SIZING HVAC EQUIPMENT

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What Is Meant by Equipment Sizing?

- The goal of all HVAC equipment sizing is to find the best match between the house and the equipment.

- Optimal size is the best match, or balance, between the rate of heat loss or heat gain of the house and the capacity of the HVAC equipment.

finitions: Heating/Cooling Load

- The heating or cooling load of the house is how many BTUs/hr the house requires to maintain the required indoor temperature at design conditions

- Typical homes have heat loss rates of between 20,000 BTUs/hr and 80,000 BTUs/hr and cooling loads of between 12,000 Btus/hr and 40,000 Btus/hr

the Customer Wants

- To be warm in winter
- To be cool in summer

ACCA HVAC Design Process

Manual J

INPUTS:
- Weather data
- Square footages
- Insulation levels
- U Values glass
- SHGC
- ACH
- Duct multipliers

OUTPUTS:
- Heating/cooling loads

Manual S

INPUTS:
- Heating/cooling loads
- Capacity tables
- Fan data

OUTPUTS:
- Unit selection

Manual D

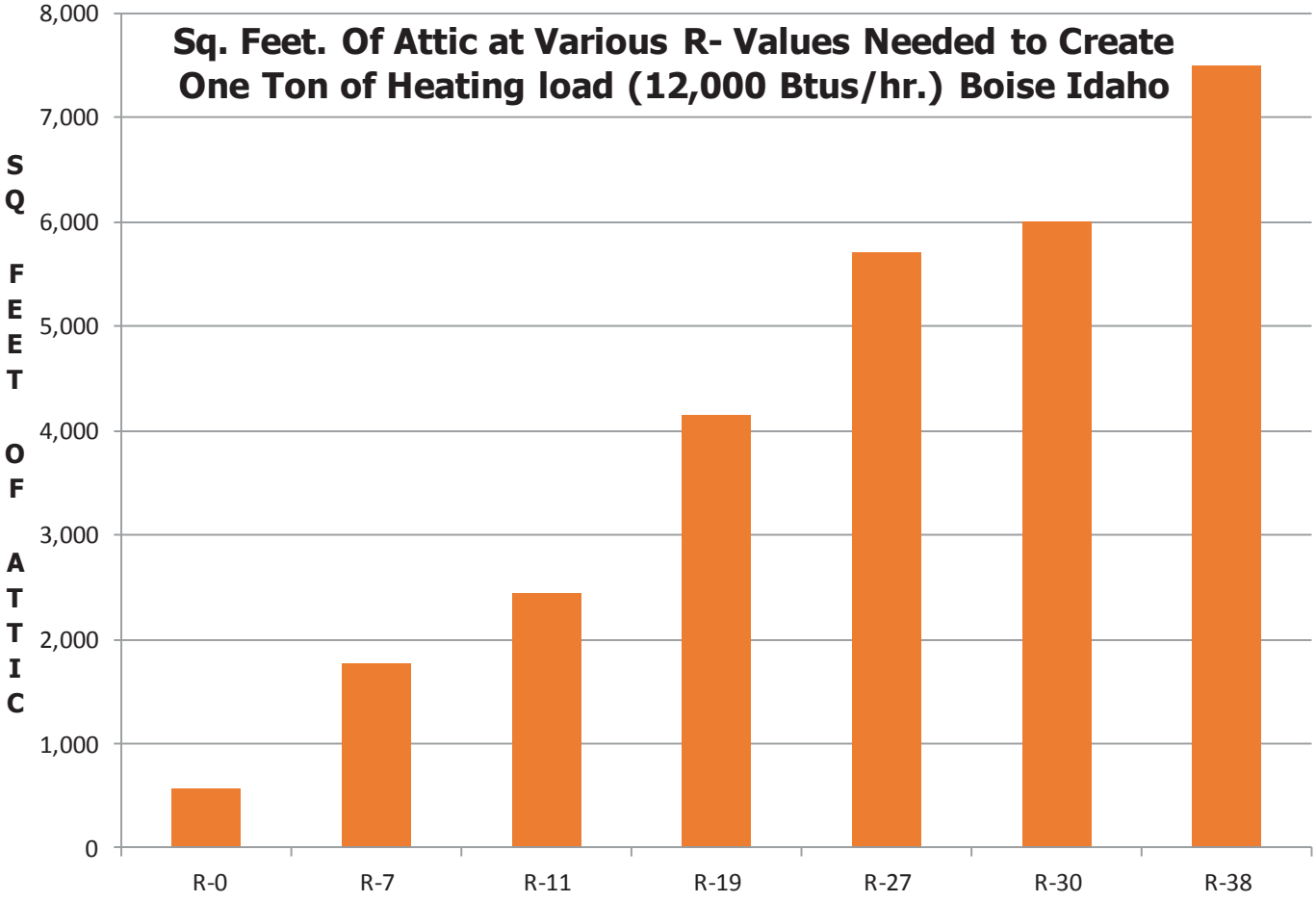
INPUTS:
- TEL
- Fan data

OUTPUTS:
- Friction rate
- Duct sizes

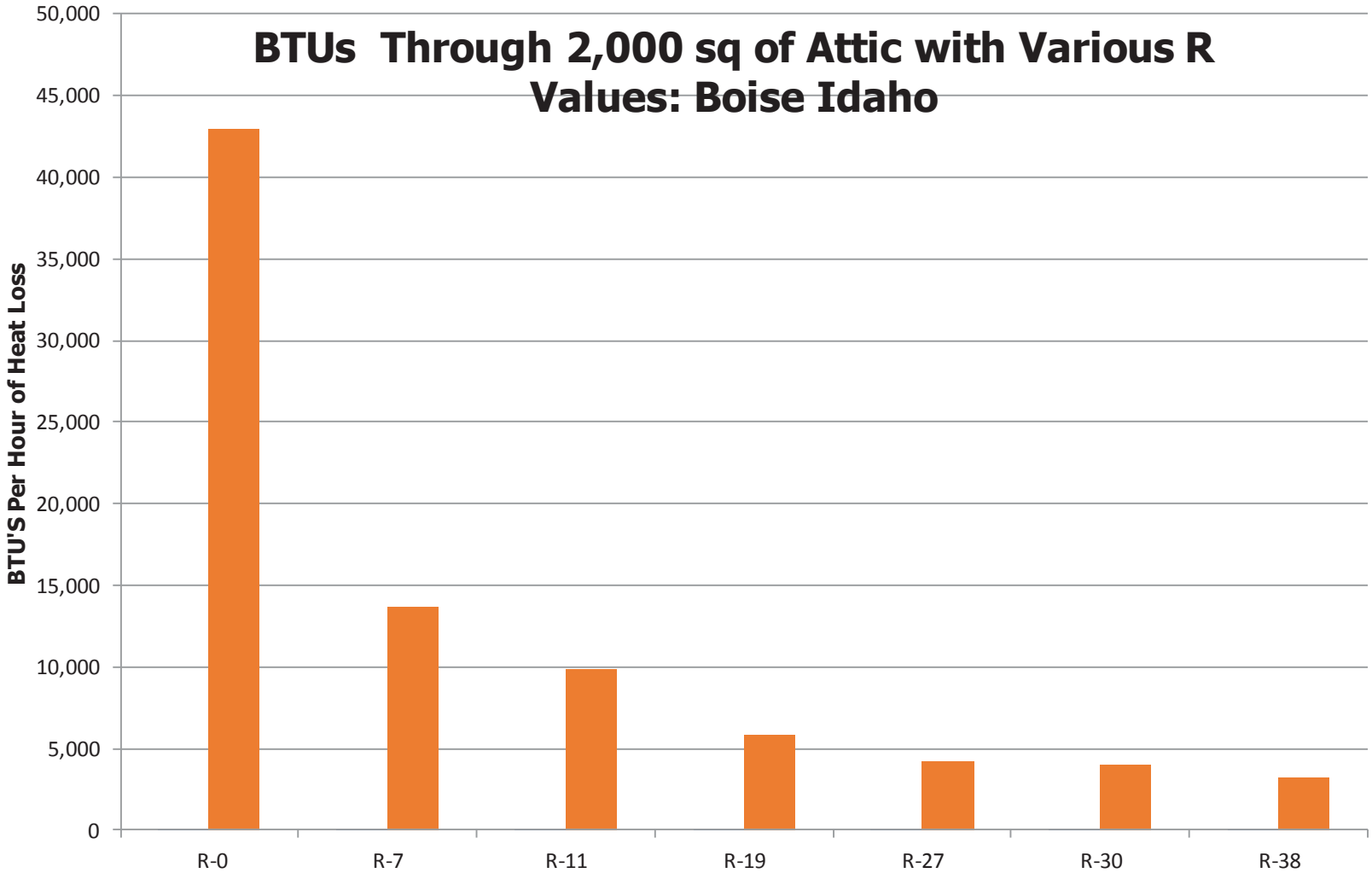
Benefits

- Lower front-end costs
- Greater comfort
- Lower energy use

the R-value that Matters…



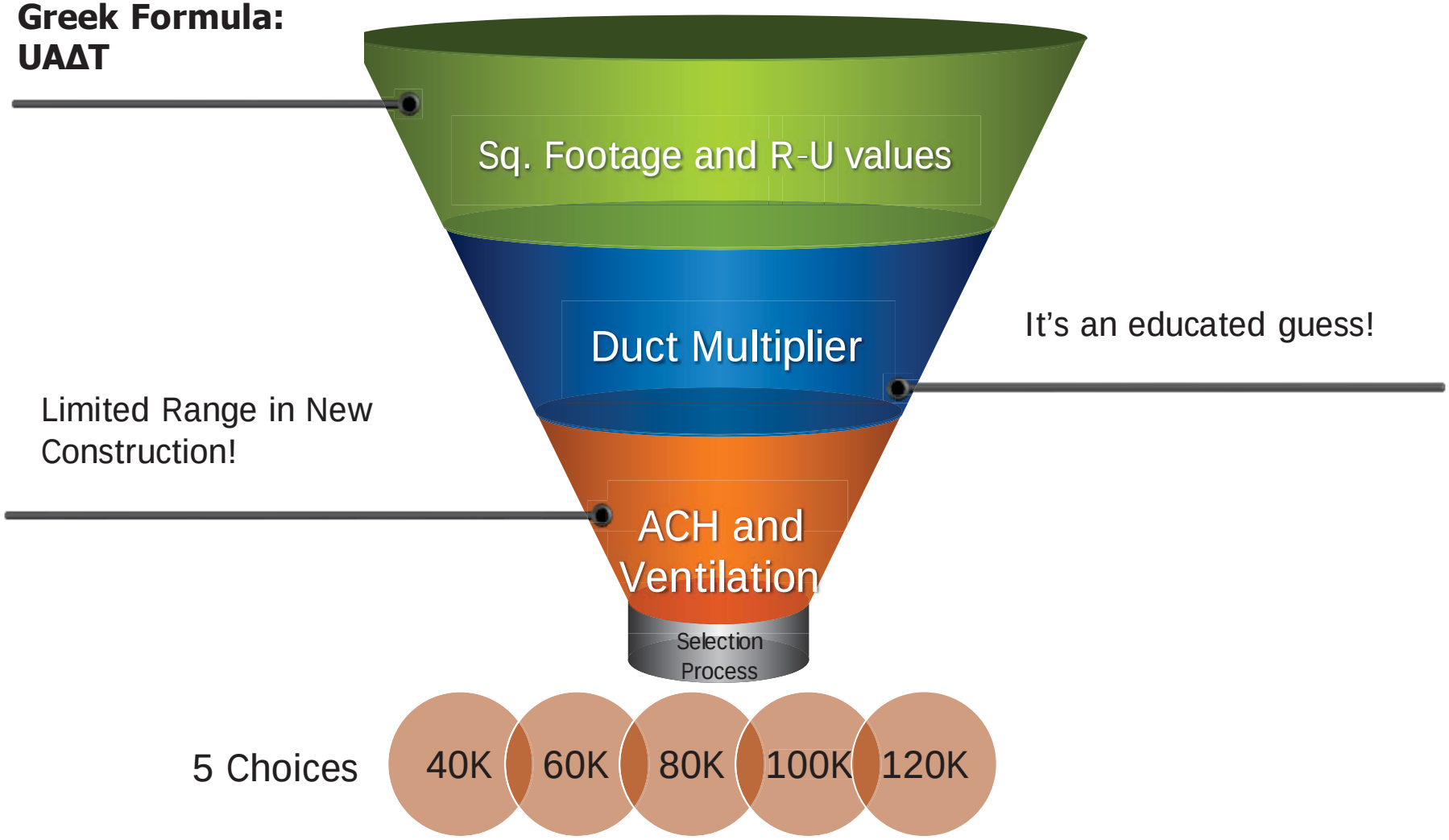
t The Square Feet



Manual J Heating Load Inputs

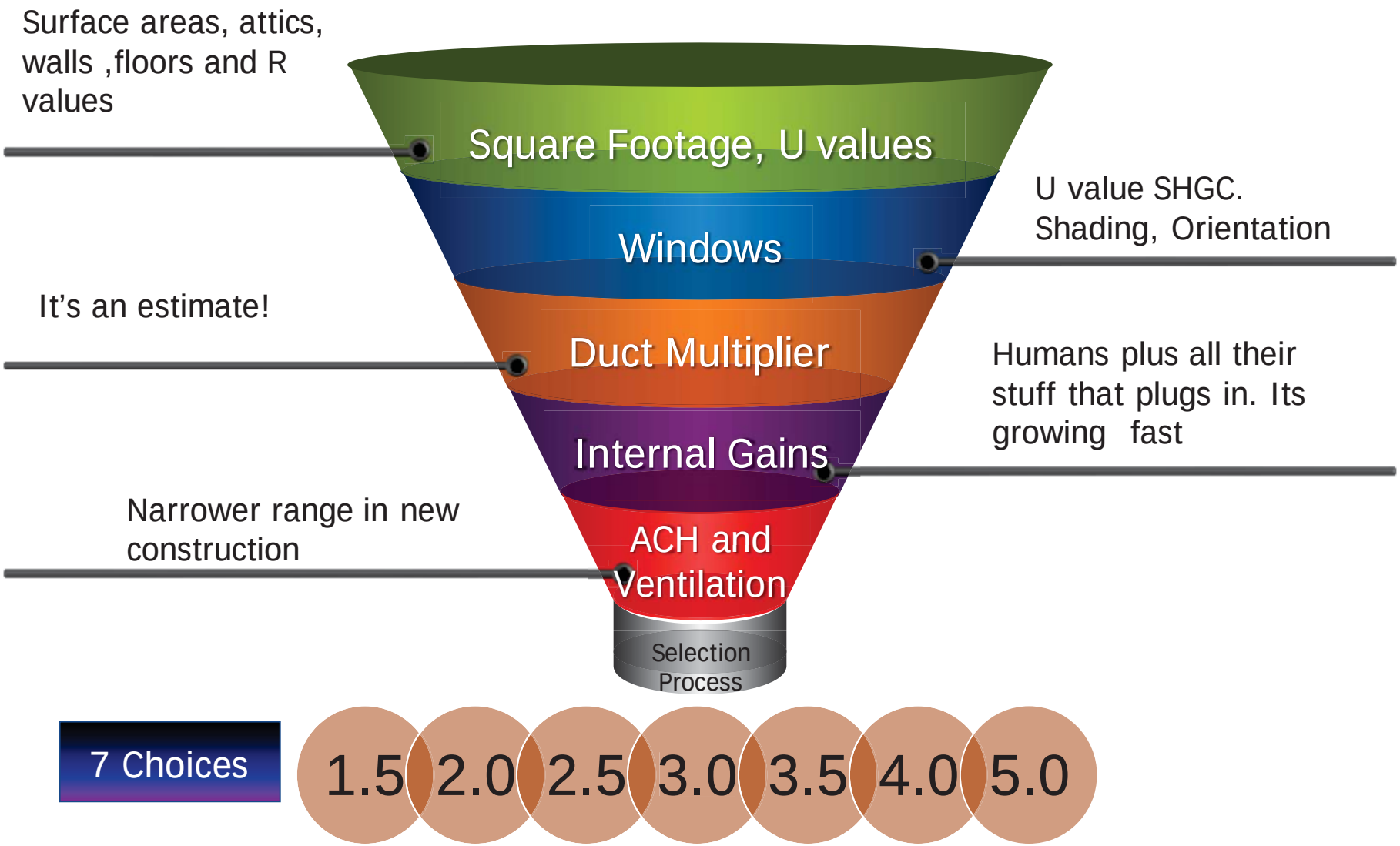
It's pretty simple

This is the old Greek Formula: UAΔT



Manual J Cooling Load Inputs

Critical Inputs include windows and Internal gain



A word about Duct Multipliers

Contractors Usually Size

- Most contractors use the “telephone method” of sizing
- If the telephone doesn’t ring, it must be the right size
- This makes sense from the contractor’s perspective

HVAC Equipment Sizing

Or, "Relax, don't panic."

It's easy and the answer does not matter as much as you might think.

(Most of the time)

n is Equipment Sizing Really Important?

- **Furnaces:**
