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U.S. DEPARTMENT OF ENERGY

Final Report

Residential ccASHP Building Electrification Study

April 22, 2022

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Study Background

Drivers of the Study

Carbon reduction targets require transformation of the built environment.

Widespread electrification is essential to achieve carbon neutral buildings.

A concerted policy push is necessary to deploy whole-home (or primary heating) electrification.

Drivers of the Study

- **Carbon reduction targets in the Northeast require transformation of the built environment.**
  - Massachusetts seeks 50% GHG reductions by 2030 and 85% by 2050.
  - New York seeks 40% GHG reductions by 2030 and 85% by 2050.
  - Direct emissions from fossil fuel combustion for space and water heating in buildings account for approximately 30% of emissions.
- **Achieving carbon neutral buildings requires:**
  - Widespread electrification of thermal loads.
  - Improved thermal performance of building envelopes.
  - Ability to store and/or shift energy use and interaction with the electric grid.
  - Supply of energy loads from zero emissions resources.
- **However, across the Northeast, most building thermal loads are served by fossil fuels (oil, gas or propane).**
  - Use of heat pumps (electrification) is increasing, though primarily for supplemental loads.
  - Greater adoption of whole home heat pumps—or heat pumps serving as the primary heating source (90% of thermal load or more)—is necessary to decarbonize building stock.

Whole-Home or Primary with Backup ASHP Deployment Barriers

A range of barriers inhibit adoption of whole home (or primary) electrification. This study focused primarily on **real or perceived technology and performance risk**.

Technology & performance risk

- Poor technology performance on coldest days of year
- Poor comfort for building occupants

Financial

- High upfront costs
- Poor return on investment
- Inadequate access to capital

Marketing & awareness

- Lack of customer awareness
- Insufficient marketing and sales from contractors

Supply chain

- Lack of training for contractors
- Undersupply of contractors

Decision-making

- Split incentives (landlord-tenant)
- Misaligned priorities

Scope of Work

Residential (1-4 family) building electrification

Assess **cold climate** air source heat pump performance in **NY** + **MA**

Whole-home and **primary** w/ backup heat pump configs

Quantitative Research	Qualitative Research
Program database review identify trends and eligible sites for study	Literature review sales, design, installation best practices
Online surveys with customers (n=628) customer satisfaction and usage behavior	Stakeholder interviews (n=4) understand electrification priorities
Site visits + metered data collection (n=43) overall energy use, performance, fossil fuel displacement	Heat pump contractor interviews (n=19) design, marketing, installation
Customer billing analysis (n=84) comparison to previous heating fuel usage	

Please refer to the Appendix for project timeline and task details.

Key Objectives of the Study

1. Are ccASHP systems meeting home comfort needs?
2. Are ccASHPs efficiently delivering heating and cooling?
3. How does performance differ between whole-home and primary with backup applications?
4. What are the grid impacts of ccASHP market scale up?
5. What continued challenges with customer and contractor experience need to be addressed to scale the market?

IMPORTANT CAVEAT: This in-depth research study focused on a small sample of homes in MA and NY. We did not select the participant sample to be statistically significant or representative of the population. Findings and conclusions from this study are intended to provide an indication of potential operational trends. We recommend additional data collection for a broader sample to draw firm conclusions about ccASHP operation in the Northeast.

Objective 1: Are ccASHP systems meeting home comfort needs?

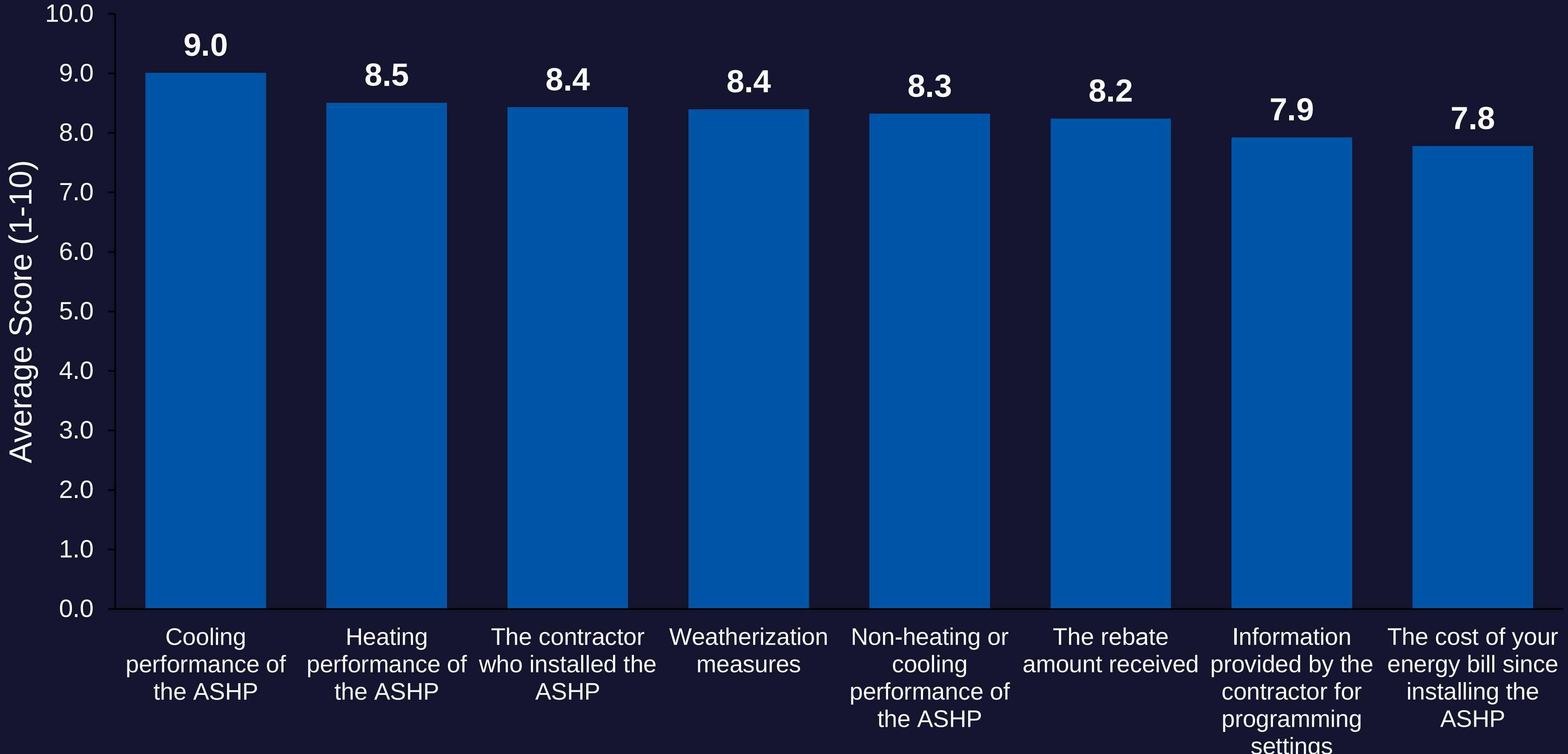
Customer Survey Key Findings

- Customers primarily installed ASHPs to **increase home comfort** and **save money on energy bills.** Customers with a whole-home configuration are especially likely to be motivated by energy savings.
- **Word-of-mouth** was the most common way that customers learned about ASHPs and found their contractor.

- **Weatherization upgrades** were usually completed at the same time as **ASHP installations.** This was especially true among those that had an energy audit completed, typically through the Mass Save program.
- Contractors were a key knowledge conduit, as **contractors are how most customers learned how to use their ASHP**.

- Performance issues were uncommon with ASHPs and nearly all customers reported lower bills.
- Customers were **highly satisfied with heating and cooling performance** (8.5/10 for heating and 9.0/10 for cooling).
- These factors lead to an **extremely high likelihood to recommend an ASHP** to others (whole-home = 8.9/10 would recommend; primary w/ backup = 9.3/10)

Customer Satisfaction



In general customers reported an **extremely high likelihood to recommend an ASHP** to others, with slightly lower likelihood for customers with whole-home systems (whole-home = 8.9/10 would recommend; primary w/ backup = 9.3/10).

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Participant Interview Key Findings

Of the 43 sampled metering sites, 42 participated in follow up phone interviews. Respondents were happy with comfort, cost, and removing fossil fuels during the heating season and even more satisfied with cooling performance. **32 of the 42 reported being ‘very satisfied’** with their heat pump in the past year, 3 ‘satisfied,’ and 7 ‘somewhat satisfied.’

Very Satisfied

- Improved comfort and temperature maintenance (n=10)
- Working well and did what we wanted it to (n=9)
- Costs less to run (n=9)
- No fossil fuels, reducing carbon footprint (n=7)
- Extremely efficient (n=4)
- Better than old system (n=4)
- Easy to use (n=3)
- Changes temperature quickly (n=2)
- Quiet and clean (n=2)
- Dehumidify function (n=2)
- ‘Free’ electricity from solar PV (n=2)
- Don’t have to haul as much firewood (n=1)

Satisfied and Somewhat Satisfied

- Distribution of heat to specific rooms is not always consistent (n=3)
- Requires more attention than previous system (n=2)
- System is oversized, so some rooms get too hot and cool too fast, need separate dehumidifiers (n=1)
- Repeated breakdown of one outdoor unit (n=1)
- Outdoor unit is too loud (n=1)
- Settings get screwed up and fan is consistently on (n=1)
- Doesn’t stay warm as long and doesn’t heat enough when its cold outside (n=1)

Blower Door Test Results

According to the National Association for State Community Services Programs,[1] homes with ACH50 values <5 are considered tight, moderate is between 5 and 10 ACH50, and leaky is >10 ACH50 (where ACH50 is the measured CFM at 50 Pa normalized for conditioned building volume).

On average, the participating homes would fall into the **'moderate'** category based on the results of the blower door tests.

However, this was a small sample of homes, and many variables factor into home leakiness, including the type and quality of existing and new insulation, home age, and test conditions.

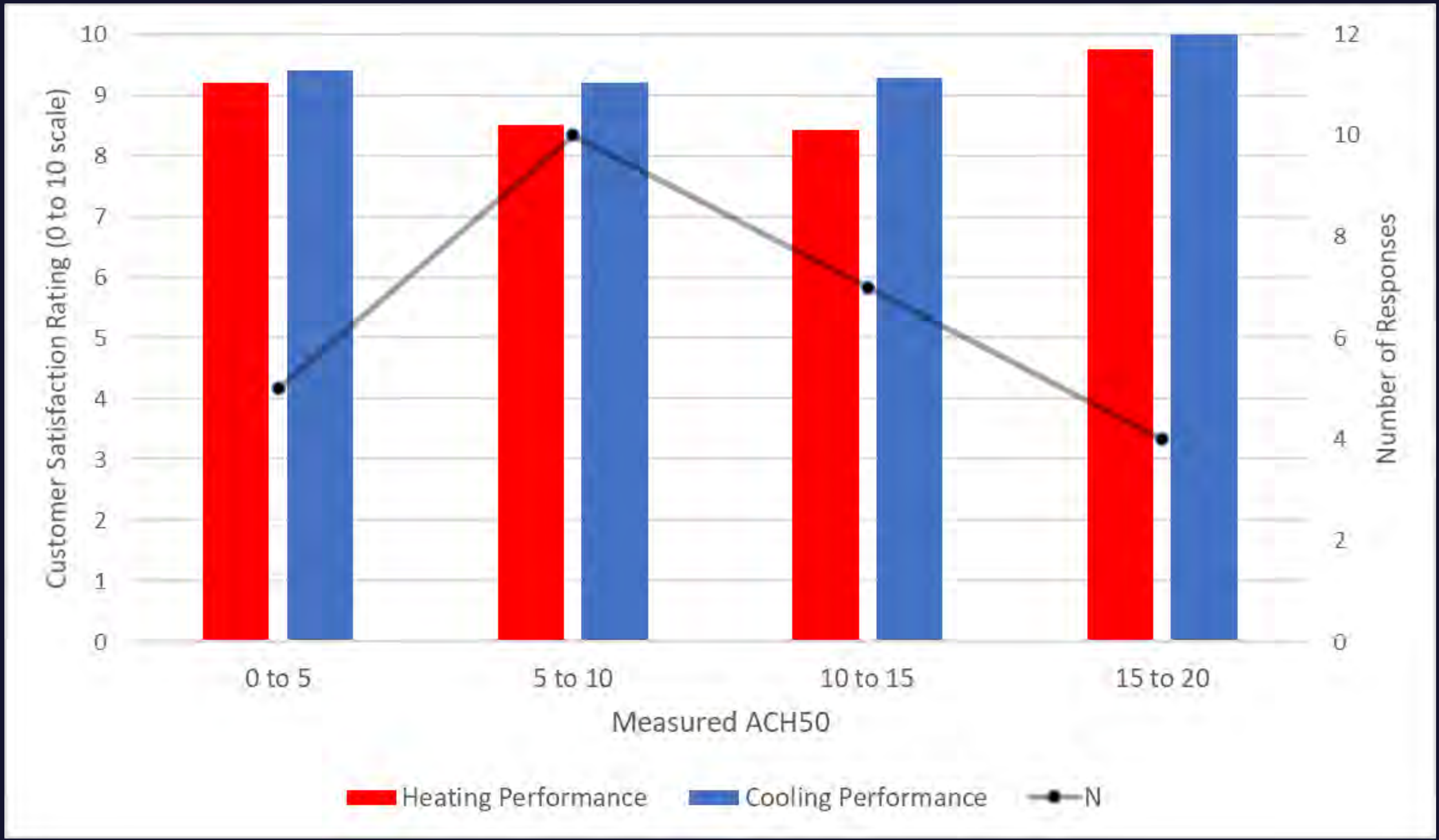
Home Weatherization Upgrade	Number of Homes[2]	Measured Airflow, CFM		Equivalent Leakage Area, ELA	Approximate ACH50
		50 Pa	25 Pa		
No change/existing	8	2,889	1,848	160.6	9.5
Pre-ASHP Installation	18	2,521	1,775	140.1	9.1
During ASHP Installation	4	2,567	1,429	142.8	10.1
Post-ASHP Installation	4	1,928	1,138	107.0	8.5
Overall	**34**	**2,543**	**1,676**	**141.4**	**9.2**

[1] National Association for State Community Services Programs. Blower Door Testing. Accessed February 2022. https://nascsp.org/wp-content/uploads/2018/02/van-der-meer_blower-door-testing.pdf

[2] Cadmus conducted blower door tests or collected contractor blower door test reports for 34 of the 43 sites.

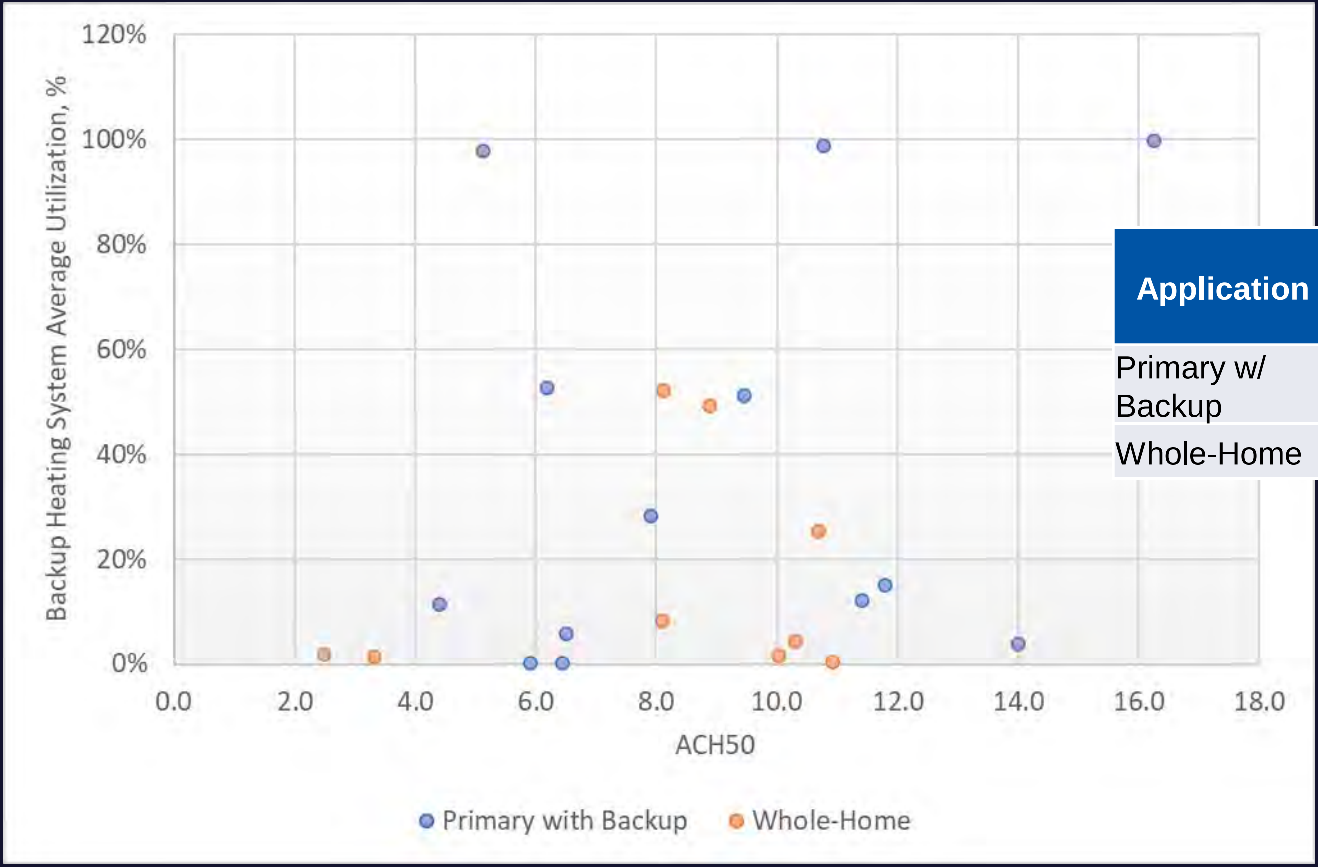
Comparison of Home Leakiness and Comfort Satisfaction

Cadmus compared participating customer survey responses with measured home insulation levels from onsite blower door tests in ACH50. On average, participants reported **very high satisfaction levels with heating and cooling performance, regardless of measured leakiness.** The lowest individual satisfaction score was a ‘5’ from a home with a 12.5 ACH50.



Comparison of Backup Fuel System Usage and Leakiness[1]

We compared leakiness to backup fuel system utilization for 22 homes where both data points were available. The results of this limited sample show that primary with backup homes had **much higher backup fuel utilization** and slightly **higher leakiness (10% higher)** than whole-home sites.



Application	Number of Sites	Average Backup Utilization[1]	ACH50
Primary w/ Backup	13	37%	8.9
Whole-Home	9	16%	8.1

[1] Where there were multiple backup fuel systems at one site, this plot reflects the system with the highest utilization.

Objective 2: Are ccASHP systems efficiently delivering heating and cooling?

Heat Pump Energy Use Intensity

Whole-home heating applications were **23% more** energy intensive than primary with backup applications. On average, the ASHP heating energy use intensity (EUI) is **almost 10 times higher** than the ASHP cooling EUI.

Application	Conditioned Area, sq. ft	Number of Homes	Heating		Cooling	
			Total Avg. ASHP System Energy Use, kWh	EUI, kWh/sq. ft.	Total Avg. ASHP System Energy Use, kWh	EUI, kWh/sq. ft.
Primary w/ Backup	500 to 1,000	1	4,018	4.46	765	0.38
	1,000 to 1,500	3	3,889	3.14	348	0.23
	1,500 to 2,000	6	3,154	1.64	326	0.17
	2,000 to 2,500	5	4,589	1.89	434	0.25
	2,500 to 3,000	3	7,143	2.51	206	0.14
	3,000 to 3,500	1	7,268	2.27	125	0.06
	3,500 to 4,000	1	6,244	1.73	2,330	0.78
Primary w/ Backup	**-**	**20**	**4,625**	**2.24**	**450**	**0.23**
Whole-Home	500 to 1,000	1	3,603	3.60	340	0.26
	1,000 to 1,500	8	3,882	2.73	563	0.29
	1,500 to 2,000	8	4,336	2.41	462	0.24
	2,000 to 2,500	4	8,433	3.60	665	0.38
	2,500 to 3,000	1	11,802	3.93	1,704	1.22
	3,000 to 3,500	1	454	0.15	101	0.04
Whole-Home	**-**	**23**	**5,015**	**2.75**	**565**	**0.31**
Overall	**-**	**43**	**4,833**	**2.51**	**512**	**0.27**

Heating Season Utilization per Outdoor Unit

ASHP systems used as the sole-source of heating were in-use 68% of metered hours during the heating season. Primary with backup systems were used 48% of the time. **Whole-home systems operated 42% more often than primary with backup systems**, on average.

Application	System Type	Number of Outdoor Units	Average Utilization
Primary with Backup	Single-zone, Ductless, Wall	8	36%
	Single-zone, Ducted, "Compact Ducted"	1	6%
	Single-zone, Ducted, Centrally Ducted	9	39%
	Multi-zone, Ductless	18	60%
	Overall	**35**	**48%**
Whole-Home	Single-zone, Ductless, Wall	11	73%
	Single-zone, Ductless, Floor	1	80%
	Single-zone, Ductless, Ceiling	1	61%
	Single-zone Ducted, Centrally Ducted	6	43%
	Multi-zone, Ductless	16	74%
	Multi-zone, Ducted	1	49%
	Multi-zone, Mix of Ductless and Ducted	1	98%
	Overall	**38**	**68%**
Overall		**73**	**58%**

Cooling Season Utilization per Outdoor Unit

Average cooling season utilization per outdoor unit was **56% less** than heating season utilization. Again, systems installed in whole-home applications were used **more than primary with backup systems (13% more)**, but overall average utilization was only 26%.

This result indicates that these participants may be using their ASHP systems primarily for heating, rather than cooling.

Application	System Type	Number of Outdoor Units	Average Utilization
Primary with Backup	Single-zone, Ductless, Wall	8	18%
	Single-zone, Ducted, "Compact Ducted"	1	0.1%
	Single-zone, Ducted, Centrally Ducted	8	29%
	Multi-zone, Ductless	18	26%
	Overall	**35**	**24%**
Whole-Home	Single-zone, Ductless, Wall	11	20%
	Single-zone, Ductless, Floor	1	3%
	Single-zone, Ductless, Ceiling	1	42%
	Single-zone Ducted, Centrally Ducted	6	26%
	Multi-zone, Ductless	16	33%
	Multi-zone, Ducted	1	55%
	Multi-zone, Mix of Ductless and Ducted	1	9%
	Overall	**37**	**27%**
Total		**72**	**26%**

Comparison of Heating Performance by System Type and Indoor Heads

Ductless multi-zone systems with more than three indoor heads (some with branch-box control) had the lowest average seasonal heating performance during the metering period. Anecdotal feedback from the advisory committee and Cadmus' experience indicate that the more zones a multi-zone system serves, the higher the likelihood that some zones may be oversized, causing a greater differential between actual load and capacity.

In contrast, ductless single-zone systems had the highest measured performance.

System Type	Description	Number of Indoor Heads	Number of Outdoor Units	Average Utilization, %	Average Seasonal Heating Performance, sCOP
Ductless	Single-zone, Wall	1	19	57%	3.23
	Single-zone, Ceiling	1	1	61%	1.85
	Single-zone, Floor	1	1	80%	3.20
	Multi-zone	2	15	66%	2.24
	Multi-zone	3	13	72%	2.57
	Multi-zone	4	3	45%	**1.12**
	Multi-zone	5	3	70%	**1.52**
Mixed	Multi-zone Mix of Non-ducted and Ducted	3	1	98%	1.97
Ducted[1]	Single-zone, Central	1	15	41%	2.25
	Single-zone, Compact	1	1	6%	N/A
	Multi-zone	2	1	49%	2.29
Individual Outdoor Unit			**73**	**58%**	**2.50**
Overall Site-Level			**43**	**-**	**2.34**

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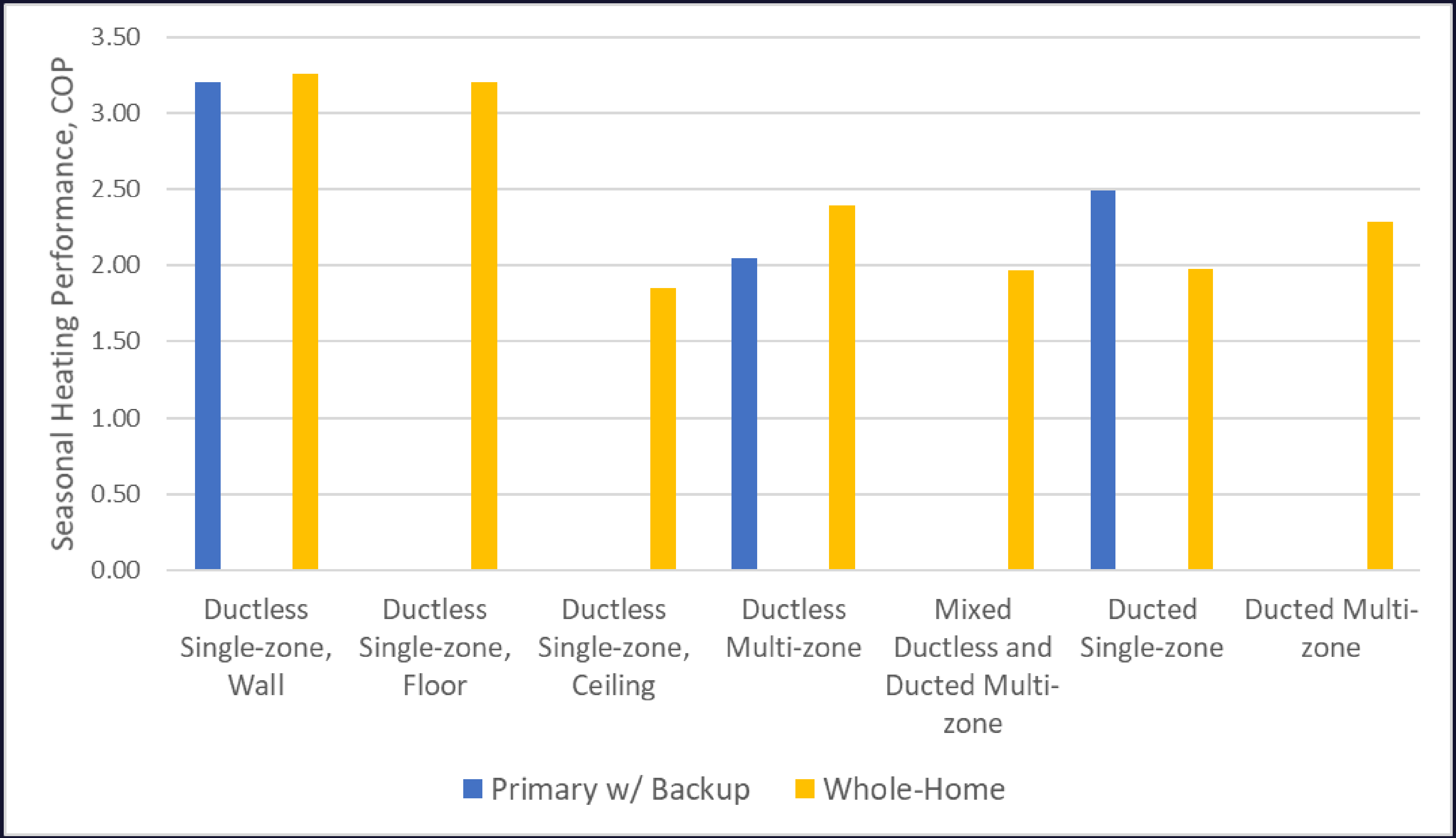
Comparison of Measured Seasonal Heating Performance by System Type

Ductless, single-zone, wall and floor-mounted systems had the highest metered average seasonal heating performance in both applications.

Ducted systems in primary with backup applications performed better than in whole-home applications, likely due in part to being utilized for heating less often during the coldest times of the year.



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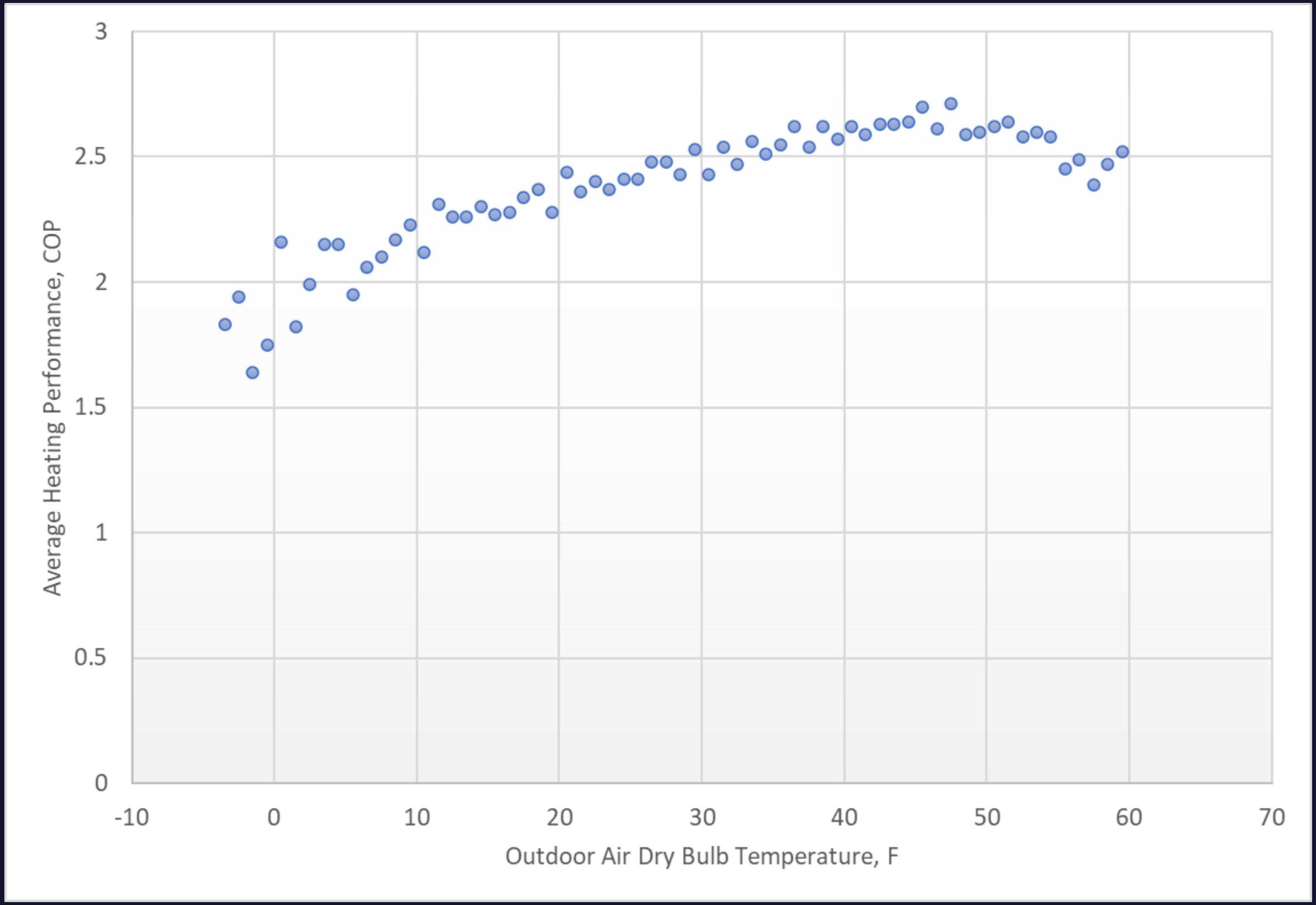
Average Heating Performance[1] by Outdoor Air Temperature Bin

As expected, the overall average heating performance for the sampled homes peaked between 40-50°F, with a pronounced drop at 10°F.



