CT R1965 HP/HPWH Baseline and Market Characterization & R2027 HP/HPWH Reliability

REPORT: REVIEW DRAFT

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SUBMITTED TO:
Connecticut Energy Efficiency Board

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Acronyms

Acronym	Meaning
AC	Air Conditioning
AFUE	Annual Fuel Utilization Efficiency
ASHP	Central, ducted Air-Source Heat Pump
BTU	British Thermal Unit
C&LM Plan	Conservation and Load Management Plan
CAC	Central Air Conditioner
Companies	The Connecticut investor-owned utilities that administer the Energize Connecticut / EnergizeCT programs (Eversource and the Avangrid companies, including the United Illuminating Company [UI], Connecticut Natural Gas Company [CNG], and Southern Connecticut Gas Company [SCG])
CFA	Conditioned Floor Area
COP	Coefficient of Performance
DHW	Domestic Hot Water
EA Team	Connecticut Energy Efficiency Board's Evaluation Administrator Team (Lisa Skumatz, Bob Wirtshafter, and Ralph Prahl)
EER	Energy Efficiency Ratio
EF	Energy Factor, a measure of water heater efficiency
GSHP	Ground Source Heat Pump
HARDI	Heating, Air conditioning, and Refrigeration Distributors International
HPWH	Heat Pump Water Heater
HSPF	Heating Season Performance Factor, a measure of the heating efficiency of a heat pump
HVAC	Heating Ventilation and Air Conditioning
HVAC heat pumps	Heat pump systems providing space conditioning (i.e., MSHP, ASHP, and GSHP)
kWh	Kilowatt Hour
MSHP	Mini or Multi-Split Heat Pump, commonly referred to as a ductless mini-split heat pump, or DMSHP
MWh	Megawatt Hour
NMR	NMR Group, Inc.
PSD	Program Savings Document
Repair	Work done to fix an issue with the [heat pump] system, an indication of an actual problem
RNC	Residential New Construction
SEER	Seasonal Energy Efficiency Ratio, a measure of cooling efficiency
Service	Regular preventative maintenance or a tune-up – work done to keep the system running smoothly, not in response to a problem
UEF	Uniform Energy Factor, a measure of water heater efficiency; an update from EF

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Executive Summary

This study, conducted for the Connecticut Evaluation Administrator (EA) Team, used primary and secondary data collection to characterize the Connecticut heat pump and heat pump water heater markets. The study describes market trends for mini-split heat pumps (MSHPs), air source heat pumps (ASHPs), ground source heat pumps (GSHPs), and heat pump water heaters (HPWHs).

Study Objectives

The study had several primary objectives:

- **Market size:** Quantify the number of units sold by heat pump type, configuration, and efficiency, including the portion incentivized by the program.
- **Trade ally perspectives:** Solicit market actor feedback to understand attitudes towards heat pumps, recommendation factors, stocking practices, and consumer interest.
- **Configurations:** Describe likely system configurations, including ducted vs. ductless, supplemental vs. whole home, pre-existing conditions, installation challenges, and baseline scenarios that describe what customers might have installed instead of their heat pumps.
- **Reliability and satisfaction:** Solicit end user feedback to understand the prevalence of repairs and service for heat pumps, satisfaction levels, and adoption barriers.
- **Customer cost-effectiveness:** Identify cost-effective heat pump installation configurations from the participant perspective to develop recommendations and inform program planning.

Main Takeaways

The Connecticut market is poised to take off with continued program intervention.

Market actors are generally interested in and comfortable with heat pump technologies, with some gaps that can be overcome.

Heat pump users reported high levels of reliability and satisfaction with them.

Connecticut has underperformed in terms of sales volume compared to neighboring states.

There are opportunities in Connecticut to boost heat pump usage and installation rates.

Program Recommendations

CHANGE PROGRAM DESIGN TO FOCUS ON BOTH SALES AND USAGE OF HEAT PUMPS.

Installers with heat pump experience and end-users reported heat pumps are usually installed as supplemental systems rather than as whole home systems that fully displace primary systems, i.e., systems that people describe as meeting or providing most of their heating and/or cooling needs. The current program design incentivizes installations in general but could also encourage heat pumps as primary heating systems, as only a small percentage of end users indicated they used their heat pumps strictly for cooling. This change may require increasing customer and contractor confidence in their ability to heat throughout winter months.

Suggested approaches to achieve recommendation:

- Encourage the use of integrated controls with backup systems.
- Increase incentives for the highest efficiency systems and emerging technologies such as GSHP or air-to-water heat pumps.
- Provide additional incentives or support for heat pumps that meet NEEP's cold climate standards.
- Encourage pairing heat pumps with solar to mitigate increased electric costs.

INCLUDE DELIVERED FUELS IN BASELINE SCENARIOS.

The Program Savings Document (PSD) uses a standard efficiency heat pump as the baseline for program installed MSHP/ASHP in fossil fuel homes. This is not always the appropriate baseline: only 9% of the end-users who heated with fossil fuels prior to installing a heat pump appear to have had a baseline that would have just been a less expensive heat pump. In fact, of all respondents, nearly half of all end-users reported that they would have purchased the exact same heat pump even without incentives.

Suggested approaches to achieve recommendation:

- Section 2.5.9 of DEEP approval of the 2021 C&LM plan update on 3/4/2021 makes clear that given increased focus on delivered fuel savings, utilities can calculate savings with a baseline that "reflects a fuel type that would have been chosen, absent incentives." This approval condition presents an opportunity to revise the current PSD entries to better reflect the true impacts of heat pumps by incorporating fuel switching and supplemental configurations, as those are common. This study confirms results from R1617 (Connecticut Residential DHP Market Characterization Study, 2019), which provided three approaches this new entry might take.

INCREASE TECHNICAL AND SALES EXPERTISE OF INSTALLERS AND DISTRIBUTORS.

Increasing installer comfort and familiarity with heat pumps should lead to more recommendations, more sales, and – based on end-user feedback to date – more satisfied customers. Customers reported high satisfaction with heat pumps, but there is some hesitancy to recommend it to certain customers: 70% of heat pump installers recommended MSHPs to customers looking for a *supplemental* system, but only 42% recommended them to *replace* a system, for example. For some contractors, there appears to be a hesitancy to recommend heat pumps particularly without a backup heating source. Some of the hesitancy may be caused by a knowledge gap that could be addressed with training. Of course, others might not recommend a heat pump in some circumstances because in their experience, heat pumps would not perform optimally or cost-effectively for the customer. Regardless, more than one-half of customers agreed to install a heat pump when it was recommended by an installer, indicating they rely on their installers' expertise and the installers' opinions substantially impact outcomes.

Suggested approaches to achieve recommendation:

- Study the real-world performance of heat pumps in Connecticut. Such research could help identify the extent to which market actor concerns are based on real or perceived system limitations, and how the program could address any limitations. This may require gathering information on shell measures and customer behavior, to identify correlations between system and shell performance and help identify cost-effective opportunities for combining electrification and weatherization measures.
- Offer webinars and trainings focused on heat pump technologies and sales techniques, including the benefits of different system types, the performance and limited incremental cost of cold climate models, and addressing difficult HPWH installation scenarios.
- Offer free or heavily discounted equipment along with weatherization services to key installers and distributors for their own homes, providing first-hand experience to encourage recommendations (similar to the NEEA Pro Deal program).[1]
- Push manufacturers to provide support to hesitant contractors and distributors.

INCREASE PROGRAM SUPPORT AND RESOURCES TO PARTICIPATING DISTRIBUTORS. Some distributors reported that compared to a downstream rebate program, the midstream program in Connecticut increases their administrative burden, which could dissuade distributors from pushing program heat pumps and lead to data quality issues. Some specific issues reported include a lack of clarity on qualifying equipment, slow communication with the program, and additional resources allocated to handling rebate applications.

Suggested approaches to achieve recommendation:

- Ensure distributor questions are addressed by program staff in a timely manner.

1 https://www.energystar.gov/sites/default/files/asset/document/2%20Jill%20Reynolds%20Warming%20Up%20to%20HPWHs_508.pdf

- Conduct outreach with participant distributors through email and phone to let them know program staff is available, alert them to new program offerings, and provide an opportunity for feedback.
- Identify and conduct outreach to any non-participant HVAC and water heating distributors that operate within the service territory.
- Provide a list of qualifying products to avoid burdening distributors to match a product to program efficiency requirements.
- Develop an app or web portal to facilitate an easy-to-use rebate application system that scans and determines qualifying equipment eligibility, collects equipment level data for program tracking, and tracks/processes incentive reimbursements

WORK WITH DISTRIBUTORS AND RETAILERS TO STOCK HPWHS FOR SAME DAY REPLACEMENT.

The water heater market is largely replace-on-failure and customers are likely to do like-for-like replacements, particularly when installers recommend the customer continue with the same type of system. HPWHs need to be a more viable option for emergency replacements.

Suggested approaches to achieve recommendation:

- Provide an incentive or other support to distributors to ensure HPWHs are available for same day replacement.
- Provide an incentive or other support to retailers to stock and prominently display HPWHs and remove electric resistance water heaters from shelves.
- Work with retailers to ensure that call centers facilitating water heater installations through retail stores recommend HPWHs over electric resistance tanks.
- Reconsider current lower incentive levels for large HPWHs (>55 gallons) relative to smaller units. Sales rely on incentives and contractors can find non-heat pump workarounds for customers who need large tanks, despite federal minimum efficiency standards for large electric water heaters.
- Monitor availability of emerging 120V “plug-in” HPWHs that can be easily installed in some applications with limited or no electrical upgrades. These may be ideal for many customers with fossil-fuel water heaters.

IMPROVE PROGRAM TRACKING DATA QUALITY.

The data request process for this study was long and difficult and the data was of mixed quality and challenging to piece together. Improving data tracking and storage would lead to more fruitful and accurate evaluation in an area of growing importance.

Suggested approaches to achieve recommendation:

- Assign a unique placeholder for account numbers that match across programs.
- Track itemized labor vs. equipment costs for system installations and end-user data as much as possible.
- Establish program tracking data quality control measures to ensure accuracy of program counts and eliminate the potential of overcounting.

FURTHER INVESTIGATE OPPORTUNITIES TO REFINE THE PROGRAMS AND TRACK MARKET PROGRESS.

The findings of this study describe the Connecticut market and opportunities. Developing a clear market transformation approach may help drive the market toward these high-performance systems. Regular process evaluations can help ensure the programs are operating as designed. Regional coordination of programs and evaluation may also ensure that programs operate consistently in the Northeast and learn from other states' successes.

Suggested approaches to achieve recommendation:

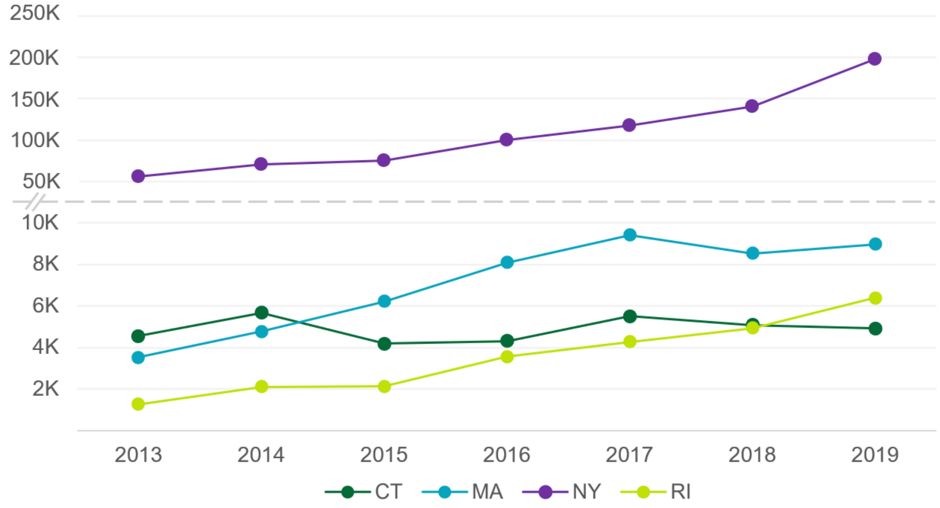
- Conduct a process evaluation for key HP/HPWH program elements.
- Consider a market transformation approach to affecting the market, tracking market progress indicators to ensure program activities lead to desired market outcomes, including building sufficient supply and demand.
- Consider a regional assessment of heat pump markets or programs to build a cohesive Northeast market.
- Consider the benefits and challenges of different program delivery methods (midstream vs. downstream) as part of process evaluation.
- In future HVAC/DHW evaluations, consider reliability/satisfaction assessments to compare against heat pump findings.

Key Findings

LANDSCAPE OF THE MSHP MARKET IN CONNECTICUT

- The overall Connecticut heat pump market has been relatively flat between 2013 and 2019. Most of the installed heat pumps are MSHPs (Figure 1~~Figure 1~~).

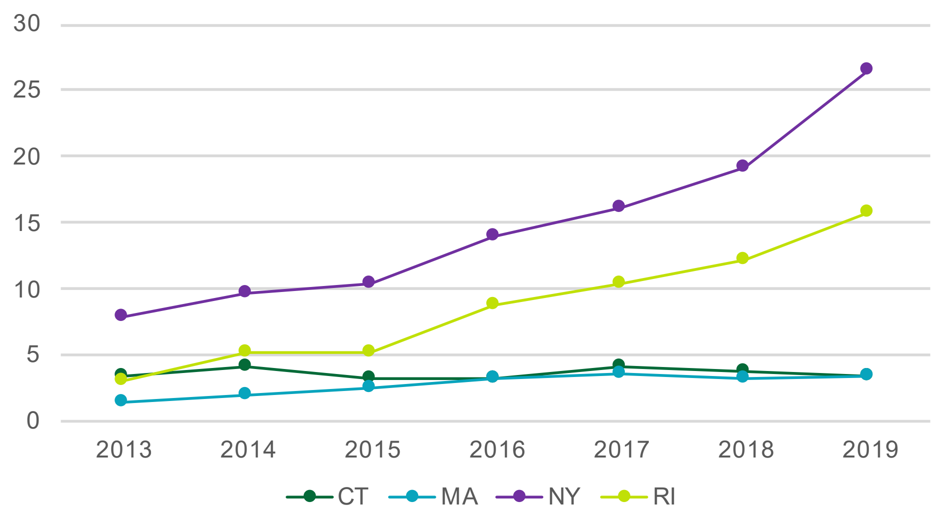
Figure 1: Regional Annual MSHP System Sales (2013-2019), HARDI*



*New York figures not to scale, given substantially larger market.

- While MSHPS installations in Connecticut remained flat from 2013 to 2019, they increased on a per household basis by approximately 140% in Massachusetts, 240% in New York, and 410% in Rhode Island (Figure 2~~Figure 2~~). On a per household basis, installations were higher in Connecticut in 2013 than they were in Massachusetts, but Massachusetts caught up by 2019; both markets saw about 3.5 MSHP installations per 1,000 households that year.

Figure 2: MSHP Unit Sales per 1,000 Housing Units



- Neighboring states saw growth between 2013 and 2019.
- The average MSHP cooling and heating efficiency in Connecticut increased from 2013 to 2019 but was the lowest in the region in 2019.
- MSHPs installed in Connecticut have evolved from single-zone air conditioners to multi-zone heating and cooling solutions, even if they are usually installed as supplemental systems.
- By 2019, 93% of MSHP installations received EnergizeCT incentives.
- MSHPs are most commonly installed as supplemental systems even though multi-zone systems increased in popularity from 2017 to 2019.

Landscape of the ASHP Market in Connecticut

- ASHP sales have remained flat in Connecticut, while surrounding states saw growth from 2013 to 2019 (Figure 3~~Figure 3~~).

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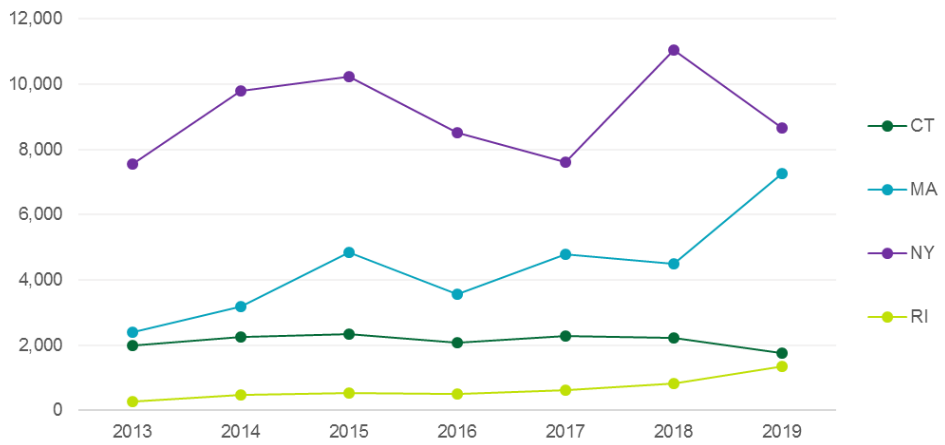
Figure 3: Regional Annual ASHP System Sales (2013-2019), HARDI



- The average ASHP cooling and heating efficiency in Connecticut increased from 2013 to 2019 but was lower than in surrounding states nearly every year.
- Program impact on the ASHP market was minor.

Installation Scenarios for MSHPs and ASHPs

- More of these heat pumps are installed in existing homes than new homes, but they are more likely to be primary systems in new homes.
- MSHPS and ASHPs are commonly installed in oil and electric resistance homes, and they typically do not entirely displace the pre-existing fuel (Figure 4~~Figure 4~~).

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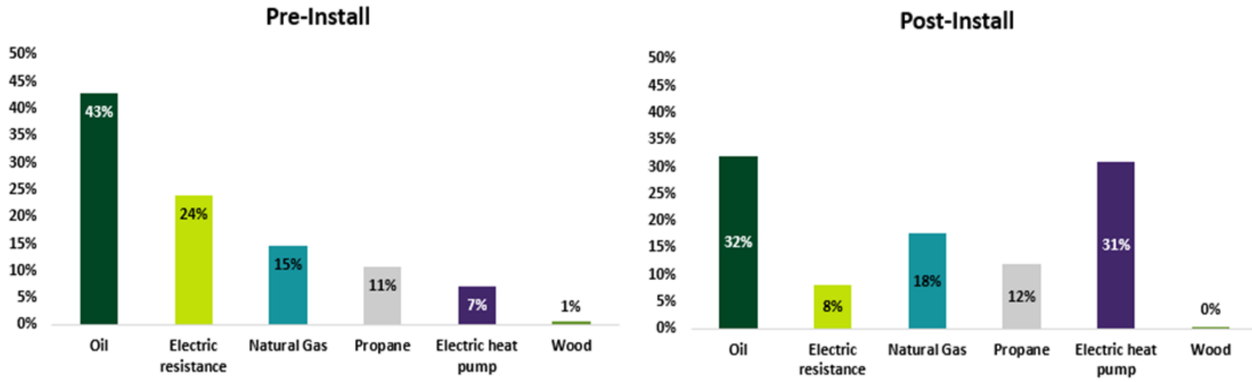
Figure 4: Primary Heating Fuel Before and After MSHP or ASHP Install (Installers)

(Source: installer survey; n= 53)



- Free-ridership appears to be high for HVAC heat pumps generally, including MSHPs, ASHPs, and GSHPs.
- The incremental cost for a cold-climate heat pump is consistent between ASHPs and MSHPs, but cold-climate MSHPs are much more common.

Landscape of the GSHP Market in Connecticut

- The GSHP market in Connecticut is small and potentially contracting. Any growth would primarily be in new construction.
- GSHP program activity is limited and trended down between 2017 and 2019, though a slight increase of GSHPs installed in RNC program participant homes was observed during the same period.
- Installers often buy GSHPs directly from manufacturers, as distributors may not carry or do not specialize in these low-volume systems.

Landscape of the HPWH Market in Connecticut

- Market size estimates and market actor feedback indicate that the HPWH market has been flat in Connecticut in recent years.
- Installers reported that over three-fourths of HPWH installations occur in homes where the water heater has failed or is close to failure.
- The HPWH market is highly dependent on program incentives.
- Most HPWHs in existing homes replace electric resistance and oil-fired water heaters.
- Free-ridership for HPWHs exists at lower rates than for MSHPs.

Installer Attitudes: HVAC Heat Pumps and HPWHs

- Installers with heat pump experience reported that HVAC heat pumps are available and reliable. These installers know how to install them, and customers ask for them. With the help of the Energize Connecticut programs, they expect to sell more of them. This indicates a strong market outlook for heat pumps in Connecticut (Figure 5~~Figure 5~~).

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- Installers also described a strong future for HPWHs, as they are available (including for emergency replacements) and reliable (Figure 6~~Figure 6~~).
- These installers also frequently recommend heat pumps and their customers accept their recommendations most of the time (Table 1~~Table 1~~).

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Figure 5: Installer Attitudes Toward HVAC Heat Pumps

(Source: installer survey; n=51)

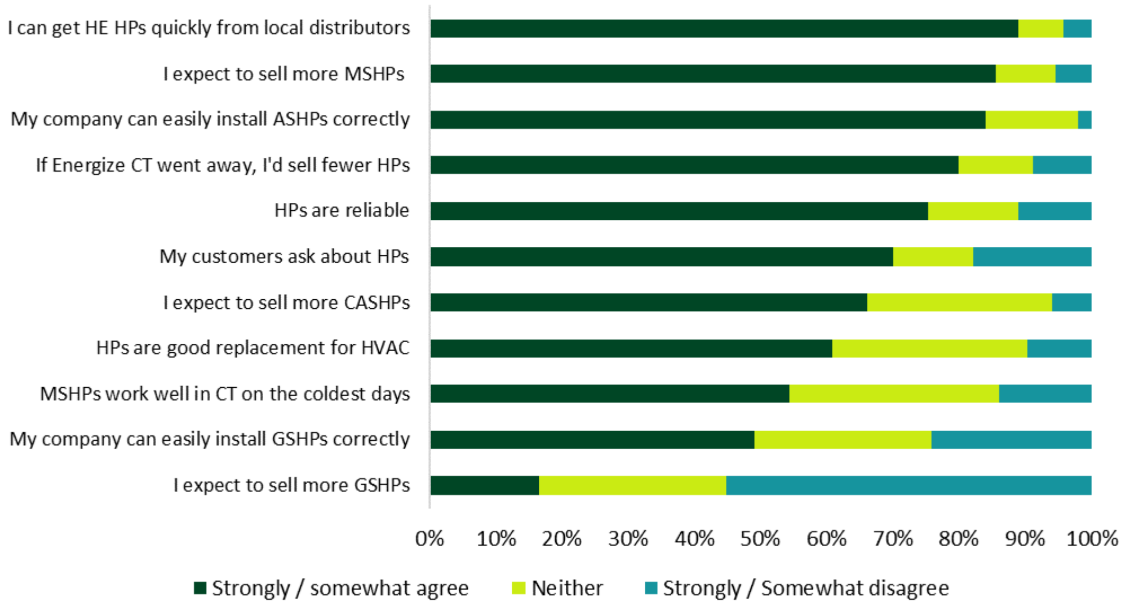

Figure 6: Installer Attitudes Toward HPWHs

(Source: installer survey; n=41)

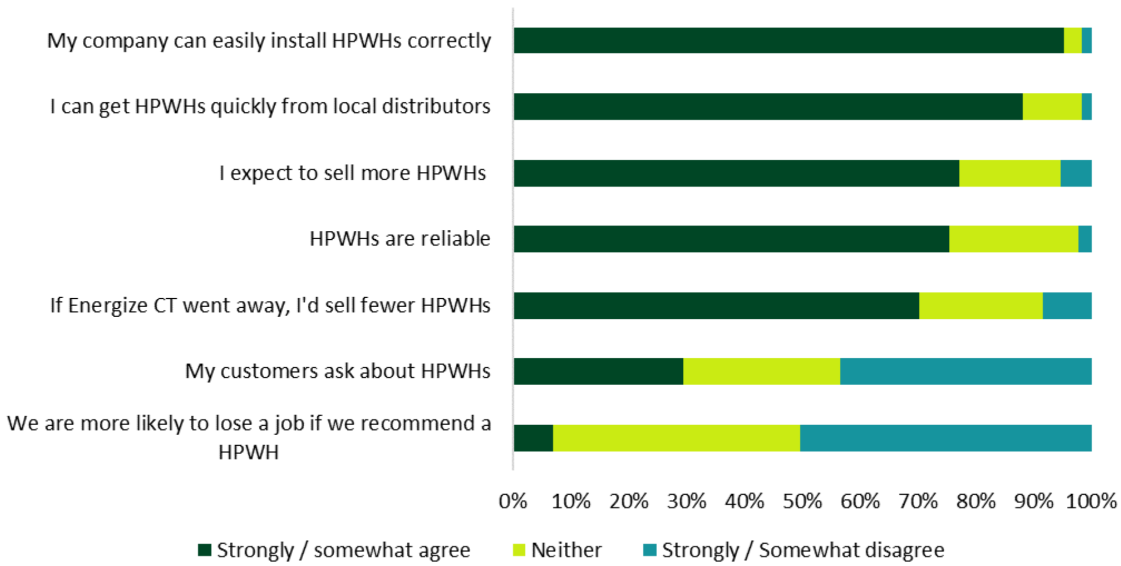

Table 1: Installers' MSHP and ASHP Recommendation Rates by Customer Type

(Source: installer survey; n=51)

Customer Type	MSHP	ASHP
Customers installing an additional heating or cooling system in an existing home	70%	58%
Customers replacing a cooling system in an existing home	54%	46%
Customers replacing a heating system in an existing home	42%	43%
Builder, contractor, or developer for new construction	37%	38%
Frequency that customers install based on recommendation	**63%**	**53%**

Satisfaction and Reliability: HVAC Heat Pumps and HPWHs

- HVAC heat pump and HPWH users reported high levels of reliability and satisfaction with their equipment (Figure 7~~Figure 7~~ and Figure 8~~Figure 8~~).

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Figure 7: End User Satisfaction with HVAC Heat Pumps

(Source: end user survey; n=188)

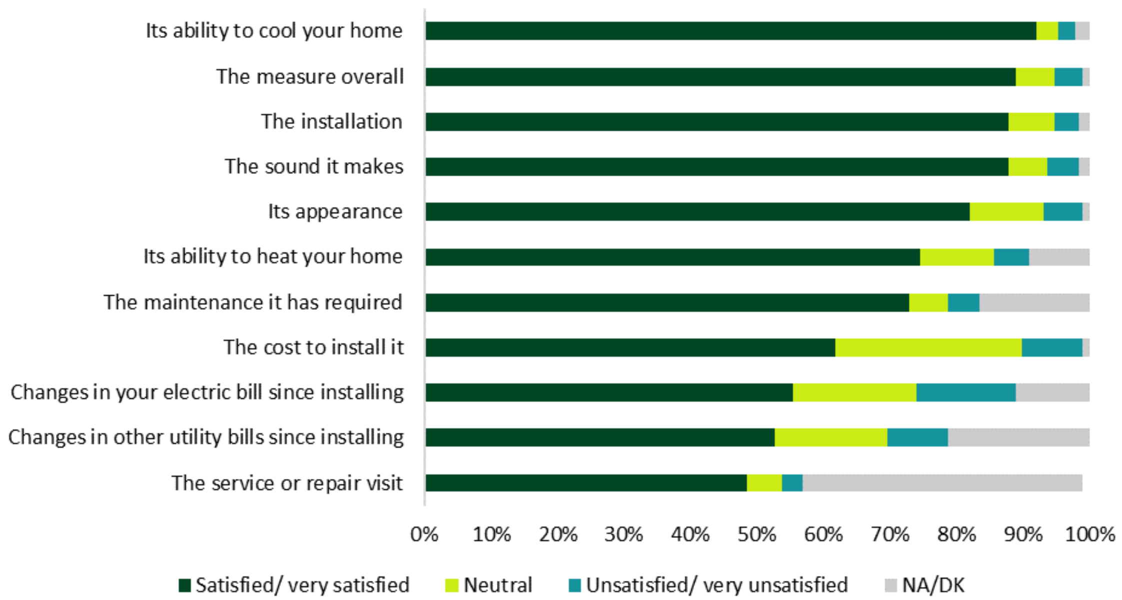
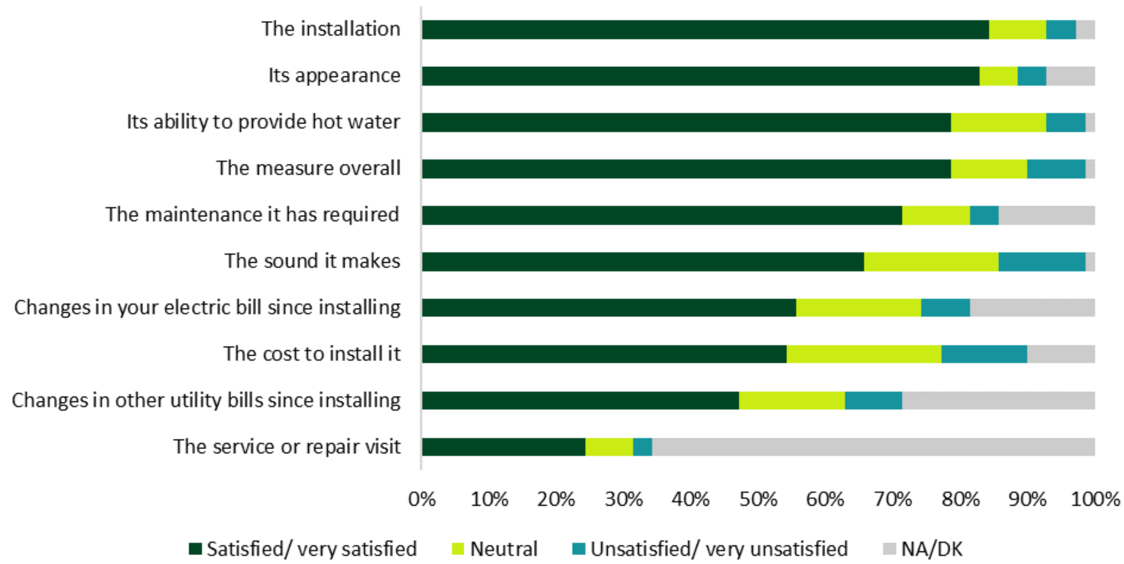


Figure 8: End User Satisfaction with HPWHs

(Source: end user survey; n=70)



- They also reported that their systems were reliable and had needed only limited repairs (Figure 9~~Figure 9~~).
- Installers reported that customer complaints about their heat pumps within the first year after installation were relatively infrequent.

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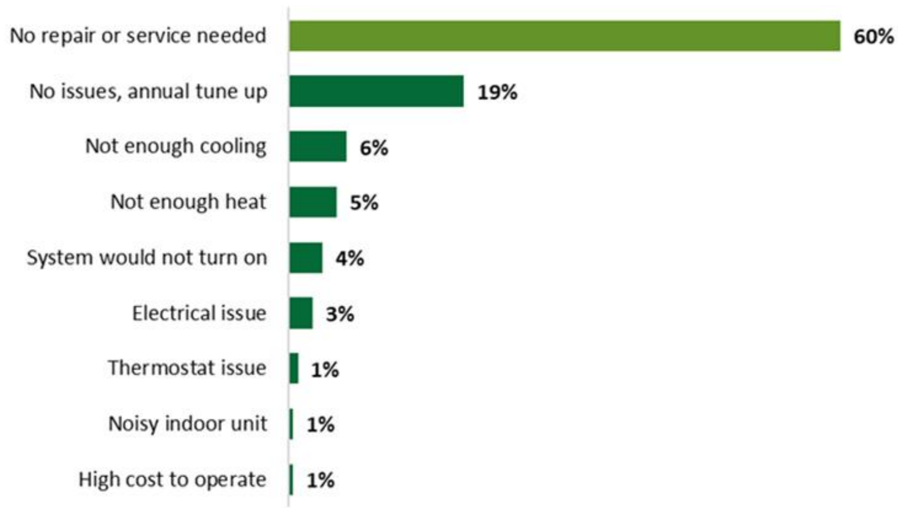
Figure 9: Reason for HVAC Heat Pump Service or Repair

(Source: end user survey; n=188)



Customer Cost-Effectiveness: MSHP, ASHP, and HPWH

- MSHPs and ASHPs are most cost effective when replacing electric resistance heat and some type of cooling.

Introduction

Current Program Design

The study evaluated the residential heat pump market from 2017 through 2019. The Companies provided data for residential heat pumps incentivized during this period through several programs including:

- Residential HVAC program (includes a midstream component for MSHPs)
- Residential HPWH midstream program
- Residential Home Energy Service program
- Residential New Construction program
- Small and large commercial projects with residential sized heat pump equipment

The historical Energize Connecticut program equipment requirements and incentive levels for heat pumps are detailed by equipment type in Appendix C. The program equipment requirements and incentive amounts for heat pumps were updated in 2021 (Table 2~~Table 2~~). The past program equipment requirements and incentive levels for heat pumps are detailed by equipment type in Appendix C. Heat pump requirements and incentive levels in other neighboring jurisdictions are presented in Appendix B.

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Table 2: Connecticut Residential Ductless Heat Pump Rebates, 2021 Update

System Configuration	Efficiencies		Incentives
	SEER	HSPF	2021
Single Zone	18.0	10.0	$250
	22.0	10.0	$500
Single Zone – Displacing ER heat	22.0	10.0	$1,000
Multi-Zone	16.0	9.5	$250
	20.0	10.0	$500
Multi-Zone – Displacing ER heat	20.0	10.0	$1,000

Study Background and Goals

This study provides background for the Companies about the state of the Connecticut heat pump and HPWH market to help inform their work to participate and influence this complicated and growing market. The study addresses the size of the market from 2017 to 2019, relying on multiple data sources. It also supplements this with current feedback about the supply chain, market trends, typical pre-existing and installation scenarios, and the value propositions for both contractors and homeowners.

This report also incorporates research topics and an additional research task that were part of the R2027 HP/HPWH Reliability Study, an add-on study to R1965 to assess participant end-user perceptions of heat pump and HPWH reliability, repair costs, and satisfaction. The study included a web survey with heat pump end-users who participated in Energize Connecticut incentive programs. This report describes the combined R1965 and R2027 research objectives and activities. Detailed results from the participant end-user survey are presented in Appendix E.

Results related to non-energy impacts (NEIs) will be included in the Non-Energy Impacts study (X1942) and are not discussed in this report.

Research Questions

Figure 10~~Figure 10~~ shows the research questions and objectives associated with the R1965 study. The study leveraged primary and secondary data to create an in-depth understanding of the state of the Connecticut market for heat pumps and HPWHs. To answer these research questions, the study team investigated the size and state of the market from 2017 to 2019, explored market actor attitudes about heat pump technology, determined drivers and barriers to heat pump installations in homes, and explored how the Companies can best promote cost-effective heat pump programs, given the rapid evolution of heat pump technologies.

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Figure 10: Research Objectives and Related Research Questions

Describe the Existing and Future Heat Pump Market	What is the size of the market for residential heat pumps in Connecticut? What types of systems are being sold? What are the current uptake opportunities and challenges? What are the Utility program penetration rates in the heat pump market? Where have the programs been successful and unsuccessful?
Determine Trade Ally Roles and Perspectives	Do trade allies see a strong value proposition for heat pumps? What system configurations are being recommended? What factors influence stocking and recommendation rates? What are the levels of consumer interest and satisfaction?
Describe Likely System Configurations and Applications	How are systems configured and integrated with existing equipment? What system types are preferred by installers and their customers: ducted or ductless, single or multi-head, and so forth? What are installation practices and challenges?
Assess Customer Satisfaction and System Reliability	How satisfied are HP owners with their equipment? often have they undergone repairs or service, and what did that cost?
Measure Cost-Effectiveness by System Configuration	What is the cost-effectiveness of different HP installation configurations? What policies can be recommended to encourage configurations with favorable impacts while discouraging those with unfavorable impacts? What are the resulting recommendations for program planning purposes?

