REPLACING A HYDRO-AIR BOILER WITH AN AIR-SOURCE HEAT PUMP

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Westford Symposium on Building Science XXVIII (XXX yrs) 2026/08/05

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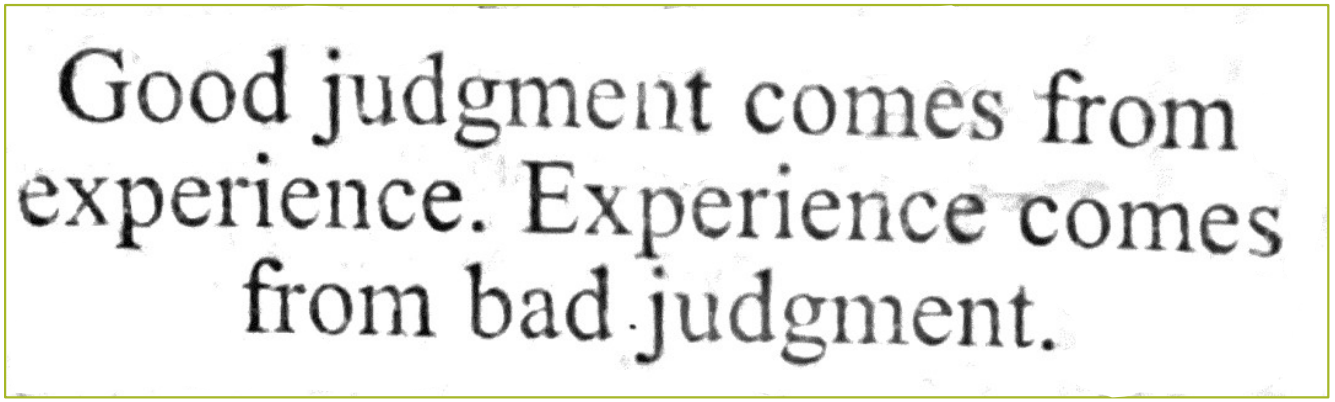


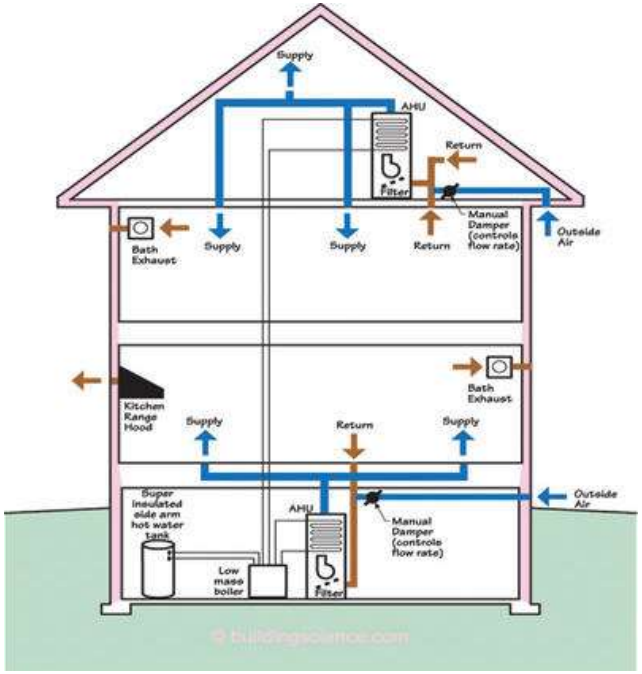
Outline

- A call for help…
- Building load calculations (2 ways)
- Sizing concerns and performance curves
  - Steps in the process
- Follow up and look ahead

The house

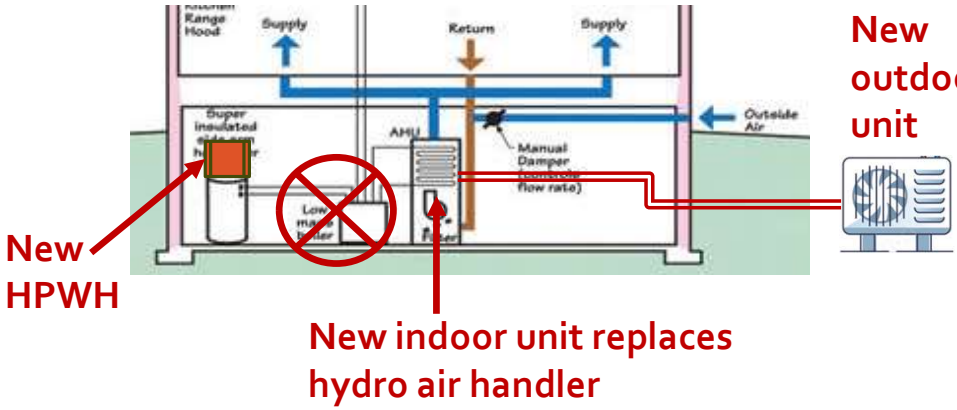
- **BSD-139: Deep Energy Retrofit of a Sears Roebuck House—A Home for the Next 100 Years**

