Center for Energy and Environment

Load Calculations for Sizing Heat Pumps in Colorado

Part 1 of FREE Heat Pump Training

You are here!

Value Proposition

Proper heat pump sizing and selection are critical for quality installation and customer satisfaction. Manual J & S calculations not only enhance your work but are also required for current and upcoming heat pump rebates from utilities, municipalities, and the State of Colorado.

Energy Smart Colorado has partnered with La Plata Electric Association, BEL-CO, Holy Cross Energy, Xcel Energy, and Platte River Power Authority to offer TWO FREE ONLINE WEBINARS to support HVAC contractors with knowledge and skills for quality installations. These trainings are facilitated by Dan Wildenhaus from the ~~Consortium for Energy Efficiency~~ (CEE).

Today:

- ✓ Importance of Right Sizing Equipment & Calculating Loads
- ✓ How Weatherization Affects Load Calculations
- ✓ Load Calculation Fundamentals
- ✓ Tools for Load Calculations

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Where you are headed!

Value Proposition

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Friday:

- ✓ Which Load to Size To
- ✓ Heat Pump Sizing Fundamentals
- ✓ Heat Pump Selection Fundamentals
- ✓ Tools for Heat Pump Sizing and Selection

Register for March 14th Session!

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A tale of two CEEs!

CEE SM
Consortium for Energy Efficiency

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Center for Energy and Environment

Your Trainer

Dan Wildenhaus

Sr Technical Manager and Trainer–
Center for Energy and Environment

15 years as a contractor doing HVAC and Weatherization

15 years as a consultant and trainer for utilities and governments

Colorado resident

We’re a mission-driven non-profit that loves to partner!

Learn more about Center for Energy and Environment in CO

What type of work we do

Technical trainings

Pilot/Program Management

- Design/Implementation
- Equity/Income-Qualified
- Commercial/Multi-family/Residential
- Energy Advising/Customer Experience

Who we have worked for

City and County of Denver
Platte River Power Authority
Xcel Energy
Gunnison County
BELCO
Energy Smart Colorado

Who we are members of

SWEEP
EEBC

Where we can be found

www.mncee.org

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Based in Minnesota with an expanding Colorado-focused team

Who is Center for Energy and Environment in CO?

Gabrielle Rinck

Program Implementation Manager- Colorado

Based in Colorado Springs, Gabrielle is responsible for the implementation and delivery of programs and pilots in Colorado

grinck@mncee.org

Robin Osindele

Energy Advisor- Electrification

Based in Englewood, Robin works with equity priority commercial building owners, contractors, and community-based organizations to advance electrification

rosindele@mncee.org

Dan Wildenhaus

Senior Technical Manager- Training & Consulting Services

Based in Longmont, Dan supports training, programs, pilots, and business development in Colorado, New Mexico, and the Northwest

dwildenhaus@mncee.org

And growing…

Center for Energy and Environment

Ideas move at the speed of revolution. People and programs move at the speed of evolution; until now... We are CEE

Why are load calculations and proper sizing important?

Level-setting

Center for Energy and Environment

What’s the worst that could happen?

Undersized system

- Does not heat the home during the coldest parts of winter
- Does not cool the home during the hottest parts of summer
- May need to run for long periods of time at FULL power/speed

Oversized system

- Short cycles (on and off A LOT)
  - Poor distribution
  - Hard on equipment
  - Annoying to residents
- Causes excess fan energy use
- May be oversized for ductwork

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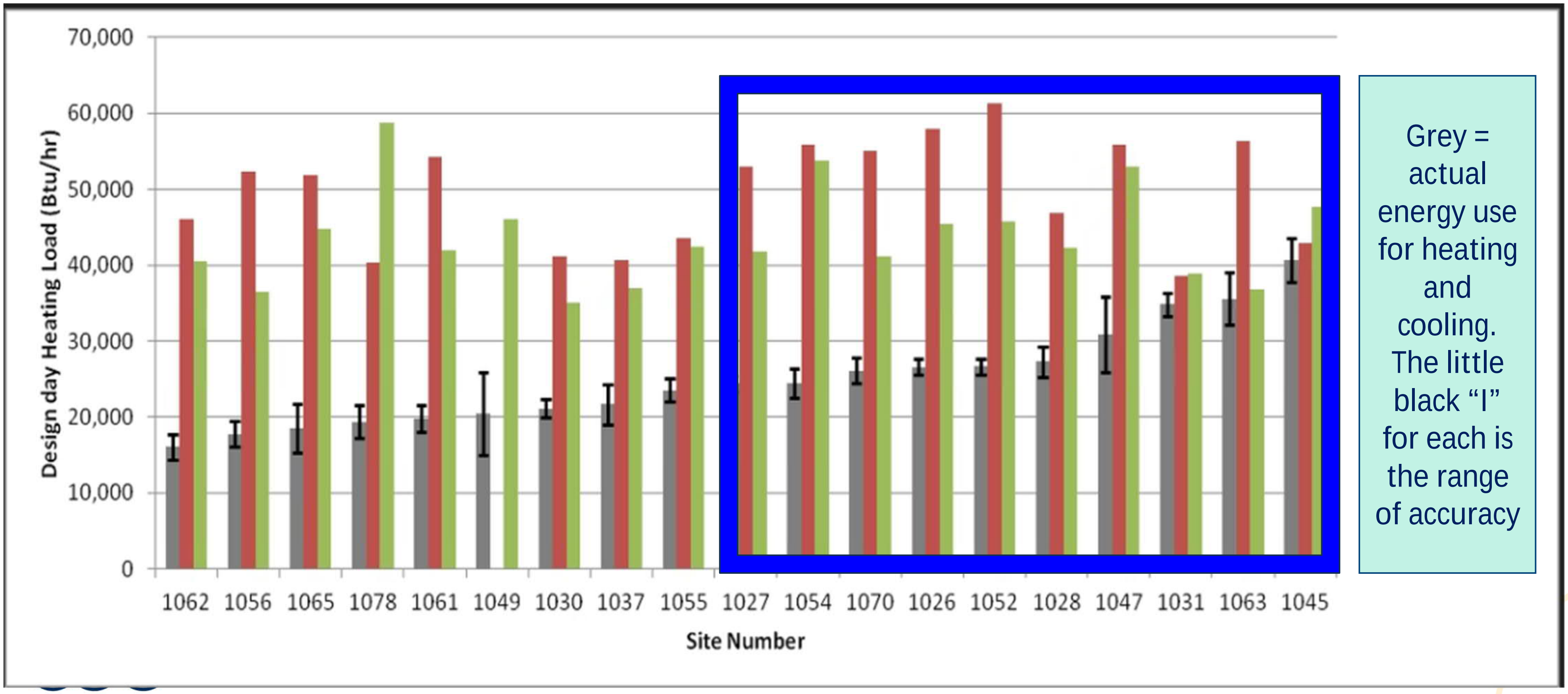
Concerned that Manual J won't size large enough?



Guess who said this? (hint, it wasn't Dan)

*"Manual J calculations should be aggressive, which means that the designer **should take full advantage of legitimate opportunities to minimize the size of estimated loads**. In this regard, the practice of manipulating the outdoor design temperature, not taking full credit for efficient construction features, ignoring internal and external window shading devices and then **applying an arbitrary "safety factor" is indefensible.**"*

*"**No additional safety factors are required** when load estimates are based on accurate information pertaining to the envelope construction and duct system efficiency. Large errors are possible if there is uncertainty about insulation levels, fenestration performance, envelope tightness or the efficiency of the duct runs installed in the unconditioned space."*

ACCA Manual J version 8

Guess who said this? (hint, it also wasn't Dan)

"We need to stop arguing about the length of the hair cut and discuss whether or not to shave the head."

HVAC and training legend, Russ King, inventor of KwikModel 3D (Dan may have gotten the quote a little off though)

"125 to 140% of the design heating load is reasonable to expect (when sizing off existing equipment)"

Natural Resources Canada's AIR-SOURCE HEAT PUMP SIZING AND SELECTION GUIDE

In one large-scale survey, nearly 40 percent of contractors indicated that they purposefully over-sized equipment, citing reasons such as "to reduce call backs," "to allow for future expansion, " or "customers demanded it."

DOEs Right-Sizing Heating and Cooling Equipment Technical Fact Sheet

Problem statement:

Sizing, design, and selection is often done based solely on rules of thumb or based on previous sized systems.

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

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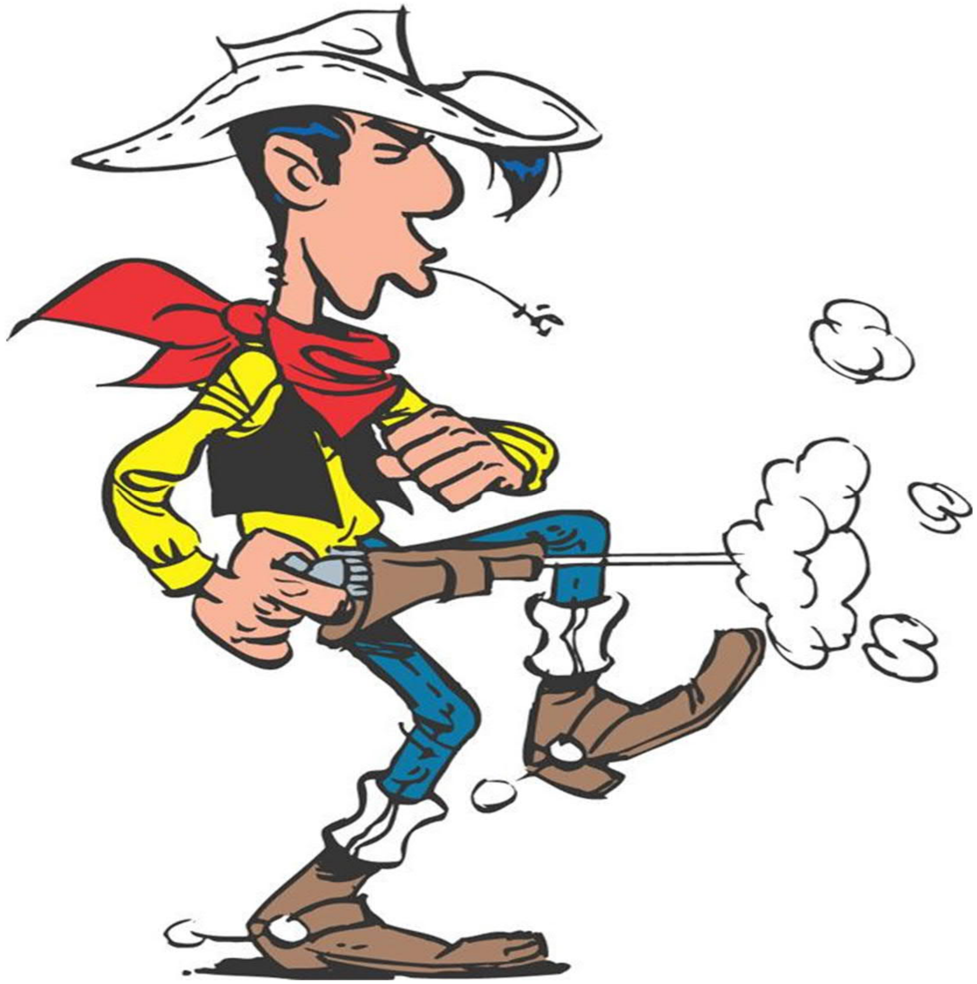
All sizing considerations – Must have a load calculation!

Level of load calculation time and effort required:

- Low
  - “Shooting from the Hip”
  - Sized off existing equipment size
  - Using rules of thumb
- Medium-High:
  - Comfort Consult + **Block load**
  - Existing equipment – with run time or utility bills
- High:
  - **Room-by-room** - Man J or equivalent – detailed envelope information needed



Does sizing really matter? - From research

If **oversized for cooling by more than 140%, some energy use increase may be seen** (depends on equipment type, brand, algorithms, control strategies and settings, etc..)