The R2027 add-on study included additional research questions and objectives that were included into the research tasks conducted for the R1965 study, including expanding the scope of topics included in the literature review and the interviews and surveys conducted with market actors. An additional task resulted from the R2027 add-on study, which was a survey conducted with HP/HPWH participant end-users. This report synthesizes the relevant information on the HP/HPWH market in Connecticut from both studies. The primary research questions from R2027 include:

- How satisfied are participants with heat pump technology?
- How often do heat pump systems need to be serviced? How does this differ from more traditional HVAC and water heating equipment?
- Why do heat pumps need to be serviced?
- How much are repair and maintenance costs? Does this differ from traditional HVAC and water heating equipment? Is there a sufficient workforce trained and available to fix or service HP/HPWHs?
- How well do they function overall in cold climates?

Key Limitations and Sources of Uncertainty

- Program data included uncertainty, such as a lack of itemized labor vs. equipment costs for installations, and the possibility of double counting in different programs' tracking data.
- Market estimates rely on assumptions about the market that cannot be precisely measured (e.g., there is no single database of every system sold in a given state).
- Market estimates only cover years prior to 2020. Market sizing was conducted early the study; subsequent research extended through 2021. The primary HVAC market data source (HARDI) did not have market data for all or 2021 or 2021, as the COVID-19 pandemic disrupted data collection. Projecting pre-2020 trends forward would not incorporate factors such as new incentives, rising costs, and other market forces.
- The purchaser survey was limited to program participants, whose views may differ from non-participants. End-user contact information was limited, given so many of these systems are incentivized via midstream channels, making recruiting challenging.
- Installers recruited for surveys already install heat pumps and may have a more positive or different impression of heat pumps than contractors who do not currently install them.
- The absence of heat pump performance data leaves ambiguity on whether the barriers identified in this study are due to lack of installer knowledge or comfort with installing heat pump technology, or if the technical limitations to heat pump operation in cold weather are limiting broader heat pump adoption. Without heat pump performance data, questions remain regarding thermal comfort, operating costs, appropriate sizing, and the level of importance the building shell plays with heat pump installations.

Report Organization

The main body of the report synthesizes the findings, methods, and research tasks that were completed as a part of this study. The main body is organized into the following sections:

- Methodology Overview~~Methodology Overview~~ provides a high-level summary of the methodology for each research task conducted in both the original study and the add-on study.
- Findings~~Findings~~ synthesizes the key findings from each research task. This section also includes the overarching key themes that were observed from the various research activities conducted in both the original study and the R2027 add-on study.

The appendices of this report contain the detailed findings, results, and methods used in the study:

- Appendix A Detailed Methodology~~Detailed Methodology~~ presents a detailed methodology for the various research tasks conducted throughout the study.
- Appendix B Literature Review~~Literature Review~~ covers the findings from the review of existing literature, the initial research task that was conducted for this study.
- Appendix C Market Sizing Detail~~Market Sizing Detail~~ presents the estimated size of the market for heat pumps and HPWHs in Connecticut. The appendix also includes a regional benchmarking comparison and estimated the estimated penetration of the program in Connecticut.
- Appendix D Market Actor Feedback Additional Detail~~Market Actor Feedback Additional Detail~~ presents the additional detail from the installation contractor web survey and interviews with manufacturers, distributors, and installation contractors.
- Appendix E End User Feedback Additional Detail~~End User Feedback Additional Detail~~ provides additional detail from the reliability and end-user satisfaction web-survey. The results in this appendix are associated with the research objectives defined as a part of the R2027 add-on study. Note that the results for non-energy impacts are presented in a separate report (X1942).

Methods

Methodology Overview

This section provides an overview of the methodologies and research tasks completed for this study. Appendix A provides additional detail about the methods used.

Figure 11~~Figure 11~~ identifies the main research objectives and associated research tasks for both the R1965 study and the R2027 add-on study.

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Figure 11: Research Objectives and Related Research Tasks

	Lit Review	Market Char.	Mfg. Interviews	Distributor Interviews	End-user Survey	Installer Survey	Installer Interviews	CE Testing
Describe existing and future market for HPs and HPWHs	✓	✓	✓	✓		✓	✓	
Determine role of trade allies in equipment promotion	✓		✓	✓		✓	✓	
Describe likely equipment configurations and applications	✓					✓	✓	
Measure cost-effectiveness of configurations	✓					✓	✓	✓
Assess HP and HPWH reliability and satisfaction					✓			

Literature Review

The study began with a comprehensive review of available literature and data sources to understand the heat pump market and develop a clear understanding of the Companies program efforts. The literature review gathered information relevant to the heat pump market in Connecticut and surrounding regions. Additionally, the literature review compiled data from various secondary sources to help inform the subsequent research tasks, such as estimating the market size for various residential heat pump technologies.

Market Sizing

The market size estimates relied on both primary and secondary data, as there is no single commercially available database of all mechanical equipment installed in a given state. Due to the limitations of available data, it is important to note that the values presented in this report represent approximations rather than actual counts. The research conducted during the literature review was leveraged to develop the market estimates. The in-depth interviews and surveys included in this study were used to qualitatively understand the quantitative data gaps and provided additional insight into the functioning of the market.

The study used the following data categories to estimate the size of the residential market for various heat pump technologies and traditional HVAC equipment:

- Heating, Air-conditioning, & Refrigeration Distributors International (HARDI) data (2013 to 2019)[2]
- Program tracking data (2017 to 2019)
- National data sources
- Connecticut evaluations
- Non-Connecticut evaluations

The study estimated the heating efficiency of ASHPs and MSHPs for the market based on the estimated cooling efficiency and capacity of the HARDI data estimates. The HARDI data included estimated cooling efficiency for ASHPs and MSHPs but did not include heating efficiency (HSPF) for these equipment types. In addition, in some cases the study had to convert program data efficiency units from EER to SEER to compare with the HARDI data. The study also leveraged the program tracking data to estimate sales by MSHP configuration type (i.e., single- or multi-head systems). These conversions are detailed in Appendix A.2.2. The detailed methodology on how the market size estimates were generated by equipment type is in Appendix A.2.

Interviews and Surveys with Market Actors

The study conducted primary data collection to identify trends in the HVAC and water heating markets in Connecticut, with a specific focus on heat pump technology. Interviews were conducted with manufacturers, distributors, and installers of heat pumps. In addition, a web-survey was conducted with both installers and end-users to assess various aspects of heat pump technology and reliability. Table 3~~Table 3~~ summarizes the targets and achieved completes for each data collection task. See Appendix A.3 for additional details on the methodology for these research tasks.

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[2] HARDI data provided sales estimates from 2013 through 2019 for ASHPs, MSHPs, CACs, furnaces, and boilers. The HARDI data estimates are primarily based on sales invoices and other reports from HVAC distributors that are HARDI members weighted to represent all sales across a given region based on the EIA's 2015 Residential Energy Consumption Survey (RECS) and Commercial Building Energy Consumption Survey (CBECS) and the U.S. Census' American Housing Survey.

Table 3: Primary Data Collection Targets and Completes by Research Activity

Data Collection Task	Target	Completes
Manufacturer Interviews	5	5
Distributor Interviews	15	12
Installation Contractor Interviews	10	10
Installation Contractor Web Survey	115*	126*
End-User Web Survey	240+	258

*These targets are based on equipment coverage due to difficulties recruiting installation contractors to complete the web survey. A total of 52 installation contractors completed the web survey with an initial target of 100 completes; many contractors installed and could speak to multiple types of systems.

Cost-Effectiveness Testing

The study included a cost-effectiveness forecast for several residential heat pump installation scenarios using the Participant Cost Test (PCT), developed by the National Action Plan for Energy Efficiency.[3] This test evaluates measures from the perspective of the customer installing the measure and deems a ratio of 1.0 or greater as cost-effective. Benefits included customer incentives and bill saving while costs included incremental equipment and installation costs. This test can also include non-energy impacts, which were not included in this study.

The study selected relevant baseline and capacity scenarios to evaluate several heat pump technologies. Cost research was performed using both primary and secondary data sources to estimate incremental costs and applicable incentives for each scenario. Savings analysis was performed using a balanced load calculation for each baseline and efficient equipment scenario. Cost-effectiveness ratios were calculated using the PCT formula which deems a measure with a ratio of 1.0 or greater as cost-effective.

The study selected relevant baseline and capacity scenarios to evaluate several heat pump technologies. The selection of scenarios was based, in part, upon baseline observations from previous Connecticut ductless heat pump (DHP) and HPWH studies (R1617, R2027, and R1965). Eighteen scenarios were run, including 12 MSHP, four ASHP, and two HPWH combinations. Key characteristics of the various runs included different unit sizes, partial or full heating displacement, and different technologies and fuels for heating and cooling systems. The study team also included an assessment of the sensitivity in results if costs were increased or decreased by 20% from those in the base estimates.

[3] Understanding Cost-Effectiveness of Energy Efficiency Programs: Best Practices, Technical Methods, and Emerging Issues for Policy-Makers, November 2008, Page 6-1.

Findings

The following sections summarize key findings from the combined R1965 and R2027 studies. Associated detail can be found in the report's appendices.

The findings section is organized by key takeaways, and includes the following sections:

- Landscape of the MSHP Market in Connecticut~~Landscape of the MSHP Market in Connecticut~~
- Landscape of the ASHP Market in Connecticut~~Landscape of the ASHP Market in Connecticut~~
- Installation Scenarios for MSHPs and ASHPs~~Installation Scenarios for MSHPs and ASHPs~~
- Landscape of the GSHP Market in Connecticut~~Landscape of the GSHP Market in Connecticut~~
- Landscape of the HPWH Market in Connecticut~~Landscape of the HPWH Market in Connecticut~~
- Installer Attitudes: HVAC Heat Pumps and HPWHs~~Installer Attitudes: HVAC Heat Pumps and HPWHs~~
- Satisfaction and Reliability: HVAC Heat Pumps and HPWHs~~Satisfaction and Reliability: HVAC Heat Pumps and HPWHs~~
- Customer Cost-Effectiveness: MSHP, ASHP, and HPWH~~Customer Cost-Effectiveness: MSHP, ASHP, and HPWH~~
- Distributor Feedback about Energize Connecticut Programs~~Distributor Feedback about Energize Connecticut Programs~~

Landscape of the MSHP Market in Connecticut

The Connecticut heat pump market has been relatively flat between 2013 and 2019, and most of the installed units are MSHPs.

The MSHP market in Connecticut has been stable in recent years. Annual installations ranged between 4,200 and 5,700 units from 2013 through 2019 (see Appendix C for additional detail). Natural gas furnaces, gas boilers, and central air-conditioners each had installation volumes two to four times as high as MSHPs (Figure 12~~Figure 12~~). [4,5,6,7] By 2017, MSHP installations outpaced oil furnaces, likely as the Companies transitioned to a midstream program. That said, there were still over 3,000 oil furnaces sold in 2019. This oil furnace market represents a substantial savings opportunity for the Companies, as they could promote heat pumps in their place.

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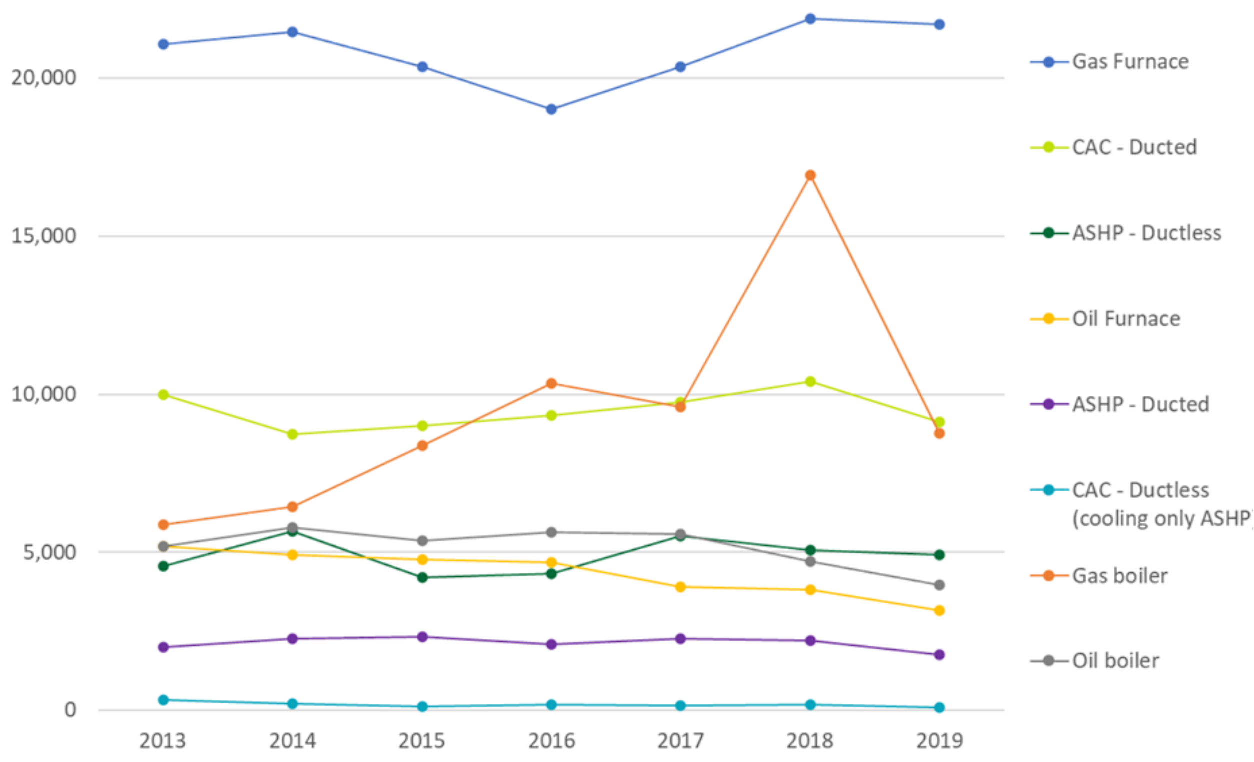
Figure 12: Connecticut Annual Equipment Unit Sales (HARDI), 2013-2019



[4] HARDI data also include estimates for gas and oil furnaces, central AC, and ductless AC (no heating function).
[5] Boiler data only available at the regional level. Regional data prorated based on number of homes in Connecticut.
[6] HARDI data exclude GSHPs. The study suggests GSHPs represent less than 200 installations per year.
[7] MSHP/ASHP estimates rely on Heating, Air-conditioning, & Refrigeration Distributors International (HARDI) data. NMR obtained all HARDI data referenced and included in this report from the HARDI Unitary Report via the DRIVE portal, prepared by D+R International under data license by HARDI members. Reuse is prohibited without permission. All rights reserved.

Market actors confirmed that ductless MSHPs dominate the Connecticut heat pump market. Installers said ductless MSHPs made up 44% of their heat pump installations in 2019, on average. Distributors reported an even higher share of 68%, though they noted that ducted MSHPs were becoming more popular as they offer installation flexibility and are visually unobtrusive (Figure 13~~Figure 13~~).

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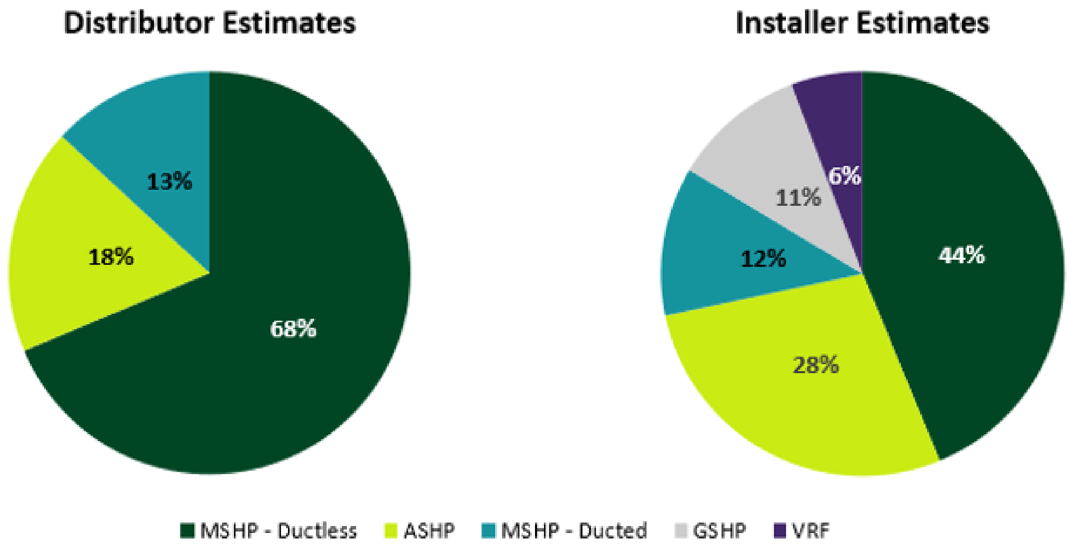
Figure 13: Annual Heat Pump Installations, by System Type

(Source: Installer survey n=66, Distributor IDI n=12)



While the Connecticut MSHP market remained mostly flat, neighboring states saw growth between 2013 and 2019.

Massachusetts and Rhode Island saw sustained growth in the MSHP market; Rhode Island installations surpassed Connecticut in 2019 (Figure 14~~Figure 14~~). The Companies increased incentives for heat pumps in 2020 and developed a two-tiered incentive structure for 2021. These changes could yield higher sales for 2021 and could continue to drive the adoption of higher-efficiency units, just as increased incentives in Rhode Island appear correlated with an increase in installations. (See Appendix C.1 for program requirements.)

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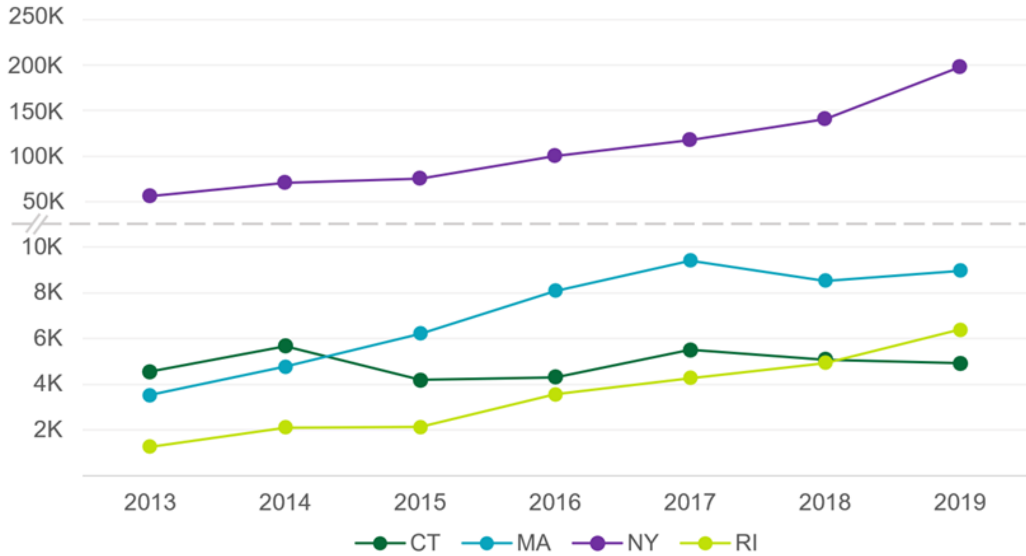
NMR Group, Inc.

Figure 14: Regional Annual MSHP System Sales (2013-2019), HARDI*



*New York figures not to scale, given substantially larger market.

MSHP installations in Connecticut remained flat from 2013 to 2019, but they increased on a per household basis by approximately 140% in Massachusetts, 240% in New York, and 410% in Rhode Island (Figure 15~~Figure 15~~). On a per household basis, installations were higher in Connecticut in 2013 than they were in Massachusetts, but Massachusetts caught up by 2019; both markets saw about 3.5 MSHP installations per 1,000 households that year. Rhode Island and New York but saw significant increases in recent years, on a total and per household basis.

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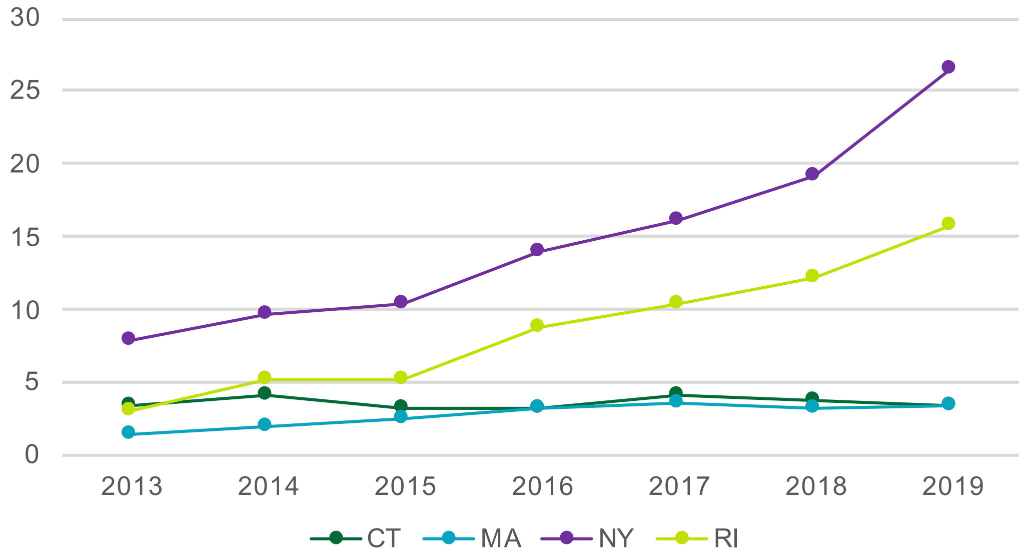
Figure 15: Regional Annual MSHP System Sales per 1,000 Housing Units (2013-2019), HARDI



Connecticut's MSHP incentives have compared favorably to those in neighboring states, indicating other factors may have limited uptake in Connecticut. The Companies have an opportunity to increase marketing, outreach, and implementation efforts to help boost installation rates to keep pace with growth in other states. Process evaluations focusing on best practices in other states may help identify specific opportunities for the Companies to drive the market.

The average MSHP cooling and heating efficiency in Connecticut increased from 2013 to 2019 but was the lowest in the region in 2019.

The average cooling efficiency (SEER) for MSHP installations in Connecticut reached 19.7 by 2019, while Rhode Island and Massachusetts had the highest average SEER MSHPs in the region (over 20 SEER) (Figure 16Figure 16). In New York, average efficiencies surpassed Connecticut in 2018.

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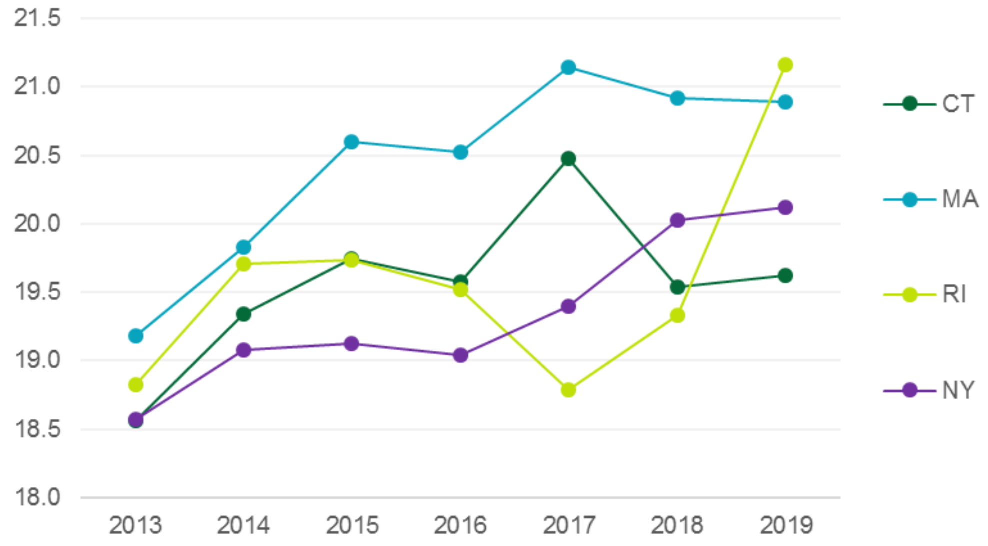
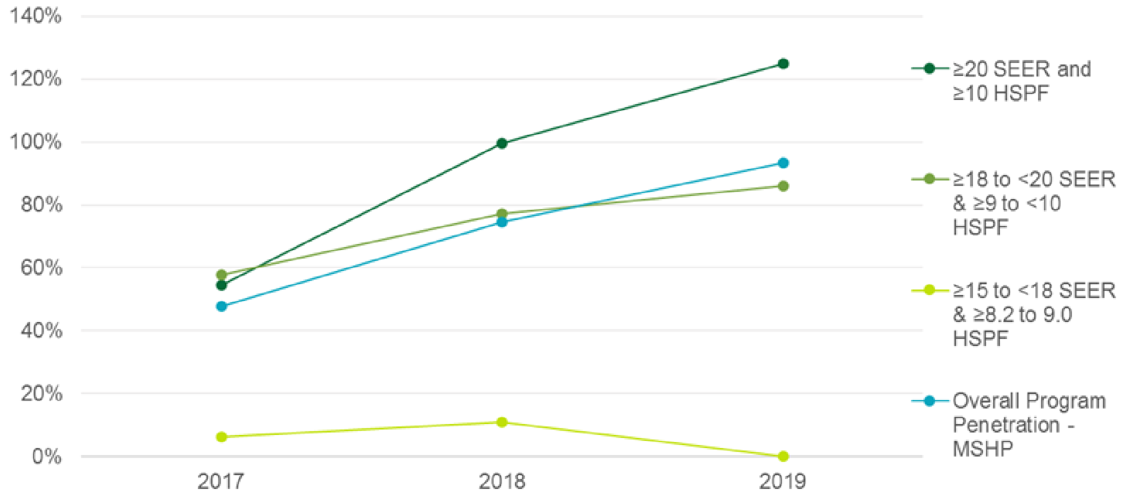
Figure 16: Average MSHP Cooling Efficiency (SEER) by State, HARDI



MSHPs incentivized by the program outperformed the market (21.5 SEER). Only 28% of MSHPs sold in Connecticut between 2013 and 2019 were over 20 SEER, but from 2017 to 2019, approximately 75% of program incentivized MSHPs were 20 SEER or higher.[8]

[8] However, HARDI data estimate there were fewer extremely high efficiency units (≥20 SEER and ≥10 HSPF) sold than the program *incentivized* in 2019, indicating that HARDI data underestimate the size of the high efficiency market. For more details on the efficiency of program units compared to the market estimates, see Appendix C.3.3.

Figure 17: Annual Program Penetration of MSHP units by Efficiency



Across the region, MSHP efficiency improved from 2013 to 2019. Connecticut had the highest growth in installations with reasonably high performance (18+ SEER and 9+ HSPF, from 59% of installations in 2013 to 84% in 2019), but these percentages remained lower than in other states (Figure 18~~Figure 18~~).[9] New York achieved an 86% market share for these higher efficiency systems; Massachusetts and Rhode Island were both over 90% in 2019. Rhode Island increased this market share by 38% from 2017 to 2019, which is likely attributable to large program incentives for MSHP equipment provided between 2018 and 2019.

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In Connecticut, the highest-efficiency market share grew at the expense of the middle efficiency tier (≥15 to <18 SEER & ≥8.2 to 9.0 HSPF). A small number of MSHP systems below federal minimum efficiency levels (<15 SEER & <8.2 HSPF) were sold each year, an indication that old stock may remain in circulation.

MSHPs installed in Connecticut have evolved from single-zone air conditioners to multi-zone heating and cooling solutions, even if they are usually installed as supplemental systems.

The proportion of single-zone MSHPs decreased in Connecticut (46%), Massachusetts (47%), and Rhode Island (45%) between 2013 and 2019.[10] Multi-zone systems generally have lower efficiencies than single-zone systems, but they have higher capacities and can condition more floor area, making them a popular choice for whole-home solutions. Even as multi-zone

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[9] Note that only SEER (cooling) values were provided in HARDI data, but HSPF efficiency values (heating) were not. The HSPF values were calculated as a function of SEER and capacity, and as a result track with the SEER values. While this study estimated HSPF values, it also should be noted that HSPF and SEER values are not perfectly correlated. For example, an MSHP or ASHP system may have a SEER value of 16 but the HSPF value may range from 9.0 – 11.0 HSPF. The variation that can exist between cooling and heating efficiency may cause an under or over-estimation of systems that fall into a certain HSPF value. See Appendix A.2.2 for methodological details.

[10] Note that the data does not allow to see in what instances these systems were the sole heating application, supplemental heating, or the level to which these systems were integrated with more conventional heating equipment for deep cold temperatures. The HARDI data also did not include information on single- and multi-zone systems. The methods used to determine the amount of single- and multi-zone systems is provided in Appendix A.2.2.

systems gained popularity in Massachusetts, the state still saw the most growth of extremely efficient systems (at least 20 SEER and 10 HSPF) in the region. The Massachusetts trend of increased overall efficiencies, even as it experiences more sales of multi-zone systems, might cross over to Connecticut with adjusted incentives and additional program efforts.

Higher adoption of multi-zone MSHP systems in and outside of the programs contributed to the decrease in average efficiency since 2017. The increase in multi-zone installations likely drove the slight decrease observed in the program's overall average efficiency, despite a dramatic increase in program penetration between 2017 and 2019. For details on the efficiency of program units compared to the market estimates by configuration type, see Appendix C.3.4.

Figure 18: MSHP Installations by Efficiency (SEER and HSPF) and State, HARDI

By 2019, 93% of MSHP installations received Energize Connecticut incentives. These largely midstream incentives appear to have helped drive sales of middle- and high-efficiency equipment but did not increase installations in the state as a whole.

The programs' MSHP market share increased dramatically – by 94% – from 2017 to 2019, but the overall market remained flat. In 2017, the programs incentivized less than half of the MSHP market (48%); by 2019, this reached 93% of the market (Table 4~~Table 4~~). Ideally, such an increase in program activity would trigger increases in system efficiency and the number of total units sold, but the market remained relatively flat. As incentives have changed in recent years, future evaluations may identify whether this increased program activity yielded increases in the size or efficiency of the MSHP market. The Companies' midstream HVAC program provided the incentives for most of these units.[11]

Table 4: MSHPs Incentivized by Programs (2017-2019)

Year	Total Incentivized Units	*Programs* Midstream HVAC	HVAC Add-on (HES)	RNC	SBEA
Total MSHP program counts (units)					
2017	2,599	2,450	109	36	4
2018	3,738	3,590	36	105	7
2019	4,479	4,344	30	95	10
Program penetration of MSHP market					
2017	48%	45%	2%	1%	<1%
2018	74%	71%	1%	2%	<1%
2019	93%	91%	1%	2%	<1%

MSHPS are most commonly installed as supplemental systems even though multi-zone systems increased in popularity from 2017 to 2019. Users confirmed that they still rely on their pre-existing heating systems.

Distributors estimated that nearly three-quarters (72%) of MSHPs are installed as supplemental rather than whole-home heating systems (Table 5~~Table 5~~). However, many distributors confirmed installers' reports about an increase in the installation of MSHP systems without back-up heating, especially in new construction where the building shell is tighter and better insulated than most older homes, allowing the heat pump to meet the full heating load of the home. Most interviewed distributors indicated that the installers they work with are still skeptical that heat pumps can deliver the full heating load of a home at low temperatures, particularly among installers that have historically installed more traditional HVAC equipment.

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Table 5: MSHP Supplemental Heating vs. Whole Home Heating

(Source: Distributor IDI; n=11)

System Type	Distributor Estimate
Supplemental	72%
Whole Home	28%

[11] For ASHPs, incentives were generally rebates provided to the end-user or contractor after installation. The Home Energy Solutions (HES) program also incentivized MSHPs for HES participants, and the Residential New Construction (RNC) program indirectly incentivized ASHPs and MSHPs as their performance can help a home qualify for an incentive based on its overall performance.

Installers and end users confirmed that MSHPs are most commonly installed as supplemental systems (Table 6~~Table 6~~ and Table 7~~Table 7~~). Although supplemental systems are the most common installation scenario, replacing electric baseboards and other existing fossil fuel systems represent a large portion of installation scenarios for both installers and end-users (39% and 25%, respectively).

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Table 6: MSHP Heating Installation Characteristics According to Installers

(Source: installer survey; n=54)

Heating Characteristic	% of Existing Home Installs
Heat spaces also served by other heating systems	28%
Add heat to previously unheated spaces	24%
Replace electric baseboards	22%
Replace existing fossil fuel systems	17%
Provide cooling only	9%

Table 7: MSHP Heating Installation Characteristics According to End Users

(Source: end user survey; n= 170, multiple response)

Heating Characteristic	End User %
Heat spaces also served by other heating systems	55%
Heats all or most of the home	25%
Heats spaces that were not previously heated	18%
Replaced electric baseboard that was removed	9%
Is the home’s only heating system	9%
Replaced a fossil fuel system that was removed	7%
Provides cooling only	5%

Almost half of MSHP owners said they use their old heating system less than they did before the MSHP install (45%), but almost as many use it about the same amount (40%). This highlights an opportunity for the Companies to encourage installation of integrated control systems and to educate homeowners on how to maximize their HVAC system for both comfort and energy savings.

Table 8: Old Heating System Use After MSHP Install

(Source: end user survey; n= 161)

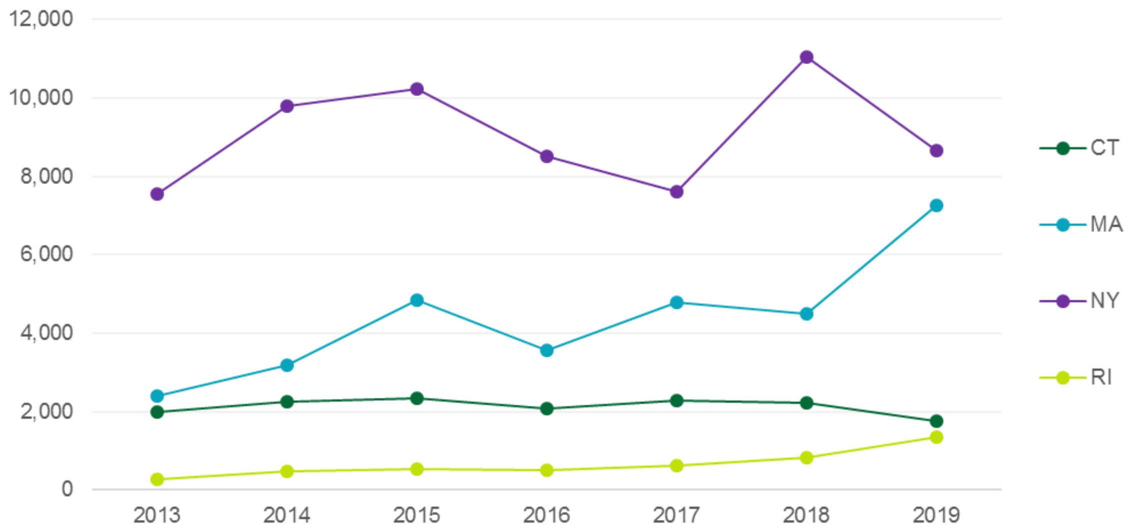
Old Heating System Use	End User %
About the same as I used to	40%
Somewhat less than I used to	25%
Much less than I used to	20%
Never; but it is still installed	7%
Never; it was removed	6%

Landscape of the ASHP Market in Connecticut

ASHP sales have remained flat in Connecticut, while surrounding states saw growth from 2013 to 2019.

The ASHP market in Connecticut was relatively flat between 2013 and 2018 but dropped by nearly 500 units (21%) in 2019 (Figure 19~~Figure 19~~). The ASHP market in New York has seen substantial year-to-year fluctuations in ASHP installations, while the Massachusetts market has seen steady growth since 2013, with a spike in 2019. The smaller Rhode Island market saw a nearly five-fold increase in installations from 2013 to 2019.

