November 26, 2019

EXP-07 Preliminary Results

- A new load-based test procedure
- Variable capacity heat pumps

Presenters: Bruce Harley, Christopher Dymond



NEEA Product Council

Charter

- Identify technology and market opportunities
- Review and disposition of unsolicited proposals and other new ideas
- Prioritize NEEA's scanning / development work and share priorities and findings
- Recommend concepts for advancement into NEEA's program portfolio
- Identify high-lights of emerging technology work to share broadly

Frequency: Weekly, Tuesdays 10:30-12:00 Pacific

Style: Informal, clarifying questions welcomed

Context and EXP-07 Objectives

Respond to stakeholder needs:

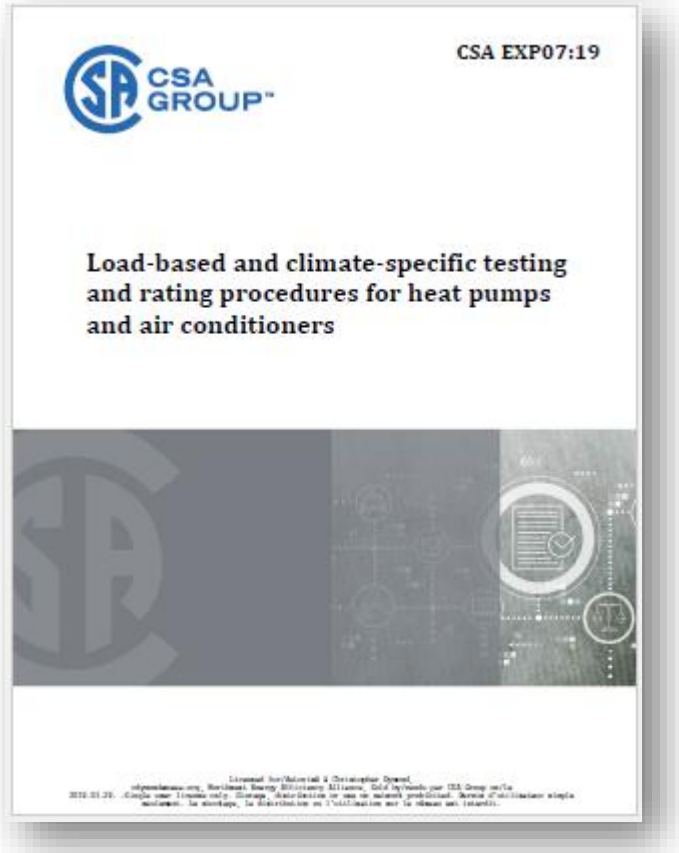
- Realistic rating for variable speed equipment
- Seasonal efficiency (SCOP) reported for a range of climate zones
- Detailed data to support performance simulation

Voluntary test – not intended as regulation

- Marketplace differentiation
- Qualified product lists, programs

“Technical Review” procedure

- For equipment ≤ 65kBtu
- Published March 29, 2019
- 1 Year for feedback / propose improvements



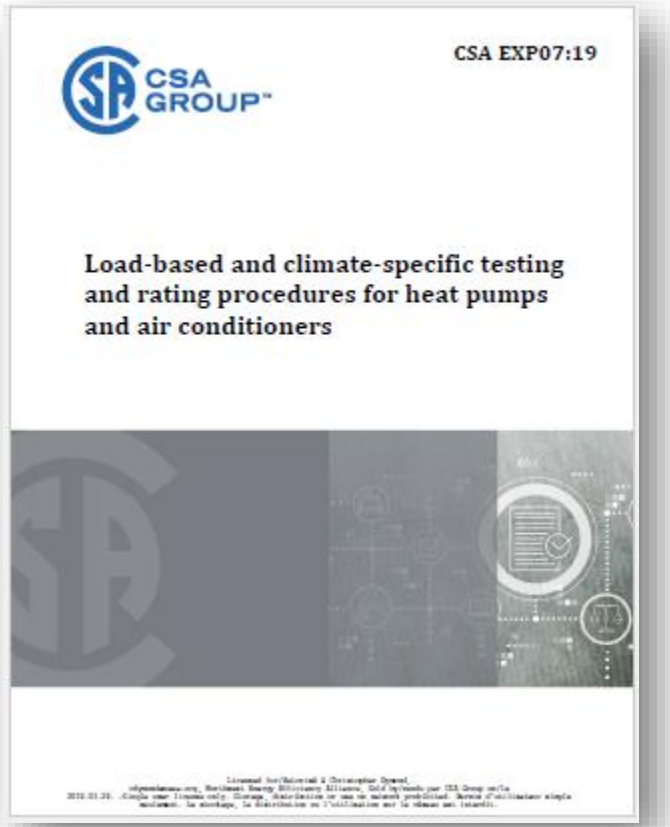
EXP-07 Approach

Test to reflect a real installation performance

- Applies a dynamic load based on outdoor unit conditions (not fixed full capacity test)
- Using “as-shipped” settings
- Using onboard controls