If **oversized for heating by more than 150%, some energy use increase may be seen** (depends on equipment type, brand, algorithms, control strategies and settings, etc..)

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%!

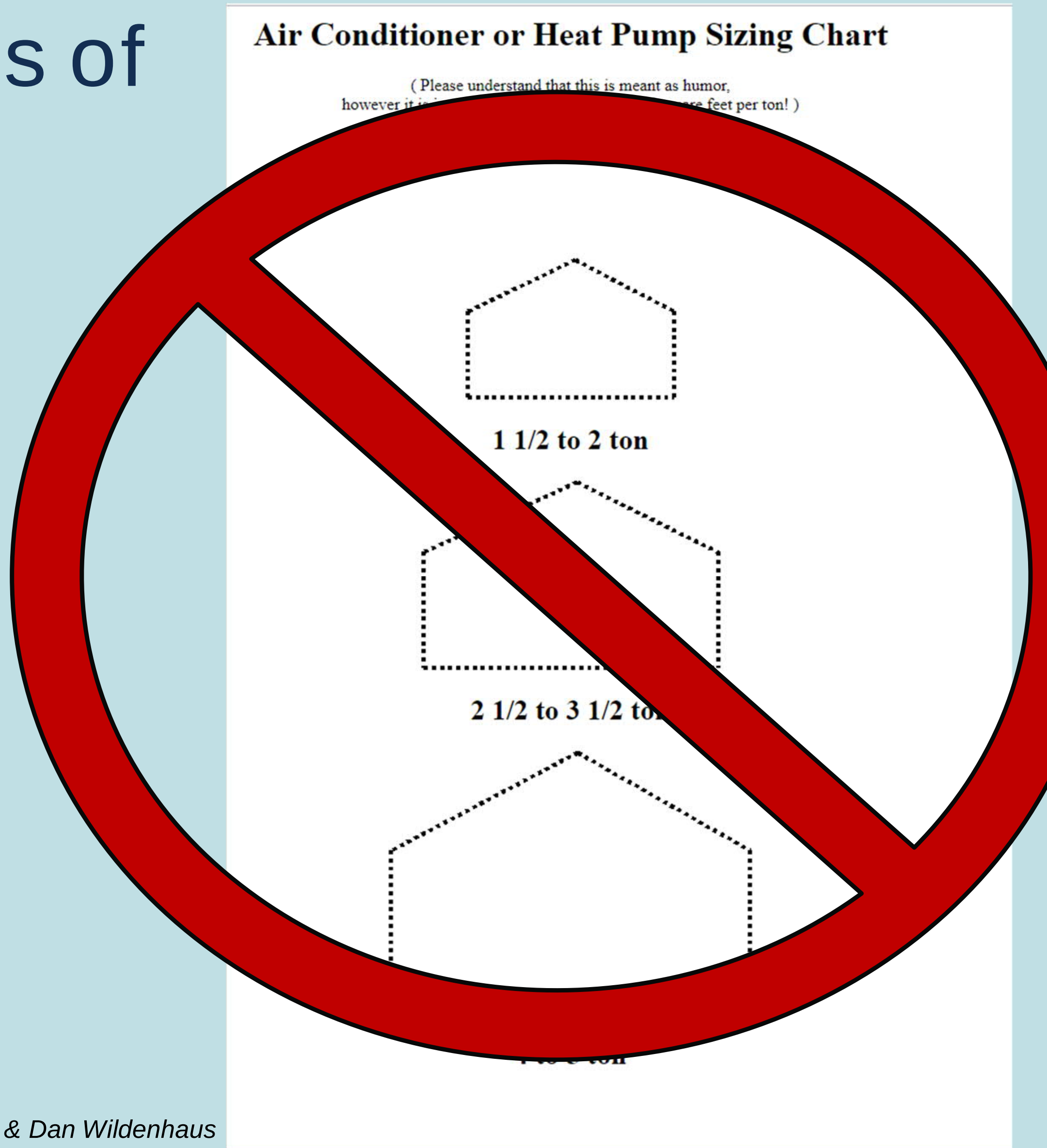
NIST, NREL, Proctor Engineering, Illinois Institute of Technology

What other real-world challenges may exist when oversizing?

- For filtration, run times matter!
- For ventilation, run times matter!
- For home destratification, run times matter!
- On and off systems can lead to larger temperature swings.
- For humidification, run times matter!
- Larger compressors and fans may require larger electrical circuits.
- Larger compressors and fans may be noisier.
- Oversized systems may struggle with existing ductwork.

System Sizing - Rules of Thumb

- One Ton Per 400 sq ft
- 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
- Rules of Thumb tool I found online!

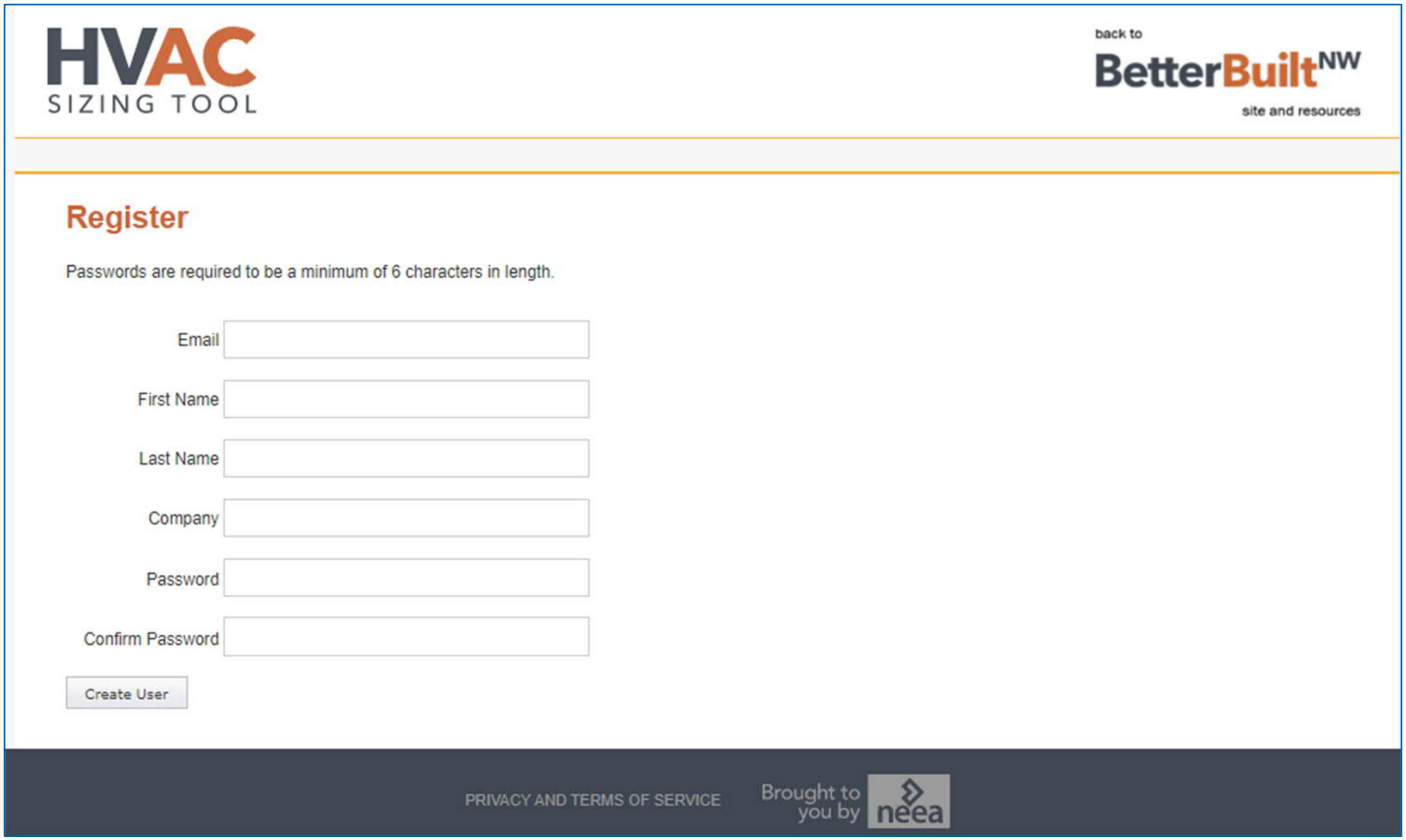


Slide courtesy Bruce Manclark & Dan Wildenhaus

Said every 6th grade teacher ever…

"You will only get out of it what you put into it!"

Free sizing tool online we are using today



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

Example **House**

1600 sq ft, 2 story home over a basement in Leadville.

Ducts mostly in the basement.

Home built in the mid-50s. Both furnace and AC are quite old (~20 years).

AC doesn’t keep up with the house.

Comfort complaints year-round upstairs.

Ductwork is all metal but seems to be a bit small and in need of evaluation.

Guestimated Loads with "rules of thumb" for this house

Heating Load = **88,000 Btu/hr**

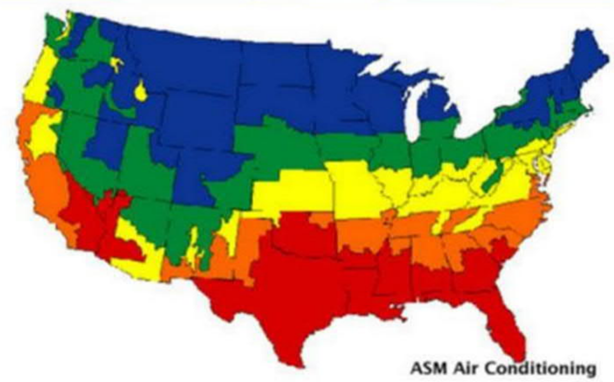
1600 sq ft, 50-60 Btus per sq ft.

Picked 55 as an average.

Cooling Load = 2.5 tons or 3 tons = **30,000** or **36,000** Btu/hr

Heating Square Footage Range by Climate Zone

ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5
30 - 35 Btu's per square foot	35 - 40 Btu's per square foot	40 - 45 Btu's per square foot	45 - 50 Btu's per square foot	50 - 60 Btu's per square foot

