Heat Pump Impact Evaluation

Final Report

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EXECUTIVE SUMMARY

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New York State Energy Research and Development Authority

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1 EXECUTIVE SUMMARY

DNV is contracted by NYSERDA to evaluate the energy impacts of heat pumps incentivized by three NYSERDA initiatives through 2018. The evaluated technologies include air-source heat pumps (ASHPs), comprising both ducted and ductless mini-split heat pump (DMSHP) systems, and ground-source heat pumps (GSHPs). Three programs administered by NYSERDA—Underutilized Products (ASHP), Heat Pumps and Solar Thermal (GSHP), and the Heat Pump Pilot Projects Demonstration—distributed rebates to residential and commercial participants that selected eligible heat pump models to partially or fully displace pre-existing or code-compliant heating and cooling systems. From their 2017 inception through 2018—the evaluation timeframe considered for this study—the programs distributed rebates to 4,515 customers and reported savings of 272,546 MMBtu across all energy sources, including electricity (at site[4]), natural gas, and delivered fuels such as propane and fuel oil. These programs are no longer administered by NYSERDA and have been superseded by the NY Statewide Clean Heat program, administered by the state's joint electric utilities. Many of the recommendations from this evaluation of New York's predecessor heat pump programs have been incorporated by the current NYS Clean Heat program.

The impact evaluation was divided into two phases corresponding to the following objectives identified in Table 1-1. Phase 1 included participant surveys, interviews with contractors, and comparison of weather-normalized consumption data between pre- and post-installation periods to determine at-the-meter impacts of the heat pump installations. Phase 2 involved on-site measurement and verification (M&V) of rebated heat pump systems at a sample of participating homes and businesses.

Table 1-1. NYSERDA Heat Pump Impact Evaluation objectives by phase

Objective	Phase 1	Phase 2
Evaluate annual gross energy impacts of ASHPs and GSHPs[5]	X	X
Establish appropriate baseline conditions	X	X
Characterize seasonal usage of ASHPs and GSHPs	X	X
Assess displacement versus replacement	X	X
Characterize and document HP control systems and usage patterns	X	X
Characterize equipment issues that impact performance	X	X
Collect information on refrigerant	X	X
Confirm and refine billing analysis through seasonal on-site metering		X
Analyze the effects of COVID on heat pump usage	X	

1.1 Evaluation Methods

In fall 2019, prior to data collection, the DNV evaluation team (or "the evaluators") conducted a literature review and administered in-depth interviews with ten industry experts to inform the evaluation data collection and analysis methodology. The literature review refined the evaluation approach by identifying best practices for measurement and verification (M&V) and analysis of heat pumps. Next, in winter 2019-2020 and spring 2021, evaluators conducted two rounds of Qualtrics-based surveys to assess heat pump characteristics among participating customers. The first occurred after heat pump installation but before the COVID-19 pandemic, while the second focused on customer behavior and heat pump usage during the pandemic. To supplement the perspectives provided by participating customers, evaluators conducted 24 in-depth interviews with installer contractors to collect information on heat pump sales practices, recommendations for quality installations, and observations on operations or maintenance issues.

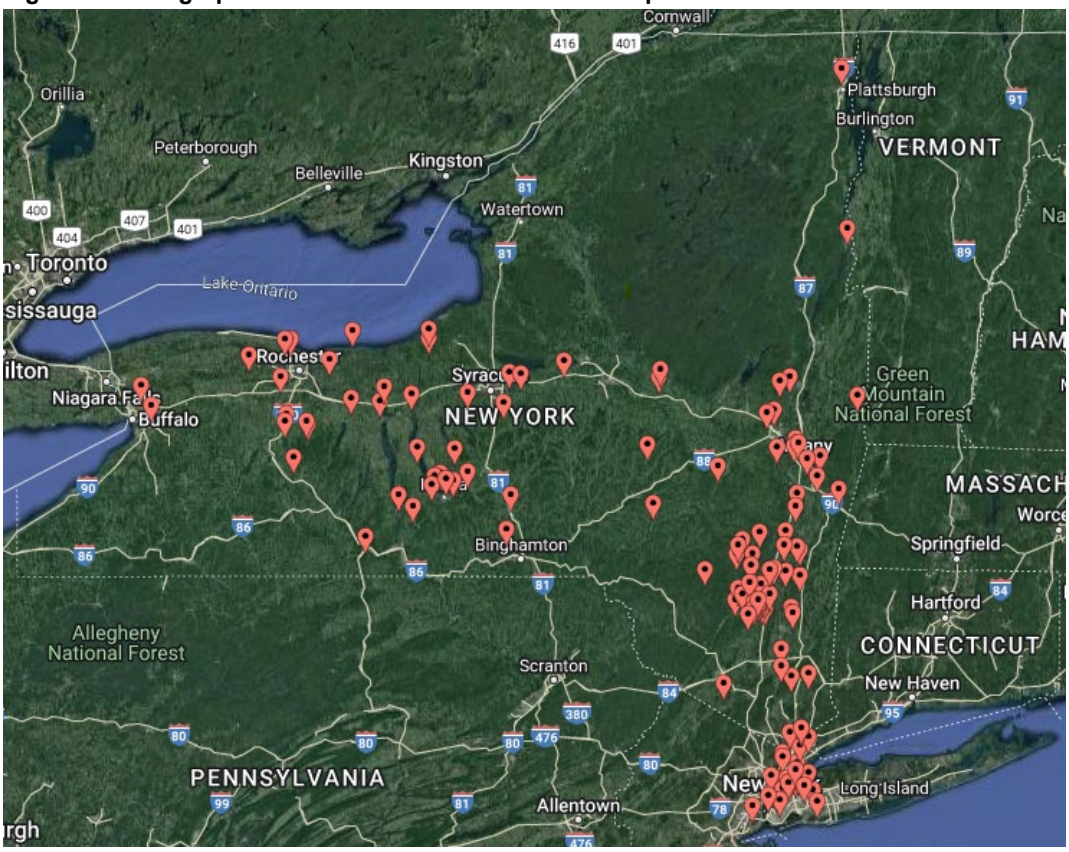
[4] All MMBtu savings in this report reflect *site* MMBtu— i.e., no electric production, transmission, or distribution efficiencies are incorporated.