Data from wide range of outdoor conditions

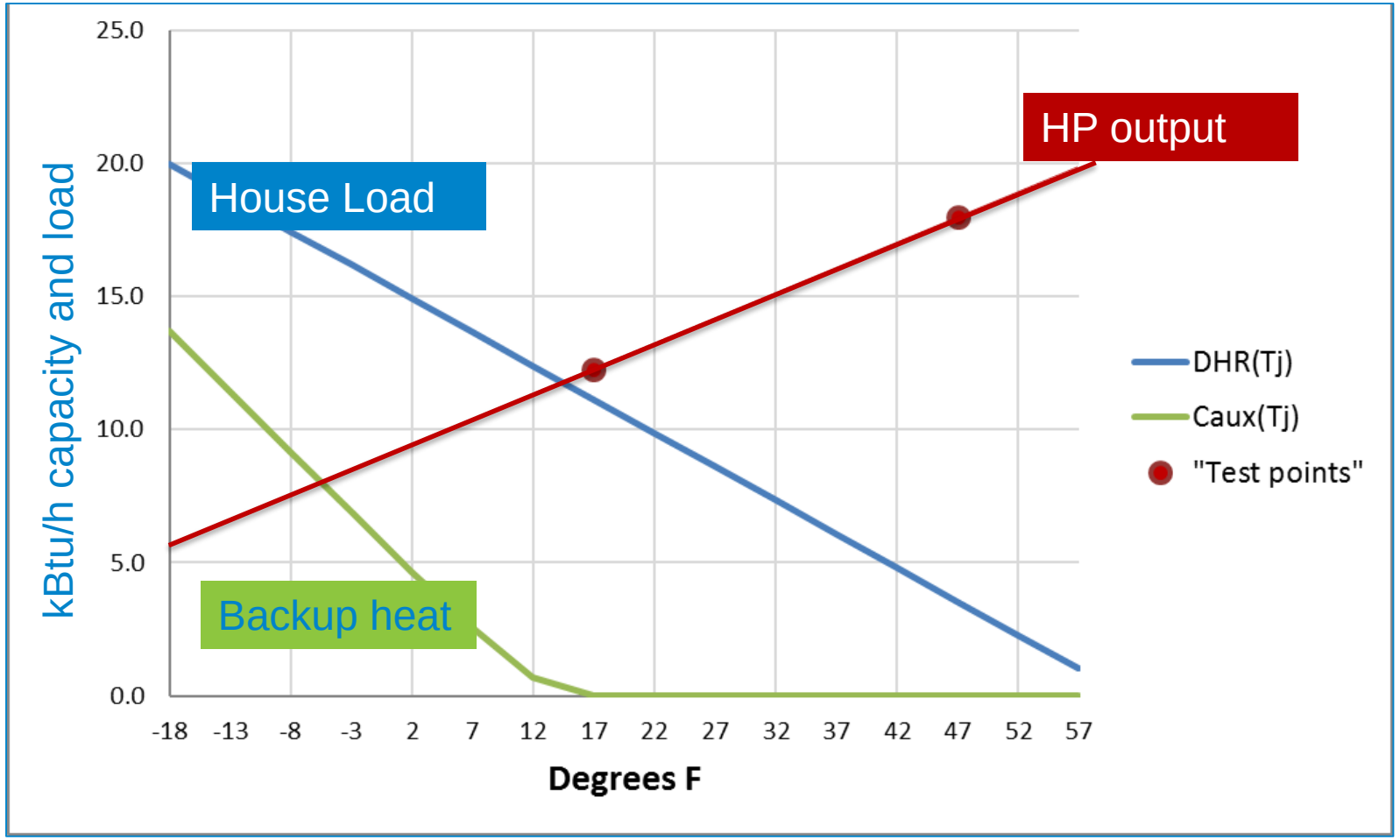
- Create climate specific seasonal ratings
  - $SCOP_{heating}$
  - $SCOP_{cooling}$
- Can be used in hourly building simulations
  - Design optimization
  - Demand impact



In development for 3 years
Published March 29, 2019

Conventional Heating Pump Test Procedure

(heating condition - simplified)



How the Dynamic Tests Works

Two Test Chambers

- Outdoor lab conditions cycle through range
- Indoor lab conditions are controlled to simulate a house response to what the heat pump is doing

Different Outdoor Conditions

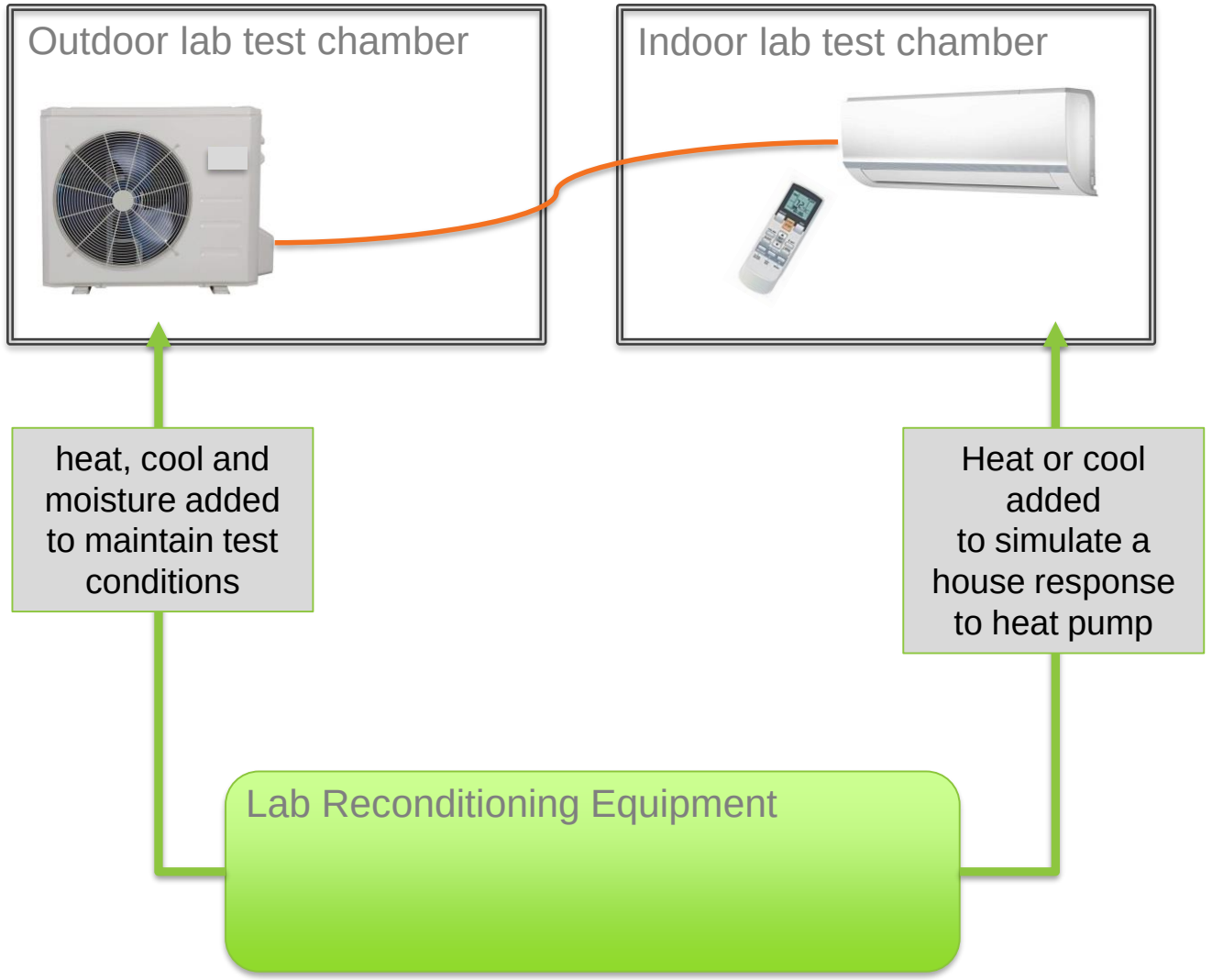
- Heating – Dry, Marine
- Cooling – Continental, Humid