The call for help:
Sorry, HVAC systems don't last 100 yr ☹

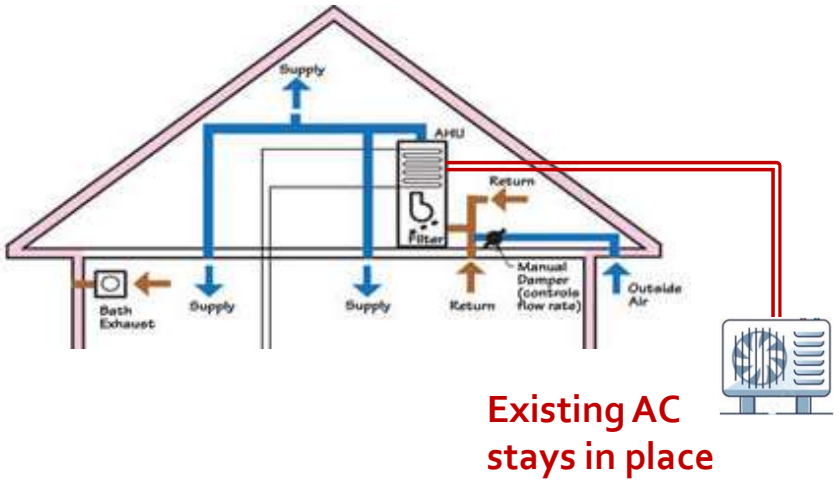


Unique in this situation: existing ducts

- No more boiler for heat supply
- Change indirect HW to HPWH
- Add air source heat pump

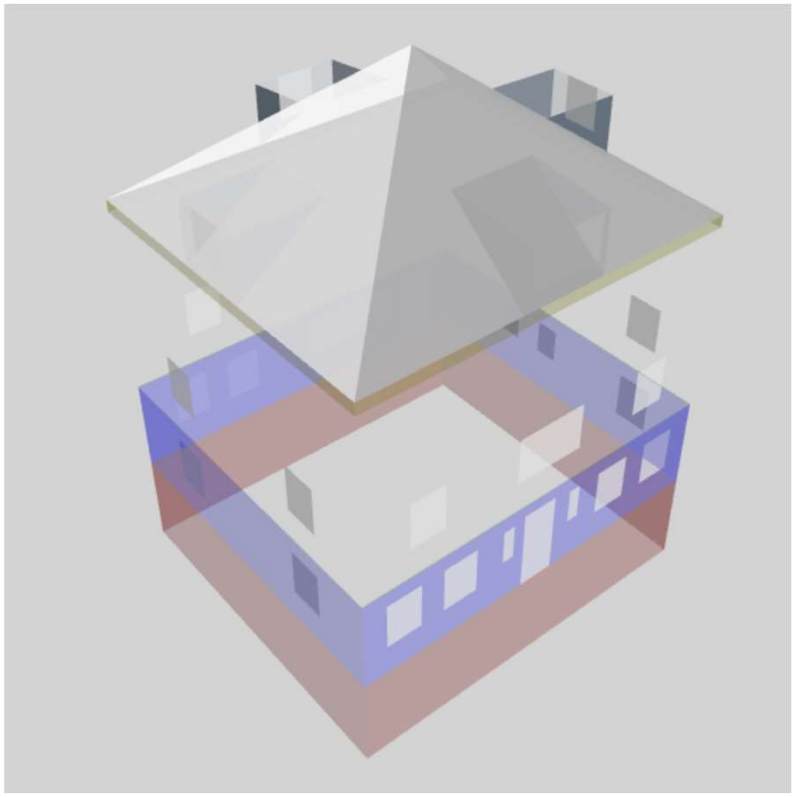


- No boiler supplied heat upstairs – AC stays in place.
- How will that go??



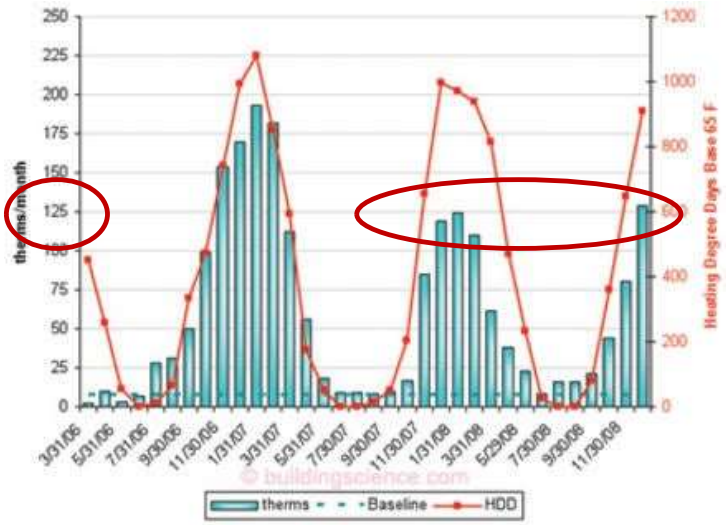
Manual J:

- Heating Btu/h @ 2°F
  - Basement & 1st: 15,047
  - 2nd & attic: 9,228
  - Total: 24,300
- Cooling: 5,200 and 7,500
- No room-by-room
  - Existing distribution equipment



Two types of heating load calculations:

2007-2008



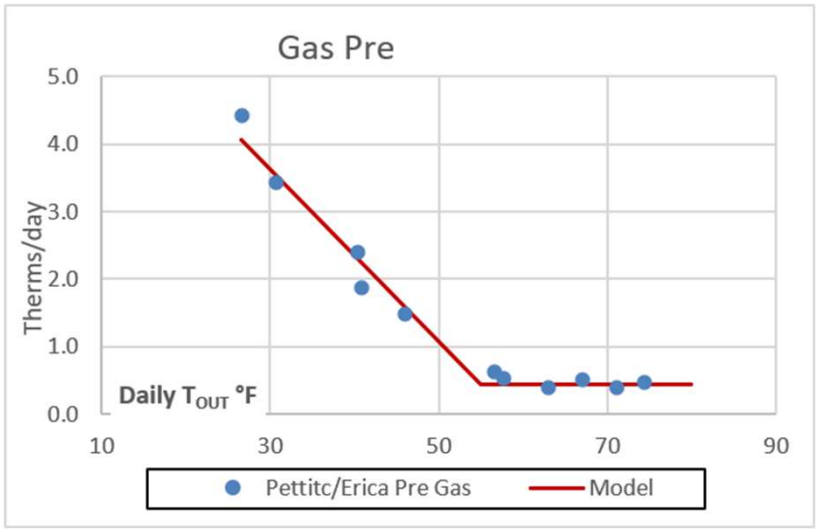
2025-26

Gas Usage History

Month	Therms	Month	Therms
Feb 25	121	Sep 25	12
Mar 25	67	Oct 25	19
Apr 25	46	Nov 25	58
May 25	16	Dec 25	103
Jun 25	16	Jan 26	137
Jul 25	14	Feb 26	124
Aug 25	12		

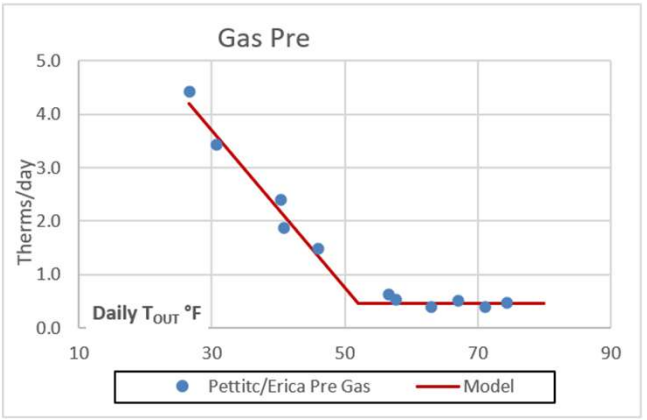
Fitting gas use to outdoor temperature:

Rsq = 0.99, MAPE = 13%



Heating load estimate:

- UA = 468 Btu/ (h·°F)
- Load = 24,340 at 2°F
  - Or maybe 26,000 (9% MAPE)



Heat Pumps

- I am VERY tired of people saying "Heat pumps …
  - … don't have enough capacity in cold weather
  - … deliver uncomfortably cool air in cold weather
  - … need 100% backup heat source in any climate
  - … have such poor efficiency in cold weather, better to use gas"

Design Temperatures (Hanscom AFB)

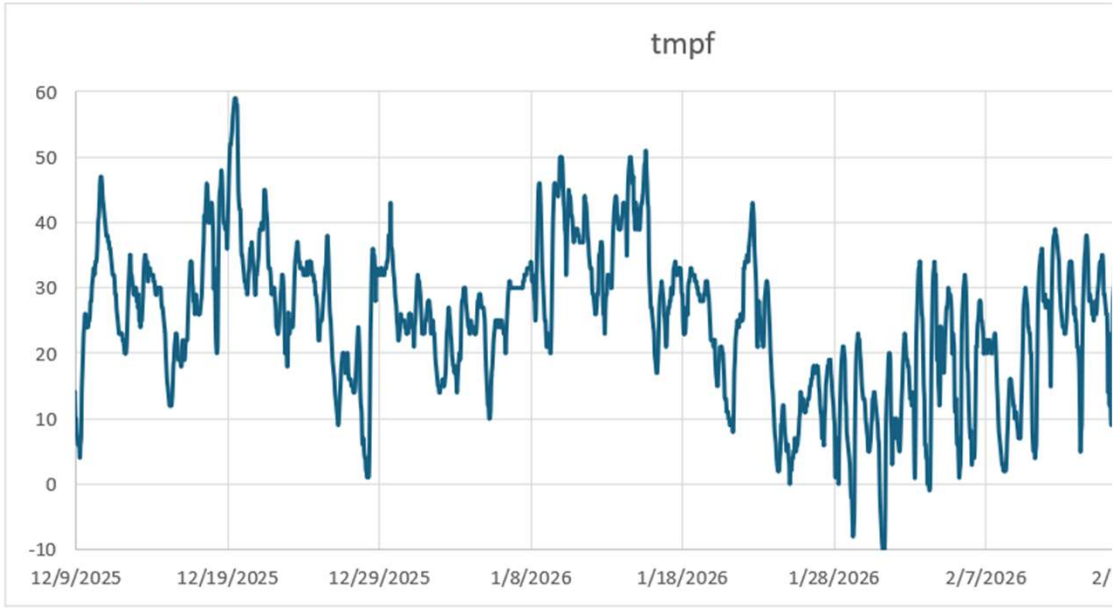
2021 ASHRAE Heating Values:

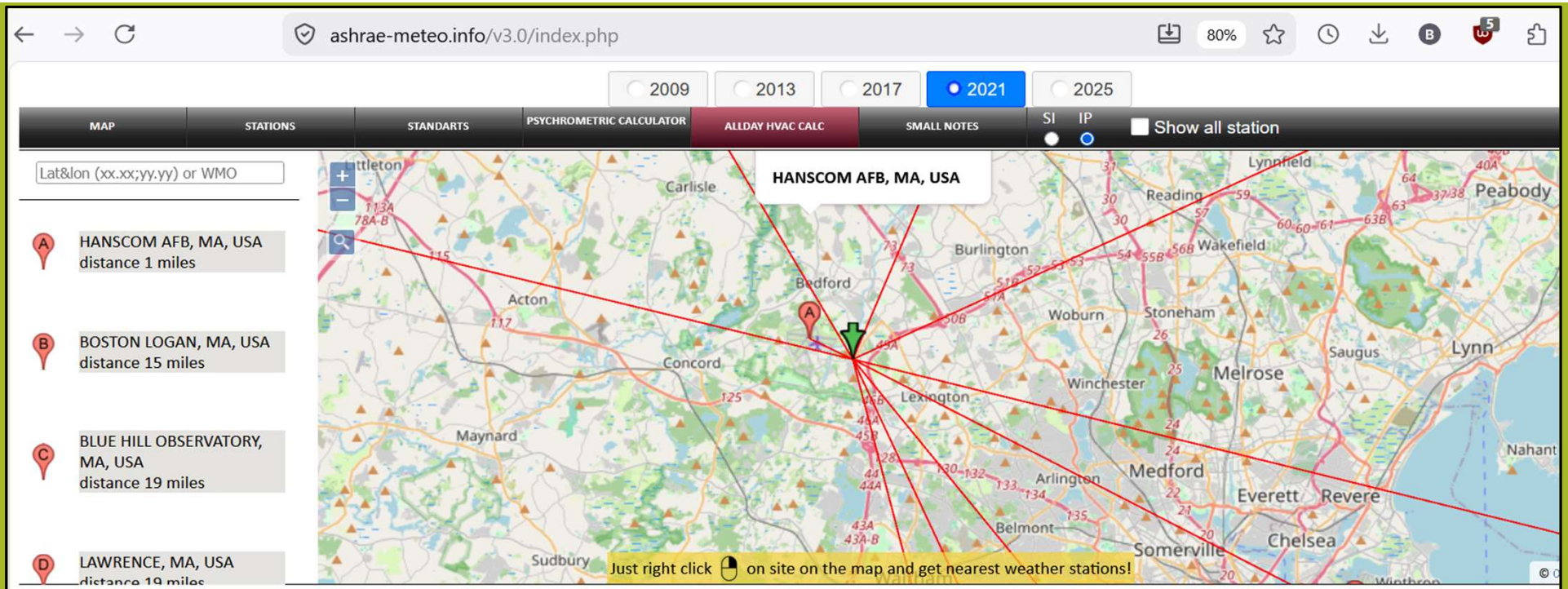
99% (standard)	7.8 °F
99.6%	2.3 °F
Mean extreme:	-4 °F

Contractor wanted to put in 24,000 Btu/h capacity at -15 °F

Winter 2025/26 (Bedford)

Temp (F)	hours below:
5	72
0	16
-5	8
-10	0





2021 ASHRAE Handbook - Foundamentals (IP)

Compare

HANSCOM AFB, MA, USA (WMO: 725059)

Lat: **42.47N** Lon: **71.289W** Elev: **133** StdP: **14.63** Time zone: **-5.00 (NAE)** Period: **99-19** WBAN: **14702** Climate zone:**5A**

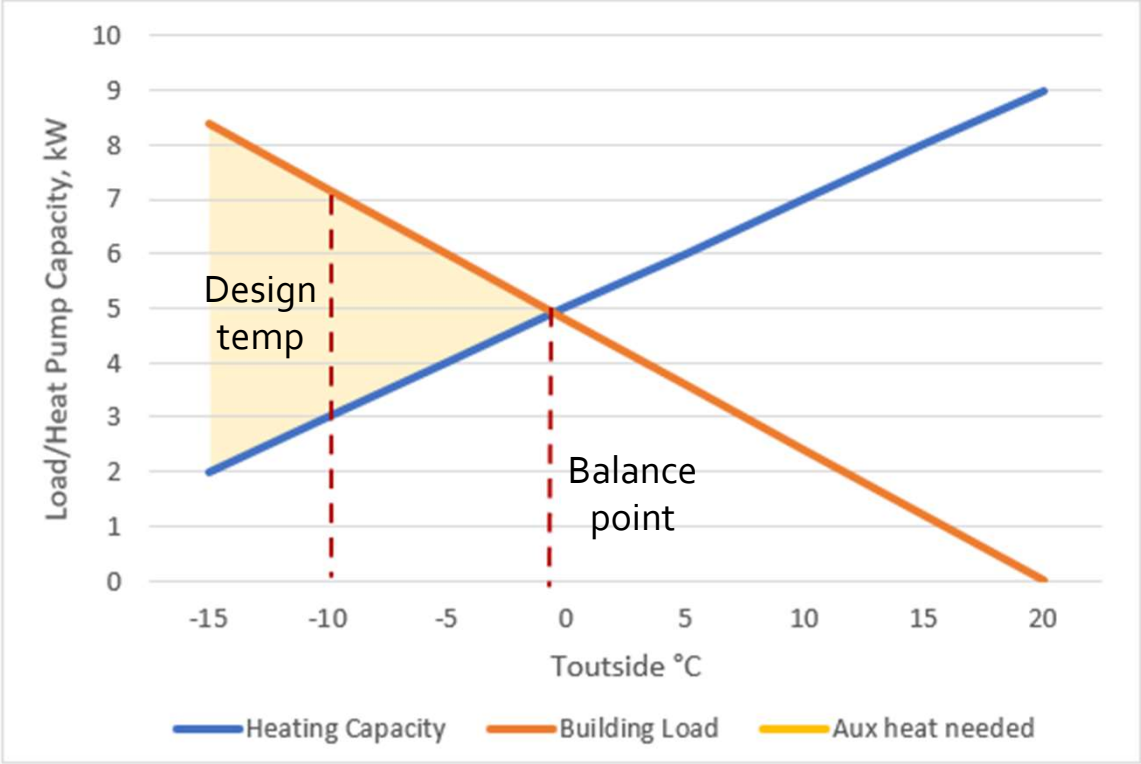
Annual Heating, Humidification, and Ventilation Design Conditions

