DNV conducted fan power and airflow testing at multiple indoor airflow levels to build correlation curves between measured indoor unit power and observed airflow. This data serves as an air mass flow rate approximation in estimating delivered heating capacity and, in combination with the measured time-series total heat pump power, approximated observed steady-state heat pump heating efficiencies (e.g., COP).

The methodology used to estimate gas energy consumption for systems that utilize furnaces for auxiliary heat is based on the calculated delivered heating capacity and the system's rated Annual Fuel Utilization Efficiency (AFUE). Delivered heating capacity is derived from the temperature difference between supply and return air, combined with airflow rates estimated from fan power. This value represents the furnace's heat output. Gas energy consumption is then determined by converting this output to an input energy rate by dividing the delivered heating capacity by the system's rated AFUE.

A similar approach is applied to systems using boilers for auxiliary heat. In this case, delivered heating capacity is calculated from the temperature difference between supply and return water across the hydronic loop, along with a water flow rate estimate calibrated to align with the system's rated maximum output. As with the furnace-based method, the resulting heat output is converted to an input energy rate—and thus estimated gas consumption—by dividing by the system's rated efficiency.

The data streams from the sub-metered equipment enabled the evaluation team to develop site-specific determinations of the electric heat pump and gas heating system operation. From this, heat output and energy inputs by mode were calculated and the distribution of heating operating modes by outdoor air temperature (OAT) was reviewed. With these profiles and distributions compiled, we could derive the following for the sample and for the expanded population[1]:

- Average heating partial displacement fraction
- Approximate steady state heat pump efficiencies
- Annual gas and electric heating load energy
- Annual heating load impacts against a baseline furnace and an all-electric cold climate air source heat pump
- Annual heating load emissions impacts
- Annual heating load operating costs to the subprogram participants.

Site inspections and sub-metering equipment installations took place in the summer of 2025 in order to collect data on the system operations throughout the 2025-2026 heating season.

Results

Sub-meter Data Analysis and Weather Normalization

Sub-meter data were analyzed for each system to determine minute-by-minute operating mode, broken down into distinct categories: off/standby, ventilation/fan-only, HP heating, auxiliary heating, and defrost. Figure 2 shows the percent distribution (shown on the y-axis) that

[1] The program population at the time of recruitment for site inspections and submetering installations consisted of 71 hybrid heating system measures installed across 67 unique customer sites, 35 of which represented participants from the initial program year which ended on June 20th, 2025, and the remaining 32 sites belonging to the second program year. Assuming a sampling error ratio of 0.5, the submetering sample achieved represents an approximate relative sampling precision level of 25% at the 90% confidence interval.

the aggregated systems operated in those modes during the 2025-26 heating season. The "shape" of the distribution matches the sums of time elapsed under each outdoor temperature bin (shown on the x-axis), and the sum of the distribution is equal to one.

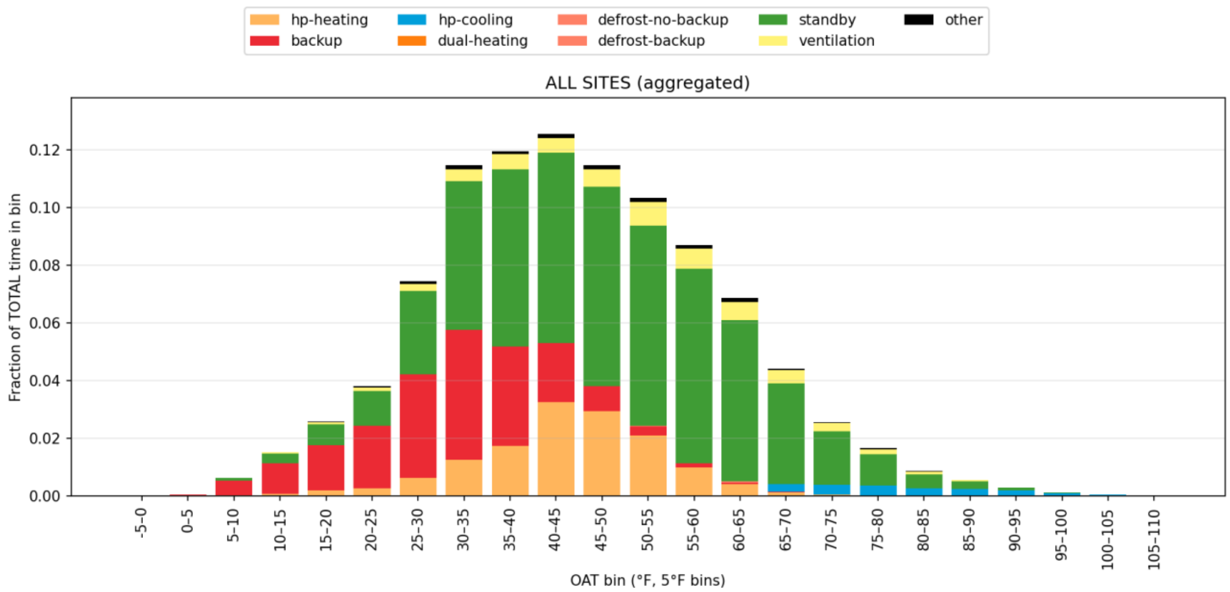

Figure 2. Field-observed aggregated hybrid system operating mode distribution by outdoor air temperature[2]