[1] Heat pump performance shown does not include intervals when electric resistance was used. The actual performance for the five ducted systems with ER is expected to be lower.

Measured Heating Load Comparisons

- Cadmus calculated space heating load using metered indoor unit supply and return temperatures and fan airflow.
- We calculated the average measured heating load during cold outdoor air conditions between 0-15°F and during a seven-hour ‘cold snap’ for each state.
- The ‘cold snap’ was defined as 12 AM to 7 AM on January 31st for MA sites and February 12th for NY sites. The average cold snap temperature for MA sites was 4.3°F and the average cold snap temperature for NY sites was 8.3°F.
- The next two slides compare the calculated space heating load during these two conditions to the installed system maximum capacity based on NEEP test procedures at 5°F, contractor design load, and Cadmus’ Manual J heating load.
- When reviewing this data, please note the following:
  - The average design temperature for the 24 Massachusetts sites is 5.2°F and 1.8°F for New York sites.
  - 2020/2021 was a mild winter and the ‘cold snap’ load may be underestimating peak load. While the average temperature for MA sites was close to design conditions, there was no prolonged period at design conditions during this winter.
  - The ‘cold snap’ load calculation includes intervals when the system was not delivering heat (0 Btu/hr). The instantaneous peak load is expected to be higher.

Comparison of Contractor Heating Load to Measured Heating Load[1]

Compared to the average measured heating load during cold outdoor air temperatures (0 to 15F) and extreme cold snaps, **contractors do not appear to be under-sizing systems.** Cadmus' Manual J heating load, which incorporates blower door test results, may be overstating the actual load. Oversized systems will result in higher upfront costs and potential performance issues.

However, the average heating load for whole-home systems was **43%** of the contractor's design load during the extreme cold snap (noting that the average incorporates intervals of zero load).

Application	Conditioned Area, sq. ft	Sites	Average NEEP Total System Capacity (5°F), Btu/hr	Contractor Design Heating Load, Btu/hr	Cadmus Manual J Heating Load, Btu/hr	Cadmus / Contractor Heating Load, %	0-15F Average Measured Heating Load, Btu/hr	Cold Snap[2] Average Measured Heating Load, Btu/hr	Cold Snap / Contractor Design Load, %
Primary w/ Backup	1,500 to 2,000	1	30,100	59,886	54,230	91%	11,207	7,640	14%
Primary w/ Backup	2,000 to 2,500	2	54,834	58,392	52,641	93%	21,623	11,721	22%
Primary w/ Backup	3,000 to 3,500	2	60,535	72,008	89,451	126%	33,416	32,232	35%
Primary w/ Backup		**5**	**52,167**	**64,137**	**67,683**	**106%**	**24,257**	**19,109**	**26%**
Whole-Home	1,000 to 1,500	2	43,000	38,344	38,575	99%	14,796	14,455	41%
Whole-Home	1,500 to 2,000	4	47,900	40,460	49,012	123%	25,106	23,417	51%
Whole-Home	2,000 to 2,500	3	45,533	42,714	51,275	118%	17,027	19,907	40%
Whole-Home	2,500 to 3,000	2	67,920	57,1623	80,785	141%	24,042	22,967	28%
Whole-Home	3,000 to 3,500	2	43,650	41,624	63,659	155%	36,628	36,266	62%
Whole-Home		**13**	**49,026**	**43,403**	**55,070**	**126%**	**21,882**	**21,917**	**43%**
Overall		**18**	**49,899**	**49,163**	**58,574**	**120%**	**22,624**	**21,039**	**38%**

[1] For the 18 project sites where contractor Manual Js were provided
[2] Cold snap defined as 12 AM to 7 AM on January 31st (MA sites) and February 12th (NY sites). The average cold snap temperature for MA sites was 4.3°F and the average cold snap temperature for NY sites was 8.3°F.

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Comparison of NEEP Heating Capacity to Measured Heating Load per Outdoor Unit

On average, metered data indicates that most systems operate **well below** their NEEP rated maximum capacity (at 5°F) during extreme cold periods, but systems in whole-home applications operated at 38% higher load than systems in primary with backup applications.

In whole-home applications, **systems <30,000 Btu/hr appear to operate closer to design capacity**, suggesting they may be more appropriately sized for the zone they serve.

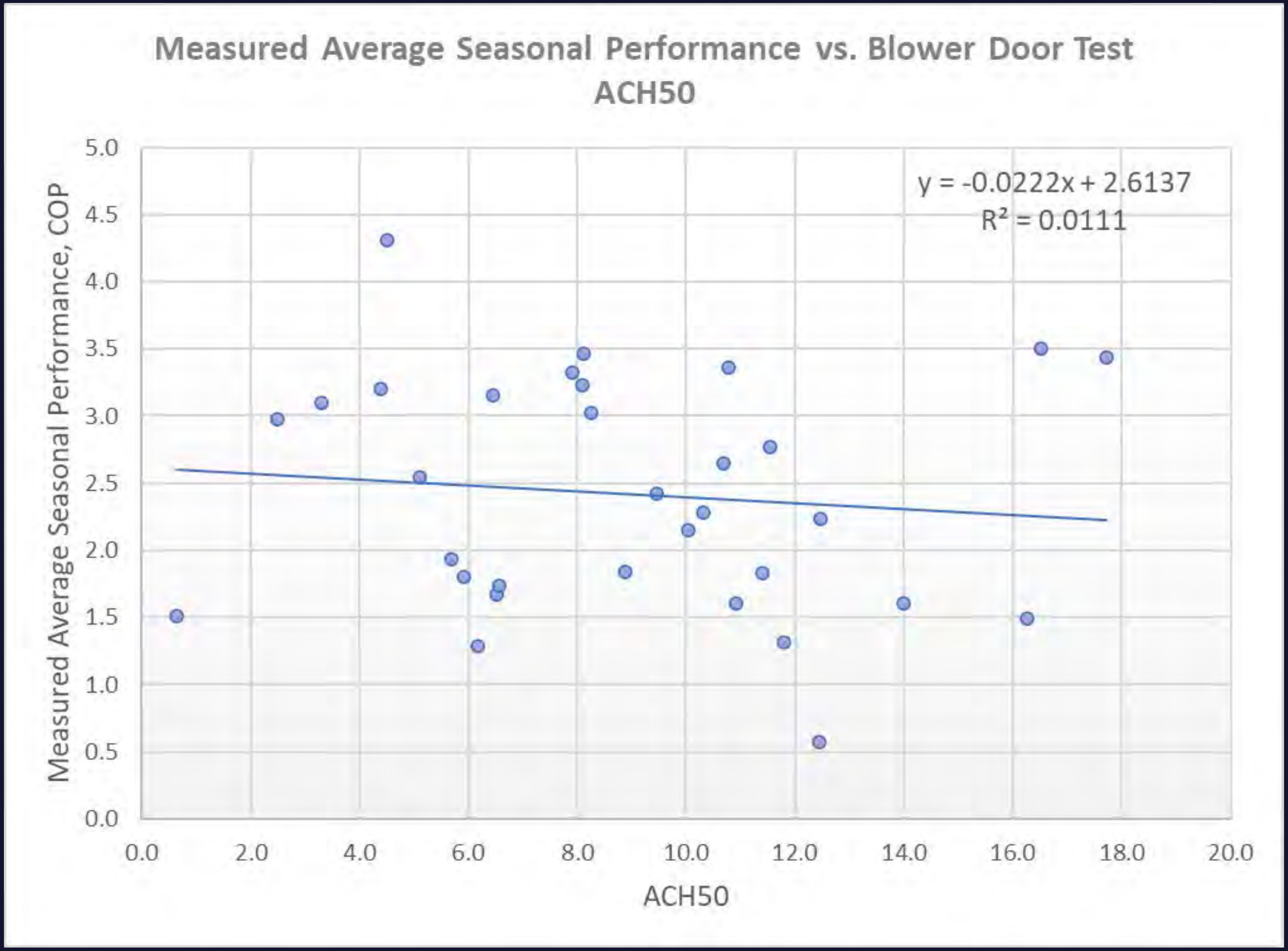
System Type	NEEP ccASHP Capacity Range (5°F), Btu/hr		Number of Outdoor Units	Population Average NEEP Capacity, Btu/hr	0-15°F Average Heating Load, Btu/hr	Cold Snap[1] Average Measured Heating Load, Btu/hr	Cold Snap Average Measured Heating Load / NEEP Capacity
	Min	Max					
Primary w/ Backup	10,000	20,000	6	15,610	5,748	1,929	12%
	20,000	30,000	17	24,696	13,262	10,575	43%
	30,000	40,000	9	35,092	11,766	6,279	18%
	40,000	50,000	4	44,568	13,683	12,575	28%
	Overall		**35**	**27,929**	**11,812**	**8,466**	**30%**
Whole-Home	0	10,000	2	8,700	2,011	0	0%[2]
	10,000	20,000	11	14,118	10,709	11,427	81%
	20,000	30,000	13	25,554	15,886	15,634	61%
	30,000	40,000	3	38,652	16,436	10,388	28%
	30,000	50,000	6	46,333	23,258	21,515	46%
	50,000	60,000	2	55,420	22,148	20,700	37%
	Overall		**38**	**27,363**	**14,834**	**13,955**	**51%**
Overall			**73**	**27,634**	**13,300**	**11,168**	**40%**

[1] Cold snap defined as 12 AM to 7 AM on January 31st (MA sites) and February 12th (NY sites). The average cold snap temperature for MA sites was 4.3°F and the average cold snap temperature for NY sites was 8.3°F.
[2] Systems were not used during the cold snap period.

ASHP System Performance vs ACH50

Measured ccASHP system seasonal heating performance is not closely tied to the measured leakiness of a home.

Home leakiness directly impacts space conditioning load, but many other factors influence performance. However, weatherization measures to reduce leakiness will help improve comfort and potentially provide fuel cost savings.



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Building Weatherization Timing

Comparison of ASHP System Heating Load, Demand, and Performance

While there was no correlation between leakiness and seasonal heating performance, in this sample we observed **higher average seasonal heating performance in homes that completed insulation upgrades** than those without any insulation upgrades, though many of these homes still had relatively high air leakage rates after completing weatherization work. However, we cannot draw conclusions from this small sample.

Weatherization Upgrade Timing	Number of Homes	Cold Snap Heating Load per Conditioned Area, Btu/hr/sq. ft.	Average Operating Demand per Conditioned Area, kW/1,000 sq. ft.	Average Utility Peak Demand per Conditioned Area, kW/1,000 sq. ft.[1]	Average Seasonal Heating Performance, COP
No change to existing insulation	12	9.44	1.10	0.76	2.09
Before ASHP system installation	20	9.75	1.02	1.01	2.43
During ASHP system installation	6	7.40	0.82	0.89	2.42
After ASHP system installation	5	7.11	1.13	0.61	2.57
Overall	**43**	**8.90**	**0.98**	**0.88**	**2.34**

Cost Effectiveness Comparison

Average installation costs were **22% higher in whole-home sites** than primary with backup relative to square footage. Energy cost savings were higher for whole-home sites, though this was driven in part by differences in energy costs between states and more New York whole-home sites.

We estimated an **energy cost penalty for natural gas customers** in this sample, which is unsurprising due to the high cost of electricity and relatively low cost of natural gas in the Northeast. This result supports targeting delivered fuel and electric resistance heating customers for ccASHP systems first where economics are a priority.

Application	Fuel Type	N	Sq. Ft.	Avg. Installation Cost[1]	Avg. Installed Cost per Sq. Ft.	Annual Cost Savings[1]	Annual Cost Savings per Sq. Ft.
Primary w/ Backup	**All**	**20**	**2,167**	**$17,695**	**$8.50**	**$280**	**$0.20**
	Non-Gas	15	2,156	$17,031	$7.90	$461	$0.32
	Gas	5	2,200	$19,686	$8.95	-$262	-$0.15
Whole-Home[1]	**All**	**20**	**1,891**	**$18,755**	**$10.31**	**$264**	**$0.17**
	Non-Gas	10[1]	1,815	$20,207	$11.13	$682	$0.42
	Gas	10	1,968	$17,142	$9.18	-$153	-$0.09
Total		**40**	**2,029**	**$18,211**	**$9.38**	**$272**	**$0.18**

[1] Missing installation cost data for one whole-home site and energy savings were not able to be estimated for three whole-home sites.

Utility Bill Impacts

Most respondents' combined utility bills (electric, gas, propane, oil, etc.) were lower since installing an ASHP.

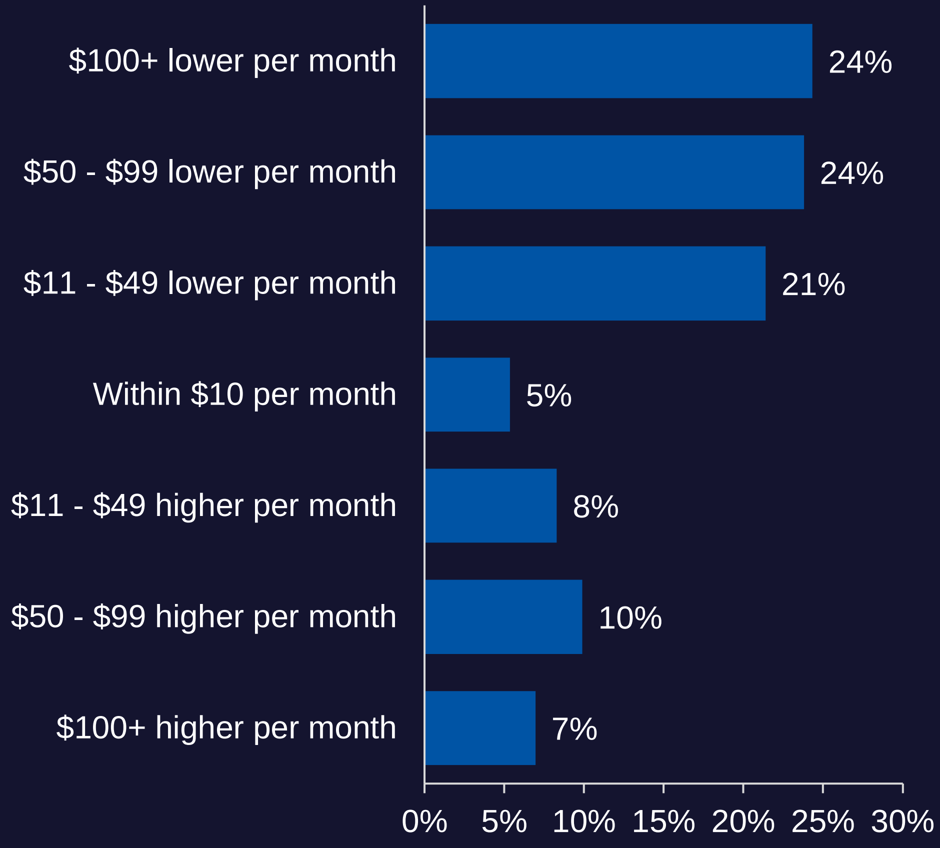
90% of respondents reported a change in their overall energy bills since installing an ASHP.

76% said the change was the same as what they expected.

Respondents who installed weatherization measures were significantly more likely to see a decrease of $100 or more per month (**26%**) compared to respondents who did not install weatherization (**19%**).

Respondents who had electric heating prior to installing their ASHP were more likely to see a decrease of at least $50 (**67%**) compared to gas (**32%**) and delivered fuel (**51%**) respondents.

Change in Overall Utility Bills since ASHP Installation



Objective 3: How does performance differ between whole-home and primary with backup applications?

Heating Season Metered Data Results

While on average, there was **no significant difference** in seasonal heating performance between whole-home and primary w/ backup applications, ductless systems tended to perform better in whole-home applications while ducted systems performed better in primary w/ backup applications.

Application	System Type	Homes	Avg. Utilization	Avg. ccASHP System Heating Season Demand, kW/1,000 sq. ft.	Avg. ccASHP System Utility Winter Peak[1] Demand, kW/1,000 sq. ft.	Measured Average Seasonal Heating Performance, sCOP	AHRI Rated sCOP (from HSPF)	Measured sCOP/ Rated sCOP
Primary w/ Backup	Ductless	14	50%	0.60	0.77	2.23	3.23	69%
	Ducted	5	38%	0.38	0.64	2.46	3.06	63%
	Mixed	1	48%	0.42	0.29	2.55	3.02	84%
	Total	**20**	**48%**	**0.54**	**0.71**	**2.30**	**3.18**	**68%**
Whole-Home	Ductless	13	75%	0.89	1.12	2.80	3.28	84%
	Ducted	6	43%	0.54	0.70	2.03	3.16	57%
	Mixed	4	69%	0.99	1.15	1.87	3.33	56%
	Total	**23**	**68%**	**0.82**	**1.03**	**2.38**	**3.26**	**71%**
Total		**43**	**58%**	**0.69**	**0.88**	**2.34**	**3.22**	**70%**

[1] Utility Winter Peak defined as 5:00 PM to 7:00 PM daily, December, January, and February.

Heating Season Metered Data Results

Study Results

- ccASHP systems used in whole-home applications were **40-50% more demand intensive** per conditioned area than in primary with backup applications.
- Overall average ccASHP system seasonal heating **performance of 2.34 sCOP was in line with results from other studies**, with slightly higher metered performance for whole-home systems.
- Ducted system utilization includes heat pump and backup ER usage, but the performance calculation reflects the heat pump power only (excludes ER). The actual performance of the five ducted systems with ER is expected to be lower.
- We used the AHRI-rated heating seasonal performance factor (HSPF) as a rough comparison metric for metered seasonal heating performance.
- For New York sites, we calculated the expected seasonal heating performance using the methodology in the New York State TRM V8.1 On average, those sites would have been expected to have an sCOP of 2.84, so the metered **seasonal heating performance was ~17% lower than expected under the TRM**.

Tentative Conclusions

- In-field ccASHP seasonal heating performance is only slightly lower than expected when AHRI ratings are normalized for the Northeast climate
- Ductless whole-home systems may perform better than ductless primary with backup systems despite operating at higher/colder hours due to various factors:
  - Continuous operation vs. more cycling during hours well below peak heating needs
  - More representative system sizing for actual space heating needs
- Ducted systems may perform less efficiently in whole-home configurations, possibly due to operating at lower outdoor air temperatures or being sized for higher heating loads, resulting in greater fan energy use.

[1] New York State DPS. Technical Reference Manual (TRM). https://www3.dps.ny.gov/W/PSCWeb.nsf/All/72C23DECFF52920A85257F1100671BDD

Objective 4: What are the electric grid impacts of ccASHP market scale up?

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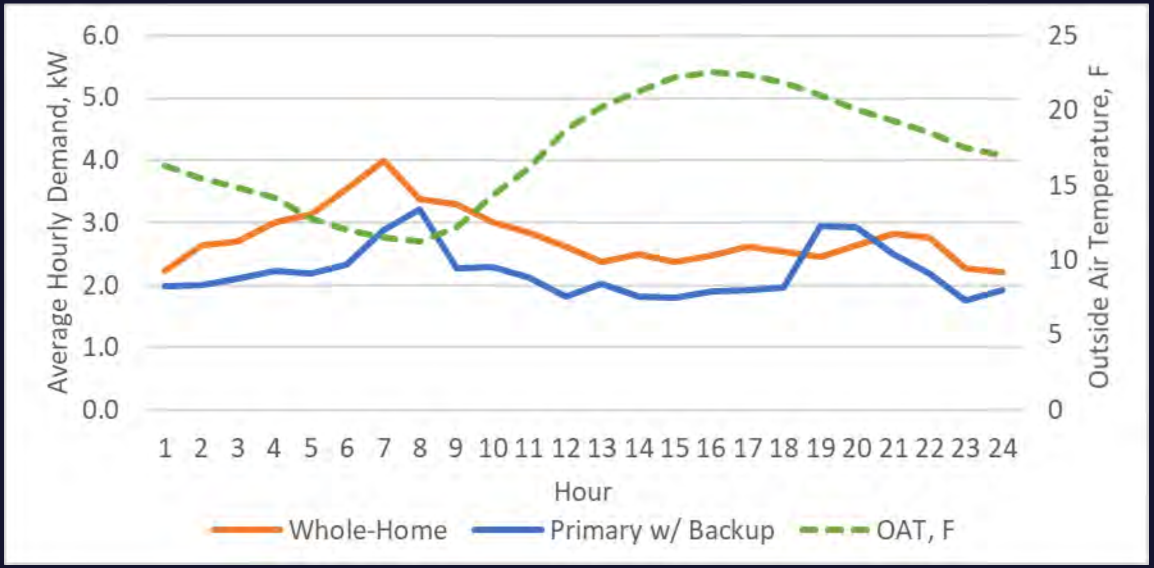
Heating Season Demand Impacts

While the average demand during the utility Winter Peak period was only 0.88 kW/1,000 square feet, the average hourly maximum demand was as high as 3.48 kW/1,000 square feet for mixed sites (both ducted and ductless systems) and instantaneous site-level demand for one mixed site was 9.12 kW/1,000 square feet.

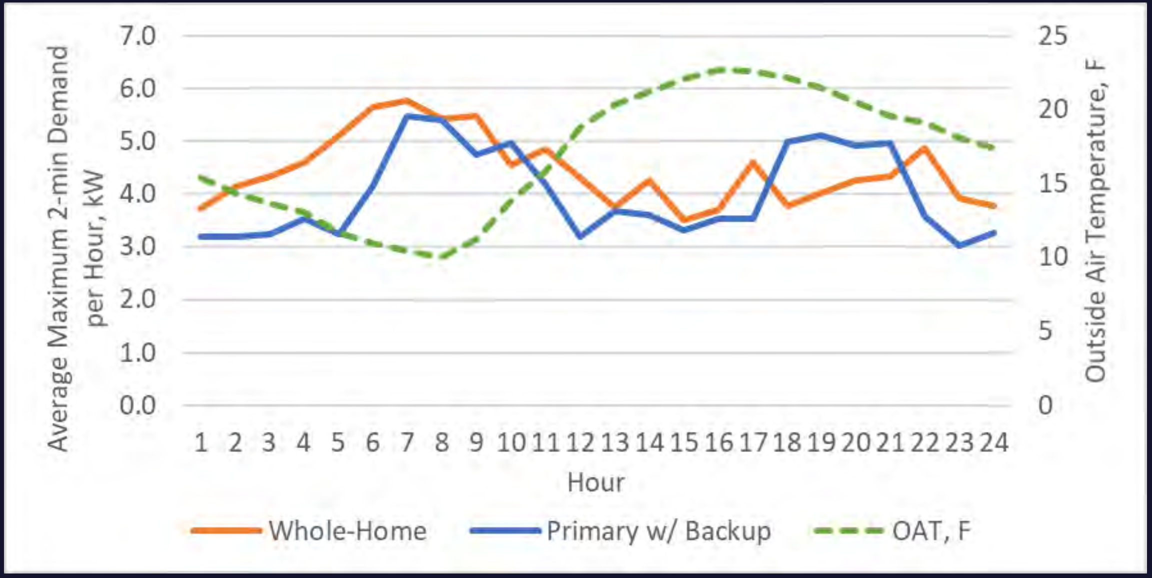
System Type	Number of Homes	Average Conditioned Area, sq. ft.	Total System Electric Energy Use, kWh/ 1,000 sq. ft	Average ASHP Operating Demand, kW/1,000 sq. ft.	Average Maximum Hourly Demand, kW/1,000 sq. ft.	Average Utility Winter Peak Demand,[1] kW/1,000 sq. ft.	Site-Level Maximum 2-Minute Interval Demand, kW/1,000 sq. ft.
Ductless	27	1,878	2,728	0.91	2.11	0.90	5.47
Ducted	11	2,281	1,453	1.10	3.04	0.64	8.47
Mixed	5	1,907	3,468	1.05	3.48	1.04	9.12
Overall	**43**	**1,984**	**2,436**	**0.98**	**2.52**	**0.88**	**-**

[1] Utility Winter Peak demand period defined as 5:00 PM to 7:00 PM daily during December, January, and February.

Whole-Home and Primary with Backup System Load Shape Comparison: New York Cold Snap Period[1]

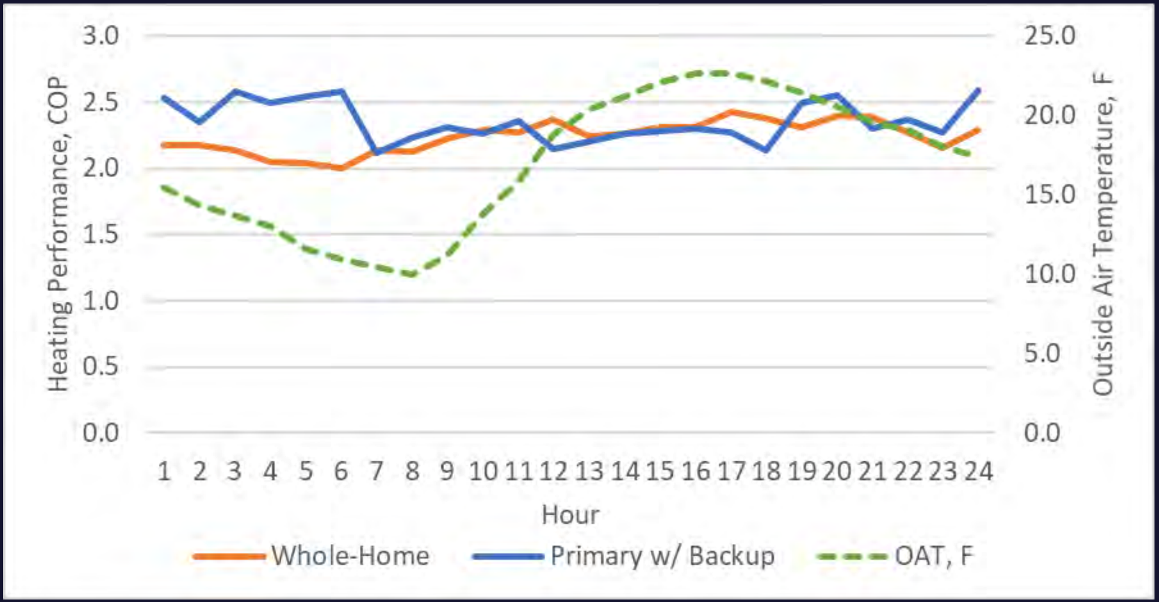


Electric grid impacts from wide-scale residential heating electrification may occur in the early morning hours when residents are waking up, implying the use of overnight space temperature setbacks.



[1] The New York three-day cold snap was defined as February 11th through February 13th (midnight to midnight). The average outdoor air dry bulb temperature across the 19 sites was 17.1°F during the three-day period.

Whole-Home and Primary with Backup System Load Shape Comparison: New York Cold Snap Period[1]



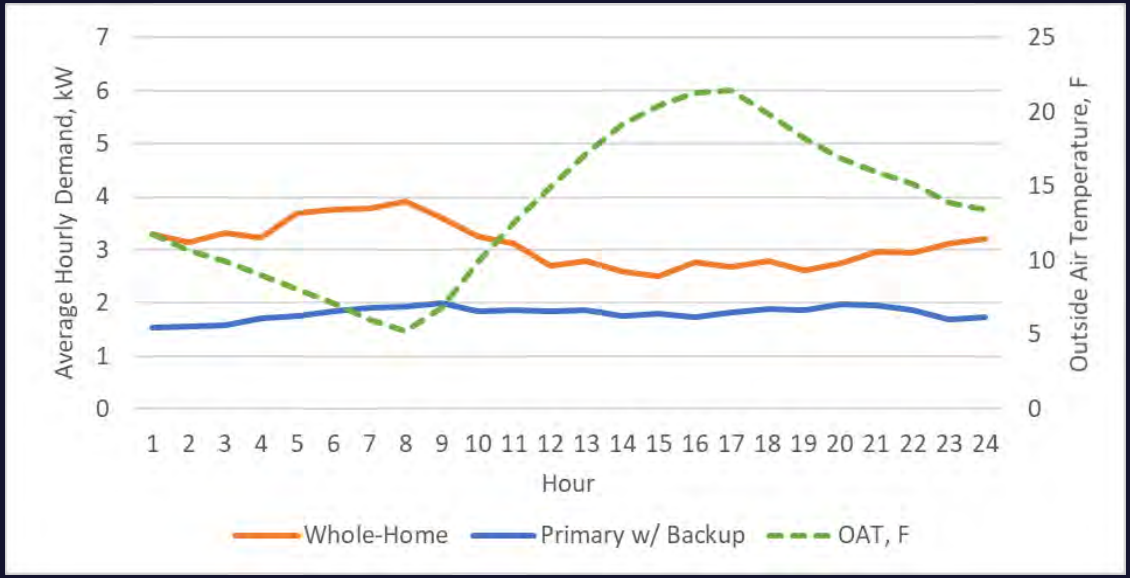
Heating performance[2] is relatively steady throughout the day.