[5] Electric demand impacts are not a focus of this study.

As part of evaluation Phase 1, the evaluation team next requested consumption data for participating homes and businesses after collecting customer authorizations via survey. Consumption data consisted of both utility monthly billing data for electric and natural gas as well as fuel delivery records for unregulated fossil fuels such as propane and heating oil. After organizing and cleaning the collected data, analysts developed pre- and post-installation regressions of energy consumption as a function of historical weather data. Regressions were next applied to typical meteorological data to determine weather-normalized energy consumption before and after the heat pump installation; the difference of these values represents the evaluated savings at the customer meter. Ultimately, evaluators assessed 220 projects using a billing analysis approach. Evaluators summarized Phase 1 results in a memorandum submitted to NYSERDA in spring 2020.

Evaluation Phase 2 involved on-site M&V at a sample of 137 participating facilities from spring 2020 through fall 2021. As illustrated in Figure 1-1, evaluators stratified the Phase 2 sample design by climate zone to ensure geographic representation throughout New York. Field engineers visited each facility to confirm survey responses, verify the installation and operability of rebated heat pumps, and deploy performance monitoring devices on the heat pump and other affected systems. For 125 sites in the sample, the evaluation team executed a “core” rigor approach by deploying remotely communicating amperage loggers on the electrical circuit serving the heat pump(s) and temperature loggers in associated ducts and, for GSHPs, piping. For the remaining 12 sites, evaluators applied an “intensive” rigor approach and deployed power monitoring devices and additional temperature/humidity loggers. The core and intensive M&V approaches were informed by the best practices identified from the preceding literature review. All site visits included spot measurements of relevant systems.

Figure 1-1. Geographic distribution of Phase 2 M&V sample



The evaluation analysts processed metered interval data to characterize the heat pump's heating and cooling outputs and operational patterns. Heat pump operation data was correlated with outside air temperatures over the metering period to determine the weather effects on heat pump operation. These correlations were extrapolated over a full year using typical weather data for the most proximate weather station in New York. To establish the baseline energy consumption, analysts considered pre-existing system types and operating conditions as well as applicable code-compliant alternatives. The difference in annual energy consumption between baseline and installed conditions constituted the evaluated savings and realization rate (RR).[6]

1.2 Results

Table 1-2 compares the program-reported savings, inclusive of all fuels including electricity in MMBtu at site, with evaluated savings for ASHP, GSHP, and overall. Results from evaluation Phase 1 and Phase 2 are presented to the right of the program-reported savings as verified gross savings (VGS).[7] Relative precision (RP) is a normalized measure of uncertainty that is standard in the industry. Because some RRs are relatively low in this study, they dramatically inflate the relative precision and appear to suggest a large amount of uncertainty. Table 1-2 includes the absolute precision (AP) as well, which shows the uncertainty in absolute terms as a percentage of a hypothetical 100% VGS realization rate.

Table 1-2. Comparison of program-reported and evaluated impacts by system type and by evaluation phase

			Phase 1 Billing Analysis Results				Phase 2 M&V Results			
Tech.	N	Gross (Program-Reported) Savings (MMBtu)	Verified Gross Savings (Site MMBtu)	VGS RR[1]	RP @ 90% CI[2]	AP 90% CI[3]	Verified Gross Savings (Site MMBtu)	VGS RR[1]	RP @ 90% CI[2]	AP @ 90% CI[3]
ASHP	4,045	228,373	62,024	27%	40%	11%	87,447	38%[4]	30%	12%
GSHP	470	42,858	21,787	51%	16%	8%	42,862	97%	16%	15%
State-wide	**4,515**	**271,231**	**83,811**	**31%**	**30%**	**9%**	**130,309**	**48%**	**21%**	**11%**

[1] Verified gross savings realization rate

[2] Relative precision at the 90% confidence interval

[3] Absolute precision at the 90% confidence interval

[4] For 15% of ASHP systems sampled for M&V, customers indicated they would have installed a HP regardless of the influence of the program. Due to complexities in establishing and discounting program influence, which extends beyond the rebate and may include factors such as a more developed contractor base and a more mature supply chain, evaluators calculated gross impacts for such projects by considering each site's most reasonable, code-compliant fossil fuel-fired system as baseline. Evaluators estimate that this baseline treatment increased the ASHP RR by 6%.

