BUILDINGENERGY BOSTON

Size and Selection Matter: Using New Data and Tools to Design Effective Heat Pump Systems

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Northeast Sustainable Energy Association (NESEA)
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Size and Selection Matter: Using New Data and Tools to Design Effective Heat Pump Systems

- Dave Lis, Director, Technology and Market Solutions
- Northeast Energy Efficiency Partnerships (NEEP)

- BuildingEnergy Boston
- March 29, 2023

Northeast Energy Efficiency Partnerships

Mission

We seek to accelerate regional collaboration to promote advanced energy efficiency and related solutions in homes, buildings, industry, and communities.

Approach

Drive market transformation regionally by fostering collaboration and innovation, developing tools, and disseminating knowledge

Key challenges to sizing/selecting ASHPs in cold climates

- “Sizing” across wide range of operating conditions and heating/cooling loads
- Availability of useful performance data

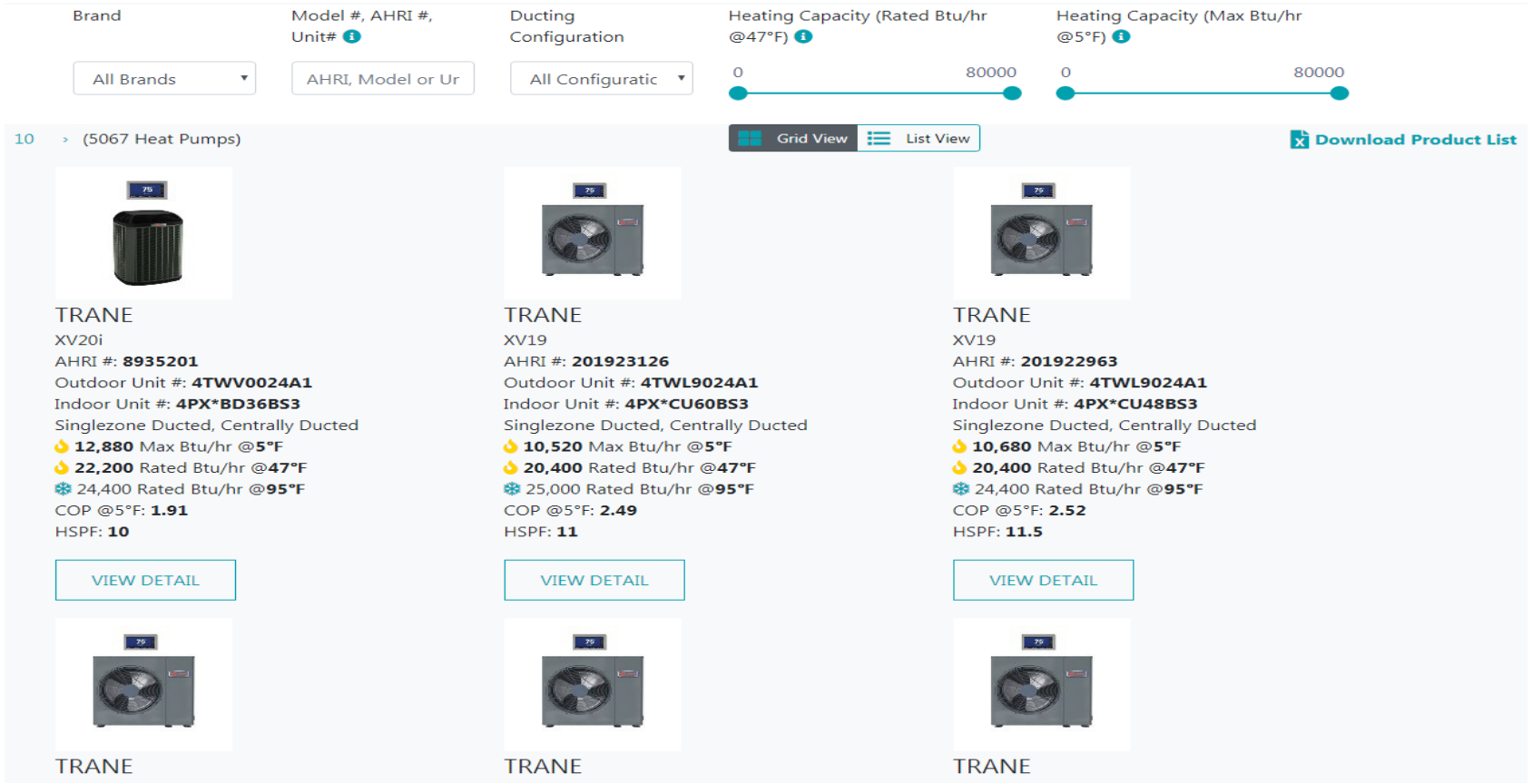
Load Matching

- Heating design load can be 3X+ cooling design load in cold climates
- Heat pumps have unique capacity “maps”
- Requires system “sizing” across wide range of operating conditions, heating/cooling loads
- Can’t be too small for heating
- Can’t be too big for moderate heating/cooling

Availability of useful heat pump performance data

- Usefulness of “Rated” performance data
  - Fixed speed testing
  - Range of temperature points
- Accessing extended performance data

NEEP's Cold-Climate ASHP Product List



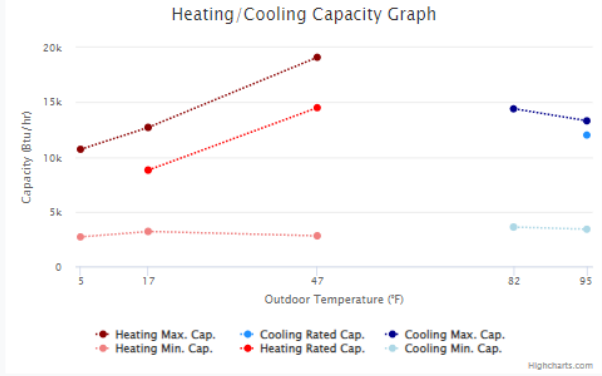
Now 40k+ systems from over 100 major brands

What do I do with this?