The research analysis defined the measured heating season as October 1, 2025, through April 30, 2026. Weather normalization of the results was achieved by adjusting the consumption for the actual observed weather to typical meteorological conditions using the full TMYx dataset from October through April using 5-degree outdoor air temperature bins. The TMYx weather has fewer hours at colder temperatures below 40 °F and more hours at mild temperatures above 40 °F than the actual weather experienced across all sites. These influences generally increased the TMY electricity usage (because the HP are enabled at mild temperatures and more TMY hours results in more HP usage) and decreased the TMY gas usage, relative to their respective actual usages. Figure 3 below shows the actual and weather-normalized electric and gas consumption for the observed heating season.

[2] Dual heating is an operating mode in which heat pump heating and auxiliary heating operate simultaneously. We did not expect (and did not see) this condition to occur for ducted heat pumps with gas furnaces because the gas furnace is typically located upstream of the indoor evaporator coil. Simultaneous heating can cause high-pressure faults that can lock out the compressor requiring HVAC contractor intervention. The "other" operating mode was any other event that was not categorized under the other operating modes. These were transient events when metering equipment measured values outside of the operating modes' criteria threshold(s)

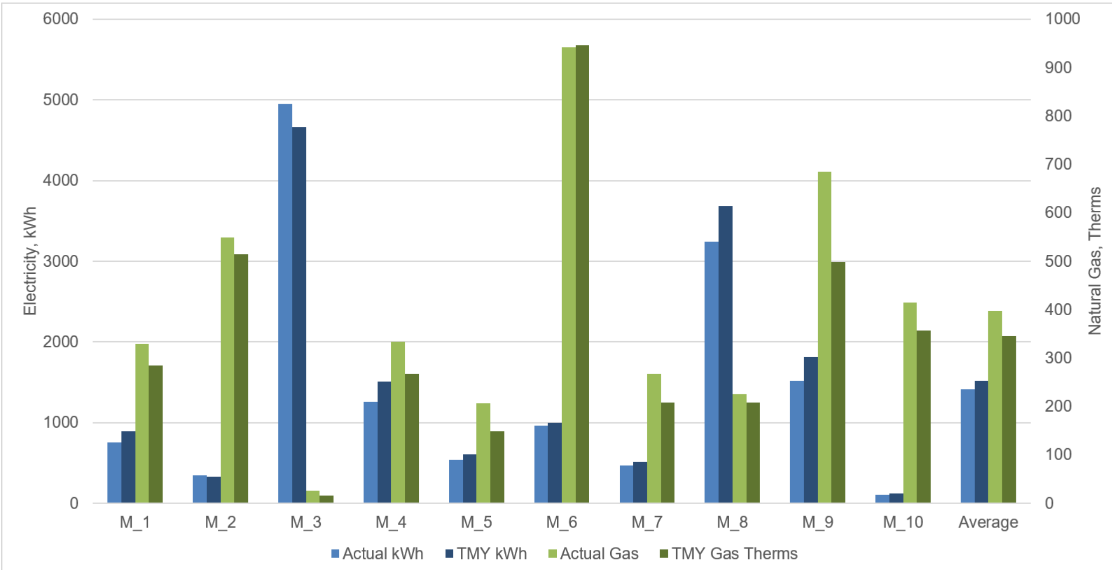

Figure 3. Actual and weather-normalized electric and gas consumption, heating season

Measured Heat Pump Steady State Efficiency

Figure 4 presents the field-measured coefficient of performance (COP) specifically for compressor-based (heat pump) heating operation at site one. COP values are during steady state operation and do not include auxiliary heat energy or distribution (i.e., duct) losses. The figure shows compressor-based heating COP at varying outdoor dry bulb temperature, binned in 5-degree increments along the x-axis. The figure shows COPs distributed in box and whisker plots. The “box” represents the interquartile range containing the first through third quartile of data (the middle 50% of the data). The orange line through the box represents the median value for the data while the green triangle represents the mean average. The “whiskers” are the minimum and maximum values for the temperature bin. The tighter box indicates less variability in the middle 50% of data and whisker length indicates variability in that quartile (Q1 or Q4).