Phase 1 analysis of premise-level consumption data showed that the programs realized 31% of claimed MMBtu impacts, with GSHPs outperforming ASHPs with nearly twice as high a RR. Premise-level analysis provided preliminary results on at-the-meter impacts for a broader pool of HP installations (n = 220), accounting for baseline scenarios as informed by the web-based customer survey. But premise-level analysis was limited in explaining the drivers of savings differences and identifying opportunities to improve savings estimates.

[6] The realization rate is the ratio of evaluated savings to program-reported savings.

[7] Termed "evaluated gross savings" in prior New York evaluation reports, VGS represent the gross savings adjusted by the program administrators' most relevant savings factors (e.g., RRs), as reasonably supported by evaluation M&V.

Phase 2 M&V (n = 130[8]) produced granular, equipment-level performance data that demonstrated an overall MMBtu savings RR of 48%, with ASHPs realizing 38% of reported MMBtu savings and GSHPs realizing 97% of reported savings. The primary drivers of the low ASHP realization rate include:

- **Reduced heating operation** – Over the course of a typical year, program-rebated ASHPs provided 44% of the annual heating output assumed within program savings claims. Reduced runtime limited the ASHPs' opportunities for savings as compared with a less efficient and more carbon-intensive baseline. Differences in operation reduced the ASHP RR by 56%. By pairing Phase 2 M&V data with rated capacities by ASHP system, evaluators determined 565 annual equivalent full-load heating hours (EFLHH). As a point of comparison, NY TRM Version 9 recommends a range of EFLHH from 786 to 1,125 for whole-home heating systems depending on region and vintage.
- **Use of preexisting HVAC systems** – Relatedly, 71% of ASHP recipients reported continued use of preexisting HVAC systems, such as fossil fuel-fired boilers or furnaces. Customers that continued to use legacy heating systems achieved 40% lower MMBtu savings than those that removed the legacy systems.
- **Cooling savings** – The program did not claim cooling impacts from ASHP installations. However, evaluators determined that ASHPs led to a 4% increase in evaluated MMBtu savings, as 94% of rebated systems involved replacement of a less-efficient pre-existing cooling system or code-compliant alternative. Phase 2 M&V data showed that ASHPs provide cooling over 434 equivalent full-load cooling hours per year.
- **Near-rated efficiencies** – Through intensive M&V, evaluators determined that ASHPs achieved heating season performance factors (HSPFs) and seasonal energy efficiency ratios (SEERs) 3% and 6% lower than manufacturer ratings for heating and cooling season performance, respectively.
- **Baseline treatment** – For 15% of sampled ASHP systems, customers indicated they would have installed a HP regardless of program intervention. From a coefficient of performance (COP) perspective, HP-to-HP projects limit the amount of achievable savings, as high-efficiency HPs achieve only an incremental COP increase (less than 1 COP point), while fossil fuel-to-HP projects achieve a significantly higher increase of two or more COP points. Due to complexities with establishing the influence of the programs on accelerating the heat pump market in New York, evaluators calculated gross impacts for such projects by considering the most reasonable, code-compliant fossil fuel-fired system as baseline. Evaluators estimate that this baseline treatment increased the ASHP MMBtu RR by 6%.

Evaluators determined that GSHP systems achieved 3% less MMBtu savings than predicted by the program. The 97% GSHP RR was the result of several savings differences that generally offset one another:

- **Reduced heating operation** – GSHPs operate for 2,099 EFLHH, or 84% of the value assumed within the program's savings calculator. This difference reduced the GSHP RR by 16%.
- **Higher annual cooling output** – On the other hand, evaluators determined that GSHPs provide more cooling than assumed within program savings claims, increasing the GSHP RR by an estimated 2%.[9] Phase 2 M&V data showed that GSHPs provide 363 equivalent full-load cooling hours per year.
- **Higher efficiencies** – Through intensive M&V, evaluators determined that GSHPs operated at HSPFs and SEERs 13% and 8% better than manufacturer ratings for heating and cooling season performance, respectively.[10] [11]

[8] Phase 1 and Phase 2 samples partially overlapped. Of the 130 sites analyzed in Phase 2, 37 ASHP and 11 GSHP projects were also included in Phase 1. The evaluators initially explored "nesting" the Phase 2 sample within the Phase 1 pool of analyzed projects; however, difficulties in recruiting customers for Phase 2 M&V during the COVID-19 pandemic reduced the overlap between phases and eliminated the possibility of a nested sampling approach.

[9] Details were limited on the program's supporting assumptions for GSHP cooling savings claims. Evaluators back-calculated the presumed reported cooling savings from available tracking data and found that evaluated cooling savings more than doubled them on average. Nonetheless, GSHP cooling savings are comparatively minor when compared with heating savings—cooling savings comprised 2% of the total evaluated GSHP MMBtu savings per year.

[10] Notably, GSHPs ratings are not comprehensive of the whole heating or cooling season like traditional HSPF and SEER. Rather, manufacturer ratings reflect full-load performance at a specific test condition.

