Ameren ILLINOIS | Energy Efficiency PROGRAM

Designing Air Source Heat Pumps

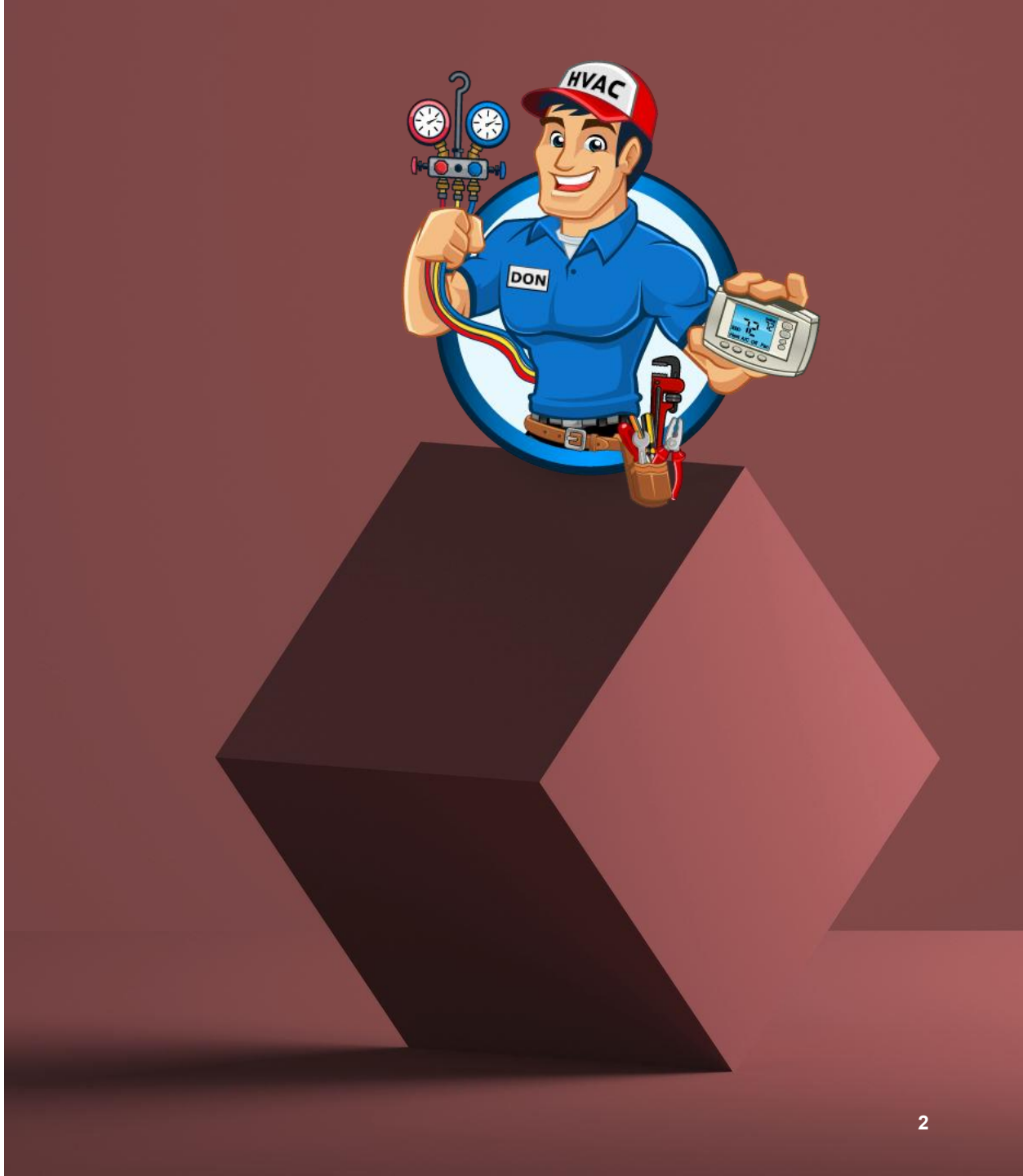
with Sizing and Selection in Mind

Overview, Potential and Ameren Illinois Support

Zak Paine and JT Stewart

Agenda

- **Why does right sizing matter?**
  - Identified gaps in practice
  - Right sizing benefits
  - Works for YOUR business case
- **How do we right size?**
  - Getting load calcs right
  - Sizing for heating vs sizing for cooling
  - Sizing primary system vs supplemental/back up heating system
  - Using new tools for equipment selection
  - Applying switchover temps
  - Connecting back to the business case



Poll:

How often do you perform full Manual J and S on projects?

Problem statement:

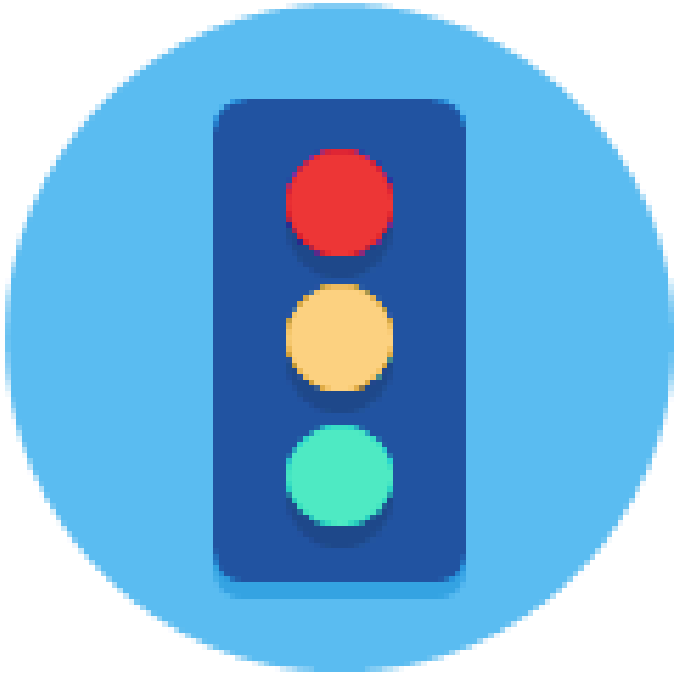
Problem: Sizing, design, and selection is often done based solely on rules of thumb and based on previous sized systems. This most often leads to oversizing!

Truth: Variable Capacity Air Source Heat Pumps perform best and meet savings goals when sized appropriately for system type, application and supplemental fuel type.

Current Common Approaches to Load Calcs

What people are putting into it most often.

- “Shoot from the hip”
- Sized off existing equipment size
- Using rules of thumb
- Utility bill analysis
- Block load calculation



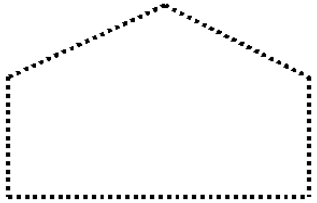
Sizing - Rules of Thumb

- One thousand BTU per 100 sq ft
- One cfm per sq. ft. of house
- 35 btu per sq ft
- Tonnage = half the number of cylinders in the customer's biggest car/truck
- What's in the shop today
- ½ ton bigger than their neighbor

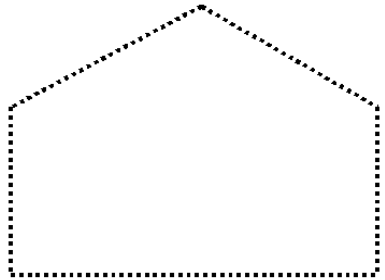
Air Conditioner or Heat Pump Sizing Chart

(Please understand that this is meant as humor,
however it is just as accurate as "x" number of square feet per ton!)

1 1/2 to 2 ton



2 1/2 to 3 1/2 ton



4 to 5 ton

Slide courtesy Bruce Manclark

Does Sizing Impact Energy Use and Utility Bills?

What's wrong with inaccurate load calculations?

For single and two speed systems, maximum efficiency happens during long run times, not starts and stops. This LIKELY has small energy penalties for over-sized systems oversized by more than 33%.

For variable capacity equipment, longer run times may mean more time spent at medium and low heat/fan speed. This LIKELY has energy penalties for systems oversized by more than 40% as they potentially will not have shorter run times and at higher heat/fan speed.