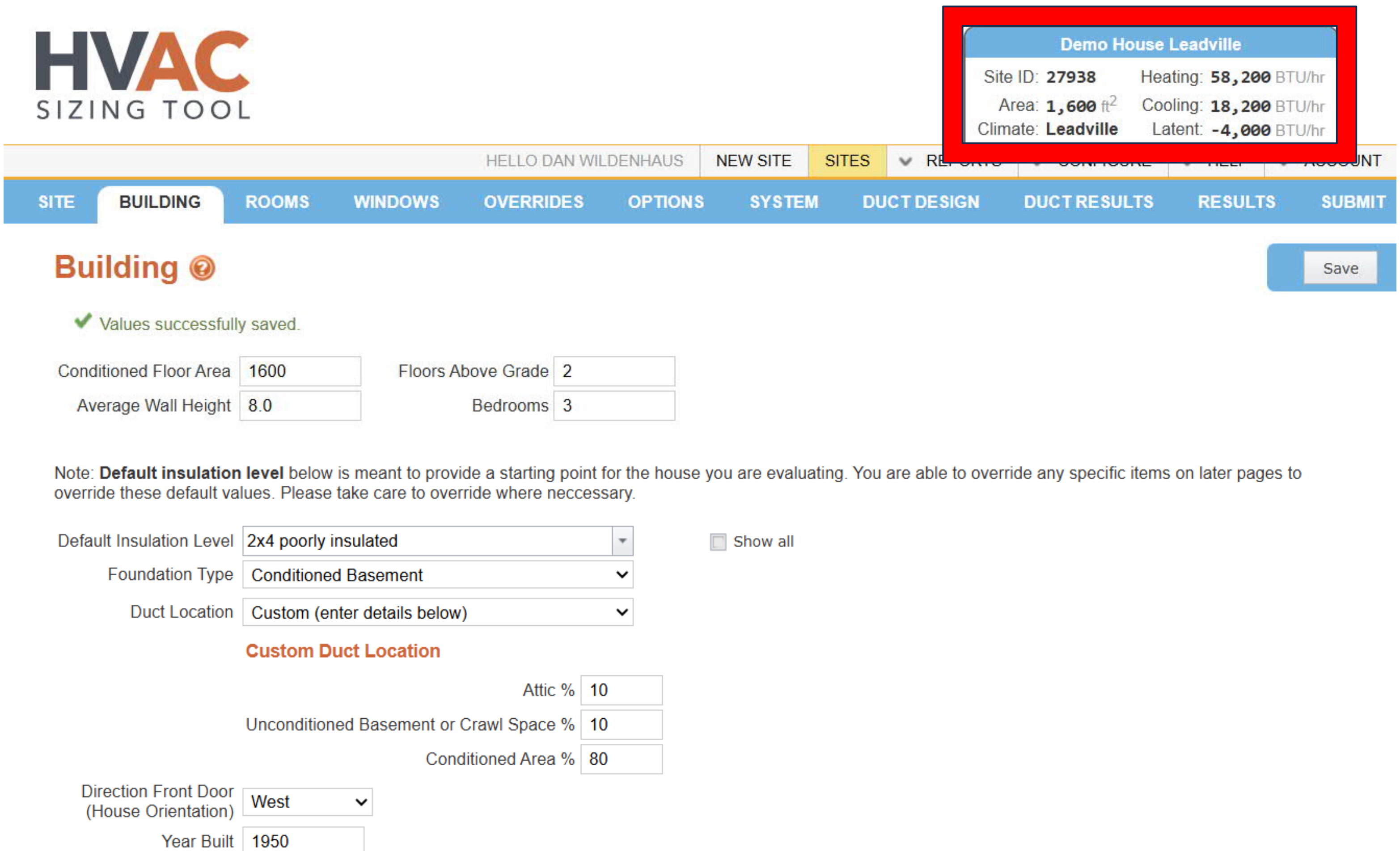


Air Conditioning Square Footage Range by Climate Zone

	ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5
1.5 Tons	600 - 900 sf	600 - 950 sf	600 - 1000 sf	700 - 1050 sf	700 - 1100 sf
2 Tons	901-1200 sf	951 - 1250 sf	1001 - 1300 sf	1051 - 1350 sf	1101 - 1400 sf
2.5 Tons	1201 - 1500 sf	1251 - 1550 sf	1301 - 1600 sf	1351 - 1600 sf	1401 - 1650 sf
3 Tons	1501 - 1800 sf	1501 - 1850 sf	1601 - 1900 sf	1601 - 2000 sf	1651 - 2100 sf
3.5 Tons	1801 - 2100 sf	1851 - 2150 sf	1901 - 2200 sf	2001 - 2250 sf	2101 - 2300 sf
4 Tons	2101 - 2400 sf	2151 - 2500 sf	2201 - 2600 sf	2251 - 2700 sf	2301 - 2700 sf
5 Tons	2401 - 3000 sf	2501 - 3100 sf	2601 - 3200 sf	2751 - 3300 sf	2701 - 3300 sf

Leadville is in Zone 5

Example House



What did we learn about old school rules of thumb?

Was heating oversized?

YES, by almost 2.5 tons!!!

Was cooling oversize?

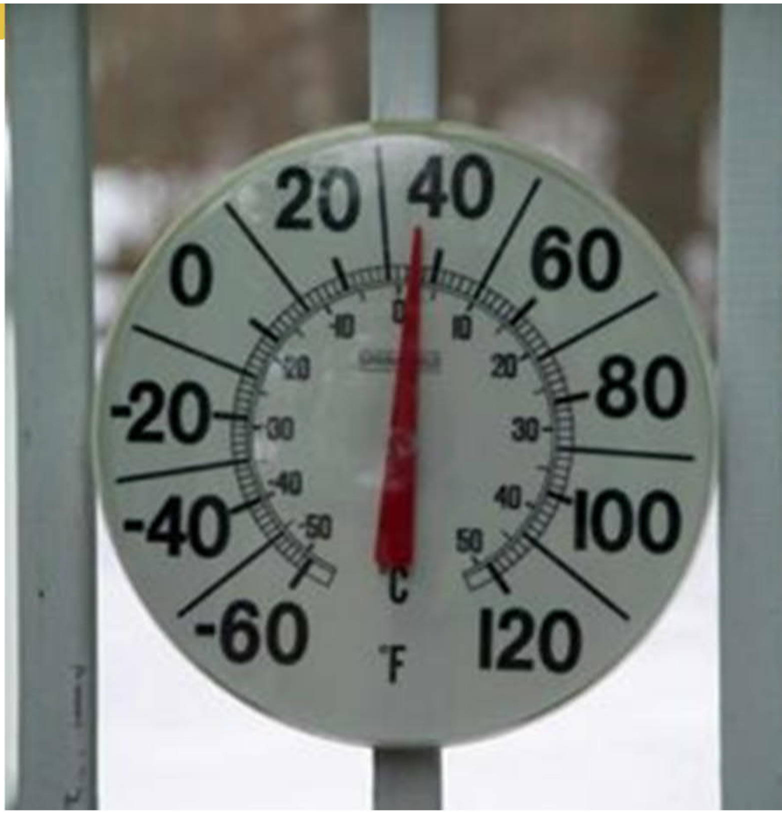
YES, by almost a ton and a half!

Doing Load Calcs

Specific to Colorado climates

Definitions:
Design Conditions

- **Design Temperature is not the coldest or hottest day of the year**
- **Winter Design Conditions: It only gets colder than this <u>0.4%-1%</u> of the time**
- **Leadville:**
  - Winter Design Condition is -8°F (99.6%)+
  - Summer Design 74°F (0.4%)*
- **Pueblo for reference:**
  - Winter +1°F (99.6%)+
  - Summer 99°F (0.4%)*



*homeowners don't care; they just want it cool in summer

+Ok to use the 99.6 & 0.4 ASHRAE numbers when going all-electric

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Definitions:
Design Conditions part 2

- **Internal design temps are also prescribed**
- **Be realistic! Interview and Educate homeowners***
- **Heating Set Point:**
  - Prescribed: 70°F
  - Flexible: 69 to 72°F
- **Cooling Set Point:**
  - Prescribed: 75°F
  - Flexible: 76 to 74°F

*Note if you did not use prescribed numbers

Educate homeowners about better mixing and longer run times with heat pumps. Likely don't ever need to go outside of flexible ranges

Using ASHRAE look up for most accurate Design Temps

ASHRAE CLIMATIC DESIGN CONDITIONS 2009/2013/2017/2021

2021 ASHRAE Handbook - Foundamentals (IP)

LEADVILLE LAKE COUNTY AP, CO, USA (WMO: 724673)

Lat:**39.229N** Long:**106.317W** Elev:**9932** StdP: **10.13** Time zone:**-7.00 (NAM)** Period:**98-19** WBAN:**93009** Climate zone:**7**

Annual Heating, Humidification, and Ventilation Design Conditions

Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB		WSF
			99.6%			99%			0.4%		1%				
	99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD	
12	**-7.8**	**-3.0**	**-17.1**	**3.1**	**1.9**	**-13.2**	**3.9**	**6.1**	**24.4**	**21.5**	**20.9**	**20.4**	**6.7**	**50**	**0.751**

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB	
		0.4%		1%		2%		0.4%		1%		2%			
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD
7	**29.1**	**74.2**	**47.8**	**72.2**	**47.4**	**70.1**	**46.9**	**52.3**	**64.3**	**51.2**	**63.5**	**50.1**	**62.3**	**10.9**	**340**

Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Extreme Max WB
0.4%			1%			2%			0.4%		1%		2%		
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB	
48.7	**74.1**	**53.3**	**47.4**	**70.5**	**52.7**	**45.8**	**66.3**	**52.1**	**25.2**	**64.2**	**24.5**	**63.3**	**23.7**	**61.6**	**60.3**

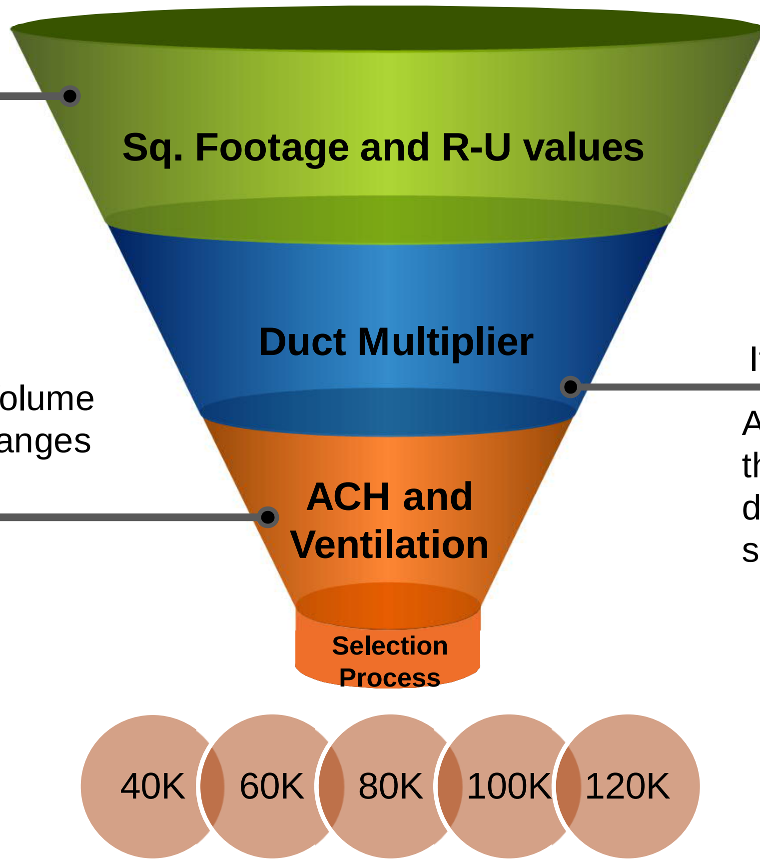
Extreme Annual Design Conditions

Extreme Annual WS				Extreme Annual Temperature				n-Year Return Period Values of Extreme Temperature							
				Mean		Standard deviation		n=5 years		n=10 years		n=20 years		n=50 years	
1%	2.5%	5%		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
20.8	**18.7**	**16.8**	DB	**-16.8**	**78.8**	**4.7**	**1.3**	**-20.1**	**79.8**	**-22.9**	**80.6**	**-25.5**	**81.3**	**-29.0**	**82.3**
			WB	**-17.3**	**55.3**	**4.5**	**1.7**	**-20.6**	**56.5**	**-23.2**	**57.5**	**-25.7**	**58.5**	**-29.0**	**59.8**

https://ashrae-meteo.info/v2.0/index.php?lat=39.833&lng=-04.658&place=%27%27&wmo=725650

Manual J Heating Load Inputs

This is the old Greek Formula: UA*ΔT



It's an educated guess!