[11] The evaluated HSPF matched the program-assumed HSPF reflected in savings claims within 1%. Details on supporting cooling assumptions were unavailable.

- **Early replacement baselines** – Evaluators determined that approximately half of sampled GSHP projects were early replacements of operable equipment, and achieved first-year savings reflected the efficiency gain as compared with preexisting systems. The program savings claims, on the other hand, more often reflected a code-compliant baseline as a result of normal replacement installations. This difference in baseline treatment led to an estimated 18% increase in the GSHP RR.

Comparison of ASHP evaluation results by phase showed that the Phase 2 equipment-level results (MMBtu RR of 38%) outperformed the Phase 1 premise-level results (MMBtu RR of 27%). This difference is primarily due to the alternative baseline treatment discussed on the prior page. Phase 2 results for GSHPs (RR of 97%) significantly exceeded the Phase 1 premise-level result (RR of 51%). Two factors primarily contributed to differences in evaluated GSHP impacts by phase. First, GSHP projects are typically more complex and therefore more likely to involve nuanced baselines that are most accurately characterized through on-site M&V (as done in Phase 2) than a web-based customer survey (Phase 1).[12] Second, only 11 GSHP projects were assessed in both Phase 1 and Phase 2. Billing analysis attrition, difficulties in recruiting, and a relatively small GSHP recruitment pool limited the evaluators' ability to assess identical sites in both phases of study. The billing analysis pool included 72 more GSHP projects than the M&V sample.

1.2.1 Impacts by Fuel

Granular results from evaluation Phase 2 allowed evaluators to examine achieved system-level impacts by fuel, as illustrated in Figure 1-1 for sampled ASHPs. The figure presents evaluated and reported site MMBtu impacts by fuel, with beneficial electrification (i.e., added electric load) illustrated as the leftmost striped bar. MMBtu savings are illustrated by the striped orange (electric energy efficiency savings during heating operation), striped blue (electric savings during cooling operation), and solid bars (various displaced fossil fuels).

The programs applied identical savings assumptions for all ASHP installations in the evaluation population. One such assumption was that all participating facilities consumed #2 fuel oil as the primary heating fuel before ASHP installation. The figure illustrates that ASHP installations offset a broader diversity of fuels as compared with the programs' oil assumption. Additionally, the figure shows the relative contributions of electric savings and penalties between heating and cooling seasons, in contrast with the program's heating-only assumption.

The primary driver of the 38% ASHP MMBtu RR—lower operating hours than reflected within program deemed savings—is evident in the figure. The evaluated bars are noticeably shorter than the reported bars for both beneficial electrification and saved MMBtu.

[12] The on-site data collection form used by field engineers in Phase 2 included a battery of questions related to operability of preexisting HVAC systems, feasibility of their continued use, and the customers' preferred heating and cooling alternatives to HPs absent the influence of the program. These complex questions are more conducive to in-person interviews than a web-based survey and served to establish the baselines used in Phase 2 analysis. 14 GSHP systems in the Phase 2 sample resulted in fossil fuel-fired normal replacement baselines, which led to significantly higher efficiency gains as compared with ASHP baselines.