Wrong sized for the ductwork can lead to much higher fan watt draw. An AHRI report showed that adding static pressure to Electrically Commutated Motors only reduced flow from 1 to 3% with increased fan power draw **up to 48%!**

NIST, NREL, Proctor Engineering, Illinois Institute of Technology

Fan Watt Draw and Pressure

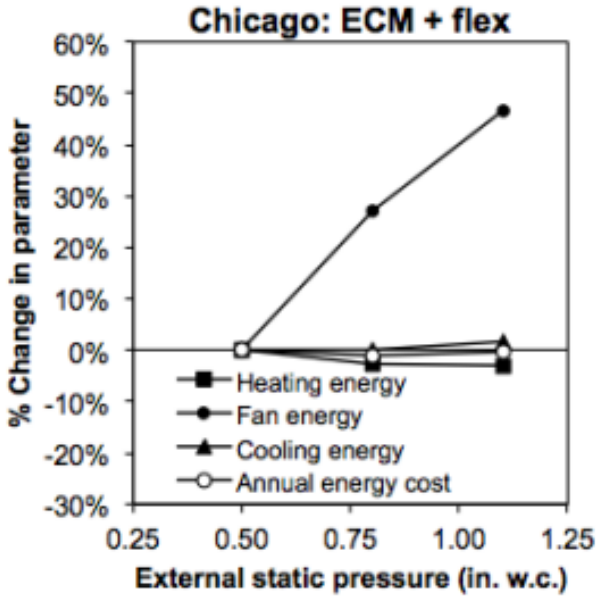


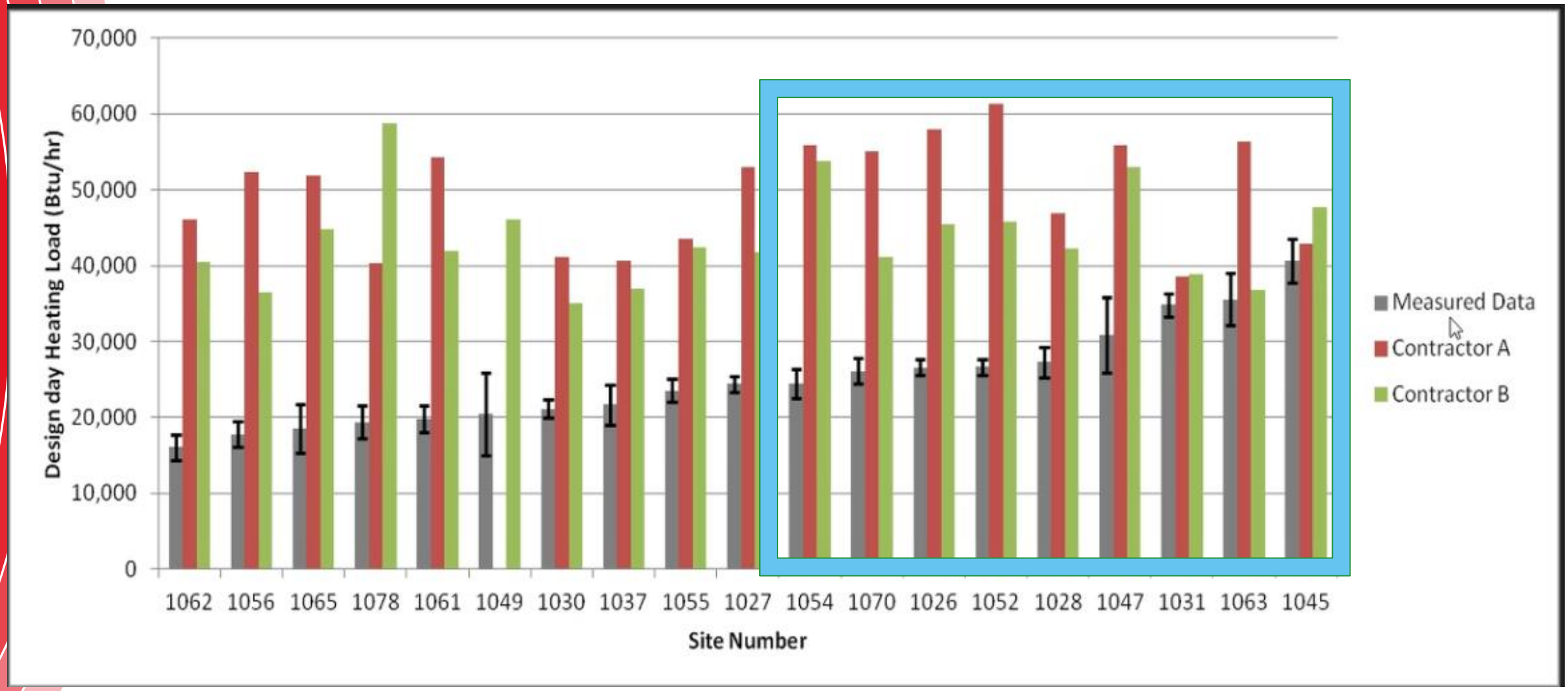
Figure 14. Estimated relative change in annual fan, cooling, and heating energy usage and total annual HVAC energy costs for the Chicago home with both types of AHU fans and both rigid and flex duct work at each duct design (using only the Chicago contractor's duct designs).

Table 10. Annual energy simulation results for both homes at baseline using the Austin contractor's designs

Home	Duct type	Blower type	Total Pressure (in. w.c.)	Airflow rate (CFM)	Cooling (kWh)	AHU Fans (kWh)	Total Electricity (kWh)	Heating ($\times 10^6$ Btu)	Total Gas Consumption ($\times 10^6$ Btu)
Chicago 3-ton AC Gas furnace 1200 CFM nominal	Flex	PSC	0.50"	1200	619	542	8108	60.95	88.88
			0.80"	964	661	531	8139	60.93	88.85
			1.10"	622	786	600	8331	63.71	91.70
		ECM	0.50"	1200	611	319	7878	61.55	89.51
			0.80"	1162	614	411	7972	60.47	88.39
			1.10"	1103	631	478	8056	60.86	88.78
	Metal	PSC	0.50"	1200	611	531	8086	59.52	87.41
			0.80"	964	656	525	8128	60.25	88.16
			1.10"	622	769	583	8300	62.17	90.12
			0.50"	1200	603	314	7861	60.10	88.02

8

Concerned that Manual J won't size large enough?



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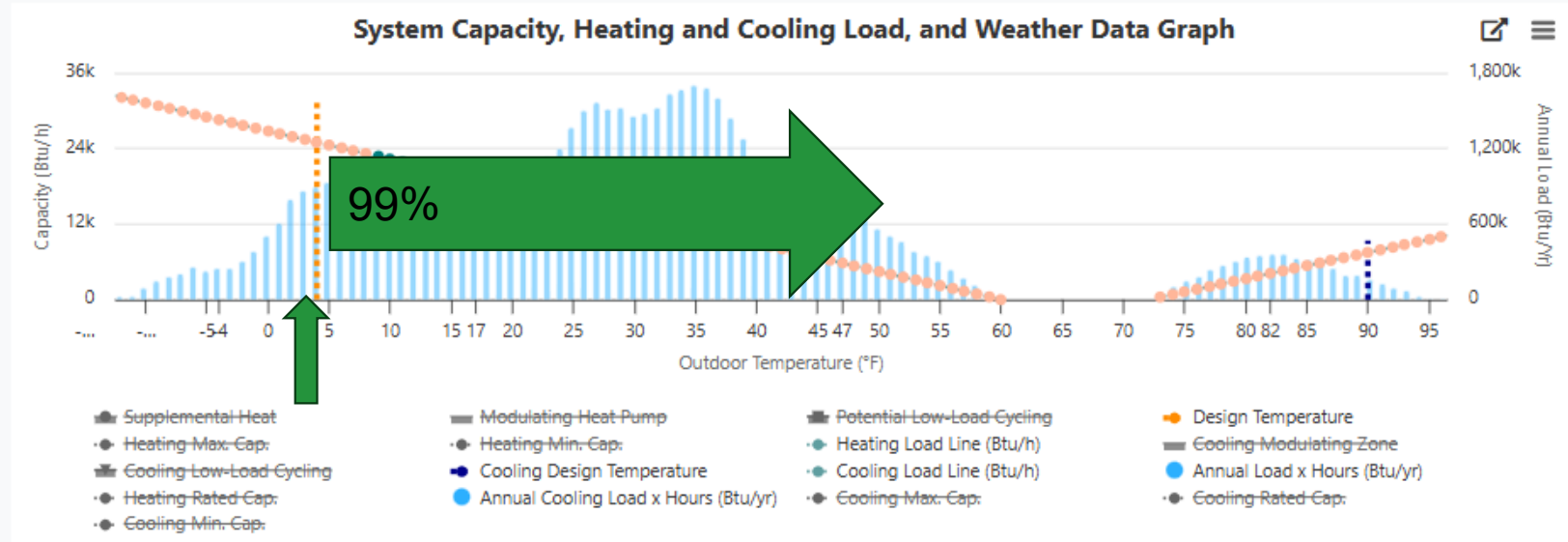
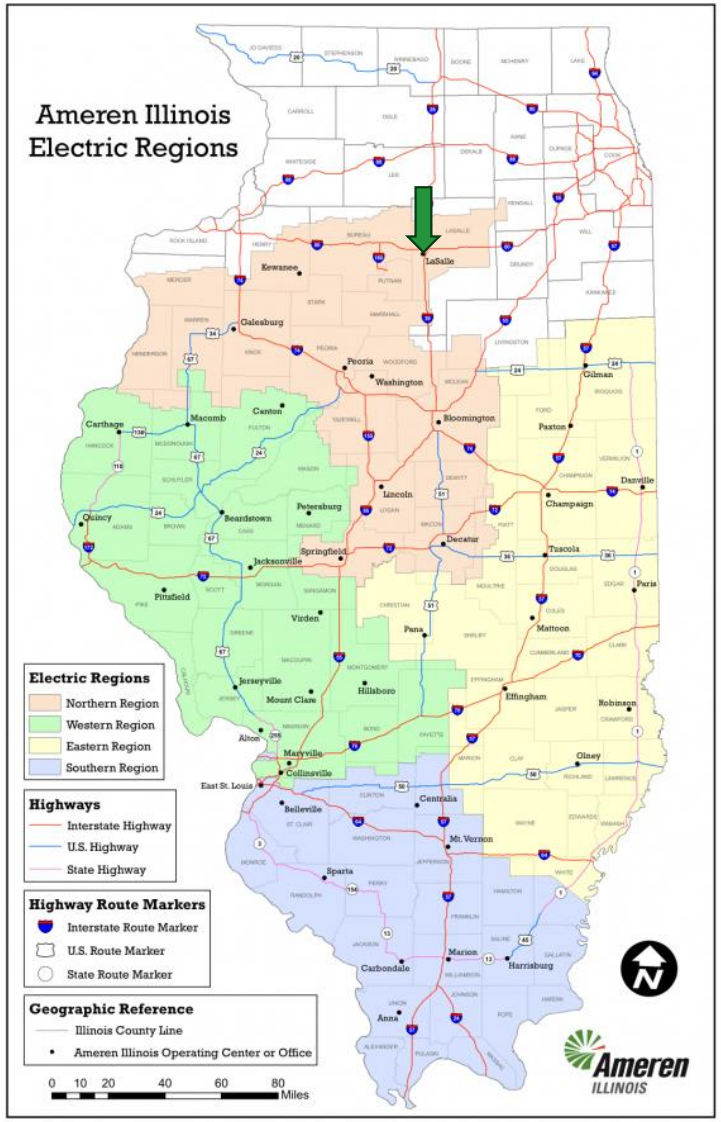
Recommended Practices for Sizing Key Takeaways Part 1