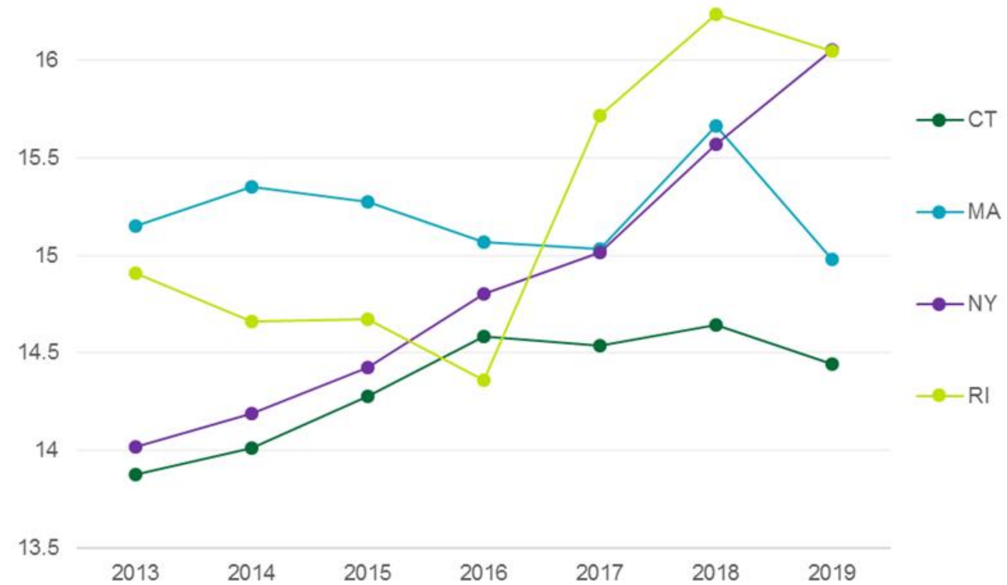
Figure 19: Regional Annual ASHP System Sales (2013-2019), HARDI



The average ASHP cooling and heating efficiency in Connecticut increased from 2013 to 2019 but was lower than in surrounding states nearly every year.

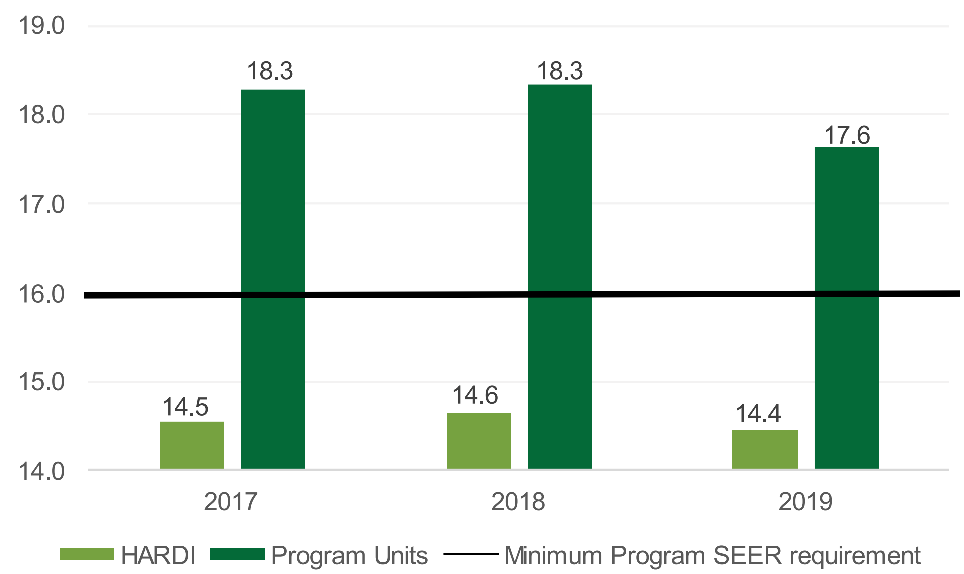
The average SEER in Connecticut increased from below 14 SEER to about 14.5 SEER between 2013 and 2019. Rhode Island and New York were the highest in the region, estimated to be over 16 SEER (Figure 20~~Figure 20~~). See Appendix C.1.2 for additional detail.

Figure 20: Average ASHP Cooling Efficiency (SEER) by State, HARDI



Program units far outperformed non-program units recently, despite the market's downward trend in efficiency. Approximately 12% of program-incentivized ASHPs were 18 SEER or higher, a higher proportion than observed in the market during this time period (6%). One potential reason that cooling efficiencies have dropped in both the overall market and in the program is an increase in availability of ASHPs with higher heating efficiencies and lower cooling efficiencies, tuned more for heating than cooling performance. Systems with lower cooling efficiencies that still meet the minimum program requirements would be cheaper for the customer and an easier sale for the contractor.

Figure 21: Average ASHP Cooling Efficiency, Entire Market vs. Program (SEER)



Less than one-fifth of the ASHP market in Connecticut was program eligible (based on the minimum program cooling efficiency criteria).[12,13] The share of the ASHP market that met minimum program qualifications ranged from 9% to 21% of the total market between 2013 and 2019 (Figure 22Figure 22). Neighboring states had a greater proportion of sales that would have met Connecticut's minimum efficiency requirements. In both Rhode Island and New York, the proportion of ASHPs that met the minimum cooling efficiency requirements of Connecticut increased to nearly 50% of their total market in 2019. In Massachusetts, that proportion ranged from 22% to 43%. This highlights the Companies' opportunity to increase marketing, outreach, and implementation efforts to help boost installation rates of higher-efficiency heat pumps to bridge the gap with other states.

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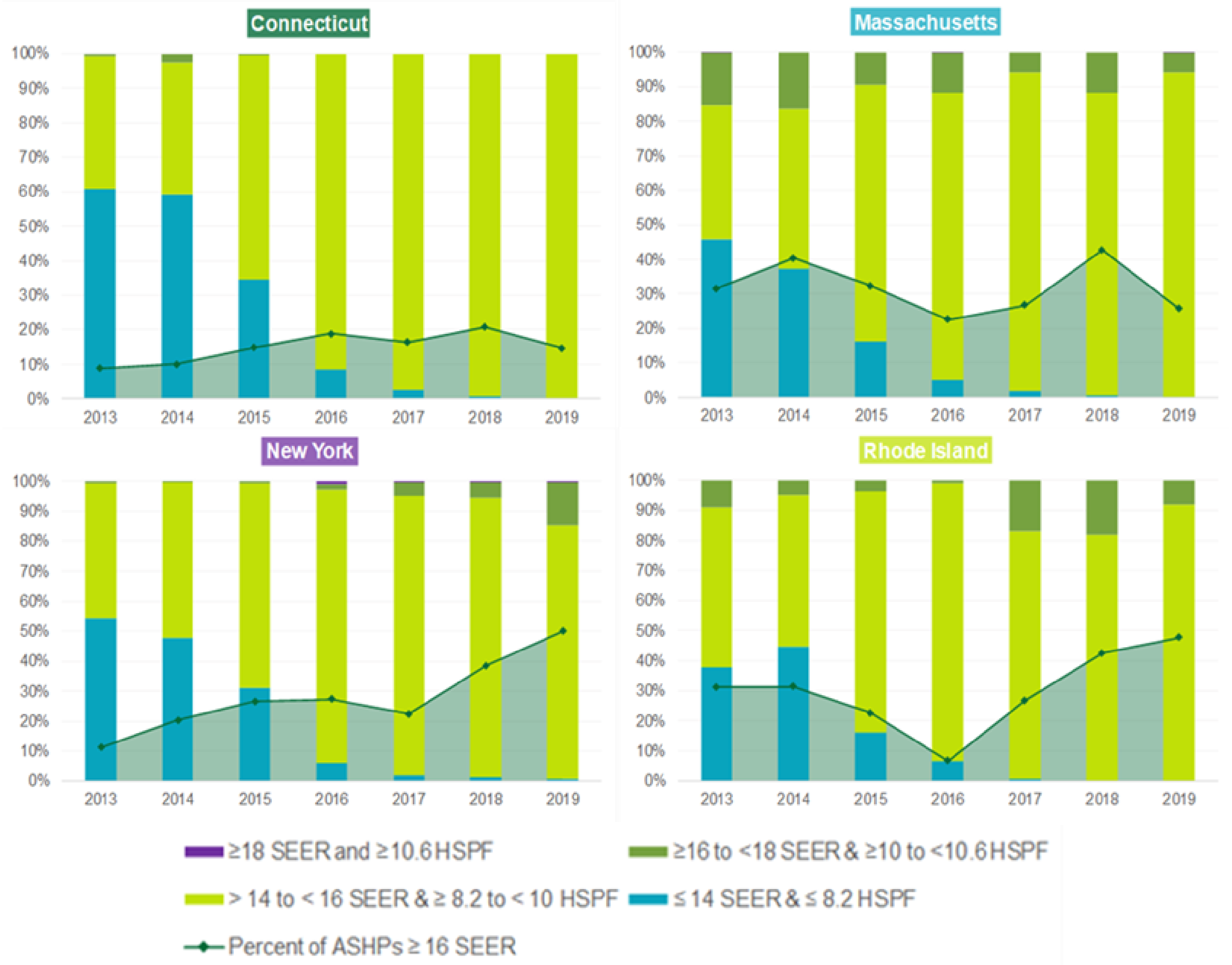
Figure 22: ASHP Installations by Efficiency (SEER and HSPF) and State, HARDI



[12] As noted in Appendix A.2.2, HSPF was calculated as a function of SEER and capacity. Due to this, the proportion of ASHPs sold into the market that were program-eligible is likely lower than what is presented in **Error! Reference source not found.**Table 6.

[13] The efficiency of the system had to meet *both* minimum efficiency requirements to meet the efficiency category requirement.

Program impact on the ASHP market was minor. Only a small subset of ASHP sales received program incentives between 2017 and 2019, as most systems are not program eligible.

In contrast to MSHPs, the programs incentivized only a small number of ducted ASHPs from 2017 through 2019 – well under 200 each year, only 5% to 8% of the market (Table 9~~Table 9~~). In comparison, the programs' market share of MSHP equipment is estimated to be 93% in 2019. This suggests that the overall market is likely promoting the installation of high-efficiency MSHP systems rather than higher efficiency ASHP systems.

Additionally, market actors show some skepticism about cold-weather performance and may be gravitating to supplemental or point-source heat pump systems where the heat pump's performance on the coldest days is less critical (see Installer Attitudes: HVAC Heat Pumps and HPWHs~~Installer Attitudes: HVAC Heat Pumps and HPWHs~~). The program could spur greater market adoption of high-efficiency ASHPs by expanding market efforts to focus on replacing inefficient ducted HVAC systems with ASHPs or centrally-ducted MSHPs. See Appendix C.3.1 for the historical program requirements and incentive levels for heat pumps in Connecticut.

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Table 9: ASHPs Incentivized by Programs (2017-2019)

		Programs			
Year	Total Incentivized Units	Midstream HVAC	HVAC Add-on (HES)	RNC	SBEA
Total ASHP program counts (units)					
2017	106	--	58	45	3
2018	167	--	53	110	4
2019	94	--	42	49	3
Program penetration of ASHP market					
2017	5%	--	3%	2%	<1%
2018	8%	--	2%	5%	<1%
2019	5%	--	2%	3%	<1%

Roughly two-thirds of higher-efficiency ASHPs do not receive program incentives (Figure 23~~Figure 23~~). This suggests low free-ridership, but also other potential barriers, such as a lack of program awareness, incentives that do not encourage ASHP adoption in place of traditional HVAC solutions, or customers focused more on cooling than heating performance.[14] ASHPs are also incentivized through a downstream program. In contrast, MSHPs and HPWHs are incentivized through a midstream program and have a much higher program penetration.

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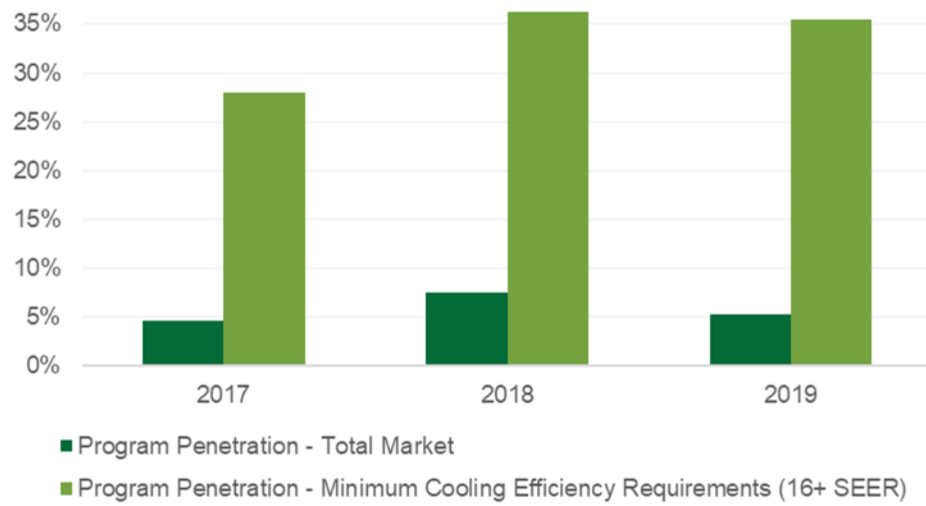
[14] It should be noted too that the program incentivized more high efficiency MSHPs than were reported in the HARDI data, which may also be a possibility with ASHPs.

Figure 23: Annual Program Penetration of ASHP units



Installation Scenarios for MSHPs and ASHPs

More heat pumps are installed in existing homes than new homes, but in new homes, they are more likely to be primary systems.

Installation rates in new vs. existing homes. Installers reported that heat pumps for space conditioning are installed more often in newly constructed homes (38% of all installs in new homes, on average) than in existing homes (29% of installs in existing homes), but both show significant market uptake (Table 10~~Table 10~~).

Table 10: Percentage of Installations that were Heat Pumps, by Home Type

(Source: installer survey)

Home Type	n	Installer % of Total (Mean)
Existing Homes % HP	64	29%
New Construction % HP	41	38%

Backup heat in new vs. existing homes. Installers estimated that even when MSHPs or ASHPs were installed as primary systems – which users rely on most or all) of the time for their heating – a non-heat pump back-up heating system was present 61% of the time in existing homes and 54% of newly constructed homes (Table 11~~Table 11~~).

Table 11: Presence of Backup Heating for MSHPs and ASHPs

(Source: installer survey; Existing n=49, New Homes n=32)

Home Type	Installer Estimate
Existing Homes	61%
New Homes	54%

Manufacturers and distributors reported that builders often favor non-heat pump systems to minimize their upfront costs, while MSHPs work well in retrofit applications because so many Connecticut homes lack duct work. In new construction, particularly for tract housing, keeping upfront costs low is a primary goal, so these homes are predominantly built with standard furnace and central air conditioner combinations. Most builders are concerned with the upfront cost and not the operational cost of the home, so they have less incentive to spend more on installing heat pumps.

Market actors also indicated that adding duct work at the construction phase is not particularly difficult, helping explain why ducted systems, rather than ductless MSHPs, are more prevalent in new construction. The challenge of adding duct work seems to be driving the popularity of MSHP in the retrofit market, as it is disruptive and costly to retrofit a home with duct work. This is particularly important in Connecticut with its older and varied housing stock, as MSHPs provide a flexible solution for a variety of scenarios.

Builders who put MSHPs into new homes slightly favor ductless options but often use ducted configurations. Inverter-driven MSHP systems (i.e., higher-efficiency units) can be configured with or without ducts. Ductless-only MSHPs are the most common configuration in new homes (51% of installations, on average), followed by ducted MSHP systems (25%). The remaining systems are configured with a mix of ducted and ductless indoor units (23%) (Table 12~~Table 12~~). Distributor interviewees also confirmed an increased popularity for centrally ducted and mixed ductless and ducted systems.

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Table 12: MSHP Configurations in New Construction

(Source: installer survey; n=31)

Configuration	Installer Estimates
MSHP – Ductless only	51%
MSHP – Ducted only	25%
MSHP – Mixed Ducted and Ductless	23%

Pre-existing and baseline scenarios: MSHPS and ASHPs are commonly installed in oil and electric resistance homes.

Installers indicated that heat pumps are most commonly installed in homes heating with oil or electric resistance, and they typically do not entirely displace the pre-existing fuel. Installers estimated that around two-thirds of MSHP and ASHP installations in existing homes were done in homes with oil or electric resistance heating (43% and 24%, respectively) (Figure 24~~Figure 24~~).[15]

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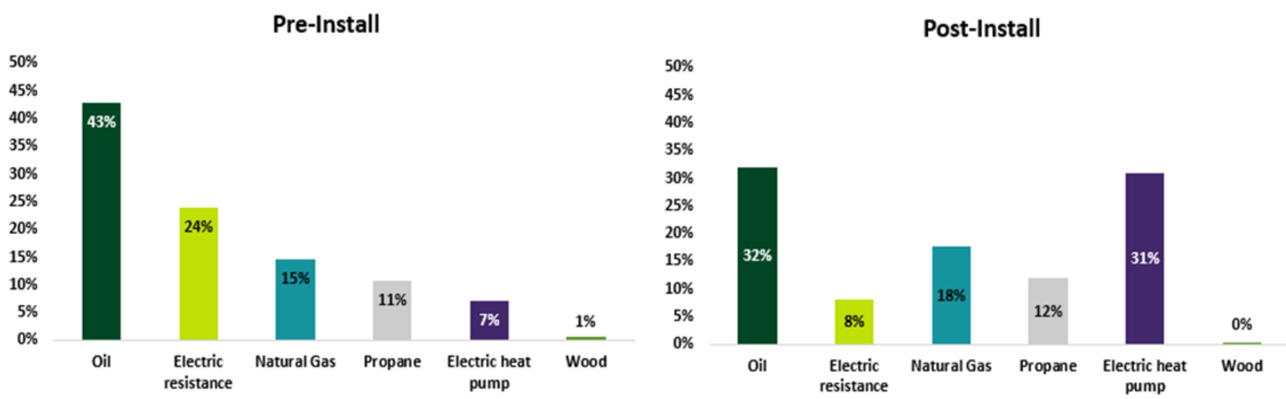
Installers reported that in existing homes where they installed MSHPs and ASHPs, electric resistance as the primary heating fuel dropped by 67%, and oil as the primary fuel dropped by 25%. Oil was still the most common primary heating fuel in existing homes *even after* the installation of a heat pump (32%), followed closely by the heat pump itself (31%).

When heat pumps were installed in new homes, they were the most common primary heating source (42%), followed by a natural gas or propane system (23% each). These findings support the results from other questions in the survey as well as distributor interviews regarding the use of backup systems in newly constructed homes.

[15] Primary fuel estimates do not suggest that the pre-existing primary system was completely replaced by the heat pump; supplemental systems are estimated to be nearly three quarters of all MSHP installations.

Figure 24: Primary Heating Fuel Before and After MSHP or ASHP Install (Installers)

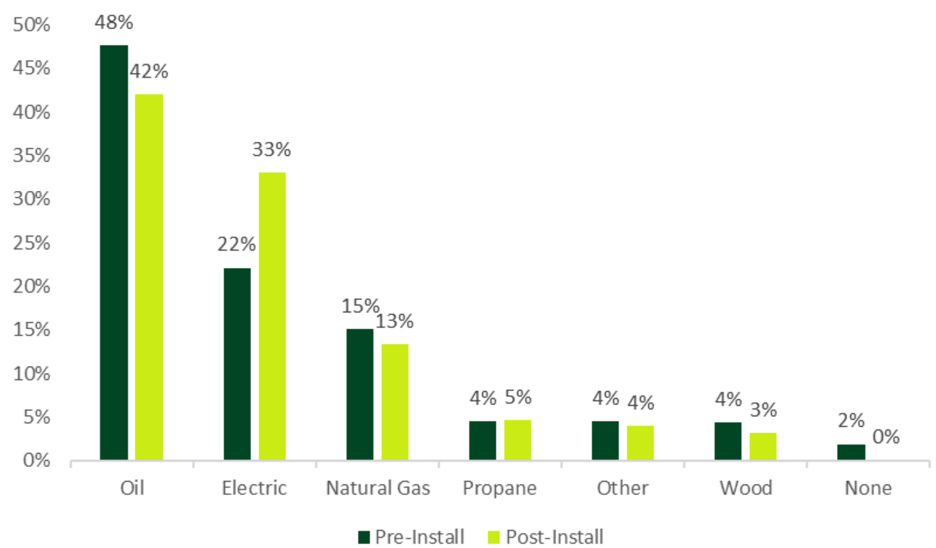
(Source: installer survey; n= 53)



End users confirmed installers' reports that MSHPS are most commonly installed in homes heated with oil or electricity, and that the MSHP is not fully displacing the pre-existing fuel in most cases (Figure 25~~Figure 25~~). Oil remained the most common primary heating fuel in these homes even after installation, suggesting that MSHPs are not displacing existing fossil fuel systems.

Figure 25: Primary Heating Fuel Before and After MSHP Install (End Users)

(Source: end user survey; n= 170)



Free-ridership appears to be high for HVAC heat pumps (MSHPs, ASHPs, and GSHPs).

Over one-third (37%) of heat pump purchasers (Energize Connecticut participants) said that they would have purchased the same exact heat pump without the program incentive, an indication of potential free-ridership. Only a small portion (9%) of participants would have installed either a less expensive or less efficient heat pump, while one-fourth (25%) would not have purchased a heat pump at all. (Figure 26Figure 26).

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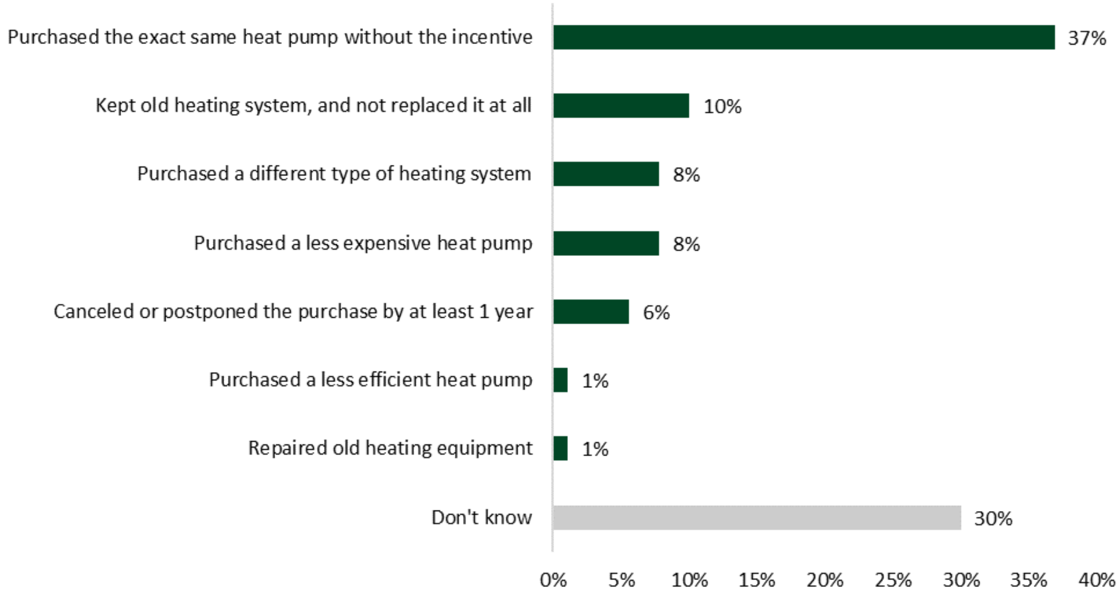
Figure 26: Heating Purchase Decision without Energize CT Incentives

(Source: end user survey; n= 179)



The incremental cost for a cold-climate heat pump is consistent between ASHPs and MSHPs (about 20% over non-cold climate models), but cold-climate MSHPs are much more common.

Cold climate heat pump prevalence and cost. Installers estimated nearly three quarters (74%) of MSHPs were cold climate models (as marketed or labeled by the manufacturer); distributors estimated closer to half (48%) for MSHPs (Table 13Table 13). Both suggested the additional cost for cold-climate heat pumps was about 20%. Installers and distributors reported fewer central ASHPs were cold climate compared to MSHPs (39% and 26%, respectively).

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Table 13: Market Share and Incremental Cost of Cold-Climate Heat Pumps Relative to Non-Cold Climate Heat Pumps

(Installer survey n=47, Distributor IDI n=11)

System Type	Installer Estimate	Distributor Estimate
MSHP	74%	48%
ASHP	39%	26%
Incremental cost (cold-climate over non-cold climate models)	**19%**	**21%**

Landscape of the GSHP Market in Connecticut

The GSHP market in Connecticut is small and potentially contracting. Any potential growth would primarily be in new construction due to the requirements for installation.

GSHP installations are uncommon; well under 200 units have been installed annually in recent years.[16] More GSHPs appear to have been installed in new homes than in existing ones (Table 14~~Table 14~~), but for both market segments, GSHPs represent a small fraction of the HVAC market.

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The proportion of GSHP installations in the new construction market has increased from approximately one-half to nearly two-thirds of the residential GSHP market. Though the volumes are small, trends suggest slow growth in the RNC market over time and limited opportunities in the retrofit market. See Appendix C.4.2 for additional detail.

GSHPs are easier to install in new homes than in existing homes. For example, installing GSHP loops or wells would disturb an established yard, while new construction lots can more readily accommodate the intrusive groundwork. Due to the complexity of GSHP installations, the likelihood of new GSHPs displacing different equipment types in retrofit scenarios is low. For example, they often require larger diameter duct work that may be hard to fit in an existing home. New GSHPs installed in retrofit scenarios are more likely to be replacing older GSHP equipment.

Table 14: GSHP Market Estimates

Year	High Estimate: Based on CT, MA, and RI Data	Middle Estimate: Average of High and Low	Low Estimate: CT Data Only
Residential retrofit			
2017	78	66	59
2018	42	29	22
2019	49	36	29
New construction			
2017	85	68	52
2018	92	72	53
2019	95	73	52
Total GSHP market			
2017	164	135	111
2018	133	102	75
2019	144	110	81

[16] The MSHP and ASHP market estimates rely on HARDI data, but HARDI data does not include GSHPs. Accordingly, the GSHP market size estimates rely on RNC and existing home baseline studies from Connecticut and surrounding states (see Appendix A.2.3 for additional details, including data limitations). This section presents GSHP market size estimates as a range, using different data sources to develop estimates of the number of systems installed.

GSHP program activity is limited and trended down between 2017 and 2019, though a slight increase of GSHPs installed in the RNC program was observed during the same period.

The number of incentivized GSHPs remained below 100 in each year and were 46% lower in 2019 compared to 2017. In 2018, GSHP installations decreased by 51% compared to 2017, and increased by 11% from 2018 to 2019. The proportion of incentivized GSHPs in the RNC program increased from 28% to 44% between 2017 and 2019 (Table 15~~Table 15~~). Note, due to the small number of systems installed, minor annual fluctuations can yield substantial percentage changes.

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Table 15: Program GSHP Counts

		Programs		
Year	Total Units	Residential Rebates	RNC	SBEA
Total GSHP program counts (units)				
2017	76	53	21	2
2018	37	16	21	--
2019	41	23	18	--

The estimated program penetration for GSHPs has decreased since 2017. In 2017, the program penetration was estimated to be between 46% and 69%, while it was between 29% and 51% of the market in 2019 (Table 16~~Table 16~~).

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The Connecticut Ground Source Heat Pump Impact Evaluation and Market Assessment conducted in 2014 found that few program eligible GSHPs are installed outside of the program.[17] Before 2013, additional incentives were available for GSHPs, such as a $2,000 per ton incentive (to a maximum of $12,000 per system) administered by the Connecticut Energy Financing and Investment Authority (CEFIA). However, this funding is no longer available.[18]

Contractors interviewed in the 2014 evaluation anticipated that installations would decrease or flatten with the expiration of the 30% federal tax credits in 2017. These tax credits were extended through 2019 before phasing out. The high installation costs and the loss of the larger state-level rebates, as well as customer awareness, may have contributed to a larger proportion of GSHP installations occurring outside of the rebate programs or contributed to lower demand overall. Currently, the Companies program offers an incentive of $750 per ton ($1,500 for oil and propane homes), capped at $15,000 per household.

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[17] https://www.energizect.com/CT/GSHPImpactEvaluation.pdf

[18] More recent GSHP installation counts for Connecticut were attempted to be procured from the Connecticut Green Bank, which formerly administered the CEFIA program. However, the information was not available.

Table 16: GSHP Program Market Share

Year	High Estimate: Based on CT, MA, and RI Data	Middle Estimate: Average of High and Low	Low Estimate: CT Data Only
Program penetration of GSHP market			
2017	46%	56%	69%
2018	28%	36%	49%
2019	29%	37%	51%

Installers often buy GSHPs directly from manufacturers, as distributors may not carry or do not specialize in these low-volume systems.

GSHPs: low volume for distributors. The interviewed GSHP manufacturer indicated that they do not sell through distributors, but directly to contractors since this is a lower volume product with niche installation contractors. Interviewed distributors confirmed that they did not do much business in GSHP.

Landscape of the HPWH Market in Connecticut

Market size estimates and market actor feedback indicate that the HPWH market has been flat in Connecticut in recent years.

The HPWH market experienced growth from 2016 to 2018 but levelled off in 2018 and 2019. Table 17~~Table 17~~ shows the estimated size of the HPWH market, including the number of HPWHs installed in retrofit and new construction applications.[19]

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Table 17: Preliminary HPWH Market and Program Estimates

Year	High Estimate: Based on CT, MA, and RI Data	Middle Estimate: Average of High and Low	Low Estimate: CT Data Only
Residential retrofit			
2016	980	943	906
2017	1,224	1,152	1,079
2018	1,483	1,373	1,264
2019	1,733	1,587	1,441
New construction			
2016	629	497	365
2017	655	561	467
2018	853	766	678
2019	635	528	404
Total HPWH market			
2016	1,609	1,440	1,271
2017	1,879	1,713	1,546
2018	2,336	2,139	1,942
2019	2,368	2,115	1,845

Installers reported that over three-fourths of HPWH installations occur in homes where the water heater has failed or is close to failure.

Most water heater replacements occur in scenarios where end-users want an immediate replacement. In these cases, most contractors favor like-for-like replacements, relying on technology that is readily available and that their customers already know. Distributors confirmed that the water heater market is predominantly replace on failure, with few water heaters replaced early. New construction installations represent a small subset of HPWH installations according to surveyed installers (8%), potentially a function of their business focus. (Table 18~~Table 18~~).

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[19] As with GSHPs, the market size estimates are presented as a range of equipment volumes given limitations in the available market data (see Appendix A.2.4 for additional details). The ranges are informed by new construction and existing baseline studies conducted in Connecticut and surrounding states.

Table 18: HPWH Installation Scenarios

(Source: installer survey; n=41)

Baseline Condition	Installer % of Total
Replacing a failed/near failure water heater	78%
Replacing a fully functioning water heater	12%
Building a new home	8%
Installing an extra water heater	2%

Growth of HPWHs in the retrofit market depends on distributors and retailers keeping larger volumes of HPWHs in stock. Switching to a HPWH typically would require effective salesmanship, a committed contractor, and sufficient, immediately available stock. The slight growth in the retrofit market suggests that distributors and retailers are stocking HPWHs more consistently. Additional details on the retrofit and new construction market estimates are in Appendix C.5.2.

Manufacturers and distributors interviewed for this project generally agreed that the HPWH market had grown in previous years but has flattened out more recently. However, over one-third of program-sponsored HPWHs are sold through retail channels, potentially giving distributors the impression that the market is smaller than it is. For additional details on distribution and retail channels, see Appendix C.5.3.

Among installers with HPWH experience, HPWHs constitute one in four water heater installations and are equally likely to be installed in both new construction and retrofit scenarios (24% in each market segment). While the rate of HPWH installs is the same, the retrofit or replacement market is far larger than the new construction market. The reported frequency in which HPWHs are installed in retrofit scenarios provides further evidence that HPWHs are available at distributors for emergency replacements.

Table 19: Percentage of Water Heater Installations that were HPWHs by Home Type

Home Type	n	Installer % of Total
Existing Homes % HPWH	48	24%
New Construction % HPWH	48	24%

The HPWH market is highly dependent on program incentives.

The number of incentivized HPWHs (including indirectly incentivized units) decreased by 13% since 2017. In 2018, incentivized HPWH installations decreased by 2% compared to 2017 and decreased by another 11% from 2018 to 2019. Table 21~~Table 21~~ displays the total number of HPWHs that were installed with the support of program incentives.

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Table 20: Program HPWH Counts

Year	Total Units	*Programs*	
		HPWH (Midstream and Instant Rebate)	RNC
Total HPWH program counts (units)			
2017	1,994*	1,803*	190*
2018	1,949	1,548	402
2019	1,726	1,620	106

* The 2017 HPWH midstream program counts are similar to HPWH activity in Connecticut reported by Connecticut Companies (n-1,807), which creates additional uncertainty in whether HPWHs in RNC program homes are included in the midstream program or if those systems are in addition.[20]

The programs' HPWH market share have decreased since 2017 but still represents the vast majority of the market. In 2017, program penetration was estimated to cover the entire HPWH market. The program coverage of the market potentially dropped to between 73% and 94% of the total market in 2019. Table 21~~Table 21~~ shows market share values for 2017 higher than 100%. These data irregularities are due to sometimes conflicting data sources. For example, baseline studies may underestimate the size of the market or program tracking data irregularities may have yielded an overestimate of program units.

Table 21: HPWH Program Market Share

Year	High Estimate: Based on CT, MA, and RI Data	Middle Estimate: Average of High and Low	Low Estimate: CT Data Only
Program penetration of HPWH market			
2017	*106%*	*116%*	*129%*
2018	83%	91%	100%
2019	73%	82%	94%

NAECA changes to federal standards have not driven universal HPWH adoption; distributors and manufacturers rarely sell HPWHs that do not get program incentives. In 2015, the National Appliance Energy Conservation Act (NAECA) raised the minimum efficiency standards of large tank (over 55 gallons) electric water heaters. Only HPWHs could meet these standards, effectively eliminating the residential market for large electric resistance tank water heaters. As HPWHs became the new federal minimum, programs like those in Connecticut dropped incentives for these large tanks. However, interviewees indicated that eliminating incentives for larger HPWHs led to a drop-off in sales almost completely. Instead of choosing large *unincentivized* HPWHs to meet customer needs, contractors can recommend other options, such as smaller electric resistance tanks set to higher temperatures, multiple smaller electric resistance tanks, large commercial tanks that bypass the federal residential requirements, and so forth.[21] Without the rebates for larger sizes, however, contractors may steer customers elsewhere, and sales of larger

[20] https://aceee.org/sites/default/files/pdf/conferences/hwf/2018/4d-moderator.pdf
[21] https://neea.org/img/documents/Northwest-Heat-Pump-Water-Heater-Initiative-Market-Progress-Evaluation-Report-5.pdf

HPWHs have suffered. The Companies have since reinstated incentives for larger HPWH tanks, which hopefully will help this technology gain market share.

Distributors also noted that the smaller capacity HPWHs may not be as attractive to end-users, especially families concerned about running out of hot water.

Most HPWHs in existing homes replace electric resistance and oil-fired water heaters.

Installers with HPWH experience said that over two-thirds of HPWH installations in existing homes replaced electric resistance units (70%) followed by oil systems (17%) (Table 22~~Table 22~~). Interviewed distributors confirmed this, noting that fuel switching was not common in the water heater market and most contractors choose to replace like with like.