@95°F: **12,000**

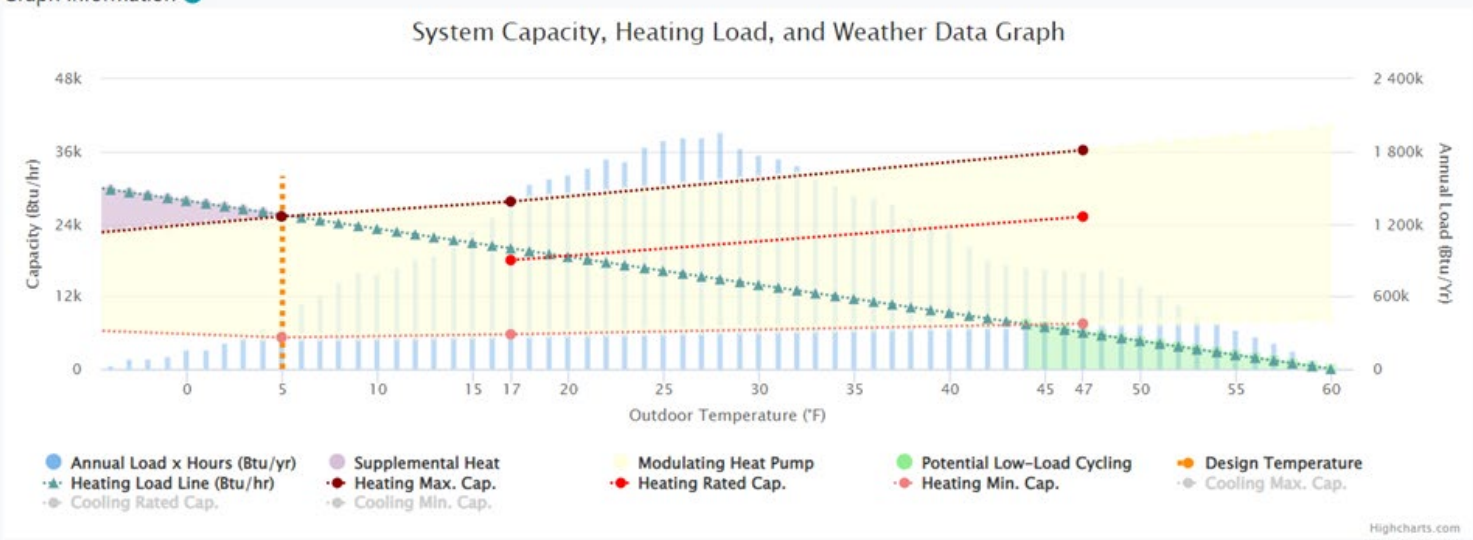
Performance Specs

Heating / Cooling	Outdoor Dry Bulb	Indoor Dry Bulb	Unit	Min	Rated	Max
Cooling	95°F	80°F	Btu/h	3,400	12,000	13,300
			kW	0.14	0.96	1.27
			COP	7.12	3.66	3.07
Cooling	82°F	80°F	Btu/h	3,600	-	14,400
			kW	0.12	-	1.09
			COP	8.79	-	3.87
Heating	47°F	70°F	Btu/h	2,800	14,500	19,100
			kW	0.14	1.03	1.67
			COP	5.86	4.13	3.35
Heating	17°F	70°F	Btu/h	3,200	8,800	12,700
			kW	0.36	0.88	1.39
			COP	2.61	2.93	2.68
Heating	5°F	70°F	Btu/h	2,700	-	10,700
			kW	0.33	-	1.28
			COP	2.4	-	2.45



New Sizing tool functionality

Graph Information



Product Sizing For Heating

Field Information

Balance Point (°F)	5
Minimum Capacity Threshold (°F)	44
Maximum Capacity at Design Temp (Btu/hr)	25,220
Percent Design Load Served	98.9%
Annual Heating Load (MMBtu)	61.7
Percent Annual Heating Load Served	97.9%

Field Information

Annual Btu's Covered by Supplemental Heat (MMBtu)	1.3
Hours Requiring Supplemental Heat	54
Percent Hours Requiring Supplemental Heat	0.9%
Percent Annual Load Modulating	83.9%
Percent Annual Load with Low-Load Cycling	12.6%

Demo time!