- Load calculations already have safety factors built in. There's no need to use estimations that increase the load calculation!
- Recommended load calculations include:
  - Energy bill or runtime analysis
  - Block load calculations (Room by Room when applicable)
- Oversized systems may struggle with existing ductwork.
- Oversized systems will cost more to run.

Illinois Design Conditions

Graph Information





Illinois Design Conditions

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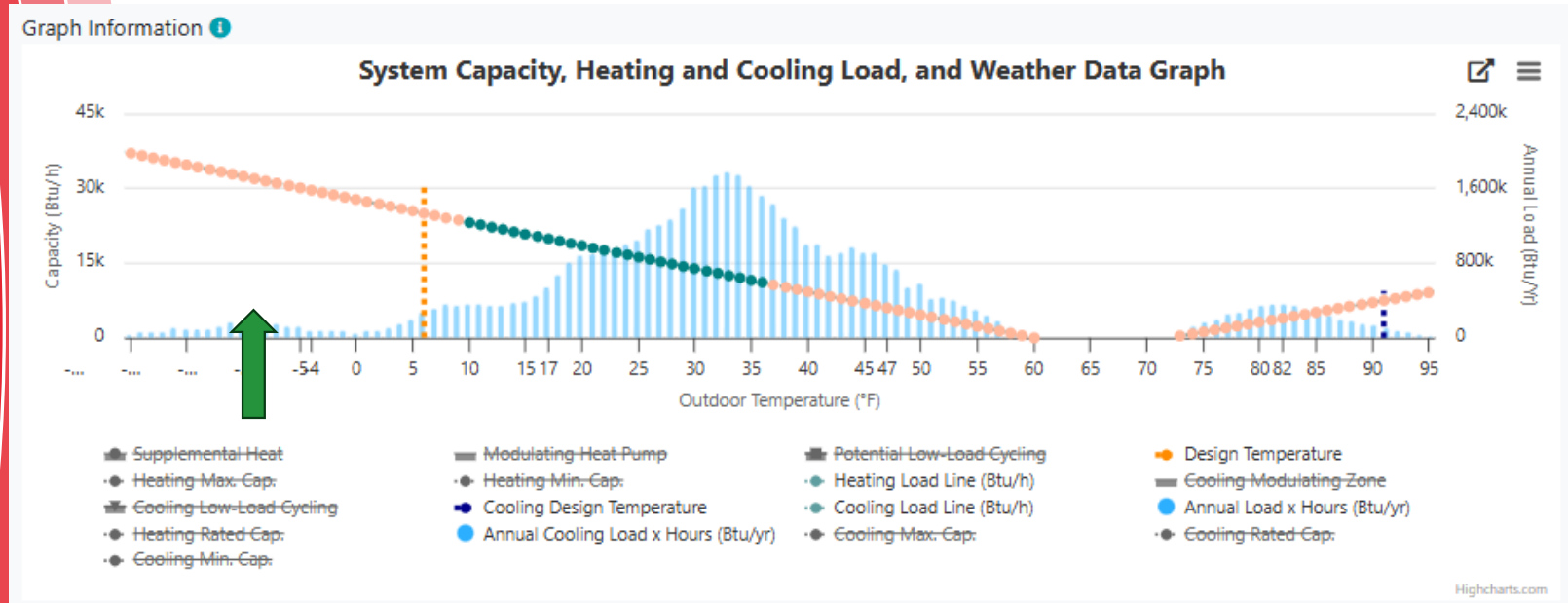
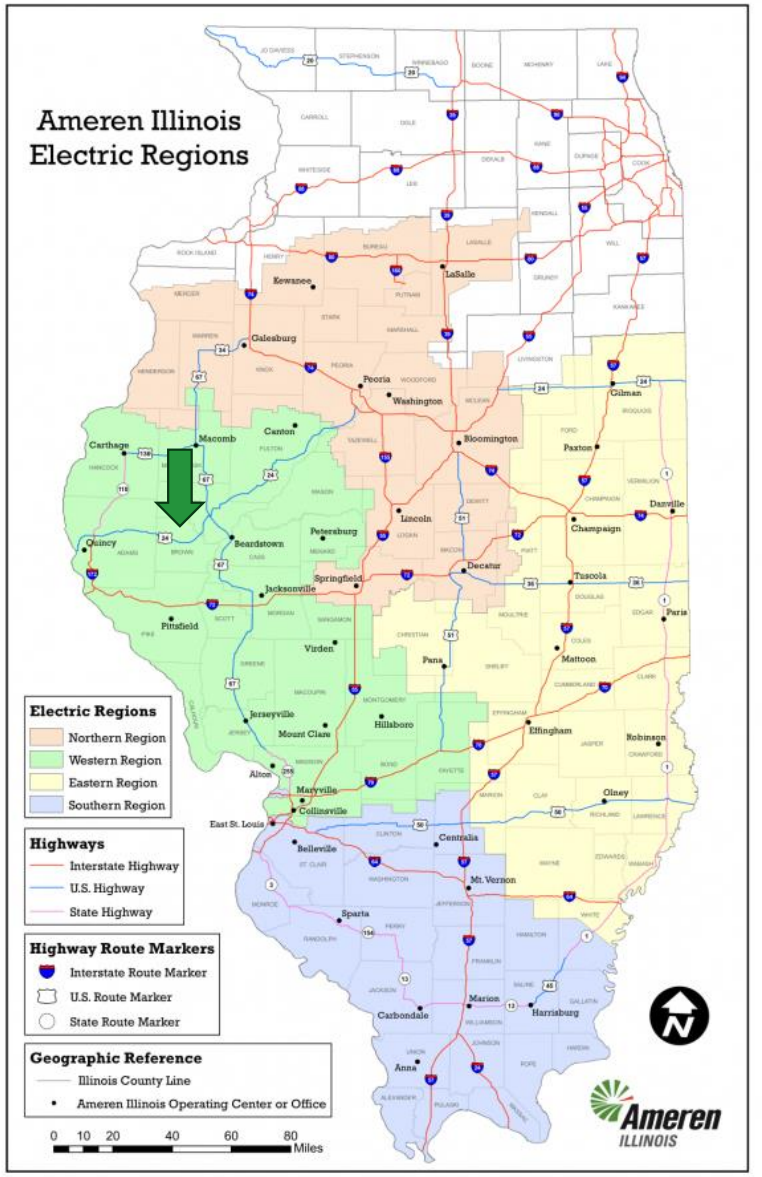
Graph Information





