# Peak Demand Comparison: ASHP, CCHP, & GSHP

**Speaker:**

Bob Brown / *WaterFurnace International*

# Heat Pump Sizing and Peak Demand Comparison

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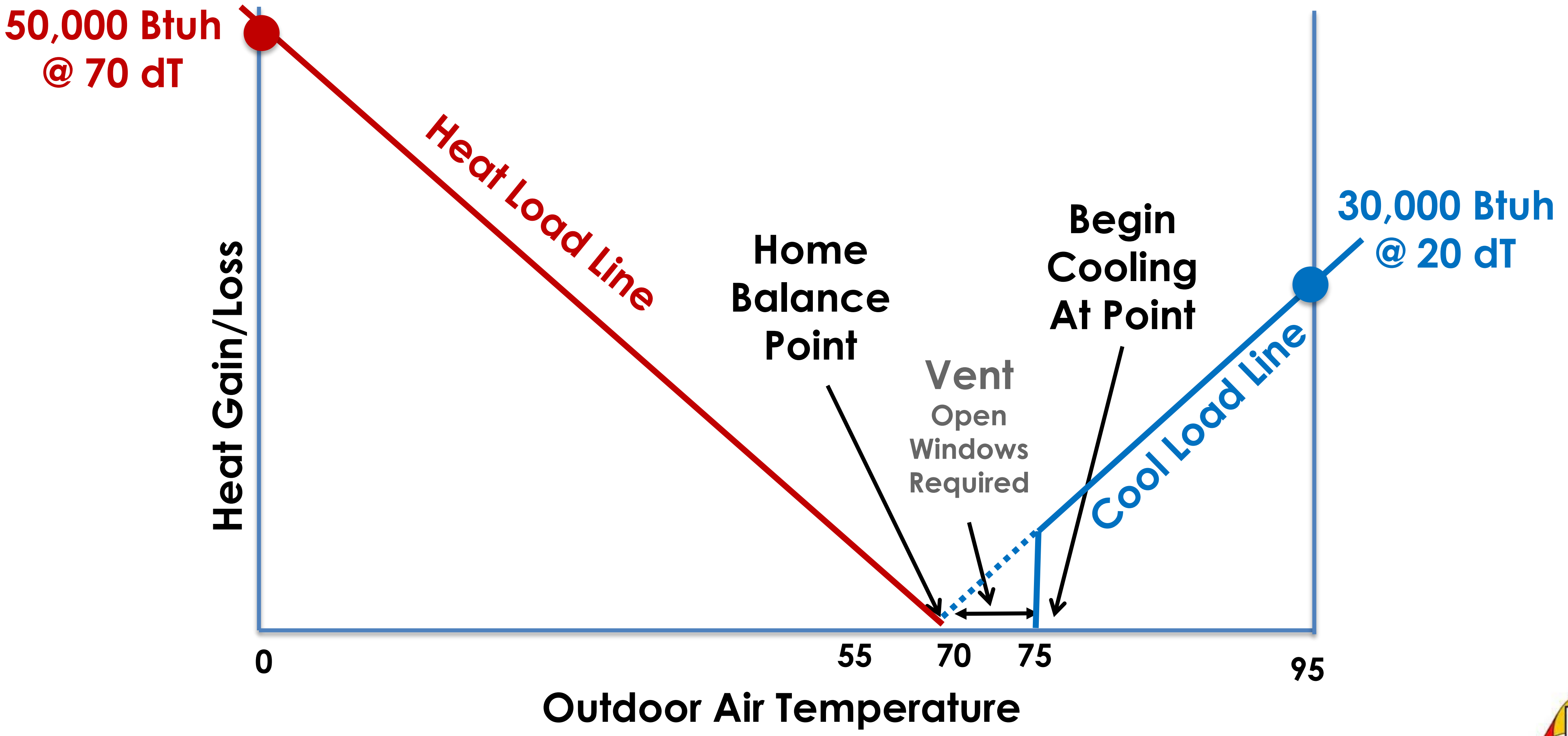
WaterFurnace
Smarter from the Ground Up™

2025 NY GEO SARATOGA SPRINGS, NEW YORK

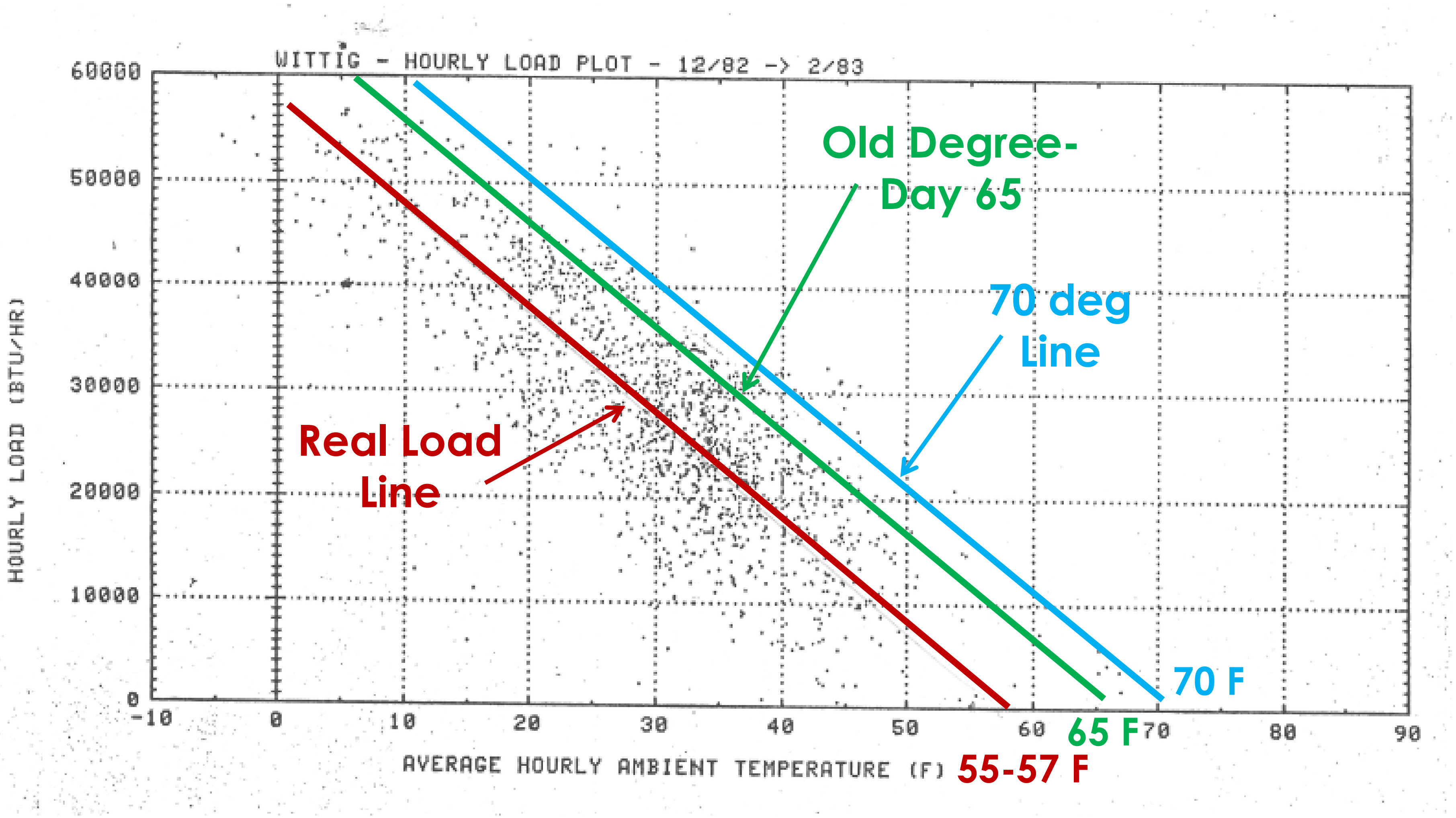
# GSHP, ASHP and CCHP Peak Demand Importance

- With the renewed interest in decarbonization and ultimately the replacement of gas appliances with heat pumps, the utility industry is once again very interested in peak demand.
- Most of the current emphasis is on cooling peak demand loads since currently the vast majority of electric utilities are all summer peaking, however it is estimated that some northern utilities will revert to winter peaking within 2-3 years, with others to follow.
- Decarbonization and winter peaking utilities will put the spotlight on sizing HP's for heating and the choice for auxiliary supplemental heat source.