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	
1	**2.3**	**7.8**	**-11.4**	**3.0**	**7.5**	**-7.4**	**3.7**	**11.4**	**25.4**	**24.7**	**23.4**	**26.2**	**6.2**	**290**	**0.527**

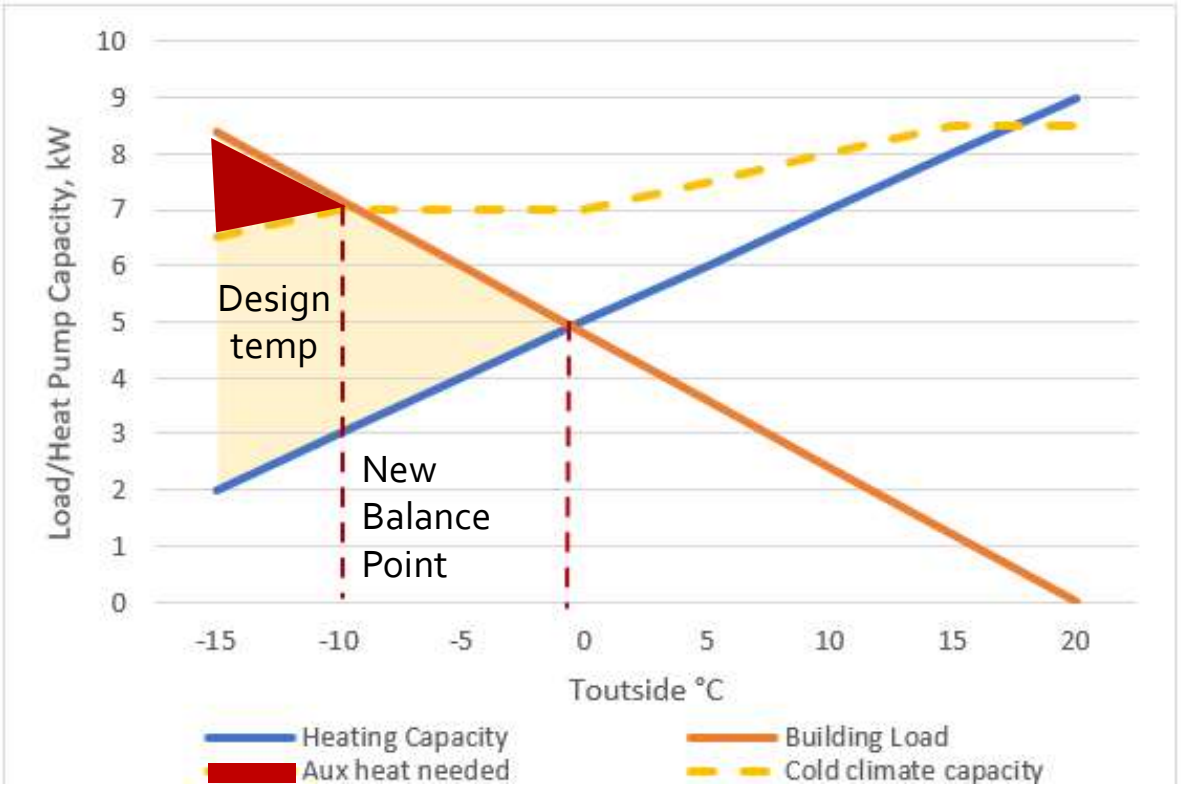
Annual Cooling, Dehumidification, and Enthalpy Design Conditions

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	**20.9**	**90.8**	**73.2**	**88.0**	**71.8**	**84.8**	**70.2**	**76.3**	**86.2**	**74.8**	**83.3**	**73.2**	**80.7**	**9.8**	**240**