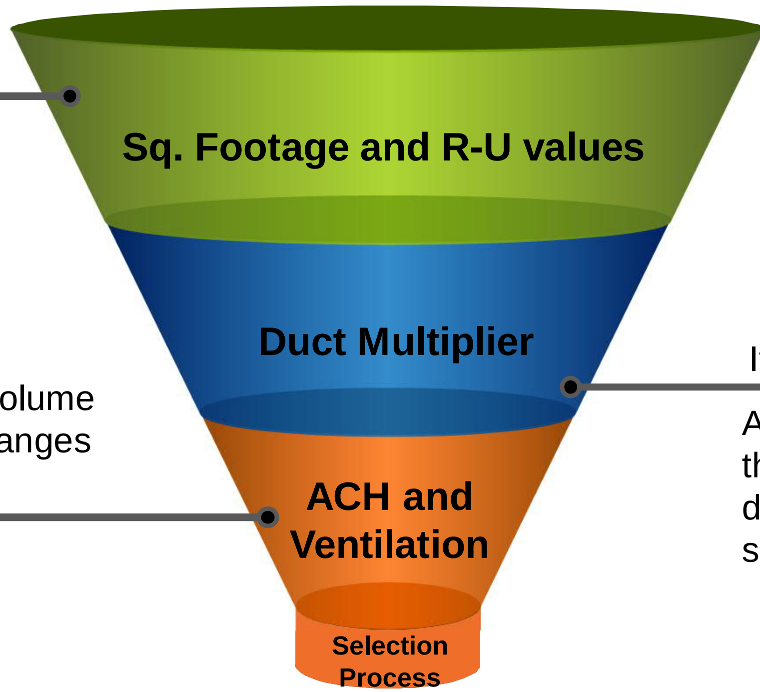
Accounts for heat loss through ducts, considering duct insulation, leakage, and surface area*

Also an old formula: Volume (ft³) x ΔT (°F) x Air Changes per Hour x 0.015

~5 Choices for furnaces

Manual J Heating Load Inputs

This is the old Greek Formula: UA*ΔT



Also an old formula: Volume (ft³) x ΔT (°F) x Air Changes per Hour x 0.015

It's an educated guess!

Accounts for heat loss through ducts, considering duct insulation, leakage, and surface area*

~7 Choices for Heat Pumps

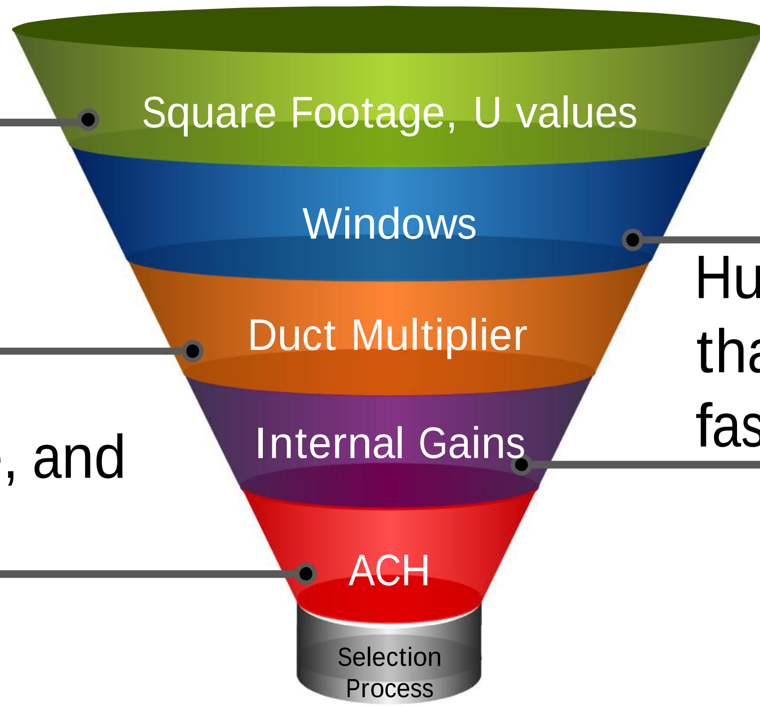
1.5 2.0 2.5 3.0 3.5 4.0 5.0

Manual J Cooling Load Inputs

Critical Inputs include windows and Internal gain

Surface areas, attics, walls ,floors and R values

U value SHGC. Shading, Orientation



It's an estimate!*

Humans plus all their stuff that plugs in. Its growing fast

Volume, leakage, and delta T

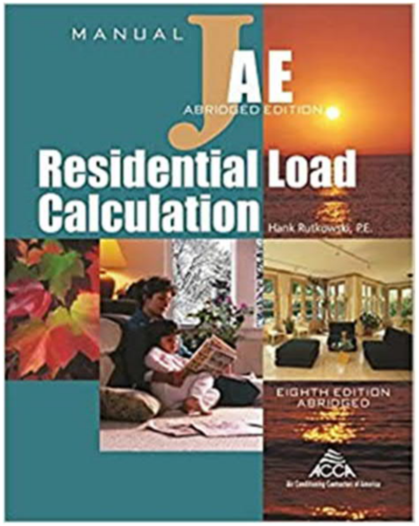
7 Choices

1.5 2.0 2.5 3.0 3.5 4.0 5.0

Accounts for heat gain through ducts, considering duct insulation, leakage, and surface area

Load Calculations

- Must perform Manual J v7 (or newer) or equivalent
  - Must use ASHRAE math
  - Must be capable of inputting low-e glazing
    - Alternatively, must be able to adjust SHGC to reflect low-e
  - Must be capable of calculating heating and cooling load
  - Must be capable of block load and room-by-room



Manual J and Equivalent Approaches

ACCA Approved

Cool Calc Manual J

MiTek WRIGHTSOFT

Elite Software

EnergyGauge Energy and Economic Analysis Software

Amply Amp up your heat pump business

conduit tech

Equivalent – versions may/may not be ACCA Approved

HVAC SIZING TOOL

Free
Man J v7 equivalent
No low-e, only SHGC

HVAC DESIGNERS OF CANADA VERIFIED F280 SOFTWARE

LoopCAD

HeatCAD

Canadian
F280 compliant
Not free

h2x

European
Getting ACCA approved
Great for hydronic

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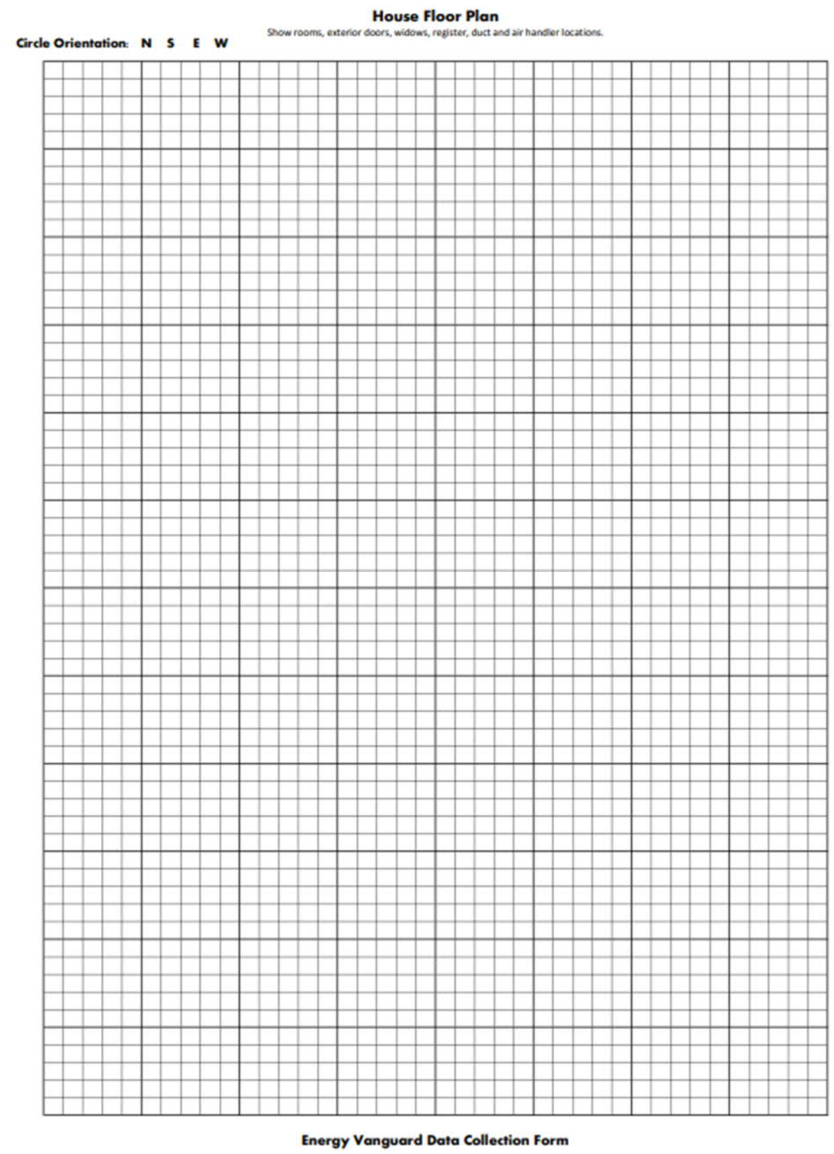
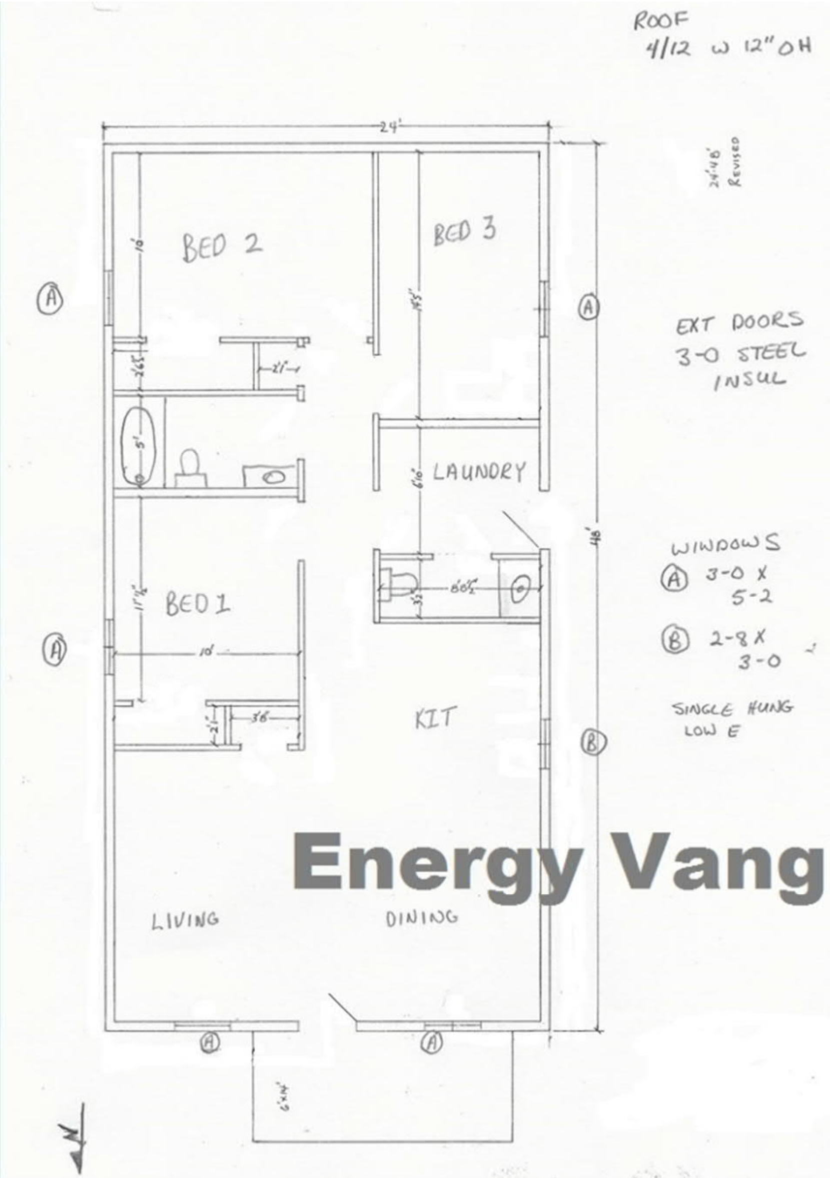
Data Collection: Three primary steps