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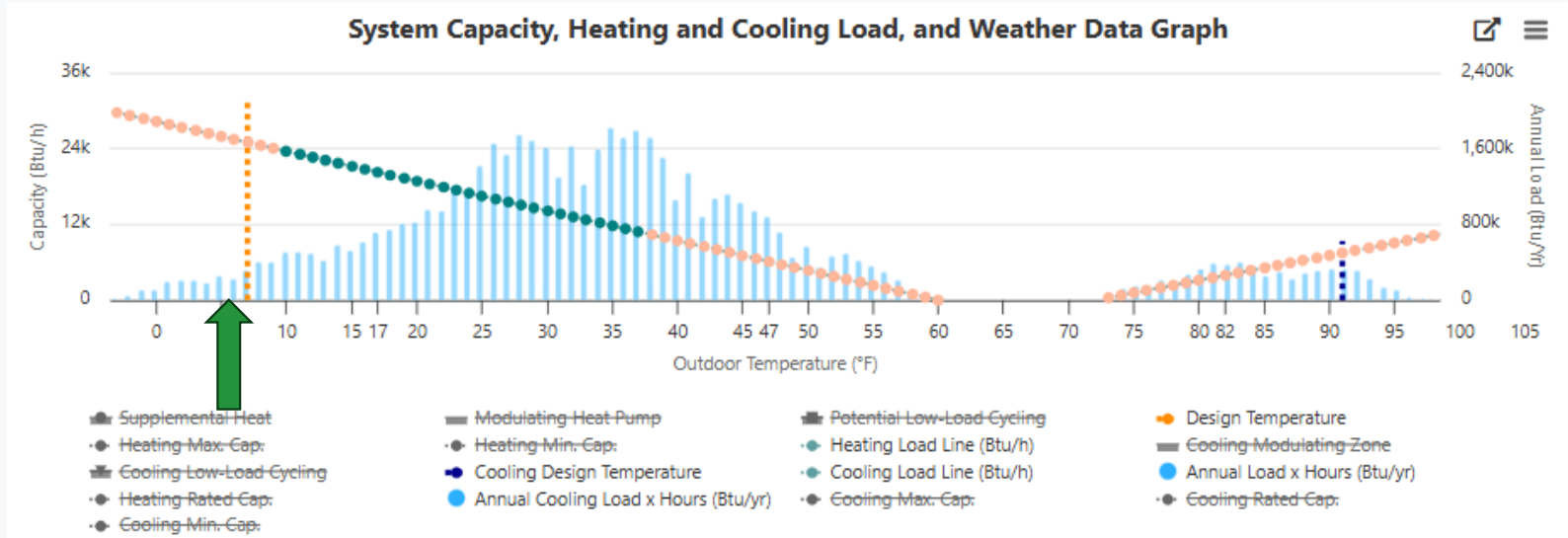

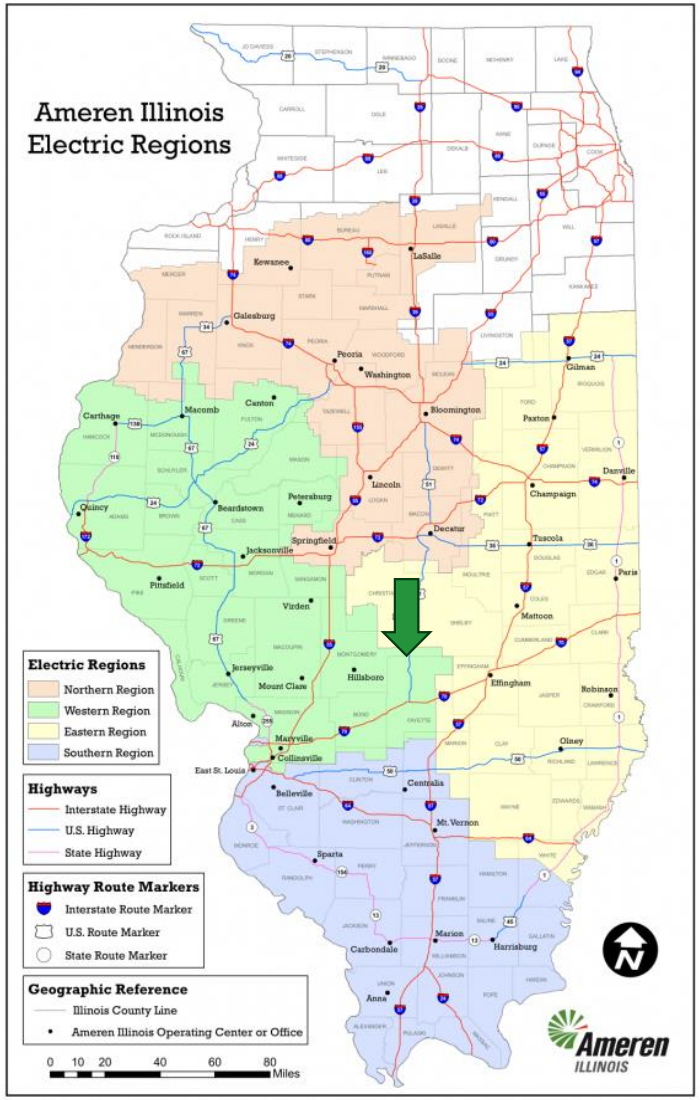

Illinois Design Conditions

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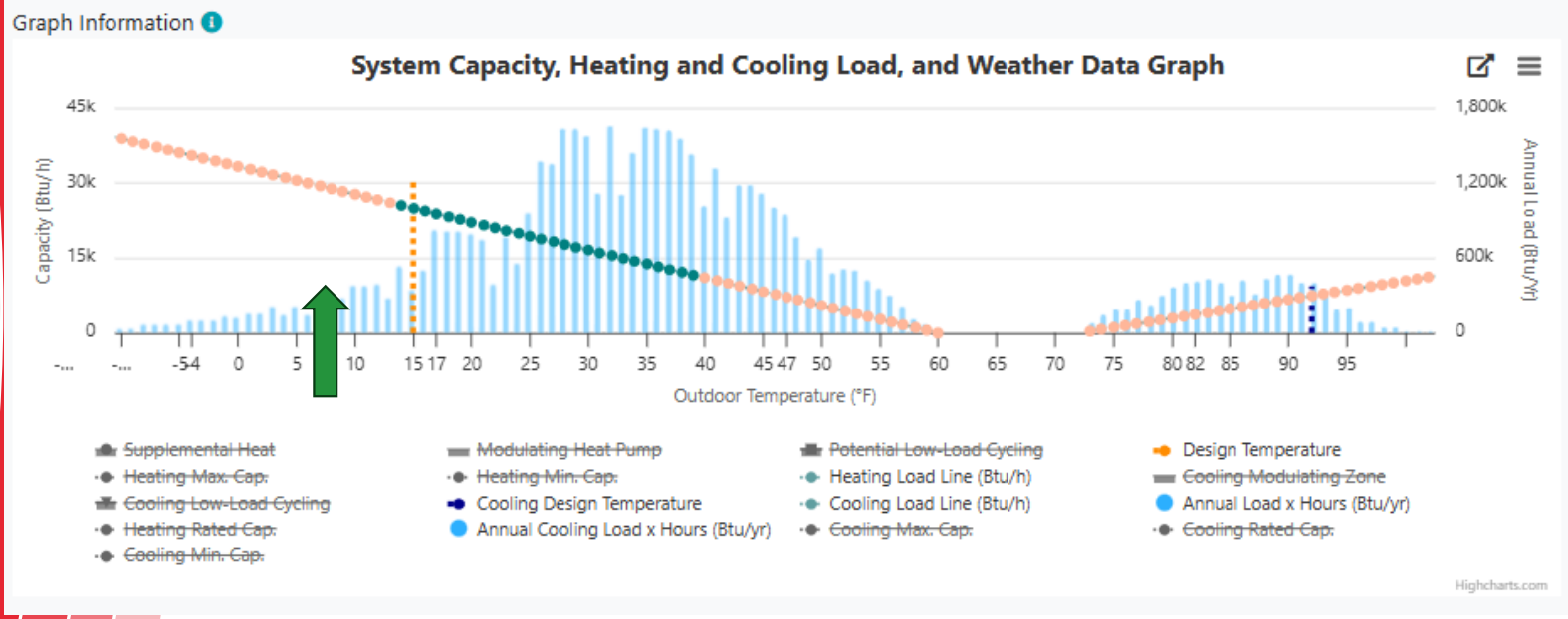