Systems with electric resistance elements will have the greatest peak demand impact, reaching over 15 kW.

Summary Parameter	Application	
	Whole-Home	Primary w/ Backup
Number of Homes	12	7
Average Metered Demand, kW	2.77	2.21
Average Maximum Demand per Hour (2-min interval), kW	4.45	4.00
Maximum Site-Level Demand (2-min interval), kW	17.25	14.11
Average Measured ASHP Heating Load, Btu/hr	20,598	19,859
Average Heating Performance, COP	2.24	2.36
Average Outside Air Temperature, °F	17.2	16.9
Average Windspeed, mph	4.9	5.4

[1] New York cold snap defined as February 11th through 13th (midnight to midnight).
[2] Note that electric resistance demand is not included in the calculation of ducted system performance shown in this table. Actual performance for the three ducted systems in New York with ER is expected to be lower.

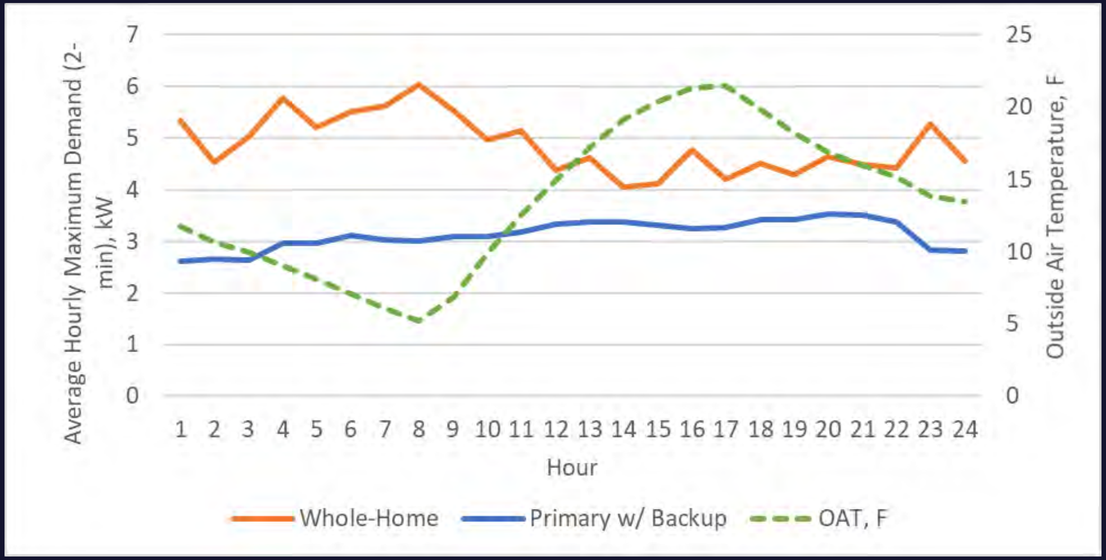
Whole-Home and Primary w/ Backup System Load Shape Comparison: Massachusetts Cold Snap Period[1]



On average, systems in whole-home applications will have a greater peak demand impact.

MA sites showed reduced early morning demand peak than NY sites, potentially due to Mass Save's set it-and-forget-it messaging.

[1] The Massachusetts three-day cold snap was defined as January 29th through 31st (midnight to midnight). The average outdoor air dry bulb temperature across the 24 sites was 12.9°F during the three-day period.



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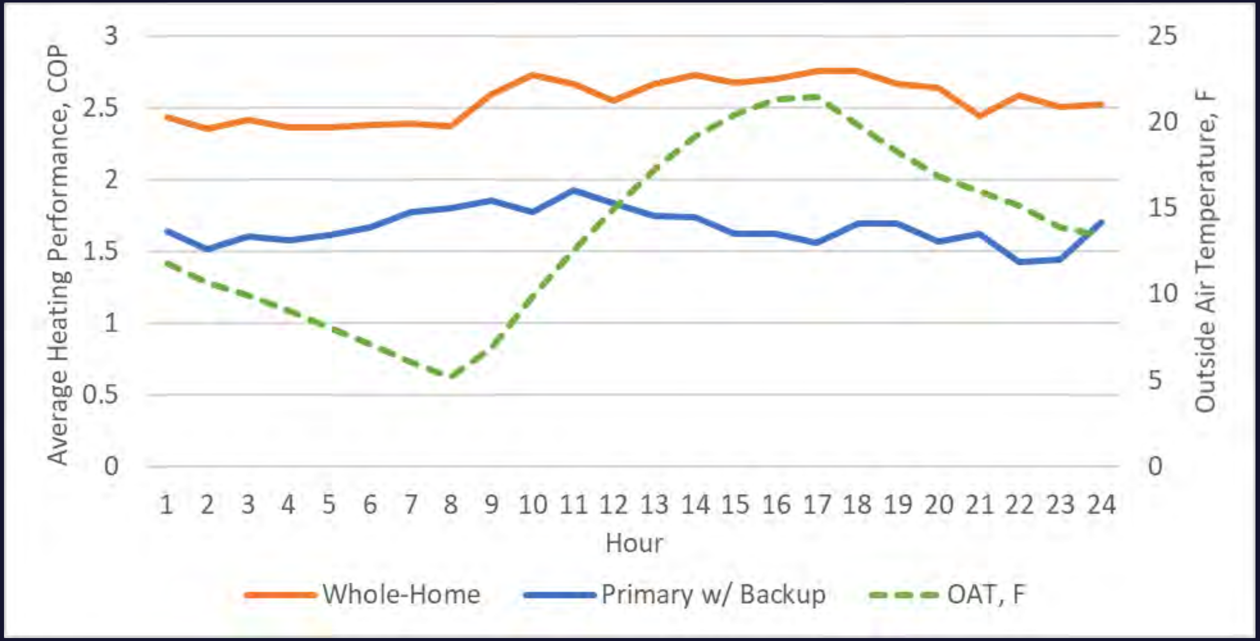
Whole-Home and Primary w/ Backup System Load Shape Comparison: Massachusetts Cold Snap Period[1]



Heating performance within applications is relatively steady throughout the day.

Summary Parameter	Application	
	Whole-Home	Primary w/ Backup
Number of Homes	9	13
Average Metered Demand, kW	3.11	1.81
Average Maximum Demand per Hour (2-min interval), kW	4.88	3.13
Maximum Site-Level Demand (2-min interval), kW	20.58	12.97
Average Measured ASHP Heating Load, Btu/hr	20,265	10,701
Average Heating Performance, COP	2.55	1.67
Average Outside Air Temperature, °F	13.6	12.5
Average Windspeed, mph	8.2	9.2

[1] Massachusetts cold snap defined as January 29th through 31st (midnight to midnight).

[2] Note that electric resistance demand is not included in the calculation of ducted system performance shown in this table. Actual performance for the two ducted systems in Massachusetts with ER is expected to be lower.

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Cooling Season Demand Impacts

The metered average utility Summer Peak demand impact from ccASHPs in cooling mode of 0.21 kW/1,000 square feet was **76% less** than the average utility Winter Peak demand impact of ccASHPs in heating mode (0.88 kW/1,000 square feet).

However, the site-level, instantaneous demand impact for ductless systems was almost **20% higher** in cooling mode than heating mode.

System Type	Number of Homes	Average Conditioned Area, sq. ft.	Total System Electric Energy Use, kWh/ 1,000 sq. ft[2]	Average ASHP Operating Demand, kW/1,000 sq. ft.	Average Maximum Hourly Demand, kW/1,000 sq. ft.	Average Utility Summer Peak Demand,[1] kW/1,000 sq. ft.	Site-Level Maximum 2-Minute Interval Demand, kW/1,000 sq. ft.
Ductless	27	1,878	293	0.44	1.16	0.21	6.52
Ducted	11	2,281	217	0.56	1.27	0.23	2.43
Mixed	5	1,907	181	0.46	1.52	0.17	3.54
Overall	**43**	**1,984**	**258**	**0.49**	**1.23**	**0.21**	**-**

[1] Utility Summer Peak demand period defined as 1:00 PM to 5:00 PM daily during June, July, and August.
[2] For reference, the Massachusetts 2020 Technical Reference Manual estimates the average residential home cooling energy consumption for a central air conditioning system with 16.5 SEER to be 823 kWh/year.

Objective 5: What continued challenges with customer and contractor experience need to be addressed to scale the market?

Stakeholder Interview Feedback

Residential Electrification

Challenges	Benefits
Economic Concerns customers may have net higher energy bills due to lower fuel costs	**Improved Customer Comfort** appropriately sized systems: temperature control, reduced noise, improved internal air emissions
Technology Awareness and Reliability lack of trust in system reliability and general lack of awareness of technology for both customers and contractors	**Customer Relationship Building** strengthen electric utility relationship with customers
Costly Grid Upgrades electric utilities may need to invest in infrastructure upgrades to meet new winter peak demand	**Reduce Electricity Costs** defray cost of utility distribution by selling more energy for same distribution
Existing Building Stock aging northeast building stock presents challenges to whole-home ASHP systems	**Reduce Distributed Energy Generation Impacts** use energy generated at local nodes, i.e., solar energy coming back on the grid
Conflicting Priorities gas utilities may lose customers resulting in stranded assets	**Reduce Demand for Additional Gas Pipelines** particular concern in downstate New York

Refer to the Appendix for additional details on the stakeholder interviews.

Stakeholder Interview Recommendations

- Encourage weatherization measures
- Provide more opportunities for New Construction whole home systems
- Increase incentives and consider upstream incentives
- Develop electric heating rates to encourage off-peak energy use
- Train contractors to properly size systems
- Educate customers on benefits of ccASHPs for heating
- Push-back on policies on integrated controls and backup systems
  - Recommending integrated controls encourages customer to retain backup fuel systems
  - Integrated controls are costly and difficult to install, even more difficult to operate correctly
  - But retaining existing system may be simplest way to get customers to invest in systems

Customer Concerns

Whole-home customers noted fewer concerns than other customer types prior to installation, but performance and cost were still top of mind.

	Whole-Home	Primary w/ Backup	Supplemental
System cost	60%	61%	64%
ASHP performance at low outside temps	44%	62%	43%
Understanding how ASHP works	45%	40%	38%
System maintenance	28%	38%	47%
ASHP ability to evenly cool or heat the required area	31%	34%	35%
Potential energy savings	24%	36%	24%
ASHP reliability	27%	31%	23%

Question C13: Did you have any questions/concerns about the air source heat pump prior to the installation? Please select all that apply. [MULTI-SELECT]

Key Findings from Contractor Interviews

- Customer **demand for ASHPs has increased** in recent years, driven by improved technology, widespread adoption, and rebates.
  - Most discussed benefits include the **higher efficiency and lower environmental impact** of ASHPs

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- Contractors are overwhelmingly recommending cold-climate models; **ductless mini-splits still dominate over ducted systems.**
  - **Primary with backup systems are most popular** in both MA and NY
  - Main barriers for ducted systems are higher cost and logistical limitations based on home features
- Customers report **few performance issues** with cold-climate models, thanks in part to the education and best practices contractors provide.

- **MA contractors appreciate rebate programs** for driving installations of ASHPs, with satisfaction being highest with the Mass Save Program.
- **NY contractors expressed more room for improvement with rebate programs**, citing opportunity to improve program design and delivery.
- Contractors had positive feedback for trainings, but reported **challenges with recruiting trained, qualified staff.**

Contractor Interviews: *ASHPs Adoption Barriers*

Barrier	General Barriers	Specific to Central System	Specific to Ductless System	Specific to ASHP as Primary Heating System	Specific to Cold-Climate Models
Cost	✓	✓		✓	✓
Aesthetics	✓		✓		
Misconceptions about the technology	✓	✓		✓	
Customer desires (e.g., want cooling only)	✓				
Building logistics (e.g., lack of ducts, electrical power, and/or physical space)	✓	✓		✓	✓

Many NY contractors (6 out of 8 interviewed) reported that customers did not believe that ASHP technology would effectively heat/cool their home, compared to 3 out of 11 contractors in MA.

Conclusion

Key Takeaways

- Customers are **generally very satisfied** with ccASHP heating and cooling performance.
- Whole-home systems tend to be utilized more often than primary with backup systems.
- Whole-home systems tended to be more expensive to install than primary with backup systems.
- The overall average seasonal heating performance of **2.34 sCOP** is in line with similar studies.
- On average, seasonal heating performance was similar between primary with backup and whole-home applications, but varied significantly by home and system type, influenced by many factors.
- Winter Peak demand impacts of wide-scale ccASHP adoption will likely occur during **early morning hours**, not during traditional utility peak periods.
- Whole-home applications with electric resistance elements will have the greatest electric grid impact during extreme cold periods.
- Heating season demand impacts will be greater than cooling demand impacts.
- Contractors reported installation costs, aesthetics, customer misconceptions, and building logistics as the top cited barriers to wide-scale ccASHP deployment.
- A customer’s existing fuel type is an important factor to cost effectiveness. Natural gas customers will likely see overall utility bills increase by switching to electric ccASHP systems for heating due to the high cost of electricity relative to natural gas in the Northeast.

Conclusion

- Policymakers and utilities involved in the project seek to understand whether study results indicate a recommendation to focus on primary w/ backup vs. whole-home applications in ASHP programs and policies.
- However, the study sample size (43 homes) is insufficient to draw statistically significant conclusions, and observations relevant to our research objectives should be considered as directional.
- With regards to our research objectives comparing primary with backup and whole-home systems:
  - (1) Comfort differences reported by customers were minimal
  - (2) Observed differences in seasonal heating efficiency were minimal
  - (3) Electrical demand was higher for whole-home systems during cold periods
- Our study data does not suggest there are significant trends that would warrant policy/program decisions encouraging or discouraging whole-home systems based on concerns around customer comfort or system performance.
- However, the observed difference in electrical grid impacts (particularly in the context of mass market adoption) may be a more important factor for policymakers and utilities to consider for informing policy and programmatic decisions.
- As discussed, cold snap periods were warmer and shorter than design conditions and did not reflect periods of prolonged extreme cold that could have greater impacts on customer comfort and grid demand. Further study with a larger sample during such a weather event may provide more definitive conclusions on comfort, performance, and grid impact issues that could influence policymakers and program administrators.

Program and Policy Recommendations

- **Incentive levels.** Based on the projects metered, most sites will not achieve a payback during the system lifetime based on the incentive received. Incentive levels have since increased substantially for many NY and MA sites, which may enable greater savings.
- **Energy savings.** Electric resistance and propane customers were most likely to see significant energy savings, as well as oil customers in NY. High electricity costs limit energy savings in MA. Utility rate structures (particularly in MA) with lower volumetric costs to reflect higher grid utilization may improve economics, though such structures may be inappropriate in the long term with increasing electrification and winter peak concerns.

Recommendations for Future ccASHP Data Collection Efforts

While this study allowed us to perform in-depth analysis on a variety of factors that may impact ccASHP performance in the Northeast, we identified the following opportunities for future data collection studies:

- Collect data for a larger sample to achieve statistically significant results for a selected region
- Collect data for a longer duration (possibly multiple years) to capture annual variances
- Focus on whole-home installations; it is challenging to estimate heating load served by backup heating sources
- Collect data for a tighter interval (30s -1 min) to investigate defrost demand and energy use
- Investigate multi-zone system (>3 indoor heads) and branch-box system potential performance challenges
- Collect indoor space temperature setpoints to investigate times when ccASHP systems are not able to maintain setpoints

APPENDIX

1. Literature Review Summary
2. Stakeholder Interview Summary
3. Data Collection & Analysis Methodology
4. Customer Survey Results
5. Heat Pump Contractor Interview Results
6. Heating Season Metered Data Results
7. Heating Season Utility Bill Analysis
8. Cooling Season Metered Data Results
9. Acadia Research Home Performance Contractor Interview Results
10. Acadia Research Customer Interview Results

1. Literature Review Summary

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Literature Review Summary

System Design/Operation

- ccASHPs operate at ~90% labeled efficiency (Cadmus VT study)
- ASHP systems typically sized to meet 2.6x cooling load needed according to manual J calcs
- EFLH tend to be significantly lower than TRM values (<50%)
- Use patterns determine system efficiency

Policies

- Biggest barrier to uptake is knowledge followed by concern for low-temp performance and high upfront costs
- Under aggressive policy scenario, NYS could expect 2/3 of households to have ASHPs by 2030
- Homeowners without cooling tend to have higher interest in ASHPs

Energy Savings/GHG Reductions

- CO_2 reductions are similar for full replacement and partial displacement ASHP systems
- Energy impacts are more influenced by baseline equipment specs than new equipment specs (and the subsequent gap)

Incentives

- Rebate levels have more impact than fuel prices in adoption rates
- Providing incentives over $500 is advised to jumpstart the market
- ASHP incentives should be targeted to homes with electric resistance, oil, or propane heating and New Construction

2. Stakeholder Interview Summary

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Stakeholder Interviews

Cadmus conducted four targeted interviews with program administrators and other experts in order to characterize decarbonization goals, discuss available programs and incentives for ASHPs, and discuss perspectives and challenges related to promotion of primary/whole building ASHP systems.

We spoke with the following stakeholders:

- Connecticut Department of Energy and Environmental Protection (DEEP)
- Massachusetts Department of Energy Resources (DOER)
- New York State Department of Public Service (DPS)
- Massachusetts Department of Public Utilities (DPU)

Key Findings

- **General**
  - More interest in EV infrastructure than electric heat (more discrete and controllable)
  - COVID-19 concerns: lower fuel costs, customer income uncertainty, contractors unable to visit homes
- **Risks**
  - Economic concerns: customers may have net higher energy bills due to lower fuel costs
  - Lack of trust in system reliability and general lack of awareness of technology for both customers and contractors
  - Electric utilities may need to invest in infrastructure upgrades to meet new winter peak demand
  - New England building stock is generally not conducive to whole home ASHP systems
  - Gas utilities may lose customers resulting in stranded assets
- **Benefits**
  - Improved customer comfort with appropriately sized systems: temperature control, reduced noise, improved internal air emissions
  - Strengthen electric utility relationship with customers
  - Defray cost of utility distribution by selling more energy for same distribution
  - Reduce distributed generation impacts by using at local nodes; i.e. solar energy coming back on the grid
  - Reduce demand for additional gas pipelines (particular concern downstate NY)

Key Findings, cont.

- **Policies**
  - Encourage weatherization measures
  - Better opportunities for New Construction whole home systems
  - Increase incentives (esp. during COVID-19) and consider upstream incentives
  - Develop electric heating rate to encourage off-peak energy use
  - Must encourage ASHP adoption to meet 2030, 2050 GHG reduction goals
- **Other Recommendations**
  - Train contractors to properly size systems and educate customers on benefits
  - Push-back on integrated controls and backup systems
    - Recommending integrated controls encourages customer to retain backup fuel systems
    - Integrated controls are costly and difficult to install, even more difficult to operate correctly
    - Comparison to plug-in hybrid vehicles
    - But, retaining existing system may be simplest way to get customers to invest in systems

3. Data Collection & Analysis Methodology

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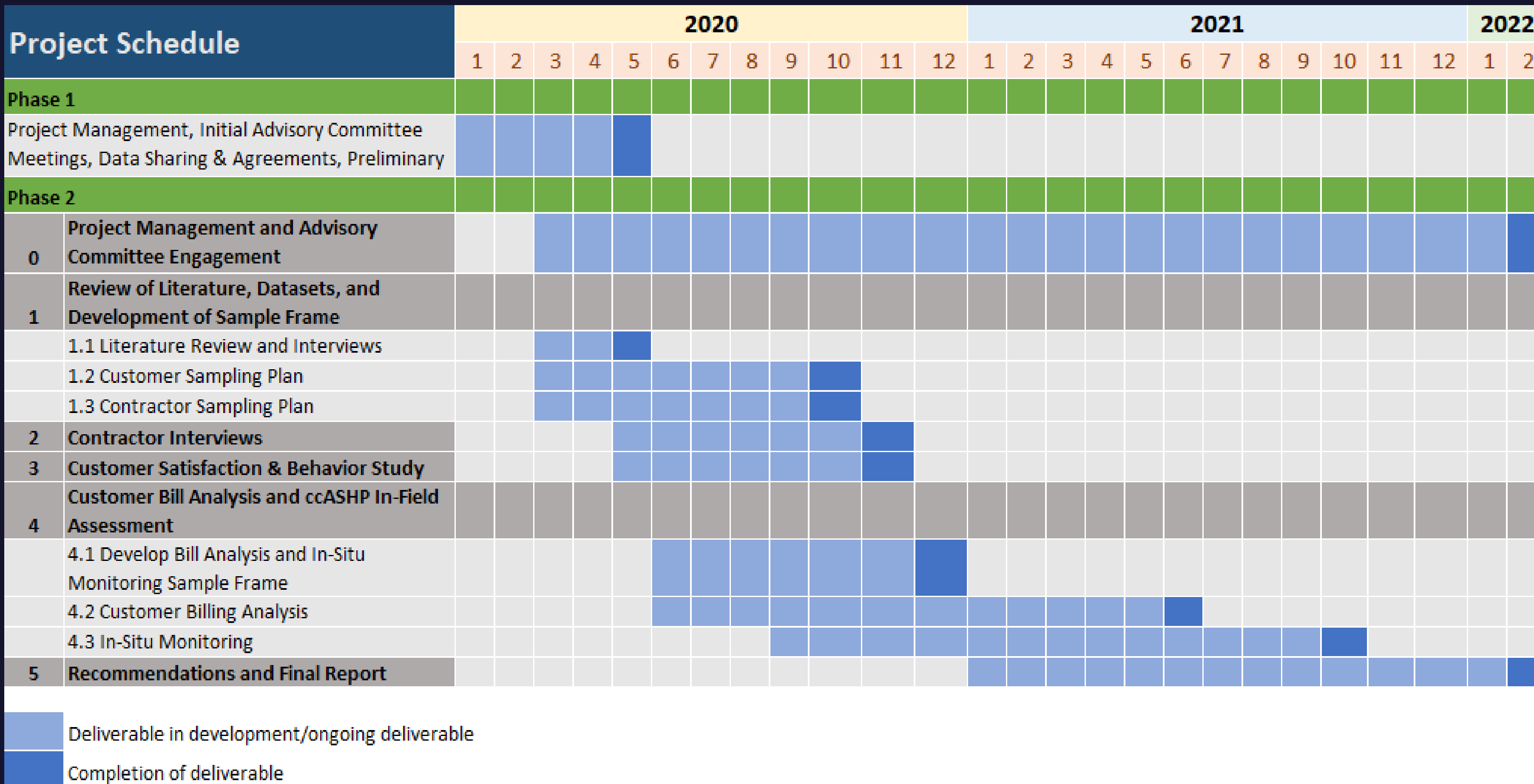
Project Timeline



Massachusetts Dataset

Overview

Primary Heating / Whole Home ASHP Rebate Data

MassCEC

Whole Home Pilot (39 projects)

- May 2019 – August 2020
- 25 Existing Building, 14 New Construction
- Avg Heating Capacity: 37.3 kBtu/hr
- Avg Sizing Factor: 120%
- Avg Cost: $19,960
- 67% Single-Family Detached

ASHP Program (20,085 projects)

- December 2014 – November 2019
- 404 projects (2%) listed as primary heating with no-backup heat
  - Avg Cost: $11,193
  - Avg Heating Capacity: 32.4 kBtu/hr
  - 9% new construction
- 3362 projects (17%) listed as primary heat with backup
  - Avg Cost: $10,916
  - Avg HP Capacity: 33.6 kBtu/hr

New York Dataset

Overview

Primary Heating / Whole Home ASHP Rebate Data

NYSERDA

Prior to implementation of whole-home rebate

- 339 (3.7%) projects considered primary heat or whole-home
- Avg project cost: $15,142

After implementation of whole-home rebate

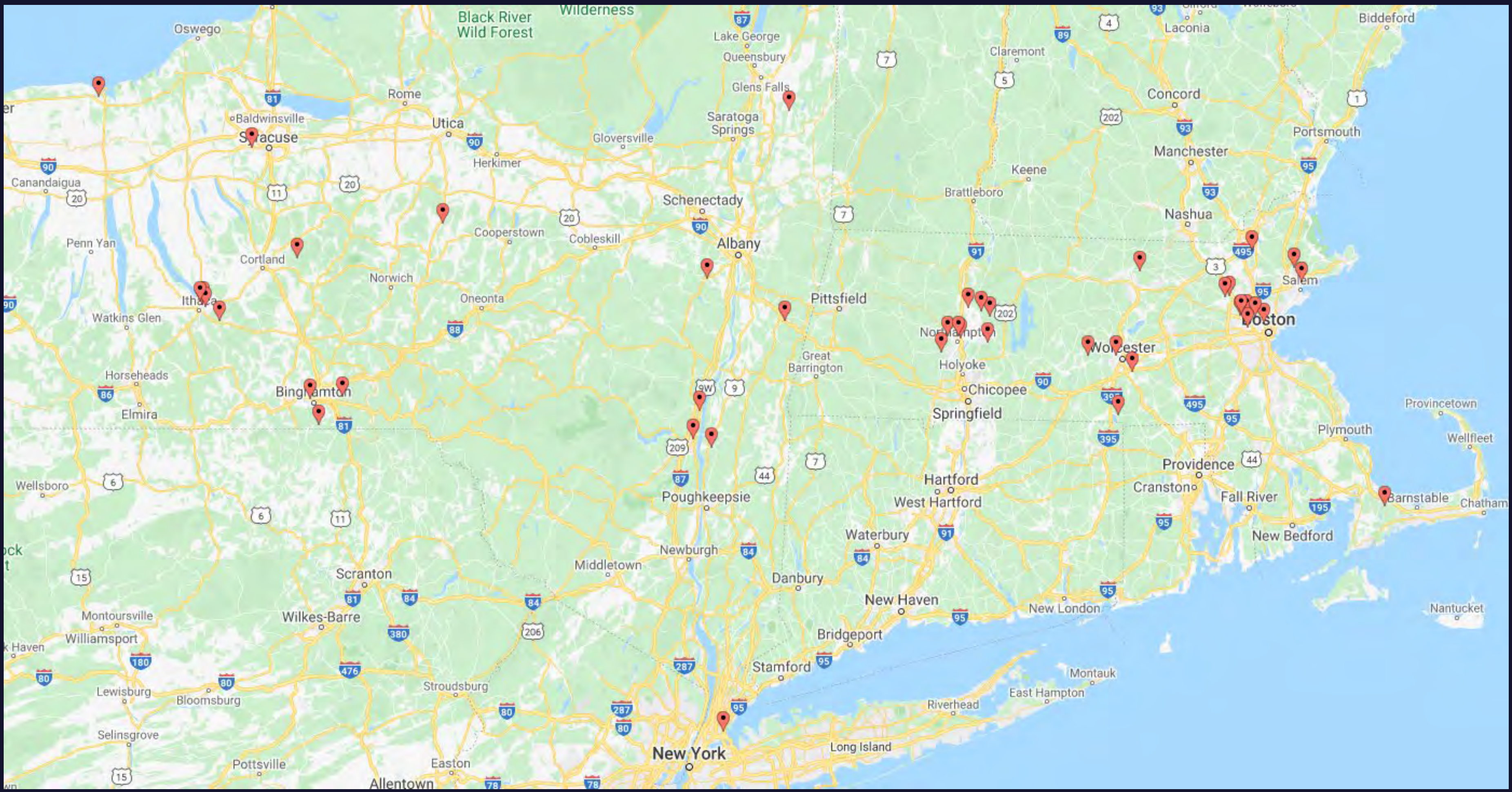
- 450 (2.1%) projects considered primary heat or whole-home
- Avg project cost: $17,110
- Avg capacity (cooling): 4.1 tons

- Use of heat pump as only source of heat not tracked in data
- Only includes 1-4 unit residential
- Whole-home defined as: heat pump conditioning >80% of conditioned sq. ft., ASHP listed as primary heating source, and (where applicable) receiving $1,000/ton rebate

Geographic Site Distribution

32 (74%) of the homes were in Climate Zone 5

State	IECC Climate Zone			Total Homes
	4	5	6	
Massachusetts	0	24	0	24
New York	1	8	10	19



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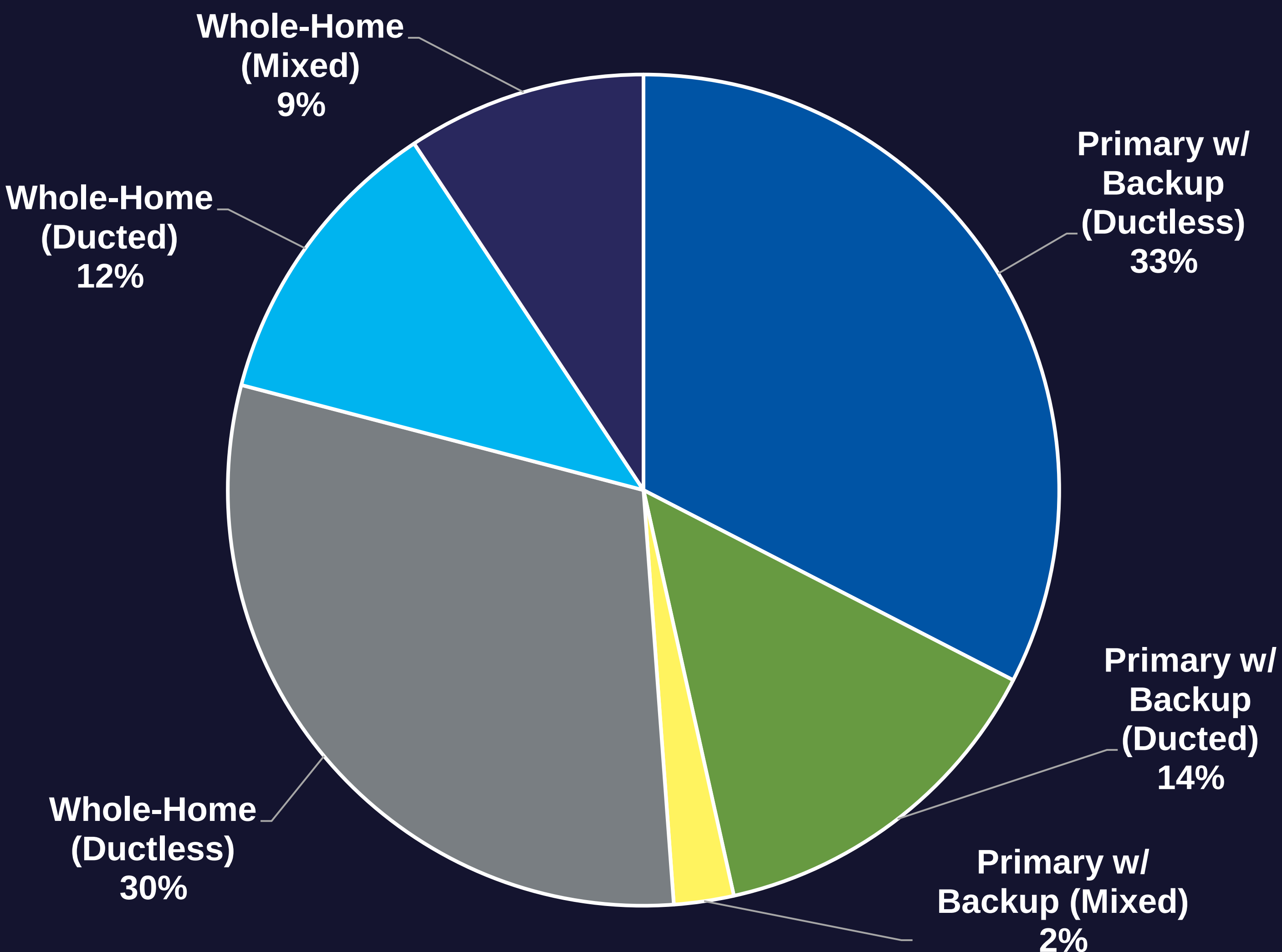
Site Sample Distribution by Application & System Type

Application	System Type	Onsite Metered Data Collection				Additional Utility Bill Data-Only Sites		
		Planned Total	**MA**	**NY**	**Total**	**MA**	**NY**	**Total**
Primary with Backup	Ductless	*15*	11	3	**14**	26	1	27
	Ducted	*5*	2	4	**5***	0	0	0
	Mixed	*0*	1	0	**1**	0	0	0
Whole-Home	Ductless	*15*	7	6	**13**	16	4	20
	Ducted	*5*	2	3	**6**	0	0	0
	Mixed	*0*	1	3	**4**	0	0	0
Supplementary	Ductless	*0*	0	0	**0**	1	4	5
Total		***40***	**24**	**19**	**43**	**43**	**9**	**52**

*Including two hybrid ASHP systems with integrated gas furnaces.