Run Each Test until Either

- COP converges
- Test exceeds time limit

This Test Incorporates

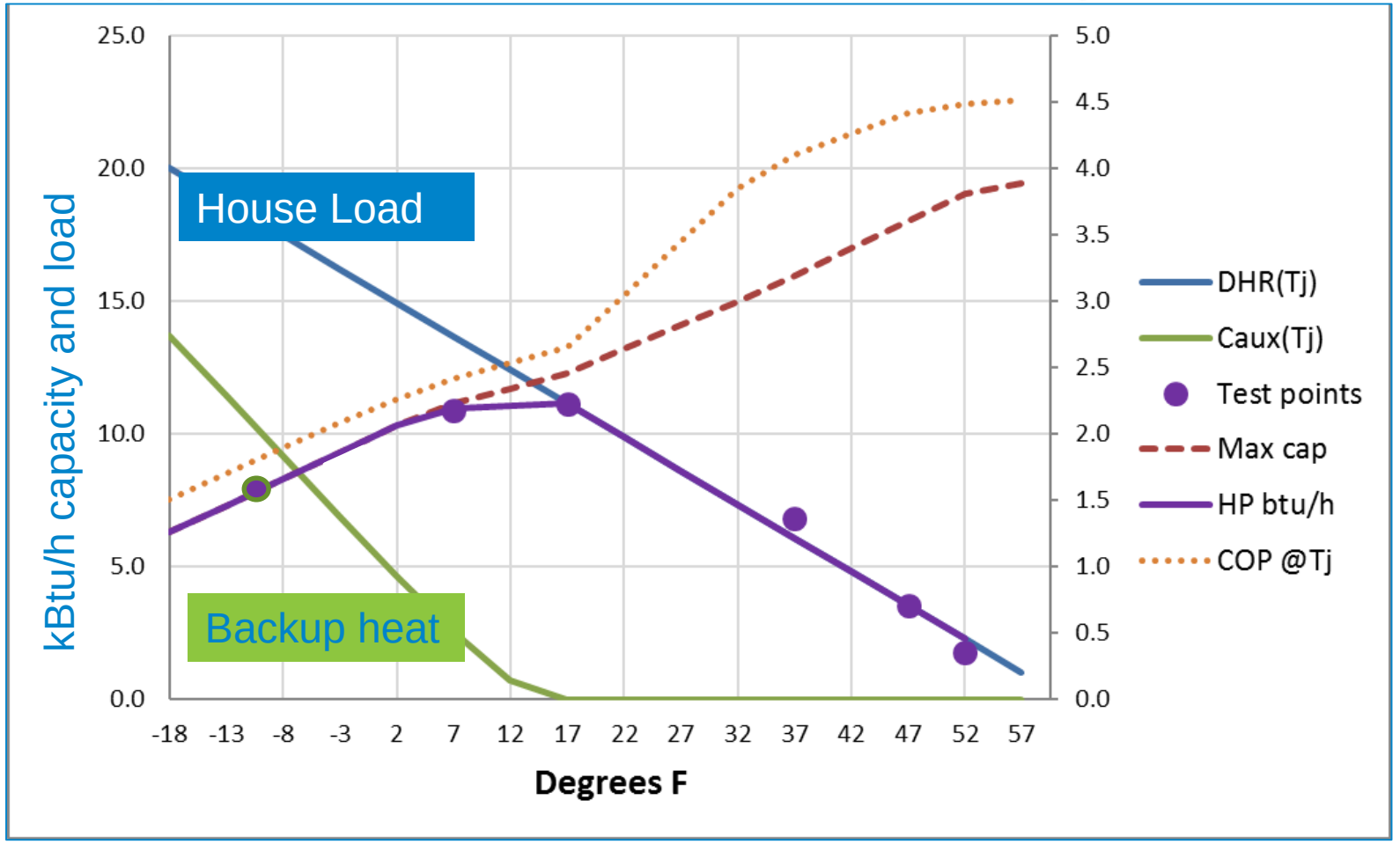
- Fan energy
- Low-load cycling and full-load tests, modulating in between
- Defrost
- Latent removal