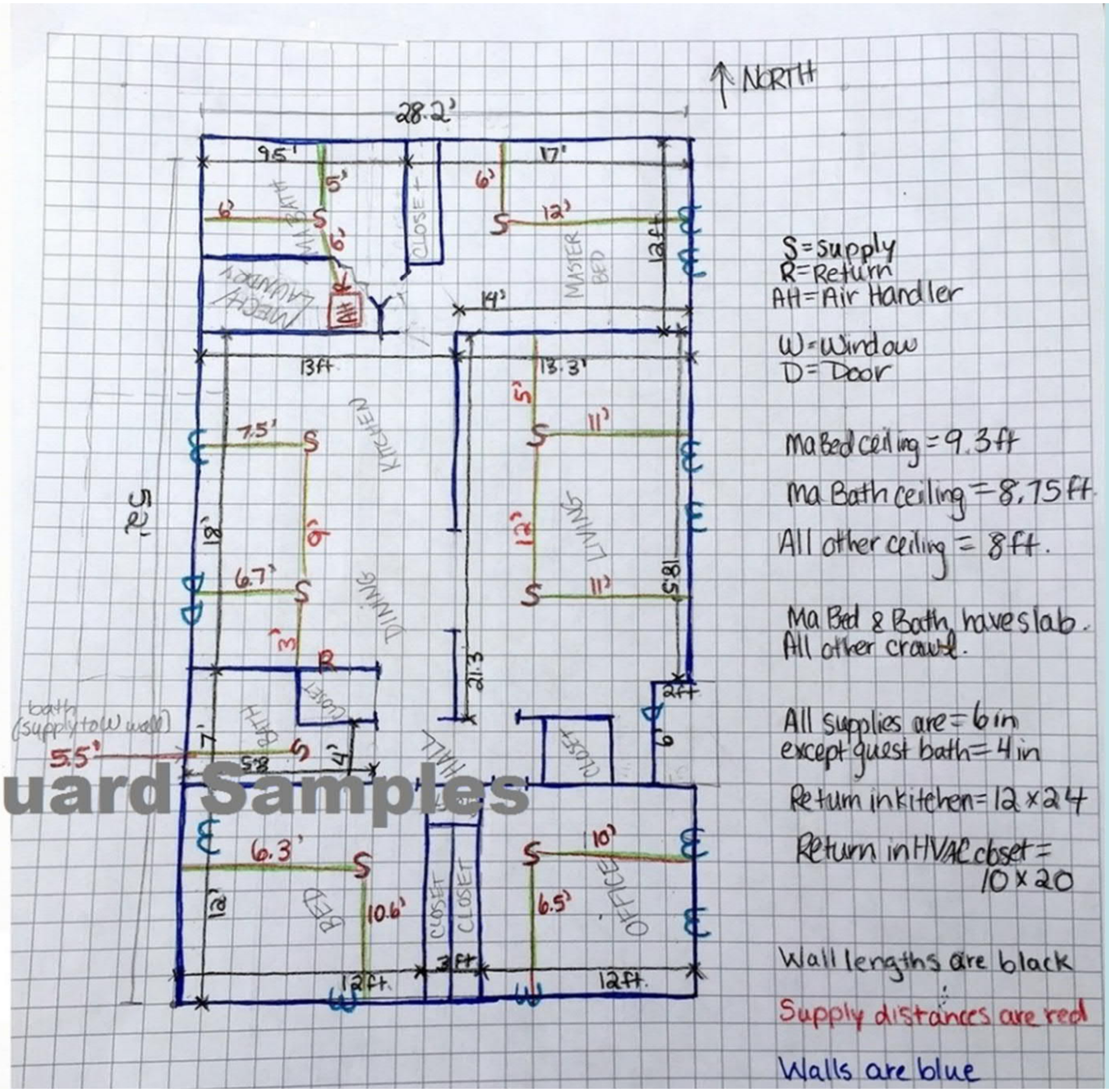
- **From my friends at Energy Vanguard**

- **Available to download from their website**

- **Start with house drawing, then move on to data, then ensure proper location and altitude.**
  https://www.energyvanguard.com/hvac-design/data-collection/




ROOF
4/12 w 12"OH
24'
48'
BED 2
BED 3
LAUNDRY
BED 1
KIT
LIVING
DINING
EXT DOORS
3-0 STEEL
INSUL
WINDOWS
A 3-0 X 5-2
B 2-8 X 3-0
SINGLE HUNG
LOW E


NORTH
28.2'
MASTER BED
MA BATH
MECH LAUNDRY
CLOSET
KITCHEN
LIVING
DINING
HALL
BATH
BED
OFFICE
S=Supply
R=Return
AH=Air Handler
W=Window
D=Door
Ma Bed ceiling = 9.3ft
Ma Bath ceiling = 8.75 ft
All other ceiling = 8ft.
Ma Bed & Bath have slab.
All other crawl.
All supplies are = 6in
except guest bath = 4in
Return in kitchen = 12 x 24
Return in HVAC closet =
10 x 20
Wall lengths are black
Supply distances are red
Walls are blue

Energy Vanguard
533 W Howard Ave, Suite E, Decatur, GA 30033
hvac@energyvanguard.com · (404) 428-3393

Manual J Data Collection Form for New Homes

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

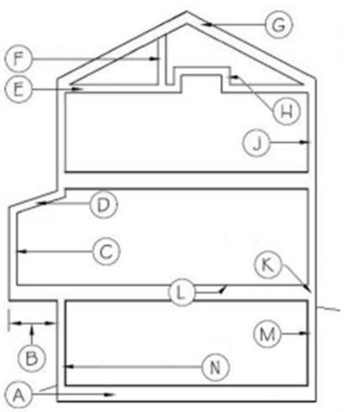
1. Front Door Faces N☐ NE☐ E☐ SE☐ S☐ SW☐ W☐ NW☐

2. Home Description

3.Air Infiltration Rate

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

4. Insulation



Location	Type	R-Value Cavity	R-Value 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 Foam

____

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

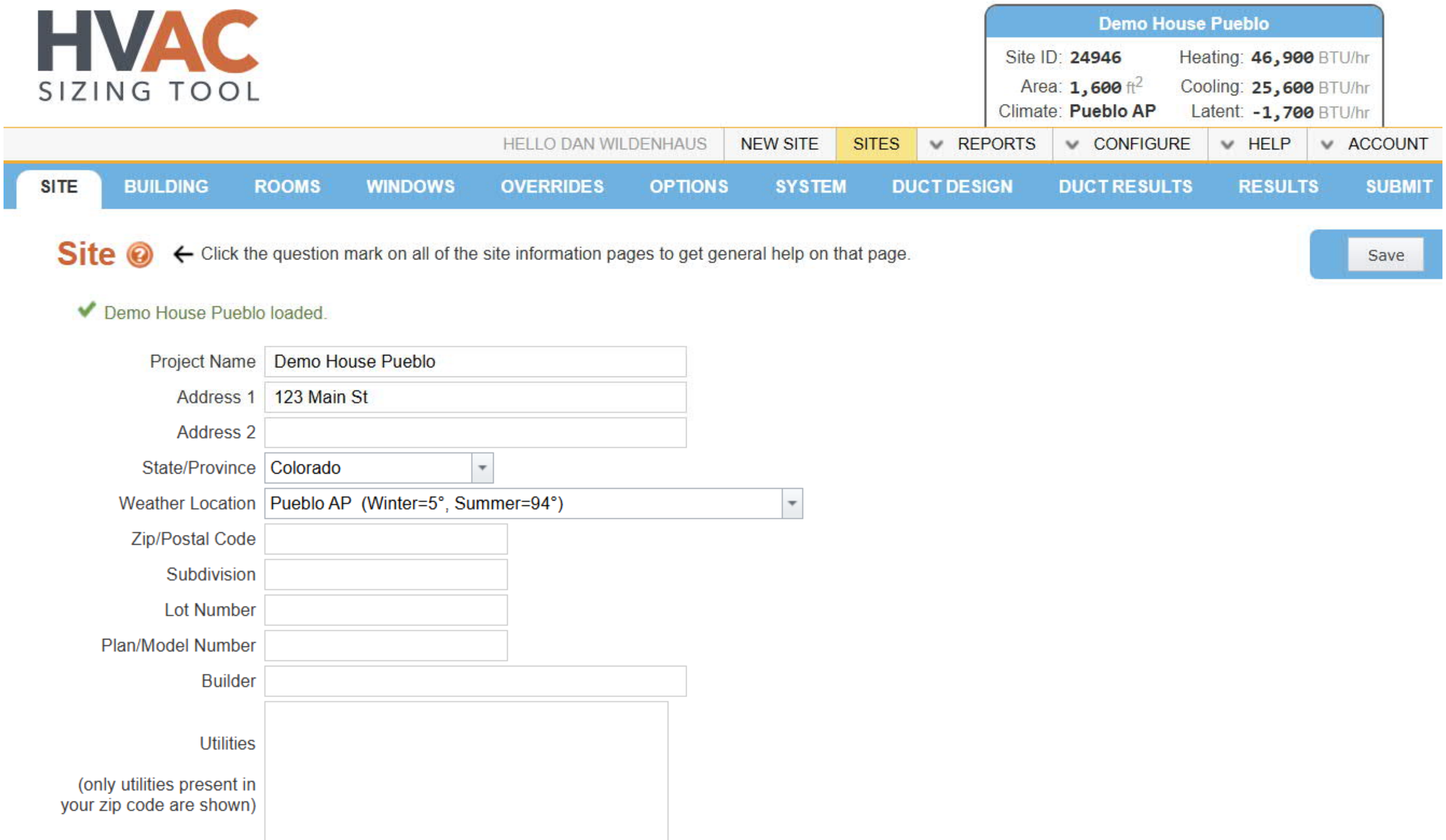
On which system(s)? ☐1 ☐2 ☐3 ☐separately ducted