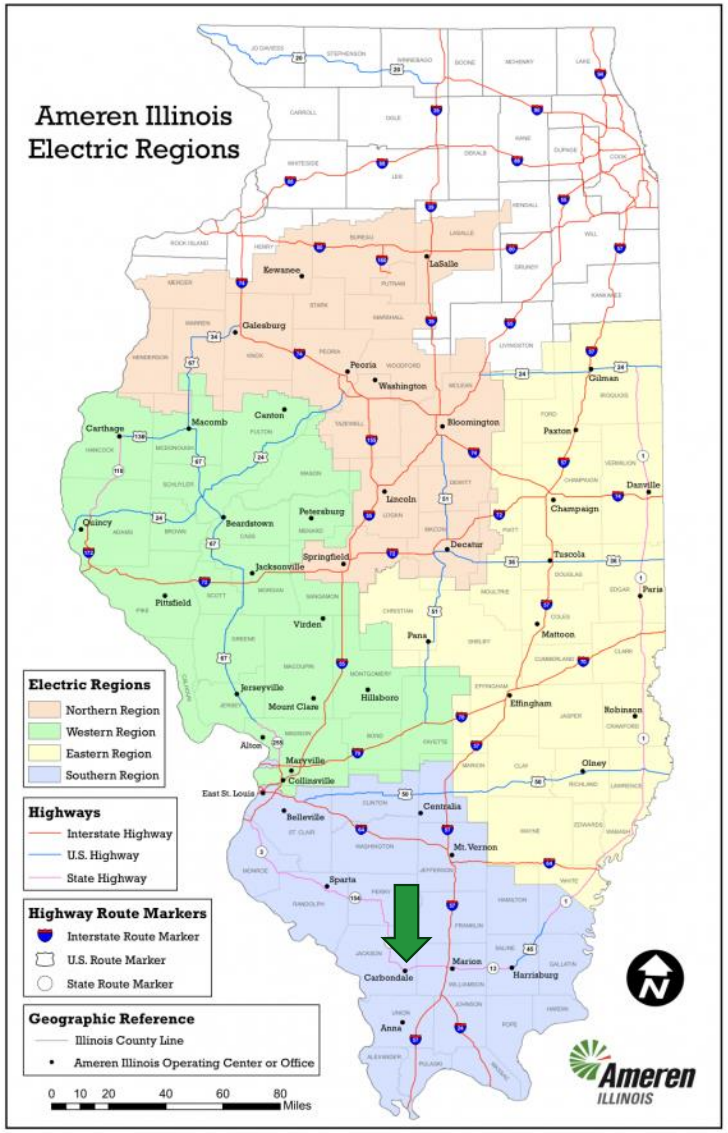

What other real world challenges may exist when oversizing?

- Run times matter!
  - Filtration
  - Ventilation
  - Destratification
  - Dehumidification
- On and off systems can lead to larger temperature swings.
- Larger compressors and fans may require larger electrical circuits.
- Larger compressors and fans may be noisier.
- Oversized systems may struggle with existing ductwork.

Free Sizing Online Tool

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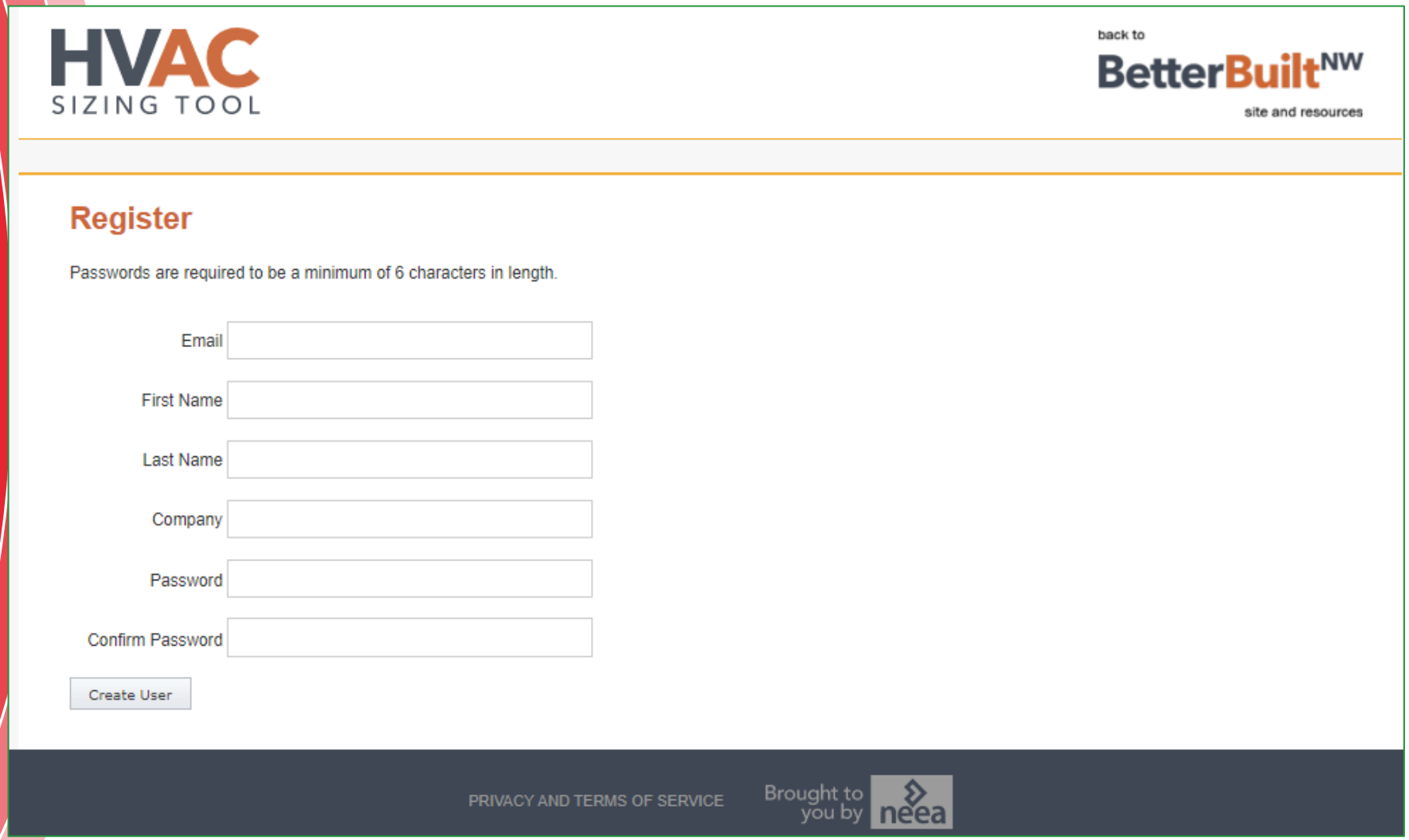


http://hvac.betterbuiltnw.com/Account/Register.aspx

energy vanguard

Date			
Data Collector		Contact #	
Homeowner / Builder		Contact #	
Property Street Address		Code Year	
City, State & Zip Code			

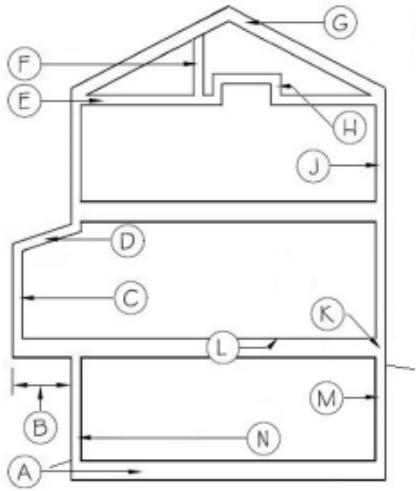
1. Front Door Faces ☐N ☐NE ☐E ☐SE ☐S ☐SW ☐W ☐NW

2. Home Description

3.Air Infiltration Rate

Blower Door @ cfm50	or	☐Tight	☐Semi-Tight	☐Average

4. Insulation



Location	R-Value Type	Cavity	Continuous
A: Slab Under			
Slab Edge			
B: Cantilevered & Frame Floors			
C: Exterior Walls, above grade			
D: Vaulted or Sloped Ceilings			
E: Flat Ceilings (typical blown attic)			
F: Attic Knee-walls			
G: Roofline (typical spray foam)			
H: Tray Ceiling Top/Side			
K: Rim/Band Joists			
L: Floor over Bsmt/Crawl/Garage			
M: Poured Bsmt or Crawl Walls Cavity			
Continuous ☐Exterior ☐Interior			
N: Framed Bsmt Walls			

XPS Extruded Polystyrene
EPS Expanded Polystyrene
ISO Polyisocyanurate
FGB Fiberglass Batts
BLN Blown Fiberglass/Cellulose
OC Open Cell Foam
CF Closed Cell Fo

5. Mark additional energy saving features present: ☐conditioned crawlspace, ☐encapsulated attic, ☐reflective shingles, ☐attic radiant barrier, ☐Energy Star home, ☐other above code certification program, ☐fireplace (sealed combustion), ☐fireplace (vented w/ outside air), ☐other: _____

6. Solid Doors (Only for information not on plans)

	Description	Location	Size (W x H x Thick)	☐R or ☐U-Value
Type 1				
Type 2				
Type 3				
Type 4				

7. Windows & Glazed Doors (=>50% glass) (Only for information not on plans)

	Description	Location	Size (W x H)	U-Value	SHGC
Type 1					
Type 2					
Type 3					
Type 4					
Type 5					
Type 6					
Glazed Doors					
Other					
Skylights					

8.HVAC System Preferences ☐no preference

	Location	Manufacturer	Area Served	Efficiency	Heat-Pump	Gas	Duct Type
1							
2							
3							

RM Round Metal **VF** Vinyl Flex
SQ Square Metal **DB** Duct Board

9. Mechanical Ventilation Preferences ☐no preference

On which system(s)? ☐1 ☐2 ☐3 ☐separately ducted

Fresh Air Intake Type	☐Vent. Dehumidifier	☐Supply Only	☐Exhaust Only	☐Balanced
Manufacturer		Model		
Rate (CFM)		Notes		

https://www.energyvanguard.com/hvac-design/

Example Houses

Older house (1950s)

- 1856 sq ft, 2 story home over a semi-conditioned basement.
- Heating load double the cooling load.