Auxiliary heat – conventional heat pump

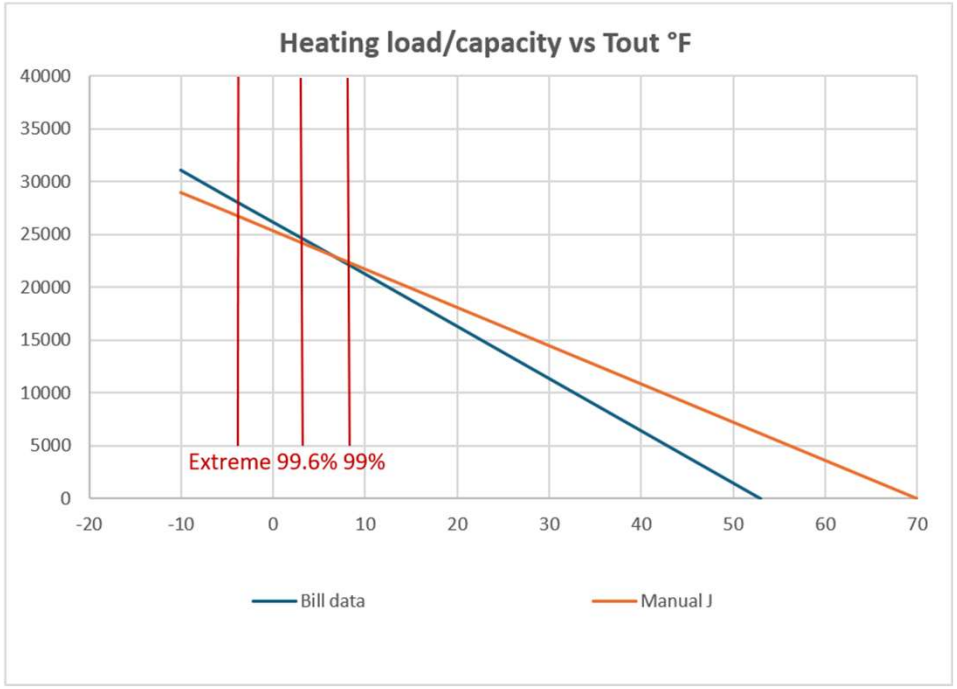


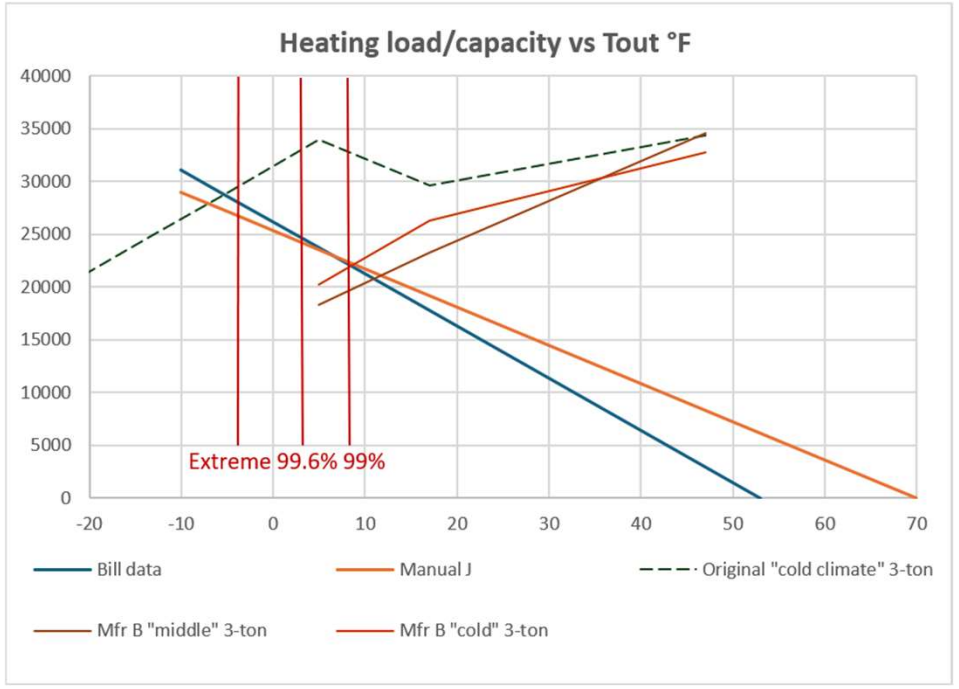
Cold climate heat pump



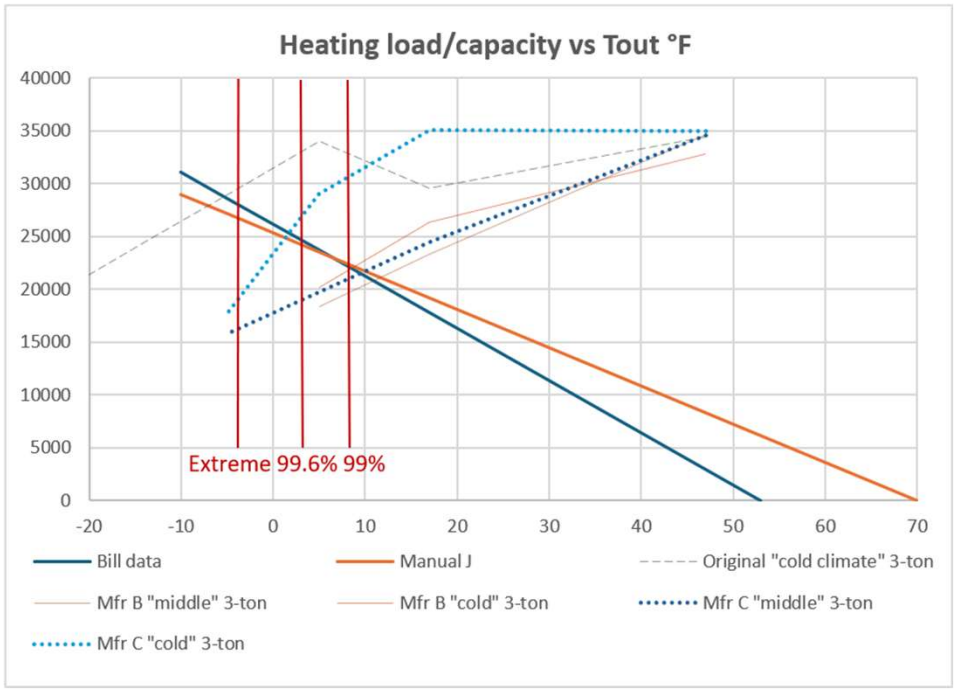
Plot load lines – Btu/h required vs. T out