- Assessing product performance match with application
  - Visualization
  - Calculations
- Impact of sizing choices within same product line
- Impact of potential load reductions
- Assessing need for supplemental/back-up heat
- Down selecting complete list

Limitations of data and tool

- Extended performance data- Manufacturer reported
  - No Industry standard procedure to determine variable performance
  - Data quality
- Unable to “build up” a solution with multiple outdoor units
- Does not include cooling load line
- Does not calculate the expected energy consumption of different options

Tracking tool users and uses

- Contractors:
  - New insights into selection decisions
  - Differentiator with customers
- Distributors:
  - Confirm they are stocking well for local climates
  - Use at the counter for engaging contractors
  - Swap outs due to supply chain issues
- Programs/Service Providers
  - Contractor training tool
  - Contractors QC
  - 1:1 coaching
- Homeowners:
  - Consumer empowerment
  - Sanity check on quotes

Abode Energy Management

ABODE'S WORK IN THE EFFORT TO SCALE HEAT PUMP ADOPTION

Client Examples	Abode's Role	Heat Pump Related Services				
		Consultations	Quote Reviews	Contractor Networks	Trainings	QA
mass save Savings through energy efficiency	Mass Save Home Performance Contractor Lead Vendor				✓	
Proud sponsor of energize CONNECTICUT	Providing Heat Pump Support for Energize CT Customers	✓	✓	✓	✓	
MASSACHUSETTS CLEAN ENERGY CENTER	Leading the Decarbonization Pathways and Triple Decker Retrofit Pilots	✓	✓	✓		✓
9 MLP Utilities and 7 Communities in MA	Providing Heat Pump Support for MLP Customers	✓	✓	✓	✓	✓