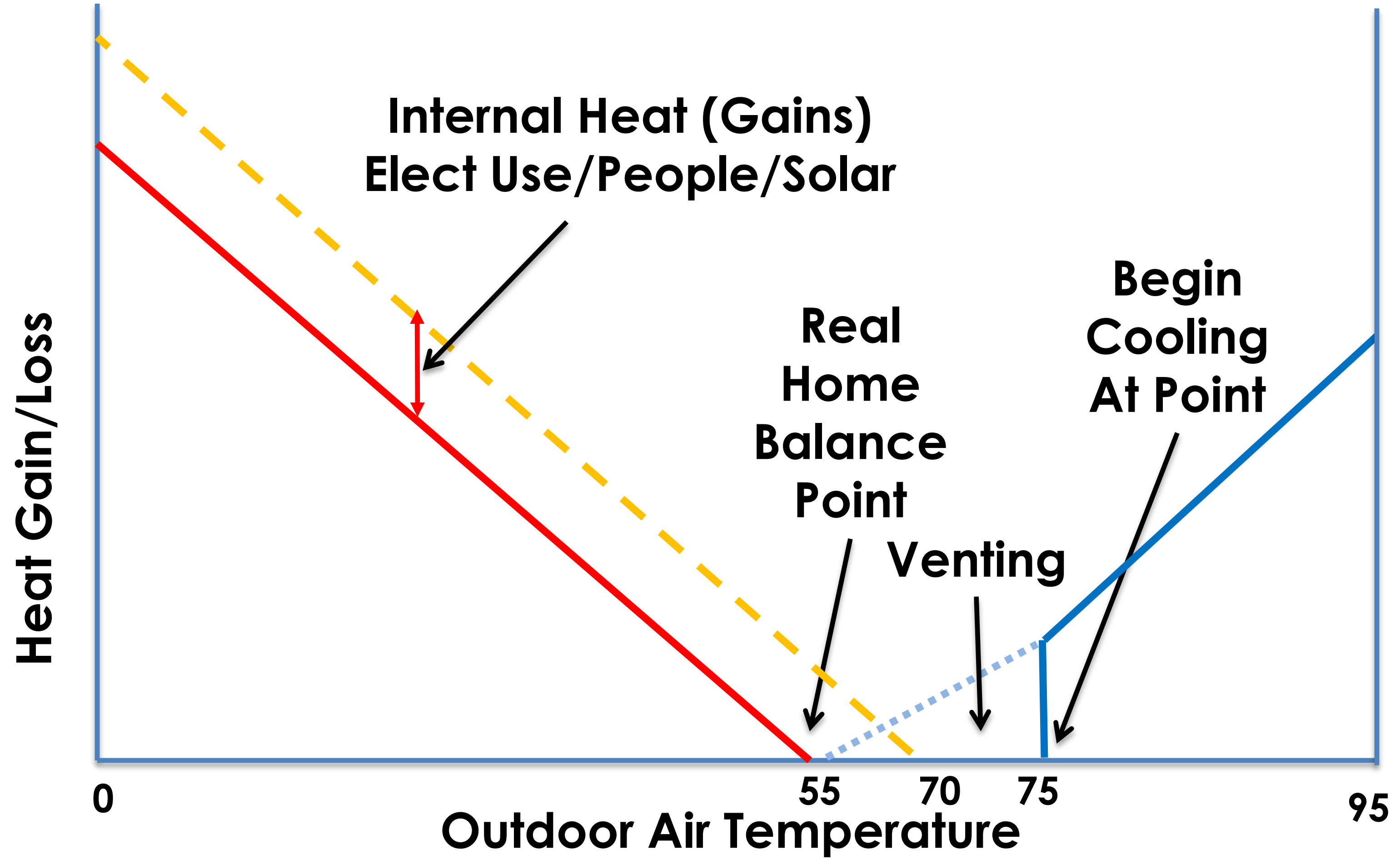
# Some Basics First - Typical House Load Basics



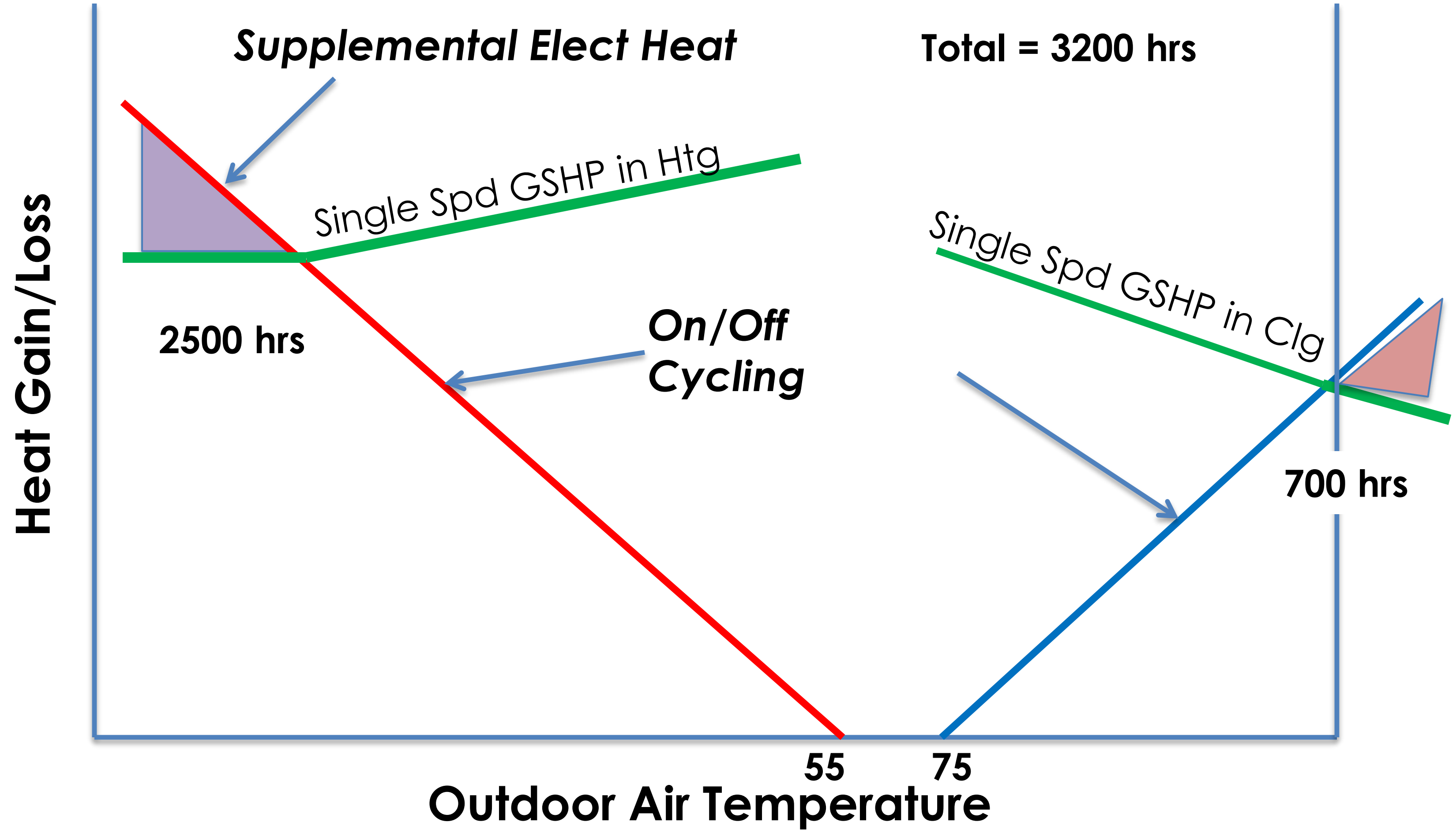
# Measured Heating Load Hours – GE Study 1982-83