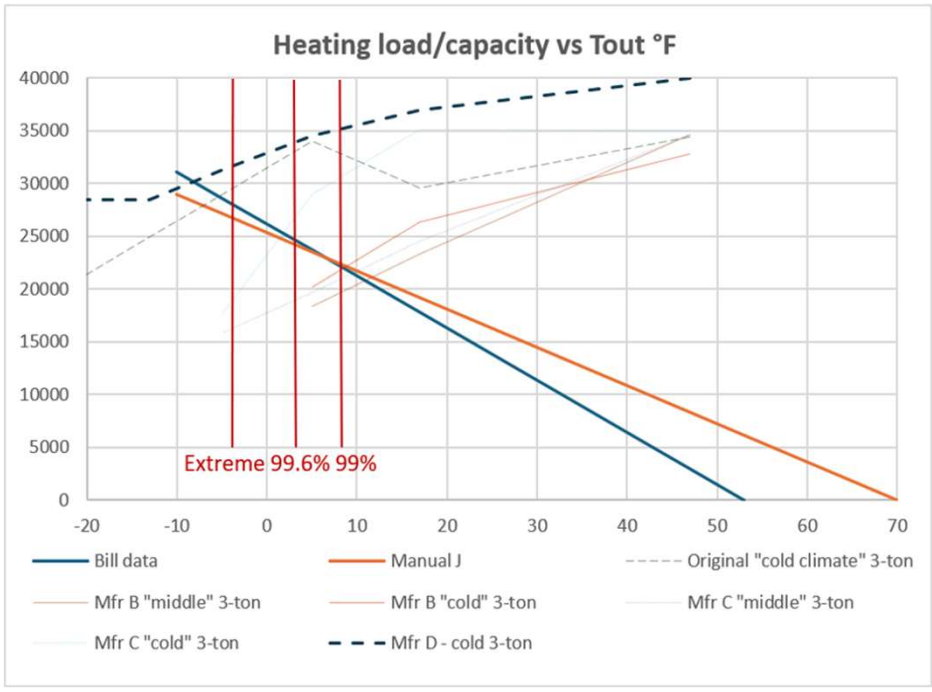
Then add equipment capacities:





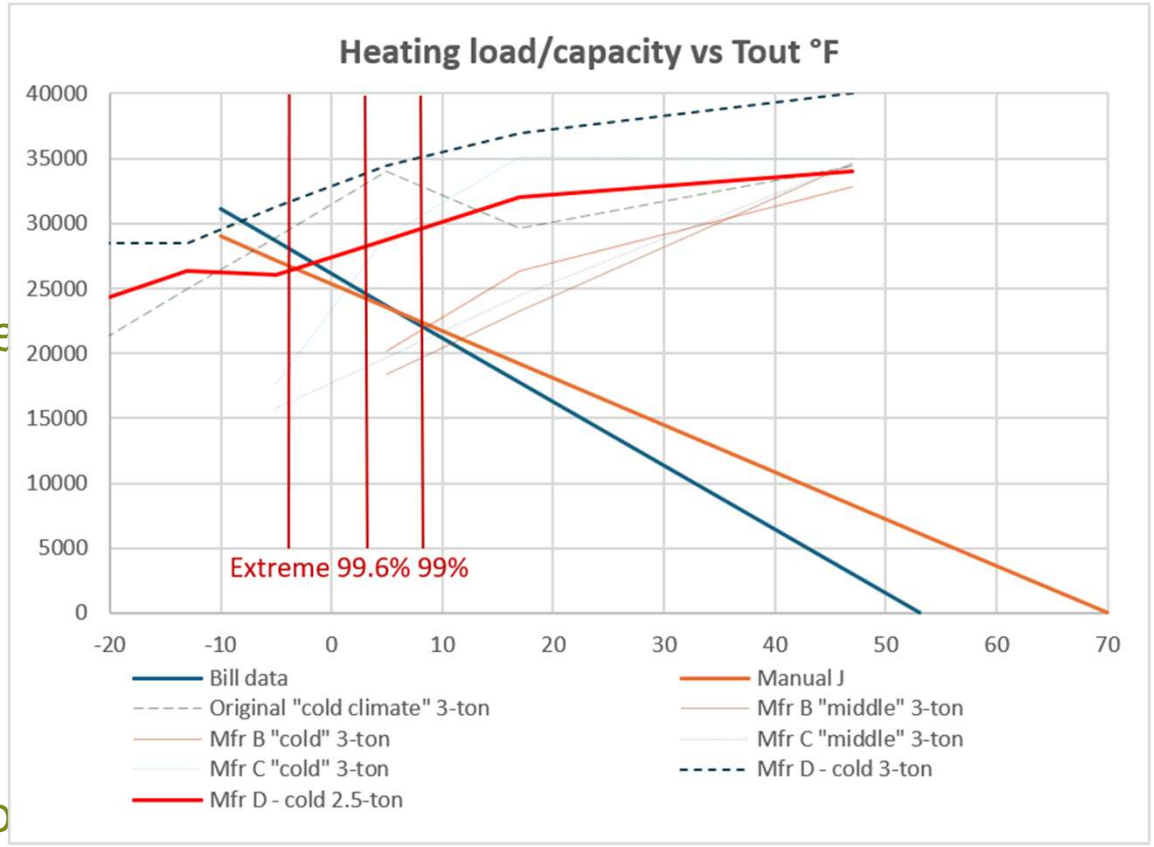
More equipment options:





Final choice

- 2.5 ton <1000 CFM rather than ~1200 CFM
  - Less fan energy
  - Ducts likely designed for higher supply air temperature
  - Less chance of noise
  - Better humidity control in summer
- This choice does better than most 3-ton units at very low temperatures
- ENTIRE house load met by 1st floor system; options remain to add heat to 2nd floor