  - They have to be big enough to heat the house! Modern furnaces do not have much of a penalty for oversizing. People like to heat their house up in a hurry. Keep it within the next size up from the “right” size. Relax.

- **Air Conditioning:**
  - In the west, cool the house on the hottest day or the phone will ring. Keeping it within the next largest size is okay (make sure it’s installed right). Relax.

- **Heat Pumps:**
  - Must be big enough to heat the house down to 30º F. Time to sweat the details a little. Getting the right size is crucial to saving energy for heat pumps.

ace Sizing

Furnaces:

1. Complete heat loss calculation at winter design conditions.

2. Size furnace not to exceed 140% of the heat load at winter design conditions (ACCA). Relax a little—oversizing on condensing gas furnaces increases the efficiency.

3. Some times you need the fan in a larger unit to handle big homes with an AC coil. Its ok to do this.(more later)

Relax: The oversizing penalty is really small or non existent

If Heat loss of house was 45,000 BTU/hr, what furnace would be the right size?

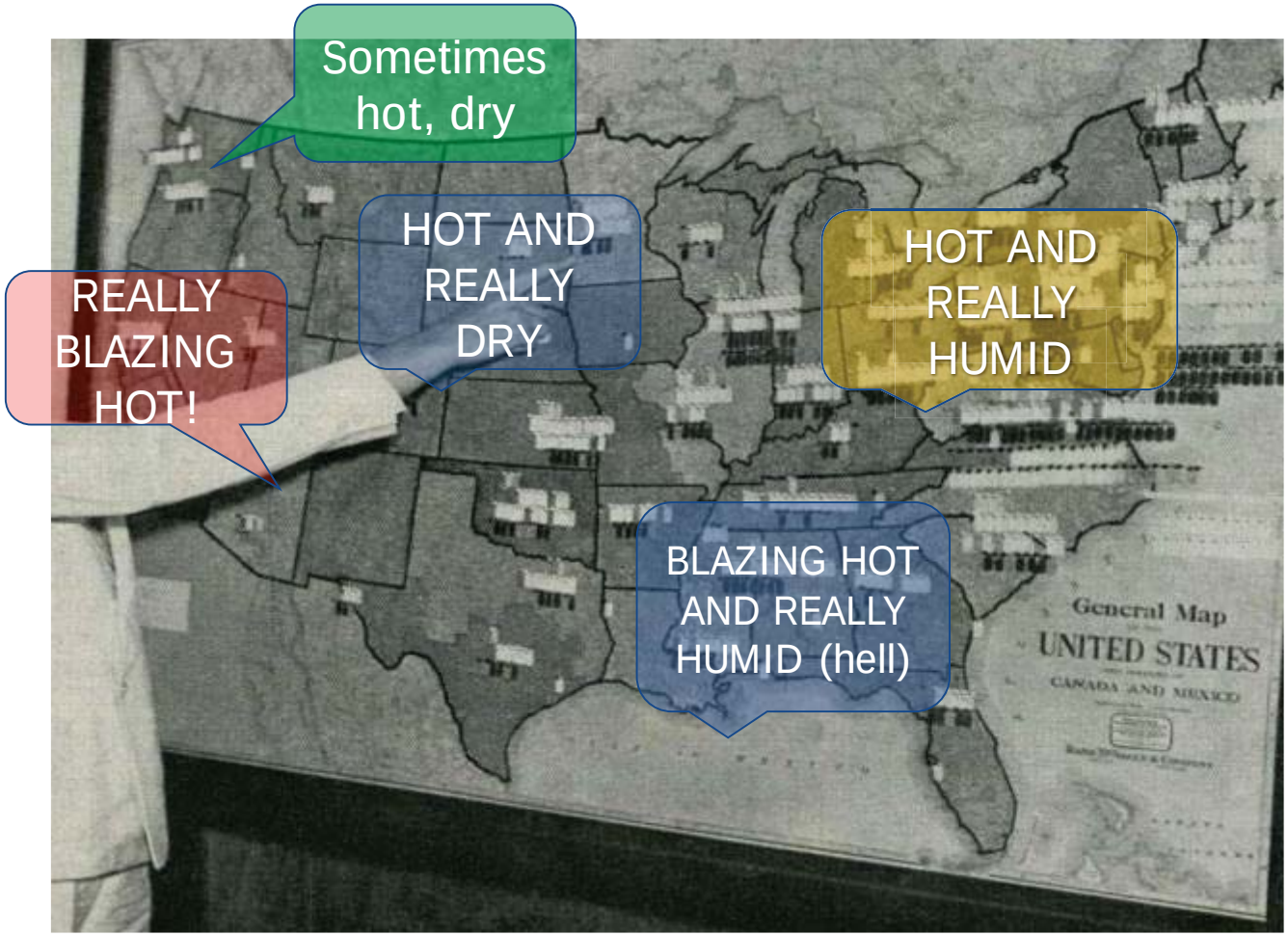
Ratings & Physical / Electrical Data

Model	Input High/Low	Output High/Low	Total Unit	AFUE
	MBH	MBH	Amps	%
TM9V040A10MP11	40/26	38/25	9	96
TM9V060B12MP11	60/39	58/37	9	96
TM9V080B12MP11	80/52	77/50	9	96
TM9V080C16MP11	80/52	77/50	12	96
TM9V100C16MP11	100/65	96/62	12	96
TM9V100C20MP11	100/65	96/62	14	96
TM9V120D20MP11	120/78	115/75	14	96

uct Specifications

	GMVC95 0453BX	GMVC95 0704CX	GMVC95 0905CX	GMVC95 0905DX	GMVC95 1155DX	GCVC95 0714CX	GCVC95 0915DX	GCVC9 1155DX
HEATING CAPACITY								
High Fire Input[1]	46,000	69,000	92,000	92,000	115,000	69,000	92,000	115,000
High Fire Output[1]	45,000	67,000	90,000	90,000	109,000	65,000	87,000	109,000
Low Fire Input[1]	32,000	48,000	64,000	64,000	80,000	48,000	64,000	80,000
Low Fire Output[1]	30,800	46,400	61,700	61,700	77,400	45,000	60,100	77,400
AFUE[2]	95	95	95	95	95	95	95	93
Tons AC @ 0.5" ESP	1.5 - 3.0	1.5 - 4.0	2.0 - 5.0	2.0 - 5.0	2.0 - 5.0	1.5 - 4.0	2.0 - 5.0	2.0 - 5.0
Temperature Rise Range (°F)	30 - 60	30 - 60	30 - 60	30 - 60	30 - 60	25-55	25-55	40-70