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Table 22: Pre-existing DHW Fuel Replaced by HPWH, Existing Homes

(Source: installer survey; n=41)

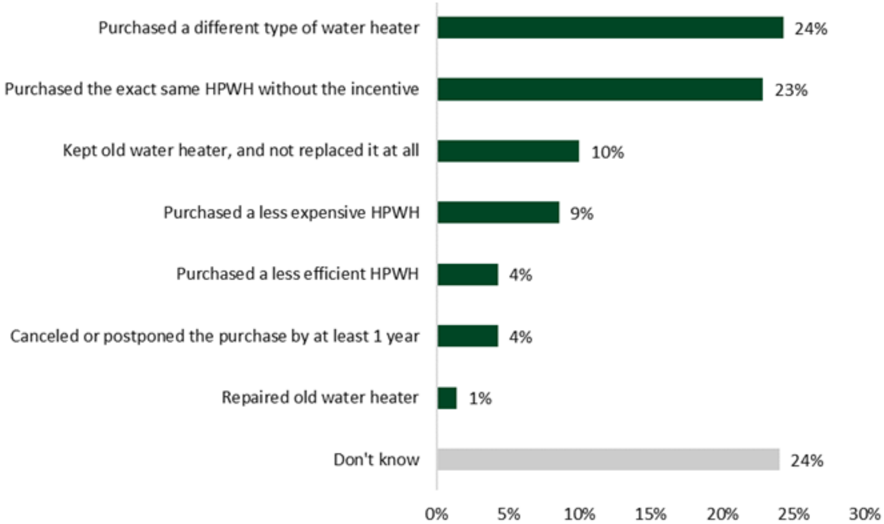
Replaced Fuel	% of Installs
Electric resistance	70%
Oil	17%
Natural gas	8%
Propane	5%

Free-ridership for HPWHs exists at lower rates than for MSHPs.

While 23% of HPWH purchasers said they would have bought the same system even without the program incentive and 24% were unsure what they would have installed, the remainder would have installed something other than the HPWH they installed. About 39% reported they would not have installed a HPWH without the incentive; 13% would have installed a cheaper or less efficient HPWH model.

Figure 27: DHW Decision Without Energize CT Incentive

(Source: end user survey; n=70)



Installer Attitudes: HVAC Heat Pumps and HPWHs

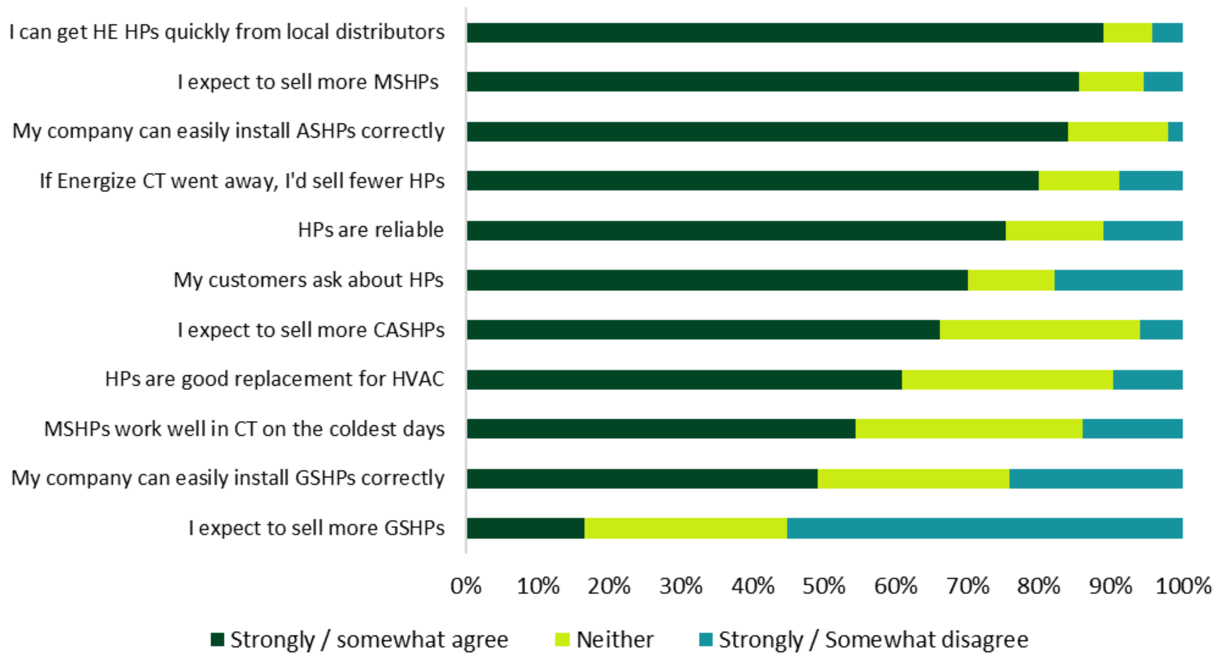
Installers with heat pump experience reported that HVAC heat pumps are available, reliable, they know how to install them, customers ask for them, and they expect to sell more of them (with the help of the Energize Connecticut programs). This indicates a strong market outlook for heat pumps in Connecticut.

Installers demonstrated highly positive attitudes toward HVAC heat pumps (including MSHP, ASHP, and GSHP) when asked to describe the extent to which they agreed or disagreed with a series of statements about them (Figure 28~~Figure 28~~). For example, the installers overwhelmingly confirmed that they can get them quickly through local distributors (89%) and that they will sell more MSHPs in the future (86%).

Some installers remain skeptical about heat pump performance in extremely cold weather and their ability to replace traditional HVAC equipment. Statements regarding cold weather performance were among the lower rated metrics, specifically that MSHPs work well in Connecticut on the coldest days (54%) and heat pumps are a good replacement for traditional HVAC (61%). This finding aligns with the study's market sizing analysis that showed that these systems are largely being installed as air conditioning or supplemental heating systems rather than as the sole system heating a home.

Figure 28: Installer Attitudes Toward HVAC Heat Pumps

(Source: installer survey; n=51)



Distributors and manufacturers reported that key barriers to heat pump adoption include contractors who are not yet comfortable recommending or installing heat pumps and low consumer awareness. They also cited equipment aesthetics, lack of support and communication from utility programs, and challenging installation issues associated with specific technologies, such as HPWHs have installation requirements such as sufficient makeup air volume, or GSHPs requiring wells or other underground loops (Table 23Table 23).

Table 23: Manufacturer and Distributor Assessments of Barriers to Heat Pump Adoption

(Source: manufacturer and distributor IDI; n=16, multiple response)

Barrier	# of Market Actors
Contractor comfort with new technology	11
Consumer awareness	11
Aesthetics	4
Lack of support from utility programs	3
Space for makeup air for HPWH	2
No barriers	2
Drilling for GSHP	1

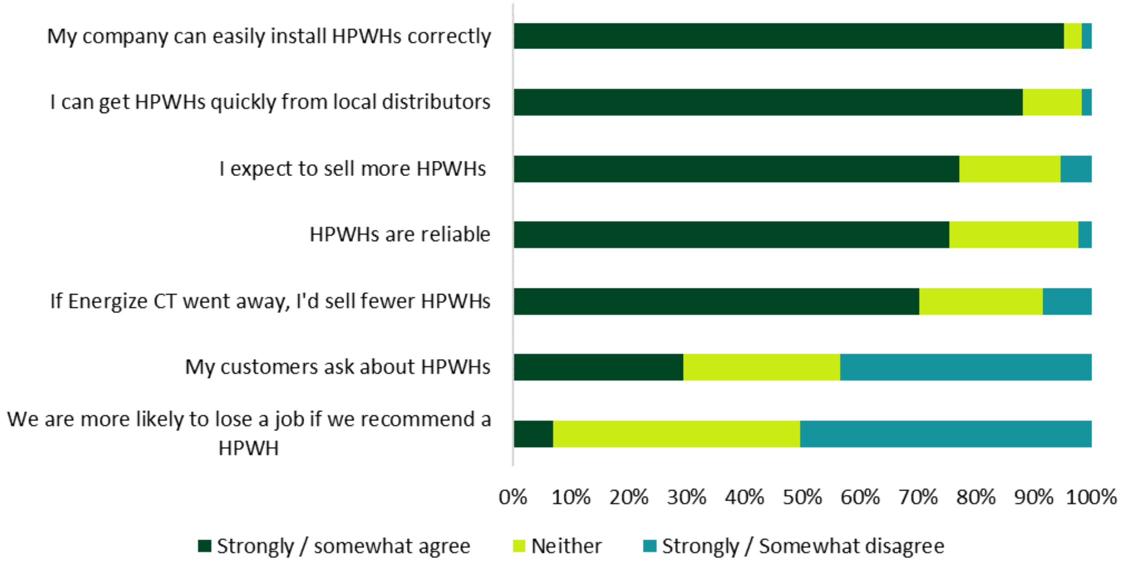
Installers described a strong future for HPWHs, as they are available and reliable.

HPWH installers indicated that they knew how to install HPWHs, they expected to sell more of them, and they are available (including for emergency replacements) and reliable (Figure 29Figure 29). To avoid callbacks, installers must be able to install these systems properly and easily – 95% of installers agreed they can. For HPWHs to be a viable option for emergency replacement scenarios, contractors must be able to purchase them locally – 88% agreed HPWHs are readily available for local distributors.

Customer awareness of HPWHs is limited. Only about one-third of installers said their customers ask about HPWHs (30%), indicating a low awareness level that would likely need to be overcome with strong salesmanship (Figure 29Figure 29).

Figure 29: Installer Attitudes Toward HPWHs

(Source: installer survey; n=41)



Installers recommend heat pumps frequently, and customers accept their recommendations most of the time.

Installers with heat pump experience frequently recommend MSHPs and ASHPs to customers, but they primarily do so for customers looking for supplemental systems. They usually recommended them to customers looking for additional heating or cooling systems in existing homes (Table 24~~Table 24~~). They recommend them less often to customers replacing entire systems or building new homes.

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Most customers accept their installers' MSHP and ASHP recommendations. Installers said their customers accepted MSHP recommendations nearly two-thirds of the time (63%), and ASHP recommendations over half the time (53%). This indicates the significant potential for installers to drive the market toward heat pumps simply by increasing their recommendation rates.

Table 24: Installers' MSHP and ASHP Recommendation Rates by Customer Type

(Source: installer survey; n=51)

Customer Type	MSHP	ASHP
Customers installing an additional heating or cooling system in an existing home	70%	58%
Customers replacing a cooling system in an existing home	54%	46%
Customers replacing a heating system in an existing home	42%	43%
Builder, contractor, or developer for new construction	37%	38%
Frequency that customers install based on recommendation	**63%**	**53%**

Installers recommended HPWHs more frequently in existing homes (66%) than new homes (50%) and customers in existing homes were more likely to accept the recommendations (71%) than were builders (42%) (Table 25Table 25). This likely indicates cost-consciousness on the part of builders, who may avoid systems with higher initial costs. However, this shows a market opportunity because new homes can be prime candidates for HPWH installations, given that they may have fewer installations challenges than in existing homes (e.g., basements with taller ceilings to accommodate physically large HPWHs).

Table 25: HPWH Recommendation Frequency by Customer Type

(Source: installer survey; n=40)

Customer Type	HPWH Recommendation Rate	Customer Uptake
Customers replacing a water heater in an existing home	66%	71%
Builder, contractor, or developer for new construction	50%	42%

In follow-up interviews, installers provided the specific factors that would drive them to recommend a HPWH to a customer. The most common factors, based on the frequency mentioned, reflect conditions where a HPWH may be cost-effective, or where it will physically fit and operate properly, such as:

- Pre-existing electric hot water heater,
- Moisture in basement (because HPWHs provide dehumidification that would be beneficial to these customers),
- Pre-existing oil hot water heater, and
- Sufficient volume of makeup air.

Most participants (77%) said their installer told them about proper HPWH settings. This indicates that installers are familiar with how these systems work and know to educate purchasers about how to use them properly. Participants said installers most frequently recommended they use hybrid mode, where the system operates as a heat pump when possible (65%, Table 26Table 26).

Table 26: HPWH Mode Settings

(Source: end user survey; n=54)

HPWH Setting	End User %
Hybrid	65%
Heat pump only	30%
Electric resistance only	2%
Don’t know	3%

Satisfaction and Reliability: HVAC Heat Pumps and HPWHs

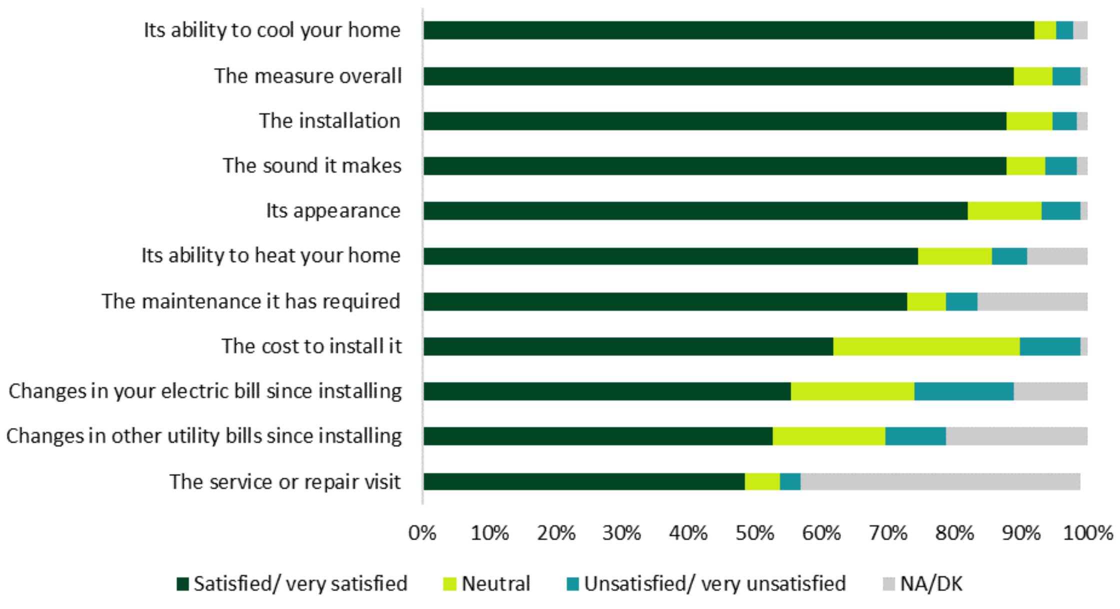
HVAC heat pump and HPWH users reported high levels of reliability and satisfaction with their equipment.

HVAC heat pump owners like their systems: 89% were satisfied overall (Figure 30~~Figure 30~~). Most surveyed owners were satisfied with the system itself and their experience with its installation, maintenance, and operation. For every metric assessed, most owners said they were satisfied or very satisfied, including potential problem areas such as the unit's ability to cool or heat the home, the sound it makes, and its appearance.

Users were least satisfied with operation and installation costs, but most were still satisfied on these metrics. Criteria with the lowest level of satisfaction were changes to the respondents' electric bill (15% unsatisfied), changes to other utility bills (9% unsatisfied), and the cost to install the heat pump (9% unsatisfied). Those unsatisfied with their bills reported that their electric bills had increased or that they did not see the savings they expected after installing the heat pump. These less-satisfied users were mostly made up by those who used oil as their primary heating fuel.

Figure 30: End User Satisfaction with HVAC Heat Pumps

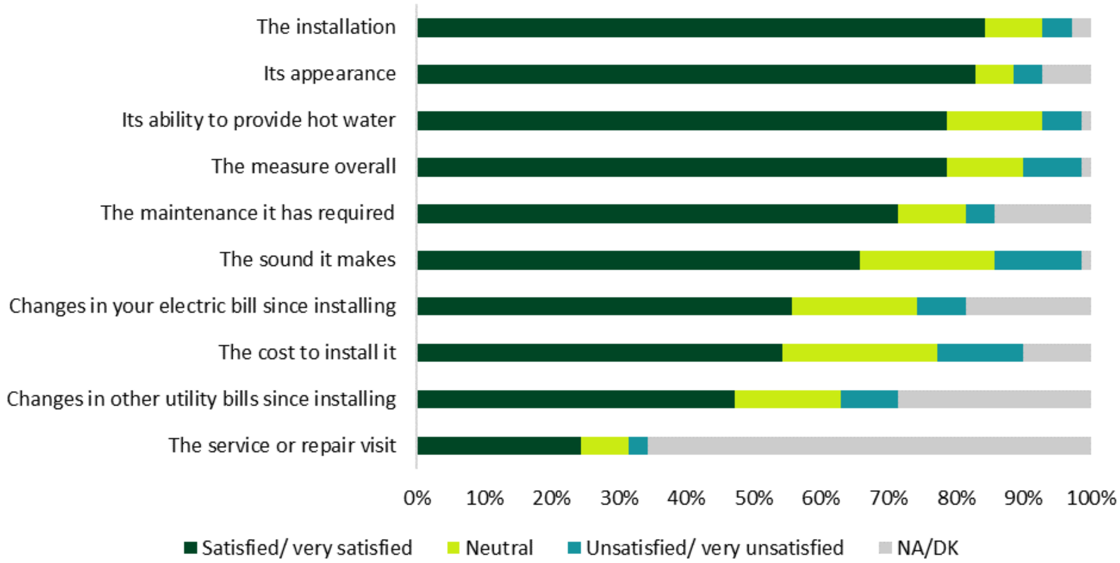
(Source: end user survey; n=188)



HPWH owners are also highly satisfied with their water heaters: 79% were satisfied or very satisfied overall. At least two-thirds of all respondents were satisfied with key aspects of their system, including the installation, the appearance of the unit, its ability to provide hot water, the water heater overall, its required maintenance, and its noise levels. Only a handful of end users expressed dissatisfaction the equipment. End users had the lowest satisfaction with the cost to install the HPWH (13% unsatisfied) and the sound it makes (13% unsatisfied).

Figure 31: End User Satisfaction with HPWHs

(Source: end user survey; n=70)



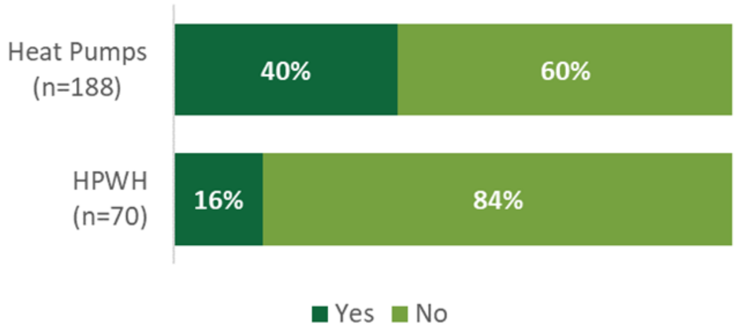
HVAC heat pump and HPWH users said their systems were reliable and had only needed limited repairs.

Surveyed respondents had multiple years of experience with their systems, as the survey was conducted in 2021 with customers who bought their units between 2017 and 2019. The survey asked respondents to consider the service and repair visits they had experienced since owning their systems. “Service” was defined as regular preventative maintenance or tune-ups – work done to keep the system running smoothly, not in response to a problem. “Repair” was defined as having work done to fix an actual problem or performance issue.

Users reported modest rates of service and repair for HVAC heat pumps, low rates for HPWHs. Two-fifths (40%) of HVAC heat pump owners reported their system had undergone repair and/or service since installation (Figure 32~~Figure 32~~). However, many of those visits were simply annual tune-ups, not a sign of malfunctioning equipment. Less than one-fifth (16%) of HPWH owners had any repair or service work done since installing their units.

Figure 32: Has the New Heat Pump Needed Service or Repair?

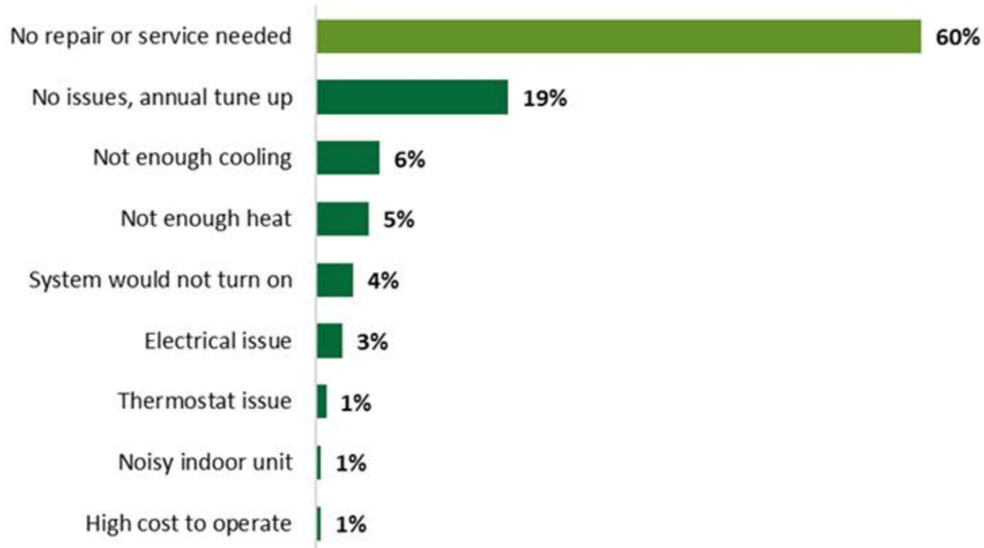
(Source: end user survey; HP n=188, HPWH n=70)



Among the 40% of HVAC heat pump owners reporting the need for service or repair, over one-half were annual tune-ups with no actual issue reported (Figure 33~~Figure 33~~). The most common issues reported were not enough cooling or not enough heat, although the system would not turn on for 4% of end users. These are not necessarily indications of an actual mechanical failure – some of these were likely minor issues or involved users not familiar with how to operate their new systems.

Figure 33: Reason for HVAC Heat Pump Service or Repair

(Source: end user survey; n=188)



Repair cost and frequency. HPWH owners reported infrequent and generally inexpensive repairs (Figure 34~~Figure 34~~). All GSHP owners reporting repairs did not report paying anything for repairs. MSHP owners generally reported more repairs, which were the most expensive. The figure below describes costs for customers who had repair visits (including those who may not have had to pay for them), and separately shows average costs across all users, including those who had no repair visits and thus no repair costs.

Of those needing repairs, MSHP end users reported an average of 1.5 total repair visits annually since installation (n=57, normalized across ownership period). Of those needing repairs, HPWH end users reported an average of 0.6 annual repair visits since installation (n=11, normalized across ownership period).

Figure 34: Cost and Frequency of Heat Pump Repair

(Source: end user survey)

		Customers w/ Repair Visits	All Customers
Customers w/ Repair Visits	MSHP (n=170)	-	26%
	ASHP (n=12)	-	33%
	GSHP (n=6)	-	33%
	HPWH (n=70)	-	13%
Avg # of Repairs/Year	MSHP	1.5	0.4
	ASHP	1.2	0.4
	GSHP	1.8	0.6
	HPWH	0.6	0.1
Avg TOTAL Repair Costs	MSHP	$205	$54
	ASHP	$113	$28
	GSHP	$0	$0
	HPWH	$167	$21

Service and repair costs – warranties often cover costs. The survey asked about warranties on their equipment as well as costs of service and repair visits.

- Nearly half (47%) of HVAC heat pump owners and over half (6 out of 11) of HPWH owners said their warranty covered the entire cost of repairs and/or service.
- Among those having service, the average cost for a MSHP service visit was about $248 (n=60). Seventeen of the 60 (28%) end users reporting a service visit paid nothing.
- The average cost for HPWH service visits was about $205 (n=9). Two of the nine HPWH end users reporting a service visit did not have to pay for it, and four of the nine reporting a repair visit did not pay anything.
- GSHP end users reported paying nothing for service or repair visits.

Most HVAC heat pump owners (88%) indicated that they did not have any difficulty finding technicians who were able to service their equipment, as did HPWH end users (10 out of 11).

Visit timing. Respondents who needed a service or repair visit described how soon after the installation they contacted a professional for a visit. Although fewer HPWH users reported the need for a repair or service visit, any visit came sooner than for MSHP owners, indicating either a higher prevalence of early issues or that customers noticed DHW problems sooner than heating/cooling issues.

- MSHP owners reported an average time of 9 months before they needed a service visit (n=60) and 9.4 months before they needed a repair visit (n=45).
- HPWH owners reported an average time of 6.8 months before they needed a service visit (n=9) and 7 months before a repair visit (n=9).

Issues needing repair. The most common issues identified at HVAC heat pump repair visits were refrigerant leaks (30%) and issues with electrical components (28%). Only eight HPWH users provided detail on the issue, the most common being water leaks, electrical components, and plumbing lines (two users each). This information should be viewed with caution, as respondents were not themselves professionals and time had passed since the visit in many cases.

Table 27: Heat Pump Component Repaired or Replaced

(Source: end user survey; n=50, multiple response)

Issue or Component	End User %
Refrigerant leak	30%
Electrical components	28%
Plumbing lines, pipes, or fittings	10%
Replaced outdoor unit	6%
Thermostat settings	4%
Thermostat itself	4%
Defrost cycle issues	4%
Filter replacement	4%
Tightening screws or fasteners	4%

As shown in Figure 35~~Figure 35~~, nearly two-thirds (64%) of HVAC heat pump owners got a service or repair visit within two to three days of requesting one. Problematically, over one-quarter (28%) had to wait two weeks or more before a technician could come out. Most HPWH end users (8 out of 11) were also able to get a service or repair visit within two to three days.

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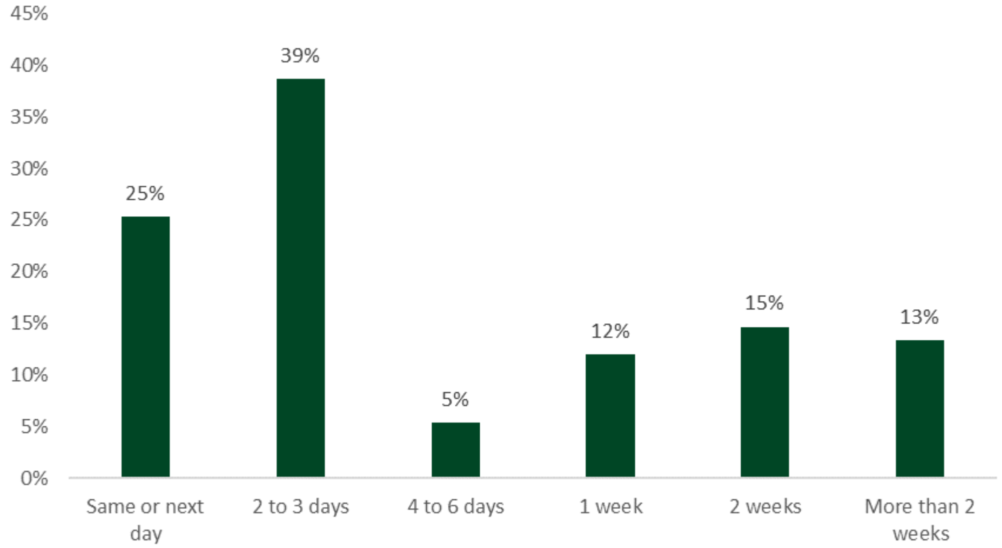
Figure 35: Wait Time for a Service or Repair Visit (HVAC Heat Pumps)

(Source: end user survey; n=75)



Installers reported that customer complaints about their heat pumps within the first year after install were relatively infrequent.

Surveyed installers – contractors who already installed heat pumps – were asked how often they got customer complaints within the first year of installation. Potential issues included aesthetic complaints, costs to repair or operate, noise, or providing insufficient heating, cooling, or hot water. Respondents could rate their complaint rates as *almost always*, *more than half of the time*, *sometimes*, *rarely*, or *never*. The following subsections describe the results of those ratings. These assessments are imperfect, as they are limited to the complaints that customers made *to installers* within the first year.

Most MSHP installers said that customer complaints in the first year were relatively infrequent – not producing enough heat was the most common issue. For almost all metrics, at least two-thirds of installers said they rarely or never got such complaints (Figure 36~~Figure 36~~). However, about half (49%) indicated that they “sometimes” got complaints that the MSHP was not producing enough heat, a potentially problematic assessment. The least frequent complaints that installers heard were about system noise, both the indoor unit (8%) and the outdoor unit (11%).

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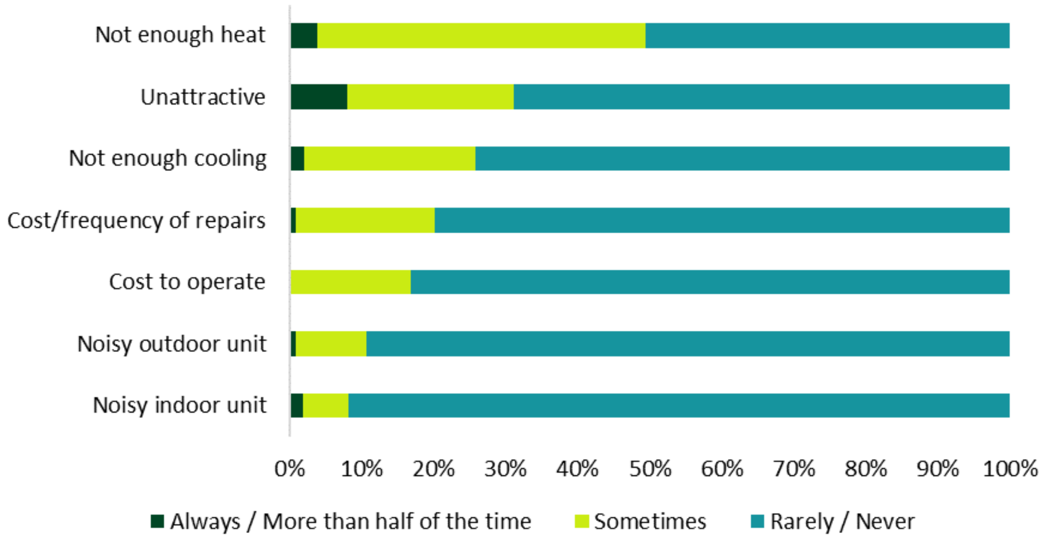
Figure 36: MSHP Frequency of First-Year Customer Complaints to Installers

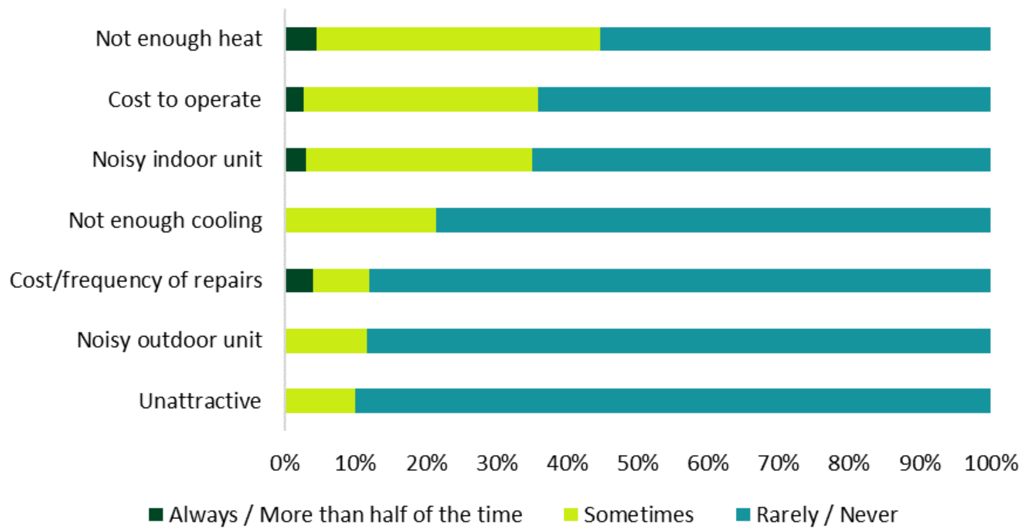
(Source: installer survey; n=48)



Like MSHPs, the most common customer complaint for ASHPs was that they did not produce enough heat, with just under half (45%) indicating it was an issue at least sometimes. The next most common complaint was the cost to operate the unit (36%) (Figure 37~~Figure 37~~).

Figure 37: ASHP Frequency of First-Year Customer Complaints to Installers

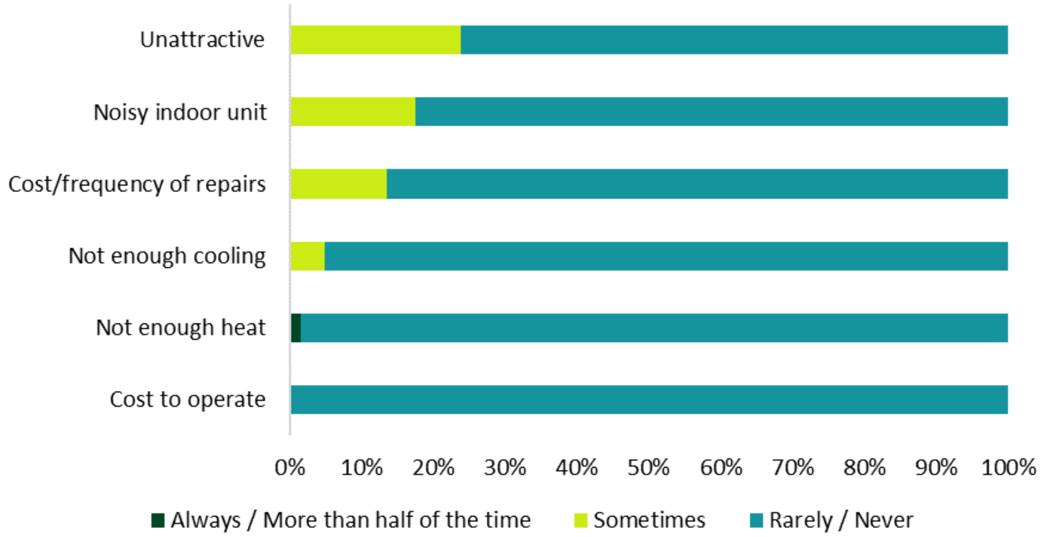
(Source: installer survey; n=45)



Installers reported fewer customer complaints for GSHP than other types of heat pumps, though sample sizes were small. The most common complaint was that the units were unattractive, for which about a quarter (24%) said it was an issue only some of the time (Figure 38~~Figure 38~~). All of the installers said that the cost to operate was rarely or never a complaint that they heard from customers, indicating high satisfaction for this high-efficiency (but high upfront cost) heat pump system.

Figure 38: GSHP Frequency of First-Year Customer Complaints to Installers

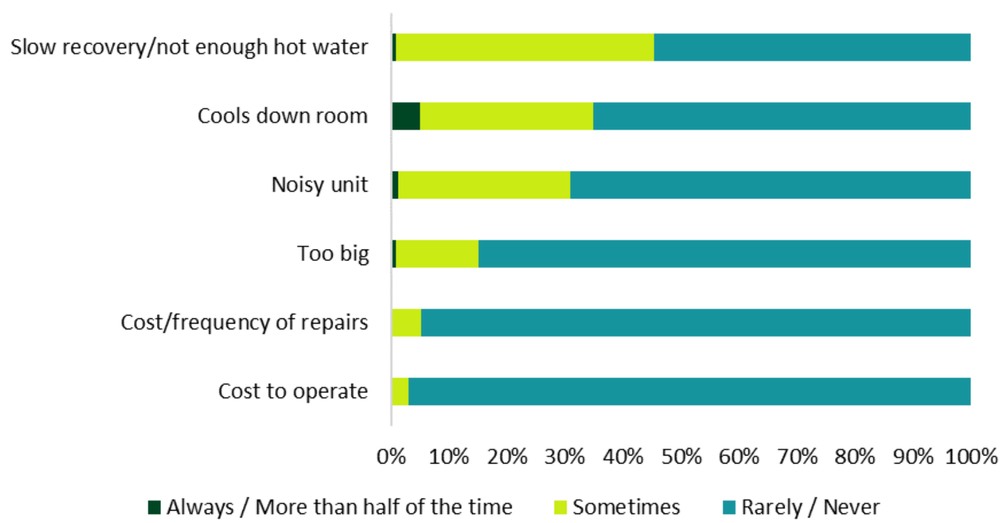
(Source: installer survey; n=14)



The most common complaint installers reported for HPWHs was slow recovery time or not enough hot water, with over half (54%) of installers saying they heard this complaint at least some of the time. Over a third (35%) said that they sometimes get complaints about the unit cooling down the room where it is located. The least common complaints were the cost to operate the unit (3%) and the cost or frequency of repairs (5%) (Figure 39~~Figure 39~~).