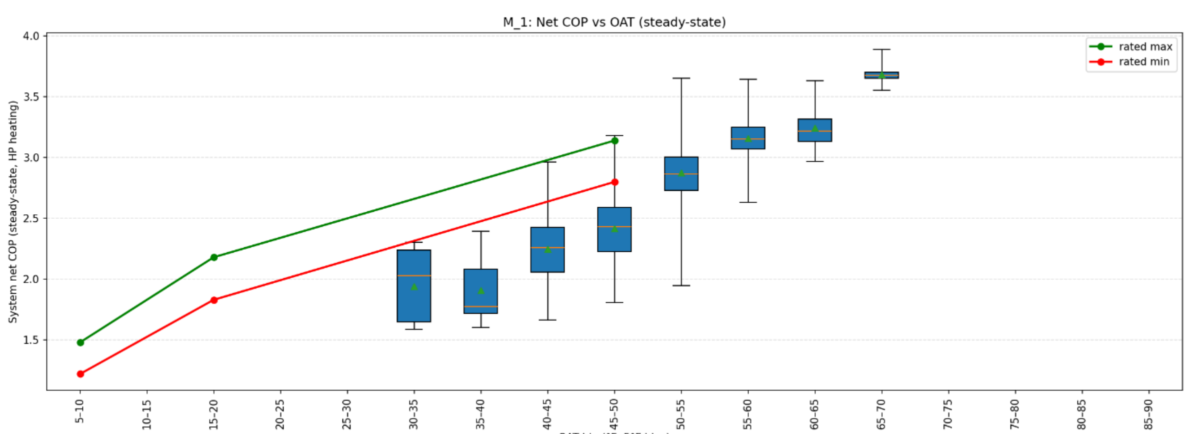

Figure 4. Rated and measured steady state heating COP for site one

The figure has a combination of green and red dots representing the manufacturer-reported heating COP at 5 °F, 17 °F, and 47 °F. Green dots represent the maximum compressor speed COP, and red dots represent the minimum compressor speed COP. Manufacturer-reported COPs were drawn from the NEEP Cold Climate product list or the ENERGYSTAR product list. They represent measurements taken with control settings and operating conditions specific to the laboratory or standards test in which they were taken. The field measurements are measured according to site-specific conditions; therefore, conditions like return air temperature (i.e., heating load), supply airflow rate, and compressor speed are almost certainly different from reported values. These operating conditions can have a large influence on heat pump performance and contribute to the discrepancies between manufacturer-reported values and field observations.

As is the case for site one shown in Figure 4, most average measured steady state COP values across the sub-metered site sample fall near or below the rated minimum manufacturer-reported COPs. There is a high degree of certainty in the measurement of the electric power draw from the heat pump system, but error in the airflow measurements, airflow-to-fan power correlation, and the supply and return dry bulb temperature measurements could impact the calculation of sensible heating capacity that factors into the calculations. It is also possible that the systems have lower airflow or higher static pressure that the systems are tested with for the manufacturer ratings, and the measured COPs are more reflective of actual in-situ performance. The measured COPs for site five, shown in Figure 5, are an exception to the generally observed trend, with the average measured steady state heating COPs falling in between the maximum and minimum manufacturer-reported COP values.