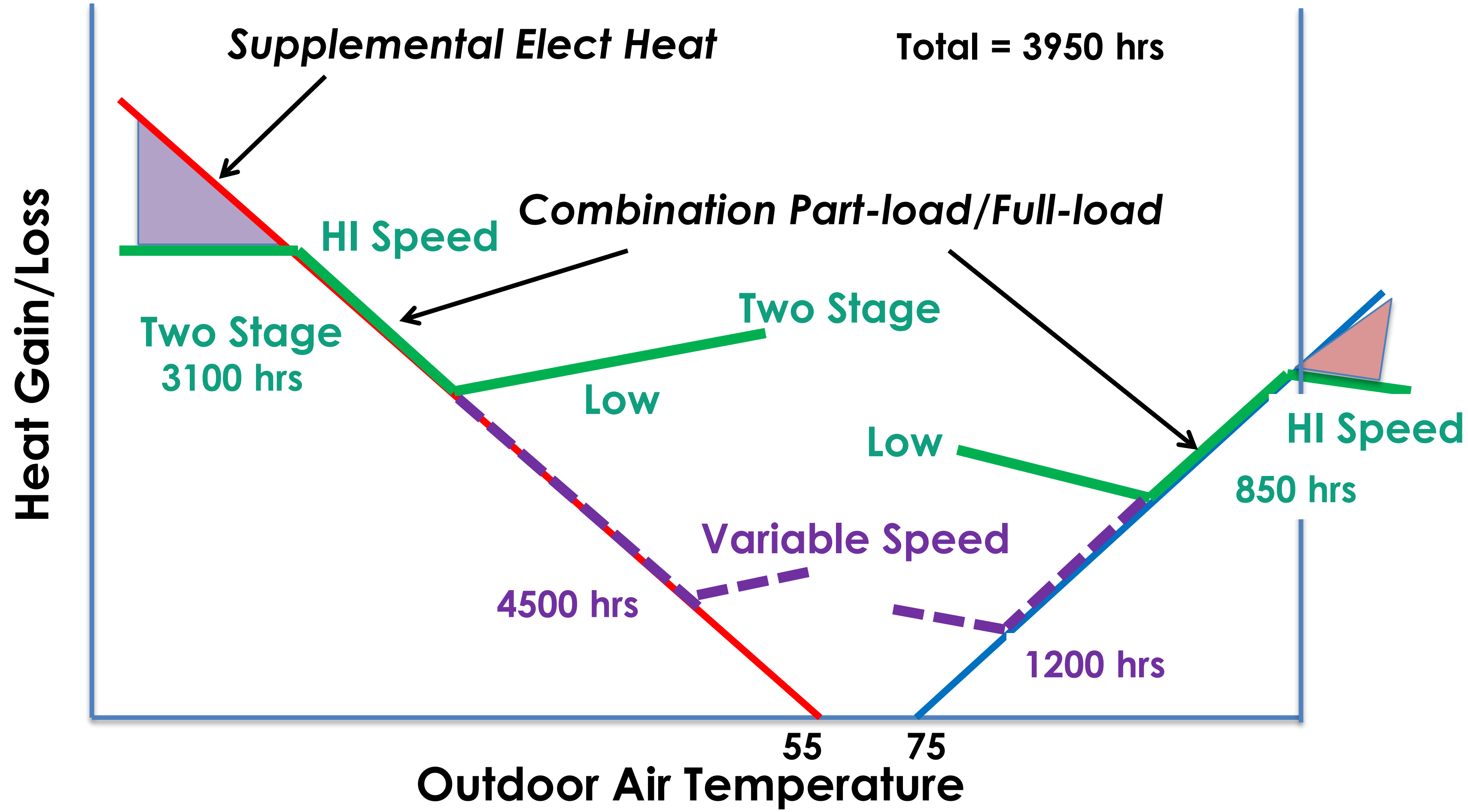
# New Typical House Real Load w/ Internal Gains



# Typical Single Stage System



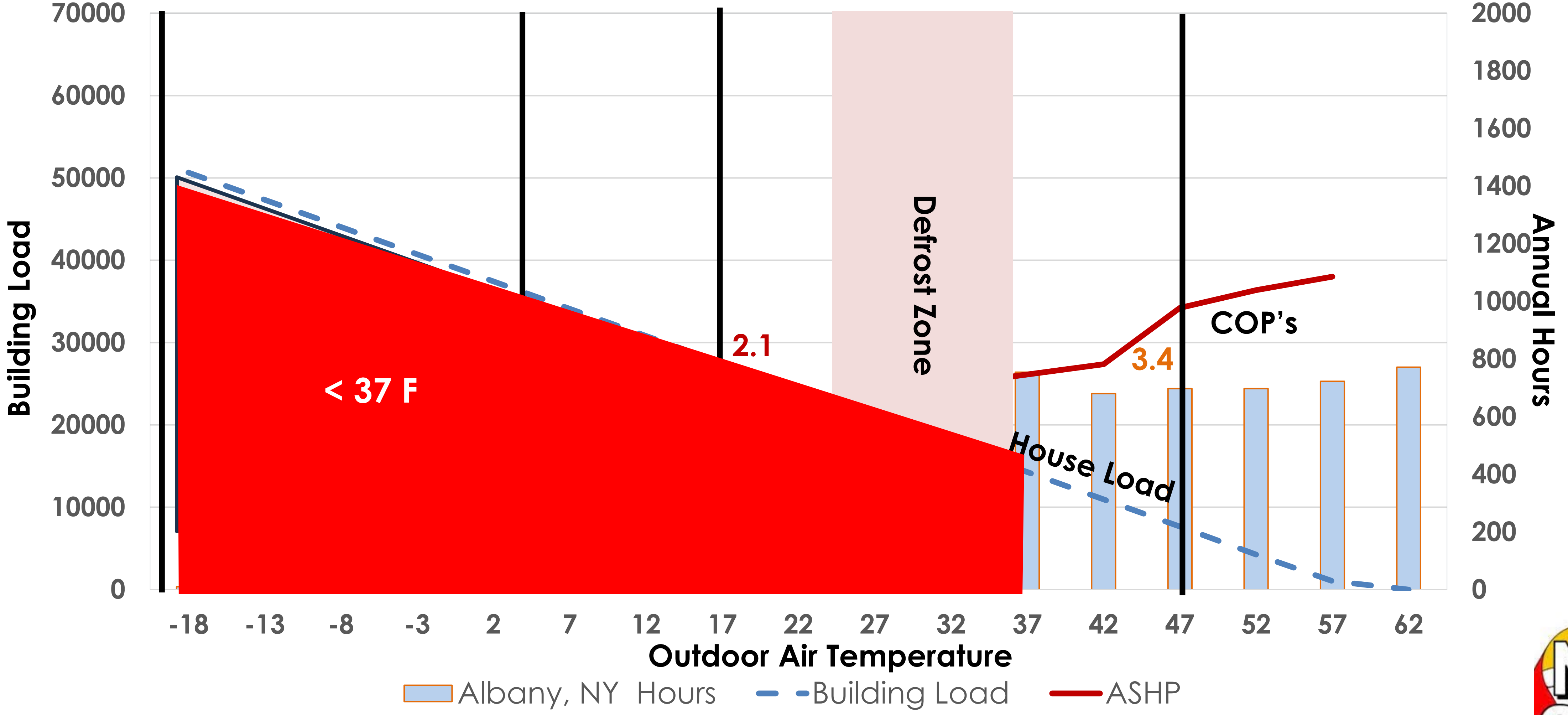
# Typical Two Stage and Variable Speed System



# ASHP Sizing Basics – Historical Perspective

- Historical ASHP's
  - Typically sized for cooling
  - Predominately central to southern product applications
  - Historically most have been 'locked out' below 37 degF
    - To limit operation in defrost and improve reliability
    - Elect heat or gas furnace backup has been 'heavy lifter' for heating in cold climates.
    - Old school practice is disappearing
  - THIS IS CHANGING! Decarbonization is relying on HP's for all heating. Some utilities and mfrs have renewed interest in dual fuel to limit electric heat use in cold temps but it counters decarb trends.