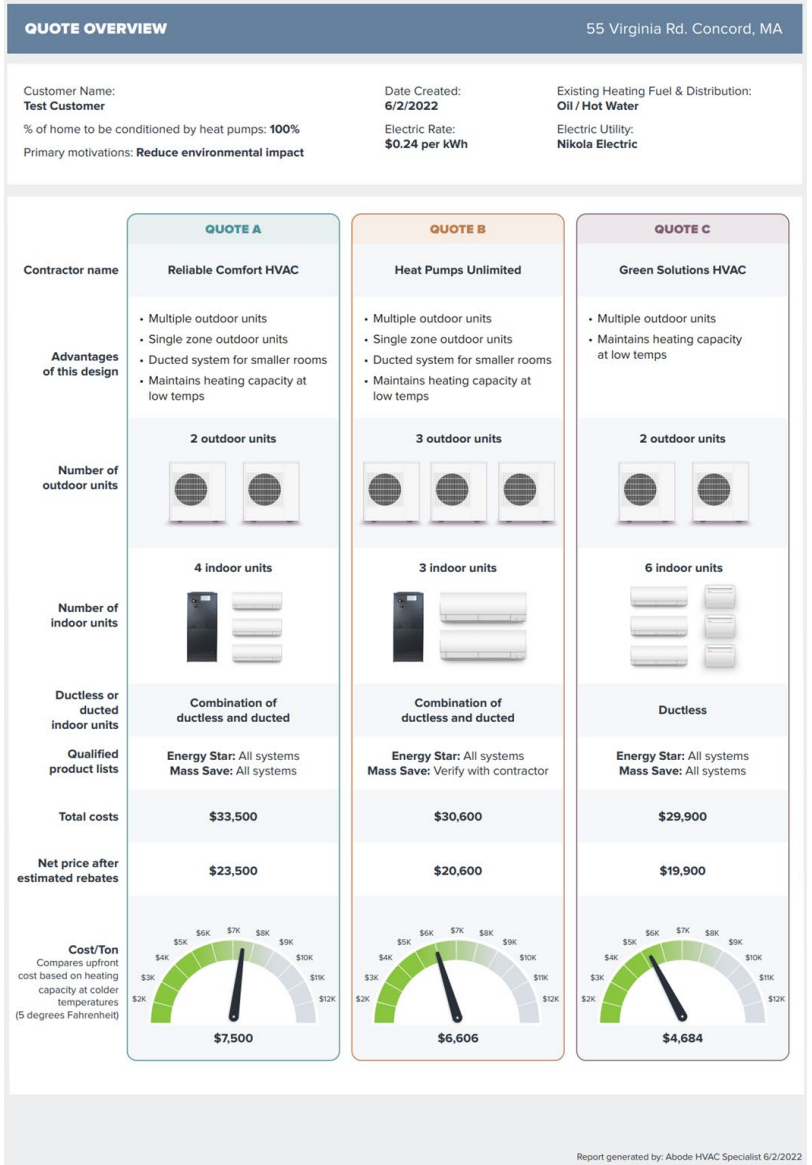
HOMEOWNERS ARE CONFUSED WHEN THEY GET QUOTES

JOB NUMBER	SALES PERSON	Dave's cell	Cellular
	Norm Provencher	781-439-4530	

DESCRIPTION	AMOUNT
THE INSTALLATION OF A 2-ZONE MITSUBISHI COOLING AND HEAT PUMP SYSTEM WITH HYPER HEAT TECHNOLOGY. THIS INCLUDES: 1. ONE MITSUBISHI MODEL # MXZ-3C36NAHZ2 OUTDOOR HEAT PUMP 17.5 SEER 12.5 EER 11 HSPF 2. ONE MITSUBISHI MODEL # SVZ-KP18NA INDOOR AIR HANDLER FOR THE SECOND FLOOR BEDROOM 3. ONE MITSUBISHI MODEL # SVZ-KP18NA INDOOR AIR HANDLER FOR THE MASTER SUITE 4. ALL NECESSARY SUPPLY AND RETURN DUCTWORK TO CONNECT THE NEW AIR HANDLERS TO THE EXISTING DUCTWORK 5. ONE MITSUBISHI 3-PORT BRANCH BOX MODEL # PAC-MKA32BC 6. ONE MITSUBISHI PORT ADAPTER MODEL # MAC-A455PE 7. TWO MITSUBISHI INTERFACE CONTROLLERS MODEL # PAC-US444CN-1 WITH TRANSFORMERS MODEL # VPL24-210 8. THREE INSULATED REFRIGERATION LINESETS COMPLETE, TWO FOR THE INDOOR UNITS AND ONE FOR THE BRANCH BOX 9. TWO PVC DRAIN LINES 10. ONE PRE-CASTED OUTDOOR CONDENSER PAD 11. ONE 12 INCH QUICK SLING STAND FOR THE OUTDOOR UNIT 12. ALL NECESSARY FORTRESS LINESET COVERS TO HIDE UNSLIGHTLY REFRIGERANT LINES AND ELECTRICAL 13. EVACUATE THE REFRIGERATION PIPING AND CHARGE THE SYSTEM WITH 410A REFRIGERANT 14. ALL ELECTRICAL WIRING INCLUDING AN OUTDOOR DISCONNECT AND A SERVICE OUTLET IF NEEDED 15. REMOVAL OF OLD EQUIPMENT 16. ONE YEAR WARRANTY ON ALL PARTS AND LABOR 17. TWELVE YEAR WARRANTY ON ALL MITSUBISHI PARTS ONLY	25,671.00

NOT ENOUGH DETAIL MAKES AN INFORMED DECISION DIFFICULT

TOO MUCH DETAIL INCREASES CONFUSION



NEEP DATA HELPS US ESTIMATE HOME SPECIFIC PERFORMANCE

Inputs

- Home characteristics
- Fuel usage data
- Contractor quotes
- NEEP data

Analysis

- Estimate heating load
- Bin temperature data analysis
- Apply cycling, defrost, and multi-zone adjustments

Home specific operating cost and CO2 comparison

Estimated seasonal performance based on location

Estimated “optimal” sizing range

Estimated cycling comparison

WHY THE DETAILS MATTER

Temperature	COP and Capacity Data	Story 1 *(HSPF2)*	Story 2 *(Quote Review)*
47 Degrees	Min		✓
	Rated	✓	✓
	Max		✓
17 Degrees	Min		✓
	Rated	✓	✓
	Max		✓
5 Degrees	Min		✓
	Rated	Optional in 2023	✓
	Max		✓
LCT	Min		✓
	Rated		✓
	Max		✓
Temperature data		Mid Atlantic Region IV (Not most of New England)	Local
Defrost penalty		✓	✓
Cycling penalty		Default	More Realistic
Multi-zone penalty			✓
Aux. electric penalty		✓	✓
Fixed sizing assumption		Locked mode	Assumes modulation

Performance data can tell different stories

Story 1

- Where we normally look to compare performance
- What qualifying product lists and rebates are typically based on

Story 2

- Based on more complete manufacturer provided data
- A more detailed model of how equipment should perform under various loads
- Others using similar bin analysis approach

WHY THE DETAILS MATTER

What we used to focus on
High HSPF & SEER
A good Manual J and avoiding oversizing
High turndown ratio
High capacity maintenance @5
Avoid large multi-zones
Encourage single-zones
Avoid branch boxes
Split systems by floor or “like conditions”
Encourage ducted systems for closed off spaces

AS WE LEARN MORE, SOME BEST PRACTICES MIGHT NEED TO SHIFT

What we used to focus on	How that's changing
High HSPF & SEER	Replace with Quote Review or deeper dive into NEEP data
A good Manual J and avoiding oversizing	Include **Min COPs** and **Min capacities** as key drivers
High turndown ratio	Replace with **Min capacity at 47, 17, and 5**
High capacity maintenance @5	Include **Max capacity below 5** and new messaging
Avoid large multi-zones	Weigh the drop in COP moving to some smaller equipment
Encourage single-zones	Always confirm COPs, some single-zones seem to "test well"
Avoid branch boxes	Jury is still out on some newer equipment that looks appealing
Split systems by floor or "like conditions"	No change
Encourage ducted systems for closed off spaces	No change