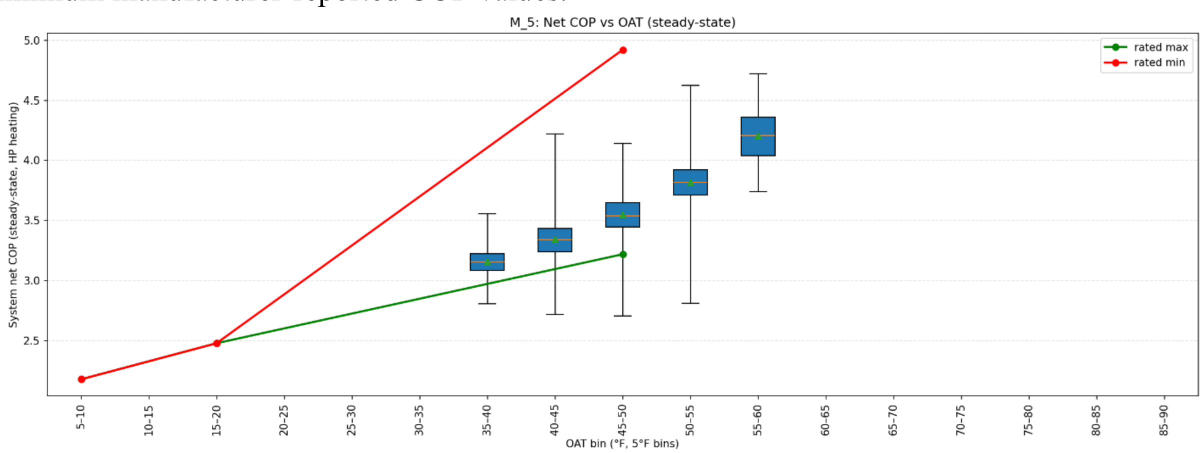

Figure 5. Rated and measured steady state heating COP for site five

Heating Season Energy Loads

Heating season energy output values are presented below in Table 1. Across the ten sub-metered sites, the average partial displacement factor, the heating load met by the heat pump, was 27%. This load factor varied widely amongst the ten sites, with some showing very low load fractions indicating very little or no heat pump utilization, while site 3 shows almost all heating delivered through the heat pump. Differences in hybrid system controls integration, controls configurations, setpoint schedules, internal loads, and some natural gas system operation above the compressor lockout temperature are likely large drivers for the variances in heat pump load factors. The New Jersey Technical Reference Manual (TRM) provides partial displacement factors as a function of the compressor lockout temperature control setpoint and New Jersey climate region of the installation (New Jersey Board of Public Utilities 2025). Most observed heat pump partial displacement load factors fall well below what the New Jersey TRM specifies given each application's location and observed control settings[3].

Table 1. Calculated heating season energy outputs and partial displacement factors

Site ID	Metered Heating Energy Output					New Jersry TRM
	Heat pump (kWh)	Heat pump (therms)	Natural gas (therms)	Heat pump and natural gas (therms)	Heat pump partial displacement factor (%)	Heat pump partial displacement factor (%)
1	1,770	60	278	338	18%	46%
2	0	0	494	494	0%	N/a
3	9,028	308	15	323	95%	46%
4	3,360	115	259	374	31%	46%
5	1,506	51	145	196	26%	46%
6	2,473	84	757	841	10%	30%
7	913	31	203	234	13%	46%
8	5,671	194	202	396	49%	66%
9	4,753	162	484	646	25%	91%
10	414	14	332	346	4%	N/a
Average	2,989	102	317	419	27%	47%

Table 2 below shows the heating energy inputs, electric kWh and natural gas therms, calculated for each sub-metered system over the measurement period. The heat pump only uses electricity, while the natural gas heating utilizes natural gas as a heating fuel while also consuming small amounts of electricity to power fans or pumps.

Table 2. Calculated heating season energy inputs

Site ID	Heating Energy Input				
	Heat pump heating (kWh)	Heat pump heating (therms)	Natural gas heating (therms)	Natural gas heating electric pump or fans (kWh)	Natural gas heating gas and pump/ fan energy (therms)
1	763	26	285	131	290
2	0	0	514	332	526
3	4,663	159	16	2	16
4	1,290	44	267	220	275
5	470	16	149	139	154
6	510	17	946	488	963
7	359	12	209	154	214
8	3,575	122	208	106	211

[3] NJ TRM partial displacement factors calculated using values for the coastal climate region in Table 2-66 Partial Displacement Factors for Ducted Heat Pumps for the corresponding 'switchover' compressor lockout temperature control setpoint and interpolating where necessary.

Site ID	Heating Energy Input				
	Heat pump heating (kWh)	Heat pump heating (therms)	Natural gas heating (therms)	Natural gas heating electric pump or fans (kWh)	Natural gas heating gas and pump/ fan energy (therms)
9	1,554	53	499	257	508
10	126	4	357	0	357
Average	1,331	45	345	183	351

Table 3 presents the heating season impacts for the hybrid system against the baseline of the installed gas heating system at each site. The heat pump energy input (shown in kWh and also shown converted to therms) is the measured electrical input energy consumed to provide the heat pump output heat in Table 1. The avoided gas energy input and avoided pump or fan energy input represent the gas and electricity that would have been needed to meet the heat output provided by the heat pump heating. Combined fuel energy savings is calculated as the difference between the avoided energy input (both gas and pump/fan) and the heat pump energy input values for each site and is presented in the unit of therms. Average energy savings across the sub-metering sample is 65 therms. This represents 23% energy savings of input energy when compared against the total input energy for the hybrid systems.

Table 3. Calculated heating season impacts against installed gas heating systems

Site ID	Heat Pump Energy Input (kWh)	Heat Pump Energy Input (therms)	Avoided Gas Energy Input (therms)	Avoided Pump or Fan Energy Input (kWh)	Avoided Energy Input (therms)	Energy Saving (therms)
1	763	26	62	29	63	37
2	0	0	0	0	0	0
3	4,663	159	334	34	336	176
4	1,290	44	118	97	122	78
5	470	16	53	49	55	39
6	510	17	106	54	107	90
7	359	12	32	24	33	21
8	3,575	122	199	102	202	80
9	1,554	53	167	86	170	117
10	126	4	15	0	15	11
Average	1,331	45	109	48	110	65

Influence of Controls Settings

The economic balance point in a hybrid heating system, which integrates a heat pump and natural gas–fueled heating system, refers to the outdoor temperature at which the heating cost of the heat pump (measured in $/MMBtu output) becomes more expensive than the gas heating system. At this point, the system will switch to using the gas heating system for more cost-effective heating. The discussion below will refer to the gas heating system as a gas furnace, because that was the common hybrid system encountered in the inspection and sub-metering sample group.