fficial Summer Climate Map of America

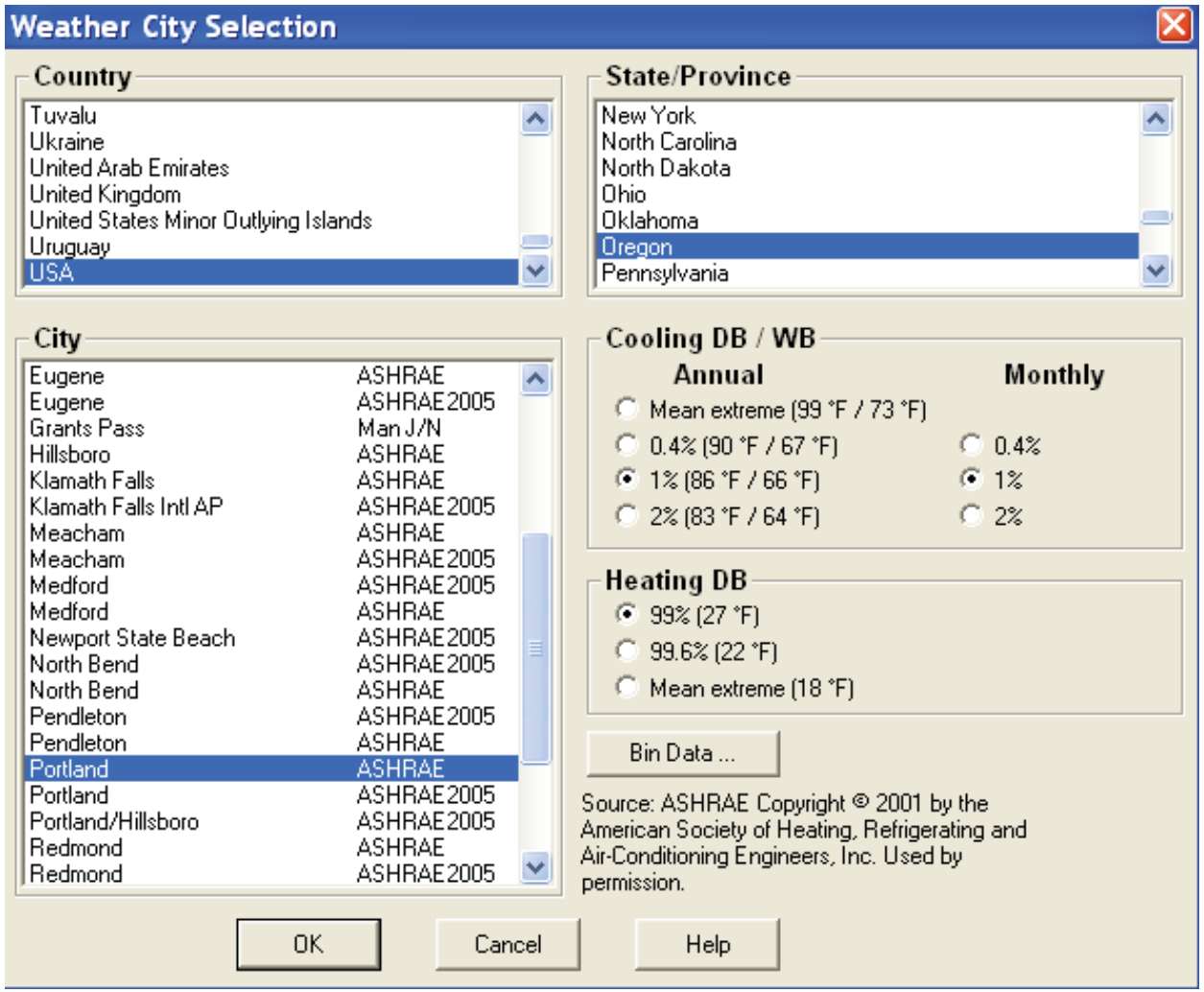


itions: Design Conditions

Design Temperature is not the coldest day or hottest day of the year

- **Winter Design Conditions: It only gets colder than this 1%-2.5% of the time**
- **Boise:**
  - Average coldest temp is -2° F (the mean extreme)
  - Winter Design Condition is 9° F
  - Summer: I don't care about what the design temp is, I want it cool now
- **Portland:**
  - Winter 23° F
  - Summer 86° F
  - What about mean extreme?

Design Temp Do You Want?



REMEMBER WE LIVE IN A DRY SUMMER CLIMATE!

1. Find the outside design temp.
2. Determine your cfm.
3. Pick the lowest Entering Wet Bulb (EWB) temp
4. Locate the sensible capacity

DETAILED COOLING CAPACITIES*

Evaporator Air		CONDENSER ENTERING AIR TEMPERATURES °F											
		85			95			105			115		
CFM	EWB	Capacity MBtuh†		Total System KW**	Capacity MBtuh†		Total System KW**	Capacity MBtuh†		Total System KW**	Capacity MBtuh†		Total System KW**
		Total	Sens‡		Total	Sens‡		Total	Sens‡		Total	Sens‡	
544B024 Outdoor Section With 517EN030 Indoor Section													
800	72	26.3	13.1	2.41	24.8	12.6	2.60	23.3	12.0	2.78	21.8	11.5	2.95
	67	23.9	16.8	2.36	22.5	16.2	2.54	21.1	15.7	2.71	19.8	15.1	2.87
	62	21.7	20.3	2.32	20.5	19.6	2.48	19.3	18.9	2.65	18.2	18.1	2.81
	57	21.2	21.2	2.31	20.2	20.2	2.48	19.2	19.2	2.64	18.2	18.2	2.81
900	72	26.6	13.6	2.46	25.1	13.1	2.65	23.6	12.5	2.83	22.0	12.0	3.01
	67	24.2	17.7	2.41	22.8	17.1	2.59	21.4	16.6	2.77	20.0	16.0	2.93
	62	22.2	21.4	2.37	20.9	20.6	2.54	19.8	19.8	2.71	18.7	18.7	2.88
	57	21.9	21.9	2.37	20.8	20.8	2.54	19.8	19.8	2.71	18.7	18.7	2.88
1000	72	26.9	14.1	2.51	25.3	13.5	2.70	23.8	13.0	2.88	22.2	12.4	3.07
	67	24.5	18.5	2.46	23.0	17.9	2.64	21.6	17.3	2.82	20.1	16.8	2.99
	62	22.5	22.3	2.43	21.4	21.4	2.60	20.2	20.2	2.77	19.1	19.1	2.95
	57	22.5	22.5	2.42	21.4	21.4	2.60	20.2	20.2	2.77	19.1	19.1	2.95
Multipliers for Determining the Performance With Other Indoor Sections													

REMEMBER WE LIVE IN A DRY SUMMER CLIMATE!

1. Find the outside design temp.

2. Determine your cfm.

3. Pick the lowest Entering Wet Bulb (EWB) temp

4. Locate the sensible capacity

6H4036B WITH ADD100R9V5+TXC037E5 AT 1200 CFM

O.D. D.B.	I.D. W.B.	TOT CAP.	SENS. CAP. AT ENTERING D.B. TEMP 72	75	78	80	TOTAL KW
85	59	33.5	27.0	30.2	33.5	34.4*	2.75
	63	36.0	22.7	25.9	29.2	31.4	2.78
	67	38.6	18.0	21.2	24.5	26.7	2.80
95	59	32.3	26.4	29.7	32.6*	33.3*	3.02
	63	34.6	22.1	25.4	28.6	30.8	3.06
	67	37.1	17.4	20.7	23.9	26.1	3.09
105	63	33.1	21.5	24.8	28.0	30.2	3.40
	67	35.4	16.8	20.0	23.3	25.4	3.44
	71	37.8	12.0	15.2	18.5	20.6	3.49
115	63	31.5	20.9	24.1	27.4	29.6	3.75
	67	33.7	16.1	19.4	22.7	24.8	3.80
	71	36.0	11.3	14.6	17.8	20.0	3.85

CORRECTION FACTORS - OTHER AIRFLOWS (MULTIPLY OR ADD AS INDICATED)

AIRFLOW	1050	1350	AIRFLOW	1050	1350
TOTAL CAP	X0.98	X1.01	SENS. CAP	X0.94	X1.06

Where does the 60% sensible 40% latent myth come from?

- 21,600/ 36000 = 60%
- This is one hot muggy house!
- This is not anyplace in the Northwest.

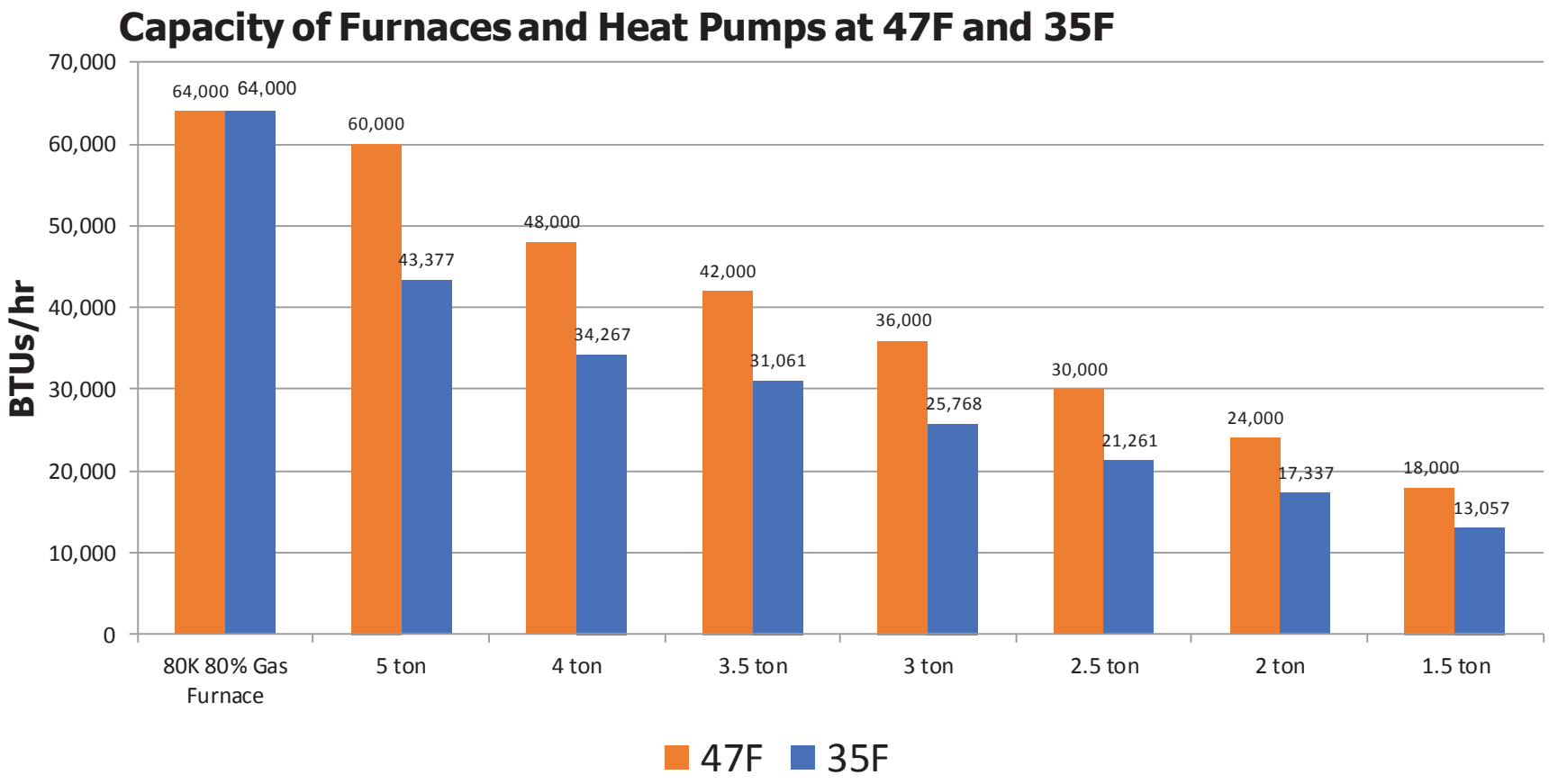
Performance Data @ ARI Standard Conditions—Cooling: RANL- JEZ