# Air Source Heat Pump Sizing



# GSHP Sizing History

- **Historical Economic Sizing**

Sized for heating with a balance point just below lowest significant hour bin (5-10 degF in New York).

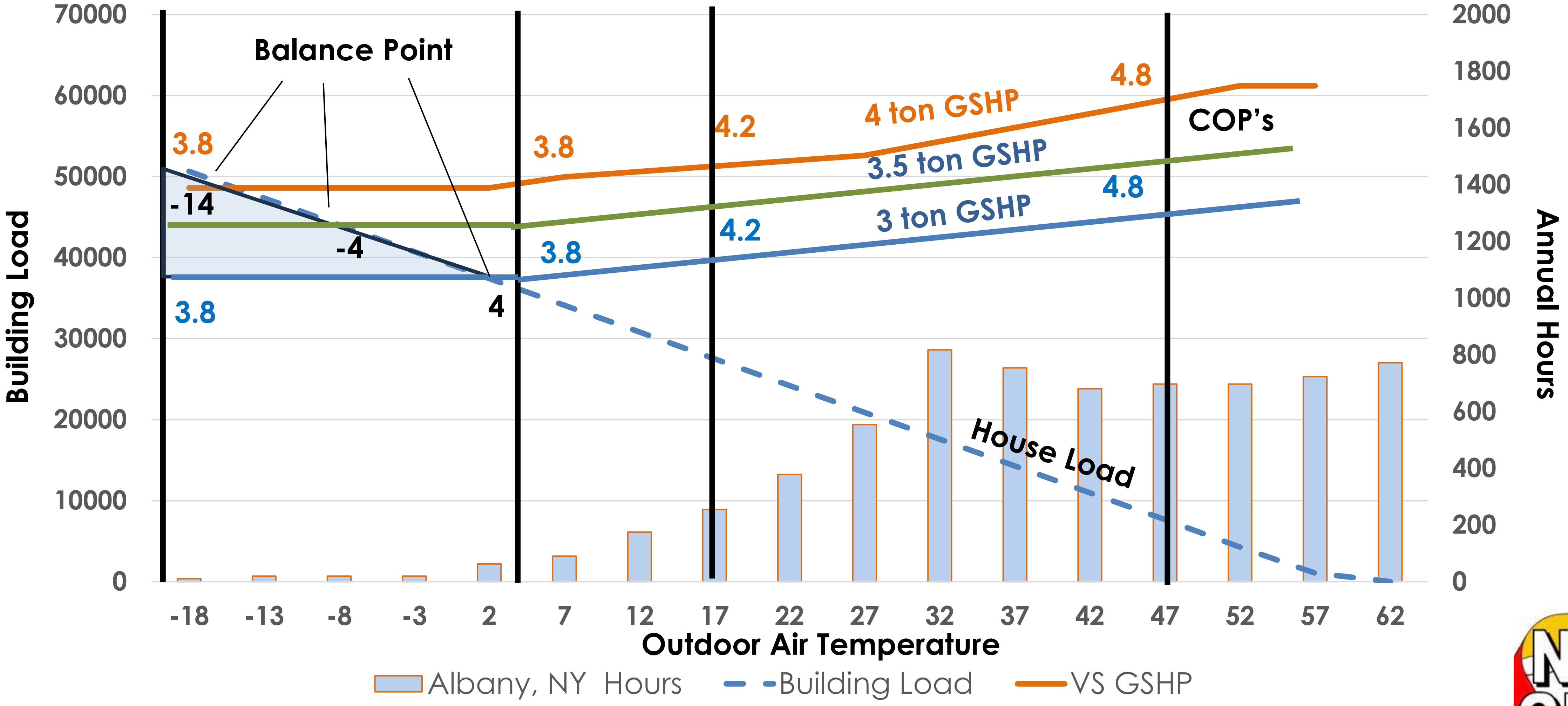
  – Retains good cooling dehumidification with slightly smaller sizing (important when single stage equip was norm)
  – Minimal backup heat (<10% of total heating) would be only $20-40 per year
  – Most economical since it offsets an extra ½-1 ton of equipment and loop. Avoids additional costs totaling more than $3-5k for loop and equipment.

- **Full heating sizing**

Full heating or no aux heat has been a requirement for rebates by several utilities/REC’s for years.

  – This was instigated to limit winter peak demand and no aux elect heat operation.
  – This concept goes back to the utility “peak demand” emphasis in the ‘90’s when several prominent utilities and REC’s were still winter peaking.
  – **This will probably need to be the norm in the future for GSHP’s.**

# 3, 3.5 and 4 ton GSHP Heat Pump Sizing

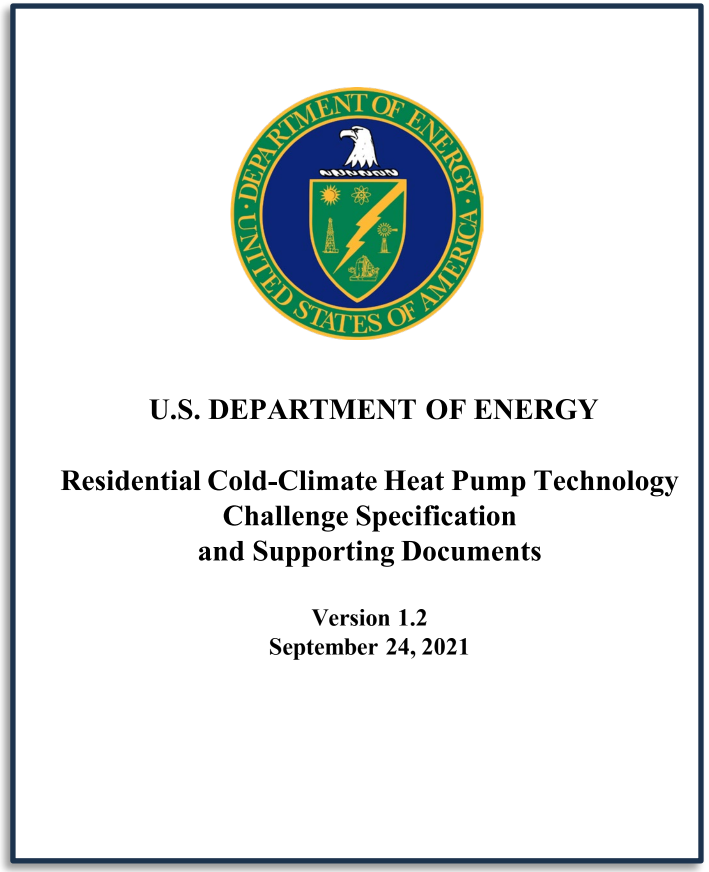


# NEW Cold Climate Heat Pump (CCHP)

- New Air Source Heat Pump design for Cold North American Markets.
- New Technology
  - Oversized Vapor-Injected Variable Speed Compressor
  - Complex Compressor Speed Management
  - COP of 1.8 at -15 degF [-25 degC] vs todays ASHP COP of 1.0
- New CCHP regulations under development are targeting northern US and Canadian Markets – Pushed heavily by utilities and decarbonization NGO's.
- Early Market had some lofty claims but standards are "catching up".