Although a heat pump can provide heat more energy efficiently than a gas furnace, the price difference between electricity and natural gas creates an intersection for economic efficiency. This intersection is influenced by gas and electric utility rates, the efficiency of the gas furnace (measured by annual fuel utilization efficiency, or AFUE), and the efficiency curve of the heat pump.

The heating efficiency of an air-source heat pump is influenced by outdoor temperature, with the COP decreasing as the outdoor temperature drops. When we translate this relationship into the cost of heating per MMBtu heating output, we get a temperature-dependent curve. In contrast, the efficiency of a gas furnace remains relatively constant regardless of outdoor temperature. As a result, the gas furnace's cost of heating per MMBtu heating output also remains fixed across outdoor temperature.

Examples of these economic balance points are illustrated in Figure 6. In this scenario, the electric utility rate is $0.21 per kWh, which translates to $61.53 per MMBtu of energy input. Meanwhile, the natural gas utility rate stands at $1.67 per therm, equating to $16.70 per MMBtu of energy input. If both the electric heater and the gas heater have a COP of 1, the cost of heating with electricity would be over 3.5 times more expensive than heating with gas. However, high-efficiency cold-climate air-source heat pumps (ccASHP) can achieve efficiencies that surpass even the most efficient gas-fired furnaces. Therefore, when assessing heating cost-effectiveness, it is essential to consider the relative efficiencies of both electric and gas-fueled equipment.

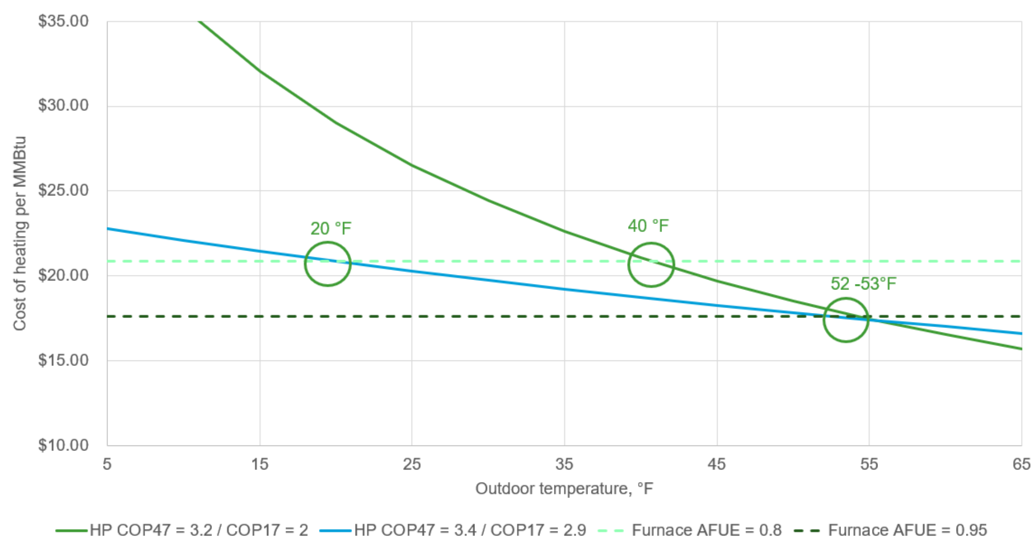

Figure 6. Illustration of the heating system economic balance points

Table 4 provides the rated heating efficiencies, calculated economic balance points, critical hybrid system lockout controls as well as the typical set point setbacks and status of the thermostats' adaptive recovery[4]. The heat pump compressor lockout set points vary significantly. However, the most common lockout temperature is at 40°F, with the "disabled" being the most

[4] Adaptive recovery, also called intelligent recovery, is a feature of some thermostats that learns the recovery rate of your home and proactively begins heating or cooling recovery from a setback temperature setpoint so that the setpoint is met at the time of the schedule shift. Utilizing this feature can reduce the likelihood of the system activating the auxiliary back up heating source to satisfy the higher setpoint when the outdoor air temperature is above the compressor lockout temperature and thus the system's heat pump heating is enabled.

frequent setting for auxiliary lockouts. When lockouts are disabled, the thermostat determines which heating stage to use — either the (first stage) heat pump or auxiliary heat — to meet the desired temperature set point, regardless of the outdoor temperature. Cold-climate heat pumps (i.e., high-efficiency, variable capacity) with disabled compressor lockouts are more likely to displace gas heating at temperatures down to 5°F.