EXP07 Heating Approach

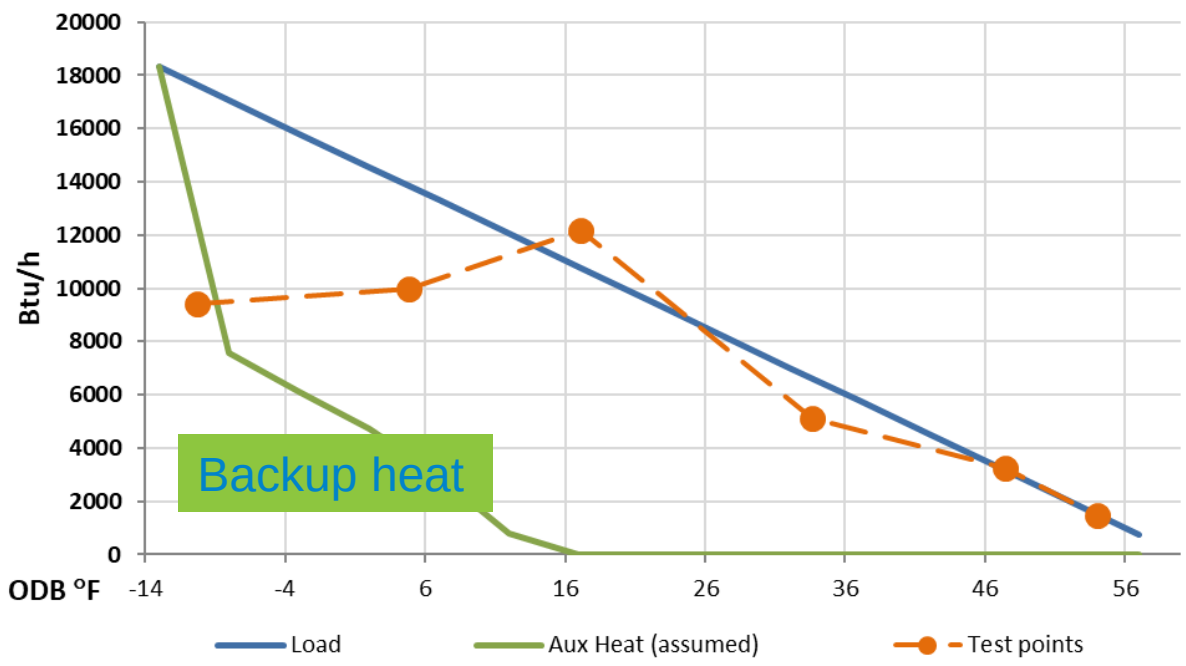
Load > HP Capacity

Load is Reduced to Capacity

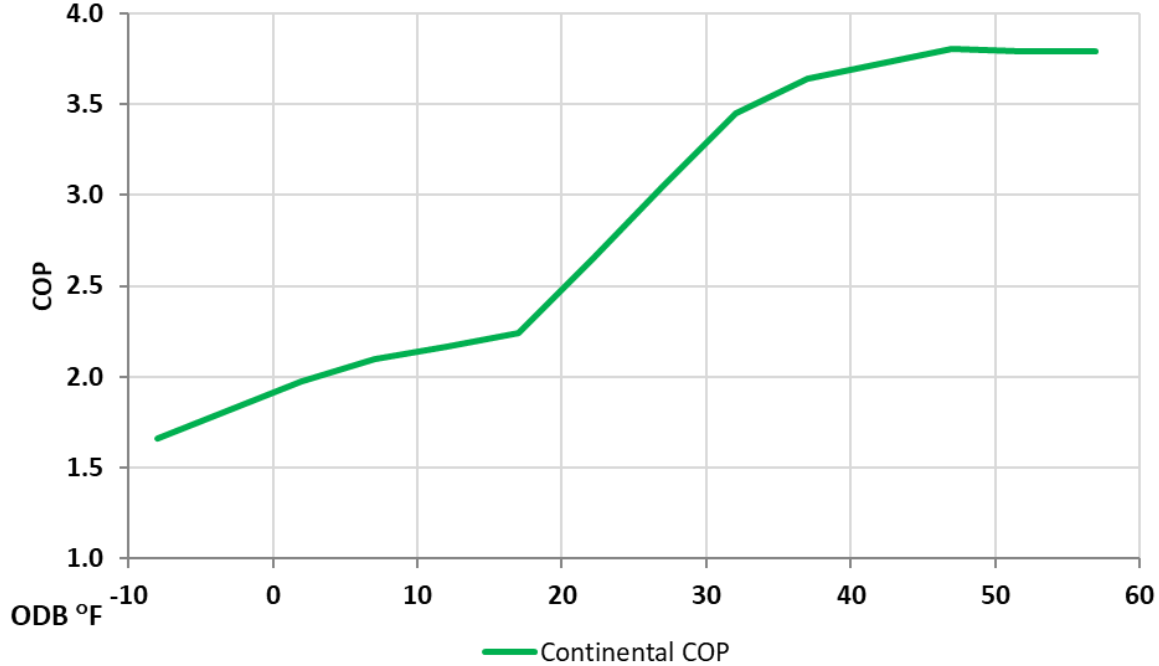


Example EXP07 Heating Results

Capacity

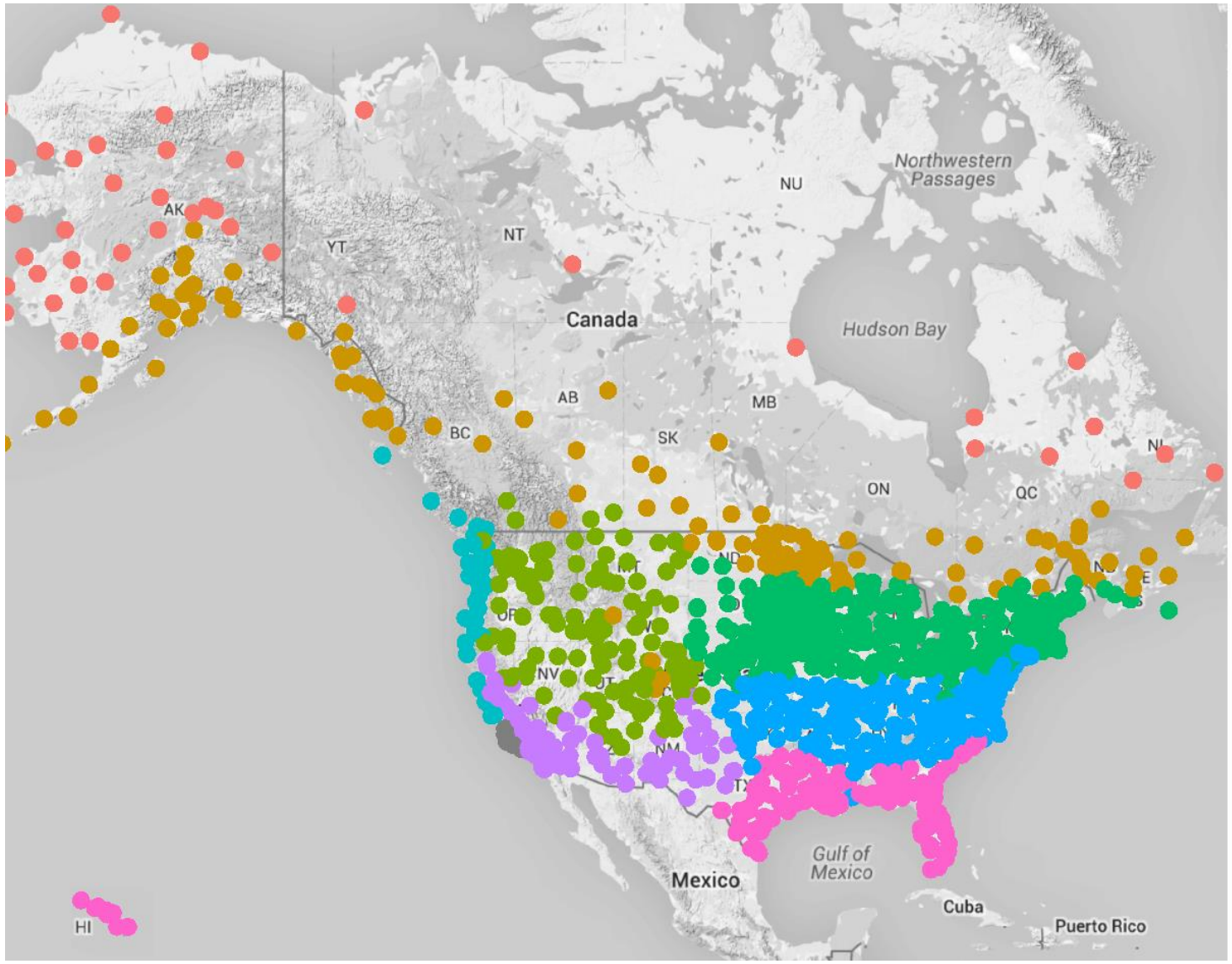


COP Map



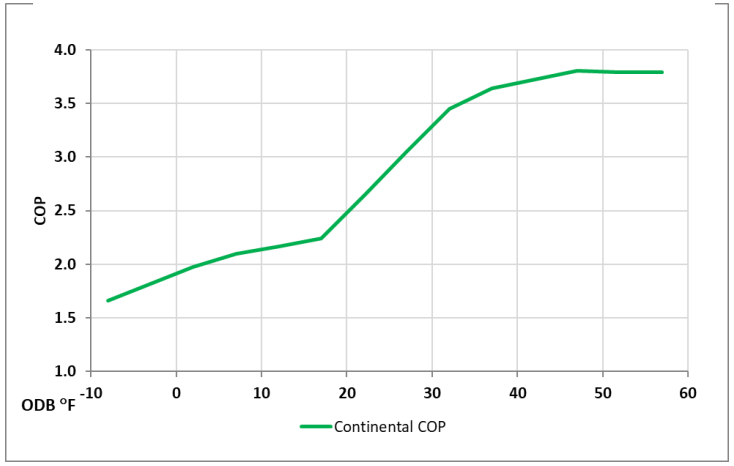
Test values are interpolated to generate this COP curve