Outdoor Unit RANL-	Model Numbers	80°F [26.5°C] DB/67°F [19.5°C] WB Indoor Air 95°F [35°C] DB Outdoor Air				
	Indoor Coil and/or Air Handler	Total Capacity BTU/H [kW]	Net Sensible BTU/H [kW]	Net Latent BTU/H [kW]	EER	SEER
Revised 9/12/2008						
	RCFL-A*3621B* (RGLR-07?BRQ?)	29,400 [8.6]	21,600 [6.3]	7,800 [2.3]	12.00	14.00
	RCFL-A*3621B* (RGPR-05?BMK?)	29,000 [8.5]	21,250 [6.2]	7,750 [2.3]	11.40	13.50
	RCFL-A*3621B* (RGPR-07?AMK?)	29,200 [8.6]	21,450 [6.3]	7,750 [2.3]	11.70	13.50
	RCFL-A*3621B* (RGPR-07?BRQ?)	29,400 [8.6]	21,550 [6.3]	7,850 [2.3]	12.05	14.00
	RCFL-H*3617A* (RGFD-07?MCK?)	29,200 [8.6]	21,450 [6.3]	7,750 [2.3]	11.40	13.50
	RCFL-H*3617A* (RGGD-06?MCK?)	29,200 [8.6]	21,450 [6.3]	7,750 [2.3]	11.45	13.50
	RCFL-H*3617A* (RGGD-07?MCK?)	29,000 [8.5]	21,300 [6.2]	7,700 [2.3]	11.35	13.50
	RCFL-H*3617A* (RGJD-06?MCK?)	29,200 [8.6]	21,450 [6.3]	7,750 [2.3]	11.45	13.50
	RCFL-H*3617A* (RGJD-07?MCK?)	29,000 [8.5]	21,300 [6.2]	7,700 [2.3]	11.35	13.50
	RCFL-H*3617A* (RGLR-07?AMK?)	29,200 [8.6]	21,450 [6.3]	7,750 [2.3]	11.65	13.50
	RCFL-H*3617A* (RGLR-07?BRQ?)	29,400 [8.6]	21,600 [6.3]	7,800 [2.3]	11.95	14.00
	RCFL-H*3617A* (RGPR-07?AMK?)	29,200 [8.6]	21,450 [6.3]	7,750 [2.3]	11.65	13.50
	RCFL-H*3621A*	28,800 [8.4]	21,150 [6.2]	7,650 [2.2]	10.95	13.00
	RCFL-H*3621A* (RGFD-07?MCK?)	29,200 [8.6]	21,450 [6.3]	7,750 [2.3]	11.45	13.50

ng for Cooling

- Most parts of the West require only sensible cooling (very low humidity levels).
- “Air conditioning” originally meant (in large part) dehumidification. Oversized equipment will not dehumidify well. In dry places, oversizing doesn’t matter since (almost) all cooling is sensible.
- Insulation of the house is important to cooling load but windows and ducts are even more important.
- Equipment output tables must be looked at carefully.

Heat Pump Sizing (For Heating) – It's Complicated



Pump Goal

- **The goal is to maximize the savings from heat pumps.**

- **HP savings are dependent on the following items to achieve the goal:**
  - Correct sizing
  - A control strategy that minimizes the use of strip heat
  - A high efficiency heat pump

Keeping the electric strip heat <u>off</u> is the KEY to maximizing energy savings from heat pumps

ing the Strip Heat Off

To minimize the use of strip heat, these two steps must be taken:

1. Size the compressor large enough to provide all the heat needed as long as the outdoor temp is above 30° F (hint: 30° F is the “balance point”).

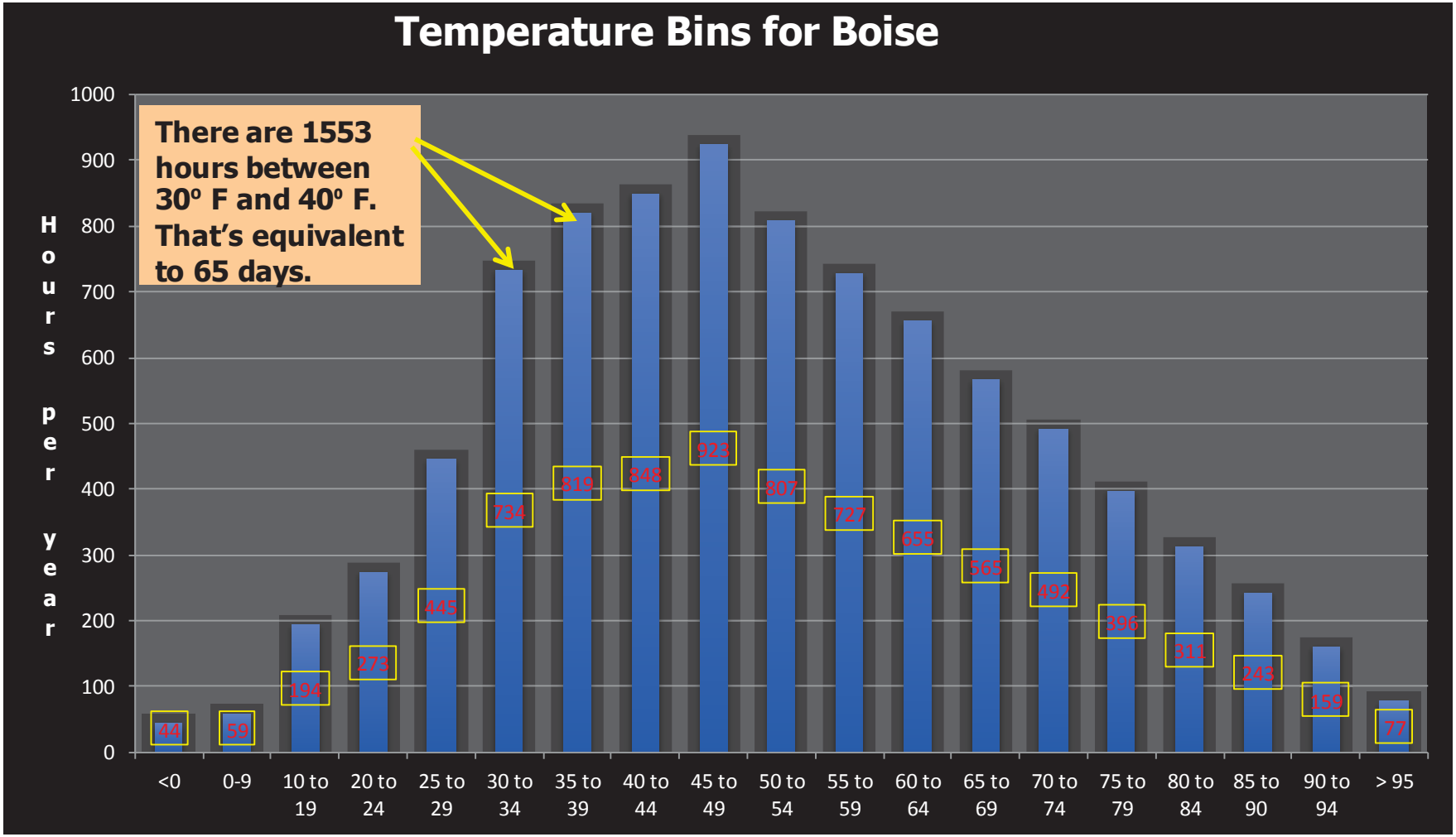
2. Controls w/ outdoor thermostat (lockout strip heat above 35 or 40° F). This prevents unnecessary strip heat use (emergency heat will still work if wired correctly).

itions: Balance Point

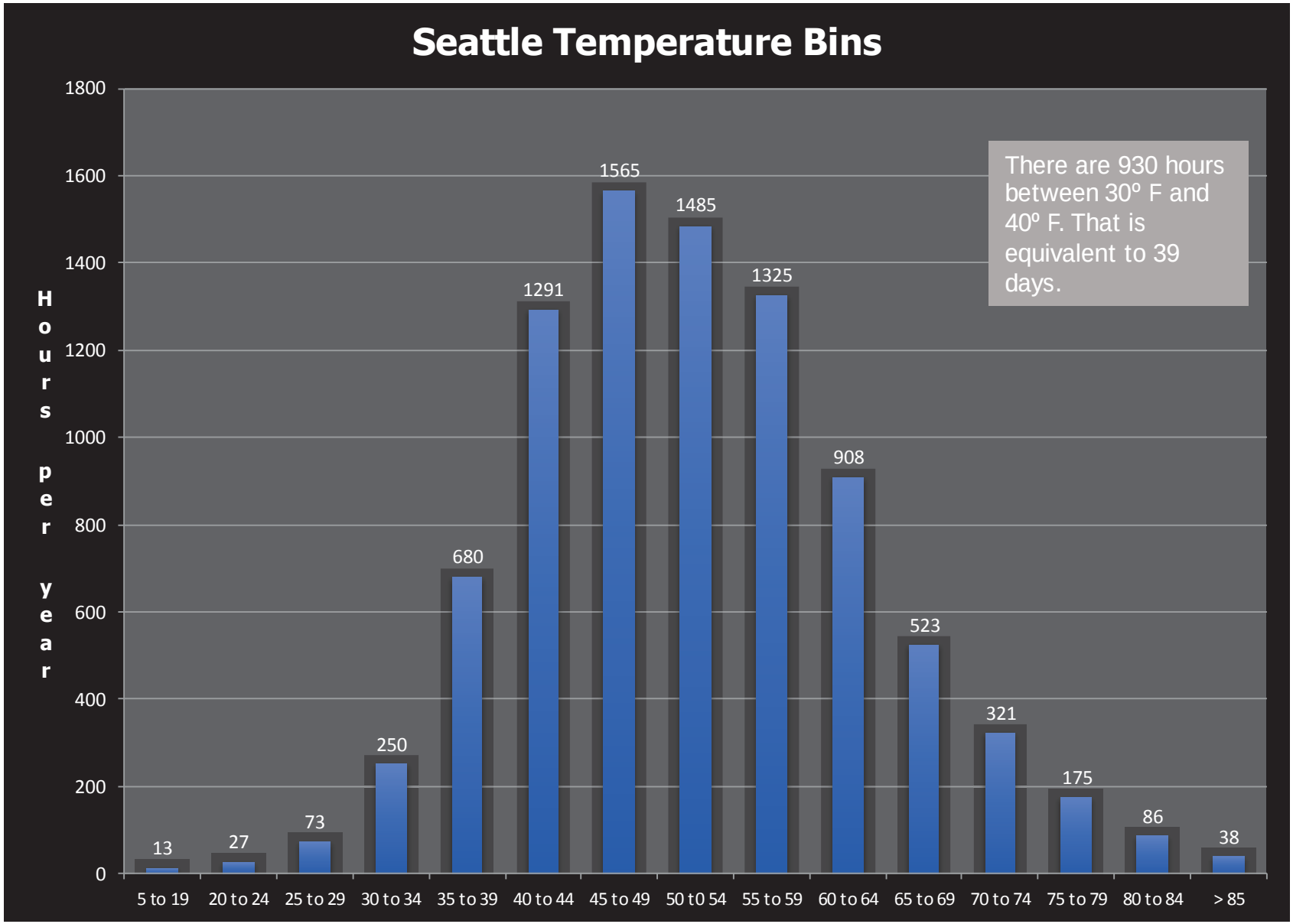
- The lowest outdoor temperature for which the output of the heat pump can heat the house by using the compressor only.
- Below this temperature, the strip heat is needed to help heat the house.
- If it's a gas backed up heat pump, use economic considerations to determine balance point(usually around 40°F)

perature Bins:

Why a 30º F balance point makes sense



perature Bins:



Heat Pump Capacity Ratings

2.5 ton

17F= 15,000

47F=28,400

3 ton

17 F= 21,600

47 F=34,200

3.5 ton

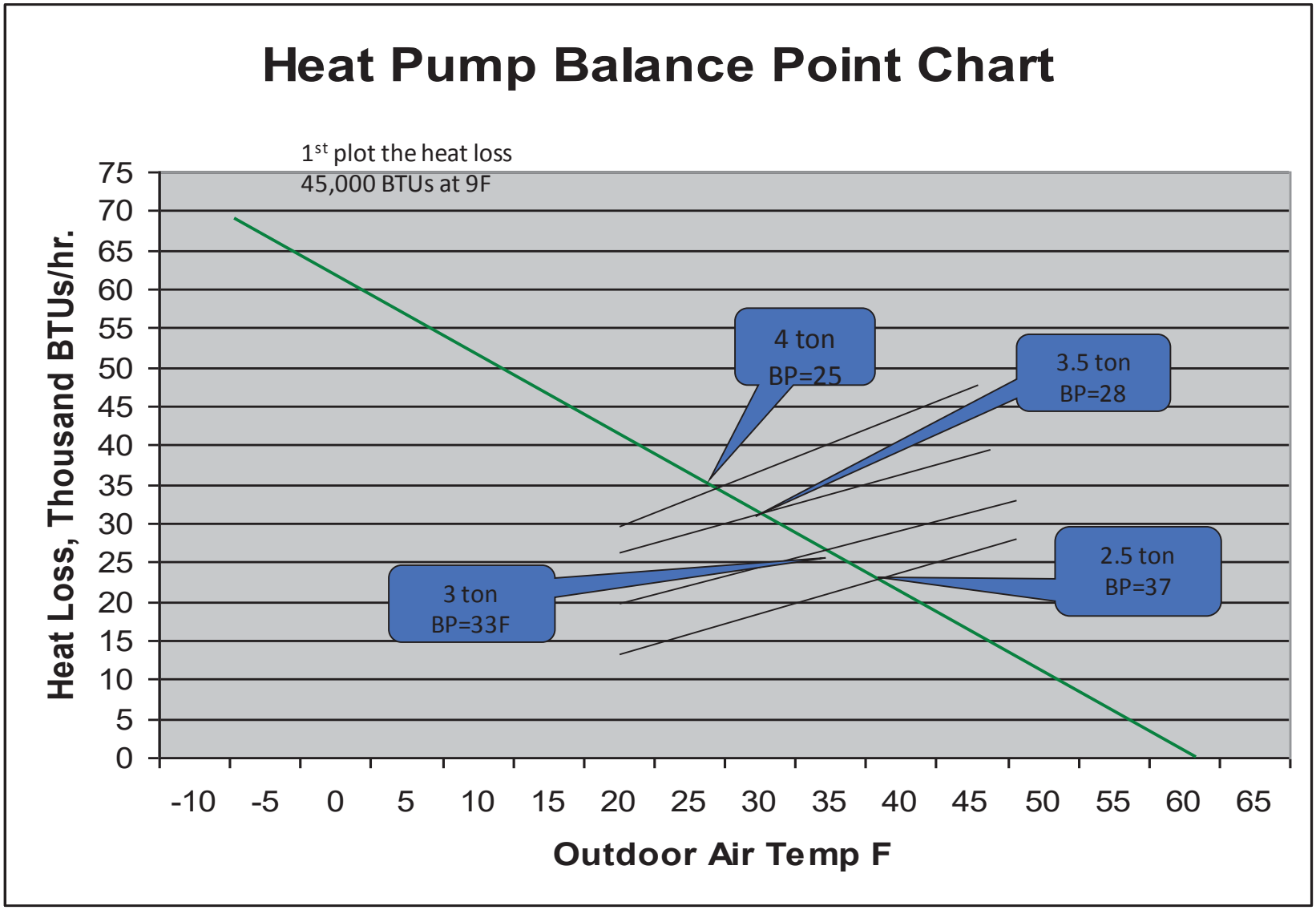
17 F= 26,200

47F =39,000

4 ton

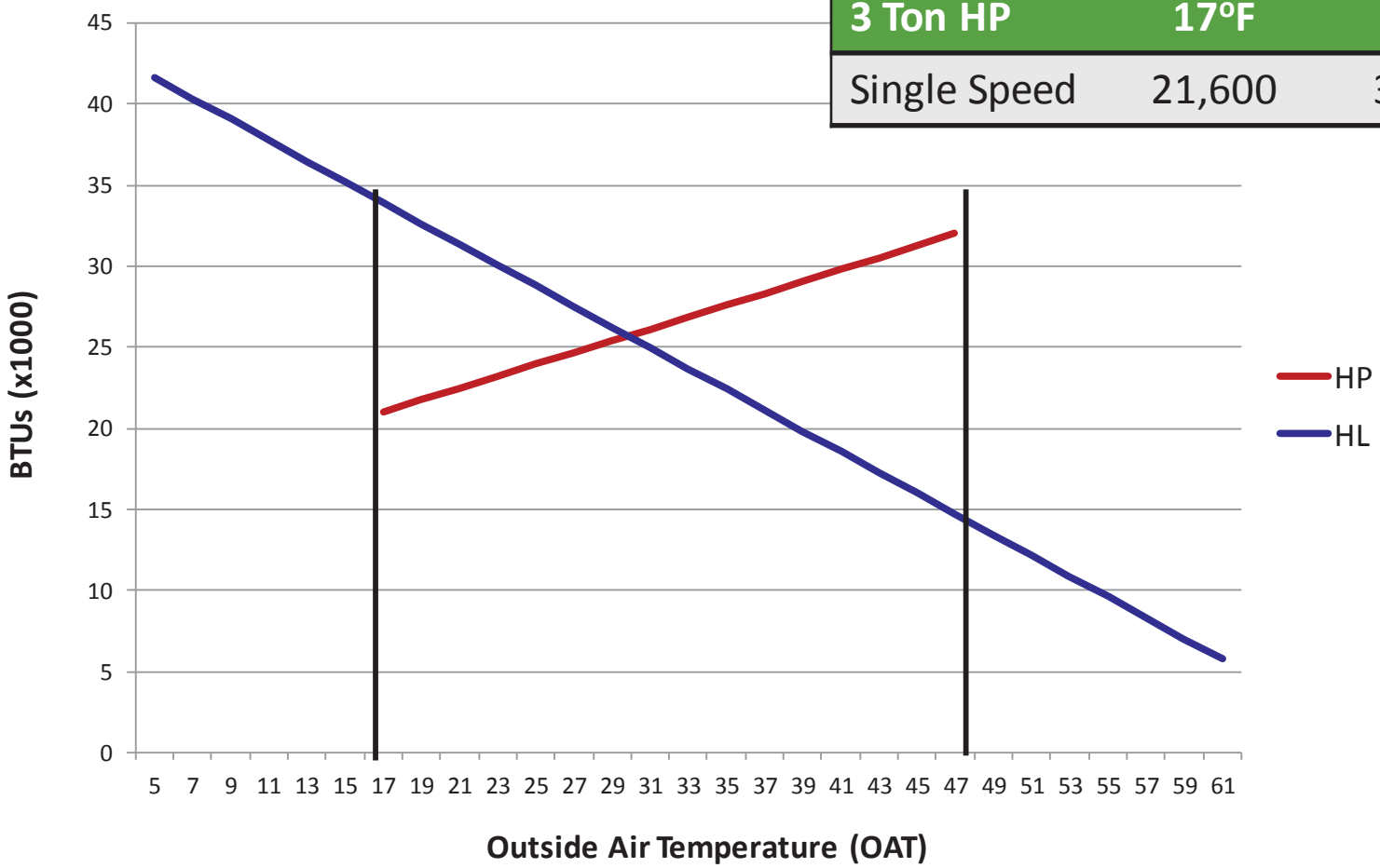
17F =29,200

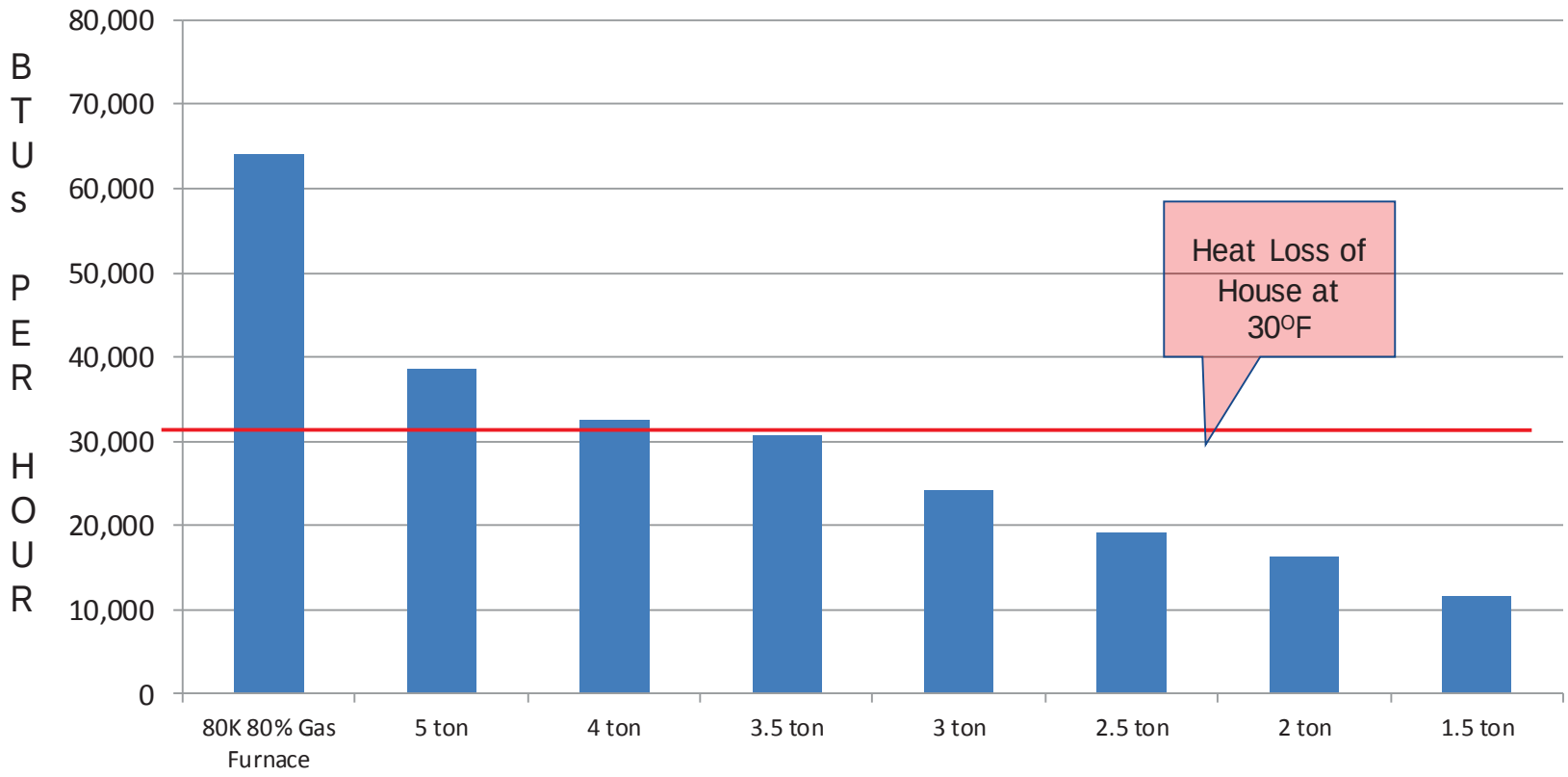
47F=47,00



e Point Using AHRI Data

3 Ton HP	17ºF	47ºF
Single Speed	21,600	34,200





Choose the size for the balance point, not the winter design temp. A three ton heat pump would provide a balance point of just below 30° F. Strip heat will supplement below 30° F. Strip heat must be sized to meet the heat at design conditions.