Figure 39: HPWH Frequency of Customer Complaints

(Source: installer survey; n=40)



Customer Cost-Effectiveness: MSHP, ASHP, and HPWH

MSHPs and ASHPs are most cost effective when replacing electric resistance heat and some type of cooling.

The study included a cost effectiveness forecast for several residential heat pump installation scenarios using the Participant Cost Test. This test evaluates measures from the perspective of the customer installing the measure. A measure with a ratio of 1.0 or greater is deemed as cost-effective.

Table 28~~Table 28~~ summarizes the Participant Cost Test results for the selected MSHP, ASHP, and HPWH installation scenarios. The table shows the primary results as well as results based on increasing and decreasing costs by 20% to show the sensitivity of results around installation cost. Scenarios that resulted in a participant cost test ratio of 1.0 or greater **in boldface** are deemed as cost-effective measures from a customer perspective. Non-energy impacts are not included in these test results, but cost effectiveness would likely improve if they were included.

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Overall, MSHPs and ASHPs are more cost-effective for customers offsetting or replacing electric resistance heating than for those offsetting oil boiler usage. This trend is observed in scenarios with oil boilers as the baseline heating being consistently lower than 1.0 (scenarios A, B, G, H, M, N) and electric resistance baseline heating being generally higher than 1.0 (scenarios C, D, E, F, I, J, K, L, O, P). This is predominately due to the cost savings from the reduction in electric use due to displacement of electric resistance heating being greater than the cost savings from the reduction in oil use.

The following trends are also observed:

- MSHP and ASHP scenarios pass the cost-effectiveness test when partially or fully offsetting electric resistance heat in areas that also have mechanical cooling (scenarios C, D, I, J, O, P).
- ASHP scenarios passed the cost-effectiveness test when offsetting electric resistance heat and central AC (scenarios O and P) and when looking at the low-end cost range for full replacement of an oil-fired boiler system and central AC (scenarios M and N).
- Replacement of both electric and oil-fired water heaters with HPWHs (scenarios Q and R) resulted in the highest cost effectiveness ratios of the heat pump system types.

Though several scenarios did not pass the overall cost-effectiveness test, all but two passed when looking at low end cost results. In fact, all except partial displacement of oil-fired boilers with MSHPs (scenarios A and B) resulted in an overall participant cost test ratio of greater than 0.8 and passed the test using the low-end cost ranges.

Table 28: Heat Pump Participant Cost Test Results

Scenario	Type	Tons/ Gall	Cooling (SEER)	Heating (HSPF/ UEF)	Heat Displacement	Heat Replacement Scenario	Baseline Cooling	Baseline Heating	Low End Cost Test	Result	High End Cost Test
A	MSHP	1	20	10.6	Partial	Retro	RAC	Oil Boil	0.81	0.62	0.50
B	MSHP	2	17.6	10.6	Partial	Retro	RAC	Oil Boil	0.80	0.61	0.49
C	**MSHP**	1	20	10.6	Partial	Retro	RAC	ER	**1.52**	**1.16**	0.93
D	**MSHP**	2	17.6	10.6	Partial	Retro	RAC	ER	**1.50**	**1.14**	0.92
E	MSHP	1	20	10.6	Partial	Retro	None	ER	**1.03**	0.82	0.69
F	MSHP	2	17.6	10.6	Partial	Retro	None	ER	**1.02**	0.81	0.68
G	MSHP	3	17.6	10.6	Full	ROF	RAC	Oil boil	**1.39**	0.97	0.75
H	MSHP	4	17.6	10.6	Full	ROF	RAC	Oil boil	**1.27**	0.91	0.71
I	**MSHP**	3	17.6	10.6	Full	Retro	RAC	ER	**2.27**	**1.73**	**1.39**
J	**MSHP**	4	17.6	10.6	Full	Retro	RAC	ER	**2.27**	**1.73**	**1.39**
K	**MSHP**	3	17.6	10.6	Full	Retro	None	ER	**1.46**	**1.17**	0.97
L	**MSHP**	4	17.6	10.6	Full	Retro	None	ER	**1.46**	**1.17**	0.97
M	ASHP	3	17.6	10.6	Full	ROF	CAC	Oil boil	**1.20**	0.86	0.67
N	ASHP	4	17.6	10.6	Full	ROF	CAC	Oil boil	**1.10**	0.81	0.64
O	**ASHP**	3	17.6	10.6	Full	Retro	CAC	ER	**2.10**	**1.62**	**1.32**
P	**ASHP**	4	17.6	10.6	Full	Retro	CAC	ER	**2.10**	**1.62**	**1.32**
Q	**HPWH**	50	N/A	3.3	Full	ROF	N/A	ER	**14.89**	**7.06**	**4.62**
R	**HPWH**	50	N/A	3.3	Full	ROF	N/A	Oil WH	**>20.00**	**17.68**	**3.74**

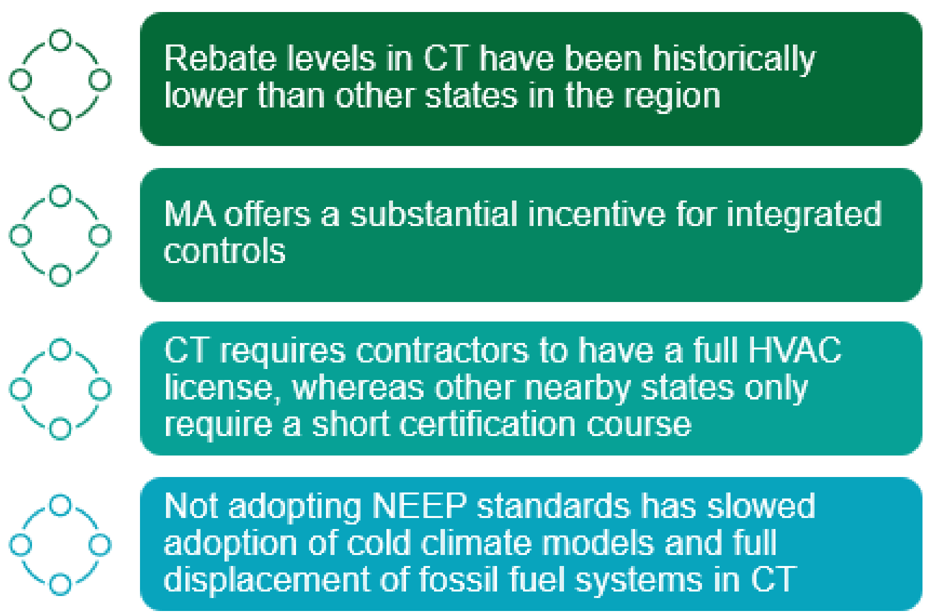
Distributor Feedback about Energize Connecticut Programs

Distributors reported that additional administrative burden has been put on them in a midstream program design, but the program can take steps to ease this.

Additional administrative burden noted by distributors could dissuade them from pushing program heat pumps and lead to tracking data with gaps or quality issues. Some specific issues reported during interviews were the following:

- Lack of clarity on qualifying equipment and no way to pre-qualify; distributors reported having to pay rebates to contractors and hope that the equipment qualified, leading to losses.
- Communication with the program has been poor; questions about qualifying equipment and program applications go unanswered for long periods of time.
- Distributors have had to hire staff or divert existing staff time to process rebates but do not recoup that money for additional effort.

Distributors also reported some differences in program delivery that may account for the regional differences seen in MSHP adoption, detailed below:



Appendices

The following appendices provide additional detail about the methodology and results from the combined R1965 and R2027 studies. The appendices include the following:

- Appendix A Detailed Methodology~~Detailed Methodology~~
- Appendix B Literature Review~~Literature Review~~
- Appendix C Market Sizing Detail~~Market Sizing Detail~~
- Appendix D Market Actor Feedback Additional Detail~~Market Actor Feedback Additional Detail~~
- Appendix E End User Feedback Additional Detail~~End User Feedback Additional Detail~~

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Appendix A Detailed Methodology

This appendix presents the detailed methodology for the research tasks conducted in the study.

A.1 Literature Review

The study began with a comprehensive review of available literature and data sources to understand the heat pump market and develop a clear understanding of the Companies' program efforts. The study focused on gathering materials that addressed:

- The sales volumes of heat pumps in Connecticut and surrounding jurisdictions.
- Efficiency, capacity, and configuration data for residential heat pump systems.
- Opportunities and challenges associated with system uptake both current and in the future.

The literature review gathered information from a variety of sources which included, but were not limited to:

- .
- Connecticut program tracking data and program materials.
- Regional and national studies.
- Sales volume data (i.e., HARDI data, AHRI, DOE, and EIA).

Overall, the study sought literature relevant to the heat pump market and reviewed eight studies that were specific to Connecticut and nine studies that were either regional or national. The reviewed studies most often covered multiple heat pump technologies (six studies) followed by MSHP and HPWH (five studies each) and then GSHP (two studies). As a part of the R2027 addition, the literature review expanded to cover sources that provided details on heat pump and HPWH reliability, customer satisfaction and perceptions of heat pump technology, and the costs associated with heat pump technology.

Note additional data sources that were found during the literature review but were only used to estimate the size of the market are detailed in Appendix A.2.1. The findings of the literature review are presented in Appendix B.

A.2 Market Sizing

The market size estimates rely on primary data and secondary data, as there is no one single, commercially available database of all mechanical equipment installed in a given state. Due to limitations of available data, it is important to note that the values presented in this report represent approximations rather than actual counts.

As previously described, the literature review task gathered relevant secondary data sources and compiled primary research efforts conducted as a part of previous evaluation and market research studies. The study conducted additional primary research to minimize data gaps and identify key data sources to provide insights into the Connecticut market. The in-depth interviews and surveys included in this study are used to qualitatively understand the quantitative data gaps and provided additional insight into the functioning of the market.

A.2.1 Data Sources

The specific methods for calculating estimates differ by equipment type as the available data varied by equipment type. The data sources used to inform the market size estimate are detailed below.

For ASHPs, both inverter and non-inverter, the study used HARDI data to determine the size of the market. The HARDI data provide sales estimates from 2013 to the date of the analysis for ASHPs, CACs, and furnaces and boilers (gas/propane and oil).[22] HARDI data are primarily based on sales invoices and other reports from HVAC distributors that are HARDI members. Those sales invoices are weighted to represent all equipment sales across a given region based on the EIA's 2015 Residential Energy Consumption Survey (RECS) and Commercial Building Energy Consumption Survey (CBECS) and the U.S. Census' American Housing Survey.

The HARDI data includes the following relevant metrics for each of the following equipment types:

- Proportion of ducted and ductless ASHPs and central air conditioners.
- Estimated efficiency distribution.
- Equipment capacity.

NMR vetted the HARDI market size estimates as a part of this study and for related work in other states.[23] For the purposes of this study, the HARDI equipment estimates are assumed to equal the size of the market for each corresponding state.

The Companies also provided tracking data for incentivized residential-grade heat pumps installed in both residential and commercial settings, from their portfolio of programs. The study used program data, secondary data, and HARDI data to analyze the past and the current state of the market, program penetration of the market, and provide insights into potential future trends of heat pump adoption in Connecticut. When the necessary data was available, the penetration of the program compared to the program-eligible market was estimated.

The study drew upon a variety of sources to understand the market and develop market estimates for each equipment type. The various data sources provided some insight into the heat pump market in Connecticut to varying degrees of usefulness. Figure 40~~Figure 40~~ depicts the data sources that were reviewed, explored, and ultimately used to develop market estimates. Additional details on how the study leveraged these different data sources are provided below.

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Program Data Limitations. The Companies provided program data for 2017 through 2019 to determine the program penetration for the equipment types covered in the study. A review of program tracking data from 2017 to 2019 identified potential overlap between programs, which

[22] Note that boiler equipment is only estimated at the census region level due to limited volumes of equipment.
[23] http://ma-eeac.org/wordpress/wp-content/uploads/TXC65_HARDI_Data_Memo_Final_2019.11.15.pdf

led to uncertainty in total program counts. Data limitations included non-unique placeholder account numbers and account numbers and system matches in different program data sets, which reflects potential double-counting of system installations. The Companies confirmed that a participant may receive two rebates for the same system, such as a midstream instant discount and an HES program electric mail-in rebate. The Companies indicate this is a part of program design and is used to encourage electric resistance conversions to heat pump technology. The program market share estimates described below reflect an attempt to identify and remove any such overlap to the extent possible, but some uncertainty remains.

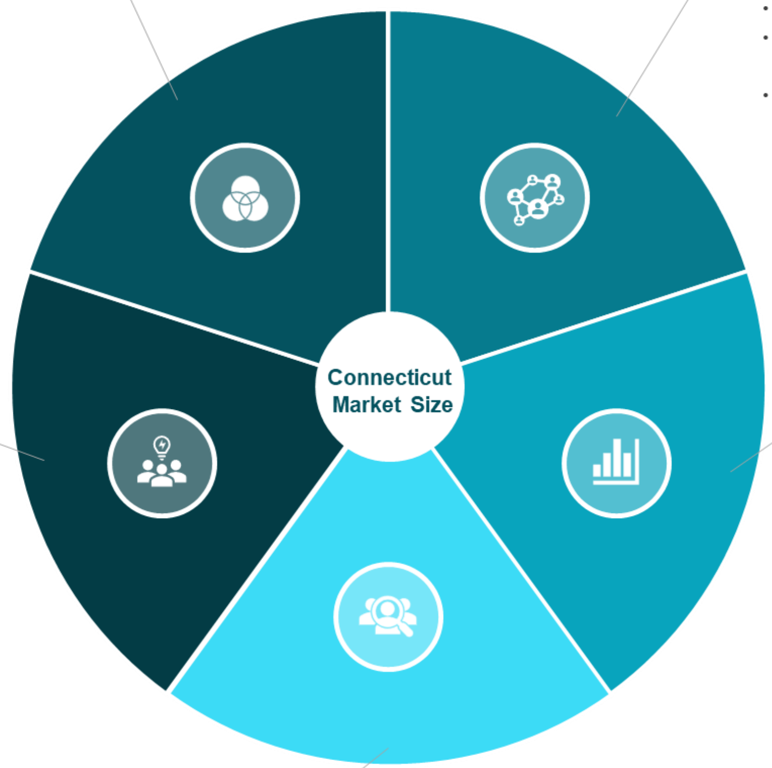
Figure 40: Market Estimate Data Sources

Non-CT Evaluations

- 2015, 2017, and 2019 Massachusetts RNC baseline studies
- 2011 and 2017 Rhode Island RNC baseline studies
- 2018-2019 Massachusetts RES-1 Existing Homes baseline
- 2018 Rhode Island Residential Appliance Saturation Survey

National Data

- AHRI Historical National Sales Data
- ENERGY STAR Database
- HARDI Data
- U.S. Census American Community Survey
- U.S. Census Building Permits Survey



CT Evaluations

- 2011 and 2017 CT RNC Baseline Studies
- 2013 GSHP Impact Evaluation and Market Assessment
- 2014 SF weatherization baseline study
- 2018 MF Baseline weatherization study
- 2018 RASS study and database

Program Data

Program Years 2017-2019

- Residential HVAC Program
- Heat Pump Water Heater Midstream Program
- Home Energy Services Program
- Residential New Construction Program
- Small Business Energy Advantage
- Large C&I programs

Primary Data

- In-depth Interviews
- Web-survey Results

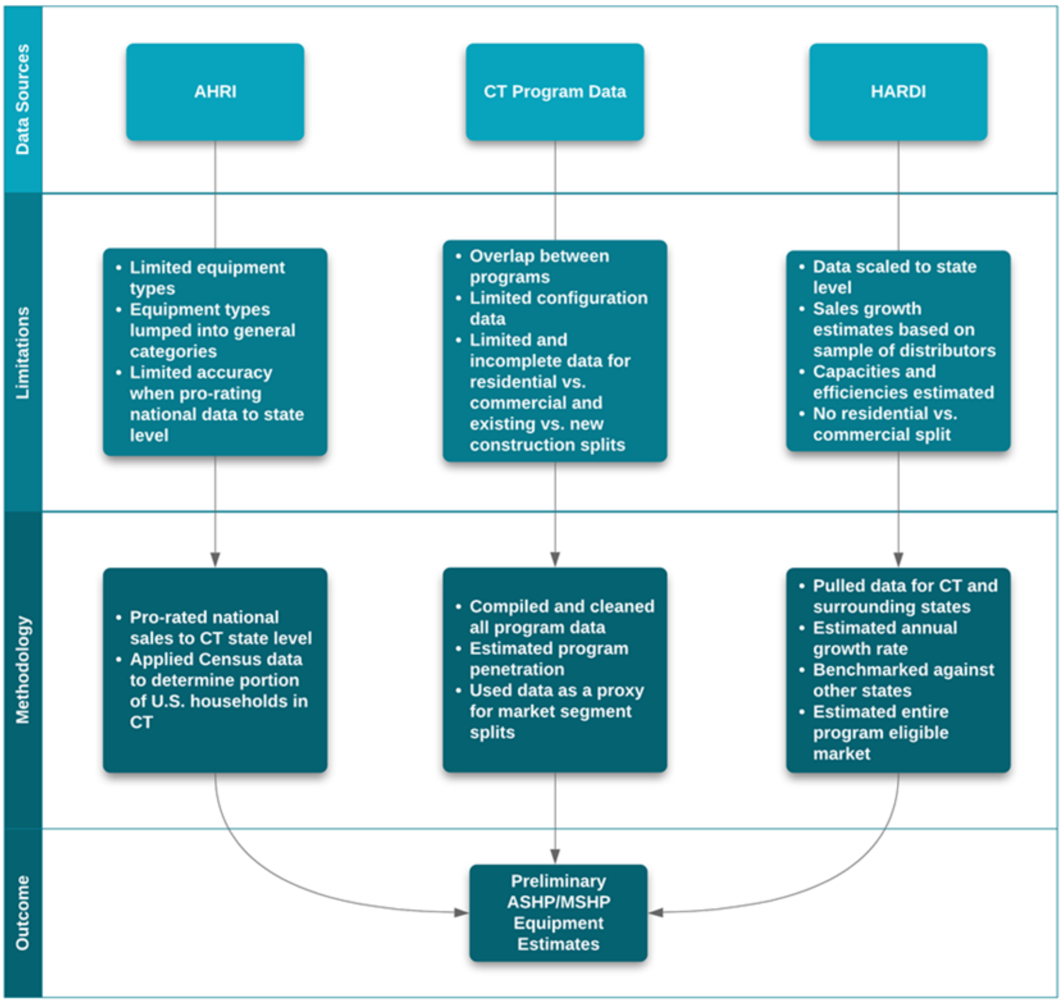
A.2.2 Estimated MSHP and ASHP Market Size Methodology

The study relied on HARDI data to construct the market estimates for ASHPs and MSHPs. The HARDI data include sales estimates from 2013 through 2019. The HARDI data was used to benchmark the Connecticut market against other states in the region including:

Connecticut | Massachusetts | New York | Rhode Island

Figure 41~~Figure 41~~ depicts, at a high-level, the methodology used to process the MSHP and ASHP data sources used for this study. Each data source has limitations that are identified within the figure.

Figure 41: MSHP and ASHP Market Estimate Methodology



Estimating Heating Efficiency. The HARDI data only provides cooling efficiency estimates in their data. To determine the heating efficiency for both MSHP and ASHP equipment, the study imputed HSPF values calculated as a function of cooling efficiency and equipment capacity, which are provided in the HARDI data. The study leveraged an approach to impute HSPF values that was developed for the Massachusetts TXC65 study (the detailed methodology is provided in Appendix A of the TXC65 report).[24] An overview of the equations used to estimate heating efficiencies in ASHP and MSHP equipment are provided below.

Rather than precise model-specific details regarding efficiency and capacity, the HARDI data groups systems into SEER values at the integer-level and cooling capacities in half-ton (6,000 BTUh) increments, which complicated efforts to develop a granular model of HSPF for the systems included in the HARDI data. After testing multiple modeling approaches, the analysis generated average HSPF values for each cooling capacity/SEER bin of AHRI data for nearly 800,000 heat pump systems from the AHRI directory and ran regressions on the resulting matrix. This approach resulted in two equations to estimate HSPF for the systems in the HARDI data: one for ASHP systems below 24 SEER and one for those at 24 SEER and above.

$$HSPF = \begin{cases} 4.176 + 0.285 \times SEER + 0.007 * CoolCapacity, SEER < 24 \\ 4.141 + 0.262 \times SEER + 0.067 * CoolCapacity, SEER \geq 24 \end{cases}$$

This equation uses one regression for all ASHP systems below 24 SEER (central ducted systems and ductless mini-split systems) and a separate regression for ductless ASHP systems 24 SEER and above because, in investigating the system-level AHRI specifications, we found that 24 SEER represented a clear break in heating performance. The resulting model has a Pearson correlation of 0.748 with the original AHRI data, and 0.958 with the model inputs.

The market size analysis considered combined heating and cooling efficiency categories for MSHP and ASHP equipment to understand the proportion of equipment that fell into certain efficiency categories. The process for binning equipment estimates into efficiency categories required that the equipment meet both the cooling and the heating minimum efficiencies displayed in the category.

EER to SEER conversion. The ASHP data for HARDI presented cooling efficiency information in SEER units while the program data only provided EER values for ASHPs. To maintain consistency for comparisons between the two data sets, the program cooling efficiency values were converted from EER to SEER. This was also done to maintain consistency with how cooling efficiency is expressed with other HVAC equipment types included in the HARDI data (i.e., MSHPs and CACs). Note the converted program efficiency values do not result in exact values that would be found using a model number lookup. The study applied the inverse of the SEER to EER conversion determined by Texas A&M University's Energy Systems Laboratory for EER values less than 15 and a simplified equation from AHRI for EER values greater than 15.[25,26]

[24] http://ma-eeac.org/wordpress/wp-content/uploads/TXC65_HARDI_Data_Memo_Final_2019.11.15.pdf
[25] http://oaktrust.library.tamu.edu/bitstream/handle/1969.1/152118/ESL-TR-13-04-01.pdf
[26] http://www.ahrinet.org/App_Content/ahri/files/standards%20pdfs/ANSI%20standards%20pdfs/ANSI.AHRI%20Standard%20210.240%20with%20Addenda%201%20and%202.pdf

$$SEER = \begin{cases} (25.2675 - 0.0043859 \times \sqrt{(33{,}189{,}100 - 2{,}280{,}000 * EER)}), EER < 15 \\ (1 \div 0.875) \times EER, EER \geq 15 \end{cases}$$

MSHP Configuration Estimates. The study used the available information in the HARDI data to determine configuration estimates for MSHP equipment (i.e., single- and multi-zone configurations) based on equipment capacity. The configuration estimates were supplemented with program tracking data, which included configuration, generally in the form of rebate amounts[27], and system capacity data. The analysis of program data indicated that there were relatively clear cut-off points for single-zone systems, generally smaller sized systems, and for typically larger multi-zone configurations. However, the analysis indicated that systems between 18 kBtu and 24 kBtu were a mix of single- and multi-zone configurations. To account for this in the broader market configuration estimates, the proportion of single-zone and multi-zone systems observed in the program data were applied to the HARDI data equipment estimates that fell into these equipment capacity ranges. The configuration assumptions are displayed in the Table 29Table 29 below.

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Note that zone configuration was sometimes provided in program data but was mostly based on the rebated amount included in the data. The program provides specific rebate amounts based on whether the MSHP system is either single-zone ($300) or multi-zone ($500).

Table 29: MSHP Configuration Estimate Assumptions by System Capacity (kBtu)

System Capacity	Single-zone	Multi-zone
<18 kBtu	100%	0%
18 kBtu	61%	39%
24 kBtu	17%	83%
>30 kBtu	0%	100%

A.2.3 Estimated Geothermal Market Size Methodology

The study relied on multiple data sources to estimate the GSHP market given that the penetration of geothermal systems in recent Connecticut studies was less than 1% of homes. Readers should note that there is inherent uncertainty involved in scaling up such a small penetration to represent an entire market. The market size estimates used a linear regression model to estimate equipment saturation over time to predict the current size of the GSHP market. The GSHP estimates were constructed under three scenarios for both new construction and existing home markets:

1. Connecticut baseline saturation results only. This is the lower estimate.
2. Connecticut, Massachusetts, and Rhode Island baseline saturation results. This blended approach relies on penetration figures from neighboring states to avoid overweighting limited baseline results in Connecticut. This yields a higher market size estimate. Note that this method only considers growth of these markets at large; the differences between

[27] Single-zone systems and multi-zone systems had different rebate amounts which could be used as a proxy in the program tracking data if the configuration data weren't included.

program and state policies, incentive levels, and program requirements are not considered.

3. An average annual growth rate of scenario 1 and scenario 2 results.

Due to extremely low saturations of residential GSHPs in both the new construction and existing homes, the market estimates should be viewed with caution as the data is scaled from on-site sample populations to state-level estimates.

To account for potential under- or over-estimating, an additional estimate was calculated based on evaluated insights from the Connecticut Ground Source Heat Pump Impact Evaluation and Market Assessment.[28] The second market estimate relies on the number of units receiving incentives and includes scenarios of installations that occur outside of the program. These estimates are supplemented with qualitative insights on the number of geothermal systems installed outside of the program, from the distributor and contractor IDIs and web-surveys.

Figure 42~~Figure 42~~ below depicts the methodology used to estimate the size of the Connecticut GSHP market. Each data source includes limitations and are highlighted within the figure. When possible, program data was used to determine market-level proxies for new construction vs. retrofit and residential vs. commercial. Supplemental findings from both surveys and in-depth interviews which provide additional insights and context on the market estimates are included in Appendix D.

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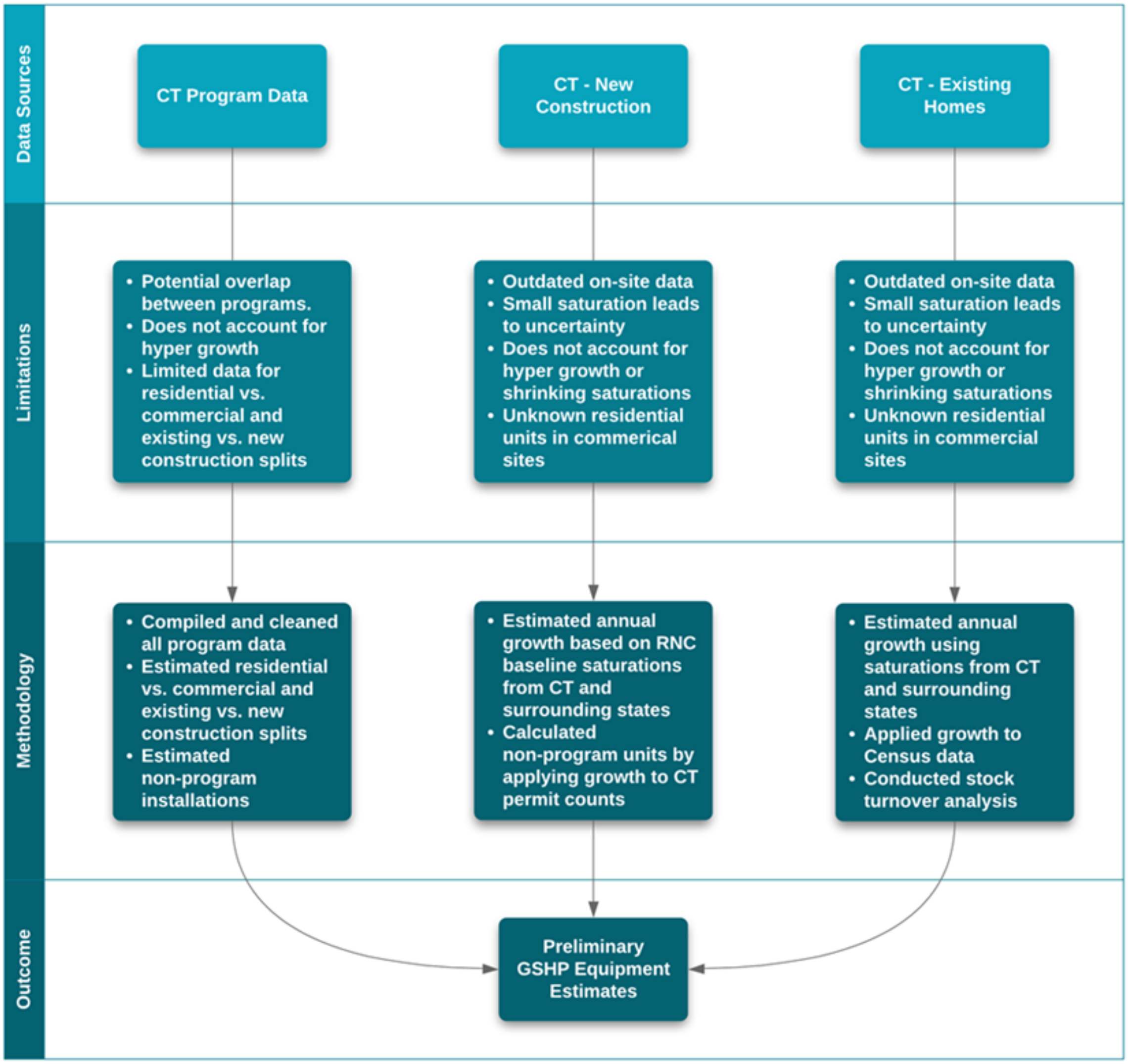
[28] https://www.energizect.com/sites/default/files/CT%20GSHP%20Impact%20Eval%20and%20Market%20Assessment%20%28R7%29%20-%20final%20report.pdf

Figure 42: GSHP Market Estimate Methodology



A.2.4 Estimated Heat Pump Water Heater Market Size Methodology

The market estimates for HPWHs relied on multiple data sources, such as the most recent Connecticut baseline studies, more recent baseline studies from adjacent states, program tracking data, and U.S. Census Bureau data. The estimates used a linear regression model to estimate equipment saturation over time. As with GSHPs, the study constructed the HPWH market estimates under three scenarios for new construction and existing home markets:

1. Connecticut baseline saturation results only. This is a lower, more conservative estimate.
2. Connecticut, Massachusetts, and Rhode Island baseline saturation results included. This blended approach relies on penetration figures from neighboring states. This yields a higher market size estimate. Note that this method only considers growth of these markets at large; the differences between program and state policies, incentive levels, and program requirements are not considered.

3. An average annual growth rate of scenario 1 and scenario 2 results.

The estimated growth rates calculated from each scenario were applied to new construction permit rates and to occupied existing home counts. A stock-turnover analysis was conducted on existing homes using a 13-year EUL.[29]

Figure 43~~Figure 43~~ below depicts the methodology that was used to understand the estimated size of the HPWH market in Connecticut. Each data source includes limitations and are highlighted within the figure. When possible, program data was used to determine market-level proxies for new construction vs. retrofit, residential vs. commercial, and distributor vs. retail channel sales.

Supplemental findings from surveys and in-depth interviews are included in Appendix D provide more context to the HPWH market.

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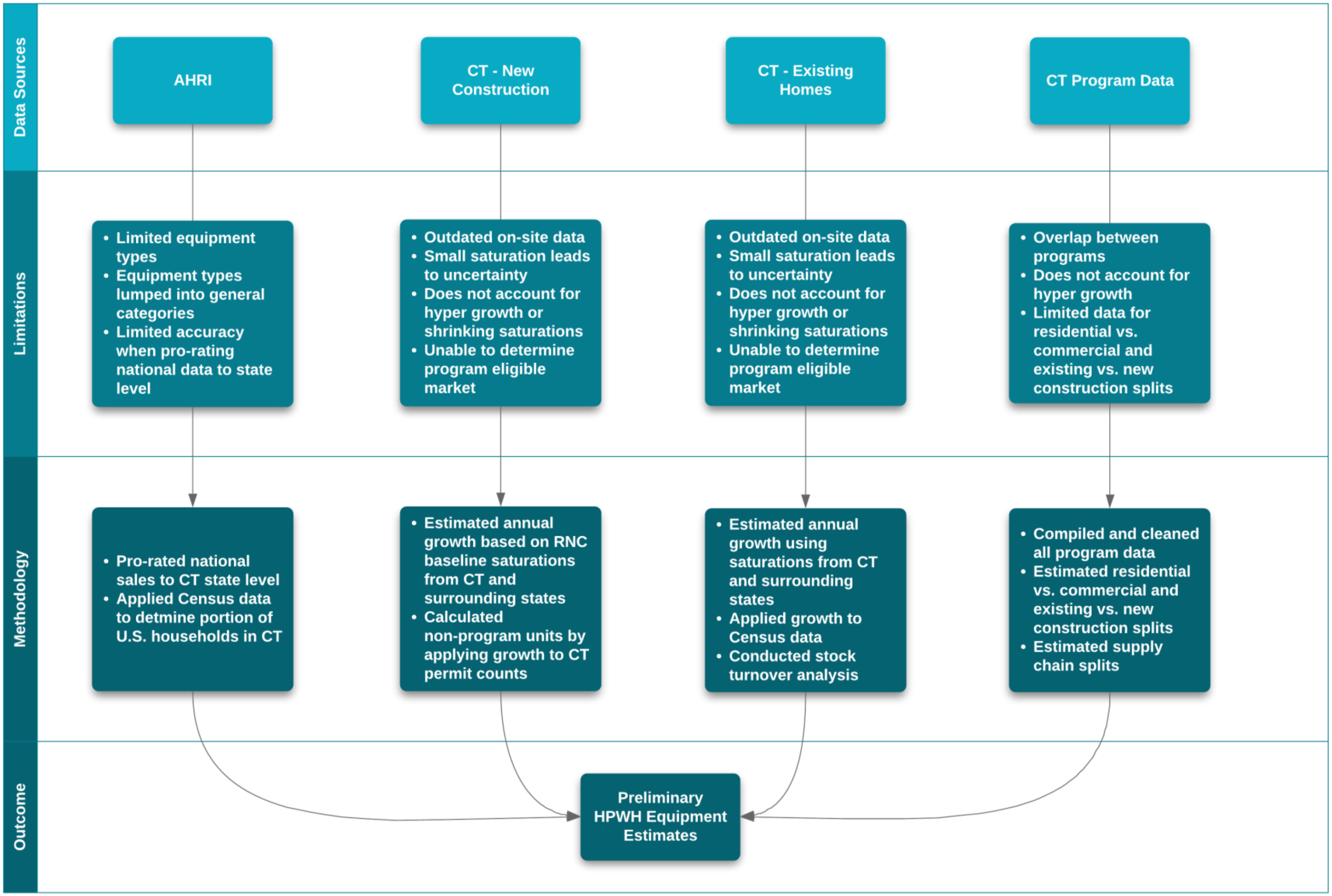
[29] https://www.energizect.com/sites/default/files/2020%20PSD_Final_3.1.20%20Filing.pdf

Figure 43: HPWH Market Estimate Methodology



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A.3 INTERVIEWS AND SURVEYS WITH MARKET ACTORS

The study conducted primary research through interviews with various market actors including manufacturers, distributors, and installers of HVAC and water heating equipment. In addition, a web survey was conducted with installers. The interviews[30] and surveys were conducted to identify trends in the HVAC market with a specific focus on heat pump technology. The objectives of this primary research include:

- **Market size:** validating or refining market size estimates, system prevalence in the market, and existing home replacements compared to supplemental system installations.
- **Market actor and end-user behavior:** drivers and barriers to adoption, installation challenges, fuel switching and integrated controls, stocking practices, whole-home or point-of-use systems, and consumer demand.
- **New HVAC technology development and distribution:** market perception of NEEP's Cold Climate ASHP specification[31] or NEEA's Advanced Water Heater Specification[32], integrated controls between different systems, and the future state of the market.
- **R2027 add-on topics:** service frequency, type and frequency of repairs, installer ability to repair, operational issues, repair costs, and customer complaints and skepticism.

The following subsections describe the interviews and surveys in the order they took place during the evaluation.