Newer house (2006)

- 2000 sq ft, 2 story home over a partial basement
- Heating and Cooling loads are similar.

Example House – Chicago Older Home

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HVAC SIZING TOOL

Site ID: 14268 | Heating: 53,500 BTU/hr
Area: 1,856 ft² | Cooling: 21,600 BTU/hr
Climate: Chicago, O'Hare AP | Latent: 4,000 BTU/hr

HELLO DAN WILDENHAUS | NEW SITE | SITES | REPORTS | CONFIGURE | HELP | ACCOUNT

SITE | BUILDING | ROOMS | WINDOWS | OVERRIDES | OPTIONS | SYSTEM | DUCT DESIGN | DUCT RESULTS | RESULTS | SUBMIT

Building

Save

✔ Values successfully saved.

Conditioned Floor Area	1856	Floors Above Grade	2
Average Wall Height	8.5	Bedrooms	3

Note: **Default insulation level** below is meant to provide a starting point for the house you are evaluating. You are able to override any specific items on later pages to override these default values. Please take care to override where neccessary.

Default Insulation Level: 2x4 weatherized w/vinyl windows ☐ Show all

Foundation Type: Conditioned Basement

Duct Location: Custom (enter details below)

Custom Duct Location

Attic %	29
Unconditioned Basement or Crawl Space %	0
Conditioned Area %	71

Direction Front Door (House Orientation): West

Year Built: 1951

Example House – Chicago Newer House

Ameren ILLINOIS | Energy Efficiency PROGRAM

HVAC SIZING TOOL

Site ID: 14269 | Heating: 36,500 BTU/hr
Area: 2,000 ft² | Cooling: 30,600 BTU/hr
Climate: Chicago, O'Hare AP | Latent: 5,300 BTU/hr

HELLO DAN WILDENHAUS | NEW SITE | SITES | ...NT

SITE | BUILDING | ROOMS | WINDOWS | OVERRIDES | OPTIONS | SYSTEM | DUCT DESIGN | DUCT RESULTS | RESULTS | SUBMIT

Building

Save

Conditioned Floor Area	2000	Floors Above Grade	2
Average Wall Height	8.5	Bedrooms	3

Note: **Default insulation level** below is meant to provide a starting point for the house you are evaluating. You are able to override any specific items on later pages to override these default values. Please take care to override where neccessary.

Default Insulation Level: 2x6 insulated w/vinyl windows — Show all

Foundation Type: Conditioned Basement

Duct Location: Custom (enter details below)

Custom Duct Location

Attic %	40
Unconditioned Basement or Crawl Space %	10
Conditioned Area %	50

Direction Front Door (House Orientation): West

Year Built: 2006

Rule of Thumb vs Manual J for Older Home

Was system oversized for heating?

35 btu per sq ft

1856 sq ft = 5.41 tons

Man J = 4.46 tons

YES, by almost a ton!!

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Rule of Thumb vs Manual J for Newer Home

Was system oversized for heating?

35 btu per sq ft

2000 sq ft = 5.83 tons

Man J = 3.1 tons

YES, by more than 2 tons!!

Image courtesy Flickr – Mike Kline

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Example Enhanced Rule of Thumb for Gut Checking Only

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Heating Load Estimator (*in BTUs per square foot of floor area*)				
	Local Design Temperature			
House Description	**Below -10˚ F**	**-10˚ F to 5˚ F**	**5˚ F to 20˚ F**	**Above 20˚ F**
No-wall Insulation; single pane window	47	41	35	29
2x4 wall w/ insulation; 2P windows	25	22	19	16
2x6 wall w/ insulation; 2P windows	18	15	13	11
New Construction (Post 2012)	16	14	12	9

Chart courtesy of the Northwest Energy Efficiency Alliance

Evaluating Existing Ductwork

1. Engaged discussion with homeowners and qualitative test - does the existing system and ductwork deliver hot/cold air to all rooms?

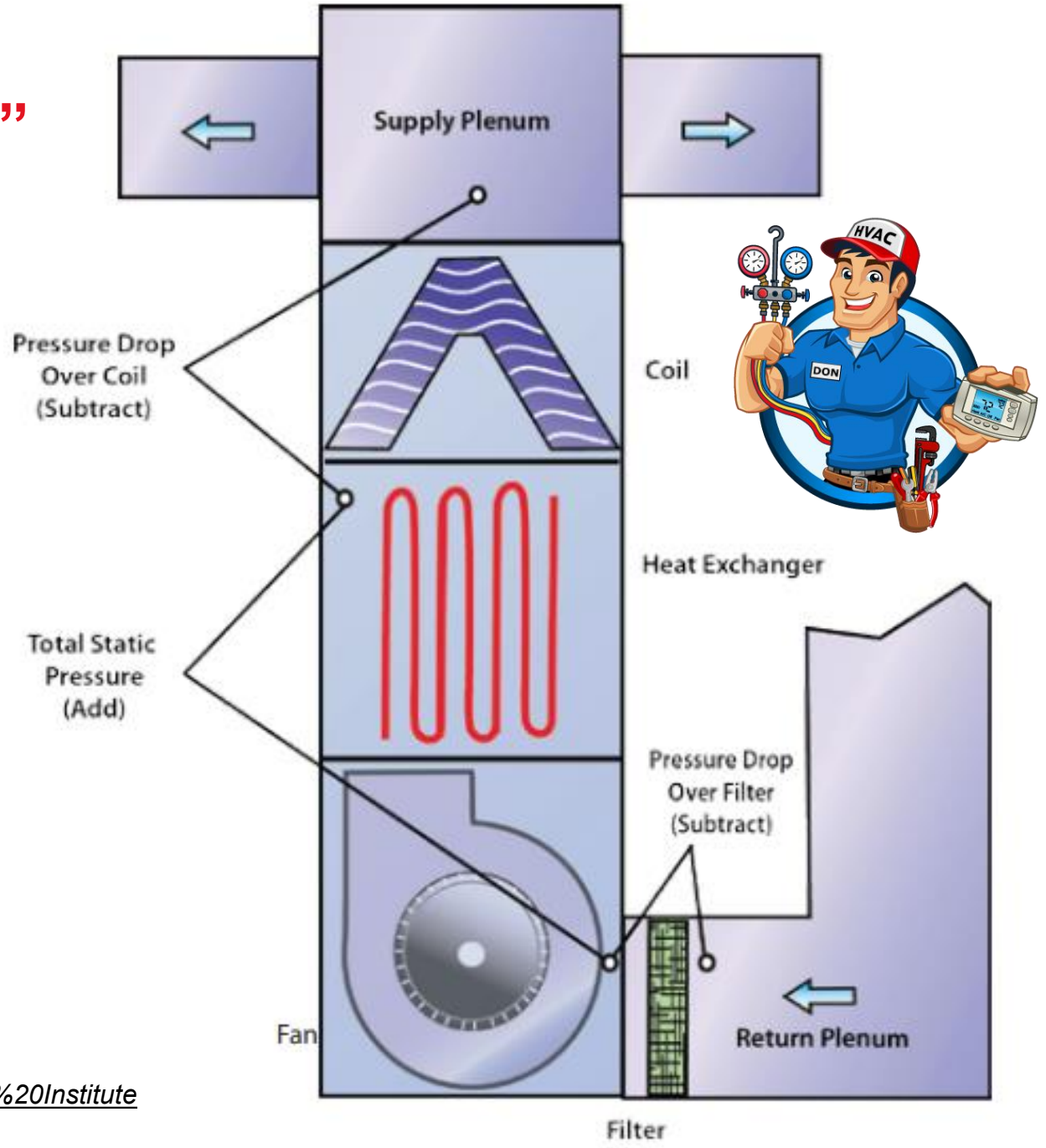
2. Visual inspection of the ductwork:
   a) Is it located in attic and unconditioned basement?
   b) Are the ducts visually damaged or leaking?
   c) Are the ducts properly insulated?
   d) Ducts that are leaky and outside the envelope can lose 25% of the heating energy!

3. **Perform static pressure test(s)**

4. **Record static pressure and identify key components that will add to static pressure build up.**

TESP, Fan Tables and What is meant by “External”

- “External” designates how the unit was shipped:
  - With a central heat pump utilizing auxiliary heat, the air handler and coil are shipped in one piece. The fan curves reflect this the resistance of the of the coil.
  - With gas furnaces with an AC or HP coil, the coil is not shipped with the air handler. The fan curves in this case, do not reflect the resistance of the coil. When testing these systems, the supply side measurement MUST be furnaces taken before the coil.



https://www.energystar.gov/sites/default/files/specs/National%20Comfort%20Institute%20-%20Measure%20and%20Interpret%20Static%20Pressures.pdf

Best Practices for Load Calculations
Key Takeaways

- Determine what tool or software you are going to use or use tools you are comfortable with.
- Decide how data collection is best done:
  - Onsite: This is very beneficial and demonstrates confidence
  - Remote: Data collection will come from the homeowner and may need to be verified before installation
- Compare against enhanced rules of thumb to ensure accuracy
- Evaluate the duct work:
  - Existing performance/location
  - Test total static pressure

General Design and Selection

Selection, often in the form of Manual S (but not always) **involves applying the results of heat and cool load sizing calcs to the selection of equipment** that will **deliver the necessary heating and cooling**, when and where it's wanted. Design and Selection needs to include existing conditions and the application type under consideration. The following is a summary from NEEP:

Manual S: Summary
Manual S directs, for central air conditioners and heat pumps, that: • The selected equipment will satisfy the building's total load requirements at design conditions • Manufacturer's product data shows that latent loads are met • Total equipment capacity is between: - 95% and 115% of total cooling requirements (for air conditioners and heat pumps) *or* - 95% and 125% of total cooling requirements (for heat pumps in heating dominated climates). • It allows stepping up to the next largest nominal piece of equipment, per the desired product line, that is available to satisfy both the latent and sensible requirements.