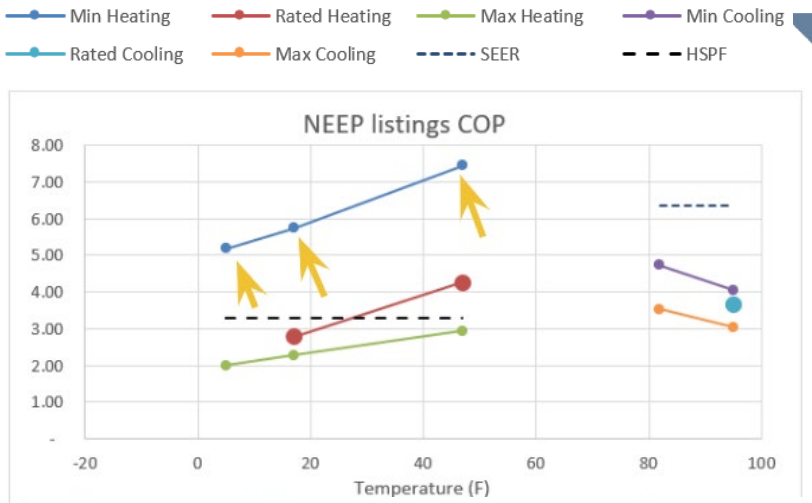
SAME PRODUCT LINE, DIFFERENT SIZE, DIFFERENT PERFORMANCE

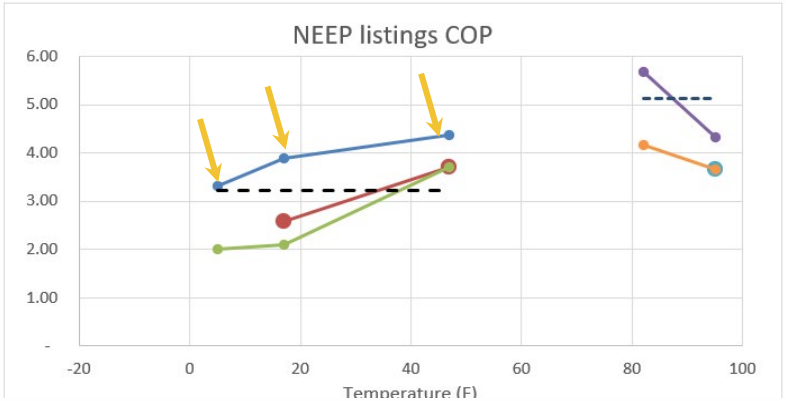
Example 1: *Commonly sold product line 1*

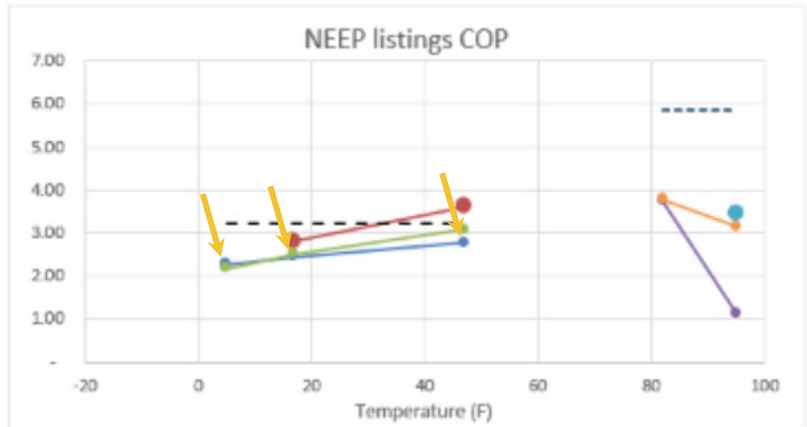
System Size	HSPF Equivalent COPH	COPH Estimated with tool	% of HSPF Equivalent
24 kbtu	3.1	**1.9**	**61%**
30 kbtu	3.2 →	**1.9**	**59%**
36 kbtu	3.4 →	**2.4**	**71%**
42 kbtu	3.4	**2.7**	**80%**

Example 2: *Commonly sold product line 2*

System Size	HSPF Equivalent COPH	COPH Estimated with tool	% of HSPF Equivalent
30 kbtu	3.2 →	**2.2**	**68%**
36 kbtu	3.3	**2.9**	**88%**
42 kbtu	3.2 →	**3.0**	**93%**
48 kbtu	3.4	**2.8**	**83%**







MIN COPS RELATIVE TO OTHER RATINGS COULD BE IMPACTFUL

High Min COPs (~3.7)
(increases SCOP)

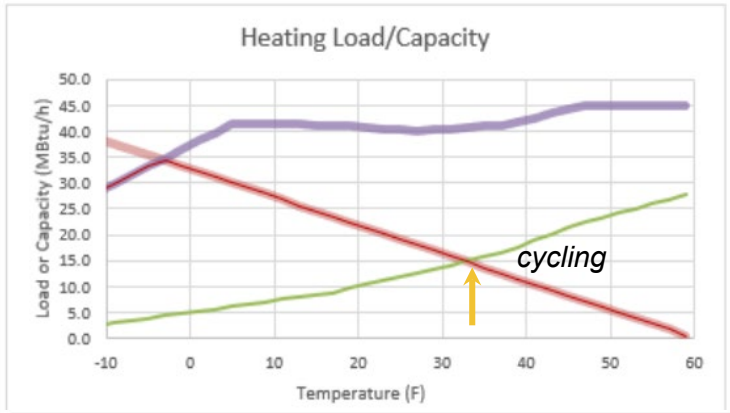
Heating / Cooling	Outdoor Dry Bulb	Indoor Dry Bulb	Unit	Min	Rated	Max
Heating	47°F	70°F	Btu/h	6,600	36,600	54,500
			kW	0.26	2.52	5.45
			COP	7.44	4.26	2.93
Heating	17°F	70°F	Btu/h	5,080	22,400	41,960
			kW	0.26	2.36	5.4
			COP	5.73	2.78	2.28
Heating	5°F	70°F	Btu/h	4,420	-	36,600
			kW	0.25	-	5.36
			COP	5.18	-	2

Average Min COPs (~2.5)
(minor decrease in SCOP)

Inverted Max and Min COPs (~1.9)
(major decrease in SCOP)