A.3.1 Manufacturer Interviews

The study completed five interviews with manufacturers of heat pump technology. The interviews were geared towards broader market level questions and to understand larger trends as heat pump technology increases in the HVAC and water heating market. The manufacturer interviews provided insight into the direction of the market, such as market growth, equipment and installation costs, sales of supplemental systems compared to whole-home systems, and other trends. The interviews also explored how upcoming technological improvements that may help address barriers to adoption. In addition, the interviews with manufacturers gathered information on the supply chain interactions that occur throughout the HVAC and water heating market and how the players in the market interact through each stage of the purchase-decision.

The study completed interviews with three HVAC heat pump manufacturers, one HPWH manufacturer, and one GSHP manufacturer (Table 30~~Table 30~~). The manufacturer sample was generated through web-scraping and leveraging professional contact networks. Program tracking data was reviewed at the manufacturer level to determine the candidates interviewed were active

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[30] The interview guide for distributors and manufacturers was developed in coordination with a Rhode Island heat pump market characterization evaluation led by Cadmus. The two study teams worked together to develop interview questions based on both studies research goals. The results presented in this report include results from interviews conducted by both teams.

[31] https://neep.org/tags/ccashp

[32] https://neea.org/our-work/advanced-water-heater-specification

in the Connecticut market. Recruitment for interviewees was done through email and phone outreach and participants were offered a $100 incentive for their time.

Table 30: Manufacturer Interview Targets and Completes

Manufacturer type	Target	Completes
ASHP and MSHP	3	3
HPWH	1	1
GSHP	1	1
Total	**5**	**5**

A.3.2 Distributor Interviews

The study completed 12 of 15 targeted interviews with HVAC and plumbing distributors representing nine companies.[33] The interviews included topics such as: sales volumes and trends, typical heat pump configurations, cold-climate heat pumps, stocking practices, installation challenges, market drivers and barriers, and whether heat pump technology was prevalent with tract builders and multifamily developments.

HVAC and plumbing distributors are a hard-to-reach audience. A total of 105 distributor contacts were gathered through internet research and 94 of those were contacted for interviews (Table 31~~Table 31~~). Outreach was conducted by both email and phone to recruit interviewees; typically, multiple contacts were made by both mediums to secure an interview. The study primarily targeted executive and regional level contacts to understand a higher-level perspective of the market. However, due to recruiting challenges, the study included some branch-level managers in interviews.

Table 31: Distributor Interview Targets and Completes

Equipment Type	Target	Completes
ASHP and MSHP (n-equipment)	10*	11
GSHP (n-equipment)	10*	3
HPWH (n-equipment	5	8
Total (n-distributors)	**15**	**12**
*ASHP and GSHP were a combined target of 10 but are separated in the table to show how many distributors sold each equipment type.		

A.3.3 Installer Survey

The web survey with installation contractors was designed to cover the following topics:

[33] The interviewed firms accounted for approximately 38% of the ASHP and 54% of the HPWH program-market based on program tracking data of incented residential heat pumps.

- Recommendation factors
- Common installation scenarios
- Ducted vs. ductless configurations
- Supplemental vs. whole home installations
- Prevalence of cold climate models
- Integration with fossil fuel systems
- Drivers and barriers to adoption
- Installer attitudes
- Repairs and service
- Customer satisfaction

The sample of installers was identified using a combination of web scraping of online directories and a program participant contact list. Installers received a $70 Amazon gift card for completing the 30-minute survey. Recruitment for the survey included emails and post cards to 3,500 contacts, yielding a total of 52 unique respondents. Table 32~~Table 32~~ shows details on the target and actual achieved completes. Installers proved difficult to reach, so targets were adjusted to reflect responses related to specific equipment types rather than unique respondents.

Table 32: Installer Survey Targets and Completes

Installation contractor equipment types	Target	Completes (No. by equipment type installed)
ASHP	10	37
MSHP	60	42
HPWH	40	37
GSHP	5	10
Total	**115***	**126***

* 52 unique respondents completed the survey, the initial target was for 100 installation contractors to complete the survey.

A.3.4 Installer Interviews

The study completed all ten targeted follow-up interviews with HVAC and plumbing installation contractors. The web survey was used to pre-recruit installers for the follow-up interviews, which included an additional $70 participation incentive (19 were pre-recruited). These interviews were targeted primarily towards HVAC contractors to gather insights about the installation configuration options for heat pumps that provide space heating and cooling, but outreach was adjusted for the R2027 add-on study to include HPWH installers (Table 33~~Table 33~~). Installers were contacted by phone and email.

Table 33: Installation Contractor Interview Targets and Completes

Installation contractor equipment types	Target	Completes
ASHP (n-equipment)	1	7
MSHP (n-equipment)	6	7
HPWH (n-equipment)	4	9*
GSHP (n-equipment)	1	2
Total (n-installers)	**10**	**10**

*Three of the installers only installed HPWHs, while the other six installed HPWHs in addition to HVAC equipment.

The primary purpose of the interviews was to understand factors that determine specific configurations and recommendations for a heat pump installation. Each installer was presented one of two installation scenarios and was asked questions about what type of HVAC system they would recommend[34], how they would configure that system, installation costs, and what other features they would recommend, such as cold-climate models, building shell upgrades, integrated controls, and efficiency specifications (Table 34Table 34). The installation scenarios also explored the alternate factors listed in the table below to see how the recommendation would change based on different scenarios. The interviews also discussed heat pump reliability, as a R2027 add-on study research objective.

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[34] If the installer did not recommend a heat pump, they were asked to consider what they would recommend if they were limited to heat pump options as well.

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Table 34: Installation Scenarios Covered During the Installer Interviews

	Scenario 1	Scenario 2
Home characteristics		
Home size	1600 sq ft, 2 stories	2000 sq ft, 2 stories + attic
Home vintage	1990	1920
Heating	oil furnace <10 yr. old	gas boiler <5 years old
Cooling	CAC <10 yr. old	None
Ducts	yes	No
Insulation	R-13 in walls, R-30 in ceiling	old R-5 in walls, R-11 attic rafters
Tightness	average for 1990 home	very leaky
Customer characteristics		
HP opinion	open to them; does not have strong opinions on them	open to them; does not have strong opinions on them
Goals	Increase comfort all year; save energy	Condition newly finished attic space (R-13 walls, R-38 roof); Interested in adding AC to the rest of the home, but not committed
Budget	High	High
Alternate factors		
Alternate factor 1	Low budget	Low budget
Alternate factor 2	Gas	Oil
Alternate factor 3	Boiler, no ducts	Furnace, w/ ducts
Alternate factor 4	Finishing basement	Recently weatherized, well-insulated, and air-sealed
Alternate factor 5	Boiler/furnace is 15 years old	Boiler/furnace is 15 years old

A.4 Cost-Effectiveness Testing

The study included a cost-effectiveness assessment for several residential heat pump installation scenarios using the Participant Cost Test, which evaluates measures from the perspective of the customer installing the measure. Benefits include customer incentives and bill savings. Costs include incremental equipment and installation.

The study selected relevant baseline and capacity scenarios to evaluate several heat pump technologies. Cost research was performed using both primary and secondary data sources to estimate incremental costs and applicable incentives for each scenario. Savings analysis was performed using a balanced load calculation for each baseline and efficient equipment scenario.

Cost-effectiveness ratios were calculated using the PCT formula which deems a measure with a ratio of 1.0 or greater as a cost-effective measure.

A.4.1 Scenario Selection

A scenario represents a hypothetical case in which a heat pump system of a specified capacity, efficiency, and configuration replaces an existing residential heating and cooling system.

Heat pump and baseline system types were chosen based on staff experience with typical residential installations in the region and informed by typical values seen in program installation data. System capacities and efficiencies were chosen based on tracking data provided by the Companies for incentivized residential-grade heat pumps from their portfolio of programs data. Some additional scenarios were also added to expand the results for comparison. Each scenario was also categorized as either “retrofit” or “replace on failure” and either full or partial heating displacement to differentiate between customers who purchase a heat pump to offset their current heating system and those who fully replace their existing heating system.

A.4.2 Cost Research

Cost research was performed using both primary and secondary data sources to estimate incremental costs for each scenario.

MSHP costs were estimated based on tracking data provided by the Companies for incentivized residential-grade heat pumps from their portfolio of programs data. Ducted ASHP costs were estimated using data from a 2018 Navigant Cost Study of Heat Pump Installations for Dual Fuel Operation prepared for Massachusetts Program Administrators.[35] Heat pump water heater costs were estimated using data from a 2018 Navigant Water Heating, Boiler, and Furnace Cost Study prepared for Massachusetts Program Administrators.[36] Baseline heating and cooling system costs were estimated using RSMeans construction cost database.[37] RSMeans data was filtered for 2020 residential data in the Hartford, CT, area. As these are cost estimates, results were also projected for low- and high-end heat pump system costs by taking a range of +/-20% of the heat pump cost estimates mentioned previously.

A.4.3 Savings Analysis

Savings analysis was performed by calculating annual heating and cooling consumption for each heat pump and baseline system. Parameters used in the calculation include capacity, efficiency, and equivalent full-load hours (EFLH). Baseline capacity is assumed to be equal to heat pump capacity for the purposes of our cost-effectiveness testing. Baseline efficiency was determined using the 2015 International Energy Conservation Code compliant values and an estimated existing efficiency based on staff experience for partial heating displacement scenarios. Equivalent full-load hours were chosen from the 2021 CT Program Savings Document and the 2021 MA TRM for full displacement cooling EFLH (not present in CT PSD).[38] [39] Water heater

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[35] https://ma-eeac.org/wp-content/uploads/RES23_Task2_AC-HP_Cost_Study_Results_Memo_v3_clean.pdf
[36] https://ma-eeac.org/wp-content/uploads/RES19_Assembled_Report_2018-09-27.pdf
[37] https://www.rsmeans.com/construction/data
[38] https://energizect.com/sites/default/files/2021-03/Final%202021%20PSD%20(Filed%203-01-2021).pdf
[39] https://fileservice.eea.comacloud.net/FileService.Api/file/FileRoom/12190505

savings were calculated using PSD Average Residential Annual Water Heating Load. The following tables provide scenario level assumptions, calculations, and consumption estimates for baseline and installed units.

Table 35: Scenarios Used for Participant Cost Assessment

A	B	C	D	E	F	G	H	I	J	K	L	M	N
Sce-nario	**Type**	**Capacity (BTU)**	**Heating Displ**	**Baseline Cooling**	**Baseline Heating**	**EER/ SEER**	**Heating Efficiency**	**EFLH (cool)**	**EFLH (heat)**	**Annual Cooling Consumption (kWh)**	**Annual Heating Consum-ption (kWh)**	**Annual Heating Consumption (MMBTU)**	**Total Annual Consumption (kWh)**
A	MSHP	12,000	Partial	Window AC	Oil Boiler	10	80%	218	535	262	-	8	262
B	MSHP	24,000	Partial	Window AC	Oil Boiler	10	80%	218	535	523	-	16	523
C	MSHP	12,000	Partial	Window AC	Electric Resistance	10	100%	218	535	262	1,882	-	2,143
D	MSHP	24,000	Partial	Window AC	Electric Resistance	10	100%	218	535	523	3,763	-	4,286
E	MSHP	12,000	Partial	No cooling	Electric Resistance	-	100%	218	535	0	1,882	-	1,882
F	MSHP	24,000	Partial	No cooling	Electric Resistance	-	100%	218	535	0	3,763	-	3,763
G	MSHP	36,000	Full	Window AC	Oil Boiler	10	84%	419	862	1,508	-	37	1,508
H	MSHP	48,000	Full	Window AC	Oil Boiler	10	84%	419	862	2,011	-	49	2,011
I	MSHP	36,000	Full	Window AC	Electric Resistance	10	100%	419	862	1,508	9,095	-	10,603
J	MSHP	48,000	Full	Window AC	Electric Resistance	10	100%	419	862	2,011	12,127	-	14,138
K	MSHP	36,000	Full	No cooling	Electric Resistance	-	100%	419	862	0	9,095	-	9,095
L	MSHP	48,000	Full	No cooling	Electric Resistance	-	100%	419	862	0	12,127	-	12,127
M	ASHP	36,000	Full	Central AC	Oil Boiler	13	84%	419	862	1,160	-	37	1,160
N	ASHP	48,000	Full	Central AC	Oil Boiler	13	84%	419	862	1,547	-	49	1,547
O	ASHP	36,000	Full	Central AC	Electric Resistance	13	100%	419	862	1,160	9,095	-	10,255
P	ASHP	48,000	Full	Central AC	Electric Resistance	13	100%	419	862	1,547	12,127	-	13,674

Column Notes:

G: Since there is no code SEER for residential units, the team based EER/SEER from 2015 commercial code.
H: Analysis used code for full displacement and estimated existing efficiency for partial
I: Partial displacement based on 2021 PSD Section 4.2.6 (Ductless Heat Pump); full displacement based on 2021 air source heat pump MA TRM for full displacement (PSD does not have a value for ASHP)
J: Partial displacement based on 2021 PSD 4.2.6 Ductless heat pump; full displacement based on 2021 PSD 4.2.2 Residential Heat Pump
K = C * (1/G) * I/1,000
H = C * (1/G) * J/3,412
M = C * (1/G) * J/3,412

The following table presents the assumptions and methods used to calculate the heat pump measure consumption values.

Table 36: Upgrade Assumptions for Participant Cost Assessment

A	B	C	D	E	F	G	H	I	J	K
Scenario	**Type**	**Capacity**	**SEER**	**HSPF**	**Heating Displacement**	**EFLH (cool)**	**EFLH (heat)**	**Annual Cooling Consumption (kWh)**	**Annual Heating Consumption (kWh)**	**Total Annual Consumption (kWh)**
A	MSHP	12,000	20	10.6	Partial	218	535	131	606	736
B	MSHP	24,000	17.6	10.6	Partial	218	535	297	1,211	1,509
C	MSHP	12,000	20	10.6	Partial	218	535	131	606	736
D	MSHP	24,000	17.6	10.6	Partial	218	535	297	1,211	1,509
E	MSHP	12,000	20	10.6	Partial	218	535	131	606	736
F	MSHP	24,000	17.6	10.6	Partial	218	535	297	1,211	1,509
G	MSHP	36,000	17.6	10.6	Full	419	862	857	2,928	3,785
H	MSHP	48,000	17.6	10.6	Full	419	862	1,143	3,903	5,046
I	MSHP	36,000	17.6	10.6	Full	419	862	857	2,928	3,785
J	MSHP	48,000	17.6	10.6	Full	419	862	1,143	3,903	5,046
K	MSHP	36,000	17.6	10.6	Full	419	862	857	2,928	3,785
L	MSHP	48,000	17.6	10.6	Full	419	862	1,143	3,903	5,046
M	ASHP	36,000	17.6	10.6	Full	419	862	857	2,928	3,785
N	ASHP	48,000	17.6	10.6	Full	419	862	1,143	3,903	5,046
O	ASHP	36,000	17.6	10.6	Full	419	862	857	2,928	3,785
P	ASHP	48,000	17.6	10.6	Full	419	862	1,143	3,903	5,046

Column Notes:

D: Determined from program data.
G: Partial displacement based on 2021 PSD Section 4.2.6 (Ductless Heat Pump); full displacement based on 2021 air source heat pump MA TRM for full displacement (PSD does not have a value for ASHP)
H: Partial displacement based on 2021 PSD 4.2.6 Ductless heat pump; full displacement based on 2021 PSD 4.2.2 Residential Heat Pump
I = C * (1/D) * G/1,000
J = C * (1/E) * H/1,000
K = I+J

A.4.4 Participant Cost Test Calculation

A measure which tests greater than or equal to 1.0 using the PCT is considered a cost-effective project from the perspective of the customer installing the measure.

The PCT Formula is:

(Lifetime customer bill savings + incentives) / (Incremental equipment and installation cost)

To estimate lifetime customer bill savings, residential energy price forecast data for the New England region was taken from the U.S. Energy Information Administration database.[40] The net present value of residential energy prices over each scenario's measure life was calculated using the DEEP nominal discount rate of 3%. These values were then used to calculate lifetime customer bill savings based on the energy savings calculated for each scenario.

Incentive rebate values are based on the current 2021 proposed CT rebate structure from DEEP 2019-2021 Electric and Natural Gas Conservation and Load Management Plan.[41]

Incremental equipment and installation costs were estimated using the methodologies mentioned above. For retrofit heating replacement scenarios, baseline heating cost is not subtracted in the calculation of incremental costs as it is assumed that the existing heating equipment is still in working condition.

A.5 Participant End-User Survey

The sample frame for the end-user survey included program participants who received heat pump equipment incentives between 2017 and 2019 for MSHPs, ASHPs, GSHPs, and HPWHs. Topics included:

- End-user satisfaction
- Frequency and type of issues
- Repair costs

Due to the small number of installations, the total number of participants that had received incentives for central ASHP and GSHP measures were targeted. For the remaining participants in the program tracking data that received incentives for MSHP and HPWH measures, 2,429 and 1,215 participants were randomly selected for each measure, respectively.

All potential respondents received mailed recruitment letters. Participants with email addresses included in the program tracking data were also emailed. The letters and emails explained the purpose of the survey and provided phone numbers and email addresses to contact the survey firm, NMR, or the Companies' program representatives for more information or to take the survey over the phone. Respondents were provided a $20 digital gift card via email after completing the survey. Two reminder emails were sent to email recipients that did not respond to the survey, as well as one round of reminder postcards to letter recipients that did not respond to the survey.

40 https://www.eia.gov/outlooks/aeo/data/browser/
41 http://www.dpuc.state.ct.us/DEEPEnergy.nsf/$EnergyView

The survey firm made outgoing phone calls to increase the number of completes for central ASHP and GSHP participants.

The end-user survey for all measures yielded a total of 258 responses, including 12 central ASHP, six GSHP, 170 MSHP, and 70 HPWH respondents. The number of responses met the study's quotas of 170 MSHP respondents and 70 HPWH respondents. We received two bounced recruitment emails and 305 returned recruitment letters, resulting in an overall response rate of 7% (Table 37Table 37).[42]

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Table 37: End-user Survey Targets and Completes

Measure types	Recruitment		Survey results	
	Mailers	Email	Target	Completes
ASHP (n-equipment)	49	40	Census	12
MSHP (n-equipment)	2,429	0	170	170
HPWH (n-equipment)	1,215	1	70	70
GSHP (n-equipment)	7	16	Census	6
Total (n-participants)	**3,700**	**57**	**240+**	**258**

[42] Response Rate = Responded ÷ (Mailed – Returned), 258 ÷ (3,757 – 307) = 7%

B

Appendix B Literature Review

The purpose of the literature review was to gather and compile data and literature that describes the market in Connecticut for heat pump systems used for space conditioning and domestic hot water and describes the Companies current program efforts. This task focused on gathering background and evaluation materials that addressed:

1. sales volumes of heat pumps
2. efficiency, capacity, and configuration of systems
3. opportunities and challenges associated with uptake, now and in the future

The following table identifies past Connecticut studies that addressed the heat pump market and points out key findings and topics associated with those studies (Table 38~~Table 38~~). Table 39~~Table 39~~ provides similar results for regional and national studies.

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Table 38: Key Findings and Topics from Past Connecticut Studies

Metric	Equipment	Findings/Topics	Studies
Market Size	ASHP	➢ Adoption rate of ductless HP ➢ Prevalence of HPs in new construction	R1617 Ductless HP Study, R1602 RNC Baseline
	GSHP	➢ Program penetration and market expectations	R7 GSHP Study
System Configuration	ASHP	➢ Focused on ductless configurations which appear to be the most common ➢ Whole home vs. supplemental configurations, use of backup heating systems	R1617 Ductless HP Study, R113 Ductless HP Evaluation, R1602 RNC Baseline
	HPWH	➢ Installation practices and efficiency implications	R1613 Heat Pump Water Heater Report
	GSHP	➢ System sizing and ground loop types	R7 GSHP Study
Drivers and Barriers	ASHP	➢ Customer and market actor feedback on recommendation factors and satisfaction	R1617 Ductless HP Study, R113 Ductless HP Evaluation, R1602 RNC Baseline
	HPWH	➢ Motivations to sell and purchase HPWHs through customer and market actor surveys	R1613 Heat Pump Water Heater Report
	GSHP	➢ System costs, design factors, customer influence	R7 GSHP Study

Table 39: Key Findings from National or Regional Studies

Metric	Equipment	Findings	Studies
Market Size	ASHP	➢ Market characterization of capacity and efficiency combinations ➢ Heat pump potential for residential heating load ➢ Baseline information for forced air distribution	RES 28 Ductless HP Cost Study, NYSERDA Residential HP Potential Study, NEEP Regional Strategic Electrification Assessment
	HPWH	➢ Market size and program penetration of HPWH in the Northeast ➢ HPWM market penetration across the U.S. ➢ HPWH market penetration in the Northwest	NEEP HPWH Market Strategies Report, CEE HPWH Midstream Programs, PNNL U.S. HPWH Market Transformation, NEEA MPER #5
System Configuration	ASHP	➢ Ducted vs. ductless configurations for cold climate heat pumps ➢ Cost of various indoor and outdoor unit combinations	RES 28 Ductless HP Cost Study, NYSERDA Residential HP Potential Study
	GSHP	➢ Vertical ground source heat pumps	NYSERDA Residential HP Potential Study
Drivers and Barriers	ASHP	➢ Costs, existing heating fuel, reliability	RES 28 Ductless HP Cost Study, NYSERDA Residential HP Potential Study, NEEP Regional Strategic Electrification Assessment
	HPWH	➢ Market actor feedback ➢ Awareness, ROF market, training, callbacks	NEEP HPWH Market Strategies Report, CEE HPWH Midstream Programs, PNNL U.S. HPWH Market Transformation, NEEA MPER #5

B.1 Current Program Offerings in Connecticut

In 2020, on the residential side, there were four program offerings for ductless mini-split heat pumps: single head installations, multiple head installations, installations displacing electric resistance heating, and installations displacing another heating fuel, with rebates ranging from $300 to $700 (Table 40~~Table 40~~). Central, ducted heat pumps had two incentive levels with the same efficiency requirements, with the higher incentive going to installations that displaced electric resistance heating. GSHPs, water source heat pumps (WSHPs), and HPWHs each had one efficiency and one incentive level, though HPWHs were incentivized through both a midstream and a downstream channel.

On the commercial side, ASHPs were incentivized at two efficiency levels and two capacity levels. WSHPs had one efficiency and incentive level.

Table 40: Connecticut Heat Pump Program Offerings

Heat Pump Type		Equipment Requirements	Incentive	Installation Requirements	Midstream or Downstream Incentive
HVAC					
ASHP	Ductless Split Heat Pumps	Single indoor unit: 20 SEER, 12.5 EER, 10 HSPF; ENERGY STAR®	$300	Installed by a licensed contractor certified by manufacturer	Midstream and Downstream
		Single indoor unit displacing ER heat: 20 SEER, 12.5 EER, 10 HSPF; ENERGY STAR®	$700		
		Multiple indoor units: 18 SEER, 12.5 EER, 9 HSPF; ENERGY STAR®	$500		
		Multiple indoor units, displacing ER heat: 18 SEER, 12.5 EER, 9 HSPF; ENERGY STAR®	$700		
	Central Air Source Heat Pump	AHRI Rated Split Systems: 16 SEER, 12.5 EER, 10 HSPF; ENERGY STAR®	$500		Downstream
		AHRI Rated Ducted System: Any Zone - displacing ER heat: 16 SEER, 12.5 EER, 10 HSPF; ENERGY STAR®	$700		

Heat Pump Type		Equipment Requirements	Incentive	Installation Requirements	Midstream or Downstream Incentive
Geothermal	Geothermal Heat Pumps (Ground or Water Source)	Geothermal closed loop or direct expansion, packaged or matched coil/split (AHRI matched) including water to water-designed types up to six tons per unit; ENERGY STAR®	$500 to $1,500 in ½ ton increments	Field testing under appropriate test conditions	Downstream
Domestic Hot Water					
HPWH		Uniform Energy Factor (UEF) of 3.0 or greater and less than 55 gallons of storage capacity; ENERGY STAR®	$750	Purchased from participating CT distributor	Midstream or combination mid- and downstream
Commercial Rebates					
ASHP		0 to <20 tons, Tier I Efficiency: 15 SEER & 8.5 HSPF if <5.4 tons, 11.5 EER is ≥5.4 tons	$80/ton	Ductless mini split systems must have inverter technology	Downstream
		≥20 to ≤30 tons, Tier I Efficiency: 10.5 EER	$70/ton		
		0 to <20 tons, Tier II Efficiency: 16 SEER & 9.0 HSPF if <5.4 tons, 12 EER is ≥5.4 tons	$150/ton		
		≥20 to ≤30 tons, Tier II Efficiency: 10.8 EER	$120/ton		
WSHP		≤11.25 tons & 14.0 EER	$150/ton		

B.2 Program Offerings in Neighboring States

Massachusetts and Rhode Island offered nearly identical incentives and were comparable to those in Connecticut in 2020. The residential offerings in New York varied widely between utilities, and in some cases included bonus incentives for cold-climate specific models and add-ons such as incentives for GSHP desuperheaters. Table 41Table 41 summarizes the residential program heat pump offerings in Massachusetts, Rhode Island, and New York. Within New York, the program offerings of Central Hudson, NYSEG and RG&E, National Grid, Orange & Rockland, and PSEG Long Island are listed separately.

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Table 41: Residential Program Heat Pump Offerings in Neighboring States

Heat Pump Type		Equipment Requirements	Incentive	Midstream or Downstream Incentive
Massachusetts				
ASHP	Mini-split heat pumps	18 SEER; 10 HSPF	$250/ton	

Heat Pump Type		Equipment Requirements	Incentive	Midstream or Downstream Incentive
	Mini-split heat pumps replacing electric, oil, or propane heating		$1,250/ton	
	Central heat pump	16 SEER; 9.5 HSPF	$250/ton	
	Central heat pump replacing electric, oil, or propane heating		$1,250/ton	
HPWH	≤55 gallons	2.0 UEF	$600	
	>55 gallons	2.7 UEF	$150	
Rhode Island				
ASHP	Central heat pump, ducted	AHRI: SEER > 15, HSPF > 9	$350/ton	
	Central heat pump, ducted replacing electric, oil, or propane heating		$1,250/ton	
	Mini-split heat pump, ducted or mixed duct	AHRI: SEER > 15, HSPF > 9	$350/ton	
	Mini-split heat pump, ducted or mixed duct, replacing electric, oil, or propane heating		$1,250/ton	
	Mini-split heat pump, non-ducted	NEEP: SEER > 15, HSPF > 10, COP 1.75 at 5°F	$150/ton	
	Mini-split heat pump, non-ducted replacing electric, oil, or propane heating		$1,250/ton	
HPWH	≤55 gallons	2.0 UEF	$600	
	>55 gallons	2.7 UEF	$150	
New York *Central Hudson*				
ASHP	Existing fuel: electric	SEER ≥15, EER ≥12, HSPF ≥8.5	$250	Downstream
	Existing fuel: oil or propane		$300	
	Existing fuel: gas or wood		$50	
HPWH	<55 gallons	≥2.3 UEF	$750	Downstream
	≥55 gallons	≥2.3 UEF	$100	
NYSEG and RG&E				
ASHP	Cold-climate MSHP, partial load heating (Manual J/S calculation)	NEEP cold climate spec. MSHP	$500/outdoor unit ($100 to contractor, $400 to customer)	

Heat Pump Type		Equipment Requirements	Incentive	Midstream or Downstream Incentive
	Cold-climate ASHP or MSHP, full load heating (Manual J/S calculation showing 90-120% of design heating load)	NEEP cold-climate spec. ASHP and MSHP	$1,500/10,000 BTUH of max. heating capacity at 5°F ($500 to contractor, $1,000 to customer)	
GSHP	GSHP, full load heating (Manual J/S calculation showing 90-120% of design heating load)	ENERGY STAR® Criteria, heating load of <135,000 Btuh	$1,500/10,000 Btuh AHRI certified heating capacity ($500 to contractor, $1,000 to customer)	
	GSHP desuperheater	ENERGY STAR Certified HPWH, add-on to GSHP system	$100 ($0 to contractor, $100 to customer)	
	Ground-source HPWH	ENERGY STAR Certified HPWH, must meet 100% of WH load	$900 ($0 to contractor, $900 to customer)	
HPWH	Air-source HPWH, up to 55 gallons	ENERGY STAR Certified HPWH	$700 ($0 to contractor, $700 to customer)	
National Grid				
ASHP	Central ccASHP	SEER ≥18, HSPF ≥9, Cooling EER 12.5, Heating COP at 5°F 1.75	$200/ton	
		SEER ≥20, HSPF ≥9, Cooling EER 12.5, Heating COP at 5°F 1.75	$350/ton	
	ccDMSHP	SEER ≥18, HSPF ≥10, Cooling EER 12.5, Heating COP at 5°F 1.75	$200/ton	
		SEER ≥22, HSPF ≥10, Cooling EER 12.5, Heating COP at 5°F 1.75	$375/ton	
GSHP	GSHP	Cooling EER 12-21, Heating COP at 5°F 3.1-4.1	$200/ton	
		Cooling EER 21.1+, Heating COP at 5°F 3.1-4.5	$400/ton	
HPWH	ENERGY STAR HPWH		$300	
Orange & Rockland				
ASHP	MSHP bonus incentive	NEEP's Cold Climate Heat Pump List	$500	

Heat Pump Type		Equipment Requirements	Incentive	Midstream or Downstream Incentive
	Central heat pump bonus incentive		$1,000	
	MSHP	SEER >= 18 EER >= 13 HSPF >= 9	$100	
		SEER >= 20 EER >= 13 HSPF >= 9	$200	
	Central heat pump	SEER ≥ 15 EER ≥ 12.5 HSPF ≥ 9	$200	
		SEER ≥ 16 EER ≥ 13 HSPF ≥ 9	$300	
		SEER ≥ 18 EER ≥ 13 HSPF ≥ 9	$500	
GSHP	GSHP	NEEP's Cold Climate Heat Pump List	$2,000	
PSEG Long Island				
ASHP	Ducted cold climate, equipment sized to 100-130% of peak heating load	SEER ≥17, HSPF ≥10	$1,000/ton new construction, $800/ton oil w/o A/C, $600/ton all other	
	ccDMSHP, equipment sized to 100-130% of peak heating load	SEER ≥18, HSPF ≥10		
	Ducted	SEER ≥15, HSPF ≥8.5	$300/ton	
		SEER ≥16, HSPF ≥8.5	$325/ton	
	Ducted, replacing electric resistance heating	SEER ≥16, HSPF ≥8.5	$800/ton	
		SEER ≥17, HSPF ≥10	$1,000/ton	
	Ducted cold climate	SEER ≥17, HSPF ≥10	$350/ton	
	Ductless mini-split	SEER ≥18, HSPF ≥8.5	$300/ton	
	Ductless mini-split, replacing electric resistance heating	SEER ≥18, HSPF ≥8.5	$800/ton	
		SEER ≥18, HSPF ≥10	$1,000/ton	
	Ductless mini-split cold climate	SEER ≥18, HSPF ≥10	$300/ton	
	Packaged terminal heat pump	EER ≥11.4, COP ≥3.3	$100/ton	
HPWH	ENERGY STAR HPWH		$650	
GSHP	GSHP – Tier I Efficiency	EER 16.0-20.1, COP 3.1-4.1, depending on equipment	$1,000/ton new construction, $500/ton retrofit	
	GSHP – Tier II Efficiency	EER 17.5-25.0, COP 3.1-4.5, depending on equipment	$2,000/ton new construction, $700/ton retrofit	

Heat Pump Type		Equipment Requirements	Incentive	Midstream or Downstream Incentive
	Desuperheater		$250	
ConEd offers rebates for HPWH, ASHP, and geothermal systems, but details of the requirements and incentive levels are not available online				

B.3 SUMMARY OF REVIEWED LITERATURE

Table 42~~Table 42~~ gives an overview of each of the studies included in this literature review, including the study type, whether it included a market sizing or baseline component, which types of equipment and system configurations were included, and any drivers or barriers to market adoption that were named.

Table 42: Summary of Reviewed Literature

Study Name	Study Type	Market Sizing/ Baseline	System Configurations	Equipment Included	Drivers/ Barriers
Connecticut Studies					
R1617 Connecticut Residential Ductless Heat Pumps Market Characterization Study (2019)	Market characterization of retrofit installations	Adoption rate of program DHPs in CT	Did not distinguish between configurations of ductless systems; collected baseline data on replaced equipment by fuel type, home/room characteristic, & heating/ cooling usage	MSHP	Electric load to building, savings baseline is dependent on a wide variety of factors
R1614/R1613 CT HVAC & Water Heat Process & Impact Evaluation/CT Heat Pump Water Heater Impact Evaluation (2017)	Impact	Baseline fuel types for existing equipment	N/A	HPWH	Customer and contractors gave high (80%+) satisfaction ratings for HPWHs

Study Name	Study Type	Market Sizing/ Baseline	System Configurations	Equipment Included	Drivers/ Barriers
R113 Ductless Heat Pump Evaluation (2016)	Impact	Baseline data collected was aimed at comparing 2011 program participants to 2013-15 participants	Did not distinguish between different configurations of ductless systems; collected baseline data on previous space conditioning	MSHP	There is evidence that many customers are adopting control strategies that reduce the overall efficiency of their DHPs.
R7 Ground Source Heat Pump Impact Study and Market Assessment (2013)	Impact & Market Assessment	Market assessment for GSHP via contractor interviews	Included a variety of GSHP configurations, results did not differentiate between them	GSHP	High costs of systems led to higher free ridership; homeowners were generally satisfied; contractors saw large opportunity for GSHPs in CT
Ductless Mini Split Heat Pumps Evaluation Report (2009)	Impact	None	Did not distinguish between different configurations of ductless systems	MSHP	Early study showing savings over ER and window A/C baseline
Connecticut Baseline Study of Single-Family Residential New Construction (2011)	Baseline	Baseline data cover many aspects of SF RNC	One geothermal installation covered by the study	HVAC/ DHW	Only one home in the study had heat pumps installed
R5 Single-Family Weatherization Baseline Assessment (2013)	Baseline	Baseline data covering Wx standard	Study includes baseline rates of ASHPs, GSHPs, & HPWHs	HVAC/ DHW	26% of studies homes complied with Wx standard (performance path)
R1602 Residential New Construction Program Baseline Study (2017)	Baseline	HP installation rates for space and water heating, equipment efficiency, ENERGY STAR status	Ducted HPs, Ductless HPs, GSHPs, HPWHs	HVAC/ DHW	Program homes perform much better than non-program homes, but non-program homes have improved substantially since the 2011 study

Study Name	Study Type	Market Sizing/ Baseline	System Configurations	Equipment Included	Drivers/ Barriers
Regional & National Studies					
U.S. National Electrification Assessment (EPRI, 2018)	White paper	None	None	Covers all electric end uses	Benefits of HPs: grid flexibility, reduction of water use (swamp coolers) in arid areas, reduction in space heating emissions (large potential), reduction in water heating emissions (low potential)
Northeast and Mid-Atlantic Heat Pump Water Heater Market Strategies Report (NEEP, 2012)	Market report	Includes market sizing for HPWH in 2012 and ERWH in 2009, along with cost data	N/A	HPWH	HPWH had a 1% market penetration in 2012. Several barriers to HPWH installation remain and emergency WH replacement remains the norm.
Promoting Water Heating through Midstream Programs Presentation (CEE, 2018)	Presentation	Penetration of program HPWH in NE market	N/A	HPWH	Top HPWH challenges according to contractors: lack of awareness makes it hard to sell in emergency situations, lack of distributor support (training, marketing, sample product), lack of manufacturer support (tech support and parts)
U.S. Heat Pump Water Heater Market Transformation Presentation (PNNL, 2017)	Presentation	HPWH market penetration in U.S.	N/A	HPWH	HPWH still have only 1% of market with latest available data in 2017, flat since 2009.
New Efficiency: New York Analysis of Residential Heat Pump Potential and Economics (NYSERDA, 2019)	Potential study	Study concludes that heat pumps could provide ~1/2 of the residential heating load in NY by 2025	Cold-climate MSHP and cold-climate ASHP and vertical ground source heat pumps (GSHP)	MSHP, ASHP, GSHP	Analysis shows that HPs are attractive to those that heat with oil or ER, but not gas. HP customers may significantly overpay on their electric bills assuming current rates.