Site Sample Distribution by Application & System Type (cont.)



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Metered Data Collection

- **Duration**
  - October 2020 through October 2021
    - Some sites not accessed until Dec/early January
  - All data collected at 2-minute intervals
- **Outdoor units**
  - Total power (kW)
  - Outdoor dry bulb temperature
  - Indoor fan amps (ductless systems)

- **Indoor units (heating season only)**
  - Supply and return temperature
  - Indoor fan amps or power (ducted)
  - Electric resistance backup amps or power (ducted)
- **Auxiliary heat source (heating season only)**
  - Gas valve status
  - Wood stove temperature
  - Electric resistance amps
  - Furnace fan amps
- **Other**
  - Blower door tests
  - Manual J calculation inputs
  - Ducted system indoor unit airflow tests

Blower Door Test Methodology

- Blower-door testing indicates the amount of air leakage for a structure, which is a primary determinant of thermal energy efficiency. Air leakage can also affect occupant comfort, indoor air quality, and building durability. The intention of collecting this data for participating sites was to understand the correlation between the leakiness of a home, ccASHP heating performance, and customer comfort.
- Cadmus used a two-point blower door test procedure, which strikes a balance between the expediency of single-point testing and the greater reliability and accuracy of multi-point testing. The two-point blower door test requires depressurizing the house to near 50 Pascals (Pa) and 25 Pa with respect to the outside.
- Example test measurements using a DG-700 Pressure and Flow Gauge:

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Manual J Calculation Methodology

- Cadmus collected onsite inputs to calculate expected heat load for each of the sampled homes and compared our results with the contractors' heat load calculations, where available to analyze whether there are any usage patterns, performance, or comfort issues related to over or under-sizing ccASHP systems.
- Cadmus worked with MassCEC to collect the installation contractor Manual J calculation outputs for the Massachusetts sites in MassCEC's whole-home program. Of the 24 participating sites, contractor Manual J heat load calculations were available for five sites.
- During the heating season data download site visits in Spring 2021, Cadmus collected site-specific Manual J calculation inputs, such as home orientation, insulation levels, conditioned floor area, ceiling height, window area, number of above and below grade floors, occupants, and other internal space loads. We input these site-specific inputs and the blower door test results, where available, into CoolCalc Manual J software, a web based, Air Conditioning Contractors of America (ACCA) approved heating and cooling load calculator to estimate the heating and cooling load at the design conditions for each home. An example CoolCalc report output for one of the Massachusetts sites is attached to this memo.

Data Analysis Methodology

Raw Data Sources

Logger Data
(1 to 5-minute intervals)

NOAA Weather Data
(hourly, including wind speeds)

ASHP System Data
(NEEP specs)

Backup Fuel System Data

Other Onsite Data (blower door test, Manual J results)

~~**Monthly Utility Data**~~
(separate analysis)

Source Data Tables

Pulled from raw data sources
Minimal processing (basic cleaning only)
Original resolution

- Project Info Table
- Utility Info Table
- Site Table
- Sensor Table
- Equipment Model Table
- Equipment Instance Table
- Timeseries Data Table
- Meter Metadata Table
- TMY3 Weather Table
- Actual Weather Table
- 5-Year Weather Table

*We will select one, 1 to 2-day period per site to analyze demand, load, and performance for each scenario:

- **ASHRAE design day:** varies by region (typ. 5F-17F)
- **"Cold snap":** varies by region, Cadmus will analyze NOAA weather station data and select coldest 1-2 day period

Intermediate Data Tables & Site-Specific Analysis

Transformed from source data tables
Unit conversion, resampling, pivot, align timestamps, QC outputs
(1 to 5-minute interval data, fine granularity)

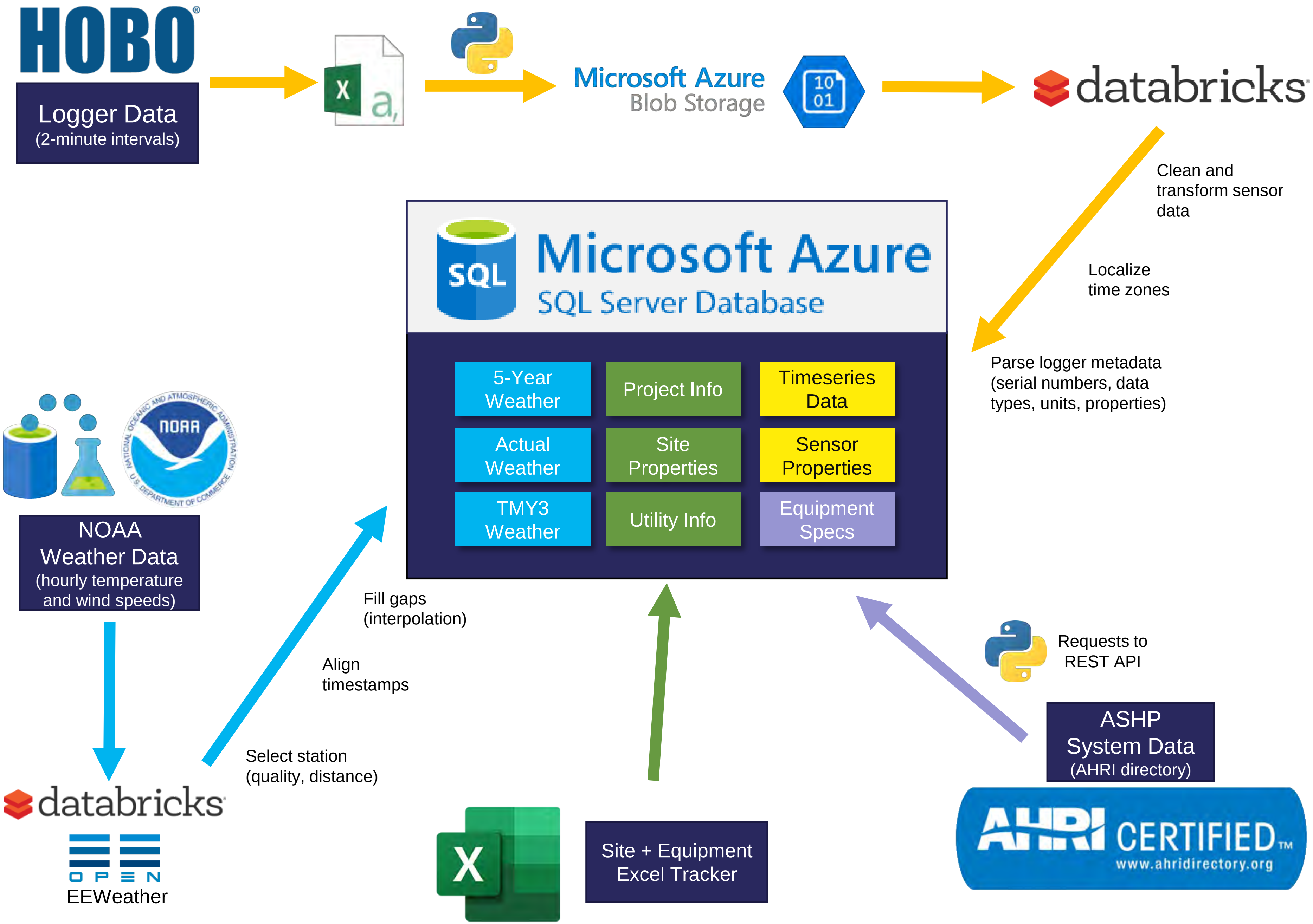
Site-specific snapshots during design day and cold snap conditions*:

- System load (Btu/hr)
- System performance (COP)
- ASHP total system peak (defrost mode) demand (kW)
- Backup heating system status (varies; kW, on/off, supply temp)

Final Analysis Tables

Transformed from intermediate data tables for bin/8760-hour modeling, simulation, etc.
(hourly data aggregation per site)

- Average heating season load shape
- Average system performance
  - Compare performance curves across various site parameters (location, system type, makes/models, weatherization levels, etc.)
- Annual total heating energy use for ASHP system and backup fuels (actual, vs TMY3, vs 5-year average)
- Average utility peak period demand
- Displaced fuel energy (actual, vs TMY3, vs 5-year average)
- System size analysis (compare max load to design load)


HOBO
Logger Data
(2-minute intervals)
Microsoft Azure
Blob Storage
10
01
databricks
Clean and
transform sensor
data
Localize
time zones
Parse logger metadata
(serial numbers, data
types, units, properties)
Microsoft Azure
SQL Server Database
SQL
5-Year
Weather
Project Info
Timeseries
Data
Actual
Weather
Site
Properties
Sensor
Properties
TMY3
Weather
Utility Info
Equipment
Specs
NOAA
NOAA
Weather Data
(hourly temperature
and wind speeds)
Fill gaps
(interpolation)
Align
timestamps
Select station
(quality, distance)
databricks
OPEN
EEWeather
Site + Equipment
Excel Tracker
Requests to
REST API
ASHP
System Data
(AHRI directory)
AHRI CERTIFIED
www.ahridirectory.org

4. Customer Survey Results

Objectives and Methodology

Research Objectives	• Identify customer motivations for specific heating applications (i.e., whole-home, primary w/ backup, supplemental) • Assess customer experience with ccASHP installation • Understand customer behavior using ASHP and managing back-up heating (e.g., controls, thermostat adjustments) • Assess customer satisfaction with ccASHP and any performance issues experienced • Understand weatherization measures installed with ccASHP and satisfaction with weatherization performance • Collect information on utility and fuel bills and recruit for in-situ monitoring
Method	Cadmus fielded survey from two data sources, NYSERDA rebate list and Qualtrics panel, with the following responses: • NYSERDA rebate data: 275 • MassCEC rebate data: 253 • Qualtrics panel: 100 (74 NY, 26 MA) • **Total responses: 628**

Customer Survey Key Findings

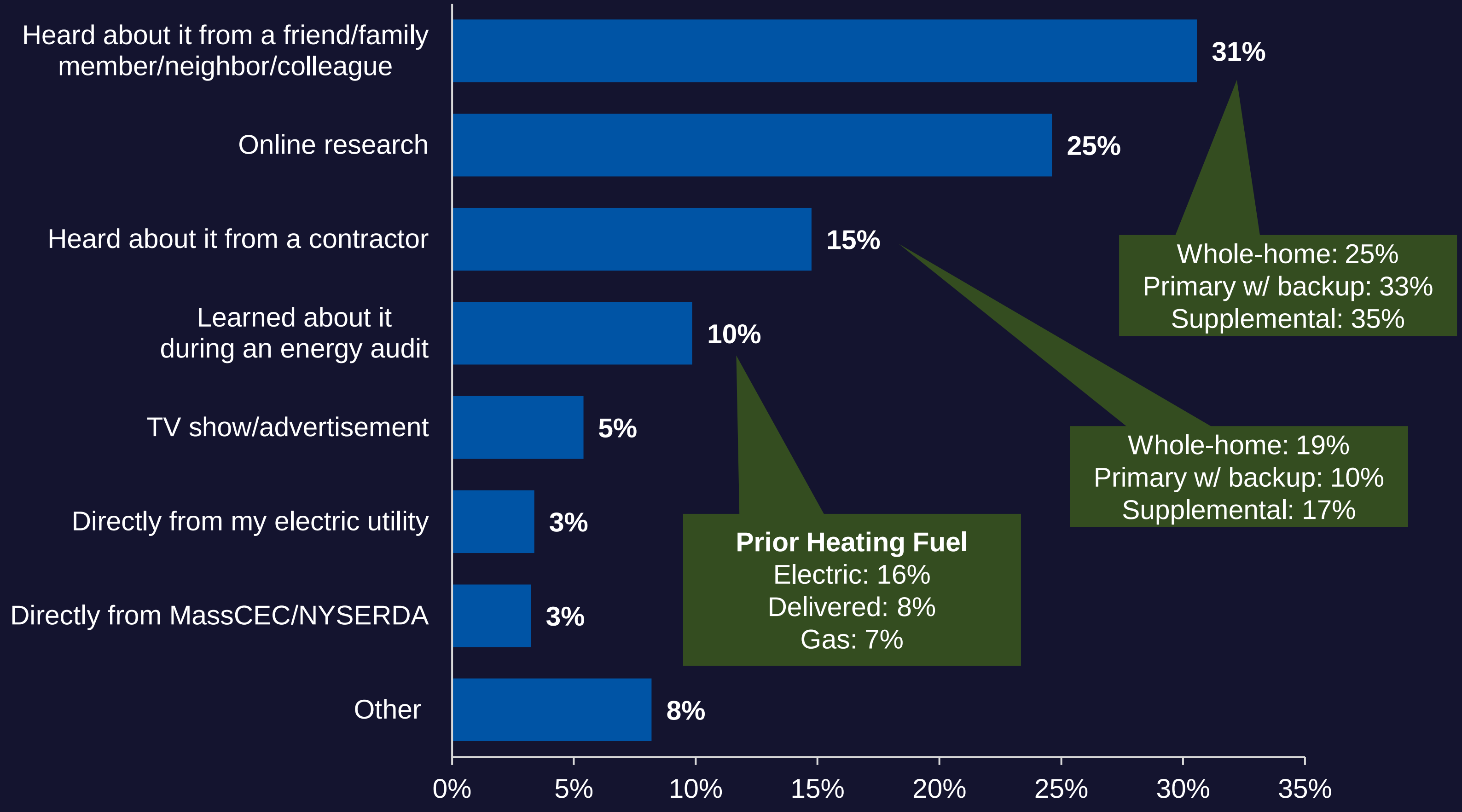
- Customers primarily installed ASHPs to **increase home comfort** and **save money on energy bills.** Customers with a whole-home configuration are especially likely to be motivated by energy savings.
- **Word-of-mouth** was the most common way that customers learned about ASHPs and found their contractor.

- **Weatherization upgrades** were usually completed at the same time as **ASHP installations.** This was especially true among those that had an energy audit completed, typically through the Mass Save program.
- Contractors were a key knowledge conduit, as **contractors are how most customers learned how to use their ASHP**.

- Performance issues were uncommon with ASHPs and nearly all customers reported lower bills.
- Customers were **highly satisfied with heating and cooling performance** (8.5/10 for heating and 9.0/10 for cooling).
- These factors lead to an **extremely high likelihood to recommend an ASHP** to others (whole-home = 8.9/10 would recommend; primary w/ backup = 9.3/10)

ASHP Awareness

Most respondents first learned about ASHPs through word of mouth; customers with a primary with backup system were more likely to learn about ASHPs through online research than whole-home customers.



Note: Single select question

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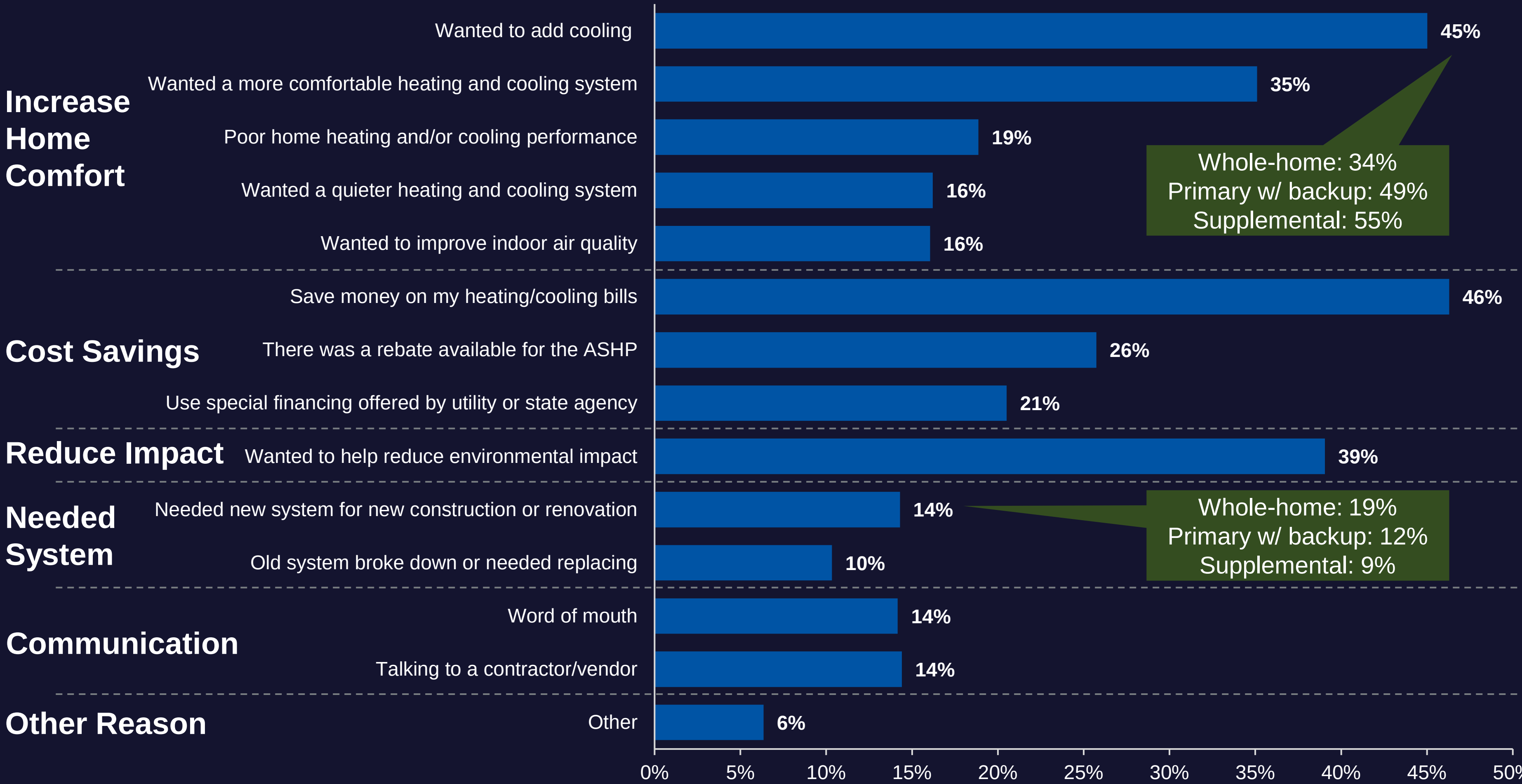
Decision to install ASHP

Most respondents installed an ASHP to increase home comfort, save money, and reduce environmental impact.



Decision to install ASHP

Top motivators for installing an ASHP differed by the prior heating fuel type, with electric respondents more focused on saving money and better home comfort levels

	Prior Heating Fuel Type		
	Electric	Natural Gas	Delivered Fuel
Save money on heating/cooling bills	70%	37%	51%
Wanted to add cooling	46%	47%	55%
Reduce environmental impact	33%	47%	53%
More comfortable heating/cooling system	43%	37%	34%
There was a rebate available	30%	32%	28%

Motivators for Configuration

Customers using their ASHP in a whole-home configuration were most influenced by environmental benefits, while primary w/ backup and supplemental customers were focused on keeping both systems.

Whole-Home	Primary w/ Backup & Supplemental
Wanted to eliminate fossil fuel usage for heating (27%)	Previous system did not need to be replaced (33%)
Wanted to minimize total bill (27%)/maximize energy savings (25%)	Recommended by contractor (33%)
Needed new system for new construction or renovation project (23%)	Concerned about ASHP performance during extreme cold (22%)

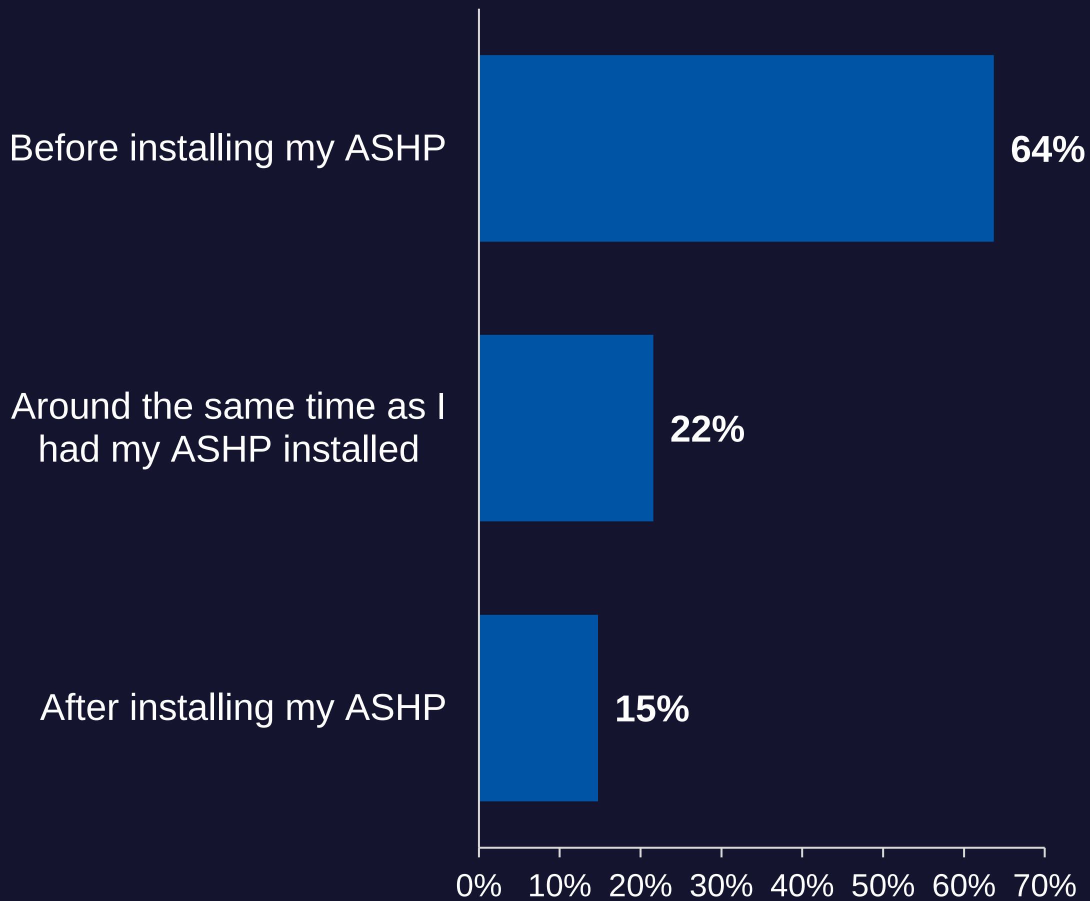
Weatherization Upgrades

Most customers completed weatherization upgrades during the process of installing an ASHP system.

60% of respondents had an energy audit before installing their ASHP

68% were recommended weatherization upgrades during audit

89% completed weatherization upgrades



Concerns

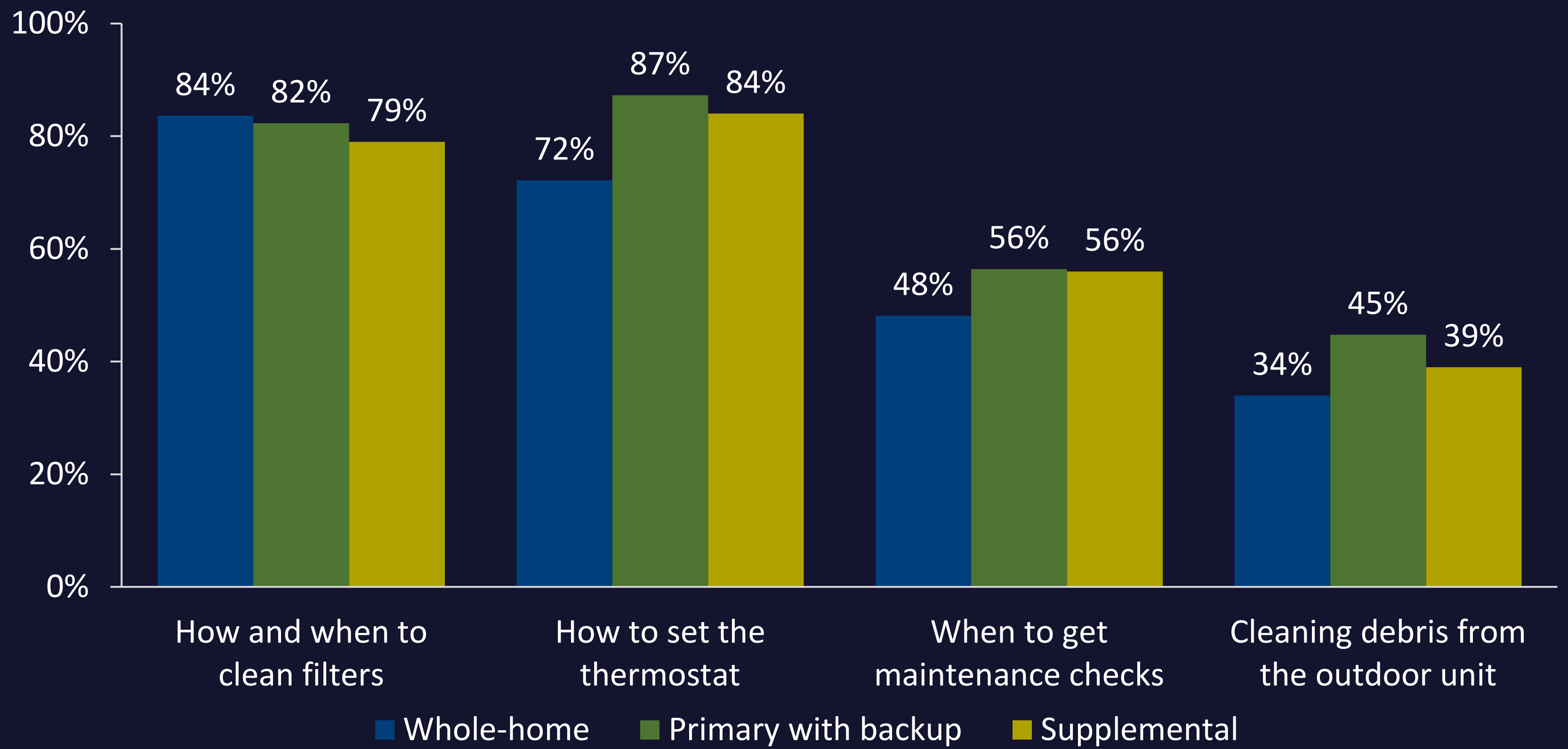
Whole-home customers noted fewer concerns than other customer types, but performance and cost were still top of mind.