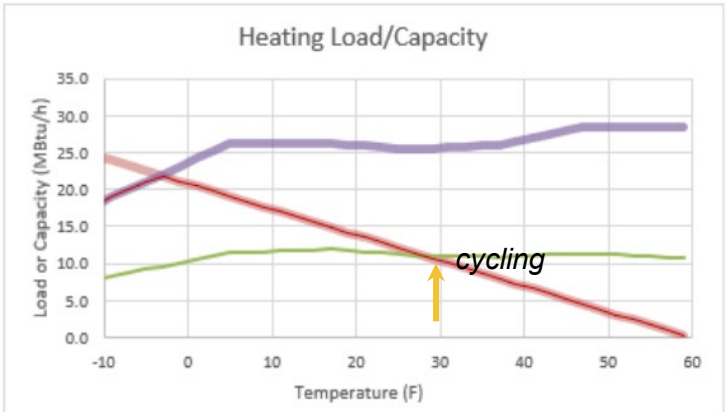
Heating / Cooling	Outdoor Dry Bulb	Indoor Dry Bulb	Unit	Min	Rated	Max
Heating	47°F	70°F	Btu/h	10,248	28,600	34,200
			kW	1.3	2.33	3.26
			COP	2.31	3.6	3.07
Heating	17°F	70°F	Btu/h	7,511	18,900	31,600
			kW	1.08	1.98	3.69
			COP	2.04	2.8	2.51
Heating	5°F	70°F	Btu/h	6,262	-	28,600
			kW	0.97	-	3.88
			COP	1.89	-	2.16

VARIABILITY IN MIN CAPACITY ADDS SIZING COMPLEXITY

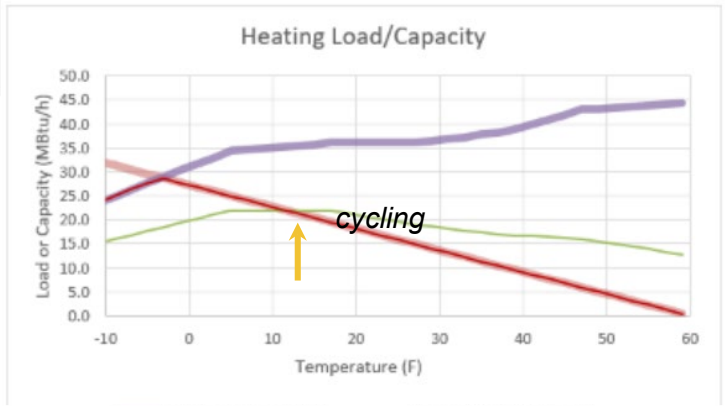


Min capacity **slopes down**
*(**More forgiving** to oversizing)*

Heating / Cooling	Outdoor Dry Bulb	Indoor Dry Bulb	Unit	Min	Rated	Max
Heating	47°F	70°F	Btu/h	27,000	54,000	54,000
			kW	1.4	4.22	4.22
			COP	5.65	3.75	3.75
Heating	17°F	70°F	Btu/h	11,620	38,000	54,000
			kW	0.92	4.13	6.87
			COP	3.7	2.7	2.3
Heating	5°F	70°F	Btu/h	8,020	-	54,000
			kW	0.74	-	7.91
			COP	3.18	-	2