# DOE Launched CCHP Challenge and Specification

- DOE launched a CCHP challenge spec in 2021
  - Min 47 F Cap no higher than 70% of max 47 F
  - Htg Cap at 5 F > 70% of 47 F Htg Cap
  - Min COP at 5 F of 1.8
  - Min of 8.5 HSPF2 Region V using M1
  - Max of 5 kW per EH stages
  - Heating Performance at 5 F (2.4/2.1 COP)
  - Cut off Temp <-10 to -15 F
  - Low GWP Refrigerant
  - Cloud Connected Product



U.S. DEPARTMENT OF ENERGY

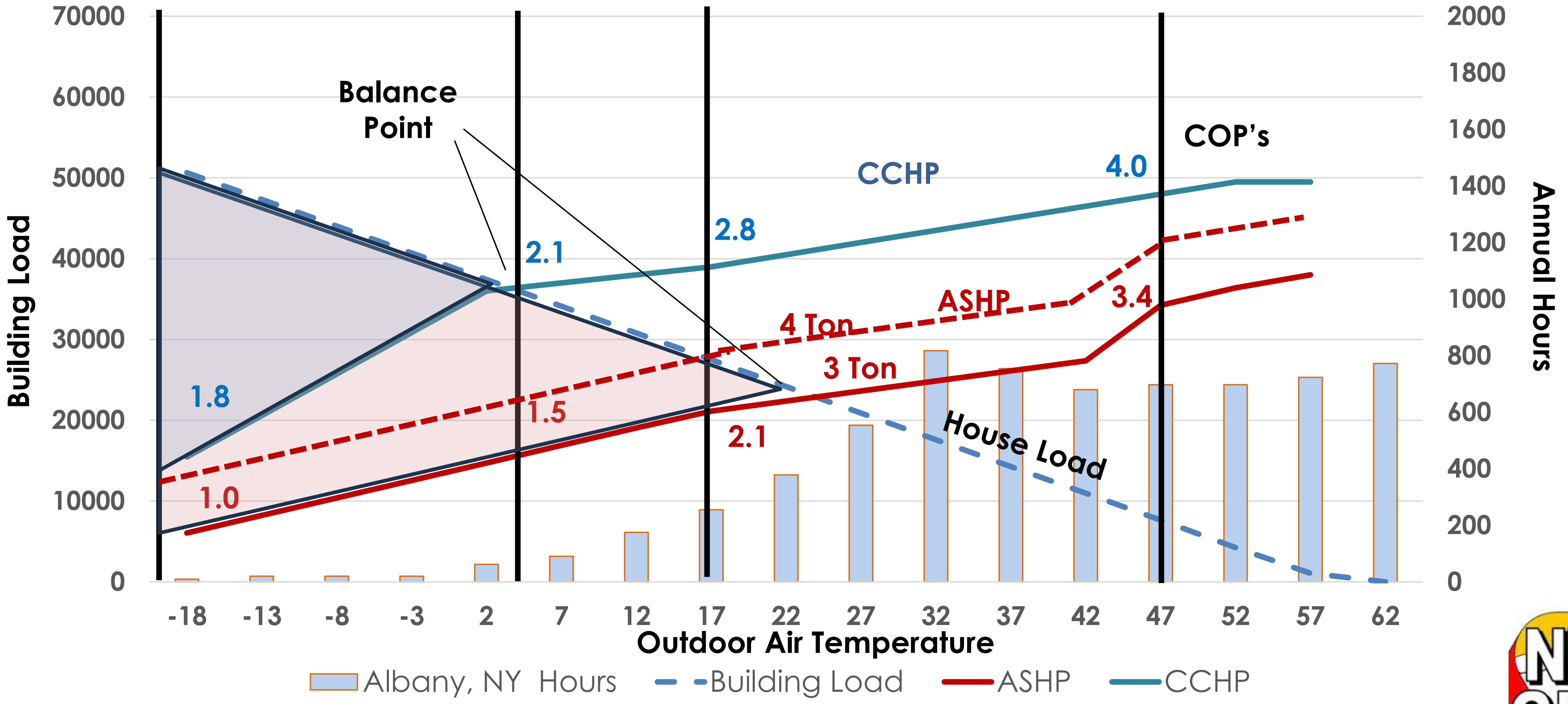
Residential Cold-Climate Heat Pump Technology
Challenge Specification
and Supporting Documents

Version 1.2
September 24, 2021

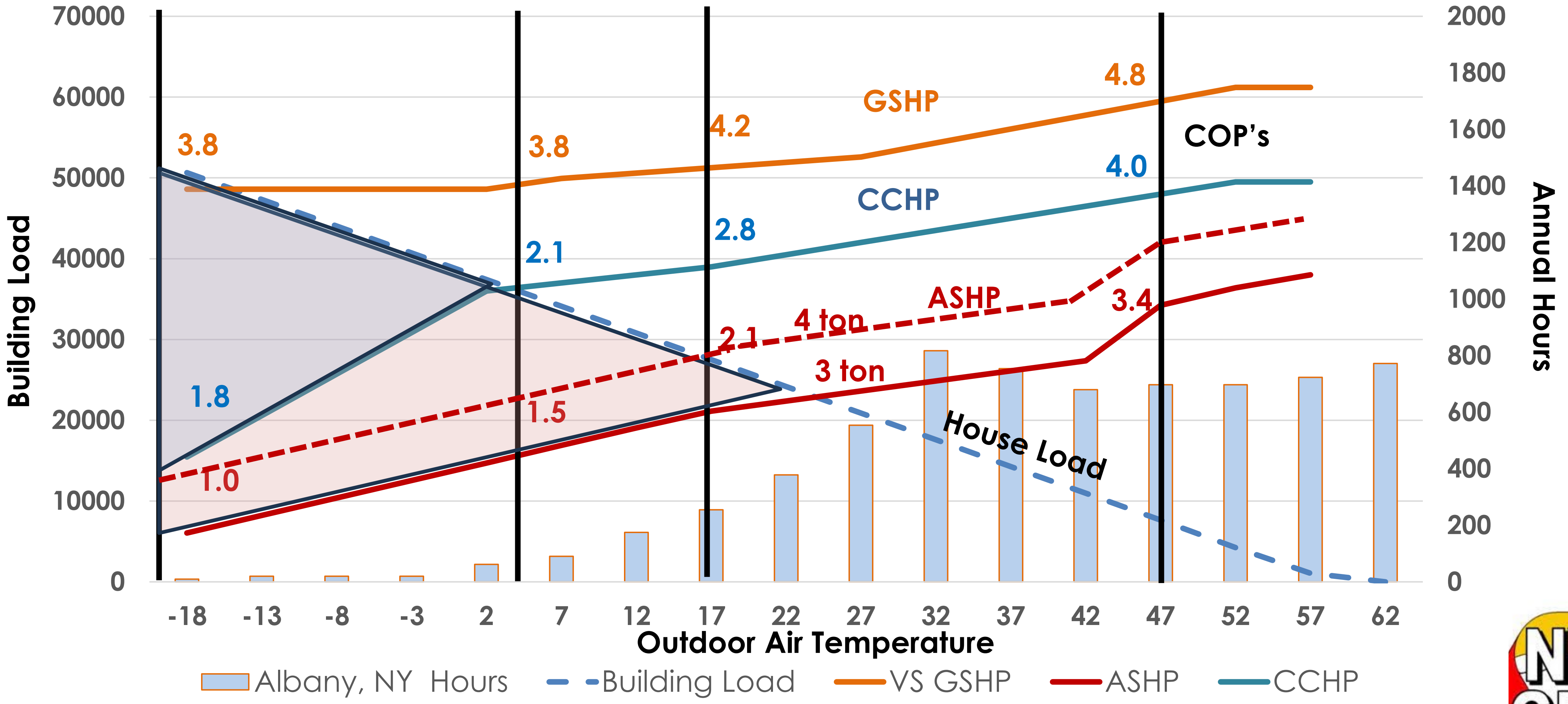
# ASHP, CCHP and GSHP Heat Pump Details

- ASHP
  - 4 ton, 2 stage, 16 SEER2, with EH
- CCHP
  - 4 ton New Market Data of VS CCHP with EH
- GSHP
  - VS GSHP, 40 EER, 5 COP (GLHP) with EH

# ASHP and CCHP Sizing



# Combined Heat Pump Comparison



# Changing Standards

- **ASHP and CCHP AHRI 210-240 moving to AHRI 1600**
  - CCHP becoming more defined
  - AHRI 1600 has COP Peak defined
  - DOE Final Rulemaking of AHRI 1600 in limbo

- **GSHP ISO/AHRI 13256-1 going to AHRI 600**
  - Commercial IEER and ACOP with system and pump power included
  - Residential (development) will mimic 1600 and SHORE/SCORE
  - Planned include Peak Demand and COP/EER at 5 and 95 F OAT
  - DOE Final Rulemaking of AHRI 600 in limbo