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

____

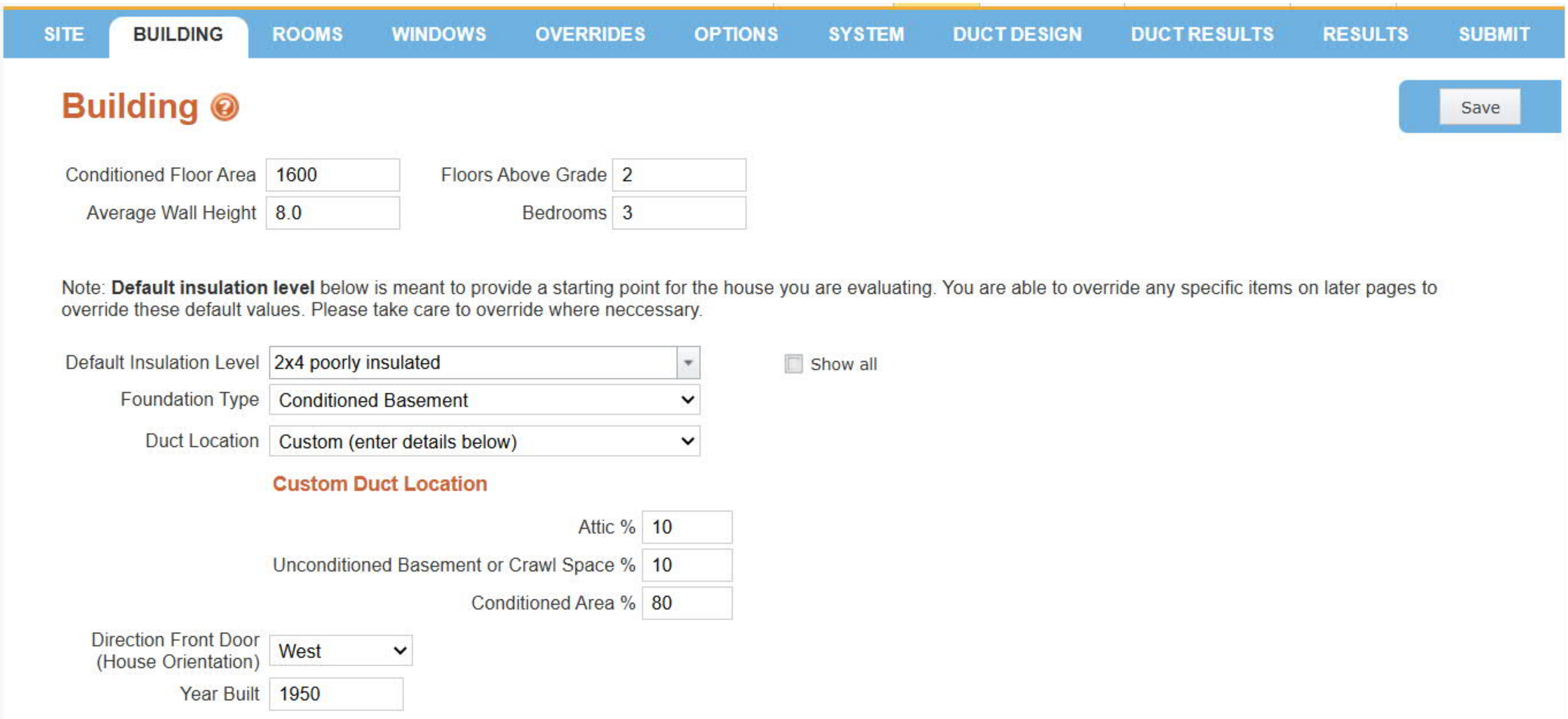
From HVAC ST

Data needs for load calcs



From HVAC ST

Data needs for load calcs


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

Building

Save

Conditioned Floor Area: 1600
Floors Above Grade: 2
Average Wall Height: 8.0
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 poorly insulated
Show all
Foundation Type: Conditioned Basement
Duct Location: Custom (enter details below)

Custom Duct Location

Attic %: 10
Unconditioned Basement or Crawl Space %: 10
Conditioned Area %: 80

Direction Front Door (House Orientation): West
Year Built: 1950

From HVAC ST

Data needs for load calcs

HVAC SIZING TOOL

Demo House Pueblo

Site ID: **24946** Heating: **46,900** BTU/hr
Area: **1,600** ft^2 Cooling: **25,600** BTU/hr
Climate: **Pueblo AP** Latent: **-1,700** 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

Rooms

Save

✔ Building sq ft correctly matches floor area.

Building Sqft: 1,600

New Room	Room Name	Floor Area	Exterior Length	Height Override	Unconditioned Above Ceiling	Unconditioned Below Floor	In Basement	Redistribute Room
Delete	Upstairs	600	100.0		100%	0%	☐	
Delete	Main floor	600	100.0		0%	100%	☐	
Delete	Basement	400	100.0	7.5	0%	100%	☑	
		Total = 1,600						

cee

From HVAC ST

Data needs for load calcs

HVAC SIZING TOOL

Demo House Pueblo

Site ID: **24946** Heating: **46,900** BTU/hr
Area: **1,600** ft^2 Cooling: **25,600** BTU/hr
Climate: **Pueblo AP** Latent: **-1,700** 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

Windows

Save

✔ Window to floor ratio: 16.6%

Window U-Value 1.000 Window SHGC 0.870

Room Name	↑ N	↗ NE	→ E	↘ SE	↓ S	↙ SW	← W	↖ NW	Door	Skylight
Upstairs		30.0		30.0		30.0		30.0		
Main floor		30.0		30.0		30.0		30.0		
Basement		12.0		4.0		4.0		4.0		

Rotate house orientation Rotate West 45° Rotate East 45°

cee

From HVAC ST

Data needs for load calcs

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

Overrides

Save

	Default	Rough Equiv	Override	Value
Ceiling U-Value	0.081	(R-11)	R-28	0.034
Floor U-Value	0.368	(R--0.3)	Default	
Wall U-Value	0.240	(R-0.0)	R-11	0.097
Basement Wall U-Value	0.148		Default	
Basement Floor U-Value	0.025		Default	
Slab F-Value	1.180		Default	
Door U-Value	0.500			
Window U-Value	1.000			
Window SHGC	0.870			
Duct Insulation	R-4		Default	
Duct Leakage	Average		Semi Tight	
Winter Infiltration ACH	0.700			
Summer Infiltration ACH	0.400			

From HVAC ST

Data needs for load calcs

Options

Save

Design Conditions

	Default	Override	Units
Elevation	4684		Feet
Latitude	38		Degrees Latitude
Heating 99% Dry Bulb	5		° F
Cooling 1% Dry Bulb	94		° F
Summer Design Grains	-30		Grains of water/Pound of dry air
Winter Thermostat Setpoint	70		° F
Summer Thermostat Setpoint	75		° F
Indoor RH	50		%
Daily Range	High	None	

Other Options

	Default	Override	Units
Number Of People	4		People
Appliance / Lighting Load	2400		BTU/hour
Ventilation CFM	46	50	Cubic Feet/Minute
Heating Duct Multiplier	3%		%
Cooling Duct Multiplier	4%		%
% Basement Below Grade	75%		%
Internal Shade Coefficient	1.0	0.70	
Additional Blower Load	1707		BTU/hour
Window Orientation	As-Is		

- [ ] Use ASHRAE 152 Duct area default
- [ ] Heated slab on grade

Decision Matrix for type of load calculations

ASHP Application	Room-by-room	Run Time or Bill Analysis	Block load	Existing Equipment Capacities
ASHP installation in a new house, or in a house with significant envelope upgrades	✓		✓	
ASHP retrofit or add-on installation in an existing house with an Energy Audit	✓	✓	✓	
ASHP retrofit or add-on installation in an existing house without an Energy Audit		*Maybe*	✓	*Maybe*

Also homes with comfort or IAQ issues

Blockloads

Works great for homes with ductless heat pumps or small simple homes.

- OK for most homes without IAQ or comfort issues.

Provides total sizing but not sizing per head/room.

Requires software training or recognized spreadsheet.

Still requires basic home information.

Using Run Time to Estimate Load

Requires smart thermostat be in place first.

Requires knowledge of local design temperatures.

Best if local weather conditions were typical.

Better than nothing if existing equipment delivered comfort.

Using run times to estimate heating and cooling loads

Need to have had a smart thermostat & access to historical data.

Need full heating and cooling season.

Use the % of hour in run time to satisfy the thermostat during:

- Nights similar to winter design temperature and
- Days similar to summer design temperature.

Multiply % by output capacity of existing equipment.

Room by Room Heat Load Calcs

For ducted homes, most accurate.

Requires time and effort.

Requires software training.

Well recognized.

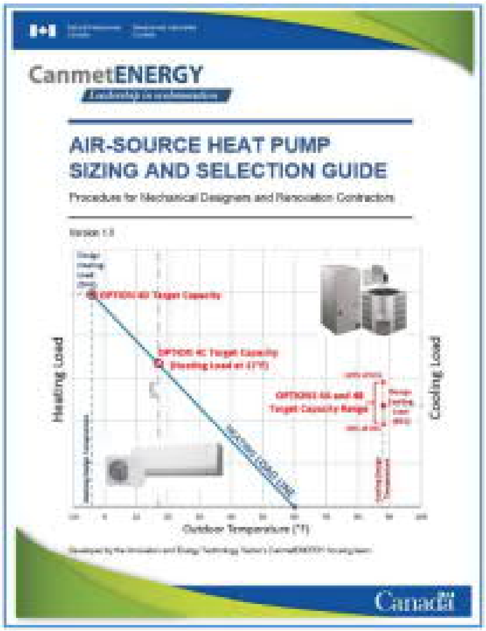
Aligns with codes and standards.

Can we size based on existing equipment size?

- Short answer: NOT REALLY, BUT MAYBE

- Longer answer: The folks at NRCAN determined a last resort, we can divide the existing BTU output by 1.33 to get a more realistic size*

  - No comfort issues
  - No weatherization since original sized



https://natural-resources.canada.ca/sites/nrcan/files/canmetenergy/pdf/ASHP%20Sizing%20and%20Selection%20Guide%20(EN).pdf

Sizing off the existing system

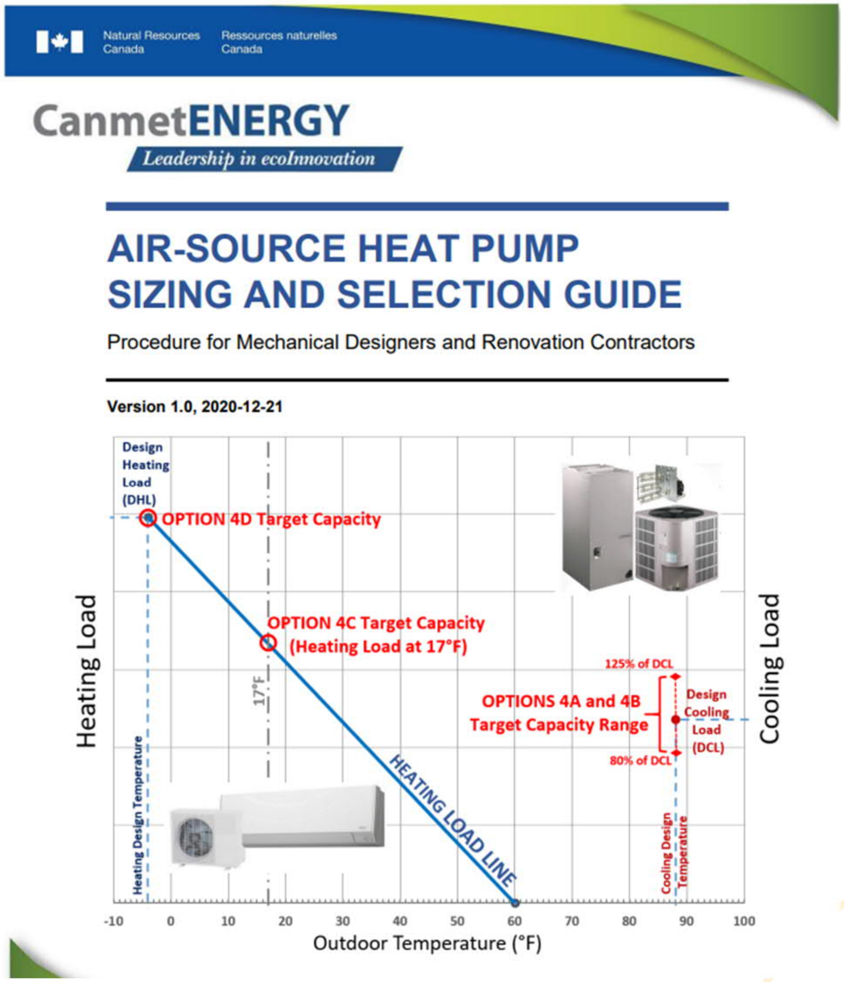
Need existing capacities of heating & cooling equipment.

For heating design load:

- Furnace or heat pump output
- Use assumption of 133% design load

80% gas furnace, rated at 60,000 Btu/h input = 48,000 Btu/hr delivered

Less the 33% oversize = 32,160 Btu/hr!