Climate Zones in EXP07

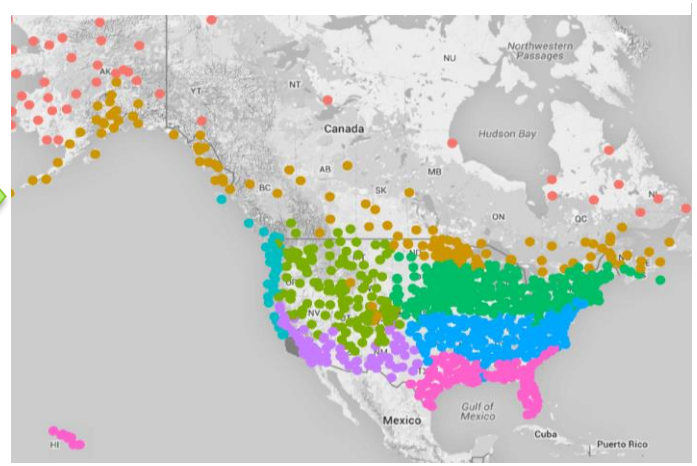


Converting COP map to SCOP

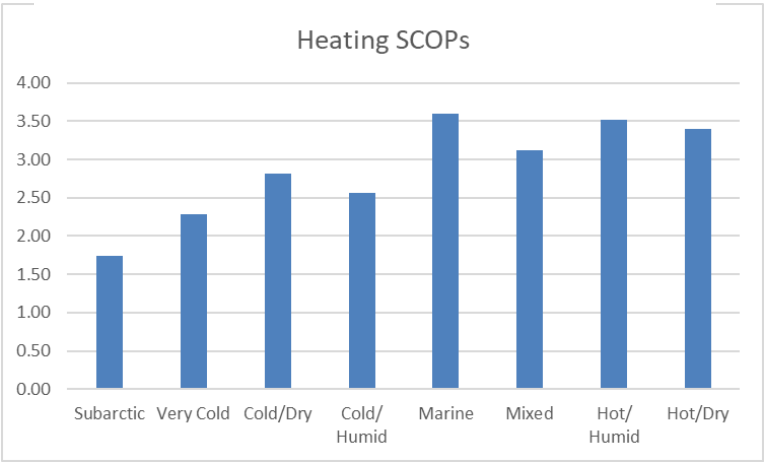
COP Map



Climate Bin-Hours



Climate Specific SCOP



2019 Lab Evaluation

Testing

- NRCan and NEEA have funded UL Plano Lab
- PG&E using their lab in San Ramon

Objectives

- Operationalize the test procedure
- Measure how different heat pumps respond using a consistent procedure
- Get idea of results for a range of similar products

Investigation Underway

- Repeatability
- Reproducibility

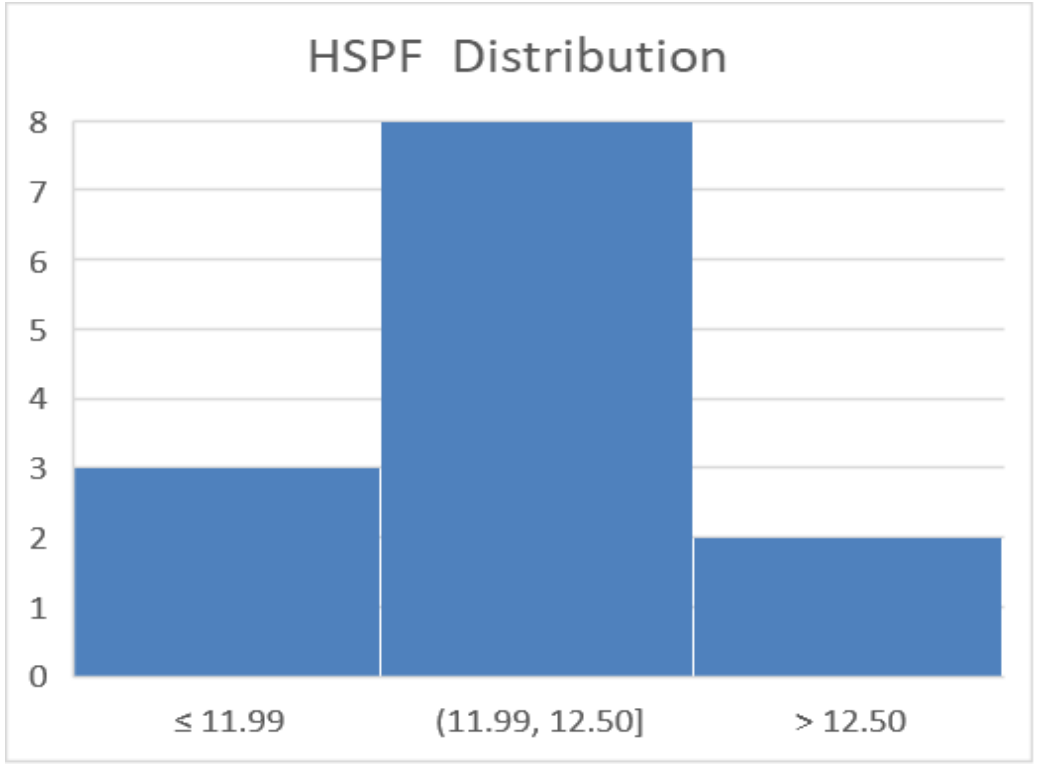
Unit Name	Status	Lab Used	Date Test Started	Nominal Capacity	% Capacity at 5F	Type	Zones
NEEA 1	complete	UL Plano	12/18/18	11,000	114%	Ductless	singlezone
NEEA 2	complete	UL Plano	04/08/19	12,000	100%	Ductless	singlezone
NEEA 3	complete	UL Plano	04/19/19	12,000	101%	Ductless	singlezone
NEEA 4	complete	UL Plano	01/07/19	10,900	105%	Ductless	singlezone
NEEA 5	complete	UL Plano	03/26/19	12,000	100%	Ductless	singlezone
NEEA 6	complete	UL Plano	09/18/19	12,000	107%	Ductless	singlezone
NEEA 7	complete	UL Plano	10/04/19	33,000	100%	Central FA	singlezone
NEEA 8	pending	UL Plano	11/26/19	35,400	63%	Central FA	singlezone
NEEA 9	testing	UL Plano	11/06/19	12,000	40%	Ductless	singlezone
NRCan 1	complete	UL Plano	03/01/18	17,200		Ductless	singlezone
NRCan 2	complete	UL Plano	06/01/18	12,000		Ductless	singlezone
NRCan 3	complete	UL Plano	12/03/19	12,000		Ductless	singlezone
NRCan 4	complete	UL Plano	02/08/19	15,000		Ductless	singlezone
NRCan 5	complete	UL Plano	2/23-3/8	15,000		Ductless	singlezone
NRCan 6	complete	UL Plano	3/6-3/26	15,000		Ductless	singlezone
NRCan 2b	0	UL Plano	01/00/00	12,000		Ductless	singlezone
NRCan 7	0	UL Plano	01/00/00	#N/A		#N/A	#N/A
NRCan 9	0	UL Plano	01/00/00	33,000		Central FA	singlezone
NRCan 10	0	UL Plano	01/00/00	24,200		Central FA	singlezone
NRCan 11	0	UL Plano	01/00/00	#N/A		#N/A	#N/A
NRCan 12	0	UL Plano	01/00/00	#N/A		#N/A	#N/A
PG&E 1	0	ATS	01/00/00	#N/A		#N/A	#N/A
PG&E 2	0	ATS	01/00/00	#N/A		#N/A	#N/A
PG&E 3	0	ATS	01/00/00	#N/A		#N/A	#N/A
PG&E 4	0	ATS	01/00/00	#N/A	0%	#N/A	#N/A