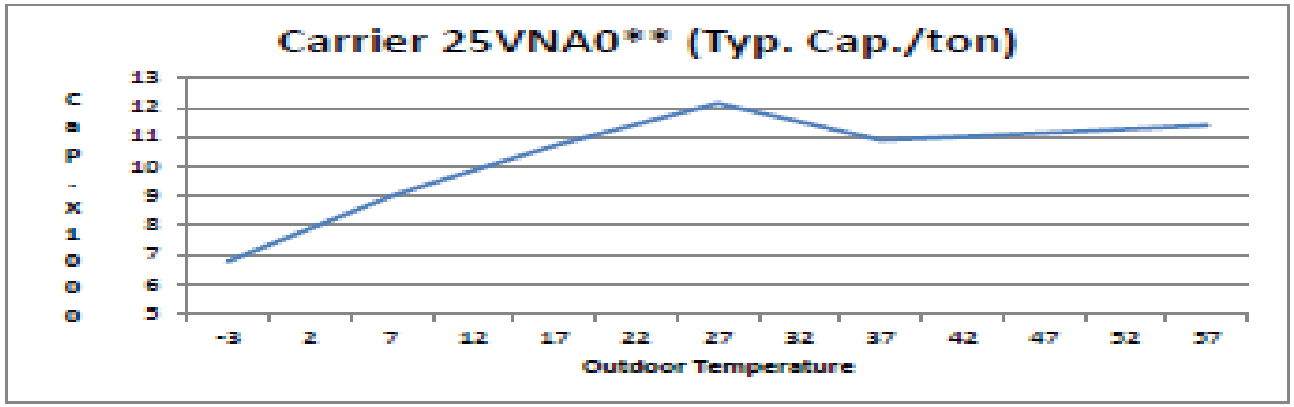
ble Speed Equipment

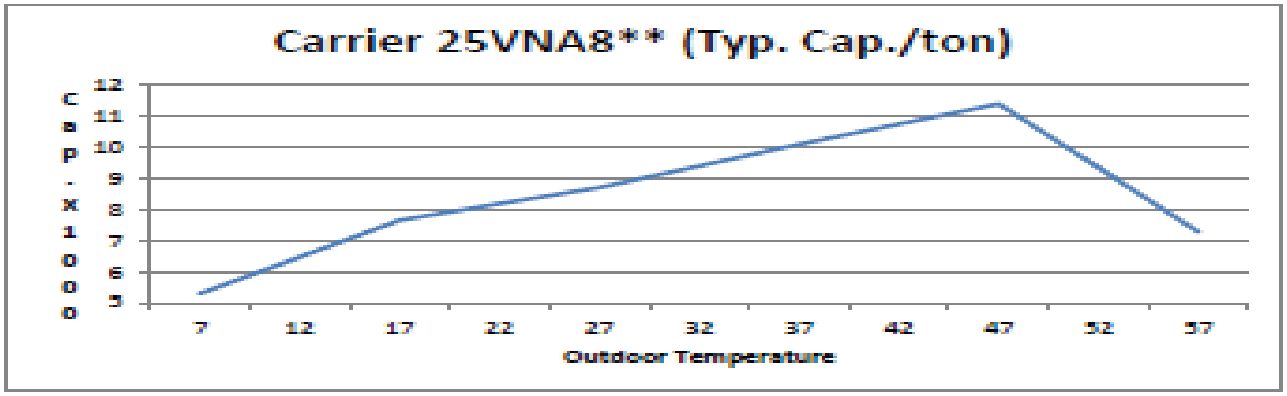
- Lower operating costs
- Higher HSPF
- Typically higher output at 30F Balance Point
  - Home with higher heat loss could use 3 ton VSHP instead of 3.5 ton or higher single-speed heat pump

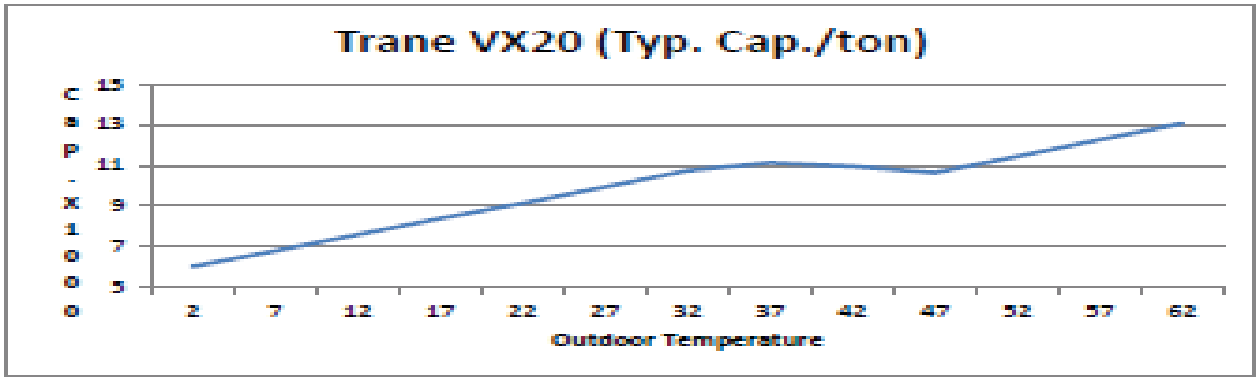
ble Speed Equipment

- Less heat pump cycling above balance point
- Sizing VSHP can be tricky
- Over sizing/under sizing concerns

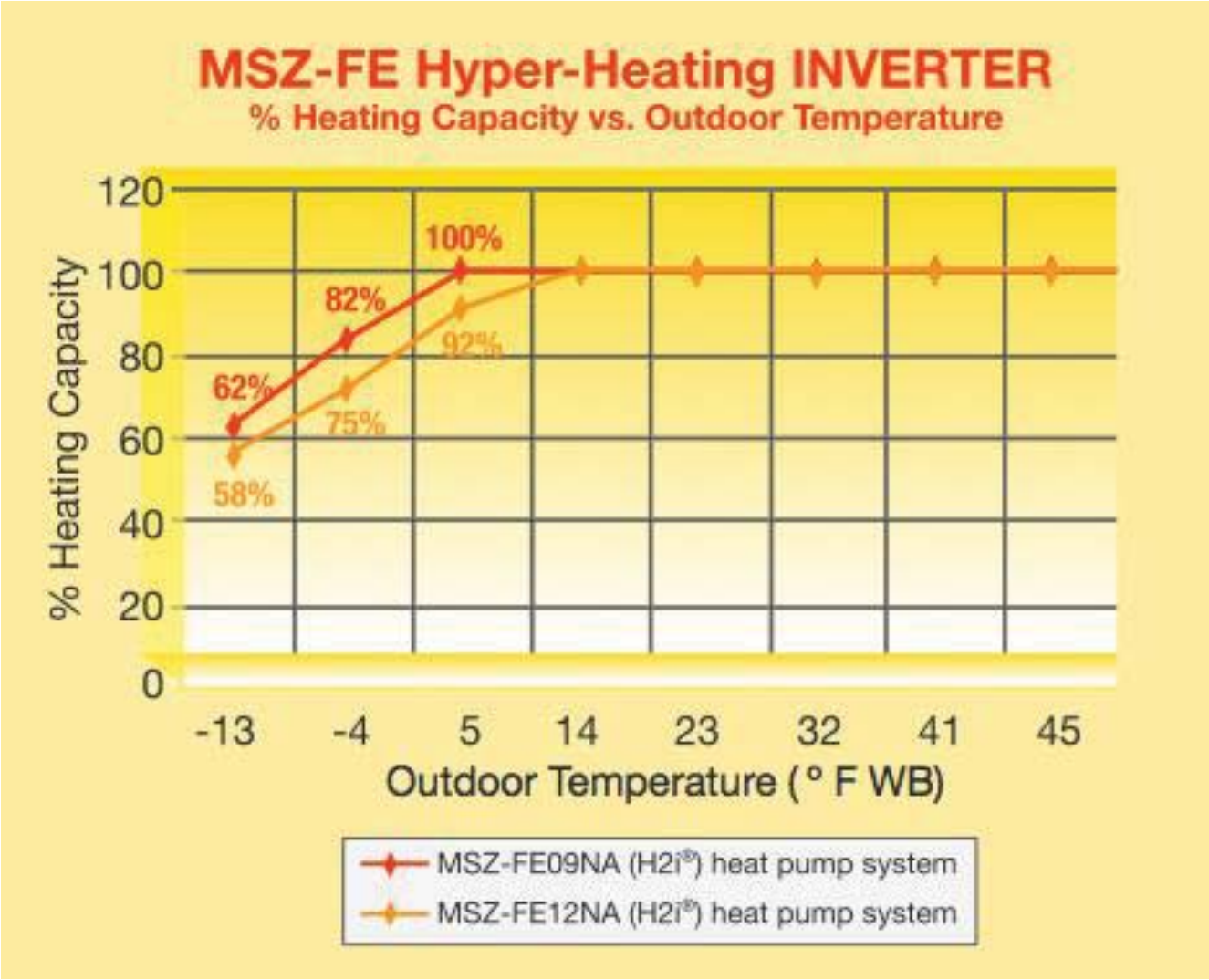
lot So Simple





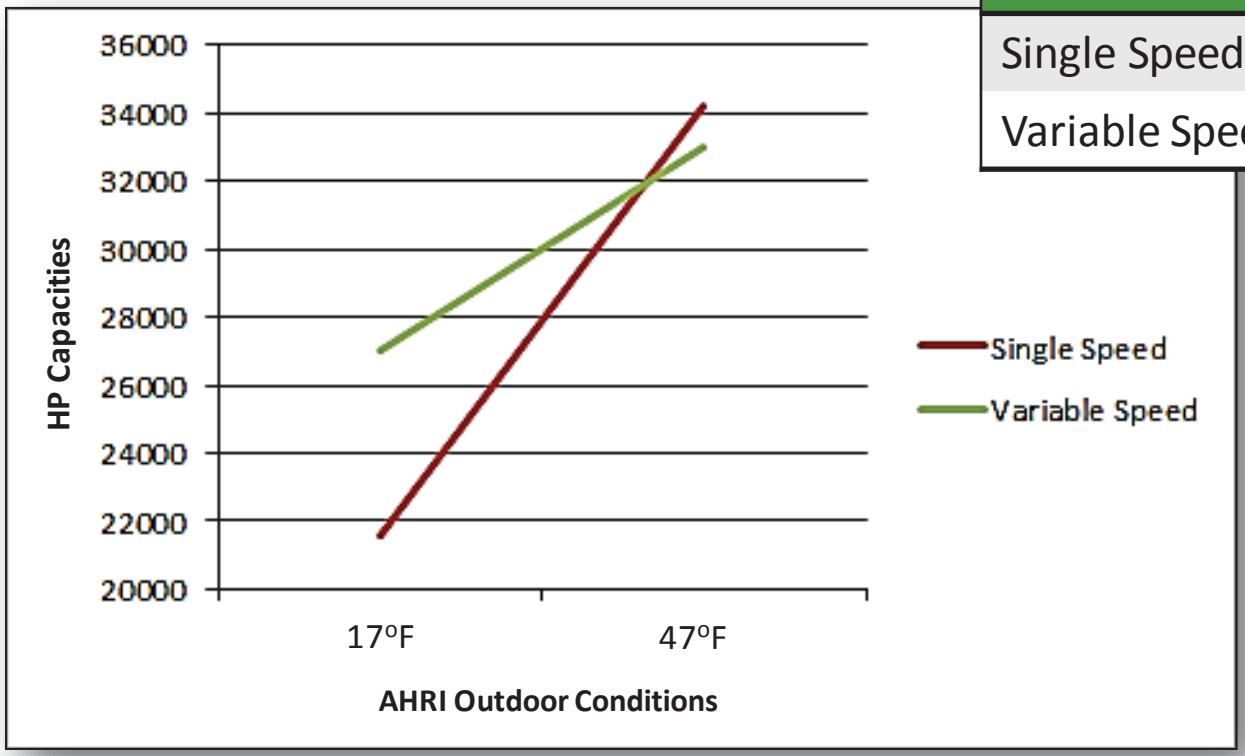


Climate Heat Pumps (no aux heat needed?)