Figure 1-2. Evaluated vs. reported ASHP impacts by fuel

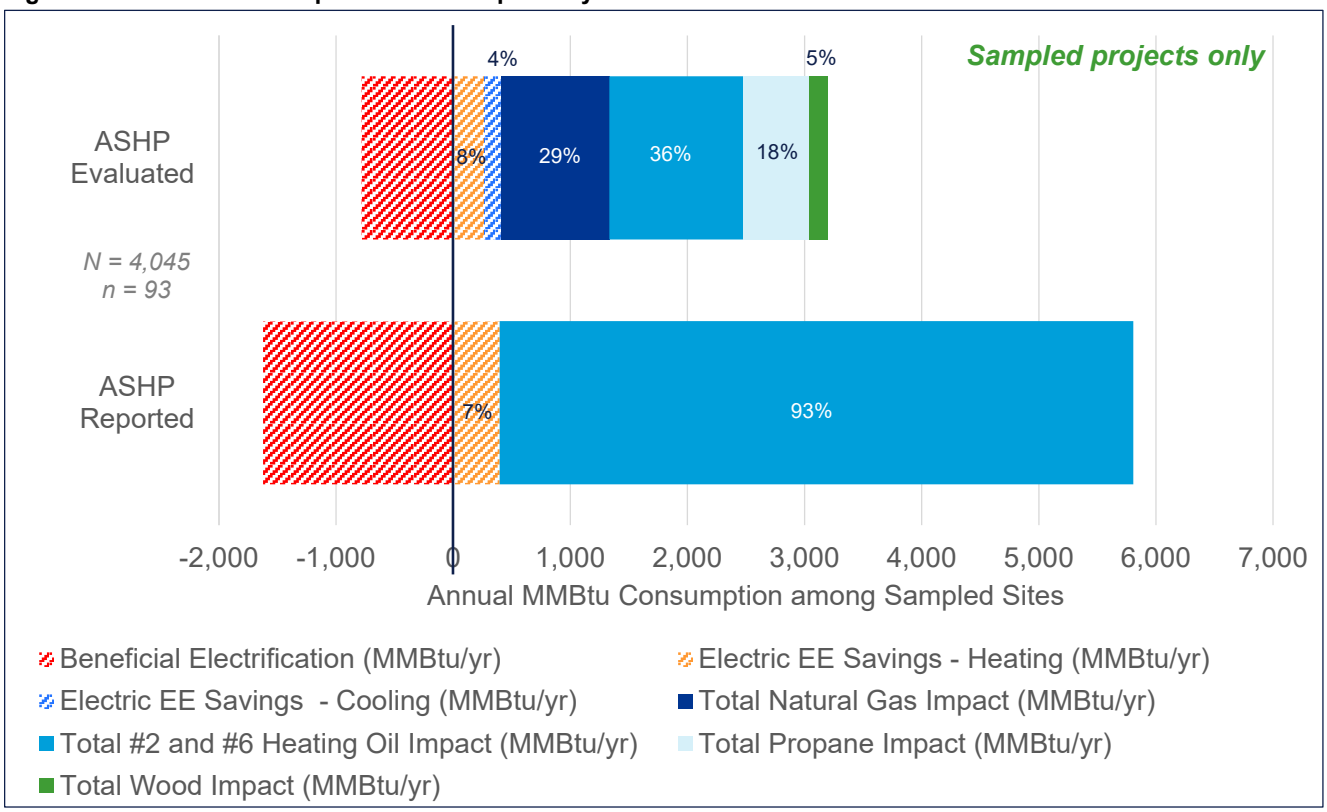
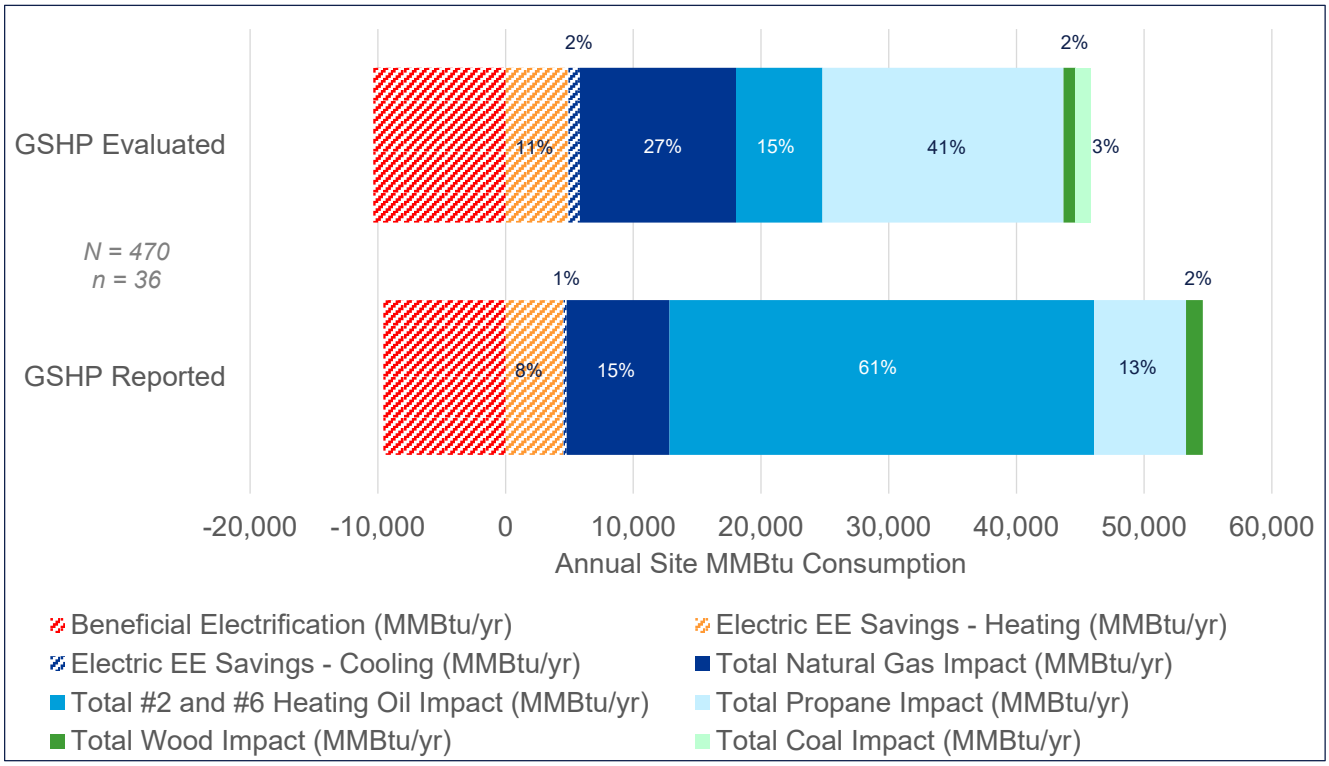


Figure 1-2 similarly illustrates the impacts by fuel for GSHP installations.[13] Unlike for ASHP, the programs claimed fossil fuel savings among natural gas, fuel oils, propane, and wood categories. This allowed evaluators to expand results by fuel from the sample to the full population of 470 GSHP projects. Overall, evaluators determined higher natural gas and propane savings, and lower fuel oil savings, than claimed by the programs.