Sizing tools:

- ACCA Manual S
- Manufacturer sizing and selection tools
- **NEEP Cold Climate Product List and NEW Sizing Tool**

Size for Heating or Cooling?

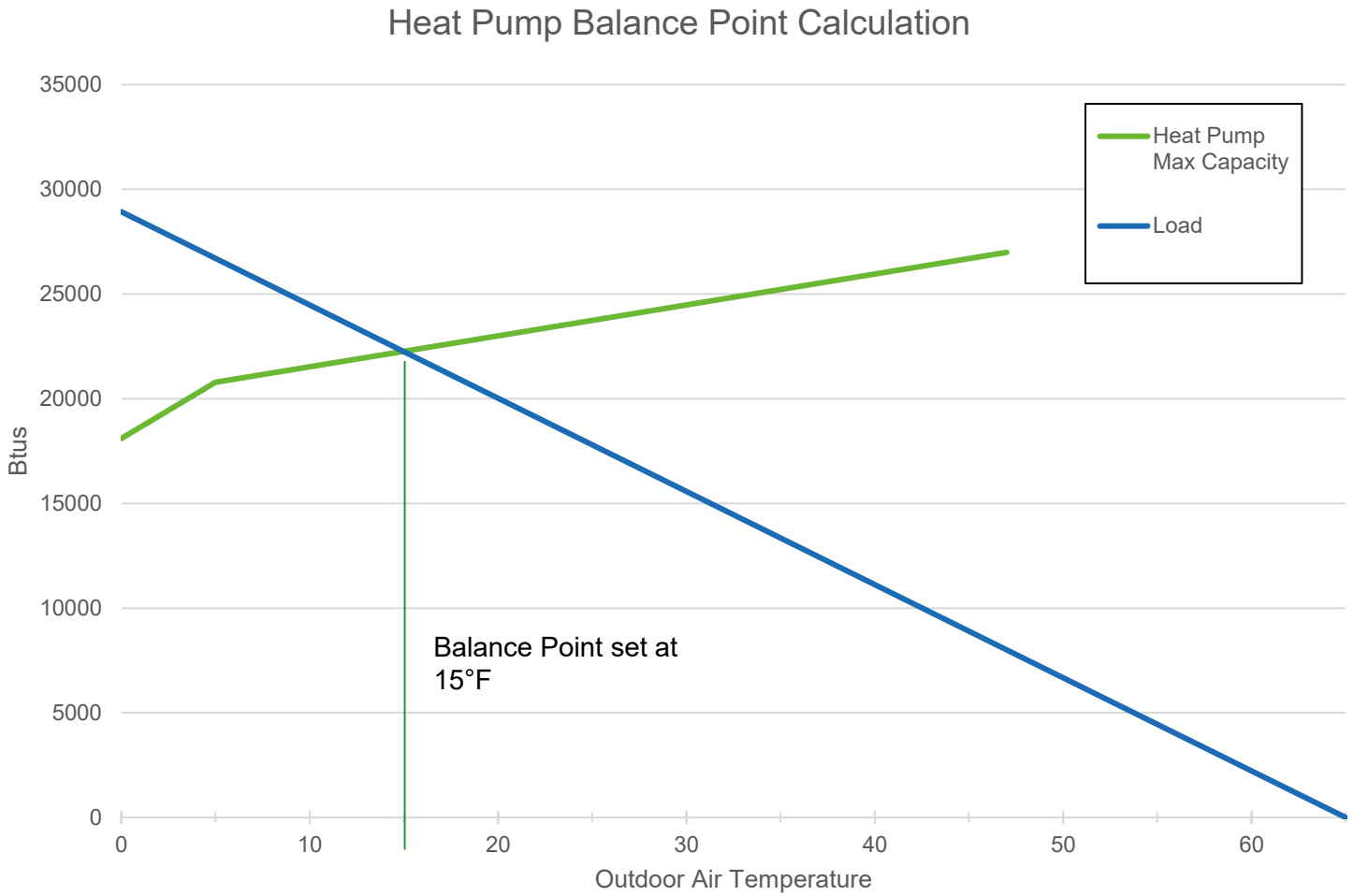
Old School

- Size for cooling and then go up a ton.
- Based on older single or two speed systems.
- Does not maximize heating potential of HPs and does not account for modulation capabilities of VSHPs!

New School

- Start by **sizing to largest load for ER, old heat pumps, propane**/home heating oil backup.
- **For natural gas, size to cooling load** unless the homeowner driver is carbon savings.
- Using Manufacturer data for Max and Min capacities, check to see if the smaller load is between the Max and Min at the design temp.
- Likely OK to be within a half ton with variable capacity HPs!

Determining the Thermal/Capacity Balance Point



Example House – Chicago Older Home

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HVAC SIZING TOOL

Site ID: 14268 | Heating: 53,500 BTU/hr
Area: 1,856 ft² | Cooling: 21,600 BTU/hr
Climate: Chicago, O'Hare AP | Latent: 4,000 BTU/hr