	Whole-Home	Primary w/ Backup	Supplemental
System cost	60%	61%	64%
ASHP performance at low outside temps	44%	62%	43%
Understanding how ASHP works	45%	40%	38%
System maintenance	28%	38%	47%
ASHP ability to evenly cool or heat the required area	31%	34%	35%
Potential energy savings	24%	36%	24%
ASHP reliability	27%	31%	23%

ASHP Education

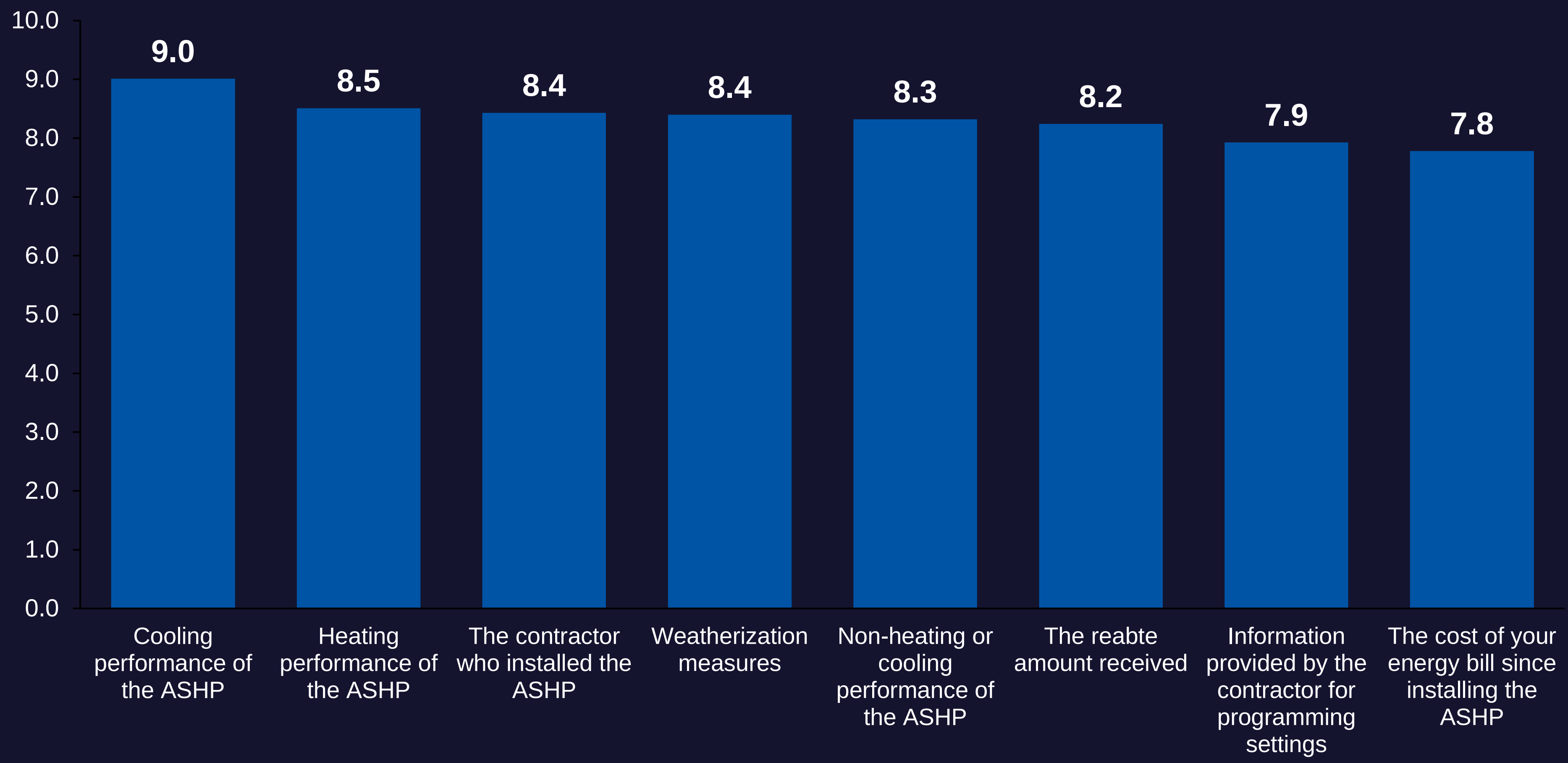
Contractors were a key conduit of ASHP knowledge for respondents.

93% of respondents reported the contractor helped them understand how to use the new system, with **80% of respondents** reporting that contractors provided leave-behind materials.



Satisfaction

Respondents were generally satisfied with most aspects of their ASHP installation, specifically the cooling and heating performance.



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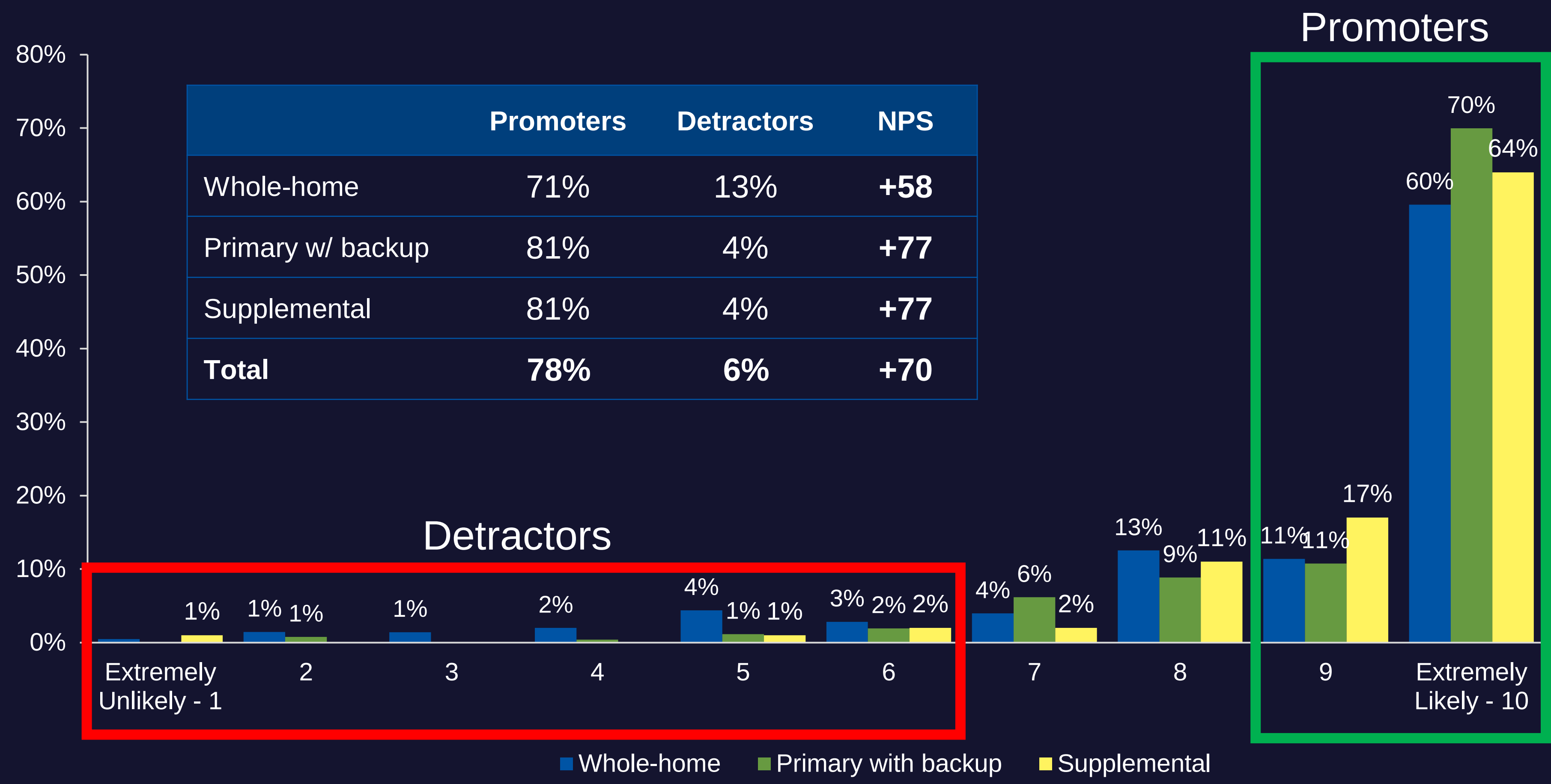
Net Promoter Score (NPS)

Reflecting their high satisfaction, ASHP owners are highly likely to recommend an ASHP to others, leading to very strong Net Promoter Scores.

	Promoters	Detractors	NPS
Whole-home	71%	13%	**+58**
Primary w/ backup	81%	4%	**+77**
Supplemental	81%	4%	**+77**
Total	**78%**	**6%**	**+70**



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Bill Impacts

Most respondents' utility bills were lower since installing an ASHP.

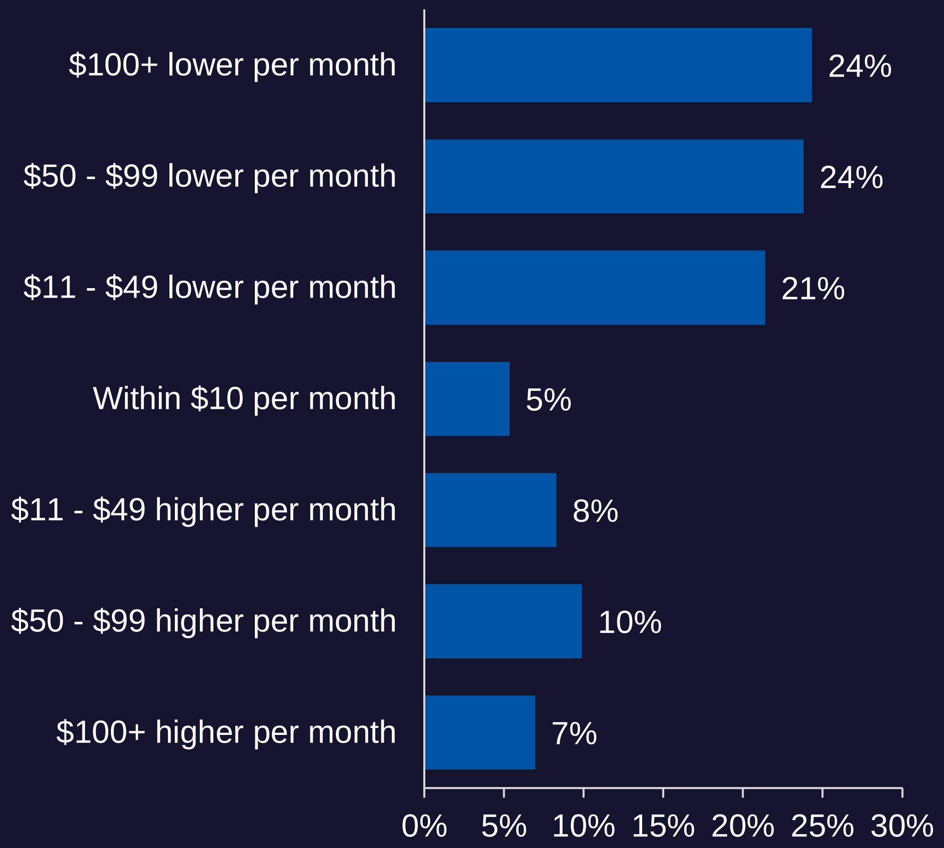
90% of respondents reported a change in their energy bills since installing an ASHP.

76% said the change was the same as what they expected.

Respondents who installed weatherization measures were significantly more likely to see a decrease of $100 or more per month (**26%**) compared to respondents who did not install weatherization (**19%**).

Respondents who had electric heating prior to installing their ASHP were more likely to see a decrease of at least $50 (**67%**) compared to gas (**32%**) and delivered fuel (**51%**) respondents.

Change in Bill since ASHP Installation



5. Heat Pump Contractor Interview Results

Objectives and Methodology

Research Objectives

- Identify customer motivations for ASHP installations and drivers of change
- Understand contractors' marketing and sales approach for different ASHP system configurations (whole-home, primary with backup, supplemental)
- Identify installation practices and frequency of consideration and installation of ASHP system configurations
- Assess contractor use of and satisfaction with training and certifications for ASHP installations
- Understand contractor experience working with ASHP promotional programs in NY and MA

Method

Conducted phone interviews with HVAC contractors in MA and NY:

	MA	NY
Unique Contractors	45	347
Interviews Completed	11	8
Response Rate	24%	2%

Key Findings

- Customer **demand for ASHPs has increased** in recent years, driven by improved technology, widespread adoption, and rebates.
  - Most discussed benefits include the **higher efficiency and lower environmental impact** of ASHPs

- Contractors are overwhelmingly recommending cold-climate models; **ductless mini-splits still dominate over ducted systems.**
  - **Primary with backup systems are most popular** in both MA and NY
  - Main barriers for ducted systems are higher cost and logistical limitations based on home features
- Customers report **few performance issues** with cold-climate models, thanks in part to the education and best practices contractors provide.

- **MA contractors appreciate rebate programs** for driving installations of ASHPs, with satisfaction being highest with the Mass Save Program.
- **NY contractors expressed more room for improvement with rebate programs**, citing opportunity to improve program design and delivery.
- Contractors had positive feedback for trainings, but reported **challenges with recruiting trained, qualified staff.**

Motivations for ASHPs

While demand for ASHPs has increased in both MA and NY, there appear to be regional differences in which system type is driving this demand.

Massachusetts

- In MA, **contractors were split** on whether they saw demand increase more for ducted versus ductless systems
- Drivers for **ducted systems**:
  - Greater number of equipment options
  - Improved efficiency of technology
- Drivers for **ductless systems**:
  - Technology is more widespread and known by customers
  - Ductwork isn't required
  - Customers are becoming more amenable to aesthetics
  - Can control temperature in each room

New York

- In NY, contractors more often expressed that **ductless systems drove most of the demand**
- Nonetheless, NY contractors reported similar demand drivers as those in MA:
  - Greater awareness and understanding of this technology as ASHPs grow more popular
  - Lower prices and more incentives and promotions
  - Technology evolution increasing versatility
  - Ability to have multi-zoned heating
  - Environmental appeal

Barriers to ASHPs Adoption

Cost, aesthetics, misconceptions about the technology, and building logistics were the top cited barriers.

Barrier	General Barriers	Specific to Central System	Specific to Ductless System	Specific to ASHP as Primary Heating System	Specific to Cold-Climate Models
Cost	✓	✓		✓	✓
Aesthetics	✓		✓		
Misconceptions about the technology	✓	✓		✓	
Customer desires (e.g., want cooling only)	✓				
Building logistics (e.g., lack of ducts, electrical power, and/or physical space)	✓	✓		✓	✓

Many NY contractors (6 out of 8 interviewed) reported that customers did not believe that ASHP technology would effectively heat/cool their home, compared to 3 out of 11 contractors in MA.

Typical System Recommendations

Contractors typically recommended cold-climate ASHPs over normal models; although contractors emphasize to customers the importance of weatherization upgrades, they typically refer customers to relevant programs or partners.

Cold-Climate vs. Normal Models

- **Usually recommend cold-climate models**
- Exceptions may include when the customer:
  - Only wants an ASHP for shoulder season
  - Does not want to support the full heating load
  - Doesn't live in home during heating season (i.e., it's a summer home)
  - Only want air conditioning
  - Cannot afford the cost
  - Already has high-efficiency system (e.g., high efficiency boiler)
  - There are logistical barriers to installation

Weatherization Upgrades

- 3 MA contractors (of 11) and 3 NY contractors (of 8) said they don't incorporate weatherization
- The remaining contractors typically incorporate weatherization by:
  - Determining insulation needs during home visit/when calculating heating load
  - Referring customers to relevant programs for an energy audit (Mass Save, HeatSmart)
  - Referring customers to partner companies who complete insulation upgrades
- Contractors in both states **emphasize to customers the importance of insulation** to optimize efficiency and cost-savings

Installation Practices

Most contractors reported completing specific calculations for system sizing and design, with the most common being the Manual J.

- 9 out of 11 MA contractors and 5 out of 8 NY contractors said they **completed a Manual J calculation**
  - The amount of time calculations take depends on home size and system type
  - In MA, about half of contractors said the process took 10-20 minutes, the other half said about 1-2 hours; in NY, most contractors said it took 1-3 hours
- Three contractors said that they sometimes use a “rule of thumb” to estimate system size

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- Several contractors described a **general process of visiting the home, collecting measurements, and documenting housing characteristics** to inform equipment selection

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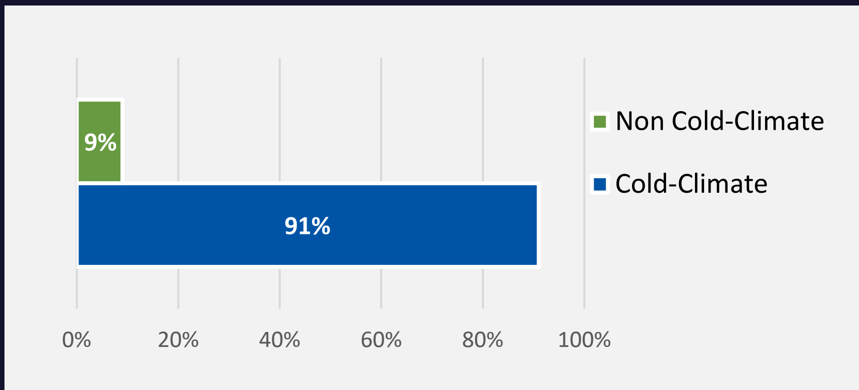
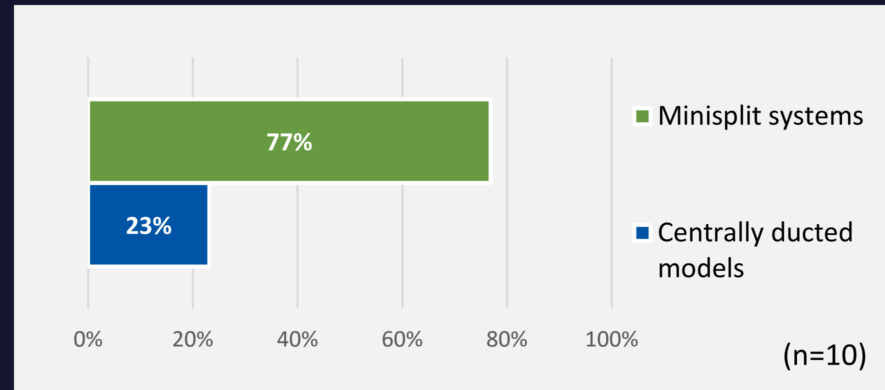
- 4 contractors across MA and NY (out of 19 total) said an estimate may be determined during the walk-through/site visit
- Most contractors said that after the home visit or the sales appointment they run calculations and determine a quote for the customer

1,784 homes,
10 respondents

Percentage of Installations (MA)

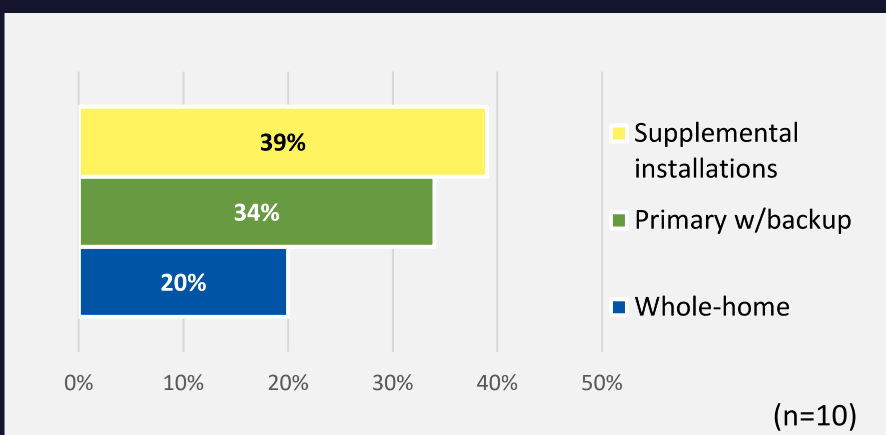
Cold-climate ductless mini-splits are the predominant technology in MA.

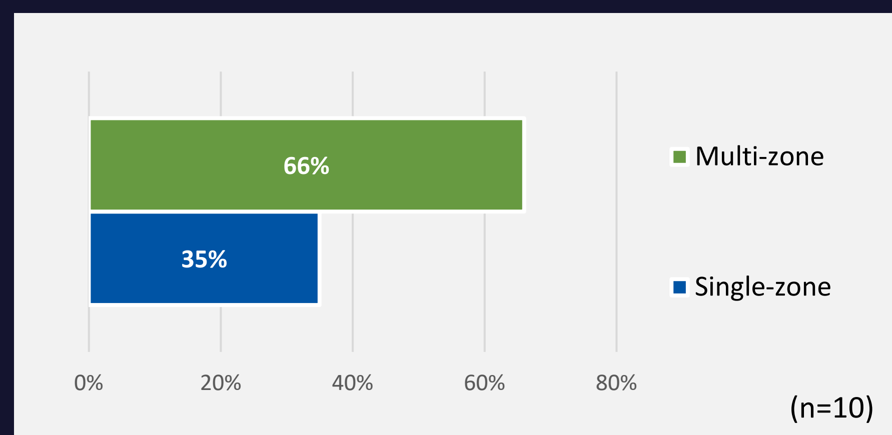




- Most installations were **cold-climate models**
- **Mini-splits were significantly more popular** than central ducted systems

- **Multi-zone systems** accounted for two-thirds of systems
- There was a **fairly even split across supplemental and primary w/backup systems,** but fewer whole-home installations

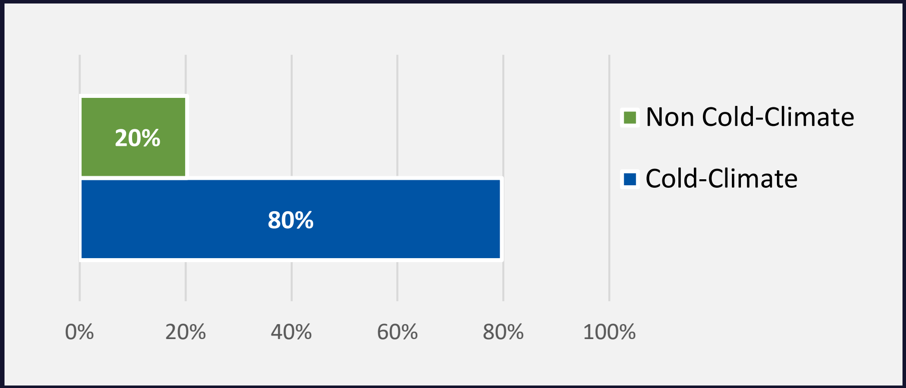


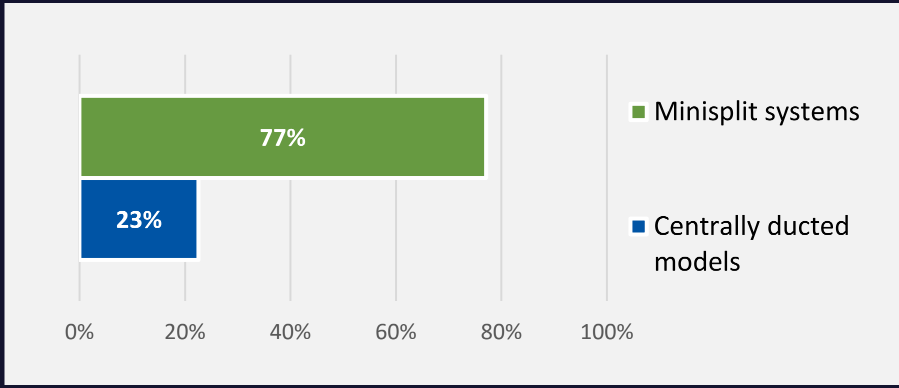


Percentage of Installations (NY)

794 homes,
9 respondents

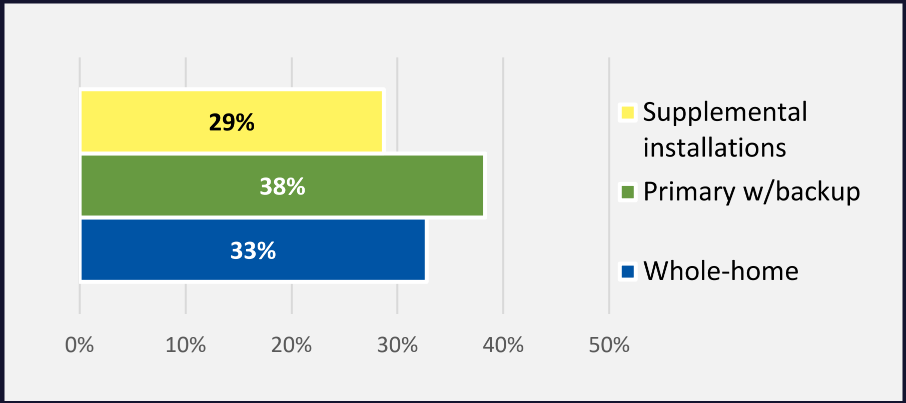
Cold-climate ductless mini-splits are most common in NY too, but whole-home system configurations are more common compared to in MA.

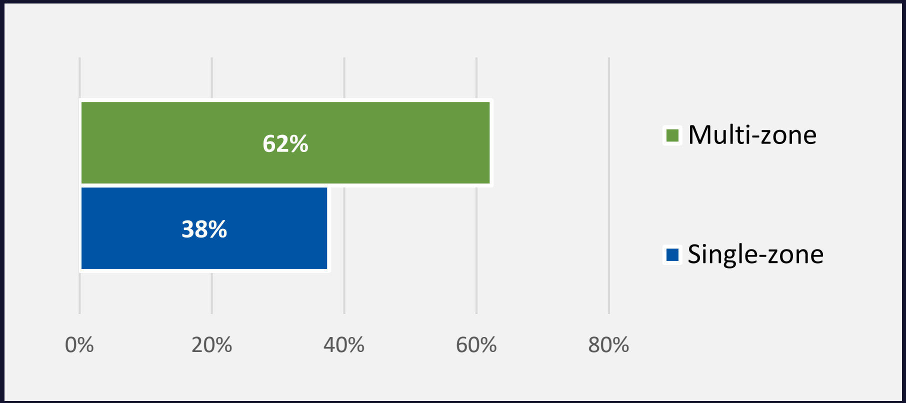




- Most installations were **cold-climate models**
- **Mini-splits were significantly more popular** than central ducted systems (around three-quarters of installations overall)

- **Multi-zone systems** accounted for more than 60% of installations
- There were **more whole-home installations** in NY versus MA





Training and Employee Retention

Contractors pointed to opportunities for improving contractor recruitment and training.

- Overall, contractors found trainings useful:
  - 8 out of 9 MA contractors and 5 out of 6 NY contractors **provided a satisfaction rating of 4-5 for most trainings**, on a scale of 1 (not at all satisfied) to 5 (very satisfied)
- Specific feedback included:
  - **Appreciate technical components**, not “salesy” ones
    - Would like more installation tips, repair and commission guidance, and hands-on trainings
    - Instructors could be more engaging since trainings can start to feel scripted
  - **Appreciate incorporation of different perspectives from installations across New England**
  - Recommend switching timing of trainings from summer to fall
  - Recommend focusing more exclusively on ASHPs

All contractors agreed that it has been difficult to recruit trained, qualified workers, especially since the industry is not attracting young, new talent.

Program Participation

Contractors generally participated in multiple rebate programs

Program	Percent of MA Contractors Participating (n=11)
Mass Save Electric Heating & Cooling Equipment Program	100%
Mass Save Integrated Controls Rebates Program	100%
MassCEC ASHP Program	82%
MassCEC Whole-Home ASHP Pilot Program	45%
Municipal Rebate Programs	45%
DOER Home MVP Pilot Program	9%

Program	Percent of NY Contractors Participating (n=8)
NYSERDA ASHP Program	100%
NYS Clean Heat Program	88%
Other Rebate Programs (individual utility programs prior to incorporation under NYS Clean Heat Program, co-op utility programs, and the HeatSmart Program)	63%

Program Satisfaction and Improvements

Contractors agreed that reducing administrative burdens could help improve the available programs

Massachusetts

Satisfaction

- High satisfaction with Mass Save Heating & Cooling program
- Moderate-high satisfaction with Mass Save Integrated Controls and MassCEC ASHP programs
- Moderate satisfaction with MassCEC Whole-Home ASHP Program

Desired Improvements

- Simplify the rebate application and reduce processing time
- Increase rebate value for higher SEER ASHPs
- Include contractors on advisory boards

New York

Satisfaction

- Lower satisfaction with both NYS Clean Heat and NYSERDA ASHP programs

Desired Improvements

- Simplify the rebate application and reduce processing time
- Modify Manual J requirements (remove requirement for partial load systems, eliminate ACCA compliance requirement)
- Increase rebate values, especially for partial load systems
- Provide more program guidance and trainings for contractors

COVID-19 Impacts

Contractors agreed that there would not be lasting negative impacts on the ASHP industry due to COVID-19, with NY contractors more often reporting that the pandemic had no impacts or, if anything, had positive impacts.