[13] Despite the overall GSHP RR of 97%, the two bars appear unequal due to fuel-by-fuel differences in RRs and reported savings claims.

Figure 1-3. Evaluated vs. reported GSHP impacts by fuel



1.3 Conclusions and Recommendations

While the evaluated heat pump programs have been discontinued, the evaluation team has framed the below conclusions and recommendations wherever possible to be applicable to the Clean Heat programs currently administered by New York's joint electric utilities. This forward-looking context has been italicized to distinguish from recommendations specific to the evaluated NYSERDA programs.

Program Accomplishments

- **The evaluated programs led to energy savings and carbon emissions reductions.** The Underutilized Products, Heat Pumps and Solar Thermal, and Heat Pump Pilot Projects Demonstration programs led to significant MMBtu savings and offsets of fossil fuels, including 82,516 MMBtu of natural gas, 175,710 gallons of heating oil, and 283,870 gallons of propane. Overall, the realized energy savings offset approximately 7,801 tons of CO_2 from fossil fuels.
- **The programs accurately predicted MMBtu impacts from GSHPs.** Evaluated (Phase 2) MMBtu savings for GSHPs correlated with program-reported savings claims within 3%. The programs' customized savings claims, which were based on contractor building heating load estimates and site-specific information on preexisting heating fuel, were generally accurate.
- **The rebated heat pumps performed near rated efficiencies.** Overall, ASHPs performed closely to rated efficiencies, achieving a weighted average heating seasonal performance factor (HSPF) of 11.34. This efficiency value means that, for every 4 Btu required by a code-compliant fossil fuel-fired system to heat a given space, the ASHP can heat the same space with 1 Btu. Evaluated GSHP heating performance exceeded manufacturer ratings by 13% due to higher measured groundwater temperatures than assumed in design conditions. During the cooling season, ASHPs and GSHPs operated within 6% and 8% of rated SEER and EER, respectively.

- **Installed heat pumps led to cooling savings when compared with baseline systems.** Approximately half of 137 customers sampled for M&V did not have cooling systems before the heat pump installation. But 90% of those customers indicated they would have installed a mechanical cooling system if they had not participated in the program. Evaluated cooling savings increased the ASHP and GSHP RRs by 4% and 2%, respectively.
- **The programs engaged contractors to act as heat pump allies.** The heat pump installers engaged in the program appear to be strong allies in the pursuit of greater adoption of heat pump technologies. Many only install heat pumps, and all are equipped to recommend them depending on conditions experienced in the field.
- **The rebated heat pumps function properly.** 89% of surveyed customers did not report any operational or maintenance issues with heat pumps. The remaining 11% reported various issues ranging from outdoor unit vibrations to misunderstanding the system control panel.

Key Evaluation Findings

- **Billing analysis results underestimated the M&V results for ASHPs.** The ASHP MMBtu savings RR from 97 measurement and verification deployments (evaluation Phase 2) was 11% higher than the RR determined from premise-level consumption data analysis of 128 ASHP projects (evaluation Phase 1). The difference is primarily attributable to the Phase 2 baseline treatment that more frequently defaulted to fossil fuel alternatives. Aligning the baseline treatment between the two phases would have reduced the Phase 2 MMBtu RR to 32%, indicating reasonable prediction from premise-level analysis.
- **Phase 2 evaluated savings significantly exceeded Phase 1 savings for GSHPs.** On the other hand, for GSHPs, M&V results demonstrated 44% higher MMBtu savings as compared with premise-level consumption analysis. Evaluators primarily attribute this difference to revised baselines in Phase 2 as a result of more comprehensive in-person interviews with customers during site visits.
- **Evaluated savings correlate with pre-existing system type and use.** Phase 1 and Phase 2 results demonstrated that savings are most realized when heat pumps are used as the primary heating equipment. Customers that no longer use pre-existing heating equipment achieved a 40% higher RR than customers continuing to use legacy systems.
- **Evaluated savings correlate with climate zone.** ASHP projects performed significantly better in upstate climate zones 5 and 6 as compared with downstate climate zone 4. Evaluators found that downstate ASHPs operated for fewer heating hours than upstate systems for two primary reasons: 1) higher likelihood of downstate customers using pre-existing heating systems, and 2) smaller conditioned square footage. Heating degree days for downstate customers are lower than for upstate customers, but weather was not as significant a factor as partial displacement frequency, customer usage patterns, and unit oversizing. GSHP projects in climate zone 5 achieved higher MMBtu savings than those in climate zone 6 by 43%.
- **Customers are adding cooling comfort to their lifestyle.** The Phase 1 web survey observed that 25% of spaces with a program heat pump installed were adding cooling to previously uncooled space.[14] For the 75% installed in spaces previously cooled with some type of compressor-based system, nearly four in every ten respondents in this study reported that they had decreased their cooling setpoint from the previous system, and the decrease was significant: an average of approximately 6 degrees. This change in temperature is a significant addition of cooling comfort that could reduce energy savings at the meter. Evaluation analysis models presume that setpoint adjustments would have been made to the baseline alternative system as well.