Min capacity is **flat**
*(**It depends**)*

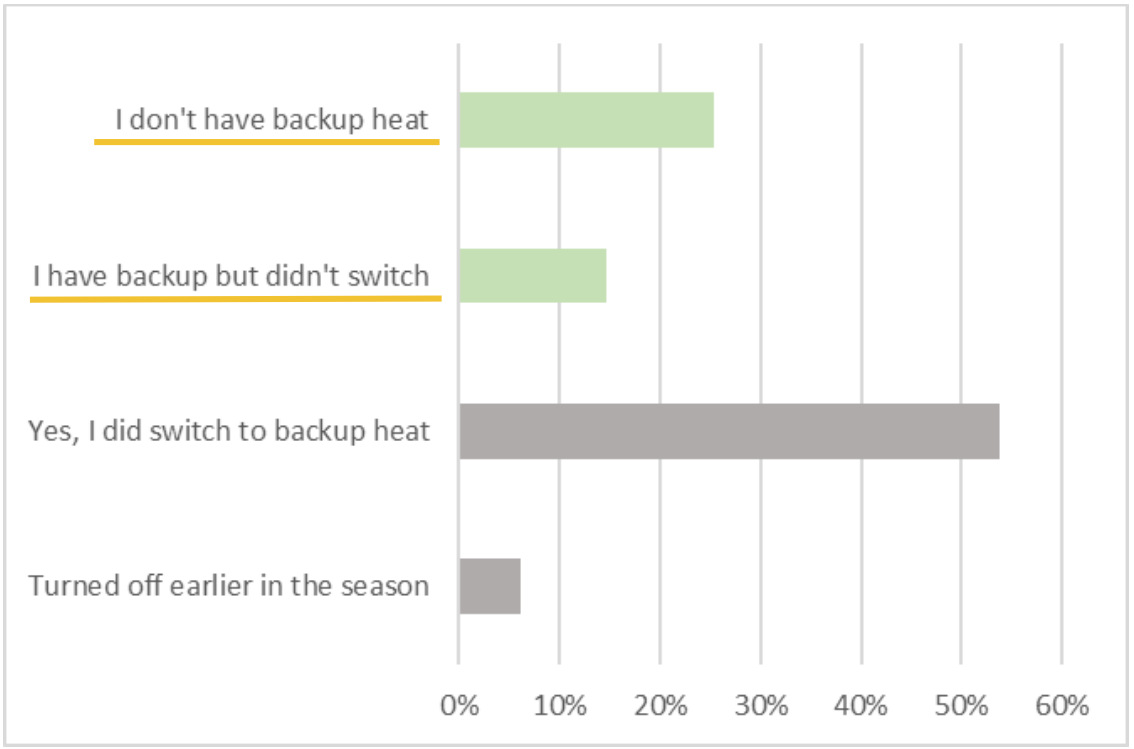


Min capacity **slopes up**
*(**Less forgiving** to oversizing)*

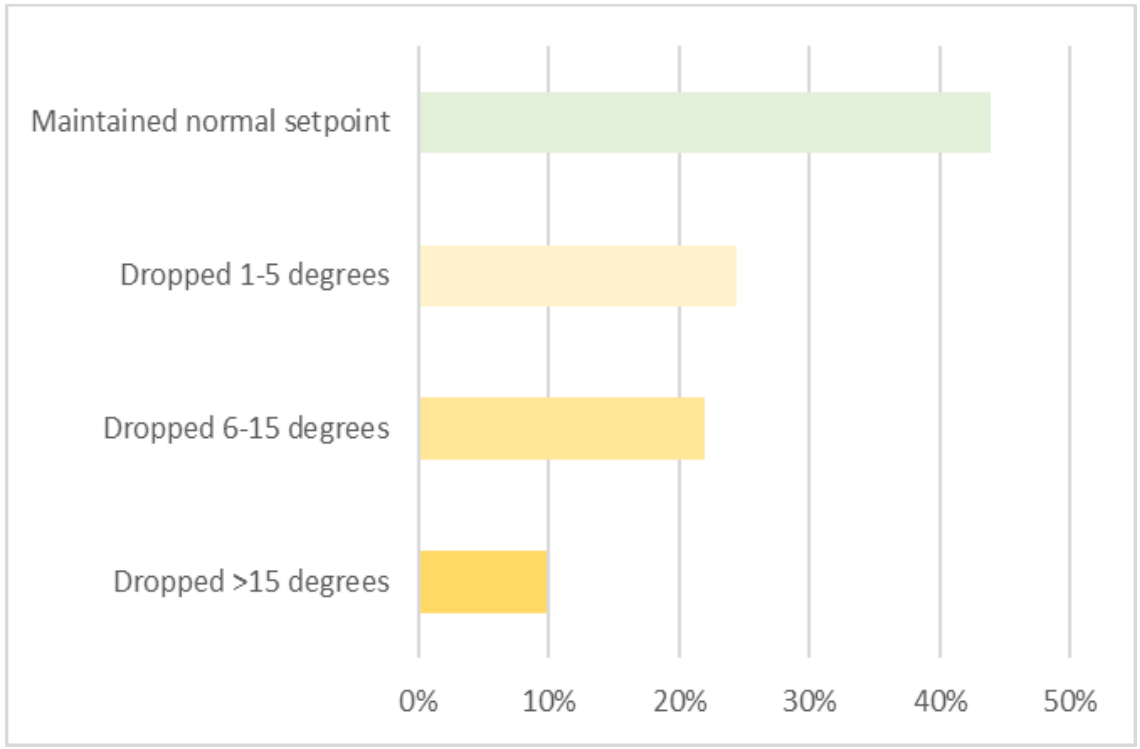
Heating / Cooling	Outdoor Dry Bulb	Indoor Dry Bulb	Unit	Min	Rated	Max
Heating	47°F	70°F	Btu/h	16,000	37,500	43,000
			kW	0.81	3.35	4.1
			COP	5.79	3.28	3.07
Heating	17°F	70°F	Btu/h	24,000	23,800	39,400
			kW	2.03	2.65	5.91
			COP	3.46	2.63	1.95
Heating	5°F	70°F	Btu/h	24,000	-	37,500
			kW	2.43	-	6.27
			COP	2.89	-	1.75

COLD SNAP IN FEB HIGHLIGHTS WHY THE DETAILS MATTER

Did you switch to a backup heat source?