Negative Impacts

- **Contractors reported some delays in projects this spring** due to:
  - Customers not being comfortable with others in their home
  - Financial hardship (job loss)
  - Some contractors temporarily closing shop
  - Some rebate programs pausing
  - Supply chain disruptions

COVID-19 Impacts - Count of Contractors

	Negative	Neutral	Positive	Total
Massachusetts	1	4	3	8
New York	3	1	4	8
Total	**4**	**5**	**7**	**16**

Benefits to the Industry

- However, contractors agreed that the **negative impact to the ASHP industry was not significant and, in some cases, the pandemic increased demand**
  - Customers care about contributing to lower emissions and improved air quality
  - Much of the installation process takes place outside with the outdoor unit
  - With more time spent at home, more people are looking for ASHPs for:
    - A cooling solution during the summer
    - Conditioning an addition or home office

6. Heating Season Metered Data Results

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Heating Data Dictionary

- **Heating Season:** Outdoor air temperatures less than 60°F between October 1, 2020, and May 1, 2021
- **Utility Winter Peak Period:** December, January, and February; 5-7 PM daily
- **Massachusetts 3-Day Cold Snap:** January 29-31st 2021, midnight to midnight
- **Massachusetts 7-hour Cold Snap:** January 31st, 2021, 12 AM to 7 AM
- **New York 3-Day Cold Snap:** February 11-13th 2021, midnight to midnight
- **New York 7-hour Cold Snap:** February 12th, 2021, 12 AM to 7 AM
- **Metered Heating Energy Consumption:** Total ccASHP system energy consumption measured during the heating season, including backup electric resistance where applicable.
- **Metered Other Energy Consumption:** ccASHP system energy consumption measured during the heating season when the measured load is 0 Btu/hr (system is not delivering heating). This includes fan only, defrost, drip pan heater, and controls energy use.
- **Metered ER Energy Consumption:** Backup electric resistance element energy consumption measured during the heating season for ducted systems with integral ER.
- **Metered Average Heating Demand:** Average total system metered demand during the heating season, including intervals when the system is off and ducted system ER and fan demand.
- **Metered Average Heating Operating Demand:** Average total system metered demand during the heating season, including ducted system ER and fan demand but excluding intervals when the system is off.
- **Metered ER Average Operating Demand:** Backup electric resistance element average operating demand measured during the heating season for ducted systems with integral ER, excluding intervals when the ER was not running.
- **Metered 2-min Maximum Heating Demand:** Absolute maximum metered total system demand measured during the heating season during a 2-minute interval, including backup ER and fan demand.
- **Metered Utility Winter Peak Average Demand:** Average total system metered demand during the utility Winter Peak Period, including ER and fan demand and intervals when the system was not running.
- **Metered Hourly Maximum Heating Demand:** Maximum total system demand during the metering period over a one-hour interval (average of 2-minute interval data), including ER and fan demand and intervals when the system was not running.
- **Date and Time of Maximum Heating Demand:** Date and time (EST) that the metered hourly maximum heating demand occurred.
- **Average Total Heating Load:** Measured average delivered heating load during the metering period, excluding intervals when the system was not delivering heat.
- **0-15F Average Heating Load:** Measured average delivered heating load during the metering period when outdoor air temperatures were between 0-15F, including intervals when the system was not delivering heat.
- **Cold Snap Average Heating Load:** Measured average delivered heating load during the 7-hour cold snap period, including intervals when the system was not delivering heat.
- **0-15F Average Heating Load/sq. ft.:** Measured average delivered heating load during the metering period when outdoor air temperatures were between 0-15F, excluding intervals when the system was not delivering heat, divided by the conditioned area of the home.
- **Average Seasonal Heating Performance:** Average system heating performance (delivered load/input power) when the system was delivering heat but excluding intervals when ducted system backup ER was running.
- **Metered Heating Degree Days:** HDD during the metering period for each home (sum of the daily difference between 65F and the average outdoor air temperature).

Massachusetts Heating Season Electric Energy Use

Site ID	Building Type	System Type	Total Conditioned Floor Area, sqft	Other Fuel	Total ASHP System Electric Energy Use, kWh	Total ASHP System Energy per Conditioned Area, kWh/sqft	Approx. Annual ASHP Operation Energy Cost @$0.22/kWh	Metered Other Energy Consumption, kWh[1]	Metered ER[2] Energy Consumption, kWh
MA_01	Primary w/ Backup	Ductless	2,000	Wood	850	0.43	$187	558	
MA_02	Primary w/ Backup	Ductless	2,000	Wood	2,452	1.23	$540	17	
MA_03	Whole-Home	Ductless	1,000	None	3,603	3.60	$793	52	
MA_04	Primary w/ Backup	Ductless	2,200	Propane	734	0.33	$161	231	
MA_05	Primary w/ Backup	Ductless	1,100	ER (baseboard)	3,105	2.82	$683	193	
MA_06	Whole-Home	Ductless	1,600	None	3,994	2.50	$879	145	
MA_07	Whole-Home	Ductless	1,700	Natural gas	7,187	4.23	$1,581	131	
MA_08	Whole-Home	Ductless	3,000	None	11,802	3.93	$2,596	107	
MA_09	Primary w/ Backup	Ductless	2,500	Natural gas	4,965	1.99	$1,092	620	
MA_10	Whole-Home	Ducted	3,100	Natural gas	454	0.15	$100	18	36
MA_11	Primary w/ Backup	Ductless	2,000	Wood	8,110	4.06	$1,784	109	
MA_12	Whole-Home	Ductless	1,360	None	4,857	3.57	$1,069	NULL	
MA_13	Primary w/ Backup	Ductless	2,400	Natural gas	4,327	1.80	$952	893	
MA_14	Primary w/ Backup	Ducted	3,600	Oil	6,244	1.73	$1,374	1,291	
MA_15	Primary w/ Backup	Ductless	2,400	Wood	6,456	2.69	$1,420	380	
MA_16	Primary w/ Backup	Ductless	1,300	Propane	4,954	3.81	$1,090	443	
MA_17	Whole-Home	Ducted	2,000	None	4,945	2.47	$1,088	3,240	1,005
MA_18	Primary w/ Backup	Ductless	900	ER (baseboard)	4,018	4.46	$884	180	
MA_19	Primary w/ Backup	Mixed	1,700	Wood	3,220	1.89	$709	250	
MA_20	Primary w/ Backup	Ductless	2,440	Wood	6,463	2.65	$1,422	871	
MA_21	Whole-Home	Mixed	1,333	None	1,604	1.20	$353	270	
MA_22	Whole-Home	Ducted	1,975	None	2,969	1.50	$653	13	
MA_23	Whole-Home	Ductless	1,300	Propane	2,908	2.24	$640	NULL	
MA_24	Whole-Home	Ductless	1,400	None	2,680	1.91	$590	14	

[1] Other includes defrost, drip pan heater, controls, and other non-heating energy use. Other energy use cannot be broken out for all sites due to missing or incomplete heating load data.
[2] Backup electric resistance heater (two MA sites with ducted systems only)

Massachusetts Heating Season Electric Demand

Site ID	Building Type	System Type	Metered Average Heating Demand, kW	Metered Average Heating Operating Demand, kW	Metered ER Average Operating Demand, kW	Metered 2-min Maximum Heating Demand, kW	Metered Utility Winter Peak Average Demand, kW	Metered Hourly Maximum Heating Demand, kW	Date and Time of Maximum Heating Demand, EST
MA_01	Primary w/ Backup	Ductless	0.18	0.93		3.52	0.06	1.18	12/9/20 08:00 AM
MA_02	Primary w/ Backup	Ductless	0.54	1.06		2.82	0.76	1.80	2/20/21 05:00 AM
MA_03	Whole-Home	Ductless	0.79	0.79		3.38	0.94	2.59	1/31/21 07:00 AM
MA_04	Primary w/ Backup	Ductless	0.16	0.79		4.18	0.35	1.54	1/3/21 07:00 PM
MA_05	Primary w/ Backup	Ductless	0.68	1.07		4.28	0.84	2.83	1/31/21 05:00 AM
MA_06	Whole-Home	Ductless	0.87	1.07		4.50	1.02	2.65	2/12/21 06:00 AM
MA_07	Whole-Home	Ductless	1.61	2.24		6.41	1.87	5.64	1/29/21 07:00 AM
MA_08	Whole-Home	Ductless	2.53	2.70		10.28	3.28	7.35	1/29/21 10:00 AM
MA_09	Primary w/ Backup	Ductless	1.07	1.60		7.61	1.71	4.41	1/29/21 08:00 AM
MA_10	Whole-Home	Ducted	0.47	2.93	7.18	14.03	N/A	N/A	N/A
MA_11	Primary w/ Backup	Ductless	1.77	1.98		6.24	2.11	4.65	1/30/21 05:00 AM
MA_12	Whole-Home	Ductless	1.07	1.33		4.26	1.35	3.61	1/31/21 06:00 AM
MA_13	Primary w/ Backup	Ductless	0.94	1.32		5.25	1.07	4.17	1/30/21 11:00 AM
MA_14	Primary w/ Backup	Ducted	1.39	2.81		13.12	2.24	10.73	1/21/21 06:00 AM
MA_15	Primary w/ Backup	Ductless	1.42	1.66		6.41	1.99	4.69	1/31/21 07:00 AM
MA_16	Primary w/ Backup	Ductless	1.09	1.56		9.15	1.79	5.27	1/30/21 08:00 AM
MA_17	Whole-Home	Ducted	1.13	1.80	5.52	19.32	1.56	7.20	12/19/20 06:00 AM
MA_18	Primary w/ Backup	Ductless	0.88	1.30		2.92	1.07	2.25	12/16/20 08:00 AM
MA_19	Primary w/ Backup	Mixed	0.72	0.95		4.63	0.50	3.03	1/31/21 05:00 AM
MA_20	Primary w/ Backup	Ductless	1.43	1.88		7.08	1.88	5.83	2/20/21 11:00 PM
MA_21	Whole-Home	Mixed	0.80	0.90		3.00	0.97	2.33	1/30/21 05:00 AM
MA_22	Whole-Home	Ducted	1.48	2.96		6.56	2.27	6.17	1/31/21 05:00 AM
MA_23	Whole-Home	Ductless	1.48	1.82		5.49	2.00	4.42	1/31/21 04:00 AM
MA_24	Whole-Home	Ductless	1.90	3.50		4.46	2.75	4.42	2/13/21 05:00 PM

[1] Backup electric resistance heater demand, for two MA sites with ducted systems with ER.

Massachusetts Heating Season Measured Load and Performance

Site ID	Building Type	System Type	NEEP Rated Capacity (5F), Btu/hr	Cadmus Heating Load Estimate, Btu/hr	Contractor Heating Load Estimate, Btu/hr	Cadmus / Contractor Heat Load Estimate, %	0-15F Average Heating Load, Btu/hr	Cold Snap[1] Average Heating Load, Btu/hr	Average Seasonal Heating Performance, COP	Metered Heating Degree Days
MA_01	Primary w/ Backup	Ductless	51,407	63,016			0	0	0.45	326,384
MA_02	Primary w/ Backup	Ductless	25,500	49,624			19,372	0	3.20	379,801
MA_03	Whole-Home	Ductless	21,900	45,601			12,743	10,392	3.45	234,633
MA_04	Primary w/ Backup	Ductless	46,900	72,802			9,631	0	3.35	360,596
MA_05	Primary w/ Backup	Ductless	36,407	47,572			9,839	14,670	1.32	360,418
MA_06	Whole-Home	Ductless	45,000	51,923			10,865	11,975	3.50	342,124
MA_07	Whole-Home	Ductless	48,000	46,191	41,239	112%	25,691	28,729	2.24	334,510
MA_08	Whole-Home	Ductless	57,200	58,686	44,842	131%	36,628	36,266	3.57	334,510
MA_09	Primary w/ Backup	Ductless	61,907	88,221			12,204	9,674	1.61	334,510
MA_10	Whole-Home	Ducted	30,100	68,631	38,406	179%	N/A	N/A	3.01	53,563
MA_11	Primary w/ Backup	Ductless	45,300	51,183			23,569	24,727	2.77	310,416
MA_12	Whole-Home	Ductless	28,600	34,066			N/A	N/A	N/A	360,596
MA_13	Primary w/ Backup	Ductless	45,000	100,216			6,612	0	1.50	360,418
MA_14	Primary w/ Backup	Ducted	76,000	98,511			19,584	2,121	1.67	334,510
MA_15	Primary w/ Backup	Ductless	48,000	53,241			10,500	8,810	1.29	253,576
MA_16	Primary w/ Backup	Ductless	65,300	52,269			14,466	15,309	2.67	234,348
MA_17	Whole-Home	Ducted	39,600	70,069	43,753	160%	11,139	23,266	0.28	330,461
MA_18	Primary w/ Backup	Ductless	20,300	44,237			12,761	0	3.29	332,736
MA_19	Primary w/ Backup	Mixed	47,500	35,048			15,745	20,179	2.55	321,763
MA_20	Primary w/ Backup	Ductless	75,667	49,504	66,478	74%	15,821	9,538	1.81	325,315
MA_21	Whole-Home	Mixed	28,100	28,932			6,821	3,755	2.15	138,925
MA_22	Whole-Home	Ducted	45,000	68,324			27,069	27,328	2.29	131,371
MA_23	Whole-Home	Ductless	48,900	43,195			N/A	N/A	N/A	143,406
MA_24	Whole-Home	Ductless	39,956	134,373			15,991	N/A	1.01	96,358

[1] Cold snap defined as 12 AM to 7 AM on January 31st (MA sites) and February 12th (NY sites). The average cold snap temperature for MA sites was 4.3°F and the average cold snap temperature for NY sites was 8.3°F.

New York Heating Season Electric Energy Use

Site ID	Building Type	System Type	Total Conditioned Floor Area, sqft	Other Fuel	Total ASHP System Electric Energy Use, kWh	Total ASHP System Energy per Conditioned Area, kWh/sqft	Approx. Annual ASHP Operation Energy Cost @$0.22/kWh	Metered Other Energy Consumption, kWh[1]	Metered ER[2] Energy Consumption, kWh
NY_01	Whole-Home	Mixed	2,500	ER (baseboard)	10,113	4.05	$2,225	460	929
NY_02	Whole-Home	Ductless	2,100	None	5,105	2.43	$1,123	848	
NY_03	Primary w/ Backup	Ducted	2,800	Natural gas	1,722	0.61	$379	65	
NY_04	Primary w/ Backup	Ductless	2,700	ER (baseboard)	8,955	3.32	$1,970	64	
NY_05	Whole-Home	Ductless	2,100	None	6,920	3.30	$1,523	131	
NY_06	Whole-Home	Mixed	2,500	Wood	11,595	4.64	$2,551	499	
NY_07	Whole-Home	Mixed	1,500	Natural gas	6,524	4.35	$1,435	361	
NY_08	Whole-Home	Ductless	1,800	None	4,635	2.58	$1,020	103	
NY_09	Primary w/ Backup	Ductless	1,300	Natural gas	3,610	2.78	$794	289	
NY_10	Primary w/ Backup	Ducted	3,200	Oil	7,268	2.27	$1,599	238	
NY_11	Whole-Home	Ducted	1,380	None	2,783	2.02	$612	144	74
NY_12	Primary w/ Backup	Ductless	3,000	Natural gas	10,752	3.58	$2,366	103	
NY_13	Whole-Home	Ductless	2,000	None	5,413	2.71	$1,191	69	
NY_14	Primary w/ Backup	Ducted	1,800	Natural gas	2,169	1.21	$477	170	
NY_15	Whole-Home	Ducted	1,440	Wood	3,693	2.56	$812	142	
NY_16	Whole-Home	Ductless	1,600	Wood	3,441	2.15	$757	20	
NY_17	Primary w/ Backup	Ducted	2,000	Wood	2,124	1.06	$467	79	886
NY_18	Whole-Home	Ducted	1,800	None	2,102	1.17	$462	84	
NY_19	Whole-Home	Ductless	1,500	Wood	6,007	4.00	$1,322	N/A	

[1] Other includes defrost, drip pan heater, controls, and other non-heating energy use. Other energy use cannot be broken out for all sites due to missing or incomplete heating load data.
[2] Backup electric resistance heater energy consumption, for three NY sites with ducted systems with ER.

New York Heating Season Electric Demand

Site ID	Building Type	System Type	Metered Average Heating Demand, kW	Metered Average Heating Operating Demand, kW	Metered ER[1] Average Operating Demand, kW	Metered 2-min Maximum Heating Demand, kW	Metered Utility Winter Peak Average Demand, kW	Metered Hourly Maximum Heating Demand, kW	Date and Time of Maximum Heating Demand, EST
NY_01	Whole-Home	Mixed	2.60	3.11	6.55	17.40	3.09	12.60	2/8/21 06:00 AM
NY_02	Whole-Home	Ductless	1.31	1.47		4.39	1.48	3.00	1/29/21 08:00 AM
NY_03	Primary w/ Backup	Ducted	0.43	0.98		3.19	0.57	2.69	12/19/20 08:00 PM
NY_04	Primary w/ Backup	Ductless	2.31	2.36		6.82	2.72	5.05	12/19/20 02:00 AM
NY_05	Whole-Home	Ductless	1.83	1.96		6.60	2.13	4.84	2/12/21 06:00 AM
NY_06	Whole-Home	Mixed	2.97	3.00		10.54	3.56	8.90	1/29/21 01:00 AM
NY_07	Whole-Home	Mixed	1.72	2.03		7.95	1.80	6.29	1/30/21 08:00 AM
NY_08	Whole-Home	Ductless	1.22	1.32		4.68	1.50	3.65	12/19/20 08:00 AM
NY_09	Primary w/ Backup	Ductless	1.06	1.29		6.45	1.16	3.67	1/29/21 08:00 PM
NY_10	Primary w/ Backup	Ducted	2.15	2.56		9.25	2.52	7.68	2/13/21 06:00 AM
NY_11	Whole-Home	Ducted	0.83	1.91	4.83	15.87	0.71	7.32	1/24/21 08:00 PM
NY_12	Primary w/ Backup	Ductless	3.11	3.12		7.91	3.49	6.31	1/25/21 06:00 AM
NY_13	Whole-Home	Ductless	1.65	1.72		6.26	1.81	4.04	1/29/21 08:00 AM
NY_14	Primary w/ Backup	Ducted	0.68	2.83		5.07	0.73	3.94	1/12/21 01:00 PM
NY_15	Whole-Home	Ducted	1.10	1.23		8.42	0.95	7.89	1/29/21 05:00 AM
NY_16	Whole-Home	Ductless	1.23	1.39		3.90	1.48	3.06	2/8/21 07:00 AM
NY_17	Primary w/ Backup	Ducted	0.61	5.76	5.69	14.91	2.36	7.81	2/11/21 06:00 PM
NY_18	Whole-Home	Ducted	0.78	1.83		8.38	0.73	8.01	2/11/21 03:00 AM
NY_19	Whole-Home	Ductless	2.16	2.69		7.14	2.79	4.17	1/29/21 07:00 AM

[1] Backup electric resistance heater demand, for three NY sites with ducted systems with ER.

New York Heating Season Measured Load and Performance

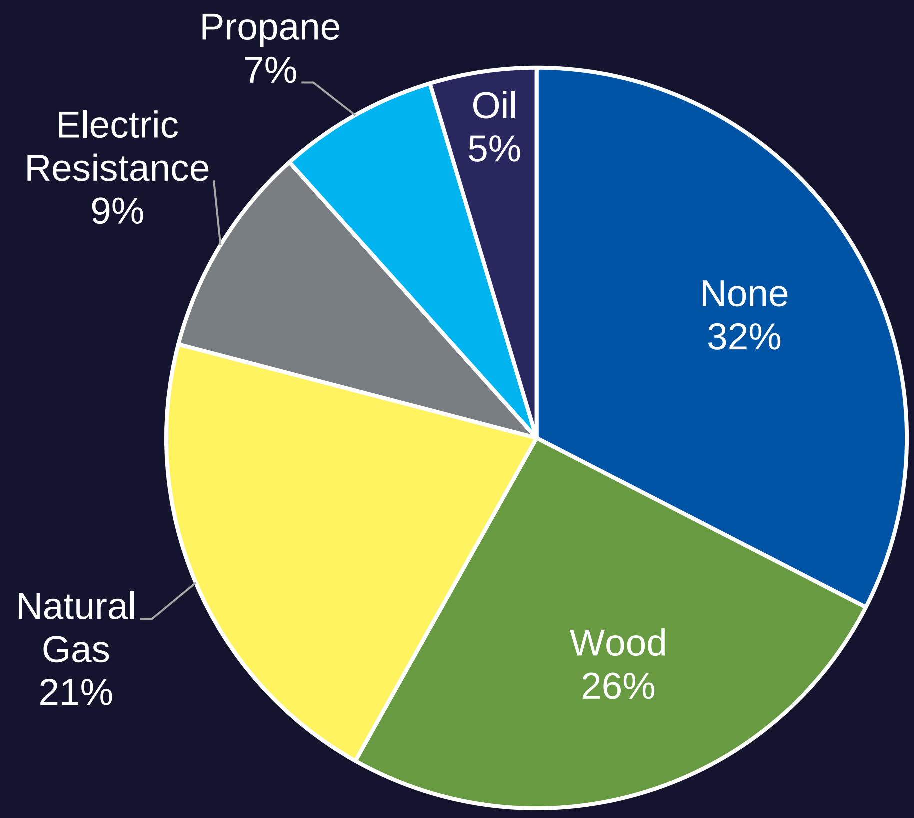
Site ID	Building Type	System Type	NEEP Rated Capacity (5F), Btu/hr	Cadmus Heating Load Estimate, Btu/hr	Contractor Heating Load Estimate, Btu/hr	Cadmus / Contractor Heat Load Estimate, %	0-15F Average Heating Load, Btu/hr	Cold Snap[1] Average Heating Load, Btu/hr	Average Seasonal Heating Performance, COP	Metered Heating Degree Days
NY_01	Whole-Home	Mixed	54,000	73,275	56,377	130%	19,092	16,201	1.49	338,352
NY_02	Whole-Home	Ductless	50,000	30,645	36,776	83%	12,403	13,120	1.51	348,416
NY_03	Primary w/ Backup	Ducted	26,340	34,656			6,295	0	4.32	228,127
NY_04	Primary w/ Backup	Ductless	70,200	83,037			32,977	33,435	3.16	213,272
NY_05	Whole-Home	Ductless	47,000	53,112	47,614	112%	27,539	23,336	3.10	319,680
NY_06	Whole-Home	Mixed	81,840	88,294	57,948	152%	28,992	29,732	1.84	346,786
NY_07	Whole-Home	Mixed	51,600	33,802			21,151	19,942	2.00	317,305
NY_08	Whole-Home	Ductless	45,400	36,756			27,815	22,505	3.22	333,155
NY_09	Primary w/ Backup	Ductless	50,600	29,439			17,229	18,507	1.83	163,000
NY_10	Primary w/ Backup	Ducted	63,870	97,469	84,427	115%	38,185	43,973	3.38	285,922
NY_11	Whole-Home	Ducted	38,000	28,804	34,849	83%	17,708	16,487	1.60	285,635
NY_12	Primary w/ Backup	Ductless	57,200	81,432	59,589	137%	28,648	20,492	3.02	201,816
NY_13	Whole-Home	Ductless	48,000	28,712			24,856	19,568	2.99	283,386
NY_14	Primary w/ Backup	Ducted	30,100	54,230	59,886	91%	11,207	7,640	1.93	209,499
NY_15	Whole-Home	Ducted	48,000	48,346	41,838	116%	11,883	12,423	2.65	288,520
NY_16	Whole-Home	Ductless	28,600	36,140	27,445	132%	22,835	21,995	3.46	158,353
NY_17	Primary w/ Backup	Ducted	34,000	55,778	50,305	111%	27,426	13,903	0.99	150,792
NY_18	Whole-Home	Ducted	48,000	64,694	42,583	152%	26,792	19,528	2.32	147,813
NY_19	Whole-Home	Ductless	67,000	49,024	50,571	97%	N/A	N/A	N/A	156,604

[1] Cold snap defined as 12 AM to 7 AM on January 31st (MA sites) and February 12th (NY sites). The average cold snap temperature for MA sites was 4.3°F and the average cold snap temperature for NY sites was 8.3°F.

Primary Backup Fuel Types at Metered Sites

Of the 43 participating sites, 14 had no source of backup heat (or did not use the backup heating equipment during the metering period). **Wood-based heating systems** (fireplaces, pellet stoves, wood stoves) were the most common backup fuel system followed by **natural gas-fired** furnaces and boilers.

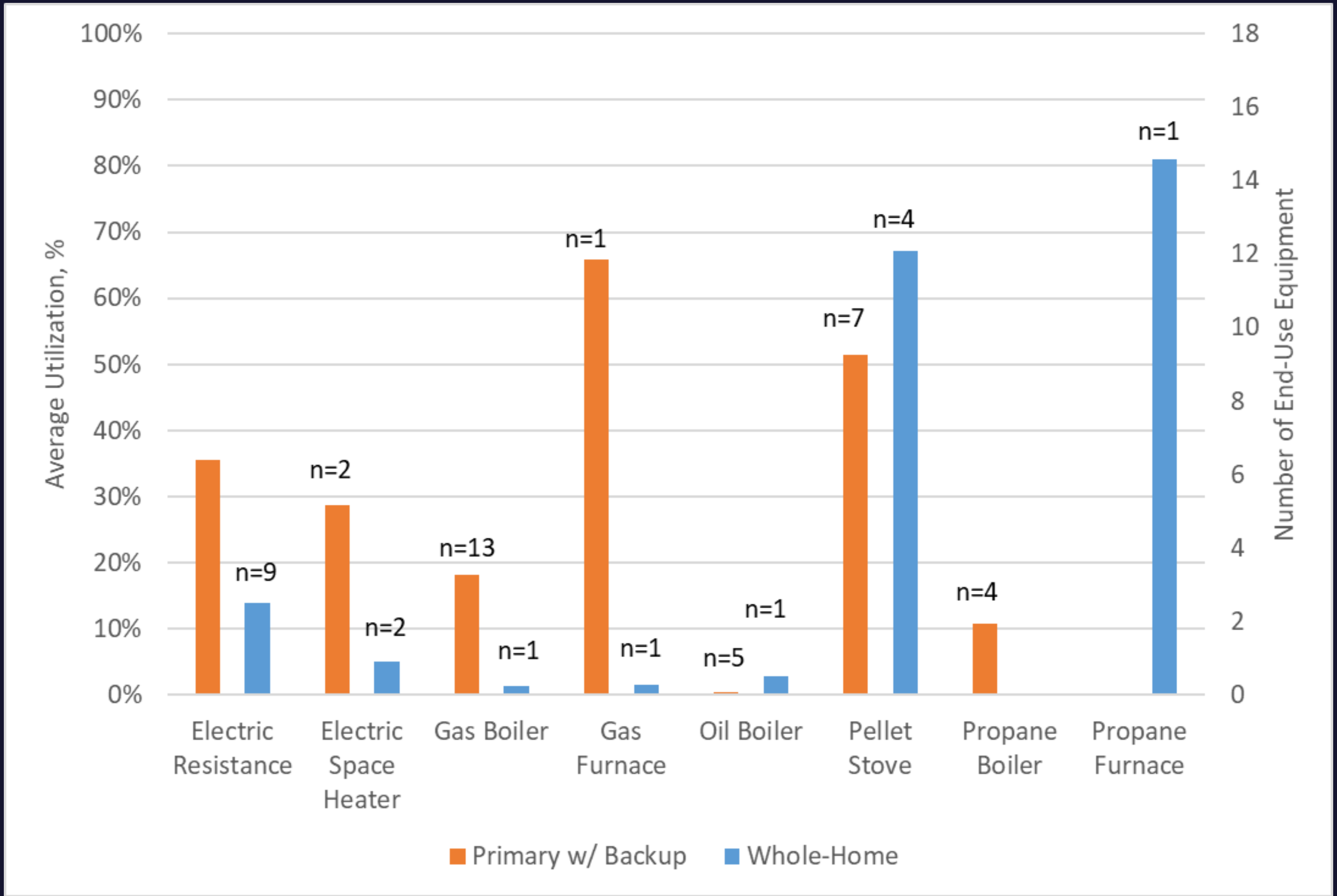
Backup Fuel	Number of Sites	Percent of Total
None	14	33%
Wood	11	26%
Natural Gas	9	21%
Electric Resistance	4	9%
Propane	3	7%
Oil	2	5%
Total	**43**	**100%**



Backup Fuel System Usage

Primary w/ Backup: collected data for **50 individual end-use equipment at 16 sites** with 28.1% average utilization during the metering period.

Whole-Home: collected data for **20 end-use equipment at 11 sites** with 24.7% average utilization.