# AHRI 1600 and 600 Bin Example – Heating – SHORE Replaces HSPF2

| | | | Capacity | | Power | COP |
|---|---|---|---|---|---|---|
| | High H3,Full | $q_{H3,Full}$ | 39500 | | | |
| H3 - 68 | High H1,Full | $q_{H1,Full}$ | 59700 | $P_{H1,Full}$ | 3320 | 5.27 |
| H2 - 50 | High H2,Full | $q_{H2,Full}$ | 49600 | $P_{H2,Full}$ | 3120 | 4.66 |
| H1 - 32 | High H3,Full | $q_{H3,Full}$ | 39500 | $P_{H3,Full}$ | 2960 | 3.91 |
| H3 - 68 | Low H1,Low | $q_{H1,Low}$ | 44300 | $P_{H1,Low}$ | 2350 | 5.52 |
| H2 - 50 | Low H2,Low | $q_{H2,Low}$ | 36500 | $P_{H2,Low}$ | 2310 | 4.63 |
| H1 - 32 | Low H3,Low | $q_{H3,Low}$ | 28100 | $P_{H3,Low}$ | 2250 | 3.66 |

| | Eq 11.109 | | | |
|---|---|---|---|---|
| SHORE | 14.86 | COP peak | 4.33 | |
| | | Htg Peak Demand | 3.18 | kW |
| $C_D^{H,Low}$ | 0.07 | <= Note: If $Cd_1$ > 0.25, then use default 0.25. | | |
| $C_D^{H,Full}$ | 0.07 | | | |
| Region | Nat | <= Enter Nat or CC. | | |

| | Eq. 11.108 | |
|---|---|---|
| $E_{S,C}$ | 57392.09 | |
| $P_1$ | 20 | <= Off Mode - Sholder Season |
| $P_2$ | 20 | <= Off Mode - Heating Season |
| $P_{CCF}$ | 0 | <= Continous Circulation Fan |
| $T_{CCH,on}$ | 0 | <= Crankcase On Heater |
| $T_{CCH,off}$ | 0 | <= Crankcase Off Heater |
| ContFan | 0 | <= Enter 1 for Continous Fan O |

Do we need to use three points for interpolation?

| | Table 20 | Loop Temp Table ? | Cond Hours Table 18 | Shldr Hours Table 18 | Load Line Eq 11.110 | Min Cap 11.157-159 | Min Power 11.160-162 | Min COP | Max Cap 11.119-124 | Max Power 11.125-129 | Max COP | Heating Load Factor Eq 11.16 | Part Load Factor Eq 11.166 | Heating Load Factor 11.173 | Heating Load Factor Eq 11.174 | High Part Load Factor Eq 11.132 | Heating Load Factor Eq. 11.180 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $t_j$ | $t_{j,loop}$ | $N_j$ | $N_{r,j}$ | $BL(t_j)$ | $q_{Low}(t_j)$ | $P_{Low}(t_j)$ | $COP_{Low}(t_j)$ | $q_{Full}(t_j)$ | $P_{Full}(t_j)$ | $COP_{Full}(t_j)$ | $HLF^{LOW}(t_j)$ | $PLF^{Low}(t_j)$ | $HLF^{Cyc,Low}(t_j)$ | $HLF^{Cyc,Full}(t_j)$ | $PLF^{Full}(t_j)$ | $HLF^{Full}(t_j)$ |
| 12 | 57.5 | 58.0 | 253 | 496 | 889 | 40233 | 2337 | 5.05 | 54089 | 3191 | | | | | | | |
| 13 | 52.5 | 56.5 | 414 | 272 | 3851 | 39512 | 2332 | 4.97 | 53222 | 3177 | | | | | | | |
| 14 | 47.5 | 54.9 | 499 | 106 | 6814 | 38791 | 2326 | 4.89 | 52355 | 3164 | | | | | | | |
| 15 | 42.5 | 53.4 | 523 | 38 | 11356 | 38070 | 2321 | 4.81 | 51487 | 3150 | | | | | | | |
| 16 | 37.5 | 51.8 | 476 | 8 | 15899 | 37348 | 2316 | 4.73 | 50620 | 3136 | | | | | | | |
| 17 | 32.5 | 50.3 | 410 | 0 | 20441 | 36627 | 2311 | 4.65 | 49753 | 3122 | | | | | | | |
| 18 | 27.5 | 48.7 | 239 | 0 | 24984 | 35906 | 2306 | 4.56 | 48886 | 3109 | | | | | | | |
| 19 | 22.5 | 47.2 | 137 | 0 | 29526 | 35185 | 2301 | 4.48 | 48019 | 3095 | | | | | | | |
| 20 | 17.5 | 45.6 | 80 | 0 | 34069 | 34464 | 2295 | 4.40 | 47152 | 3081 | | | | | | | |
| 21 | 12.5 | 44.1 | 44 | 0 | 38611 | 33742 | 2290 | 4.32 | 46284 | 3067 | | | | | | | |
| 22 | 7.5 | 42.5 | 28 | 0 | 43154 | 33021 | 2285 | 4.24 | 45417 | 3054 | | | | | | | |
| 23 | 2.5 | 41.0 | 16 | 0 | 47696 | 32300 | 2280 | 4.15 | 44550 | 3040 | 4.30 | N/A | N/A | N/A | N/A | N/A | 1.00 |
| 24 | -2.5 | 41.0 | 9 | 0 | 52239 | 32300 | 2280 | 4.15 | 44550 | 3040 | 4.30 | N/A | N/A | N/A | N/A | N/A | 1.00 |
| 25 | -7.5 | 41.0 | 2 | 0 | 56781 | 32300 | 2280 | 4.15 | 44550 | 3040 | 4.30 | N/A | N/A | N/A | N/A | N/A | 1.00 |
| 26 | -12.5 | 41.0 | 1 | 0 | 61324 | 32300 | 2280 | 4.15 | 44550 | 3040 | 4.30 | N/A | N/A | N/A | N/A | N/A | 1.00 |
| 27 | -17.5 | 41.0 | 0 | 0 | 65866 | 32300 | 2280 | 4.15 | 44550 | 3040 | 4.30 | N/A | N/A | N/A | N/A | N/A | 1.00 |
| 28 | -22.5 | 41.0 | 0 | 0 | 70409 | 32300 | 2280 | 4.15 | 44550 | 3040 | 4.30 | N/A | N/A | N/A | N/A | N/A | 1.00 |
| 29 | -27.5 | 41.0 | 0 | 0 | 74951 | 32300 | 2280 | 4.15 | 44550 | 3040 | 4.30 | N/A | N/A | N/A | N/A | N/A | 1.00 |
| 30 | -32.5 | 41.0 | 0 | 0 | 79494 | 32300 | 2280 | 4.15 | 44550 | 3040 | 4.30 | N/A | N/A | N/A | N/A | N/A | 1.00 |

| | Bin Temp | Loop Temp | Load Line | 5 deg Cap | Deg HP Power | COP peak | System Peak Demand |
|---|---|---|---|---|---|---|---|
| Peak Demand | 5 | 41.8 | 45425 | 44984 | 3.05 | 4.33 | 3.18 |


| | Eq 11.109 | | | |
|---|---|---|---|---|
| SHORE | 14.86 | COP peak | 4.33 | |
| | | Htg Peak Demand | 3.18 | kW |
| $C_D^{H,Low}$ | 0.07 | <= Note: If $Cd_1$ > 0.25, then use default 0.25. | | |
| $C_D^{H,Full}$ | 0.07 | | | |
| Region | Nat | <= Enter Nat or CC. | | |