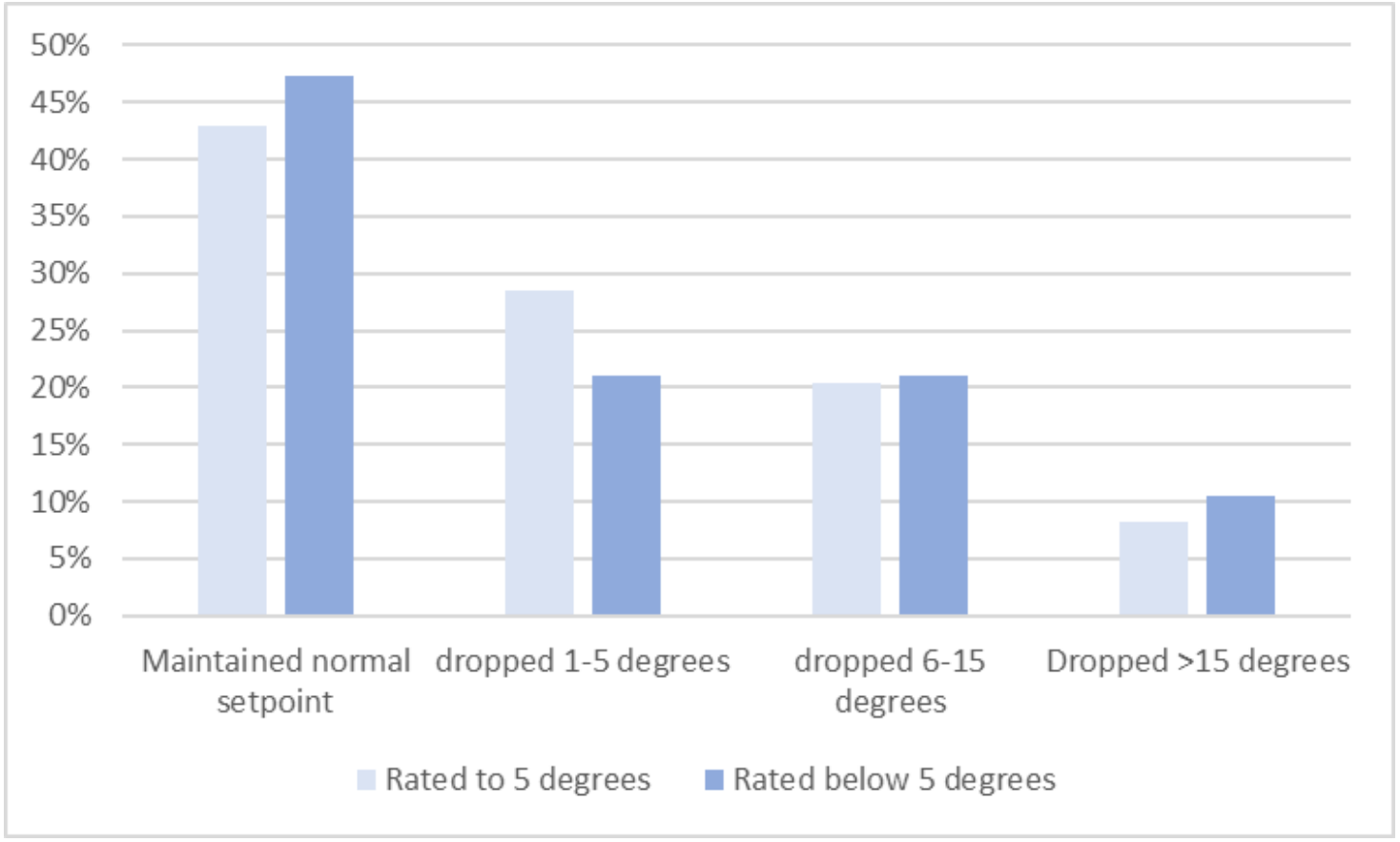
Did the heat pumps maintain normal temperatures?



Based on survey responses from 200 "whole home" heat pump owners in eastern Massachusetts

"Whole home" defined as equipment sized to serve at least 90% of the home and 100% of the heating load

ABILITY TO OPERATE AT LOW TEMPS APPEARS LESS MEANINGFUL THAN THE CAPACITY RATING



This doesn't change how you size equipment, but might change what you select, and how you message backup heat

Other Interesting Survey Results

- Ducted vs. ductless didn't seem to have a meaningful impact on temperature drop
- Of the group where the temperature dropped, 51% said they were expecting the HPs to fall behind, 22% were not, and 27% didn't know what to expect
- Of the group that switch to a backup, 88% switched to a fossil fuel system
  - Of those, 86% maintained temperature

SUMMARY

- HSPF and SEER have limited value in New England
- Min, Max, and Rated values are the best window we have into heat pump performance under various loads
- If accurate, there's more variability in performance than expected
- As we learn more, some best practices might need to shift
- Initial areas of focus (for now)
  - Check ratings when moving up or down a size in a product line
  - Look for high Min COPs and avoid inverted Min COPs
  - Get the full Min Capacity picture at all 3 temperatures
  - Don't change how you size but consider capacity maintenance below 5 degrees

abode

Related Activities

- Version 2.0 of sizing tools in the works
  - Multi-product buildup
  - Weather station selection improvement
  - Multi-unit comparison view
  - Cooling capacity, latent load cross check
- NEEP Rating Representativeness project
- Standardizing expanded performance data
- Updates to ACCA Guides
- Updating NEEP Sizing/Selection Best Practice Guides and Videos

Group Discussion

- What improvement opportunities resonate with stakeholders in the audience?
- Are there other future directions we should be considering?

Links

- Cold Climate Air-source Heat pump Product List (including sizing tools); https://ashp.neep.org/
- User Guide: Cold Climate Heat Pump Sizing Support Tools; https://ashp-production.s3.amazonaws.com/NEEP_ccASHP+Heating+Visualization+User+Guide_v2.2_TRC_04.01.22.pdf
- Cold Climate Air-source Heat pump Specification; https://neep.org/heating-electrification/ccashp-specification-product-list
- Installer Guides/Videos; https://neep.org/high-performance-air-source-heat-pumps/air-source-heat-pump-installer-and-consumer-resources
- Heat Pump Initiative; https://neep.org/smart-efficient-low-carbon-building-energy-solutions/air-source-heat-pumps

Multi-zone indoor head oversizing

- What happens when only one zone is calling for heat?
- Avoid situations where the minimum steady-state capacity of the outdoor unit (at 47F) is higher than the smallest indoor unit's heating capacity.
- Can impact humidity control as well if short cycling during the cooling season