Table 4. Heating system rated efficiencies with the calculated and observed hybrid system thermostat control settings

Site ID	Heating COP at 47 °F	Heating COP at 17 °F	Gas heating AFUE, (%)	Calculated heat pump lockout economic balance point (°F)	Observed heat pump lockout (°F)	Observed gas heating lockout (°F)	Setpoint Setback (°F)	Adaptive recovery enabled
1	3.14	2.18	97%	61	40	Disabled	N/A	Yes
2	3.66	2.00	96%	45	Disabled	Disabled	2	Yes
3	3.40	2.40	90%	45	40	55	0	Yes
4	3.37	2.40	97%	53	40	50	N/A	Yes
5	3.22	2.48	97%	61	40	50	N/A	Yes
6	3.30	2.50	80%	34	45	Disabled	4	Yes
7	3.66	2.00	97%	45	40	Disabled	8	No
8	3.32	2.34	97%	55	33	Disabled	4	Yes
9	3.20	2.30	97%	59	25	50	2	Yes
10	3.30	2.30	90%	48	Disabled	Disabled	4	No
11	2.94	2.00	99%	70	35	50	N/A	Yes
12	3.30	2.30	95%	53	45	Disabled	2	Yes
13	3.81	2.00	96%	42	Disabled	Disabled	N/A	Yes
14	3.44	3.20	96%	59	20	40	8	Yes
15	3.81	2.00	97%	43	25	45	3	Yes
16	3.98	2.00	96%	40	25	45	3	Yes

The lockout set points for heat pumps are significantly higher than the minimum operating temperatures recommended for high-efficiency variable-speed heat pumps in cold climates; all observed heat pumps can function at temperatures as low as 5 °F. Nonetheless, based on program guidelines aimed at optimizing operating costs, most heat pump lockout set points appear to be set conservatively above 5 °F but are well below their economic balance points, with the average observed lockout temperature (35 °F), excluding those with disabled lockout controls, being 16 below the average calculated lockout (51 °F). Site six is an exception to this general observation, with the observed lockout set to 45 °F while the calculated economic balance point is 34 °F. Site six has the lowest calculated balance point, as a result of having a moderately efficiency heat pump paired with the only baseline efficiency (80% AFUE) furnace in the sample of inspected sites. Survey responses from installation contractors suggest few of them are utilizing the program's balance point calculator tool determine the compressor lockout setpoint, and this analysis shows significant deviation from the values that the evaluation team calculated.

Most systems use “adaptive recovery,” with only two systems (7 and 10) having the feature disabled. The two systems with disabled adaptive recovery happen to also have aggressive setbacks of 4°F and 8°F. These large setbacks, combined with uncontrolled recovery, increase the likelihood of the thermostats engaging backup heating during morning warmups when outdoor conditions and thermostat thresholds would otherwise allow heat pump heating to recover set point. In other words, these heat pumps may not offset as much gas heat as intended.

Nighttime heating set point setbacks were relatively large, with 44% (seven of the 16 systems) of the systems having setbacks of at least 3°F. Two systems had setbacks of 8°F. All systems were programmed to come out of their setbacks between 5 a.m. and 7 a.m., which is often the coldest period of winter days. While heat pump systems with deep setbacks have previously indicated higher frequencies of auxiliary heating usage when heat pump heating is available (i.e., when recovery begins, the outdoor temperature is above the compressor lockout), newer thermostats with adaptive recovery prevent the systems from resorting to using their less efficient auxiliary heating stage.

Table 5 presents the hybrid system thermostat control settings, calculated partial displacement factors, and energy savings for sub-metered sites. The field observation of controls and the calculated displacement factor and energy savings for site 2 suggest that it is not properly commissioned to operate as a hybrid system and did not utilize the heat pump equipment to meet any heating load. Site three appears to have an opposite issue, with the system heating almost exclusively using the heat pump. It is unclear if the observed lockout settings or other configurations that could cause this result were altered subsequent to the field observations. The observed configuration of equipment and hardware at site ten suggest to the evaluator that this system’s heat pump and natural gas heating (hydronic boiler) controls were not integrated under one thermostat, as the program requires, and that the homeowner manually managed heating between the two systems.

Table 5. Hybrid system thermostat control settings, calculated partial displacement factors, and energy savings for sub-metered sites

Site ID	Calculated heat pump lockout economic balance point (°F)	Observed heat pump lockout (°F)	Gas heating lockout (°F)	Setpoint Setback (°F)	Adaptive recovery enabled	Heat pump partial displacement factor	Energy savings, as a percent of total input energy
1	61	40	Disabled	N/A	Yes	18%	12%
2	45	Disabled	Disabled	2	Yes	0%	0%
3	45	40	55	0	Yes	95%	101%
4	53	40	50	N/A	Yes	31%	24%
5	61	40	50	N/A	Yes	26%	23%
6	34	45	Disabled	4	Yes	10%	9%
7	45	40	Disabled	8	No	13%	9%
8	55	33	Disabled	4	Yes	49%	24%
9	59	25	50	2	Yes	25%	21%
10	48	Disabled	Disabled	4	No	4%	3%
Avg.	51	38	51	3.4	8 of 10	27%	23%