# AHRI 1600 and 600 Bin Calculation – GSHP Heating

| | OAT | Loop Temp | Cond Hours | Shldr Hours | Load Line | Min Cap | Min Power | Min COP | Max Cap | Max Power | Max COP | Load Factor | Load Factor | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Table ? | Table 18 | Table 18 | Eq 11.110 | 11.157-159 | 11.160-162 | | 11.119-124 | 11.125-129 | | Eq 11.165 | Eq 11.166 | |
| | $t_j$ | $t_{j,loop}$ | $N_j$ | $N_{s,j}$ | $BL(t_j)$ | $q_{Low}(t_j)$ | $P_{Low}(t_j)$ | $COP_{Low}(t_j)$ | $q_{Full}(t_j)$ | $P_{Full}(t_j)$ | $COP_{Full}(t_j)$ | $HLF^{LOW}(t_j)$ | $PLF^{Low}(t_j)$ | |
| 12 | 57.5 | 58.0 | 253 | 496 | 889 | 40233 | 2337 | 5.05 | 54089 | 3191 | 4.97 | 0.02 | 0.93 | |
| 13 | 52.5 | 56.5 | 414 | 272 | 3851 | 39512 | 2332 | 4.97 | 53222 | 3177 | 4.91 | 0.10 | 0.94 | |
| 14 | 47.5 | 54.9 | 499 | 106 | 6814 | 38791 | 2326 | 4.89 | 52355 | 3164 | 4.85 | 0.18 | 0.94 | |
| 15 | 42.5 | 53.4 | 523 | 38 | 11356 | 38070 | 2321 | 4.81 | 51487 | 3150 | 4.79 | 0.30 | 0.95 | |
| 16 | 37.5 | 51.8 | 476 | 8 | 15899 | 37348 | 2316 | 4.73 | 50620 | 3136 | 4.73 | 0.43 | 0.96 | |
| 17 | 32.5 | 50.3 | 410 | 0 | 20441 | 36627 | 2311 | 4.65 | 49753 | 3122 | 4.67 | 0.56 | 0.97 | |
| 18 | 27.5 | 48.7 | 239 | 0 | 24984 | 35906 | 2306 | 4.56 | 48886 | 3109 | 4.61 | 0.70 | 0.98 | |
| 19 | 22.5 | 47.2 | 137 | 0 | 29526 | 35185 | 2301 | 4.48 | 48019 | 3095 | 4.55 | 0.84 | 0.99 | |
| 20 | 17.5 | 45.6 | 80 | 0 | 34069 | 34464 | 2295 | 4.40 | 47152 | 3081 | 4.49 | 0.99 | 1.00 | |
| 21 | 12.5 | 44.1 | 44 | 0 | 38611 | 33742 | 2290 | 4.32 | 46284 | 3067 | 4.42 | N / A | N / A | |
| 22 | 7.5 | 42.5 | 28 | 0 | 43154 | 33021 | 2285 | 4.24 | 45417 | 3054 | 4.36 | N / A | N / A | |
| 23 | 2.5 | 41.0 | 16 | 0 | 47696 | 32300 | 2280 | 4.15 | 44550 | 3040 | 4.30 | N / A | N / A | |
| 24 | -2.5 | 41.0 | 9 | 0 | 52239 | 32300 | 2280 | 4.15 | 44550 | 3040 | 4.30 | N / A | N / A | |
| 25 | -7.5 | 41.0 | 2 | 0 | 56781 | 32300 | 2280 | 4.15 | 44550 | 3040 | 4.30 | N / A | N / A | |
| 26 | -12.5 | 41.0 | 1 | 0 | 61324 | 32300 | 2280 | 4.15 | 44550 | 3040 | 4.30 | N / A | N / A | |
| 27 | -17.5 | 41.0 | 0 | 0 | 65866 | 32300 | 2280 | 4.15 | 44550 | 3040 | 4.30 | N / A | N / A | |
| 28 | -22.5 | 41.0 | 0 | 0 | 70409 | 32300 | 2280 | 4.15 | 44550 | 3040 | 4.30 | N / A | N / A | |
| 29 | -27.5 | 41.0 | 0 | 0 | 74951 | 32300 | 2280 | 4.15 | 44550 | 3040 | 4.30 | N / A | N / A | |
| 30 | -32.5 | 41.0 | 0 | 0 | 79494 | 32300 | 2280 | 4.15 | 44550 | 3040 | 4.30 | N / A | N / A | |
| | Bin Temp | Loop Temp | | | Load Line | | | | 5 deg Cap | Deg HP Power | | | COP peak | System Peak |
| Peak Demand | 5 | 41.8 | | | 45425 | | | | 44984 | 3.05 | | | 4.33 | 3.18 |

# AHRI 1600 and 600 Bin Calculation – GSHP Cooling

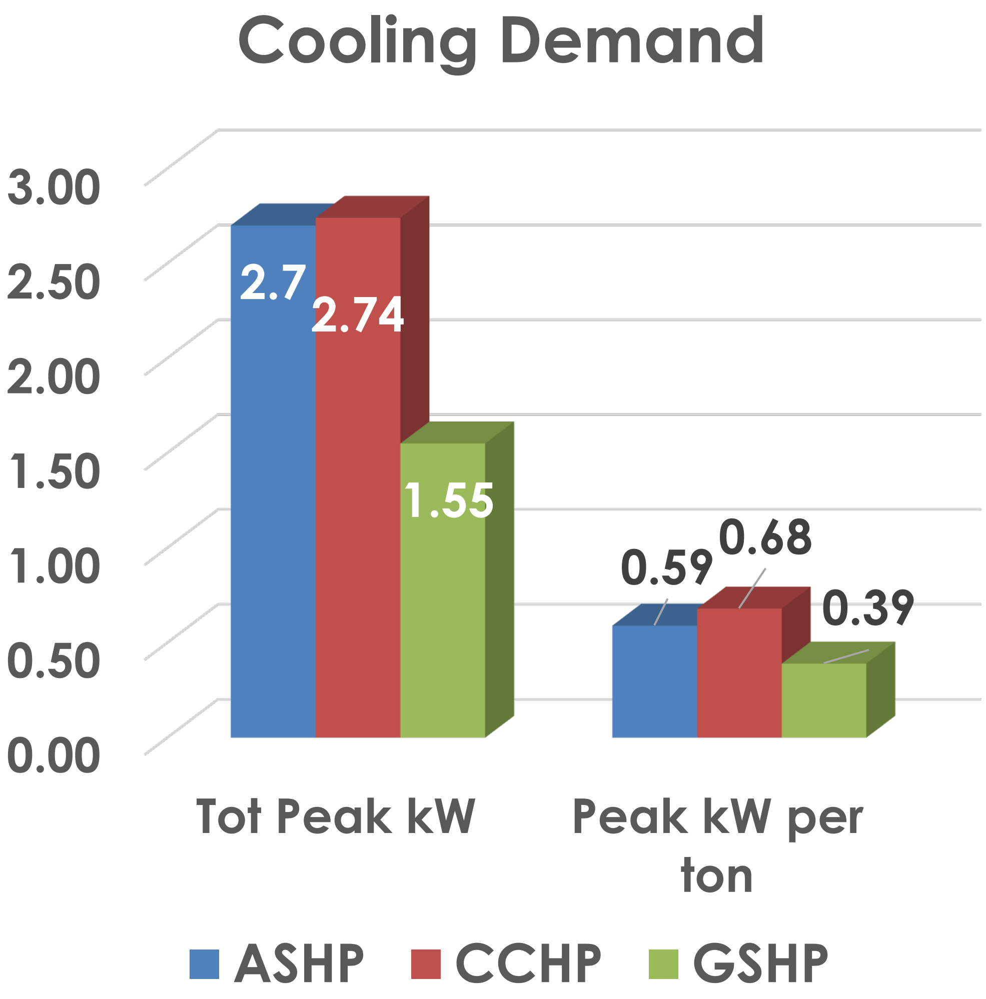
| | OAT | Loop Temp | Cond Hours | Shldr Hours | Load Line | Min Cap | Min Power | Min EER | Max Cap | Max Power | Max EER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Table ? | Table 15 | Table 15 | Eq 11.65, (b) | Eq 11.74 | Eq 11.75 | | Eq 11.76 | Eq 11.77 | |
| | $t_j$ | $t_{j,loop}$ | $N_j$ | $N_{s,j}$ | $BL(t_j)$ | $q_{Low}(t_j)$ | $P_{Low}(t_j)$ | $EER_{Low}(t_j)$ | $q_{Full}(t_j)$ | $P_{Full}(t_j)$ | $EER_{Full}(t_j)$ |
| 1 | 112.5 | 82.0 | 2 | 0 | 56856 | 39422 | 2068 | 19.07 | 48222 | 2981 | 16.18 |
| 2 | 107.5 | 79.6 | 9 | 0 | 50871 | 39556 | 2018 | 19.60 | 48716 | 2916 | 16.71 |
| 3 | 102.5 | 77.2 | 24 | 0 | 44886 | 39689 | 1969 | 20.16 | 49209 | 2850 | 17.26 |
| 4 | 97.5 | 74.8 | 62 | 0 | 38902 | 39822 | 1920 | 20.74 | 49702 | 2785 | 17.85 |
| 5 | 92.5 | 72.4 | 176 | 0 | 32917 | 39956 | 1870 | 21.36 | 50196 | 2720 | 18.46 |
| 6 | 87.5 | 70.0 | 398 | 0 | 26932 | 40089 | 1821 | 22.01 | 50689 | 2654 | 19.10 |
| 7 | 82.5 | 67.6 | 653 | 0 | 20947 | 40222 | 1772 | 22.70 | 51182 | 2589 | 19.77 |
| 8 | 77.5 | 65.2 | 842 | 0 | 14962 | 40356 | 1722 | 23.43 | 51676 | 2524 | 20.48 |
| 9 | 72.5 | 62.8 | 855 | 37 | 8977 | 40489 | 1673 | 24.20 | 52169 | 2458 | 21.22 |
| 10 | 67.5 | 60.4 | 593 | 251 | 5074 | 40622 | 1624 | 25.02 | 52662 | 2393 | 22.01 |
| 11 | 62.5 | 58.0 | 310 | 497 | 1171 | 40756 | 1574 | 25.89 | 53156 | 2328 | 22.84 |