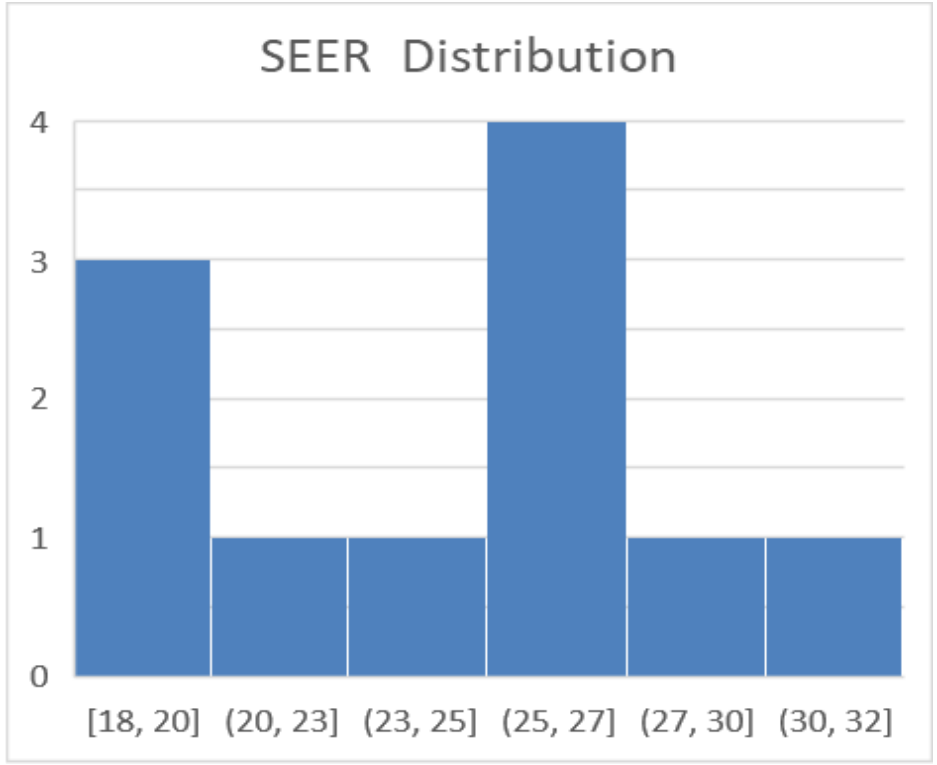
Tested so far:

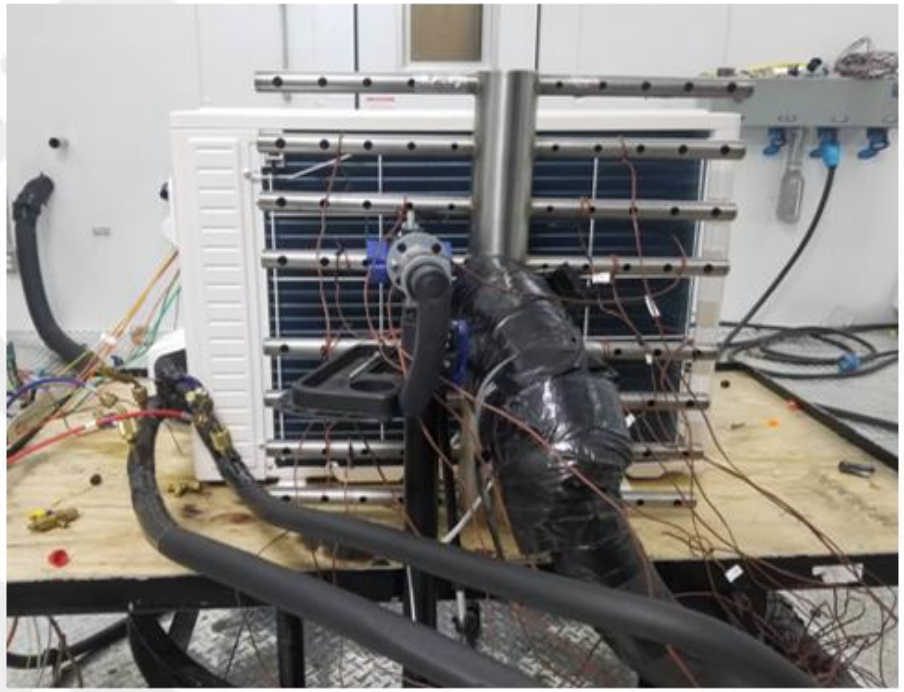
12 Ductless

- 8@ 1 Ton
- 4@ 1.25 Ton (2 without cooling tests)