[14] The Phase 2 M&V sample showed a higher share of such customers with at least one *system* that cooled a previously uncooled space.

Opportunities to Improve Savings Estimates

- **Evaluated ASHP savings fell short of program-reported estimates.** Program-rebated ASHP installations led to 62% lower evaluated MMBtu savings compared to program-reported values. The key contributors to the 38% RR for ASHPs are summarized in bullets below.
- **Installed heat pumps provide less heating than assumed by the programs.** The primary driver of the ASHP RR is 56% lower annual heating output than assumed within program savings claims. Phase 2 metered data, extrapolated over a full year and correlated with installed equipment capacities, led to 565 average annual full-load heating hours across the ASHP population of projects, of which over 99% involved DMSHPs. While the body of heat pump evaluation research is rapidly growing, other DMSHP studies in the Northeast have shown similar findings of approximately 450 annual full-load heating hours.[15] In the context of the current New York TRM heat pump savings algorithm, evaluated ASHP projects demonstrated a sizing ratio of approximately 0.3 on average as compared to a typical whole-home heating load. For GSHPs, evaluators determined weighted average FLHs of 2,325 (per installed capacity) or 2,099 (per tracked Manual J building heating load), whereas the program's savings calculator featured FLHs ranging from 2,230 to 2,604.
- **Contractors use sizing tools, but there is room for improvement.** Rightsizing is a point of emphasis in New York's energy code and heat pump programs. Rightsizing maximizes savings. Installers were found to use fairly standard means of sizing, usually Manual J (63%, including three of the four largest contractors) or manufacturer/industry tools (17%). Others rely on experience, pre-existing equipment size, or other tools. This leaves room for improvements, which could be a point of emphasis in contractor engagement.
- **A single deemed savings value is not appropriate for heat pump installations.** With ASHPs encompassing 90% of the evaluation population, their results had significant impacts on the program-level VGS realization rates. The programs assumed a single deemed savings value per outdoor unit for all ASHP installations, not accounting for unit size, baseline, displacement share, or climate. The programs' ASHP savings claims reflected oil offsets based on whole-home NEEP research, derated to account for displacement vs. replacement projects and an assumed 25% share of electric-to-HP projects. When the participant population consistently deviates from deemed assumptions, such as this program's high proportion of downstate installations and their lower annual heating loads, use of a deemed value contributes to significant variability in evaluation results.
    - **Recommendation:** Reflecting the above four conclusions, ASHP savings claims should be based on site-specific baseline fuel, system type if electric, unit size, location, and expected load displacement relative to size. This study's DMSHP results suggest a default displacement factor of 0.3 relative to total building heating load. The current version of the New York TRM[16] provides detailed guidance on estimating heating and cooling loads for partial- and full-displacement installations. Use of either a quasi-prescriptive calculator, or deemed savings options based on displacement fraction, would markedly improve savings estimates. Crucial to the success of this recommendation is contractor training and oversight to ensure that installed systems are right-sized and credibly characterized based on the portions of heating and cooling loads to be satisfied by the heat pumps. *Based on the evaluators' review of its program manual, the Clean Heat Program requires administering utilities to abide by the current New York TRM. When an installation is not covered by a prescribed measure in the TRM, the program requires a custom track.* [17]

[15] Massachusetts and Rhode Island Electric and Gas Program Administrators. 2016. "Ductless Mini-Split Heat Pump Impact Evaluation." <http://www.ripuc.ri.gov/eventsactions/docket/4755-TRM-DMSHP%20Evaluation%20Report%2012-30-2016.pdf>

[16] New York State Joint Utilities, "New York TRM Version 9," effective January 2022. https://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/72c23decff52920a85257f1100671bdd/$FILE/NYS%20TRM%20V9.pdf

[17] New York State Joint Utilities, "NYS Clean Heat Statewide Heat Pump Program Manual Version 5," October 2021. https://saveenergy.ny.gov/NYScleanheat/assets/pdf/NYS-Clean-Heat-Program-Manual.pdf