ingle Speed vs. Variable Speed

3 Ton Single Speed and Variable Speed HPs Using AHRI Data



3 Ton HP	17°F	47°F
Single Speed	21,600	34,200
Variable Speed	27,000	33,000

Heat Pump Sizing Calculator

PTCS Heat Pump and Central Air Conditioner Sizing Calculator		
Project Location		
Contractor		
Technician		
Equipment Description		
Calculator Version 3_7, Last Revised 09/29/11	Today's Date	1/20/2016
	Select Location=>	Portland
	Cooling Design Temperature for Selected Location (F)	85
	Cooling Design Delta-T for Selected Location (F)	7
	Enter Home Size (sq.ft.)	1200
	Select vintage that best matches home's insulation characteristics	Post - 2000
	Ceiling/Attic Insulation	R38
	Above Grade Wall Insulation	R21
	Below Grade Wall Insulation	R19
	Floor Insulation	R30
	Exterior Doors	Insulated Metal or Fiberglass
	Select Home's Window Type	NFRC Rated Window
	Enter U-Factor of NFRC Rated Window	0.55
	Enter SHGC of NFRC Rated Window	0.55
	Enter Window Area by Orientation (sq.ft.)	
	North	50
	North East	
	East	50
	South East	
	South	50
	South West	
	West	50
	North West	
	Total Window Area	200
	Select Heat Pump Balance Point (F)	30
	Heat Pump Size (Tons) - Heating	2.0
	Central Air Conditioner Size (Tons) - Cooling	1.0
	Design Load - Heating (Btu/h)	14,100
	Design Load - Cooling (Btu/h)	14,000

A new calculator is being developed that will provide the sizing for variable capacity units.

Note: Click on above image to link to online calculator

Location

Vintage

Window Type

Balance Point

Calculated Heat Pump Size

Calculated Design Load

Sizing Considerations with DHPs

Ductless Heat Pumps

Size to meet the load of the zone(s) at design conditions

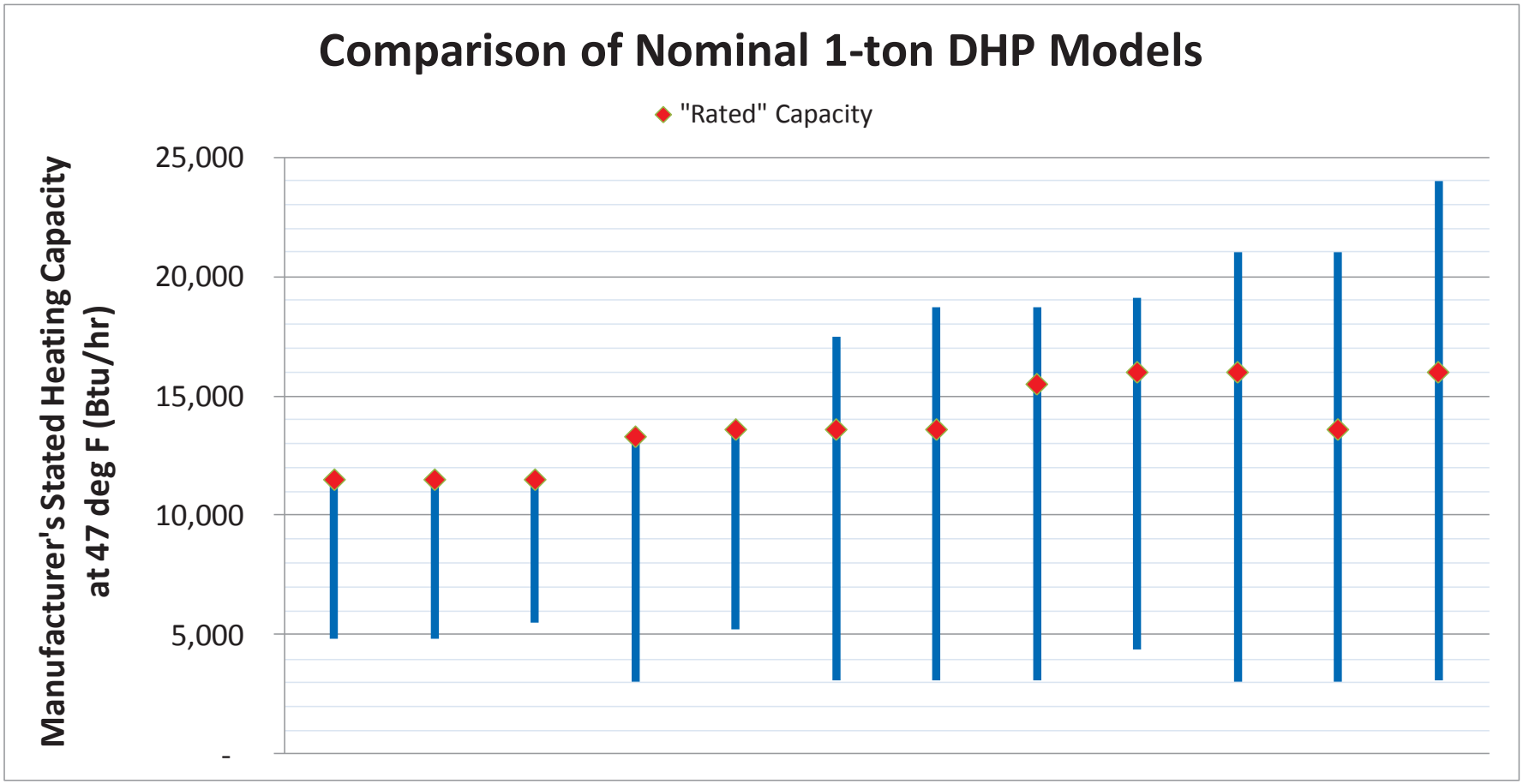
- Take into account supplemental sources and overall design

When sizing, the minimum capacity is nearly as important as the maximum capacity

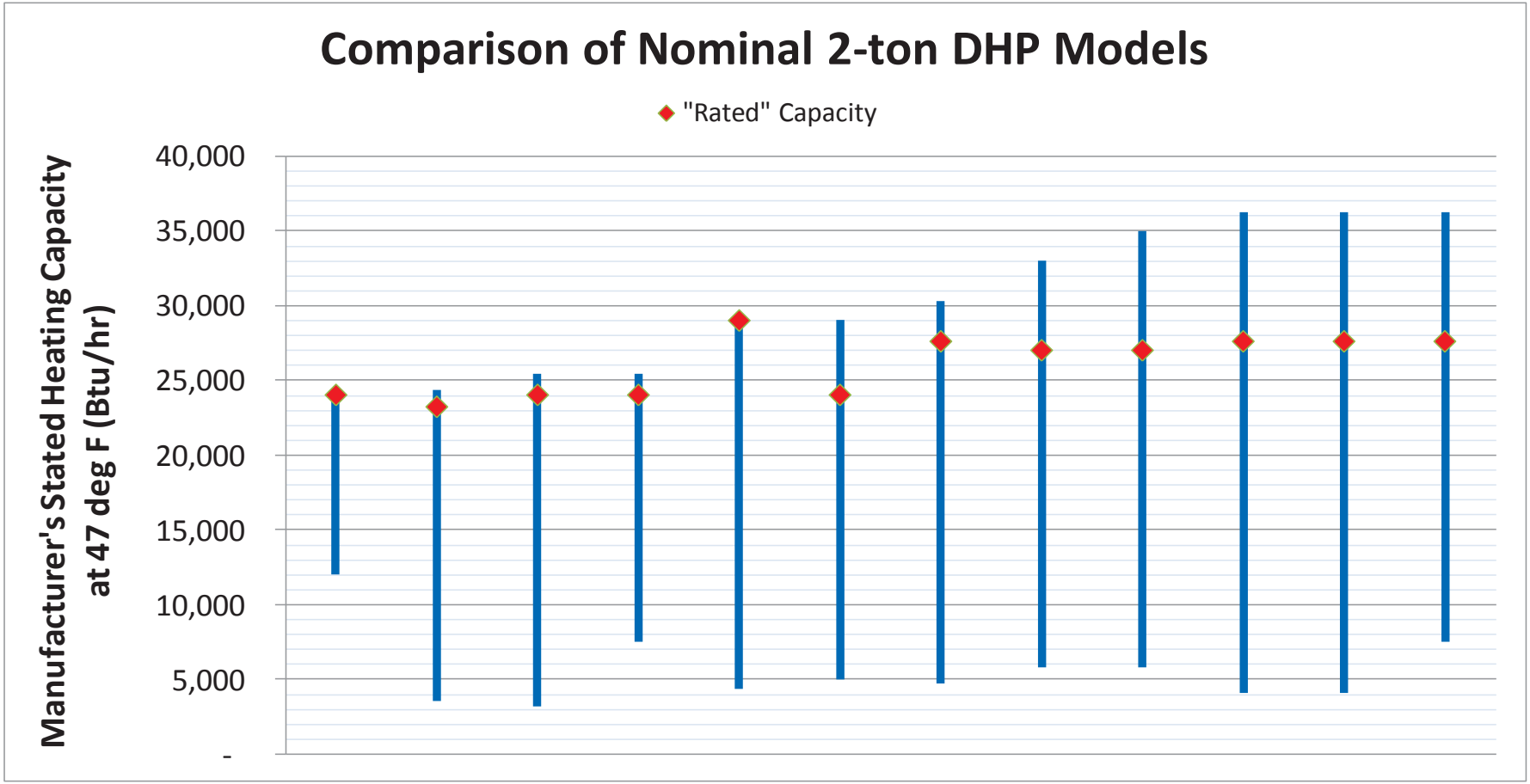
- When the house load drops below minimum capacity, performance drops from severe short-cycling
- A look at the max/min capacity at 47° F can be an indicator of how the unit will perform in these conditions
- We call this the unit's "turn-down ratio".
- It varies greatly by model.