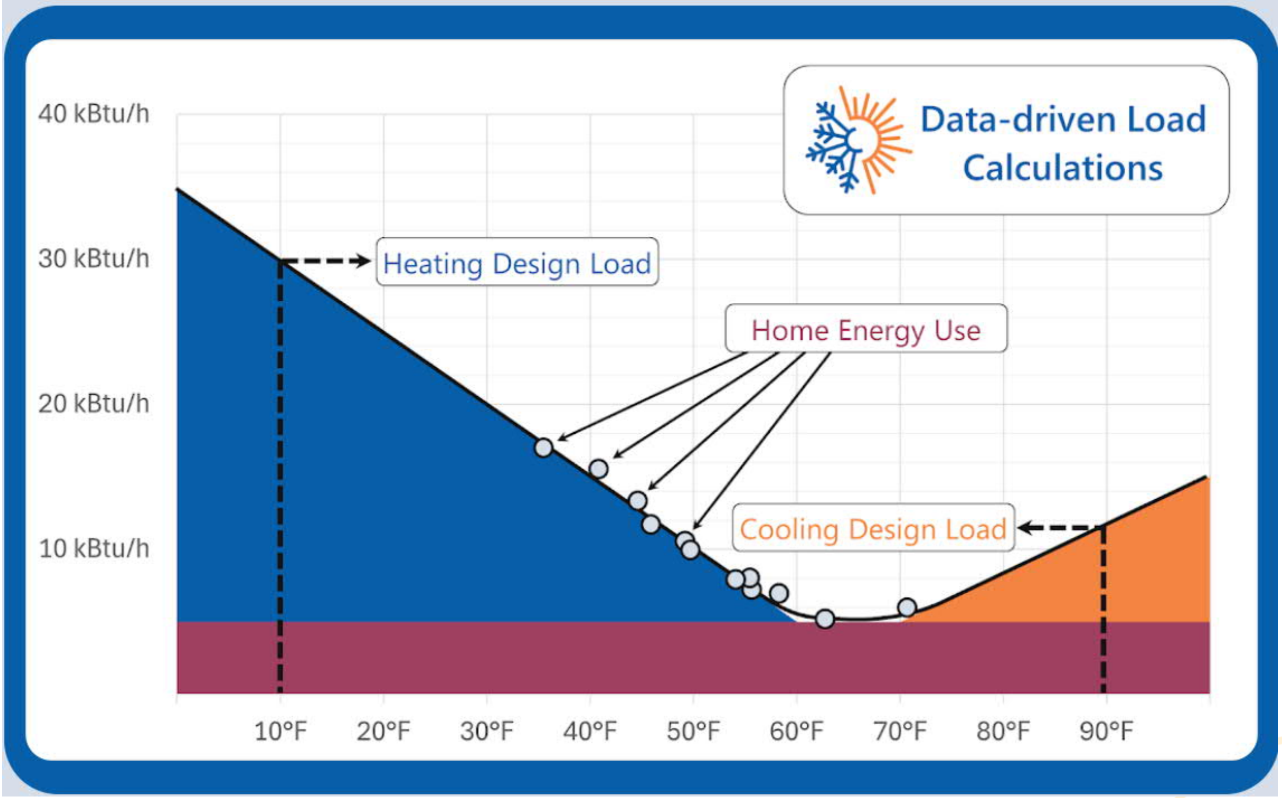
Bonus approach – using utility bills

Can be accurate, with enough data

Typically, at least one heating & cooling season needed*

No abnormally warm years if you want a heating load

New tool available to help, but only in WA, OR, and CA



The new kids on the block!

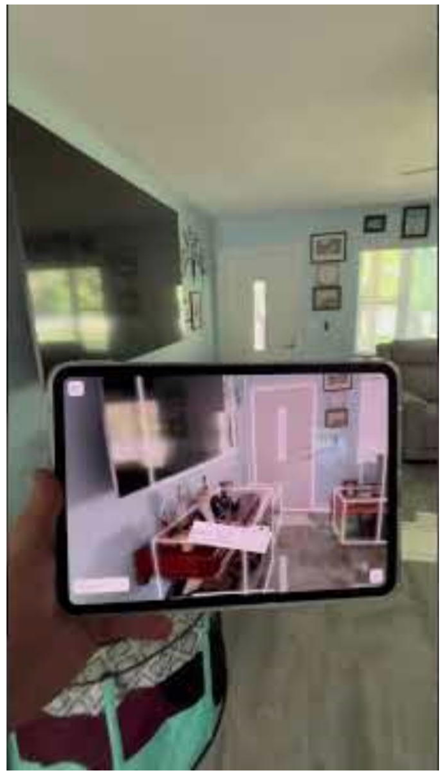
Amply and Conduit Tech

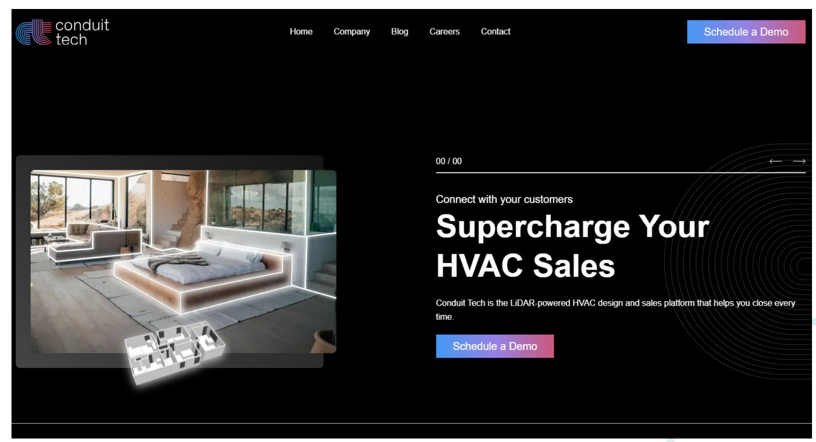
Use Lidar on iPad Pro tablets

Produce:

- Floor plan
- 3D model
- With pull downs, full Manual J room by room!
- ACCA Approved

Related - https://www.zerohomes.io/howitworks





Same math but streamlined data collection and presentation of results!

Rules of Thumb

May have value for most homes as a truth check.

Need to be enhanced rules of thumb.

Useful for ductless heat pump displacement homes.

Does not align with many programs, codes, or standards.

May or may not be better nothing if existing equipment delivered comfort.

Using the Heating Load Estimator

This **tool is designed for rough estimations, training, and gut checks** of heating loads for existing equipment or to truth check a Manual J or ASHRAE based heating load calculator. **<u>This is NOT intended to replace Manual J or locally approved heat load calculators.</u>**

For each temperature range and construction type, a range of Btuh/sq ft is provided. The simple approach is to use the bolded, central number. This is most commonly used when checking another tool as a guide. Homes with basements tend to have less heat loss in winter, but slightly more in late spring and early fall. To that point, a second set of estimated BTUH/sq ft has been provided for basement homes.

For evaluating an existing heating system capacity to determine if right, under, or over sized, it's most helpful to generate a range. If the equipment capacity in a heating climate is HIGHER than the range, it is likely oversized. If LOWER than the range, it is likely undersized.

If a blower door number is known, then using the appropriately aligned number may provide greater accuracy. A home where the CFM50 divided by the square footage of the home is 0.75 to 1.0, the home is of average tightness. Below 0.75 indicates a somewhat tight home. Over 1.0 is a somewhat leaky home. See next slide for a visual representation…

Find Winter Design Temperatures here (recommend using most current year data): ASHRAE Climatic Design Conditions or use the winter design temperatures assigned by local codes/programs.

CFM50/Square Foot assessment

Notes and Example

Building tightness is most useful when compared to the building size.

If you don't know the blower door number, use the center value for insulation level vs design temp.

If you do know the blower door number, refer to the table on the right of this slide.

Somewhat tight, average, somewhat leaky

CFM50\Sq Ft	1000	1250	1500	1750	2000	2250	2500	2750	3000	3250	3500	*Sq Ft Home*
749	0.749	0.599	0.499	0.428	0.375	0.333	0.300	0.272	0.250	0.230	0.214	
1000	1.000	0.800	0.667	0.571	0.500	0.444	0.400	0.364	0.333	0.308	0.286	
1250	1.250	1.000	0.833	0.714	0.625	0.556	0.500	0.455	0.417	0.385	0.357	
1500	1.500	1.200	1.000	0.857	0.750	0.667	0.600	0.545	0.500	0.462	0.429	
1750	1.750	1.400	1.167	1.000	0.875	0.778	0.700	0.636	0.583	0.538	0.500	
2000	2.000	1.600	1.333	1.143	1.000	0.889	0.800	0.727	0.667	0.615	0.571	
2250	2.250	1.800	1.500	1.286	1.125	1.000	0.900	0.818	0.750	0.692	0.643	
2500	2.500	2.000	1.667	1.429	1.250	1.111	1.000	0.909	0.833	0.769	0.714	
2750	2.750	2.200	1.833	1.571	1.375	1.222	1.100	1.000	0.917	0.846	0.786	
3000	3.000	2.400	2.000	1.714	1.500	1.333	1.200	1.091	1.000	0.923	0.857	
3250	3.250	2.600	2.167	1.857	1.625	1.444	1.300	1.182	1.083	1.000	0.929	
3500	3.500	2.800	2.333	2.000	1.750	1.556	1.400	1.273	1.167	1.077	1.000	
CFM50												

Somewhat Tight
Average
Somewhat Leaky

Heating Load Estimator

Design Load ROUGH Estimator/Gut Checker Btuh/sq. ft.				
Climate Winter Design Temp in °F @99% (best for dual fuel HPs or when code requires) Climate Winter Design Temp in °F @99.6% (for all electric heat pumps, but follow code/permitting requirements)				
	Below – 10°F	**-10°F to 5°F**	**5°F to 20°F**	**Above 20°F**
No wall insulation (leaky, average, tight)	50, **47**, 44	44, **41**, 38	38, **35**, 32	32, **30**, 28
2x4 Const w/ Insul (leaky, average, tight)	27, **25**, 23	24, **22**, 20	21, **19**, 17	19, **17**, 15
2x6 Const w/ Insul (leaky, average, tight)	20, **18**, 16	17, **15**, 13	15, **13**, 11	13, **11**, 10
Newer const 2012 + (leaky, average, tight)	17, **16**, 15	15, **14**, 13	13, **12**, 11	11, **9**, 8

Original estimator created by the Northwest Energy Efficiency Alliance, edited for variable capacity heat pumps by Dan Wildenhaus

Heating Load Estimator – Basement Houses

Design Load ROUGH Estimator/Gut Checker Btuh/sq. ft.				
Climate Winter Design Temp in ºF @99% (best for dual fuel HPs or when code requires) Climate Winter Design Temp in ºF @99.6% (for all electric heat pumps, but follow code/permitting requirements)				
	Below – 10ºF	**-10ºF to 5ºF**	**5ºF to 20ºF**	**Above 20ºF**
No wall insulation (leaky, average, tight)	47, **44**, 41	41, **38**, 35	35, **32**, 29	30, **28**, 26
2x4 Const w/ Insul (leaky, average, tight)	25, **23**, 21	22, **20**, 18	19, **17**, 15	17, **15**, 13
2x6 Const w/ Insul (leaky, average, tight)	18, **16**, 14	15, **13**, 11	13, **11**, 9	11, **10**, 9
Newer const 2012 + (leaky, average, tight)	16, **15**, 14	14, **13**, 12	12, **11**, 10	9, **8**, 7

Original estimator created by the Northwest Energy Efficiency Alliance, edited for variable capacity heat pumps by Dan Wildenhaus

Heating Load Estimator with ducts outside the thermal envelope

Design Load ROUGH Estimator/Gut Checker Btuh/sq. ft.				
Climate Winter Design Temp in °F @99% (best for dual fuel HPs or when code requires) Climate Winter Design Temp in °F @99.6% (for all electric heat pumps, but follow code/permitting requirements)				
	Below – 10°F	**-10°F to 5°F**	**5°F to 20°F**	**Above 20°F**
No wall insulation (leaky, average, tight)	53, **50**, 47	47, **44**, 41	41, **38**, 35	35, **33**, 31
2x4 Const w/ Insul (leaky, average, tight)	30, **28**, 26	26, **24**, 22	23, **21**, 19	21, **19**, 17
2x6 Const w/ Insul (leaky, average, tight)	23, **21**, 19	20, **18**, 16	17, **15**, 13	15, **13**, 11
Newer const 2012 + (leaky, average, tight)	20, **19**, 18	18, **17**, 16	15, **14**, 13	13, **11**, 10