- **Quantifying evaluated impacts by fuel proved difficult.** For all ASHP installations, the programs claimed all fossil fuel savings as oil, limiting the evaluators' ability to expand evaluation results from the sample to the population of projects. Among 86 ASHP projects in the evaluation sample, we found that program-rebated installations led to a diversity of savings by fuel, including natural gas (comprising 29% of total MMBtu savings across all fuels), fuel oils (36%), propane (18%), and wood (5%). For GSHP installations, the program claimed a broader diversity of fuel-specific savings, though evaluators determined higher shares of natural gas and propane, and lower shares of fuel oils, than claimed.
    - **Recommendation:** Heat pump savings claims should distinguish among different displaced heating fuels as documented by the installation contractor. Fuel-specific impacts are critical for measuring program success versus statewide carbon emissions reduction goals. A single installation might displace more than one heating fuel; therefore, approved contractors should be trained to collect defensible information on pre-existing heating fuel types and shares. When feasible, utility-led programs should leverage historical natural gas consumption data at the participant address to corroborate the tracked estimates for pre-existing natural gas systems.
- **A minority of participating customers would have installed heat pumps regardless of the program.** For 15% of rebated ASHPs, customers indicated via in-person interviews that they would have installed heat pumps regardless of program intervention. Heat pump baselines reduce the achievable savings significantly, as heat pumps can satisfy heating loads much more efficiently than fossil fuel- or resistance-based systems. Due to complexities with establishing the influence of the programs on accelerating the heat pump market in New York, evaluators calculated gross impacts for such ASHP projects by considering the most reasonable, code-compliant fossil fuel-fired system as baseline. Evaluators acknowledge that these predecessor heat pump programs likely included early adopter participants whose decision-making might not be representative of future heat pump program participants.
    - **Recommendation:** For heat pump installations in new construction or end-of-life scenarios, savings should be informed by the customers' preferred alternative systems and fuel choices in the absence of the program. While accounting for program influence will continue to be a challenge, evaluators recommend that future heat pump installations comport with the guidance in the active New York TRM.[18] Eligible Program tracking databases should intake relevant site-specific variables and triangulate the most appropriate baseline against which new construction or end-of-life performance is measured.
- **Evaluators observed a small share of GSHP-to-GSHP installations.** During the evaluation planning process, evaluators identified that an additional 20 GSHP installations in the population involved replacement of existing GSHP systems. These projects were removed from the evaluation sampling frame. The New York TRM currently does not accommodate a GSHP baseline.[19]
    - **Recommendation:** GSHP-to-GSHP replacements should be considered as a prescribed scenario by the New York TRM Committee, as the team expects this to become more common as first generation GSHPs begin to reach their effective useful life. *The Clean Heat Program does not appear to accommodate such a baseline, though new construction GSHP projects are required to be submitted through a custom track.*

[18] NY TRM Version 9, active at the time of this writing and referenced below, states that "The baselines used in [the ASHP] measure are determined by the type of equipment that would have been installed without the influence of the program supporting the installation of this measure."

[19] New York State Joint Utilities, "New York TRM Version 9," effective January 2022. https://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/72c23decff52920a85257f1100671bdd/$FILE/NYS%20TRM%20V9.pdf

- **A majority of participants continued to use pre-existing HVAC systems.** The Phase 1 web survey found that approximately 75% of program participants continued to use pre-existing heating and cooling systems after heat pump installation. These partial displacement scenarios reduce the achievable savings as demonstrated by lower-than-expected outputs and full-load hours as described above.
    - **Recommendation:** Program administrators should consider a tiered incentive approach that rewards full-displacement installations. Training and requiring approved contractors to credibly collect and track this information is crucial to the success of this recommendation.
    - **Recommendation:** Programs should reward partial-displacement installations that include integrated controls that manage heat pump use with legacy systems. There may be limitations to the ability of controls on older pre-existing systems that will need to be acknowledged in such an effort. *Based on the evaluators' review of its program manual, the Clean Heat Program has established nine installation categories with varying incentive structures and eligibility criteria that distinguish among system types, partial- and full-displacement installations, and inclusion of integrated controls.*[20]
    - **Recommendation:** Programs should educate eligible contractors and participating customers on the best practices for optimal heat pump usage, particularly for installations that supplement existing heating systems. Heat pump adoption and savings potential rely heavily on customer awareness of heat pump benefits and their ability to satisfy heat loads during extreme winter temperatures. *The Clean Heat Program manual recommends continuous contractor training, and its website includes a list of educational resources for participating contractors.*[21] *It is unclear if or how the program administrators ensure that contractors review such resources.*

COVID Implications

- **COVID has led to higher energy usage per customer.** Total customer-level energy usage increased by 6.5 MMBtu or 8% between the COVID period (post-March 2020) and pre-COVID periods (pre-March 2020). The disaggregated energy usage shows that the increase in total usage comes from increases in heating (4.9 MMBtu or 12% increase in heating load) and base load (1.9 MMBtu or 5% increase in base load). The cooling load oddly decreased during the COVID period (-0.3 MMBtu or 12% decrease in cooling load). As the change in cooling load represented less than 1% of the total energy usage, monthly billing analysis may not be sensitive enough to detect these smaller changes in cooling load.

  Relatedly, participants indicated similar occupancy behavior across weekdays and weekends during the COVID period, spending more than 21 hours per day in their homes. This represents an increase of 3 hours per day for weekdays and 1.3 hours per day over weekends indoors as compared to the pre-COVID period. This behavioral change of staying indoors more increases the amount of occupancy hours for a home, and primarily leads to driving up base load usage in terms of increased plug-in appliance and lighting loads.
- **Most customers have not adjusted their comfort preferences during COVID.** More than 75% of participants indicated they had no change in the temperature setting during the heating or cooling seasons. For those who did change temperature settings, there was an average increase of 0.1°F (warmer) in temperature setpoint in the heating season and an average decrease of 0.2°F (cooler) in temperature set point during the cooling season. Participants who increased their heating setpoint saw a direct correlation in an increase in their heating load (3.6 MMBtu or 14% increase in heating load).

[20] New York State Joint Utilities, "NYS Clean Heat Statewide Heat Pump Program Manual Version 5," October 2021. https://saveenergy.ny.gov/NYScleanheat/assets/pdf/NYS-Clean-Heat-Program-Manual.pdf

[21] https://saveenergy.ny.gov/NYScleanheat/resources/