Look for a unit with at least a 4:1 ratio or higher between its maximum and minimum capacity at 47° F

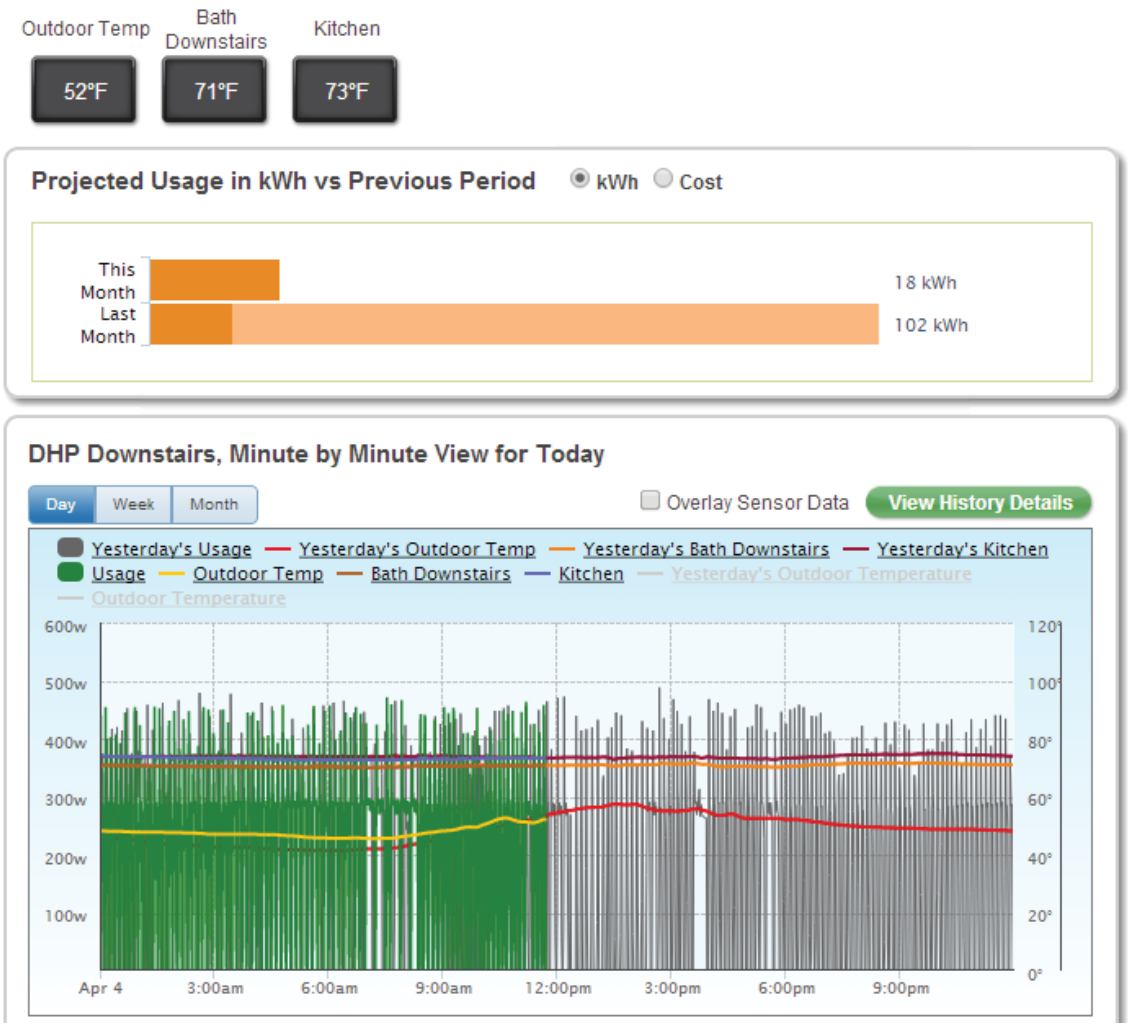
Ductless Heat Pumps



Ductless Heat Pumps



Ductless Heat Pumps



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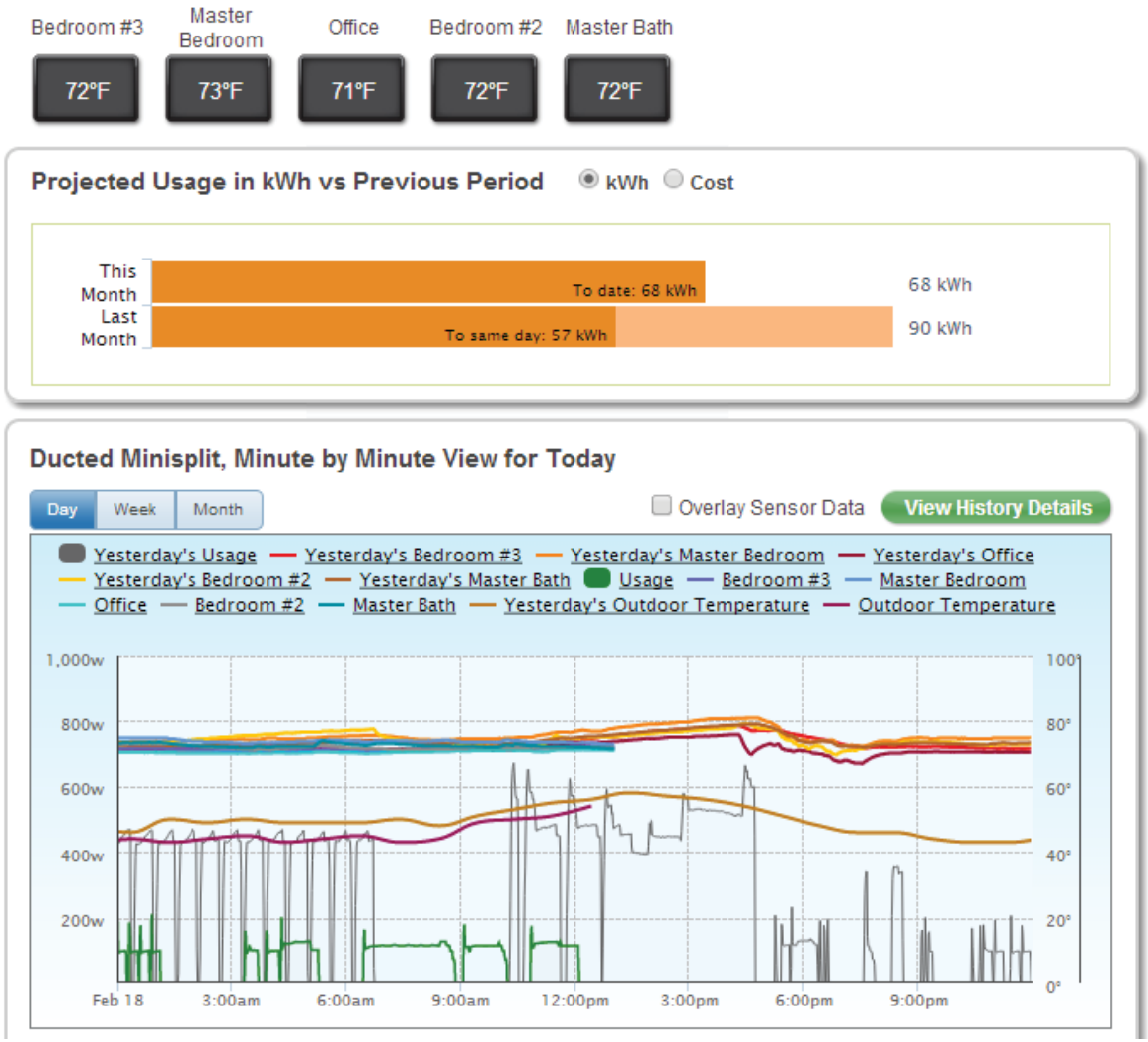
Ductless Heat Pumps



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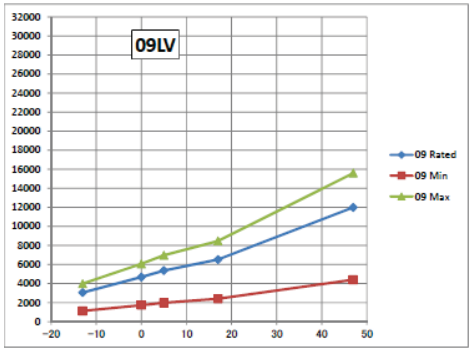
ve Have Learned

- Sizing and Selection is REALLY important!
- Placement is really important
- Homeowner education is really important
- There are BIG differences between models with same nominal size

Heating Cooling Loads Must Be Calculated



DETAILED CAPACITY MUST BE KNOWN

zing for Zones

Heated Zone Sq. Ft	• 2 X 4 wall	2X6 Wall	• Built since 2004
<500	• 15K	• 12K	• 9K
500 to 750	• 18K	• 15K	• 12k
+750	• 24K	• 18K	• 15K

gy Trust's Heat Pump Pilot

- Energy Trust – Oregon territory
- 110 manufactured homes
- Flat fee to participant
- RFP, limited contractor pool

ilot

- $1000 copay from the participant
- ~$3500 from Energy Trust
- Heat pump, crossover repair
- What wasn't included:
  - Furnace replacement
  - Electrical panel upgrades
  - Duct sealing

ping Prices Down

- Avg. 8.5 HSPF
- Contractors bid a fixed price by system tonnage
- Tight specs around what was and wasn't included in the off
- Incentive rammed up to the limits of cost-effectiveness
- Contractors floated the Energy Trust payment
- Contractors were encouraged to offer financing

Pump Sizing Guidelines

Single wides	2X4 walls	2X6 walls
Single wide	2 ton	1.5 or 2 Ton
Double wides	2X4 walls	2X6 walls
28 X48	2 ton	2 ton
28X52	2.5 ton	2 ton
28X 56	2.5 ton	2 ton
28 X60	2.5 ton	2 ton
28X72	3 ton	2.5 ton

r Underestimate the Power of a Good Contractor

- 2 contractors sold almost all the systems
- Both had extensive MH contacts
- One did a mailer, one worked their network
- Both contributed significantly to the final technical spec

at Contractors Said

- “We got energy saving heat pumps into the hands of peopl
  couldn’t otherwise afford it and it was good for our busin

- “It was a platform to educate homeowners about ener
  efficiency.”

lts

- 110 heat pumps sold
- 0 applications rejected
- Contractors paid within 30 days 100% of the time
- Average cost $4700

The Really Good Results Are…….

An Average savings of 3,400 kWh/year

Reached a segment of the market that did not know they were in the market

t was found

Site ID	City	Year Built	Sq. ft.	MH Type	Tonnage	Strip Heat Ratio
683853	Bend	1996	1400	Double-wide	2	49%
683890	Bend	1997	1400	Double-wide	2	14%
677995	Bend	1997	1620	Double-wide	2.5	9%
139287	Oregon City	1991	1292	Double-wide	2	7%
25106	Oregon City	1991	1080	Double-wide	2	5%
690344	Terrebonne	1997	1296	Double-wide	2	4%
689461	Bend	1997	1200	Double-wide	2	3%
543542	Oregon City	1995	1800	Double-wide	3	2%
497998	Oregon City	1995	1290	Double-wide	2	2%
325913	Bend	1988	1980	Double-wide	3	2%
690383	Oregon City	1996	1296	Double-wide	2	1%
689451	Bend	1995	1810	Double-wide	3	1%
583813	Oregon City	1987	1296	Double-wide	2	0%
562026	Oregon City	1990	1568	Double-wide	2.5	0%
520339	Portland	2014	1500	Double-wide	2.5	0%
467510	Bend	1997	1400	Single-wide	2	0%
231255	Oregon City	1990	1400	Double-wide	2.5	0%
467251	Bend	1997	1400	Double-wide	2.5	0%
683842	Oregon City	2013	1917	Double-wide	3	0%

We Found

	Aux Heat Ratio	Delta Capacity	% Below or Above	Thermostat Settings	Reasons for high aux heat ratio
1173489	0	2114	9%	Strip heat locked out at 35F.	
1156226	0	-6009	-20%	Max Savings	
231255	0	-3272	-11%	Max Savings	
562026	0	-5961	-20%	Max Savings	
1171519	4	54	0%	Max Savings	
139287	7	-5427	-23%	Max comfort	Set to Max Comfort, 23% low on capacity
1138572	9	-11966	-40%	Max comfort -	Set to Max Comfort, Very low capacity
1156212	14	-1709	-7%	Max Savings	Homeowner used deep set backs
				Locked out compressor at	Locked out

minary Conclusions

- All thermostats can cause control problems
  - But connected thermostats can find them!
- Maybe by comparing run times and using connected therm
  "problem" homes or systems can be found