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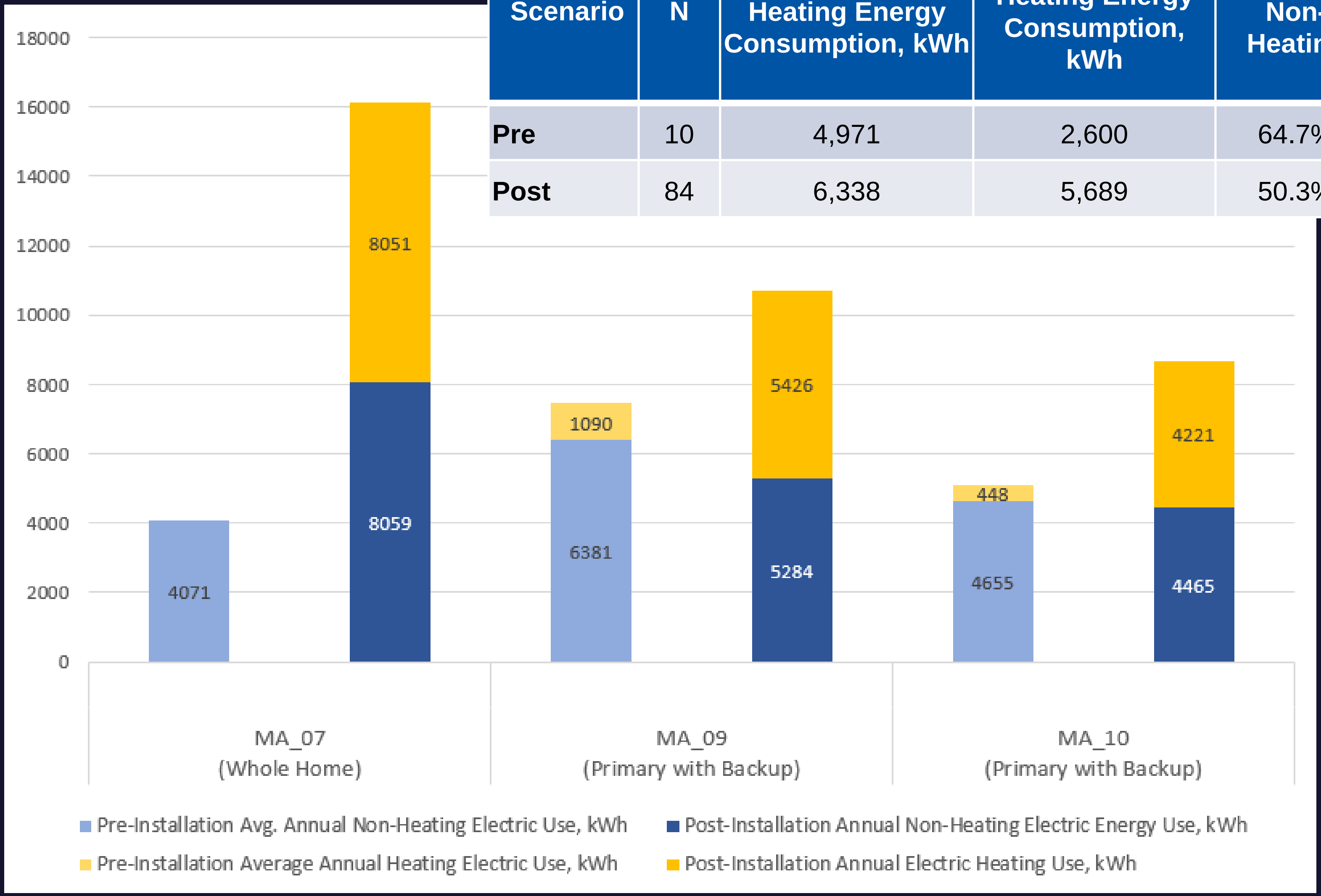
7. Heating Season Utility Bill Analysis

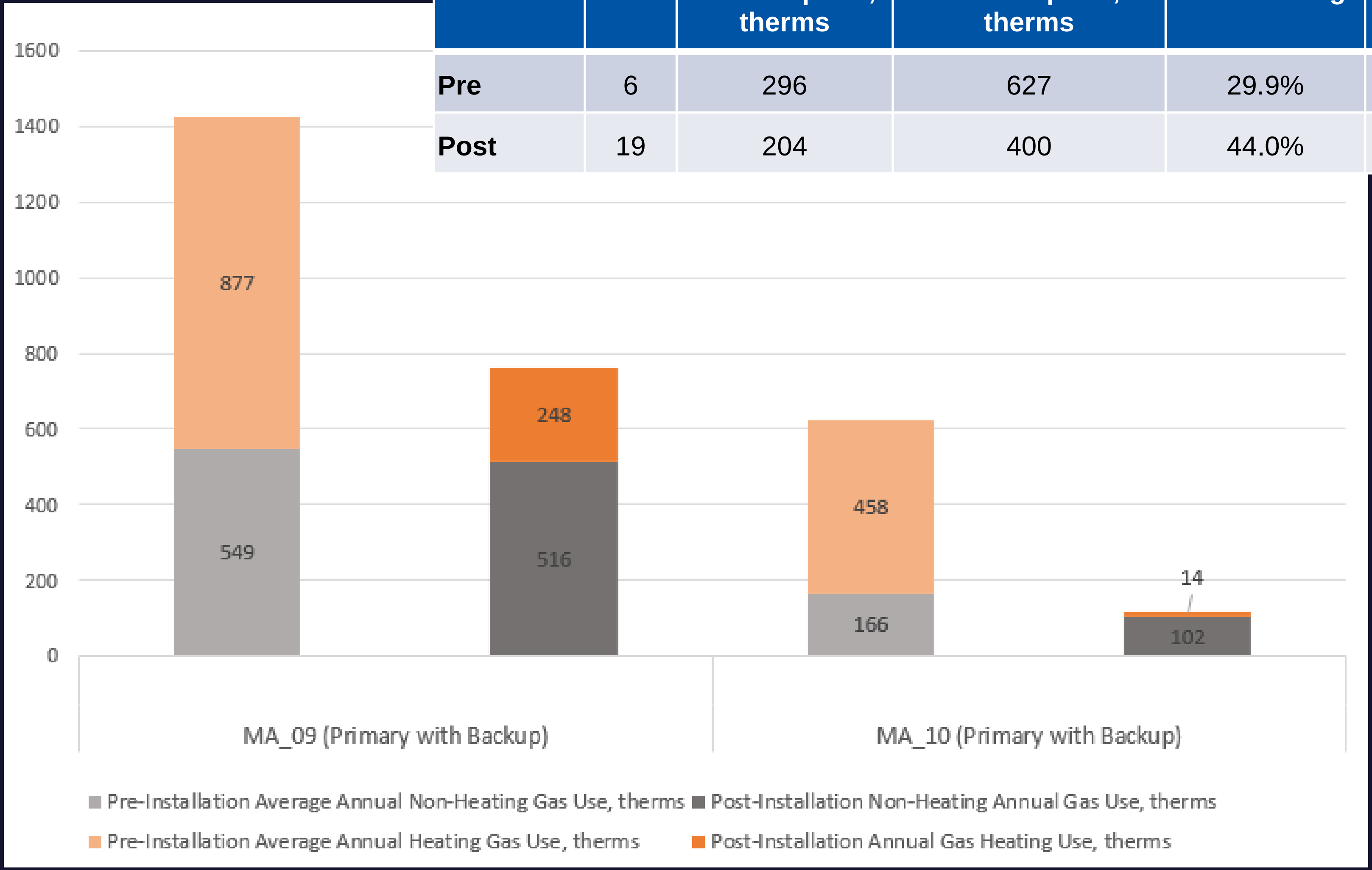
Utility Bill Analysis: Electric Energy Consumption

Scenario	N	Average Non-Heating Energy Consumption, kWh	Average Actual Heating Energy Consumption, kWh	Average % Non-Heating	Average % Heating
Pre	10	4,971	2,600	64.7%	17.3%
Post	84	6,338	5,689	50.3%	41.8%



Utility Bill Analysis: Natural Gas Consumption

Scenario	N	Average Non-Heating Gas Consumption, therms	Average Actual Heating Gas Consumption, therms	Average % Non-Heating	Average % Heating
Pre	6	296	627	29.9%	70.1%
Post	19	204	400	44.0%	56.0%



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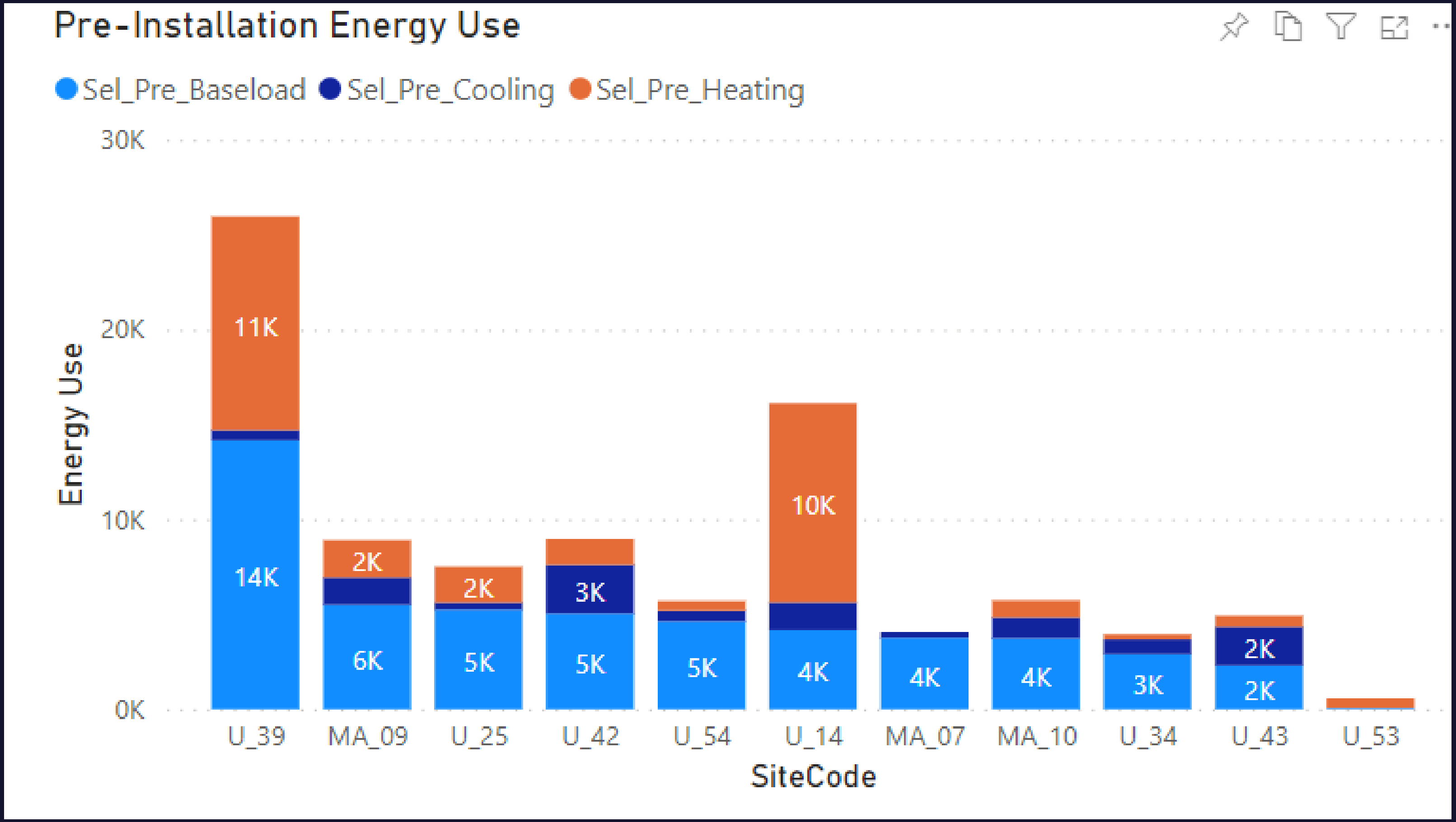
Utility Bill Analysis: Pre-Installation Electric Energy Consumption[1]



[1] Only 11 utility data participants (including 8 non-metering sites, indicated with “U_XX”) provided pre-installation electric energy bill data.

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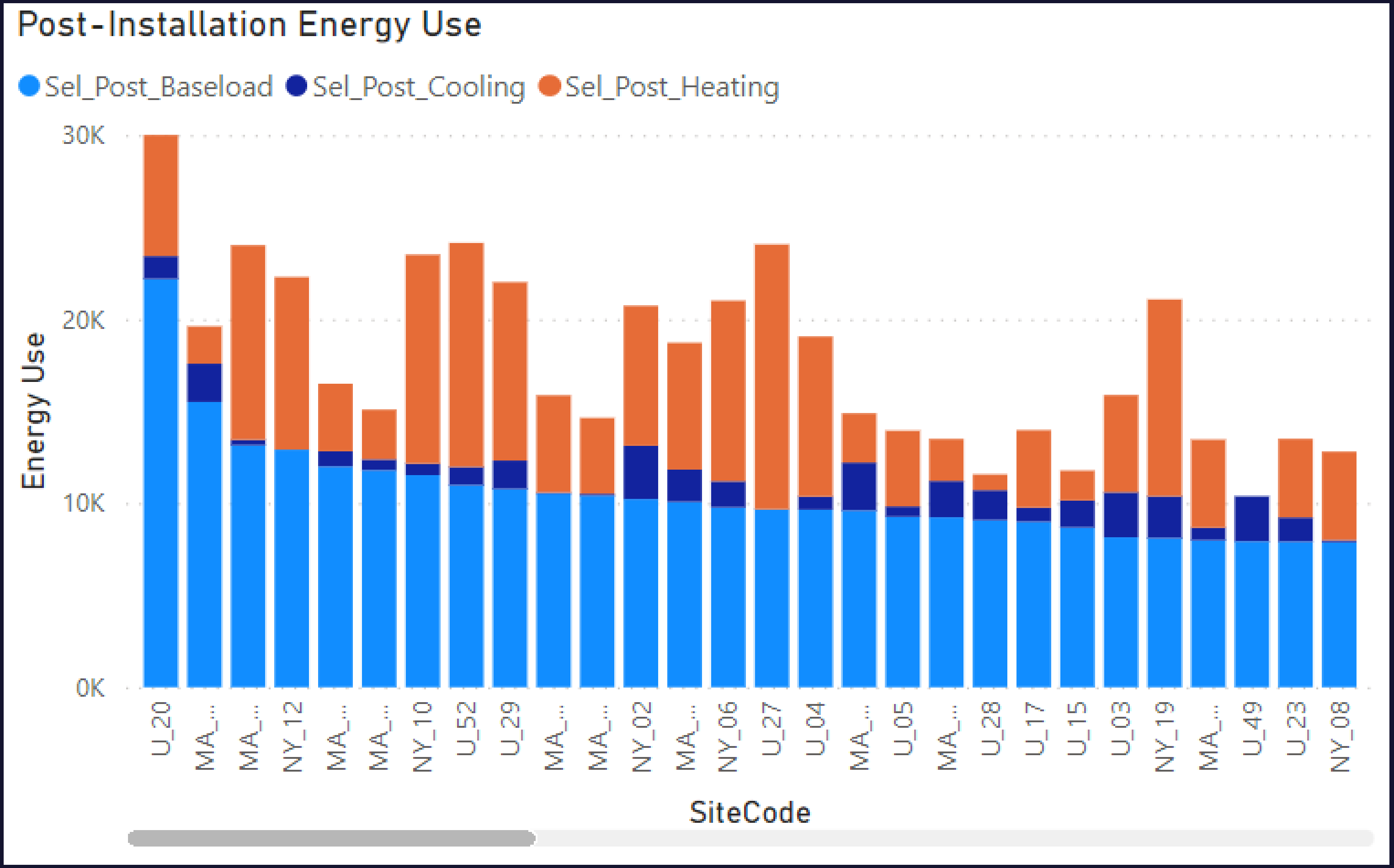
Utility Bill Analysis: Post-Installation Electric Energy Consumption



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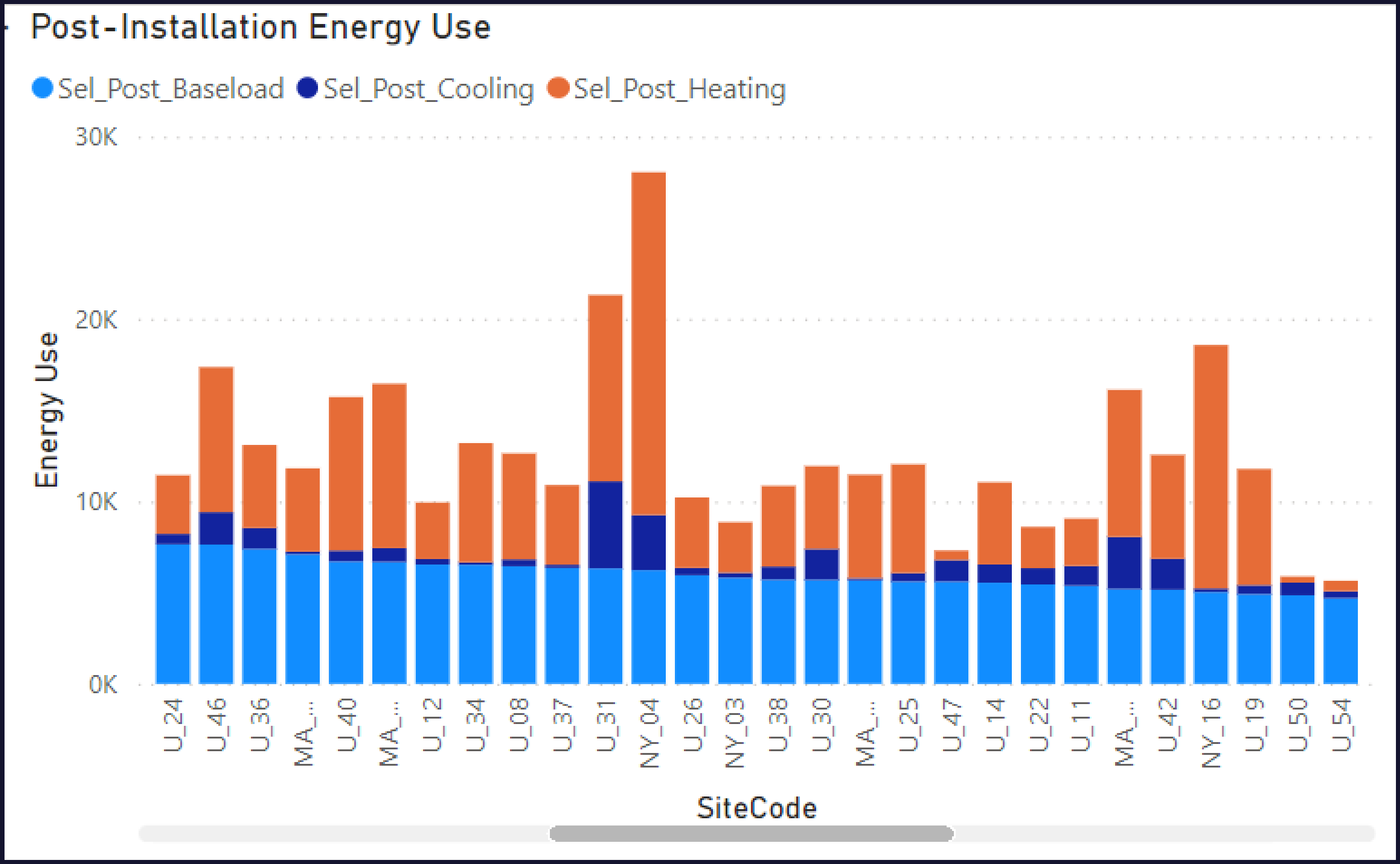
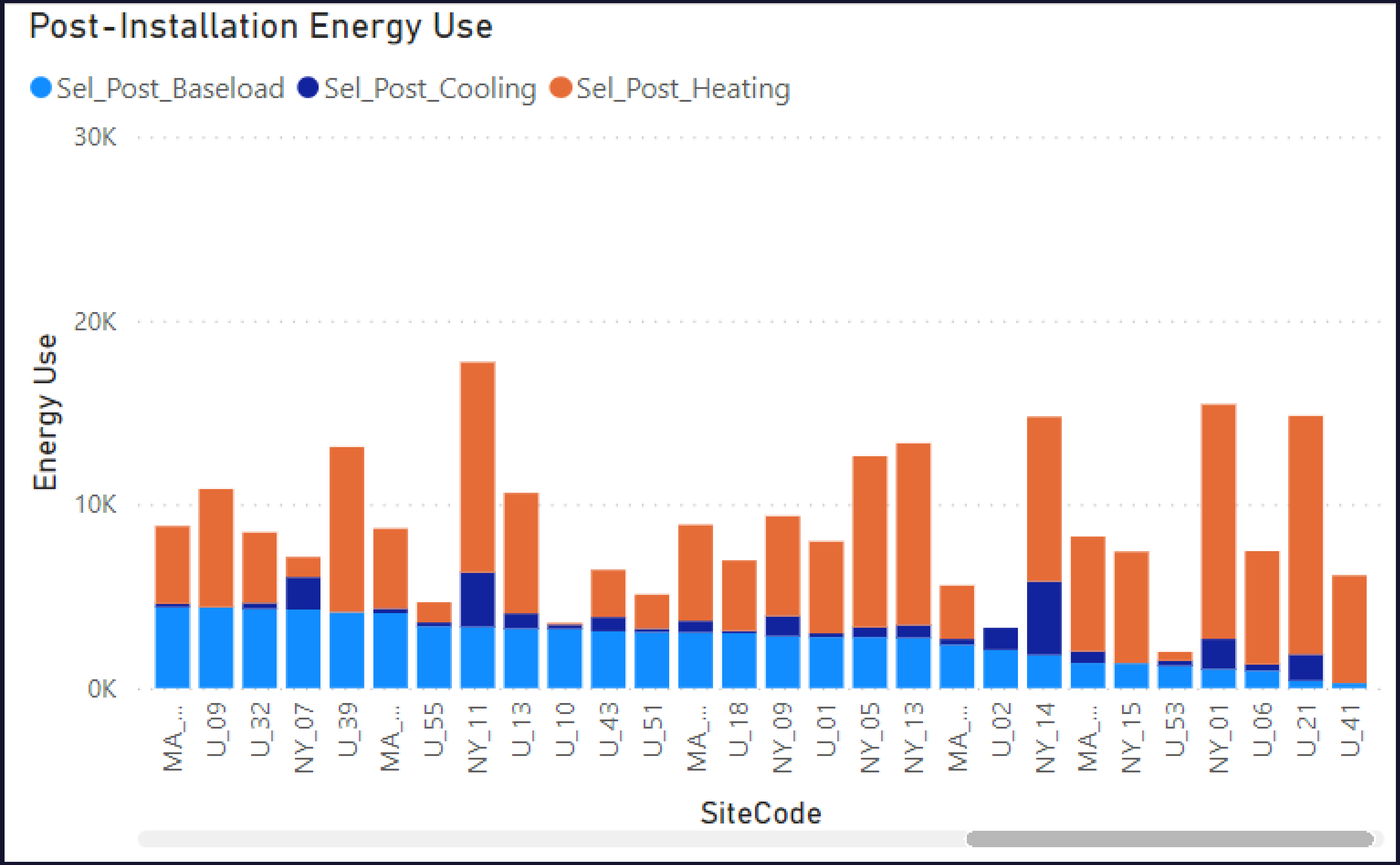
Utility Bill Analysis: Post-Installation Electric Energy Consumption



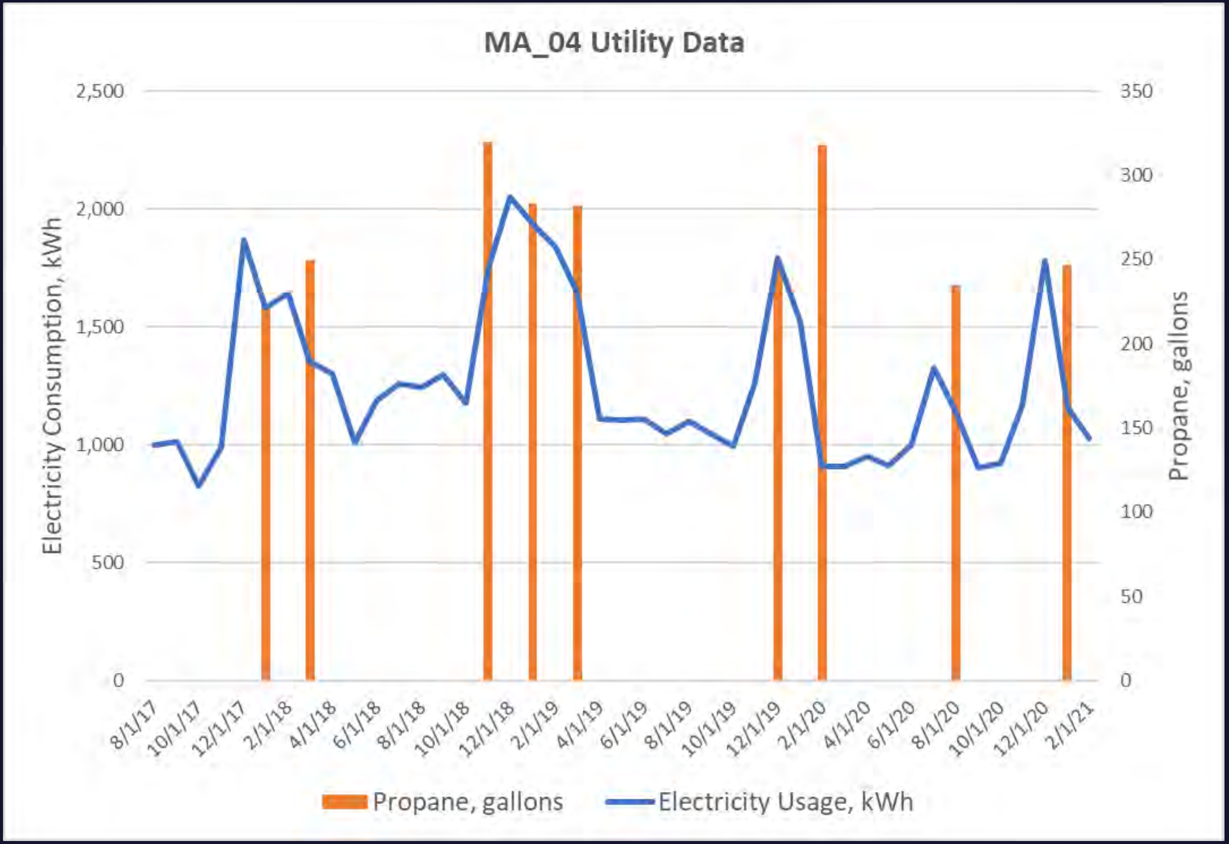
Utility Bill Analysis: Post-Installation Electric Energy Consumption



Site MA_04

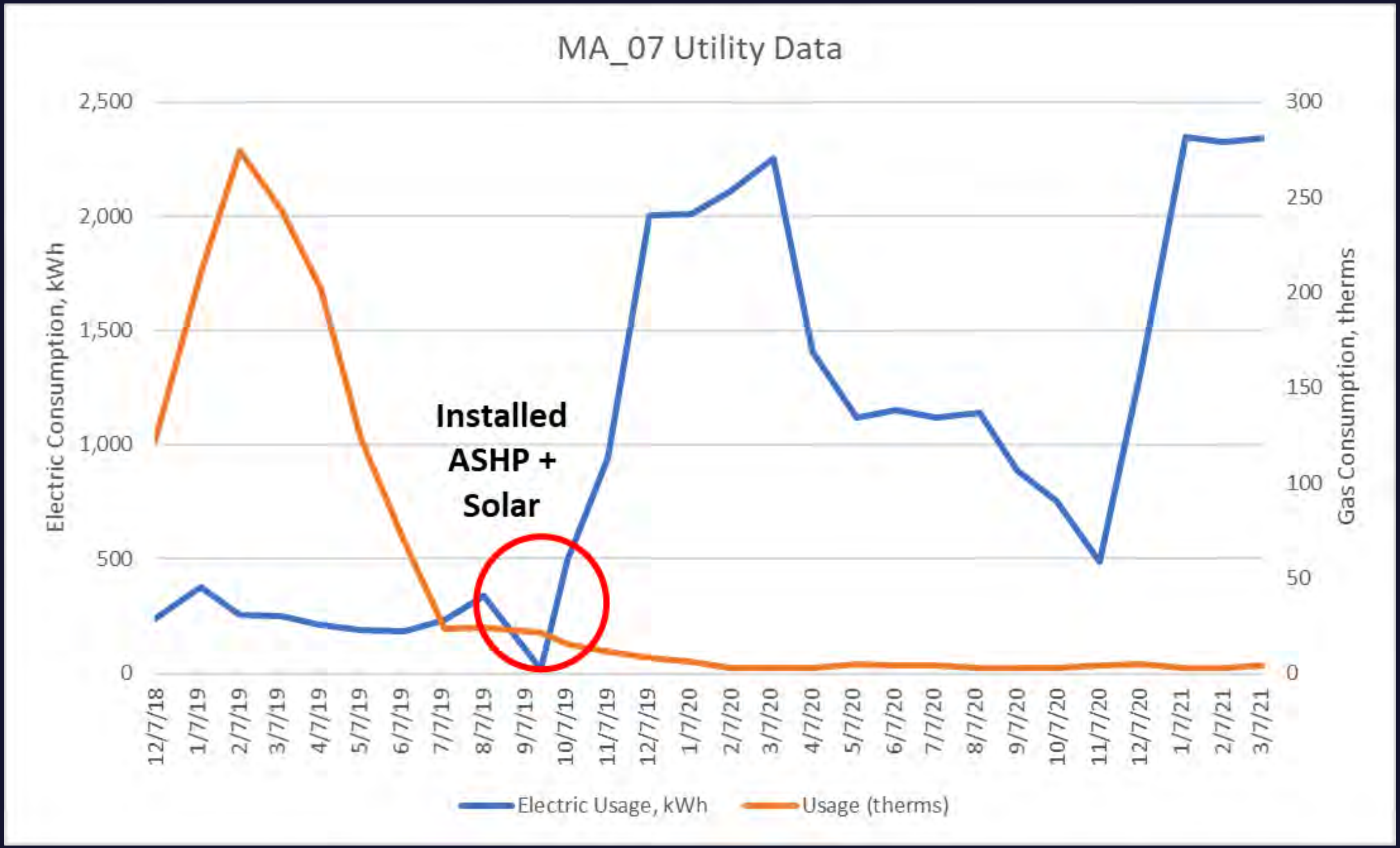
- ASHP system installed in 2016
- Onsite solar PV system (reflected in total consumption below)
- Propane boiler serves four space heating zones and DHW
  - Typically use ~900 gallons per year
  - **Use propane boiler when OAT <25-30 F**

Meter Installation Notes:
Site uses propane boiler at low OATs because <u>site contact heard that ASHP units are inefficient at low temperatures</u>. After discussion, site may try to utilize them more for heating this winter.



Site MA_07

- **Category:** Whole Home
- **ASHP System:** Ductless, one multizone outdoor unit and five indoor heads
- **Backup:** None



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8. Cooling Season Metered Data Results

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Cooling Data Dictionary

- **Cooling Season:** Outdoor air temperatures greater than 70°F between May 1, 2021 and October 1, 2021.
- **Utility Summer Peak Period:** June, July, and August; 1-5 PM daily
- **Metered Cooling Energy Consumption:** Total ccASHP system energy consumption measured during the cooling season.
- **Metered Average Cooling Demand:** Average total system metered demand during the cooling season, including intervals when the system was off.
- **Metered Average Cooling Operating Demand:** Average total system metered demand during the cooling season, excluding intervals when the system was off.
- **Metered 2-min Maximum Cooling Demand:** Absolute maximum metered demand during the cooling season during a 2-minute interval.
- **Metered Utility Summer Peak Average Demand:** Average total system metered demand during the utility Summer Peak Period, including intervals when the system was off.
- **Metered Hourly Maximum Cooling Demand:** Maximum total system demand during the metering period over a one-hour interval (average of 2-minute interval data), including intervals when the system was not running.
- **Date and Time of Maximum Cooling Demand:** Date and time (EST) that the metered hourly maximum cooling demand occurred.
- **Metered Cooling Degree Days:** CDD during the metering period for each home (sum of the daily difference between the average outdoor air temperature and 65F).