Study Name	Study Type	Market Sizing/ Baseline	System Configurations	Equipment Included	Drivers/ Barriers
RES 28 Ductless Mini-Split Heat Pump Cost Study (Navigant, 2016-2017)	Cost study	Market characterization of capacity/ efficiency combinations	Wall type, outdoor unit location, indoor unit (wall mounted or ceiling cassette), number of systems installed	MSHP	No specific drivers/ barriers addressed, but some configuration were many times more expensive than the base case
RLPNC 17-14: Mini-Split Heat Pump Incremental Cost Assessment (NMR, 2018)	Incremental cost study	None	Ducted MSHPs	MSHP, HPWH	The combined annual HVAC and DHW operating cost for the mini-split house is 133% of the combined annual HVAC and DHW operating cost for the traditional house.
Northeastern Regional Assessment of Strategic Electrification (NEEP, 2017)	White paper	Baseline information: forced air distribution systems, A/C	Did not distinguish between ducted and non-ducted installations for baseline data	All heat pumps	Most installed ccASHP systems are not powerful enough to heat the entire home. Upfront costs are high and payback periods long; installs rarely make sense in homes that heat with gas (unless it's NC).
Northwest Heat Pump Water Heater Initiative Market Progress Evaluation Report #5 (NEEA, 2019)	Market characterization	Market penetration of HPWH	N/A	HPWH	1 in 6 installers reported costly callbacks as the result of problems with HPWHs (slow recovery being the most common problem - could be solved w larger tank)

Table 43Table 43 summarizes the major findings from each of the papers included in this literature review.

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Table 43: Major Findings from Literature Reviewed

Study Name	Major Findings
Connecticut Studies	
R1617 Connecticut Residential Ductless Heat Pumps Market Characterization Study (2019)	• The R1617 Ductless Heat Pump (DHP) study examined the installation circumstances, impacts, and estimated adoption rate of program DHPs installed in Connecticut. • The baselines from DHPs produced a very diverse set of energy impacts among multiple fuels, incl. the possibility of electric load building. The mix of baselines in this study, however, produce an avg. reduction in MMBtu/home. The study found that the assumed measure baseline (a standard DHP) in this formula unrealistically oversimplifies the vast majority of baseline conditions observed in this study and is unlikely to produce an accurate estimate of savings. • The current PSD only credits electric savings to DHP installations; due to standing EEB policy that ratepayer funds do not support fuel switching. The baseline assumptions in the current PSD approach overstates true electric impacts as it does not include instances of load building. DHPs can be a valuable part of an efficiency portfolio, a vehicle to carbon reduction, and/or a means to induce strategic electrification. • Key program recommendations: 1) consider whether/how to incentivize fuel switching and 2) consider only incentivizing installs that will not increase electric load (i.e., by having contractors or customers fill out a questionnaire)
R1614/R1613 CT HVAC & Water Heat Process & Impact Evaluation/CT Heat Pump Water Heater Impact Evaluation (2017)	• Program tracking data quality was low, particularly for HPWHs. • Realization rate of 54% for kWh, 55% for winter peak kW, and 95% for summer peak kW. There were no gas savings claimed in the PSD, but the report estimated a savings of 4.3 MMBtu/yr. NTG was 59% (42% FR, 1% SO). • Customer and contractors gave high (80%+) satisfaction ratings, but distributors were dissatisfied with rebate processing and program communication.
R113 Ductless Heat Pump Evaluation (2016)	• This study was undertaken to identify the causes of the lower-than-expected realization rate for ductless heat pumps (DHPs) reported in the R16 Impact Evaluation of the 2011 program year and to help the utilities get the most savings from DHPs. • This study identified three primary drivers of the realization rate in the R16 Impact Evaluation: (1) Participants in the R16 study had a moderate number of installations that added to heating loads, which was not accounted for in the PSD calculation used at the time. (2) The PSD cooling saving factor is based on program operations and installation conditions that differ from conditions among the 2011 participants, and (3) There is evidence that many customers are adopting control strategies that reduce the overall efficiency of their DHPs. • Regarding point 3, customers are not using their DHP in the winter or are using it as a backup to their pre-existing system.

Study Name	Major Findings
R7 Ground Source Heat Pump Impact Study and Market Assessment (2013)	• This study looked at energy and demand savings over two baselines: going from oil boiler/CAC to GSHP and going from 'standard-efficiency' GSHP to HE GSHP. On an MBTU basis, there was energy and demand savings over both baselines, except for cooling over standard CAC. • Overall NTG was 0.71. The federal tax credit had the biggest effect, and NTG was higher for those that received it (0.75) than those that did not (0.53). Retrofit projects had a higher NTG (0.77) than NC (0.63). High costs of GSHP and high incomes of participants lead to depressed NTG values. • GSHPs are sized to meet the home's heating needs. The systems appear to be performing somewhat below spec. efficiencies but the rated capacities and recovery fields for the loop seem correct. • Process findings: Homeowners are generally satisfied with the GSHP program and their new GSHP systems. Contractors all used Manual J for sizing. • Market assessment: contractors think there is a large opportunity for residential GSHPs in CT, but some were concerned about federal tax credits going away in 2017.
Ductless Mini Split Heat Pumps Evaluation Report (2009)	• This study is a historical look at heating and cooling savings over baseline (ER heating/window AC) and cost data in 2009.
Connecticut Baseline Study of Single-Family Residential New Construction (2011)	• RNC baseline study of 69 non-program homes. Only looks at energy features of homes, not code compliance.
R5 Single-Family Weatherization Baseline Assessment (2013)	• The study involved on-site visits to 180 single-family homes across the state. The Team assessed compliance with the weatherization standard using both the prescriptive and performance paths. The evaluation determined 26% of the sampled homes comply with the performance path. Only 5% of the sampled homes comply with applicable prescriptive requirements. • New homes are more likely to comply than old homes. Non-LI homes are more likely to comply than LI homes. Compliant homes exceeded the weatherization standard by an avg. of 13%, while non-compliant homes failed by an avg. of 48%. The three prescriptive components with the lowest compliance rates are floors over unconditioned basements (15%), flat ceilings (34%), and air leakage (39%). The highest compliance was windows (82%). • Weatherization standard doesn't address MF buildings, but they're 36% of housing units in CT.
R1602 Residential New Construction Program Baseline Study (2017)	• SF RNC baseline study. The study answered two key questions about the market at the end of the 2009 IECC code cycle: (1) how has the market baseline changed over time, and (2) what kinds of changes in building practices and equipment have occurred? This study included site visits to 70 new, non-program homes (46 spec- and 24 custom-built). On-site data collection covered all aspects of home energy performance, and HERS ratings were conducted at all homes to update the UDRH. There was a billing analysis to compare REM/Rate model to actual billing data.

Study Name	Major Findings
	• Program homes perform much better than non-program homes, but non-program homes have improved substantially since the last study. Baseline averages meet 2009 IECC for most measures. REM/Rate models are similar to actual billing data.
Regional & National Studies	
U.S. National Electrification Assessment (EPRI, 2018)	• This is a national level study of electrification under 4 scenarios: conservative > reference > progressive (moderate C tax) > transformation (high C tax). • In the US, electricity has grown from 3% of site energy in 1950 to approximately 21% today. Across the four scenarios, electricity's role continues to grow, ranging from 32% to 47% of final energy in 2050 (due in part to strategic electrification). This contrasts with a drop in site energy consumption. • Natural gas use continues to grow in all four EPRI scenarios based on its operational flexibility and an assumed ongoing cost around $4/MMBtu. • Carbon intensity of electric generation and carbon emissions fall under all scenarios. • Increased use of electric heating and the inefficiency of EVs in winter months will shift electric demand to winter months. • Need to focus on system resiliency as you electrify -- both from extreme weather and cyber-attacks. • Actions to realize benefits of SE: grid modernization (TOU rates, storage, reliability), continued tech advantages (e.g., batteries), update codes to remove fuel bias, etc.
Northeast and Mid-Atlantic Heat Pump Water Heater Market Strategies Report (2012)	• HPWH have a 1% market penetration. Key barriers include (1) Lack of Consumer Awareness/Education, (2) Lack of Midstream Market Actors Awareness/Expertise, (3) High Incremental Cost in Relation to Electric Resistance Water Heaters (ERWH), (4) Inconsistent Product Performance (when operated in conditions typical of colder climates). History has given us too many examples of emerging technologies that have been poorly introduced to the market, delaying and in some cases altogether preventing their potential from ever being realized. • There are significant opportunities here however: if all residential ER water heaters were replaced with HPWHs, 340 million kWh would be saved annually, and summer peak would be reduced by 30MW. • CT estimated a 5.8-year payback period in 2012. • Emergency water heater replacement is the norm. Even if replacing ERWHs, this is a hard sell in such a situation.
Promoting Water Heating through Midstream Programs Presentation (2018)	• Residential water heating programs increasingly becoming midstream programs. ES suggests cooperative agreement where distributors pass along discount to contractors. Customers do not like forms or waiting for rebates. With lighting savings going away, now is the time to focus on HPWHs (next highest potential measure in the NW). • CEE gives an overview of member water heating program. E.g., types of WHs covered, incentives, efficiencies covered, etc. HPWH programs reached between 0 and 0.5% of electric customers in 2016.

Study Name	Major Findings
	• Energy Star has a distributor focused midstream WH program site, it mentions EnergizeCT, which saw a 1000% increase in participation by moving midstream. ES says midstream is better for PAs (increased participation and no rebate breakage), manufacturers (they sell more HPWHs), plumbers (incentive is instant, no paperwork), and homeowner (gets HPWH during an emergency). Distributors are skeptical (they're the ones taking the risk and doing the paperwork) but they can be persuaded -- higher margins on HPWH. ES also has a WH contractor finder & lets you compare HPWH models. • Top HPWH challenges according to contractors: lack of awareness makes it hard to sell in emergency situations, lack of distributor support (training, marketing, sample product), lack of manufacturer support (tech support and parts)
U.S. Heat Pump Water Heater Market Transformation Presentation (2017)	• Water heating is the second largest energy use in U.S. residences (17% of total energy). HPWH uses 60% less electricity than ERWH (2700 kWh, $340 annually) • HPWH still have only 1% of market with latest available data in 2017, flat since 2009. This represents 15-20% of electric heating market. Energy Star has spec as does NEEA (northern climate + advanced spec). CO2 HPWH is an emerging technology.
New Efficiency: New York Analysis of Residential Heat Pump Potential and Economics (2019)	• The Report concludes that, based on a conservative application of constraint assumptions, heat pumps could serve approximately half of the thermal energy load in the small residential sector (over 2019-2025), with potential to increase this estimate as barriers such as landlord-tenant constraints or availability of hydronic heat pump systems are overcome. The analysis also assumes the ""missing money"" will be addressed with programs and incentives. • The technical potential (50% of res sites) is found by multiplying the # of sites by the thermal load that could be served at that site. Does not consider cost of speed of adoption but does include technological limitations (e.g., insufficient space for GSHP drilling) and barriers related to landlord-tenant situations. Analysis assumes no HPs will be installed in homes with radiators, but systems may become available soon. • Economic potential: Analysis shows that HPs are attractive to those that heat with oil or ER, but not gas. HPs will reduce summer peak demand and avoid carbon emissions. HP customers may significantly overpay on their electric bills assuming current rates.
RES 28 Ductless Mini-Split Heat Pump Cost Study (2016-2017)	• Study lists install costs of different DMSHP configs (Table 2-3 in report). • On average, the total cost of a retrofit DMSHP installation is about $75 higher than the total cost of a replacement DMSHP installation. • On average, installations through brick exterior walls cost about $260 more than installations through other exterior wall types (with +$200 for labor and +$60 for supplies), but this varies depending on the specifics of the installation site and the contractor's in-house capabilities. • Relative to the base case installation where the outdoor condenser unit is located on a ground pad: o Mounting the outdoor unit to an exterior ground-floor wall is $70 less expensive.

Study Name	Major Findings
	o Mounting the outdoor unit on the roof is about $400 more expensive. o Mounting the outdoor unit on an exterior wall above the ground floor is about $1,000 more expensive. • Installing an indoor ceiling cassette unit that is embedded in the ceiling of the conditioned space is about $1,050 more expensive than the base case installation where the indoor unit is an exposed wall-mounted unit.
RLPNC 17-14: Mini-Split Heat Pump Incremental Cost Assessment (2018)	• The combined initial HVAC and DHW cost for the mini-split house is 106% of the combined initial HVAC and DHW cost for the traditional house. The traditional house with gas heat also has lower operating costs than the mini-split house. Even though the mini-split house requires less energy to heat, the higher cost of electricity relative to gas means that the mini-split house costs $485 more than the traditional house to heat each year. Similarly, the mini-split house's heat pump water heater requires less energy than the traditional house's tankless gas water heater, but the higher cost of electricity relative to gas means that it costs $19 more per year more to supply hot water to the mini-split house. The mini-split house costs slightly less than the traditional house to cool ($124 compared to $132). The combined annual HVAC and DHW operating cost for the mini-split house is 133% of the combined annual HVAC and DHW operating cost for the traditional house
Northeastern Regional Assessment of Strategic Electrification (2017)	• Only 54% of Northeast homes have forced air distribution systems, compared to >70% nationally. Nearly one quarter of New England homes have no AC, while about half of Northeast homes use window ACs. ~3% of Northeast homes have space HPs, though most are likely non-cc; 8% of NC homes have HPs but growth in NC is very slow (<0.4% annually). The replacement rate of space heating is limiting: <5% annually in the 10.5 million 1–4-unit homes in the Northeast. • Most installed ccASHP systems are not powerful enough to heat the entire home. Upfront costs are high and payback periods long; installs rarely make sense in homes that heat with gas (unless it's NC). Performance is still poor at <0 deg F.
Northwest Heat Pump Water Heater Initiative Market Progress Evaluation Report #5 (2019)	• In 2018 in the NW, HPWHs represented 7.7% of the electric water heater market in SF homes, including both new and existing homes. Recommendation: incentives for retrofit should be higher than NC. • Distributor stocking practices increase HPWH delivery time, impeding growth in the emergency replacement market – but evidence suggests that stocking larger-capacity HPWHs at the branch level could now be relatively common. • Almost half of program-trained installers commonly use workarounds to avoid installing HPWHs in place of large electric resistance tanks. 1 in 6 installers reported costly callbacks as the result of problems with HPWHs (slow recovery being the most common problem - could be solved w larger tank). There were many installation challenges cited, and many said that few technicians were prepared to service HPWHs.

Appendix C Market Sizing Detail

This section provides additional detail from the market sizing effort, which estimated the number of heat pump and HPWH systems installed in Connecticut in 2017 through 2019 and the market share captured by the Companies' programs.[43] As described in Appendix A.2, the values presented in this section represent approximations rather than actual counts.

C.1 Regional Benchmarking Results

Using the HARDI data, the study team explored the differences between the HVAC market in Connecticut and the surrounding states.[44] A regional benchmarking analysis was not conducted for GSHPs and HPWHs equipment due to limited comparison data.

C.1.1 MSHP Regional Market Efficiency

The estimated average heating efficiency (HSPF) for MSHPs in Connecticut increased from 2013 to 2019 but was also the lowest in the region (Figure 44Figure 44). Additional details on how HSPF values were estimated are provided in Appendix A.2.2.

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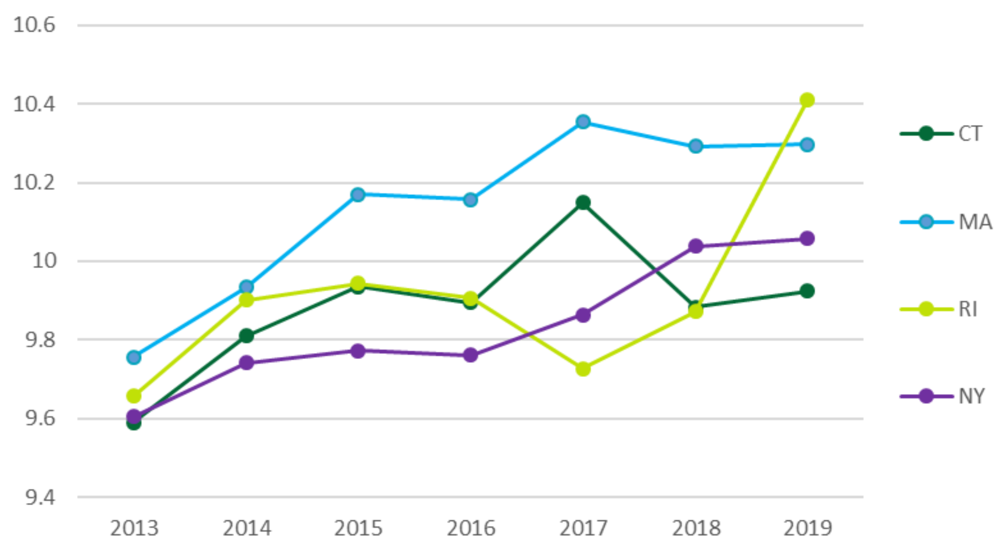
Figure 44: Regional Estimated Annual Average Heating Efficiency (HSPF) for MSHPs (2013-2019), HARDI

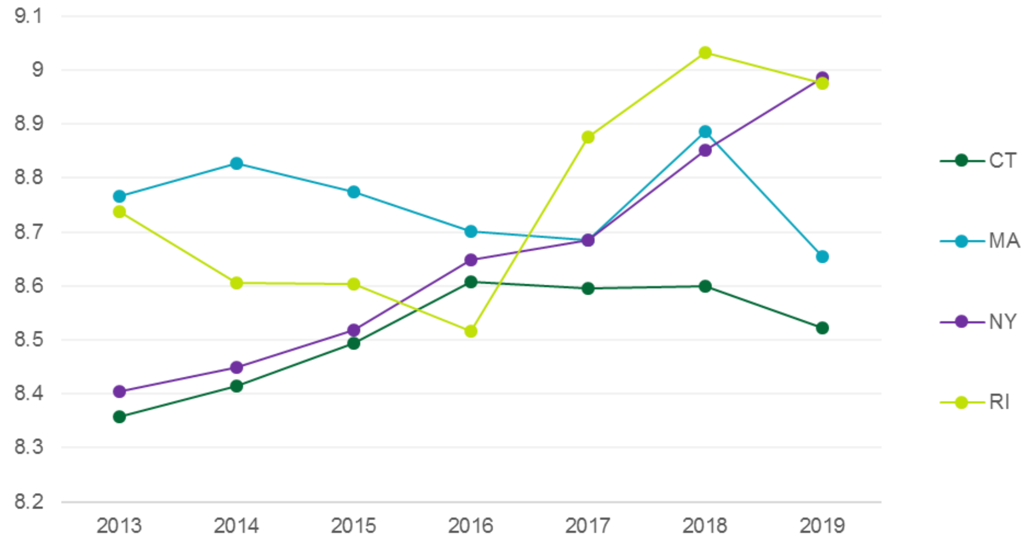


C.1.2 ASHP Regional Market Efficiency

[43] The study focuses on equipment rated for residential use, including any residential-grade systems that might be installed in light commercial applications.
[44] Details on what is included in the HARDI data is provided in Appendix A.2.

The estimated average heating efficiency (HSPF) for ASHPs in Connecticut increased from 2013 to 2019 but was also the lowest in the region nearly every year (Figure 45~~Figure 45~~).[45]

Figure 45: Regional Estimated Annual Average Heating Efficiency (HSPF) for ASHPs (2013-2019), HARDI

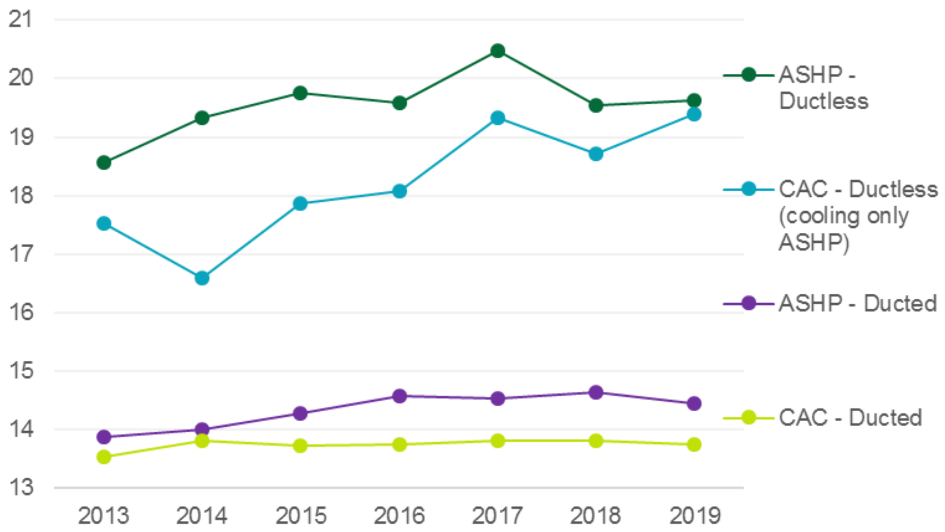


C.2 CONNECTICUT MARKET OUTLOOK – EQUIPMENT COMPARISON

The cooling efficiency (SEER) of inverter-driven heat pumps was vastly superior to ducted heat pumps and central ACs from 2013 to 2019 (Figure 46~~Figure 46~~).

[45] As noted in the MSHP section, HSPF values were estimated for HARDI data.

Figure 46: Estimated Average Efficiency (SEER) of Cooling Equipment in Connecticut (2013-2019), HARDI



C.3 MSHP and ASHP Market Size

This section provides additional detail about the size of the Connecticut market for MSHPs and ducted ASHPs. The methodology used to estimate the market size, including the limitations of available data sources, is provided in Appendix A.

C.3.1 Program Background

From 2015 to 2020, ductless MSHP rebates were divided into four categories: single-zone, single-zone displacing electric resistance heating, multi-zone, and multi-zone displacing electric resistance heating. While the incentive amounts changed over time, the efficiency requirements remained the same (Table 44Table 44). In 2014, a $150 rebate for a packaged terminal heat pump was offered with an EER requirement.

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Table 44: Connecticut Residential Ductless Heat Pump Rebates, 2014-2020

	Efficiencies		Incentives (per ton)		
System Configuration	SEER	HSPF	2014	2015-2016	2017-2020
Ductless HP	14.5	8.2	$250	-	-
Ductless HP – Displacing ER heat	14.5	8.2	$1,000	-	-
Single Zone	20.0	10.0	-	$300	$300
Single Zone – Displacing ER heat	20.0	10.0	-	$1,000	$700
Multi-Zone	18.0	9.0	-	$300	$500
Multi-Zone – Displacing ER heat	18.0	9.0	-	$1,000	$700

Similarly, the Companies offered rebates for a variety of ducted heat pumps ranging from $250 in 2014 to $1,000 in 2020 (Table 45~~Table 45~~). Formatte

Table 45: Connecticut Residential Ducted Heat Pump Rebates, 2014-2020

System Configuration	Efficiencies		Incentives (per ton)		
	SEER	HSPF	2014-2015	2015-2016	2017-2020
Packaged ASHP	14.0	8.0	$250	-	-
	16.0	8.2	-	$500	$500
Split ASHP	14.5	8.2	$250	-	-
	18.0	10.0	$500	$500	-
	16.0	10.0	-	-	$500
Split ASHP – Displacing ER heat	16.0	10.0	-	-	$700-$1,000 [a]

[a] Incentives for displacing ER heat were increased from $700 in 2019 to $1,000 in 2020.

C.3.2 Market Size

MSHP and ASHP market size estimates from 2013 through 2019 were based on HARDI data (see Appendix A.2 for additional details).[46] Equipment volumes presented in Table 46~~Table 46~~ represent the total market size for MSHP and ASHPs that provided heating and cooling functions.[47] Formatte

Table 46: CT MSHP and ASHP Market Estimates (HARDI)

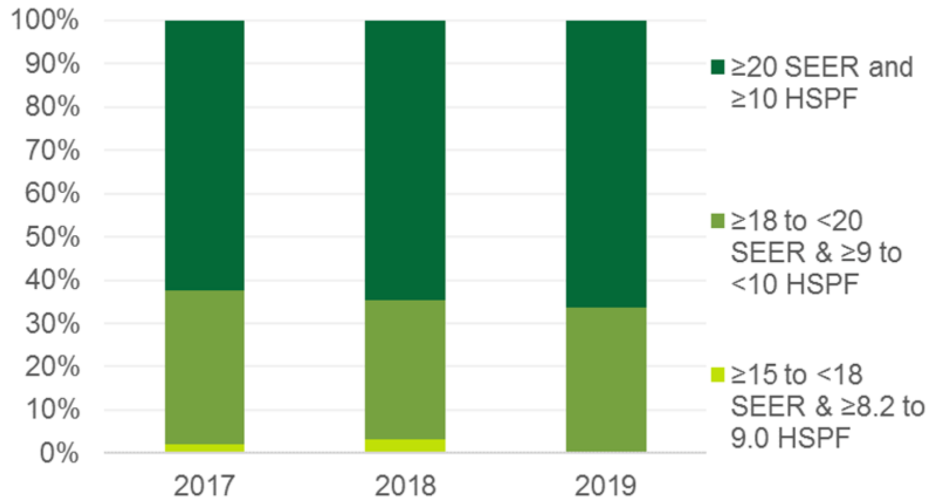
Year	MSHPs (units)	ASHPs (units)	All ASHP and MSHP equipment
2013	4,552	1,985	6,537
2014	5,673	2,259	7,932
2015	4,168	2,336	6,504
2016	4,246	2,083	6,329
2017	5,460	2,273	7,733
2018	5,023	2,212	7,235
2019	4,799	1,758	6,557

C.3.3 Program Efficiency

Approximately two-thirds of incentivized MSHPs were 20 SEER and 10 HSPF or higher from 2017 to 2019. In 2019, all program MSHPs were at least 18 SEER or higher. The program had a higher proportion of units that were 20+ SEER and 10+ HSPF than the market average (approximately 66% vs. 50%).

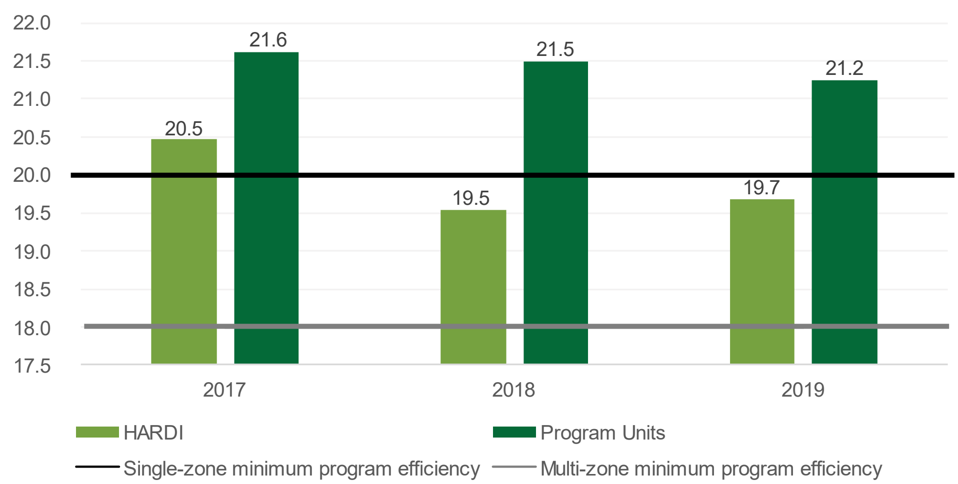
[46] Retrofit vs. new construction installations and residential vs. commercial sales, or MSHP configuration (single-zone vs. multi-zone vs. centrally ducted) details are based on program tracking data and results from IDIs and surveys; those breakdowns are not included in the HARDI data.
[47] This excludes HARDI's estimate for cooling-only ductless heat pumps.

Figure 47: Annual Program MSHP Units by Efficiency (SEER and HSPF)



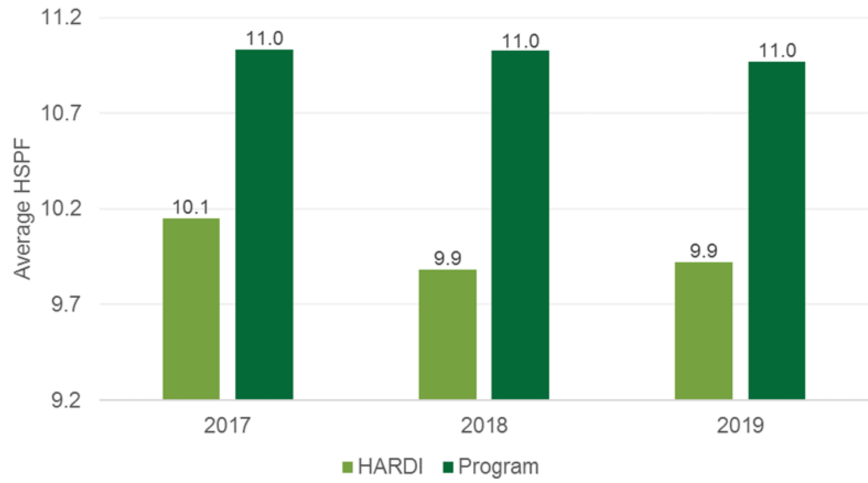
The average SEER of MSHP units dropped slightly (4%) from 20.3 in 2017 to 19.7 in 2019. The average SEER of program MSHP units remained higher overall, but still decreased slightly, from 21.6 to 21.2 SEER (Figure 48~~Figure 48~~).

Figure 48: Average Efficiency of MSHP Market vs. Average Efficiency of Program MSHPs (SEER)



The average HSPF of program MSHP units decreased slightly - by less than one percent - from 2017 to 2019 but remained higher than the broader MSHP market (Figure 49~~Figure 49~~).

Figure 49: Average Efficiency of MSHP Market vs. Average Efficiency of Program (HSPF)



From 2017 to 2019, the amount of incentivized ASHP units that were 18 SEER and 10.6 HSPF or higher decreased by almost 10% (Figure 50Figure 50).[48]

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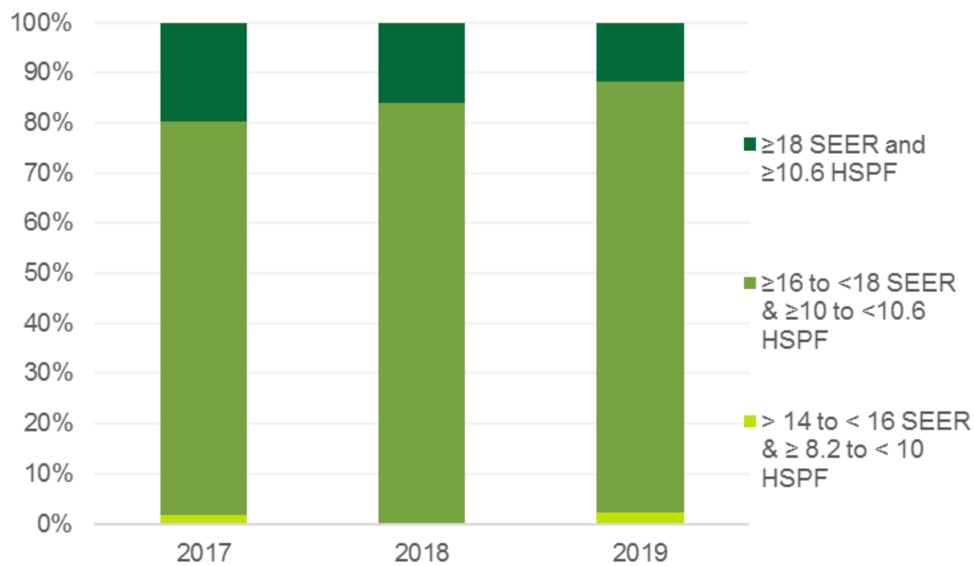
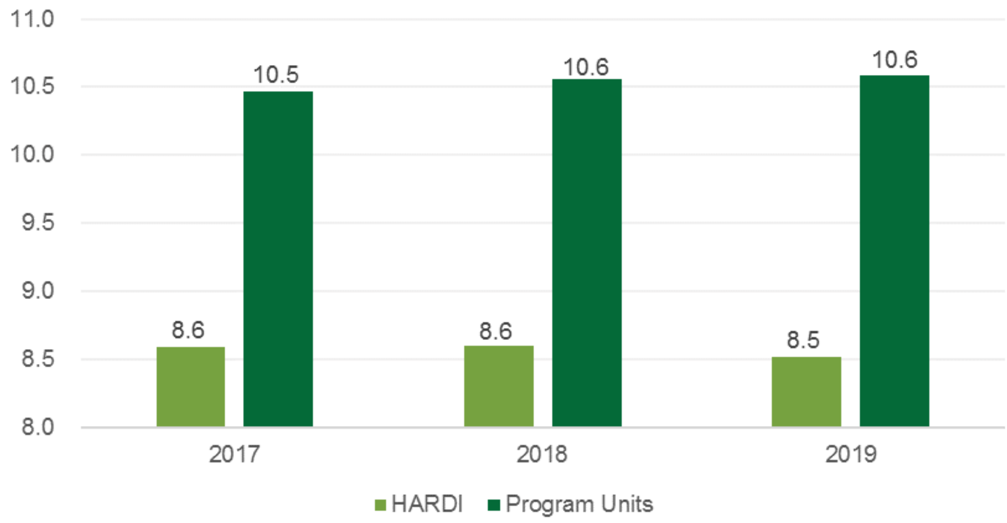
Figure 50: Annual Program ASHP Units by Efficiency (SEER and HSPF)



The average HSPF of ASHP units in the overall market dropped slightly (1%) since 2017, while program MSHP units remained higher than the broader market, and increased slightly, by one percent since 2017. As mentioned above, this may be due to more ASHP systems available in the market that have lower cooling efficiencies with higher heating efficiencies.

[48] Note that the program data that was provided included cooling efficiency values expressed in EER units, rather than SEER. To compare with the HARDI data, the program data efficiency values were converted from EER to SEER. This may explain the small percentage of units that do not meet the program minimum requirements that are seen in the figure below. Additional details are provided in the detailed methodology, Appendix A.2.2.

Figure 51: Average Efficiency of ASHP Market vs. Average Efficiency of Program (HSPF)



C.3.4 Efficiency by Configuration

Table 47~~Table 47~~ presents the estimated counts of single- and multi-zone equipment in the market and within the program.

Table 47: MSHPs by Number of Zones (Overall Market and Program)

Year	Unit Counts		Configuration Proportion	
	Single-zone	Multi-zone	Single-zone	Multi-zone
Total Market Configuration Splits (HARDI)				
2013	2,062	2,490	55%	45%
2014	2,494	3,180	56%	44%
2015	1,900	2,268	54%	46%
2016	2,106	2,140	50%	50%
2017	2,439	3,020	55%	45%
2018	2,665	2,359	47%	53%
2019	2,571	2,227	46%	54%
Total Program Configuration Splits				
2017	1,460	1,099	57%	43%
2018	1,806	1,821	50%	50%
2019	1,892	2,482	43%	57%

Table 48~~Table 48~~ presents comparisons between single-zone and multi-zone efficiencies for both the program units and the broader market.