Across the sub-meter sample, for sites that are properly commissioned the data suggest that higher energy savings are primarily achieved when the heat pump lockout controls are enabled and set lower than the economic balance point to increase actual heat pump displacement—especially by avoiding premature heat pump lockout—while deeper thermostat setbacks do not appear to help and may reduce savings

Carbon Emissions Impacts

Annual heating load emissions were estimated across the three scenarios, the installed hybrid systems and two hypothetical scenarios, to assess the impacts of distributing emissions across multiple heating fuels and heating efficiencies. One hypothetical scenario assumed pre-existing heating systems using a baseline 80% AFUE forced-air gas furnaces while the other scenario assumes an all-electric cold-climate heat pump system (ccASHP) capable of serving the entire heating load observed and measured by our equipment over the heating season. The all-electric heat pump scenario assumes that the system has no backup electric strip heat and has a compressor-based heating performance (COP) derived from the observed COP for the system installed at site three. The evaluation team chose to use system three because the system coincidentally operated over a large temperature range covering the TMY weather. It also represents what we considered to be a cold-climate, variable capacity heat pump that could hypothetically be sized to serve 100% design heating load for the sampled homes.

For the analysis of emissions from electricity consumption, we applied an electric line loss factor of 1.087 (New Jersey Board of Public Utilities 2023) and the actual marginal electrical grid emissions reported for the measurement period by the PJM independent transmission organization, the independent system operator or ISO, to the electric energy consumption (PJM Interconnection 2026). The analysis of gas emissions was calculated using by applying a gas line loss factor of 1.023 (New Jersey Board of Public Utilities 2023) and a static natural gas CO_2 emissions factor of 12.86 pounds of CO_2 per therm (U.S. EIA 2024). Table 6 below shows the calculated emissions from electricity and gas consumption for the installed hybrid, the hypothetical ccASHP, and the hypothetical baseline furnace systems.

Table 6. Calculated heating load emissions for hybrid, ccASHP, and baseline furnace systems

Site ID	Hybrid system CO_2 emissions (lbs.)			ccASHP system CO_2 emissions (lbs.)			Baseline furnace system CO_2 emissions (lbs.)		
	Electricity	Gas	Total	Electricity	Gas	Total	Electricity	Gas	Total
1	951	3,755	4,706	5,969	0	5,969	476	5,563	6,039
2	401	6,765	7,165	8,903	0	8,903	209	8,118	8,326
3	5,537	208	5,745	5,525	0	5,525	416	5,304	5,721
4	1,724	3,515	5,240	6,466	0	6,466	508	6,148	6,655
5	703	1,963	2,666	3,470	0	3,470	238	3,226	3,464
6	1,115	12,448	13,563	14,273	0	14,273	656	13,834	14,489
7	629	2,747	3,376	4,465	0	4,465	143	3,843	3,986
8	4,434	2,730	7,165	6,514	0	6,514	770	6,505	7,275
9	1,956	6,565	8,521	11,273	0	11,273	510	10,627	11,136
10	137	4,695	4,831	6,274	0	6,274	147	5,688	5,835
Avg.	1,759	4,539	6,298	7,313	0	7,313	407	6,885	7,293

The calculated average combined electricity and gas heating load emissions of the metered hybrid systems is 6,298 pounds of CO_2. A hypothetical all-electric ccASHP systems would have resulted in average emissions of 7, 313 pounds of CO_2 and a baseline furnace would have resulted in average emissions of 7,293 pounds of CO_2. There is a high variability in the emissions between systems in the sample, which is likely a result of varying equipment efficiencies and variability in the partial displacement load factors. The average emissions reductions for the hybrid systems are 13.9% over a ccASHP system, and 13.6% over a baseline furnace system. These results represent the emissions impacts from the 2025-2026 winter heating season. Electricity emissions impacts could shift over the useful lifetime of the heating equipment as the emissions intensity of the electricity generation for the PJM ISO change. Relative to the hypothetical baseline gas furnace systems, the hybrid or ccASHP systems could realize greater emissions reductions in future years if the electricity generation emissions intensity is reduced.

Customer Bill impacts

As was the case with the analysis of carbon impacts, the analysis of seasonal heating operating costs to customer's bills was conducted across the same three scenarios (installed hybrid, all-electric ccASHP, and baseline furnace systems). Electric energy operating costs were calculated using a flat rate of $0.21 per kWh and gas energy operating costs were calculated using a flat rate of $1.67 per therm, which were the prevailing residential service rate during the study observation period. Table 7 presents the energy consumption and operating costs for each system type, by fuel and combined where applicable.