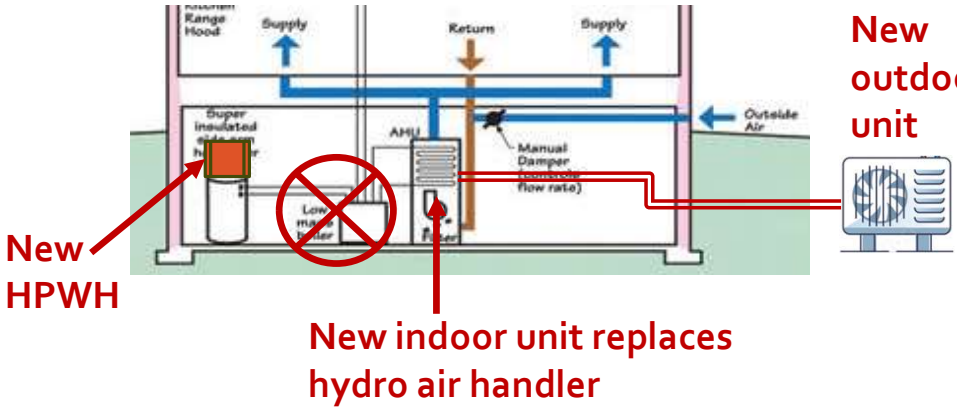


Risks:

- Inadequate capacity for a few of the coldest hours / year
  - Mitigated by ability to add some heating capacity upstairs
- Unknown design supply air temperature for original ducts
  - Guess: hydro air had design air temp ~130-140 °F (HP ~100 °F)
  - Lower heat pump supply temp = more CFM needed *for a given load*
  - *Can cause noise, low air flow issues if existing ducts are used as-is*
  - Mitigation: (1) hydro air likely slightly oversized; (2) 2.5 ton, **875 CFM**
- Possibility that upstairs rooms won't be comfortable
  - Indeed, that was the case even in spring March/April weather
- Concern about heat requirements of HPWH in basement
  - Tight, well insulated space
  - Suggestion to add supply registers in basement

Unique to this situation:

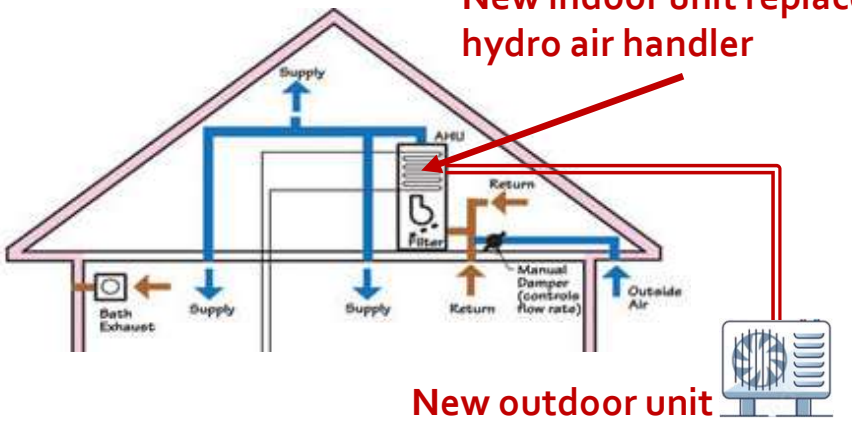
- No more boiler for heat supply
- Change indirect HW to HPWH
- Add air source heat pump



- No boiler supplied heat upstairs – AC stays in place.
- How did that go??

☹ Chilly upstairs: spring

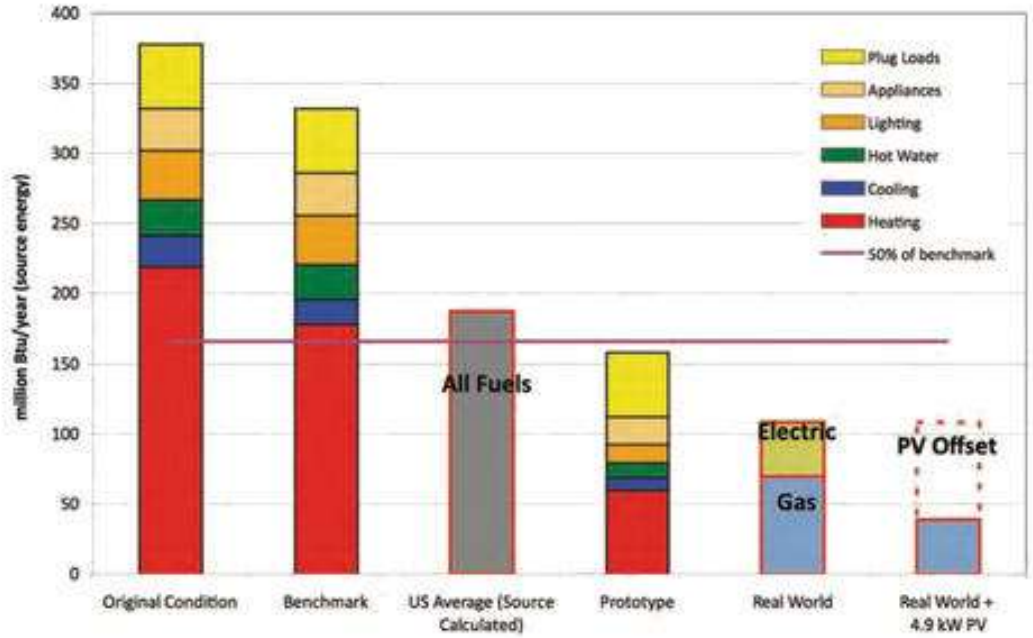
New indoor unit replaced hydro air handler



Take aways for heat pump heating design

- Plan ahead
- Upstairs rooms may need heating distribution
  - Kohta Ueno *et al*, 2013 – sometimes it works, sometimes not so well
- Trust the (conservative) load calculations
  - And still keep an eye on *reasonable* extremes
- Pay attention to equipment performance data! Capacity at Tout…
- Be aware of risks/tradeoffs

Follow up over 1-2 years:



- Compare new energy/cost with previous analysis

Thank you!

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