| | OAT | Loop Temp | | | | | | | 95 Max Cap | )5 Max Powe | EER peak |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Peak Demand** | **95** | **73.6** | | | | | | | **49949** | **2.75** | **18.15** |

# Demand Comparison Assumptions

- Peak Demand OAT
  - Heating 5 degF
  - Heating -15 degF
  - Cooling 95 degF
- ASHP
  - 2 stage, 16 SEER2, with EH
- CCHP
  - New Market Data of VS CCHP with EH
- GSHP
  - VS GSHP, 40 EER, 5 COP with EH

# Peak Demand Cooling Summary @ 95 degF




| | Total Peak kW | Total Peak EER | Peak kW per ton |
|---|---|---|---|
| ASHP | 2.70 | 12.8 | 0.59 |
| CCHP | 2.74 | 12.6 | 0.68 |
| GSHP | 1.55 | 22.2 | 0.39 |

*Note:*
*Assumes new unit and does not include dirty coil degradation.*

# OUTDOOR COIL DEGRADATION

- An outdoor condenser with:
  - 40% condenser fouling cause a performance degradation of 16%.
  - 30% refrigerant leakage cause a performance degradation of 12%
- Whereas in case of an indoor evaporator fouling the performance degradation was less than 3% to negligible. GSHP relatively unaffected.
- Therefore, from seasonal simulations of the heat pump along an entire machine lifetime of 12 years, it is found that none of the maintenance strategies analysed can significantly reduce the number of scenarios penalized by faults.
  - *Mauro, Pelella, Viscito - Department of Industrial Engineering, Università degli Studi di Napoli – Federico II, P.le Tecchio 80, 80125, Naples, Italy 2023*

- Industry accepted degradation after 5 years (ASHRAE).

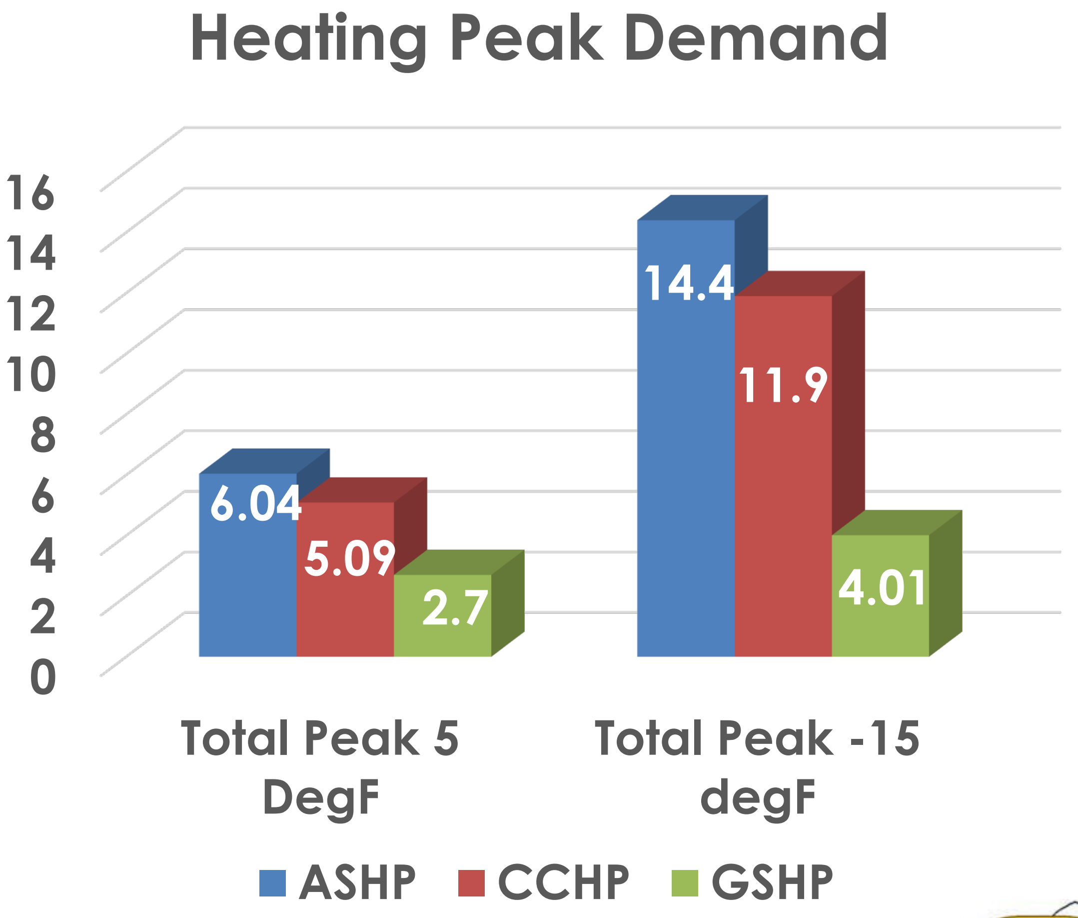
| Coil Degradation | Capacity | Power kW | EER |
|---|---|---|---|
| ASHP | 0.97 | 1.03 | 0.94 |
| CCHP | 0.97 | 1.03 | 0.94 |

# Peak Demand Heating Summary

| | HP Peak kW 5 degF | Total Peak kW 5 degF | HP Peak COP 5 degF | Total Peak COP 5 degF | HP Peak kW -15 degF | Total Peak kW -15 degF | HP Peak COP -15 degF | Total Peak COP -15 degF |
|---|---|---|---|---|---|---|---|---|
| ASHP | 3.44 | 6.04 | 2.16 | 1.87 | 3.24 | 14.4 | 1.0 | 1.0 |
| CCHP | 5.07 | 5.09 | 2.12 | 2.08 | 2.85 | 11.9 | 1.85 | 1.21 |
| GSHP | 2.70 | 2.70 | 3.89 | 3.89 | 3.76 | 4.01 | 3.78 | 3.59 |

# Heating Peak Demand

| | Peak kW per ton 5 degF | Peak kW per ton -15 degF |
|---|---|---|
| ASHP | 1.51 | 3.6 |
| CCHP | 1.27 | 3.6 |
| GSHP | 0.68 | 1.0 |



# Summary

- Although CCHP are a distinct improvement over ASHP in primarily heating climates, peak demand is still dominated by the necessary elect heat.  Peak Demand is prominent at 5 degF and worse at -15 degF.
- CCHP will be forced to operate in the adverse conditions of winter in the north the whole season.  This is largely an unproven environment for most historical ASHP's.
- GSHP are still the only viable solution to dependably limit peak demand for winter peaking utilities in northern climates.

## *QUESTIONS?*

# Peak Demand Comparison: ASHP, CCHP, & GSHP

**Speaker:**

Bob Brown / *WaterFurnace International*