Table 7. Seasonal heating energy use and operating costs for hybrid, ccASHP, and baseline furnace systems

Site ID	Hybrid system					ccASHP system		Baseline furnace system				
	Electric		Gas		Total costs ($)	Electric		Electric		Gas		Total costs ($)
	Energy (kWh)	Costs ($)	Energy (therms)	Costs ($)		Energy (kWh)	Costs ($)	Energy (kWh)	Costs ($)	Energy (therms)	Costs ($)	
1	894	188	285	477	664	5,160	1,083	400	84	423	706	790
2	333	70	514	859	929	7,352	1,544	173	36	617	1,031	1,067
3	4,664	979	16	26	1,006	4,603	967	351	74	403	673	747
4	1,510	317	267	446	763	5,351	1,124	438	92	467	780	872
5	609	128	149	249	377	2,869	603	200	42	245	410	452
6	998	210	946	1,580	1,790	12,099	2,541	567	119	1,052	1,756	1,875
7	512	108	209	349	456	3,607	757	115	24	292	488	512
8	3,681	773	208	347	1,120	5,356	1,125	644	135	494	826	961
9	1,811	380	499	833	1,214	9,547	2,005	449	94	808	1,349	1,443
10	126	26	357	596	622	5,222	1,097	125	26	432	722	748
Avg.	1,514	318	345	576	894	6,117	1,284	346	73	523	874	947

Across the ten metered systems, the average calculated seasonal heating operating costs for the installed hybrid heating systems is $894, of which gas consumption contributed 65% of the combined cost. The average calculated seasonal heating operating costs for an all-electric ccASHP system is $1,284, a 44% cost increase over operating the hybrid system, whereas the average calculated seasonal heating operating costs for a baseline furnace system is $947. While operating costs savings for the hybrid system is generally significant over the all-electric ccASHP, the benefit is more modest when comparing against the costs of operating a baseline furnace. These results highlight the challenge of affordably electrifying residential heating to achieve decarbonization within existing utility rate structures. The program achieves its aim of minimizing the participant's heating operating costs while realizing some level of decarbonization but reaching higher emissions reductions under the same utility rates would likely come with higher operating costs to customers.

Conclusions

This study presents one of the first field-based evaluations of a utility-sponsored residential hybrid heating program designed to balance decarbonization, affordability, and system reliability. Using detailed sub-metering, onsite inspections, and weather-normalized analysis, the evaluation provides insight into real-world performance of hybrid heat pump systems operating alongside gas-fired backup heating across a range of homes and control configurations.

The findings demonstrate that hybrid systems are capable of delivering measurable energy savings and emissions reductions relative to baseline gas heating systems, while also maintaining lower operating costs than fully electrified configurations under current utility rate structures. Across the metered sample, hybrid systems reduced total input energy by an average of 23% (65 therms annually) and achieved approximately 13–14% reductions in CO_2 emissions compared to both baseline furnaces and a modeled all-electric heat pump scenario. Importantly, hybrid systems also resulted in the lowest average seasonal heating costs ($894), compared with $947 for baseline furnaces and $1,284 for all-electric systems.

However, the analysis also highlights substantial variability in system performance, driven primarily by differences in installation quality, controls integration, and thermostat configuration. The average heat pump contribution to heating load (27%) fell well below Technical Reference Manual assumptions, with some systems exhibiting minimal or no heat pump utilization. Incorrect commissioning, disabled or misaligned lockout settings, and operational behaviors such as aggressive setbacks without adaptive recovery likely significantly limited heat pump runtime in several cases. These findings underscore that the realized benefits of hybrid systems are highly sensitive to commissioning practices, contractor implementation, and user settings.

Control strategies emerged as a critical determinant of system performance. While most installations targeted the economic balance point to minimize operating costs, opportunities exist to optimize for alternative objectives, such as maximizing emissions reductions. The observed mismatch between calculated economic balance points and implemented lockout temperatures in some systems suggests that additional contractor guidance, commissioning verification, and potentially adaptive or dynamic control strategies could improve outcomes.

From a policy and program design perspective, the results highlight both the promise and the limitations of hybrid heating as a decarbonization pathway. Hybrid systems offer a pragmatic near-term solution that can reduce emissions without imposing significant operating cost burdens on customers or increasing peak electric demand. At the same time their dependence on current grid emissions intensity indicates that deeper decarbonization will ultimately require continued grid decarbonization and potential evolution of rate structures.

Overall, the study demonstrates that hybrid heat pump systems can play a meaningful transitional role in residential decarbonization strategies, particularly in regions with high electric-to-gas price differentials and winter peak constraints. To fully realize their potential, programs should emphasize proper system design, controls optimization, and quality installation practices, while continuing to evaluate performance as technology, rates, and grid emissions evolve.

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