Original estimator created by the Northwest Energy Efficiency Alliance, edited for variable capacity heat pumps by Dan Wildenhaus

Example

- Home is 2x4 construction with insulation. No basement.
- **Home tightness is not known.**
- Home is 2,000 square feet
- Home is expecting to have a dual-fuel/hybrid heat pump.
- Home is in a location where the winter design temperature at 99% is -2°F.
- **Existing system is a 60k BTU furnace**

Design Load ROUGH Estimator/Gut Checker Btuh/sq. ft.				
Climate Dual Fuel HP Winter Design Temp in °F @99% Climate All Electric HP Winter Design Temp in °F @99.6%				
	Below – 10°F	**-10°F to 5°F**	**5°F to 20°F**	**Above 20°F**
No wall insulation (leaky, average, tight)	50, **47**, 44	38, **41**, 44	32, **35**, 38	32, **30**, 28
2x4 Const w/ Insul (leaky, average, tight)	27, **25**, 23	$\boxed{24, \mathbf{22}, 20}$	21, **19**, 17	19, **17**, 15
2x6 Const w/ Insul (leaky, average, tight)	20, **18**, 16	17, **15**, 13	15, **13**, 11	13, **11**, 10
Newer const 2012 + (leaky, average, tight)	17, **16**, 15	15, **14**, 13	13, **12**, 11	11, **9**, 8

A projected range for the heating load is likely to be between:

24 x 2,000 = **48,000**

20 x 2,000 = **40,000**

System is likely oversized!

Example 2

- Home is 2x4 construction with insulation. No basement
- **Home tightness is known:**
  - **Blower door test is 1750 CFM50**
- Home is 2,000 square feet
- Home is expecting to have a dual-fuel/hybrid heat pump.
- Home is in a location where the winter design temperature at 99% is -2°F.
- **Existing system is a 48k Btu furnace**

Design Load ROUGH Estimator/Gut Checker Btuh/sq. ft.				
Climate Winter Design Temp in °F @99% (best for dual fuel HPs or when code requires) Climate Winter Design Temp in °F @99.6% (for all electric heat pumps, but follow code/permitting requirements)				
	Below – 10°F	**-10°F to 5°F**	**5°F to 20°F**	**Above 20°F**
No wall insulation (leaky, average, tight)	50, **47**, 44	38, **41**, 44	32, **35**, 38	32, **30**, 28
2x4 Const w/ Insul (leaky, average, tight)	27, **25**, 23	24, $\boxed{\textbf{22,}}$ 20	21, **19**, 17	19, **17**, 15
2x6 Const w/ Insul (leaky, average, tight)	20, **18**, 16	17, **15**, 13	15, **13**, 11	13, **11**, 10
Newer const 2012 + (leaky, average, tight)	17, **16**, 15	15, **14**, 13	13, **12**, 11	11, **9**, 8

Using the blower door number to get a more specific design load estimate

1750 / 2000 = 0.875 = Average

Heating load estimate = **44,000 Btuh**

System is within the right nominal size

DOES THE ENVELOPE MATTER?

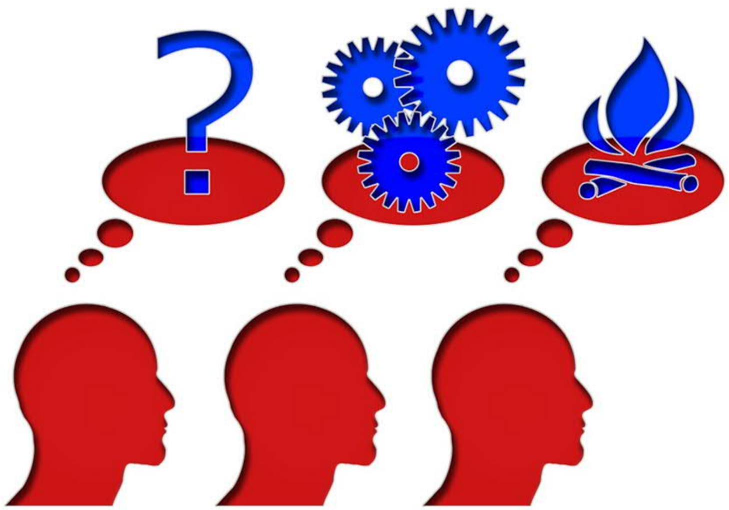
Considerations:

Where is the end of your heating system distribution?

What determines human comfort?

Colorado - **Mean radiant surface temperature**, air temperature, humidity, clothing, metabolism

Do smaller sized heat pumps cost less?



Why the envelope should matter to you!

Sizing and design is dependent on heating and cooling loads, and retrofits change those.

Homeowners often need help in planning retrofits over time.

New incentives and tax credits may encourage phased projects over time.

Comfort is not based on delivered air temperature and RH alone.

Guestimated Loads with "enhanced rules of thumb" for this house with air sealing only done

Heating Load before air sealing = **somewhat leaky**

1600 sq ft, **22 Btus** per sq ft.

That's 35,200 Btu/hr

Heating Load after air sealing = **somewhat tight**

1600 sq ft, **18 Btus** per sq ft.

That's 28,800 Btu/hr

Heating Load Estimator – Basement Houses

Design Load ROUGH Estimator/Gut Checker Btuh/sq. ft.				
Climate Winter Design Temp in °F @99% (best for dual fuel HPs or when code requires) Climate Winter Design Temp in °F @99.6% (for all electric heat pumps, but follow code/permitting requirements)				
	Below – 10°F	**-10°F to 5°F**	**5°F to 20°F**	**Above 20°F**
No wall insulation (leaky, average, tight)	47, **44**, 41	41, **38**, 35	35, **32**, 29	30, **28**, 26
2x4 Const w/ Insul (leaky, average, tight)	25, **23**, 21	22, **20**, 18	19, **17**, 15	17, **15**, 13
2x6 Const w/ Insul (leaky, average, tight)	18, **16**, 14	15, **13**, 11	13, **11**, 9	11, **10**, 9
Newer const 2012 + (leaky, average, tight)	16, **15**, 14	14, **13**, 12	12, **11**, 10	9, **8**, 7

Original estimator created by the Northwest Energy Efficiency Alliance, edited for variable capacity heat pumps by Dan Wildenhaus

Guestimated Loads with "enhanced rules of thumb" for this house with insulation only done

Heating Load before weatherization = 2x4 construction

1600 sq ft, **20 Btus** per sq ft.

That's 32,000 Btu/hr

Heating Load after Wx = 2x6

1600 sq ft, **13 Btus** per sq ft.

That's 20,800 Btu/hr

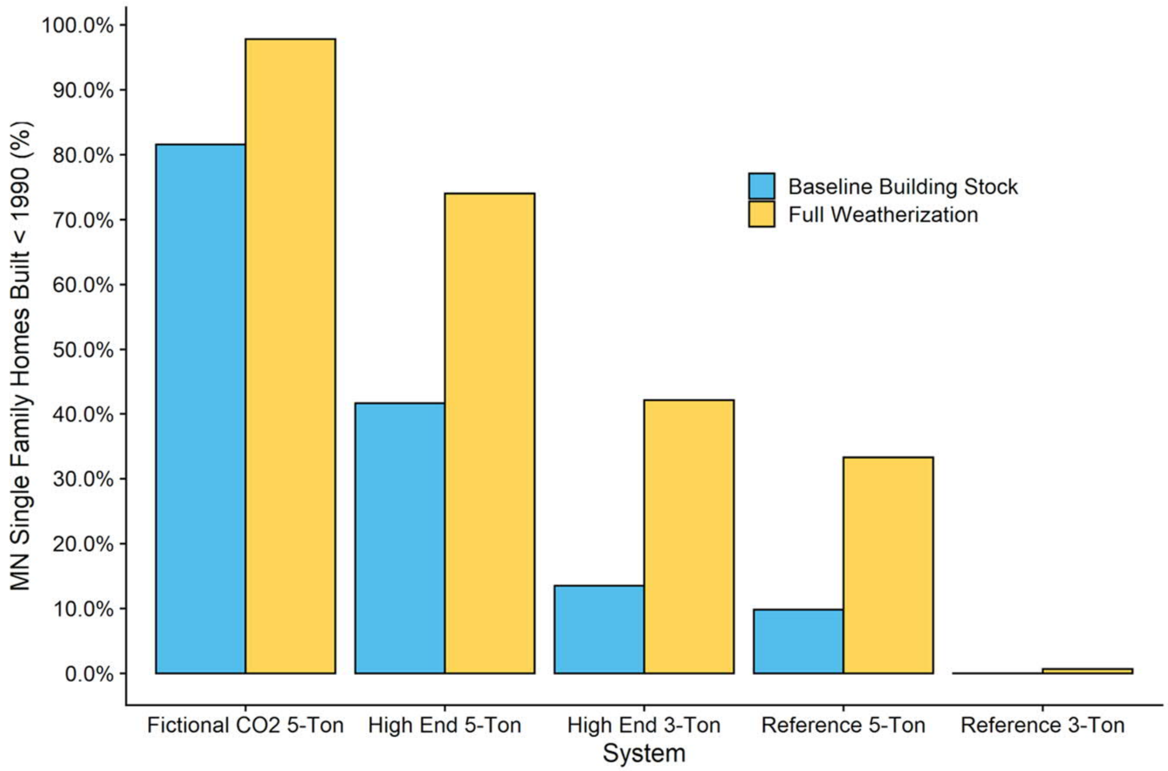
Heating Load Estimator – Basement Houses

Design Load ROUGH Estimator/Gut Checker Btuh/sq. ft.				
Climate Winter Design Temp in °F @99% (best for dual fuel HPs or when code requires) Climate Winter Design Temp in °F @99.6% (for all electric heat pumps, but follow code/permitting requirements)				
	Below – 10°F	**-10°F to 5°F**	**5°F to 20°F**	**Above 20°F**
No wall insulation (leaky, average, tight)	47, **44**, 41	41, **38**, 35	35, **32**, 29	30, **28**, 26
2x4 Const w/ Insul (leaky, average, tight)	25, **23**, 21	22, **20**, 18	19, **17**, 15	17, **15**, 13
2x6 Const w/ Insul (leaky, average, tight)	18, **16**, 14	15, **13**, 11	13, **11**, 9	11, **10**, 9
Newer const 2012 + (leaky, average, tight)	16, **15**, 14	14, **13**, 12	12, **11**, 10	9, **8**, 7

Original estimator created by the Northwest Energy Efficiency Alliance, edited for variable capacity heat pumps by Dan Wildenhaus

Envelope Improvements Show Results

- After Wx, high end system 5-ton, now can meet load on 75% of <1990 homes
- Even reference 5-ton system meets 33% of homes
- *25% peak load reduction*



From Minnesota work

Ideal order of operations

1

Envelope Efficiency

2

Mechanicals

3

Renewables, storage, EVs

cee

Envelope Consideration – When to install the heat pump?

Is the homeowner considering or willing to weatherize?		What should we discuss or do in response?
No, this is an emergency replacement	→	Can we install a heat pump that is flexible to future lower loads?
Yes, they are very interested in improved comfort, lower bills, and right sized mechanical systems	→	Best to install HP at the same time or after weatherization is completed!
Not sure, but want to learn more	→	Can we introduce the homeowner to a weatherization service?

Ask yourself how this approach would reflect on you to a homeowner!

What we covered

- Sizing methods to complete accurate load calculations
- The risks of oversizing and low-quality load calculations
- The value of high-quality load calculations
- What tools are you most likely to use

THANK YOU

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