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Table 48: Average Efficiency of MSHP Market vs. Average Efficiency of Program by Configuration

Year	Weighted HSPF			Weighted SEER		
	All MSHPs	Single-zone MSHP	Multi-zone MSHP	All MSHPs	Single-zone MSHP	Multi-zone MSHP
Total Market Configuration Splits (HARDI)						
2013	9.6	9.9	9.2	18.6	19.8	17.1
2014	9.8	10.2	9.3	19.3	21.0	17.2
2015	9.9	10.4	9.4	19.7	21.6	17.5
2016	9.9	10.3	9.5	19.6	21.1	18.0
2017	10.1	10.7	9.5	20.5	22.4	18.1
2018	9.9	10.3	9.5	19.5	21.1	18.1
2019	9.9	10.3	9.6	19.7	21.4	18.2
Total Program Configuration Splits						
2017	11.0	11.7	10.2	21.6	22.8	20.0
2018	11.0	11.9	10.2	21.5	23.4	19.6
2019	11.0	11.9	10.3	21.2	23.2	19.7

C.4 Connecticut Residential Geothermal Market Size Estimates

This subsection focuses on the Connecticut market for geothermal or ground-source heat pump (GSHP) systems and the market share of the Companies' programs (i.e., the percentage of installed units that received program incentives). The methodology used to determine the GSHP market estimates, the data sources used, and the limitations within the data are provided in Appendix A.

C.4.1 Connecticut Geothermal Program Background

GSHPs are incentivized by the Companies through a downstream rebate application administered typically through the HES-HVAC and the RNC programs. The program began providing increased incentives for displacement of electric resistance and oil/propane systems in 2020 (Table 49~~Table 49~~).

Table 49: Connecticut Residential Incentives for GSHPs, 2014-2020

System Configuration		Efficiencies		Incentives (per ton)	
		EER	COP	2014-2019	2020
Closed Loop Water to Air	Standard	17.1	3.6	$250	-
	Displacing ER heat	17.1	3.6		$750
	Displacing oil/propane	17.1	3.6	-	$1,500
Direct Expansion Refrigerant	Standard	16.0	3.6	$250	-
	Displacing ER heat	16.0	3.6	-	$750
	Displacing oil/propane	16.0	3.6	-	$1,500
Water to Water	Standard	16.1	3.1	$250	-

NMR Group, Inc.

Displacing ER heat	16.1	3.1	-	$750
Displacing oil/propane	16.1	3.1	-	$1,500

C.4.2 GSHP Market Trends - New Construction vs. Retrofit

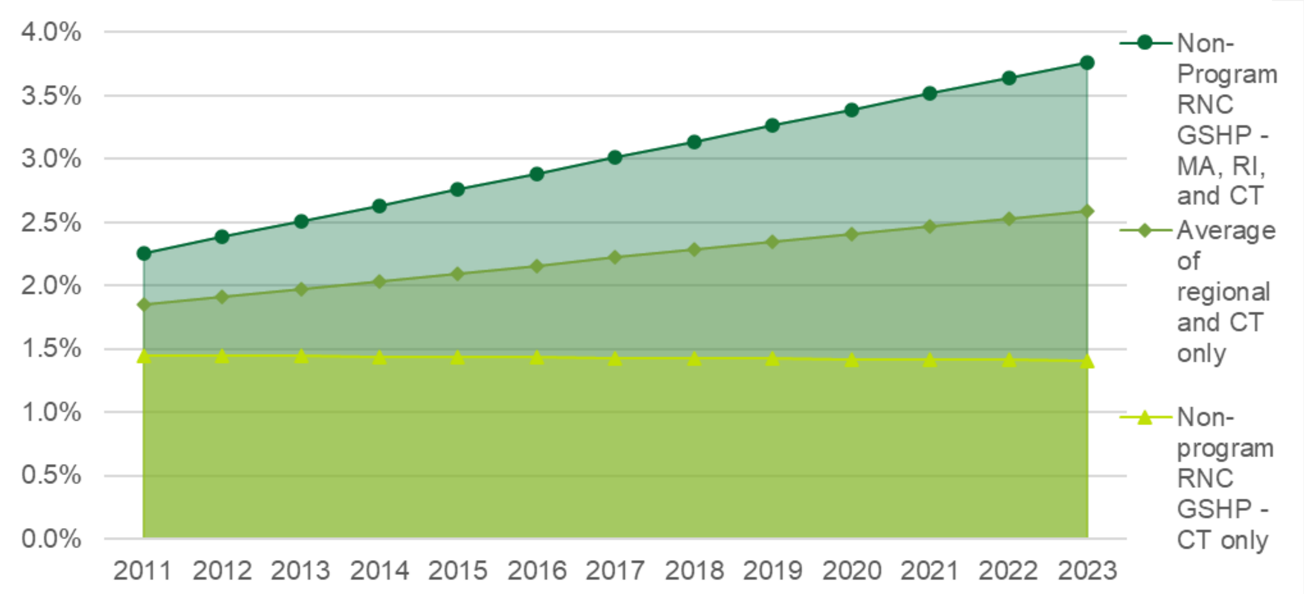
The proportion of GSHP installations in RNC program homes increased by less than 1% between 2017 and 2019. The penetration of GSHPs into the RNC program is higher than the non-program RNC market since 2017 (Table 50~~Table 50~~).

Table 50: Program and Non-Program RNC GSHP Penetration

Year	RNC Program – GSHP penetration	2016-17 CT RNC Baseline – GSHP penetration	Estimated GSHP Penetration		
			High	Average	Low
2017	3.2%	1.4%	3.0%	2.3%	1.4%
2018	4.3%		3.1%	2.3%	1.4%
2019	3.9%		3.3%	2.3%	1.4%

The penetration of GSHPs into the non-program RNC market remains low, between 1% and 4%, and may have experienced subtle growth or decline since 2016.[49] However, there is evidence in the RNC program data that GSHP installations have remained relatively flat over the 2017 to 2019 period, which may indicate the non-program market has remained relatively flat.

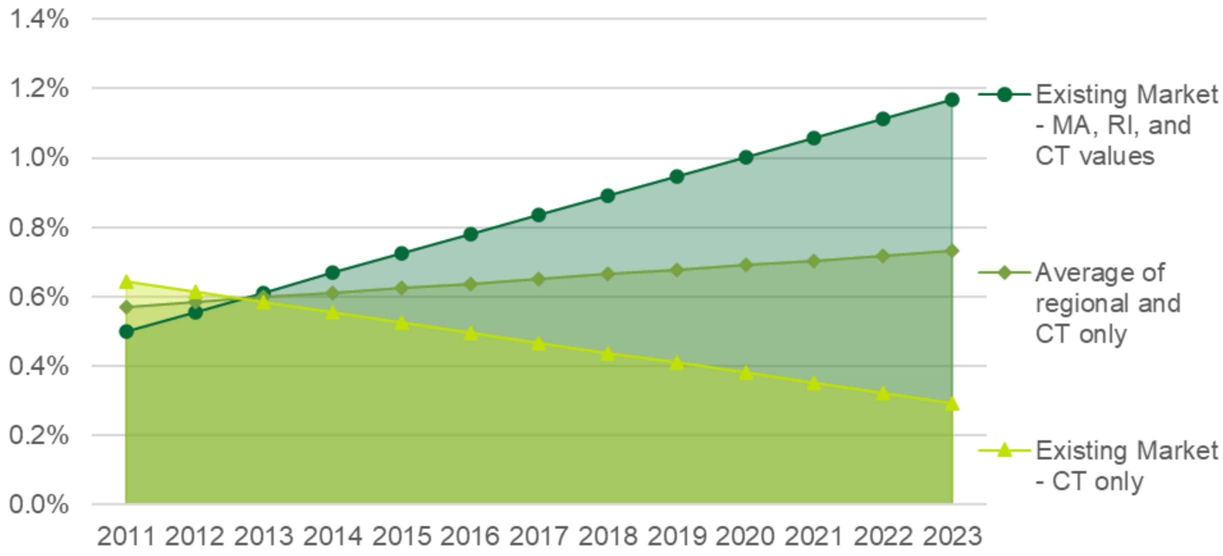
Figure 52: Estimated Annual Growth and Penetration of GSHPs in Non-Program Residential New Construction



[49] The non-program new construction market size is determined based on annual Connecticut residential permit count subtracted by the number of RNC program participants. Residential permit data was obtained through the U.S. Building Permit Survey for years 2015-2019: https://www.census.gov/construction/bps.

The penetration of GSHPs in the existing market is expected to remain low, with all estimate scenarios less than 1% (Figure 53~~Figure 53~~). The estimated growth for the entire existing home (retrofits and replacement) market suggests a flat GSHP market. However, the number of incentivized GSHP installations in existing home programs have decreased over the 2017-2019 period, which may indicate the overall retrofit market has also contracted.

Figure 53: Estimated Annual Growth and Penetration of GSHPs in Existing Homes



The proportion of GSHP installations in the new construction market has increased from approximately one-half to nearly two-thirds of the market (Table 51~~Table 51~~).

Table 51: Estimated GSHP Installations in New Construction Vs. Retrofit

Year	High - Includes CT, MA, and RI Saturation Data		Average – High and Low Estimate		Low - Only CT Saturation Data	
	New construction	Retrofit	New construction	Retrofit	New construction	Retrofit
2017	52%	48%	51%	49%	47%	53%
2018	69%	31%	71%	29%	71%	29%
2019	66%	34%	67%	33%	64%	36%

The proportion of program sponsored GSHP installations varies year-by-year, but generally is higher in the retrofit scenarios compared to new construction. The RNC program varies between 28% and 57% of program sponsored GSHP installations.

Table 52: GSHP Installations in RNC Program vs. Rebate Program

Year	*Programs*		
	Residential Rebates	RNC	SBEA
2017	70%	28%	3%
2018	43%	57%	--
2019	56%	44%	--

C.4.3 GSHP Market Trends - Residential vs. Commercial

Only one percent of program sponsored GSHPs were installed in commercial spaces since 2017. There were two GSHPs incentivized in the Small Business Energy Advantage (SBEA) program in 2017 (3%). There were no incentivized commercial installations of GSHPs in 2018 or 2019. Limitations in previous evaluations and lack of secondary information on installations of residential-sized GSHPs in commercial settings reduced the ability to understand the proportion of installations in commercial buildings.

C.5 CONNECTICUT RESIDENTIAL HPWH MARKET ESTIMATES

This section focuses on the size of the Connecticut market for HPWH systems and the market share of the Companies' programs in the overall market (i.e., the percentage of installed units that received program incentives). The methodology is provided in Appendix A.

C.5.1 Connecticut HPWH Program Background

Between 2014 and 2020, HPWH rebates increased from $400 to $750 with a corresponding increase in energy factor (EF) from 2.0 to 3.0 (Table 53~~Table 53~~). In 2019, incentives were only for HPWHs less than 55 gallons (presumably in response to raised efficiency requirements in 2015 from the NAECA standards), but incentives are now available for larger units.

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Most of the residential HPWHs incentivized by the Companies pass through the midstream program. This program uses two delivery channels: one through the distributor, where the buy-down reduces the cost to the installer, and one with an instant discount at retail outlets, such as Lowe's or Home Depot. The HES program also incentivizes HPWHs as an add-on measure for HES participants, and the RNC program indirectly incentivizes HPWHs as they contribute to a home's overall performance.

Table 53: Connecticut Residential Incentives for HPWHs, 2014-2022[50]

System Configuration		Efficiency	Incentives (per ton)					
		EF	2014	2015-2016	2017	2018	2019-2020[a]	2020[a]-2022
HPWH <= 55 gallons	Displacing ER tanks	2.0	$400	-	-	-	-	-
	Standard	2.0	-	$400	-	-	-	-
		2.4	-	-	$600	-	-	-
		3.0	-	-	-	$500	$750	$750
HPWH > 55 gallons	Displacing ER tanks	2.0	$400	-	-	-	-	-
	Standard	2.0	-	$400	-	-	-	-
		2.4	-	-	$600	-	-	-
		3.0	-	-	-	$500	-	$400

[a] The Companies updated HPWH incentives in July of 2020.

C.5.2 HPWH New Construction vs. Retrofit Market Size

Electric water heaters are similarly common in program and non-program homes, but HPWHs are much more common in program homes (19%-33% vs. 6%) (Table 54Table 54). However, HPWH installations in new program homes fell by 42% between 2018 and 2019. In addition to the removal of incentives for HPWHs greater than 55 gallons, reduced RNC program penetration into the broader RNC market, use of centralized systems in multifamily buildings, or negative perceptions of HPWH technology with end-users and installers may have lowered the use of HPWHs in 2019 RNC program homes.

Table 54: RNC Program and Non-Program Electric Water Heater Penetration

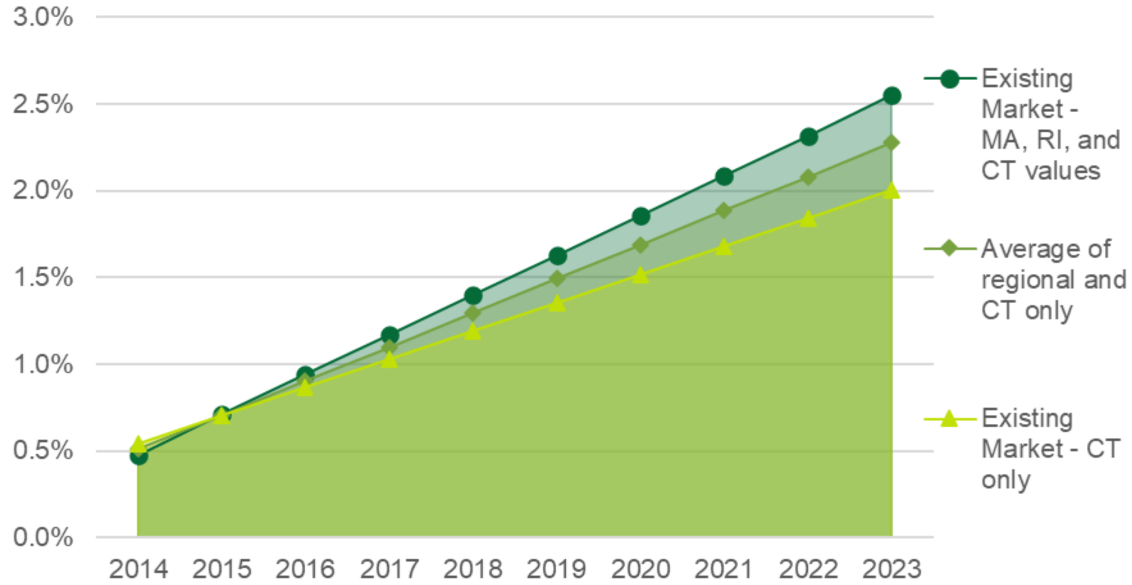
Year	Electric DHW Penetration		HPWH Penetration	
Year	RNC Program	2016-2017 CT RNC Baseline	RNC Program	2016-2017 CT RNC Baseline
2017	24%		23%	
2018	33%	25%	33%	6%
2019	27%		19%	

The penetration of HPWHs in the retrofit market is anticipated to slowly increase over time. If the trend holds, by 2023 the estimated HPWH penetration into the retrofit market may lay between 2% and 2.5%, which is not a strong indication of rapid displacement of other water heating technology and fuels with HPWHs. Due to limited data points and observed trends that HPWHs

[50] Prior to 2019 there was no size requirement associated with the HPWH incentive. In 2019, the program added an equipment size requirement of ≤55 gallons of capacity and increased the overall incentive amount from $500 to $750.

are slowly increasing penetration in the retrofit (planned and emergency replacement) market, the estimated growth projection is positive over time. However, the quantity of incentivized HPWHs decreased from 2017 to 2019 and may indicate that broader HPWH market may have also contracted.

Figure 54: Estimated Annual Growth and Penetration of HPWHs in Existing Homes



Although penetration of HPWH technology in the new construction market is much higher than the retrofit market, the retrofit market represents a larger portion of HPWH installations (Table 55~~Table 55~~).

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Table 55: Estimated HPWH Installations in New Construction Vs. Retrofit

Year	High Estimate: Based on CT, MA, and RI Data		Middle Estimate: Average of High and Low		Low Estimate: CT Data Only	
	New construction	Retrofit	New construction	Retrofit	New construction	Retrofit
2016	39%	61%	34%	66%	29%	71%
2017	35%	65%	33%	67%	30%	70%
2018	37%	63%	36%	64%	35%	65%
2019	27%	73%	25%	75%	22%	78%

C.5.3 HPWH Distribution vs. Retailer Channels

The majority of HPWH systems are incentivized through the distributor channel (between 56% and 63%), however a large portion of incentivized HPWHs is also flowing through the retail channel (Table 56~~Table 56~~).

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The Companies provided data for the HPWH midstream program which contained data on the supply channel through which the incentivized equipment flowed. Market-level estimates of supply channel sales were not calculated due to limitations in the data sources used to construct market-level estimates. However, additional insights from previous evaluations conducted in other jurisdictions are included to provide context into how HPWHs are sold through different supply channels (Table 57~~Table 57~~).[51,52]

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Table 56: Program Sponsored HPWH Sales by Supply Channel in Connecticut

Year	Distributor channel sales (units)	Retail channel Sales (units)	Percent of sales – distributor channel	Percent of sales – retail channel
2017	936	721	56%	44%
2018	889	512	63%	37%
2019	863	667	56%	44%

Table 57: HPWH Sales by Supply Channel in Outside Jurisdictions

Evaluation	Distribution	Retailer
MPER #4 – NEEA Region	75%	25%
MPER #5 – NEEA Region	81%	19%
MPER #5 – Washington	86%	14%
MPER #5 – Oregon	69%	31%
MPER #5 – Idaho	51%	49%
MPER #5 – Montana	57%	43%

51 https://neea.org/img/documents/HPWH_MPER4_FINAL.pdf
52 https://neea.org/img/documents/Northwest-Heat-Pump-Water-Heater-Initiative-Market-Progress-Evaluation-Report-5.pdf

Appendix D Market Actor Feedback Additional Detail

The study included research activities aimed at soliciting feedback on the heat pump and HPWH market from different market actors. This included interviews with manufacturers (n=5) and distributors (n=12) of HVAC heat pumps and HPWHs, a web survey of heat pump installation contractors (n=66), and follow-up interviews with installers who had completed the web survey (n=10). The following section provides additional detailed findings from those research efforts.

D.1 Pre-Existing Conditions

D.1.1 Heating

Primary fuel before and after HP install. Installers estimated that around two-thirds of MSHP and ASHP heat pump installations in existing homes were done in homes with oil or electric resistance as their primary pre-existing heating fuel (43% and 24%, respectively).

Installers reported that in existing homes where they installed MSHPs and ASHPs, electric resistance as the primary heating fuel dropped by 67%, and oil as the primary fuel dropped by 25%. Oil was still the most common primary heating fuel in existing homes even after the installation of a heat pump (32%), followed closely by the heat pump itself (31%).

In new construction, the installed heat pump was the most common primary heating source (42%), followed by a natural gas or propane system (23% each).

Table 58: Primary Heating Fuel Before and After MSHP or ASHP Install

(Source: installer survey; n=53)

Primary Heating Fuel	Existing Homes		New Homes (n=32)
	Pre-Install % (n=53)	Post-Install % (n=52)	
Oil	43%	32%	11%
Electric heat pump	7%	31%	42%
Electric resistance	24%	8%	2%
Natural gas	15%	18%	23%
Propane	11%	12%	23%
Wood	1%	<1%	<1%

D.1.2 Cooling

According to installers, the most common MSHP installation scenario for cooling with MSHP systems in existing homes was to provide cooling to an uncooled space (44%) or to replace room air-conditioner units (30%). Only 19% of MSHP installs were to replace a central AC system and 6% were to supplement an existing cooling system.

Table 59: MSHP Cooling Installation Characteristics in Existing Homes

(Source: installer survey; n=55)

Heat Pump Cooling Characteristic	% of Installs
Add cooling to spaces that did not have AC	44%
Replace room AC	30%
Replace CAC	19%
Cool spaces also served by CAC	6%

D.2 Hypothetical Installation Scenarios Presented to Installers in IDIs

The study asked a subsample of surveyed installers to participate in a follow up interview about their heat pump recommendations in specific scenarios. These interviews described the conditions of a hypothetical home, including its size, age, insulation levels, and current HVAC equipment and asked respondents to indicate what type of heat pump system they would recommend to the homeowner. There were two potential home scenarios that could be given to the respondents, details of which can be found in Appendix A.3.4.

D.2.1 Scenario 1: 1990 Home, Oil Furnace, Central AC

Scenario 1 described a newer home built in 1990 with relatively good insulation, an oil furnace, and central AC. The interview asked respondents to give a few different options they might present to a homeowner in such a home, and then indicate which of those options they believed the homeowner would likely choose, based on their real-world experience. As shown in Table 60Table 60, all respondents given this scenario opted for a ducted ASHP due to the existence of duct work in the home, and most decided that they would install a cold climate model and remove the existing system entirely.

Table 60: Installers' Recommendations for Installation Scenario 1

Interviewee	System	Keep existing as backup?	Cold Climate HP?
1	Inverter driven ASHP	No	Yes
2	Inverter driven ASHP	No	Yes
3	Two stage ASHP	No	Yes
4	Inverter driven ASHP	No	Yes
5	Two stage ASHP	Yes	No

Interviewers then offered a series of adjustments to that scenario and asked respondents whether each of those changes would trigger a change in their initial recommendation. Table 61Table 61 describes how the respondents' recommendations would (or would not have) changed in each of the five different alternative scenarios. In an alternative scenario in which there was no duct work in the home, all respondents changed their recommendation to a MSHP – the presence of ducts was a primary factor in their recommendation. If the existing furnace was fueled by natural gas instead of oil, four of five respondents changed their recommendation to keep the existing furnace and use it in tandem with the new heat pump, rather than removing the old system. If the homeowner had a smaller budget than expected, four of five respondents changed their recommendation to a cheaper and less efficient heat pump – only one suggested installing a non-heat pump system. When given the alternative that the customer was also finishing their basement while considering this HVAC upgrade, two of the installers changed their recommendation to MSHPs. None of the respondents changed their recommendation when given the alternative that the boiler was 15 years old instead of less than five years old.

Table 61: Installation Scenario 1: Recommendations in Response to Scenario Adjustments

Initial Scenario: 1990 home, oil furnace, central AC, unknown customer budget							
#	**Original Recommendation**	**Scenario Adjustments**					
		Small Budget	**No Ducts**	**Finishing Basement**	**Gas Furnace**	**Older Pre-existing` System**	
1	Inverter driven ASHP	Cheaper ASHP	MSHP	MSHP	Dual fuel ASHP	Same	
2	Inverter driven ASHP	Cheaper ASHP	MSHP	Same	Dual fuel ASHP	Same	
3	Two stage ASHP	Cheaper ASHP	MSHP	Same	Furnace/CAC	Same	
4	Inverter driven ASHP	No HVAC upgrade	MSHP	MSHP	Dual fuel ASHP	Same	
5	Two stage ASHP	Cheaper ASHP	MSHP	Same	Dual fuel ASHP	Same	

Table 62~~Table 62~~ summarizes how many respondents provided the same recommendation in response to each of the scenario adjustments described above.

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Table 62: Installation Scenario 1: Recommendations in Response to Scenario Adjustments

Initial Scenario: 1990 home, oil furnace, central AC, unknown customer budget					
Recommendation	**Scenario Adjustments**				
	Small Budget	**No Ducts**	**Finishing Basement**	**Gas Furnace**	**Older Pre-existing System**
No change to initial recommendation	-	-	3	-	5
Dual fuel ASHP	-	-	-	4	-
Cheaper ASHP	4	-	-	-	-
MSHP	-	5	2	-	-
Furnace/CAC	-	-	-	1	-
No upgrade	1	-	-	-	-

D.2.2 Scenario 2: Old, Poorly Insulated Home, Newer Gas Boiler, No Cooling, No ducts

Scenario 2 described an old home that was poorly insulated, with a new gas boiler and no cooling or ducts. In this hypothetical scenario, the homeowner was also planning to finish the attic space and would need to condition this newly finished space. Similarly, respondents were asked to present the most likely realistic options they would present to the homeowner (Table 63~~Table 63~~). Without pre-existing duct work, two of the three respondents chose MSHP systems while keeping the existing system installed for backup heat. One respondent indicated they would not recommend any type of HVAC upgrade to this home.

Table 63: Installers' Recommendations for Installation Scenario 2

Interviewee	System	Keep existing as backup?	Cold Climate HP?
6	MSHP	Yes	No
7	MSHP	Yes	Yes
8	No HVAC change	N/A	N/A

As with Scenario 1, interviewers then adjusted some of the home's characteristics and asked how these adjusted factors might change their recommendation. Adding ducts changed the two respondents' choice from a MSHP to a ducted system: an ASHP for one respondent, and a furnace and central AC for the other. In the event the customer had a small budget, one respondent changed their recommendation to a less efficient and cheaper MSHP. Having the home undergo recent weatherization and the heating system either being older or being heated with oil did not change either of the respondents' overall system recommendations.

Table 64: Installation Scenario 2 Alternatives

Initial Scenario: Old home, poorly insulated, newer gas boiler, no AC, no ducts, unknown customer budget						
#	Original Recommendation	Scenario Adjustments				
		Small Budget	Ducts	HES Weatherization	Oil Heat	Older Pre-existing` System
6	MSHP	Same	ASHP	Same	Same	Same
7	CC MSHP	Cheaper MSHP	Add CAC to furnace	Same	Same	Same
8	No Change	N/A	N/A	N/A	N/A	N/A

Reasons for recommending specific heat pump systems for heating and cooling. The absence of ductwork is a primary driver for recommending MSHPs over ASHPs. Interviewed installers indicated they almost never recommend GSHPs. This aligns with the study's market sizing findings and interviews with both distributors and installers that MSHPs are the most common heat pump system sold and installed into the market, whereas ASHP and GSHP are relatively flat markets. The subset of installers who were interviewed provided specific reasons why they typically recommend different types of heat pumps. Table 65Table 65 identifies the most common recommendations, listed by frequency mentioned, for MSHP, ASHP, and GSHP systems.

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Table 65: Installer Reasons for (+) or against (-) Making Heat Pump Recommendations

(Source: installer IDI; n=8)

MSHP	ASHP	GSHP
• No existing ducts (+) • Target specific areas (above garage, addition, etc.) (+) • Add supplemental/ shoulder season heat (+) • No AC (+)	• Existing ducts (+) • Rarely recommended (-) • New construction (+) • Heating w/electric resistance or oil (+)	• Almost never recommended (-) • Upfront cost too high (-) • Customer with high budget (+)

Appendix E End User Feedback Additional Detail

E.1 Pre-Existing Conditions

E.1.1 Heating

Electric resistance as the primary heating system dropped by 88% among surveyed MSHP purchasers. Boilers and furnaces saw the next highest drops in usage as the primary system, but only by reductions of 14% and 11%, respectively. Most participants reported having either a furnace (38%) or boiler (36%) as the pre-existing primary heating system, of which 64% were heated by oil. A smaller number (18%) reported electric resistance as their primary heating before the MSHP install, but only 2% of respondents reported electric resistance as the primary system after the MSHP installation, an 88% reduction.

Table 66: Primary Heating System Before and After MSHP Install

(Source: end user survey; n=161)

Primary Heating System	Pre-Install %	Post-Install %
Furnace	38%	34%
Boiler	36%	31%
Electric resistance	18%	2%
Wood stove	4%	3%
Electric heat pump	2%	29%
None	1%	0%
Propane Stove	0%	1%

This was different for ASHP participants, most of whom (7 out of 12) reported having an electric heat pump as their primary heating system *before* installing the new heat pump. For ASHP and GSHP, all but one respondent primarily heated with the electric heat pump after install.

Over one-third (37%) of participants indicated that they would have purchased the same exact heat pump without the Energize Connecticut incentive, an indication of potential free-ridership. Only a small portion (9%) of participants would have installed either a less expensive or less efficient heat pump (Figure 55~~Figure 55~~).

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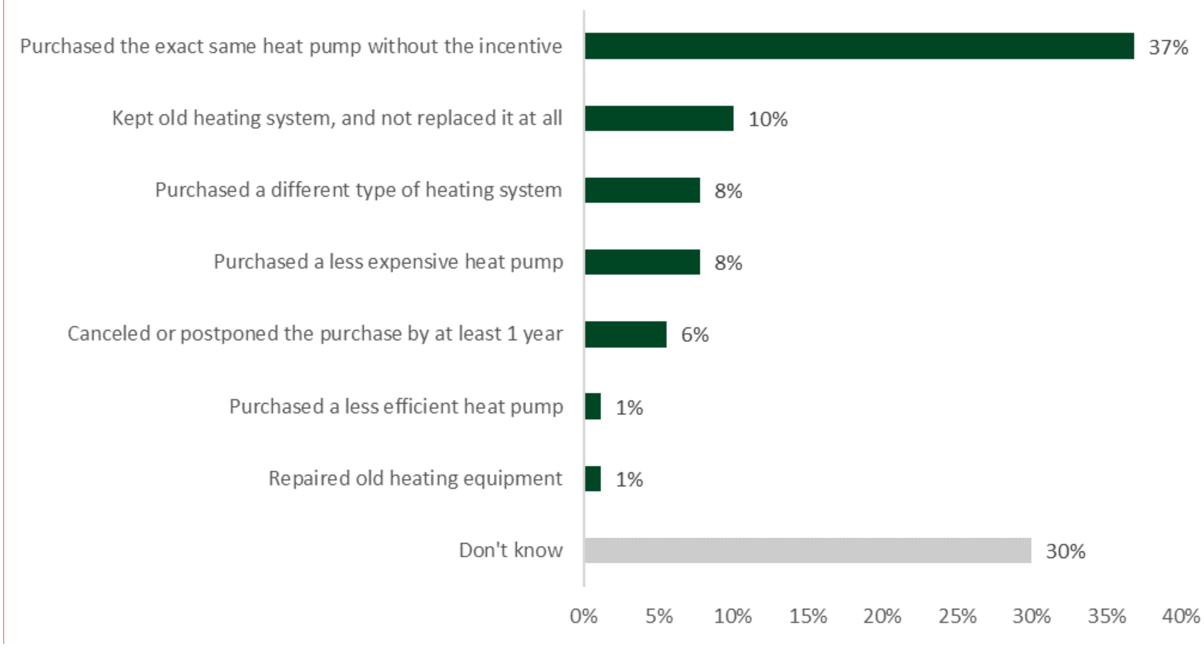
Figure 55: Heating Decision Without Energize CT Incentives

(Source: end user survey; n=179)



E.1.2 Cooling

According to purchasers, the most common MSHP installation scenario for cooling was to add cooling to spaces that were not previously cooled (61%), representing new cooling load. Another 39% of participants replaced an older AC system with MSHPs. MSHPs were the only cooling system in 52% of participant homes and 48% of homes used cooling for the entire home. It was uncommon for the MSHP to serve an area that was also served by a separate permanent cooling system such as a central air conditioner (7%).

Table 67: MSHP Cooling Installation Characteristics

(Source: end user survey; n= 170, multiple response)

Heat Pump Cooling Characteristic	End User %
Cools spaces that were not previously cooled	61%
Is the home’s only cooling system	52%
Cools all or most of the home	48%
Replaced other AC system that was removed	39%
Cools spaces also served by another permanent cooling system	7%

Nearly all ASHP and GSHP end users reported that their system was the only cooling system in the home and that it served all or most of the home.

The most common pre-existing cooling type was window air conditioners (61%), followed by no cooling system (29%). Central air conditioners were not a common pre-existing condition for MSHP installations (6%), which is to be expected customers would be more likely to add a central ASHP if a home already has ducts.

Table 68: MSHP Pre-Existing Cooling

(Source: end user survey; n= 170, multiple response)

Pre-Existing Condition	End User %
Window air conditioner	61%
No cooling	29%
Portable air conditioner	10%
Central air conditioner	6%
Ductless air conditioner or mini-split	1%
Whole house fan	1%

Most ASHP end users reported either a central air conditioner or ASHP as the previous cooling system. Three of the six GSHP end users had no previous cooling.

MSHPs typically become the primary cooling system, except when the pre-existing system is a central air conditioner. The most common primary cooling system before customers installed their MSHPs was window air conditioners (59%), followed by central air conditioning (18%). After installing the MSHP, a majority (76%) of end users reported that it served as the primary cooling system in their home (Table 69~~Table 69~~). The percentage of end users reporting central air conditioners as their primary cooling did not change because of the installation, suggesting that MSHPs are used for additional or supplemental cooling for homes with central air conditioners.

Table 69: Primary Cooling Before and After MSHP Install

(Source: end user survey; n=170)

Primary Cooling System	Pre-Install %	Post-Install %
Window air conditioner	59%	4%
Central air conditioner	18%	18%
No cooling	16%	0%
Portable air conditioner	4%	0%
MSHP	0%	76%
ASHP	0%	1%

Over half of participants removed window air conditioners when installing MSHPs. One quarter of participants did not have any previous cooling (25%), and a smaller portion kept their old cooling system in place (14%).[53]

Table 70: Cooling Systems Removed During MSHP Install

(Source: end user survey; n=170, multiple response)

Cooling System Removed	End User %
Window air conditioner	52%
None; no previous cooling	25%
None; kept old cooling system	14%
Portable air conditioner	9%

[53] The previous table focuses on primary cooling systems; the percentages in this table include all respondents, so percentages about pre-existing and removed systems differ.

Central air conditioner	2%
Ductless air conditioner or mini-split	2%
Ceiling or portable fan	1%
ASHP	1%

The survey asked how often the end users used their old cooling system since they had the MSHP installed. Nearly half of end users reported that their old cooling systems were removed (Table 71~~Table 71~~). More end users reported that they use their old cooling system about the same amount (15%) than said they use it either somewhat or much less (13%) after the MSHP install.

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Table 71: Old Cooling System Use After MSHP Install

(Source: end user survey; n=170)

Old Cooling System Use	End User %
Never; it was removed	48%
N/A; no previous cooling	22%
About the same as I used to	15%
Much less than I used to	9%
Somewhat less than I used to	4%
Never; but old system still installed	2%

E.1.3 Domestic Hot Water

Purchasers reported that new HPWH installations replaced tank-style water heaters nearly 90% of the time. Nearly two-thirds (64%) reported having conventional storage tanks, followed by indirect storage tanks (16%).

Table 72: Pre-Existing DHW Type

(Source: end user survey; n=70)

Pre-existing DHW Type	End User %
Conventional storage	64%
Indirect storage	16%
Tankless	10%
HPWH	9%
N/A	1%

Over half of participants indicated their old water heater was fueled by electricity (56%), followed by oil (37%). None of the HPWH end users reported transitioning from a natural gas water heater to a HPWH.[54]

[54] Accordingly, customer cost-effectiveness assessments included in this study exclude natural gas baseline scenarios (Section 0~~3.5~~).

Table 73: Pre-Existing DHW Fuel

(Source: end user survey; n=70)

Pre-existing DHW Fuel	End User %
Electricity	56%
Oil	37%
Propane	6%
Natural Gas	0%
Other	1%

E.1.4 Early Retirement or Replace on Failure

End users were asked about the condition of their pre-existing equipment. This section of the survey first asked MSHP end users to indicate whether their new system was primarily used for heating or cooling the space. Among those MSHP end users primarily using the system for cooling, three-quarters (75%) reported that their existing cooling system was working with no need of repair, suggesting a higher early retirement status for MSHP installs that are primarily used for cooling. This differed for MSHP installs that were primarily used for heating, in which about a third (34%) of end users indicated that their existing heating system needed either a minor or major repair. HPWH end user responses leaned even further towards a replace on failure status, with over half (55%) indicating that their existing water heater was either in need of major repair or no longer working at all.

Table 74: Status of Existing System Status Before Heat Pump Installation

(Source: end user survey)

Existing System Status	End User %		
	Heating (before MSHP install; n=51)	Cooling (before MSHP install; n=96)	DHW (before HPWH install; n=70)
Working with no need of repair	57%	75%	29%
Working with need of minor repair	18%	14%	14%
Working with need of major repair	16%	3%	24%
No longer working	4%	3%	31%
Don't know	6%	5%	1%

For MSHP end users, more than half of installations were determined to be early retirement for both cooling (55%) and heating (53%) (Figure 56~~Figure 56~~). Water heating differed, with over two-thirds (69%) of installations being determined to be replace on failure. Nearly all (10 of 11) ASHP end user installations were determined to be replace on failure, and the few GSHP end users were split evenly between early retirement and replace on failure.

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Figure 56: Early Retirement or Replace on Failure Determination
(Source: end user survey; MSHP Cooling n=110, MSHP Heating n=51, HPWH n=70)