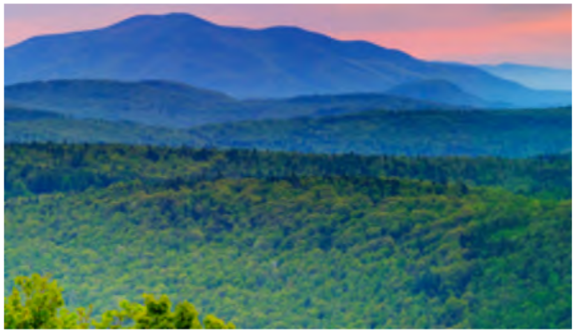
Massachusetts Cooling Season Metered Data

Site ID	Building Type	System Type	Total Conditioned Floor Area, sq. ft.	Total System Electric Energy Use, kWh	Approximate Annual ASHP Operation Energy Cost @$0.22/kWh	Average Total Power, kW	Average Total ASHP Operating Power, kW	Peak Demand During Utility Peak Period, kW	Maximum Hourly Average Demand, kW	Date & Time (EST) of Max Hourly Demand	Cooling Degree Days
MA_01	Primary w/ Backup	Ductless	2,000	569	$125	0.74	2.314	0.92	7.215	8/26/21 3 PM	67,001
MA_02	Primary w/ Backup	Ductless	2,000	189	$42	0.12	0.509	0.13	1.152	8/25/21 5 PM	57,659
MA_03	Whole-Home	Ductless	1,000	127	$28	0.08	0.174	0.10	0.663	6/25/21 12 PM	45,949
MA_04	Primary w/ Backup	Ductless	2,200	231	$51	0.14	0.793	0.24	2.484	6/29/21 5 PM	64,444
MA_05	Primary w/ Backup	Ductless	1,100	402	$88	0.25	0.504	0.29	0.908	8/12/21 12 PM	64,722
MA_06	Whole-Home	Ductless	1,600	183	$40	0.12	0.393	0.19	1.404	6/6/21 8 PM	64,340
MA_07	Whole-Home	Ductless	1,700	550	$121	0.31	1.023	0.51	2.913	8/11/21 1 PM	68,113
MA_08	Whole-Home	Ductless	3,000	2,330	$513	0.67	0.855	0.73	1.878	6/8/21 2 PM	68,113
MA_09	Primary w/ Backup	Ductless	2,500	177	$39	0.11	0.721	0.17	3.107	8/26/21 9 PM	68,113
MA_10	Whole-Home	Ducted	3,100	96	$21	0.06	1.54	0.03	2.068	8/13/21 11 PM	68,113
MA_11	Primary w/ Backup	Ductless	2,000	765	$168	0.52	0.717	0.58	1.524	7/16/21 5 PM	57,739
MA_12	Whole-Home	Ductless	1,360	194	$43	0.12	0.654	0.15	1.049	8/21/21 7 PM	64,444
MA_13	Primary w/ Backup	Ductless	2,400	916	$201	0.56	0.921	0.63	2.205	8/12/21 5 PM	64,722
MA_14	Primary w/ Backup	Ducted	3,600	178	$39	0.32	1.392	0.37	3.175	6/7/21 5 PM	23,312
MA_15	Primary w/ Backup	Ductless	2,400	183	$40	0.11	0.898	0.08	2.137	8/13/21 12 AM	38,887
MA_16	Primary w/ Backup	Ductless	1,300	718	$158	0.44	1.259	0.62	3.213	8/25/21 7 PM	45,949
MA_17	Whole-Home	Ducted	2,000	125	$28	0.07	0.852	0.13	1.64	6/30/21 1 PM	68,113
MA_18	Primary w/ Backup	Ductless	900	257	$57	0.16	0.385	0.16	0.996	6/19/21 3 PM	73,636
MA_19	Primary w/ Backup	Mixed	1,700	175	$39	0.11	0.518	0.17	1.655	7/7/21 5 PM	67,001
MA_20	Primary w/ Backup	Ductless	2,440	644	$142	0.34	0.678	0.50	2.049	6/9/21 3 PM	73,610
MA_21	Whole-Home	Mixed	1,333	340	$75	0.19	0.325	0.31	1.134	6/29/21 3 PM	68,113
MA_22	Whole-Home	Ducted	1,975	1,013	$223	0.66	1.195	1.05	4.589	6/30/21 5 PM	70,929
MA_23	Whole-Home	Ductless	1,300	193	$43	0.11	0.906	0.19	3.281	6/30/21 1 PM	63,749
MA_24	Whole-Home	Ductless	1,400	1,704	$375	1.08	2.695	1.09	3.726	8/24/21 11 PM	63,436

New York Cooling Season Metered Data

Site ID	Building Type	System Type	Total Conditioned Floor Area, sqft	Total System Electric Energy Use, kWh	Approximate Annual ASHP Operation Energy Cost @$0.22/kWh	Average Total Power, kW	Average Total ASHP Operating Power, kW	Peak Demand During Utility Peak Period, kW	Maximum Hourly Average Demand, kW	Date & Time (EST) of Max Hourly Demand	Cooling Degree Days
NY_01	Whole-Home	Mixed	2,500	101	$22	0.19	1.895	0.27	4.650	6/26/21 9 PM	18,963
NY_02	Whole-Home	Ductless	2,100	958	$211	0.52	0.59	0.59	0.687	6/5/21 5 PM	53,154
NY_03	Primary w/ Backup	Ducted	2,800	454	$100	0.57	0.949	0.74	1.909	6/27/21 5 PM	28,921
NY_04	Primary w/ Backup	Ductless	2,700	865	$190	0.60	1.077	0.62	3.189	6/21/21 8 PM	43,149
NY_05	Whole-Home	Ductless	2,100	230	$51	0.07	0.515	0.11	1.093	6/28/21 2 PM	58,353
NY_06	Whole-Home	Mixed	2,500	234	$51	0.21	0.96	0.17	3.838	6/26/21 9 PM	48,208
NY_07	Whole-Home	Mixed	1,500	876	$193	0.50	0.722	0.70	3.202	6/19/21 4 PM	63,353
NY_08	Whole-Home	Ductless	1,800	363	$80	0.21	0.344	0.28	1.407	8/10/21 9 PM	51,971
NY_09	Primary w/ Backup	Ductless	1,300	613	$135	0.28	0.733	0.40	2.191	8/13/21 4 PM	56,646
NY_10	Primary w/ Backup	Ducted	3,200	953	$210	0.55	0.967	0.81	3.766	8/12/21 2 PM	63,353
NY_11	Whole-Home	Ducted	1,380	731	$161	0.48	1.146	0.46	1.896	8/11/21 7 PM	58,353
NY_12	Primary w/ Backup	Ductless	3,000	432	$95	0.42	0.824	0.46	2.854	8/11/21 6 PM	38,498
NY_13	Whole-Home	Ductless	2,000	418	$92	0.23	0.909	0.36	2.786	7/7/21 6 PM	58,353
NY_14	Primary w/ Backup	Ducted	1,800	508	$112	0.49	1.378	0.57	2.138	8/25/21 6 PM	30,270
NY_15	Whole-Home	Ducted	1,440	44	$10	0.04	2.658	0.02	3.250	8/13/21 8 PM	58,316
NY_16	Whole-Home	Ductless	1,600	409	$90	0.40	0.617	0.43	1.675	8/7/21 10 AM	38,498
NY_17	Primary w/ Backup	Ducted	2,000	661	$145	0.35	1.853	0.85	3.589	6/29/21 2 PM	45,663
NY_18	Whole-Home	Ducted	1,800	681	$150	0.44	0.911	0.65	3.950	7/27/21 1 PM	45,663
NY_19	Whole-Home	Ductless	1,500	223	$49	0.22	0.511	0.28	1.000	6/29/21 2 PM	38,498

9. Acadia Research Home Performance Contractor Interview Results






Home Performance Industry Heat Pump Research

Executive Summary

Acadia Consulting Group - December 14, 2020

Background/Research Objectives

- E4TheFuture engaged Acadia Consulting Group to conduct research with the Home Performance industry in New York and Massachusetts to get their feedback, insights and experience with Air Source Heat Pumps.
- 32 telephone interviews were conducted with key contacts at Home Performance Contractors (21) and CLEAResult (1) as well as with a random group of CLEAResult Energy Specialists (10).
- The information from these interviews will be used to inform an extensive study of Air Source Heat Pumps being done for E4TheFuture by Cadmus.
- Major research objectives included:
  - Determine awareness, familiarity and experience with Air Source Heat Pumps.
  - Obtain knowledge and impressions of Heat Pump programs, rebates and incentives.
  - Get insights as to the level of interest in Heat Pumps among home performance service providers and their customers.

Methodology

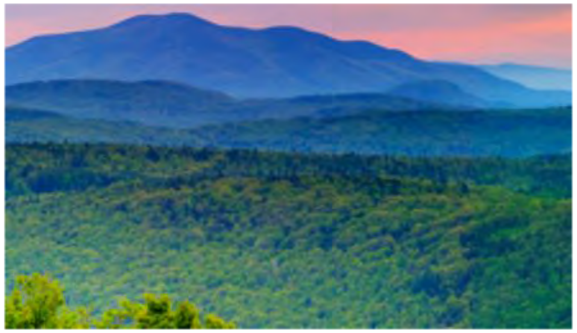
- Acadia conducted 32 in-depth telephone interviews from July 28th to August 21st, 2020 with key contacts at Home Performance (HPC) Contractors (21), CLEAResult (1) and MA CLEAResult Energy Specialists (10).
  - Acadia recruited research participants by phone and email from a list of principal program contacts provided by E4TheFuture, CLEAResult, Eversource and National Grid.
  - E4TheFuture sent a prenotification email to New York and Massachusetts Home Performance Contractors letting them know about the research.
  - CLEAResult provided a list of 10 randomly selected Energy Specialists and sent them a prenotification email.
  - Because we wanted to get insights from both those who were interested in and familiar with Heat Pumps and those that may not be, research participants were not told in advance that the main topic of the research was heat pumps.
  - Interviews typically ranged from 30-40 minutes and respondents received a $50 VISA gift card to thank them for their participation.

Research Caveats & Definitions

- Please note that while these interviews provide important attitudinal and directional input, it is important to remember that this research is qualitative in nature and therefore is not statistically projectable to the entire, defined universe.
  - Qualitative research is often used in product & service development due to the ability to have conversations and probe deeply not only into what respondents are thinking, but why they are thinking that.
  - Most questions are **unaided**, open-ended questions that objectively capture respondents top of mind thoughts. All questions in these interviews that were aided called for a yes or no answer, familiarity/importance scale or 1-10 rating.
  - In qualitative research, instead of numbers and percentages, the following terms are used to indicate the amount of consensus. An example of terms you might see include:

None → A Few → Several → Some → Many → Half → A Majority → Most → Virtually All → All

  - If most respondents are thinking a certain way, there is consensus. However, it can also be valuable to pay attention to concerns or ideas expressed by a few or even a single participant.






Summary of Findings

Summary of Findings

Current Familiarity & Experience with Air Source Heat Pumps

- Most respondents (24/32) cited that they were familiar to very familiar with Air Source Heat Pumps (ASHPs).
- Most Home Performance Contractors (18/21) we interviewed indicated that they currently install ASHPs (16/21) or have relationships with other companies to install heat pumps (2/21) for their customers.
- Virtually all respondents (30/32) cited that they had a good sense as to when ASHPs were a good fit for a customer.
- All MA respondents (18/18) and most NY respondents (12/14) reported that they participated in programs that incentivized ASHPs, citing the Mass Save program in MA and several programs in NY.
- Most NY respondents (11/13) and half of MA respondents (9/18) who were familiar with ASHPs believed that heat pumps can meet a home's entire heating and cooling needs. However, many caveated that the house must be well insulated and/or a backup was needed in very cold temperatures.

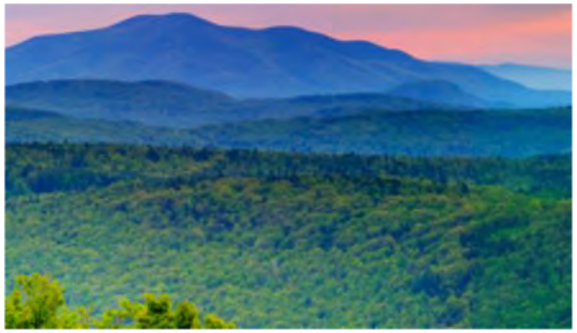
Summary of Findings

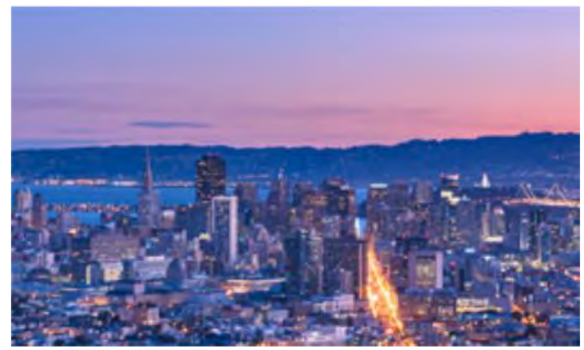
Perceived Level of Customer Interest in ASHPs

- Most MA respondents (15/18), but only half of NY respondents (7/14) reported that customers are asking or talking about ASHPs during home energy assessments/audits.
- Most respondents (29/32) cited that they had received requests from customers about potentially installing an ASHP.
  - The majority of respondents indicated that customers were looking to add a heat pump in order to add cooling.
  - The majority of NY respondents also indicated customers were interested in comfort, while many MA respondents also reported customers were looking to lower energy costs.

Thoughts on the Future of ASHPs

- Half of the HPC and CLEAResult key contacts (11/22) and most MA CLEAResult Energy Specialists (7/10) felt it was important to very important to increase the number of residential ASHPs.
- HPC respondents cited that they were very interested (16/21) or somewhat interested (5/21) in promoting and installing ASHPs (or partnering to do so) in the future.
- Respondents suggested stimulating interest in ASHPs by increasing awareness and continuing and/or boosting rebates/incentives.





Acadia Observations

Acadia Observations

- In these interviews, we learned that **awareness of ASHPs is high** in the MA and NY Home Performance Industry, **many HPCs are already installing them** and there is a **positive attitude and inclination for promoting ASHPs** in the future.
- The following things may help the Home Performance industry to assist in advancing the growth of ASHPs:
  - **More marketing and homeowner education** to increase awareness of ASHPs.
  - Maintaining **high rebates/incentives** in MA and increasing rebates/incentives in NY (higher maximums for insulation plus ASHP, higher income limits for receiving rebates/incentives).
  - **Developing data/apps** that can be used by HVAC and Home Performance professionals to provide customers with estimates of potential cost savings from utilizing an ASHP vs. using their current heating/air conditioning equipment.
  - **Developing an industry consensus** as to whether/when ASHPs can be effectively used without a back-up heating source. Provide data for HPCs, Auditors/Energy Specialists and educational tools to use with their customers.

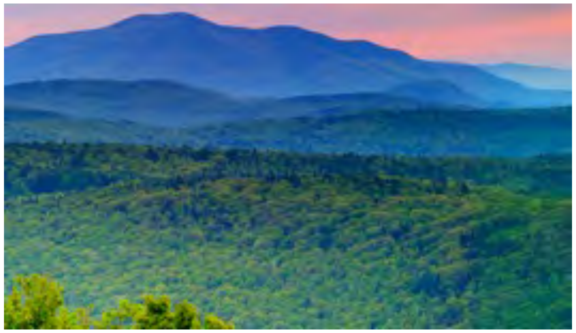
Presented By

ACADIA

CONSULTING GROUP

10. Acadia Research Customer Interview Results

CADMUS



Residential ASHP Building Electrification Study

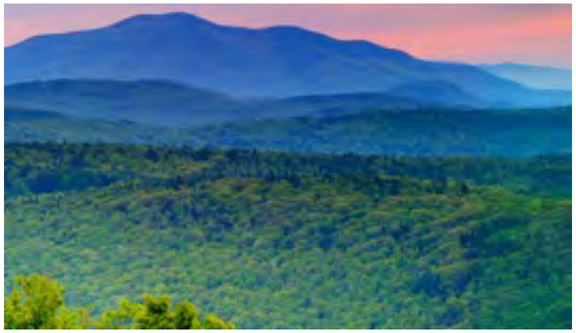
Summary of Metering Participant Interviews

Acadia Consulting Group - November 12, 2021

DRAFT REPORT

Background/Research Objectives

- E4TheFuture engaged Acadia Consulting Group to conduct a series of interviews with homeowners who participated in the site metering components of the Residential ASHP Building Electrification Study.
- Major research objectives included:
  - Determine overall satisfaction and experience with their heat pump.
  - Get feedback and insights as to satisfaction and experience using their heat pump for cooling.
  - Answer site specific questions that arose during the heating season metering.
- 42 telephone interviews were conducted from October 4th - 26th. All respondents had been using their heat pump for at least two heating and two cooling seasons.
- Interviews typically lasted 20-30 minutes and respondents received a $50 VISA gift card to thank them for their participation.






Summary of Findings

Overall Satisfaction

- Most respondents (32/42) were very satisfied with their heat pump in the past year, most frequently because it worked well, provided comfort, lowered costs and helped them move away from fossil fuels.
  - The remainder of respondents reported being satisfied (3/42) or somewhat satisfied (7/42) with their heat pump, most noting specific issues or citing that it required more attention than their prior heating equipment.
- All respondents said they used their heat pump for both heating and cooling.
  - While the majority of respondents (29/42) were equally satisfied with their heat pump in heating and cooling modes, some indicated more satisfaction with cooling (10/42) and a few were more satisfied with heating (3/42).
- All respondents said that they would recommend a heat pump to friends and family, with many adding that they have already done so.
  - When asked what they would say in recommending their heat pump, respondent comments most frequently revolved around getting away from fossil fuels, saving money and being more efficient.

Heat Pump Benefits & Drawbacks

- Respondents most frequently cited the biggest benefits of their heat pump <u>for heating</u> were getting off fossil fuels (15/42), increased comfort (13/42) and cost savings (11/42).
- The biggest <u>cooling</u> benefits cited were comfort/just having cooling (11/42), energy efficiency (10/42) and dehumidification (8/42).
- There was no consensus on any specific heat pump drawbacks.
  - Some (10/42) cited that there were no drawbacks.
  - Others (9/42) reported drawbacks related to the system design - citing areas that were hard to heat or cool, location of the units or system sizing. Most of these respondents (8/9) had ductless units.
  - Several (6/42) cited heat pump performance on the coldest days , said that their unit was noisy (6) or indicated that cost was a drawback (5/42).
  - A few (3) mentioned perceived drawbacks related to the heat pump controls/remotes for ductless units.

Differences in Experience with Heat Pump vs. Previous Equipment

- Most respondents indicated that there were differences in using their heat pump versus their previous heating and cooling equipment. The majority of respondents pointed out positive differences.

POSITIVE

- Cheaper (8)
- More even, consistent temperature (8)
- Quieter (7)
- Cleaner (7)
- More convenient (5)
- Faster to heat and cool (3)
- More efficient (2)
- More control (2)
- Easier to maintain (2)

NEGATIVE

- Controls are more difficult (4)
- Heat doesn't last as long (2)
- Not as easy/requires more attention (2)
- Learning curve (2)
- Doesn't cover full space (1)
- Splotchy heat (1)
- Need to clean filters (1)

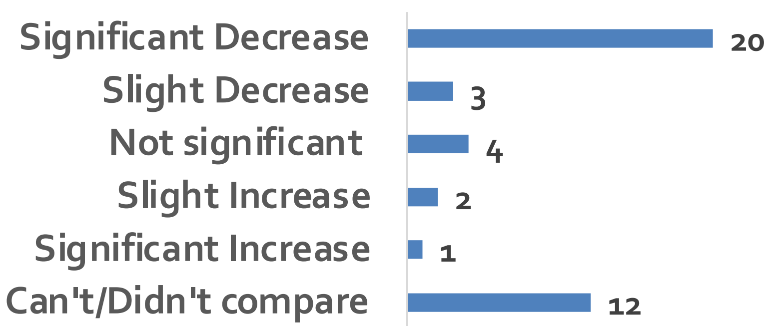
NEUTRAL

- Don't turn heat down at night (2)

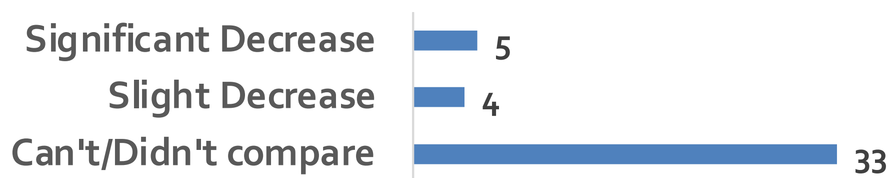
Change in Costs for Heating and Cooling with a Heat Pump

- Over half of respondents (23/42) thought that their heating costs had decreased using their heat pump versus their prior equipment. Many couldn't or didn't compare costs (12/42), especially those with solar panels.
- While some thought their heat pump had lowered their cooling costs (9/42), most didn't or couldn't compare because they didn't have cooling before, had solar (difficult to compare) or felt it was a small portion of their costs.

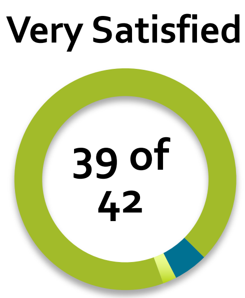
Change in Heating Costs



Change in Cooling Costs



Experience During the Recent Cooling Season



- The vast majority of respondents (39/42) were very satisfied with using their heat pump during the recent cooling season. There were no respondents that were dissatisfied.
  - Prior to their heat pump, most respondents had window ACs (24/42) or no cooling (11/42). Only 2 respondents used backup cooling last summer, using window ACs for rooms not supported by their heat pumps.
- Respondents most liked the comfort, speed, dehumidification and control their heat pump provided for cooling. The majority cited that there was nothing they didn't like about using their heat pump for cooling.

Liked Best

- Very comfortable (11)
- Cools fast (10)
- Worked well (9)
- Dehumidifies (8)
- Better control/cool only rooms you want (7)
- Just having AC (5)
- Even, constant temperature (5)
- Efficient (5)
- Easy to use (2)

Didn't like

- Nothing (27)
- Cools too quickly to remove humidity (2)

Heat Pump Cooling Experience Comments

"When it's hot and humid, it's like a luxury upon luxury having a house that was cool and comfortable."

" I love it. It really is so great. I feel greedy and guilty, it's really wonderful. It brings you a better quality of life - no mildew or insects, better for the house and pets."

"Life-saving."

"On hot days, cool air is such a godsend. It provides good, consistent temperature."

"It's quiet, efficient, goes from 90 to 68 degrees in a matter of minutes. Hard to believe."

"Loved dehumidify mode, it drops the temperature too. I used that instead of cooling half of the time."

"It did a phenomenal job, kept the house quite cool."

"It keeps the house comfortable all the time, throughout the whole house. Consistently comfortable. I'm always happy to come home!

"You can cool off quickly, breathe in dry air and it filters mold and pollen all year."

"Is very the highest rating?"

How to make using the Heat Pump Easier or Better

- Most respondent suggestions revolved around improving the controls (23/42) and were made by those with ductless systems.
  - Want a smart thermostat (5)
  - Make the temperature more accurate and easier to control (4)
  - Better Wi-Fi, connect it directly to the unit as Wi-Fi apps are hard to set up (3)
  - A single remote for all units (2)
  - Add a timer to the Heat Pump so it can turn on and off at certain times (2)
  - Make the remotes more intuitive (2)
  - Have one setting to control both heating and cooling (1)
  - Track energy use better (1)
- Many respondents (11/42) cited that there was nothing they could think of that would make using their heat pump easier or better.
- Others suggested better instructions (5/42), better performance on very cold days (3/42) or wanted heat pump operating costs to be lower than gas furnaces (2/42).

Educational Materials & Instructions

- Most respondents (34/41*) reported getting educational materials or instructions on how to use their heat pump for cooling.

How Helpful?	
Very Helpful	17
Somewhat Helpful	15
Other (Helpful)	2

  - Those receiving materials or instructions cited getting a walk through (29/34) and/or a heat pump manual (27/34) from the installer. Only 3 reported getting any other types of materials (Tips, an LG brochure and a thermostat guide).
  - All found the information to be helpful, about half cited it was very helpful.
  - About half (21/41) wished that additional information or instructions had been provided, most frequently:
    - Better instructions, explanations and troubleshooting (10)
    - Maintenance information/schedule (5)
    - More/better instructions for remotes and thermostats (4)
    - Better Wi-Fi instructions (1)

*This question was not asked of one respondent due to time constraints.

How Respondents are Using their Heat Pump

- Half of respondents (21/42) said that they have made changes to their house or their behavior to make their heat pump work more effectively for them.
  - Most frequent changes reported were adding weatherization (8/21) and opening or closing doors to specific rooms (5/21).
- Most respondents (31/42) reported that they did not have to upgrade their electrical panel before or after their heat pump was installed.
- Almost half (20/42) cited that they made changes to thermostats or settings.
  - Most frequent changes to thermostats/settings were keeping the temperature more constant (9/20) or turning the backup heat temperature way down (5/20).
  - A few respondents reported tweaking the temperature (2), setting it a bit higher (2) or setting it room by room (1).
  - A couple had to use external temperature sensors (1) or a thermostat for backup heat (1) to determine actual temperature as it was not on the remote or the unit.

How Respondents are Using their Heat Pump (cont'd)

- Most respondents with a backup heat option (20/30) indicated that they never needed to entirely use the backup system.
  - Those that did have to entirely use the backup system (10/30) did so when it was very cold (9/10) or when the power was out (1/10).
  - A few who never had to entirely use the backup system (4/20) cited that when it was very cold they used both their heat pump and their backup system (2 used electric heat and 2 used wood/pellet stoves for their backup).
- All respondents who had backup systems for heating and cooling (30/30) were satisfied in their ability to manage the use of one system vs. the other.
- Most respondents with ducted systems (12/16) reported that they set the indoor fan to be in auto mode or constantly on to reduce temperature stratification. Half (6/12) said their contractor suggested it.

How Respondents are Using their Heat Pump (cont'd)

- The vast majority of respondents with multi-zone ductless systems (19/21), reported that they did <u>not</u> implement any controls to reduce airflow and cooling to downstairs units and increase airflow to upstairs units.
  - Most respondents who didn't implement these controls (16/19) also did not set upstairs thermostats lower during cooling season and downstairs thermostats higher during heating season.
  - Many respondents indicated that they adjusted and turned heat pump units on and off independently either room/unit by room/unit (8) or floor by floor (5).

Anything Else?
Selected Respondent Comments/Suggestions

<u>Units & controls</u>

"It would be great to have an indicator light as to what mode the system is in on the remote or the Fujitsu unit. It's a mystery as to what's going on with it (the ASHP)."

"I have to keep playing with the temperature settings. It says 70,but it feels like 60. I would like to have to do less management of the temperature."

"Suggest to Mitsubishi to make the controls easier/more user friendly on the remote."

"It would be nice if it were a floor unit, with heat closer to the floor. I was told they have floor units, but they don't work as well."

"The outside unit is ugly. And it's. next to the front door. Could it be nicer looking, put something around it or put it somewhere else?"

"The system has many sensors and error messages to tell what's not working, but none to tell you it's low on refrigerant. Need a sensor, control and message for that."

"I would like to know if it's going to last a long time. I would like a guarantee (like a 100k mile guarantee for a car)."

Anything Else?

Selected Respondent Comments/Suggestions

Design

"Installers need to take into account the customer's situation. Do a better evaluation of the place."

"I wish I had put in a few more floor units vs. the ones on the wall. Would like to have had better information upfront for making system design choices - people's personal experiences, pros and cons of different units and configurations. It could be online."

"Designing the system is critical. I think contractors overdesign in an emergency situation or if they are afraid customers might be cold and be mad at them."

"When the system was being installed, I probably said 'put it there' for the downstairs unit. The technician should have given more advice as to a better place to put it, as I think it could have had better airflow and heat."

"The planning stage was the hardest. I tried to research to get the best solution. It was hard to know what doing the right thing was. It was difficult to understand how well it would work in winter (replacing a non-working gas furnace with no backup). In reality, it is excellent in cold temperatures. It's actually too strong for the house."

Anything Else?
Selected Respondent Comments/Suggestions

The Contractor/Installer

"Having a good installer really helped."

"Both solar contractors and HVAC contractors undersold the heart pump system. They were really selling AC and 'by the way, you can use the heat pump to take the edge off in the fall and spring'. They didn't think it was a reliable alternative for heating. I was blown away that I could heat without a backup. Contractors told me I really needed to keep my oil boiler."

"I told the installer that they should have their salespeople know if you have to upgrade your electrical panel. I had to do it later. It was expensive."

"Installers are putting in heat pumps and are too busy to do maintenance appointments. When you call with issues, they're not helpful or they don't call back."

"You have to think about the whole system. How do we convince the contractor business to adopt and integrate? How does all this stuff work together (solar, heat pump, etc.)?"

Anything Else?

Selected Respondent Comments/Suggestions

Performance/Experience

"You couldn't improve my experience. I'm not shy about telling the truth. It's one of the best decisions we've made."

"All the things we have done have increased our comfort and decreased our impact on the planet. And now natural gas prices are going through the roof."

"I have been thrilled with the heat pumps. I couldn't be happier. My next step is to hook up solar."

"Overall, a really good experience."

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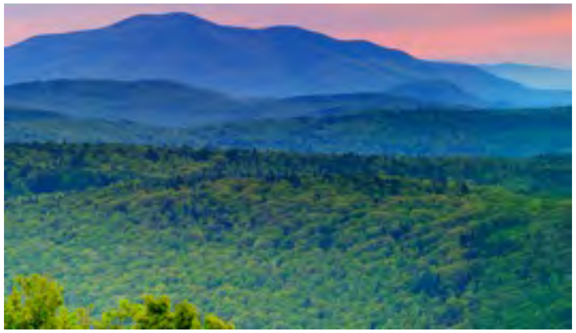




Acadia Observations

Acadia Observations

- Heat Pump satisfaction was <u>extremely</u> high. During heating season, respondents were <u>very</u> happy with comfort, cost and getting off fossil fuels. Cooling satisfaction and experience descriptions were the best we've seen for any product or service.
- There is a learning curve with operating a heat pump, especially for more complex and ductless systems.
  - Providing a simple card upon install with basic instructions on one side and maintenance information/schedule on the back could help. The card should also provide an easy to navigate website for troubleshooting, FAQs, tips, etc.
- Contractor knowledge, expertise and responsiveness are critical for positive customer experience and word of mouth, especially at the following touchpoints:
  - **Upfront system design** - Understanding customer needs, explaining options, designing a system that works well for the customer's situation, setting customer expectations.
  - **The Install** - Providing a good walk-through, setting up Wi-Fi, explaining thermostats and remotes, leaving educational materials and encouraging customers to call with questions.
  - **Post Install Ongoing Support** - Proactively following up with customers, being responsive to customer calls and issues.

Presented By

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