HELLO DAN WILDENHAUS | NEW SITE | SITE ... UNT

SITE | BUILDING | ROOMS | WINDOWS | OVERRIDES | OPTIONS | SYSTEM | DUCT DESIGN | DUCT RESULTS | RESULTS | SUBMIT

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Year Built: 1951

NEEP Cold Climate Product List

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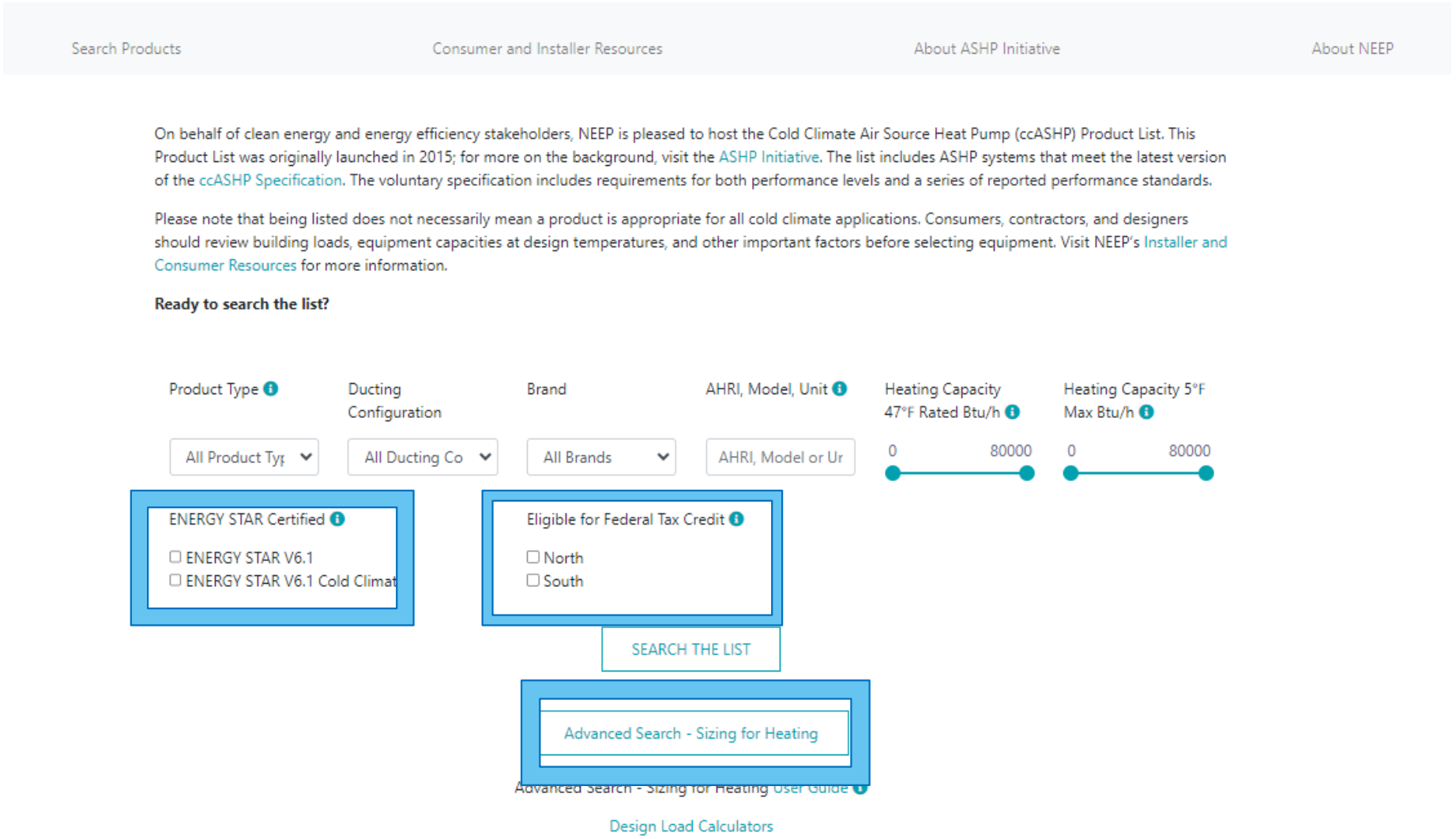
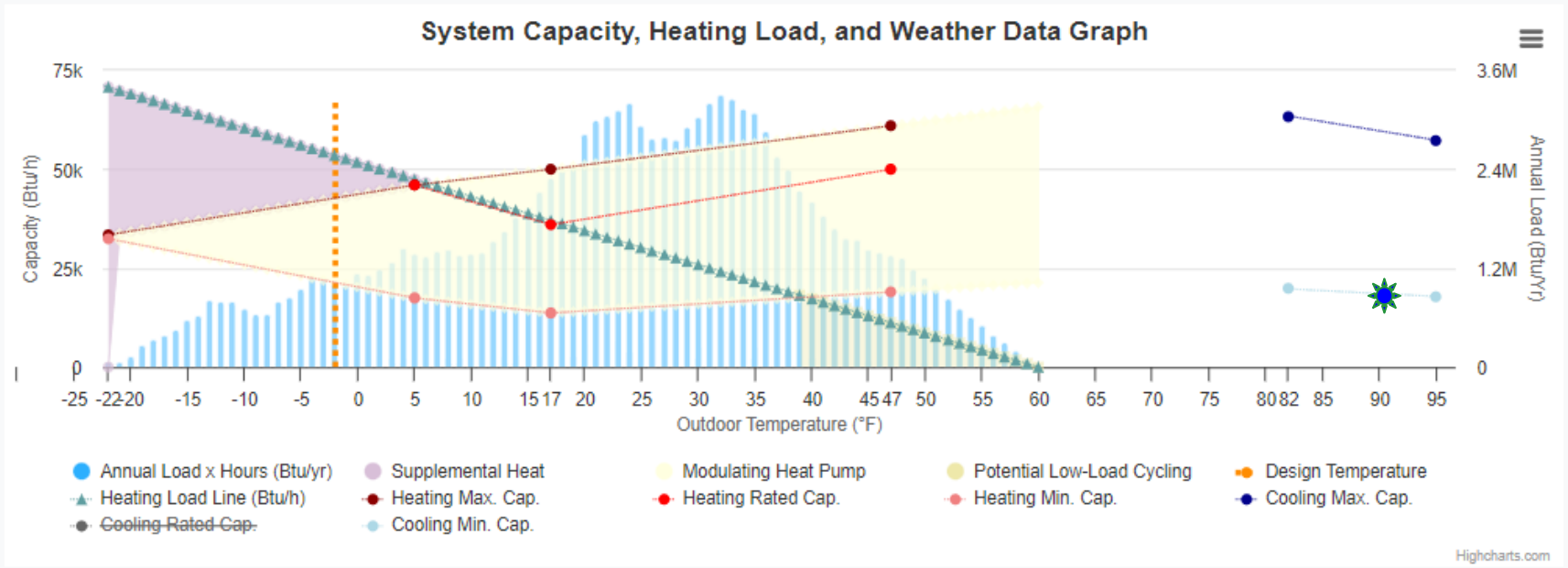


Example System

Graph Information



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Area: **1,856** ft²
Climate: **Chicago, O'Hare AP**
Heating: **53,500** BTU/hr
Cooling: **21,600** BTU/hr
Latent: **4,000** BTU/hr

Product Sizing For Heating

Field Information

Capacity Balance Point (°F)	6
Minimum Capacity Threshold (°F)	39
Maximum Capacity at Design Temp (Btu/h)	42,741
Percent Design Load Served	79.9%
Annual Heating Load (MMBtu)	125.9
Percent Annual Heating Load Served	86.9%

Field Information

Annual Btu's Covered by Supplemental Heat (MMBtu)	16.5
Hours Requiring Supplemental Heat	395
Percent Hours Requiring Supplemental Heat	6.9%
Percent Annual Load Modulating	68.4%
Percent Annual Load with Low-Load Cycling	16.8%

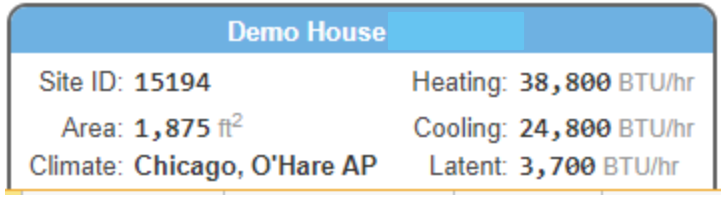
Remember our heating and cooling load for the older home?

https://ashp.neep.org/

Dehumidification and “Right Sizing”

Sensible Heat Ratio

- Ratio of sensible vs latent heat loads in the building



- For this building, the latent load for cooling is 3,700/24,800 or 15%. This means the sensible heat ratio is 85%

Sensible Heat Fraction

- This is the capability of the equipment you are selecting.
- Modern, high SEER2 heat pumps (and ACs) have much higher sensible heat fractions when compared to older systems.
- Your selected equipment should have a sensible heat fraction of **0.85 (85%) or lower** to dehumidify during typical run times. In addition, this fraction is only for once the system hits its full system capability, which depending on equipment could be 20 minutes.
- ***Therefore, you need to BOTH pick systems with the right SHF and have longer run times to ensure that the system is running at rated capabilities to properly dehumidify!***

Sizing Guidance Resources

- NEEP Installer Resources - Guide to Sizing and Selecting Heat Pumps
- Air-Source Heat Pump Sizing and Selection Guide NRCAN
- NEEP Size for Heating Users Guide

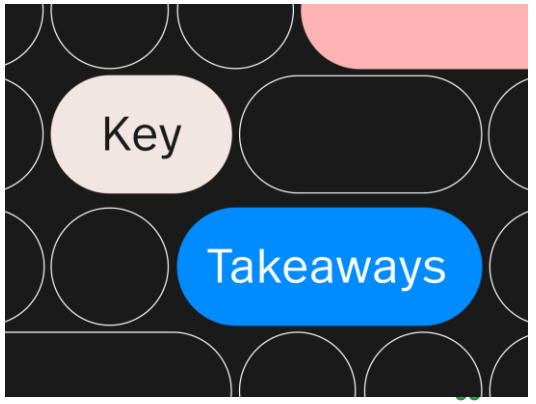
HVAC Sizing Tool

NEEA Heat Pump Recommendations

NEEP ASHP Search Tool

Best Practices for Equipment Selection
Key Takeaways

- Use the NEEP tool or expanded performance data to view system performance
- Compare different size products against the load
- Ensure the heat pump can run at low enough capacity to properly maintain the cooling load
- Communicate the systems performance to the customer
  - Ensure proper control strategy
  - Ensure proper balance point settings



Switchover (Changeover/Cutoff) Temperatures and Service Contracts

Typically, around 70% of contractors offer service/maintenance contracts

Of these, the average close rate on contracts is around 50%

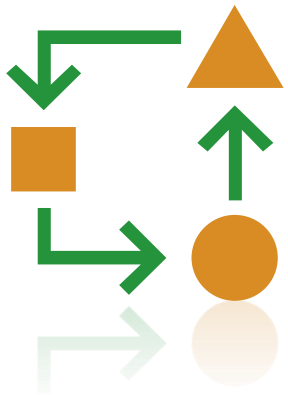
What if your service contract included adjusting switchover temperatures to minimize homeowner utility bills (or comfort)?

Do you think your competitors are doing this?

Typical Switchover Temperatures by Application

Application	Typical switchover temp
ccDHP displacing baseboard heat or gas boiler	0-5º F (compressor lockout no higher than this)
ccASHP displacing propane furnace	Depends on cost of propane and sizing, including duct evaluation: 5-25º F
ASHP displacing natural gas furnace	Depends on gas and electric rates and customer motivation: 25-45º F (ccASHP) 35-45º F (two stage HP)

Summary of Key Milestones



Understand	Understand the resident's goals, pain points, wants, and budget as a guide
Perform	Perform an accurate load calculation
Design around	Design around application and fuel types
Evaluate	Evaluate ductwork
Size and Select	Size and Select to the right application and fuel type
Use Tools	Use tools that help you sell and instill confidence!

Q&A

Thank you for attending today’s training!

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Thank you!

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