1 Ducted @ 2.75 Ton

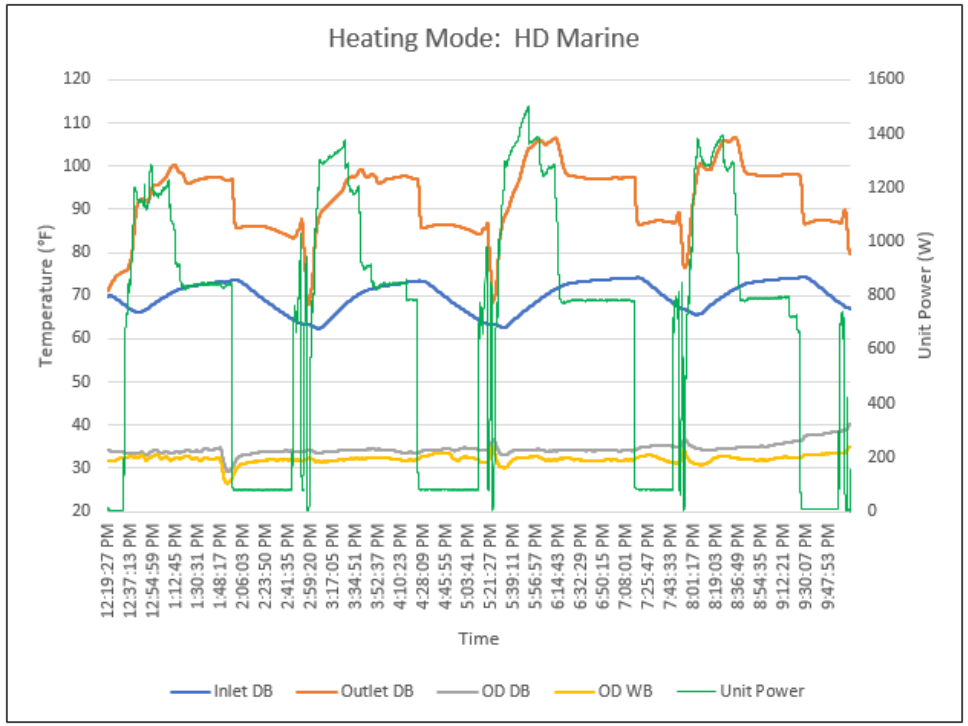






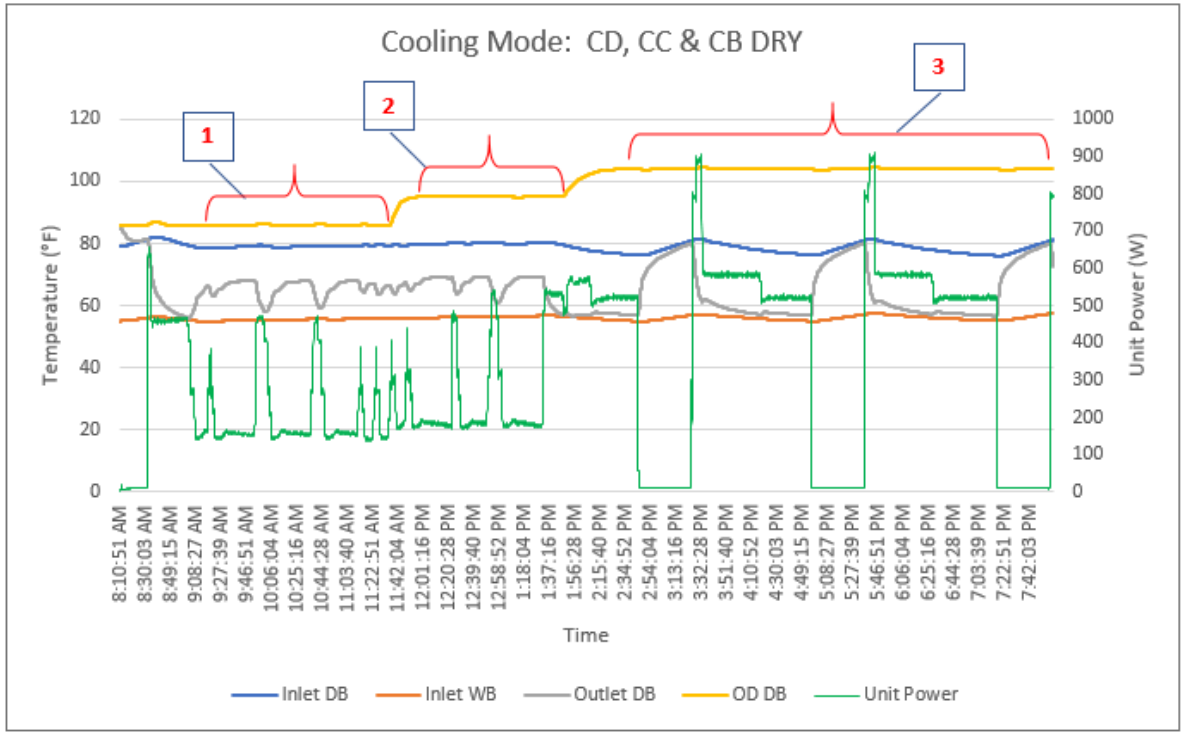

Sheathing

Anomalies happen in lab as well as field:



Some machines behave oddly

This makes it challenging to identify when convergence has been achieved

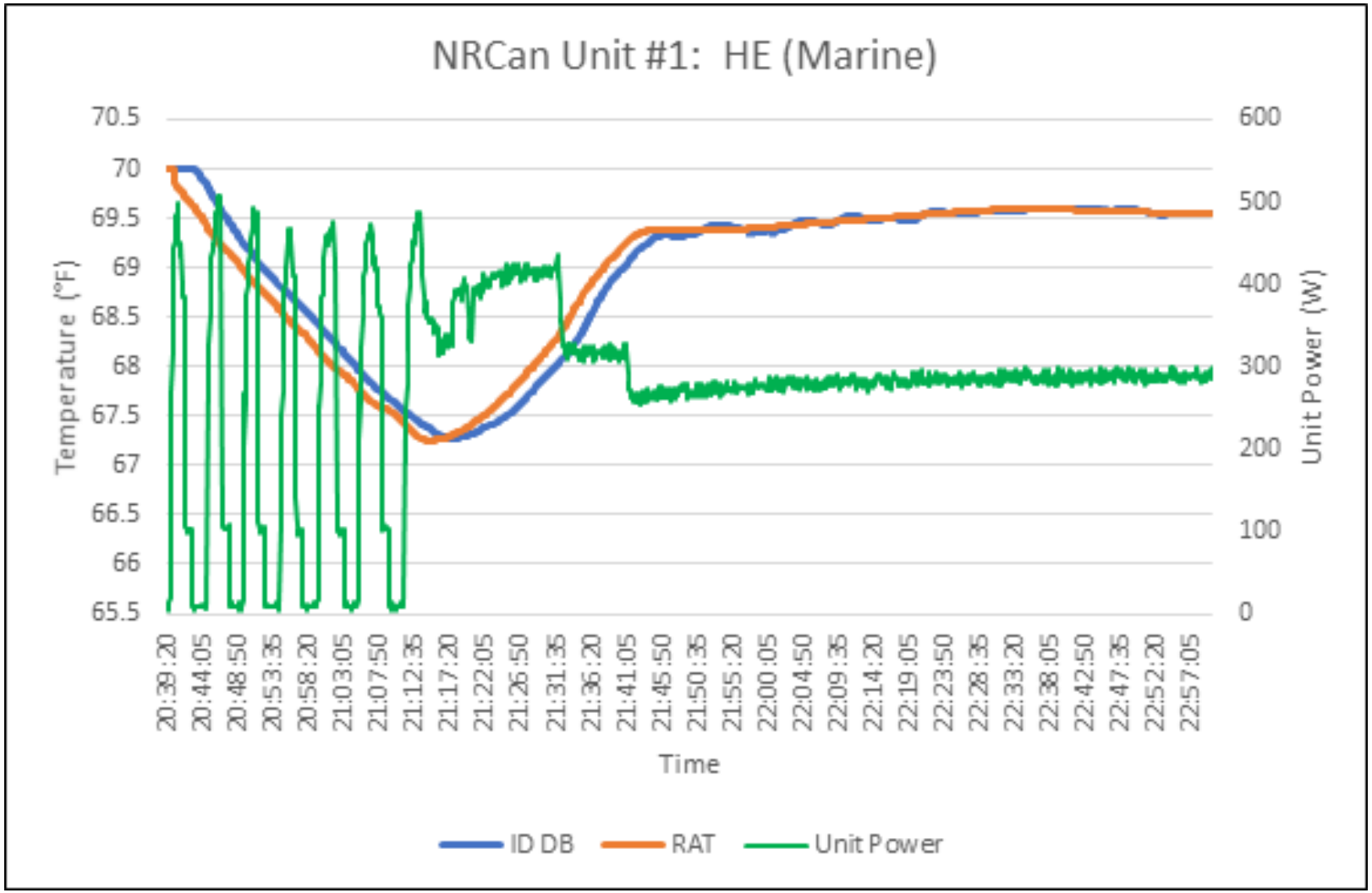


Cooling convergence is typically quick but some modes are unstable

Finding its "groove"…

This unit ran for over 60 minutes before it "found its groove":

Generating enough capacity to reach room temperature, then modulating to sustain it



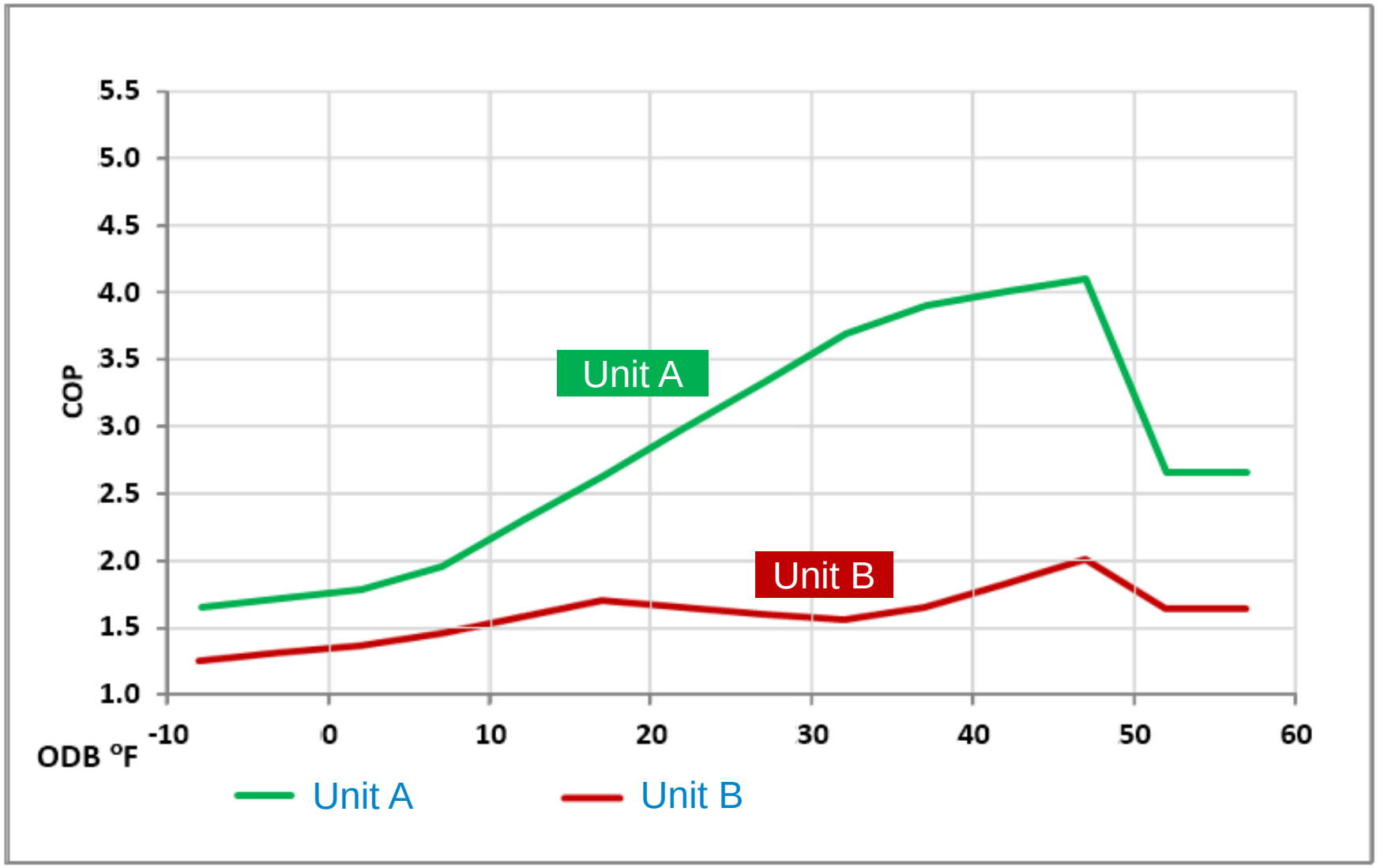
Example – 2 similar units

Both units look nearly the same to potential customers using AHRI Certified Ratings (in accordance with AHRI 210/240)

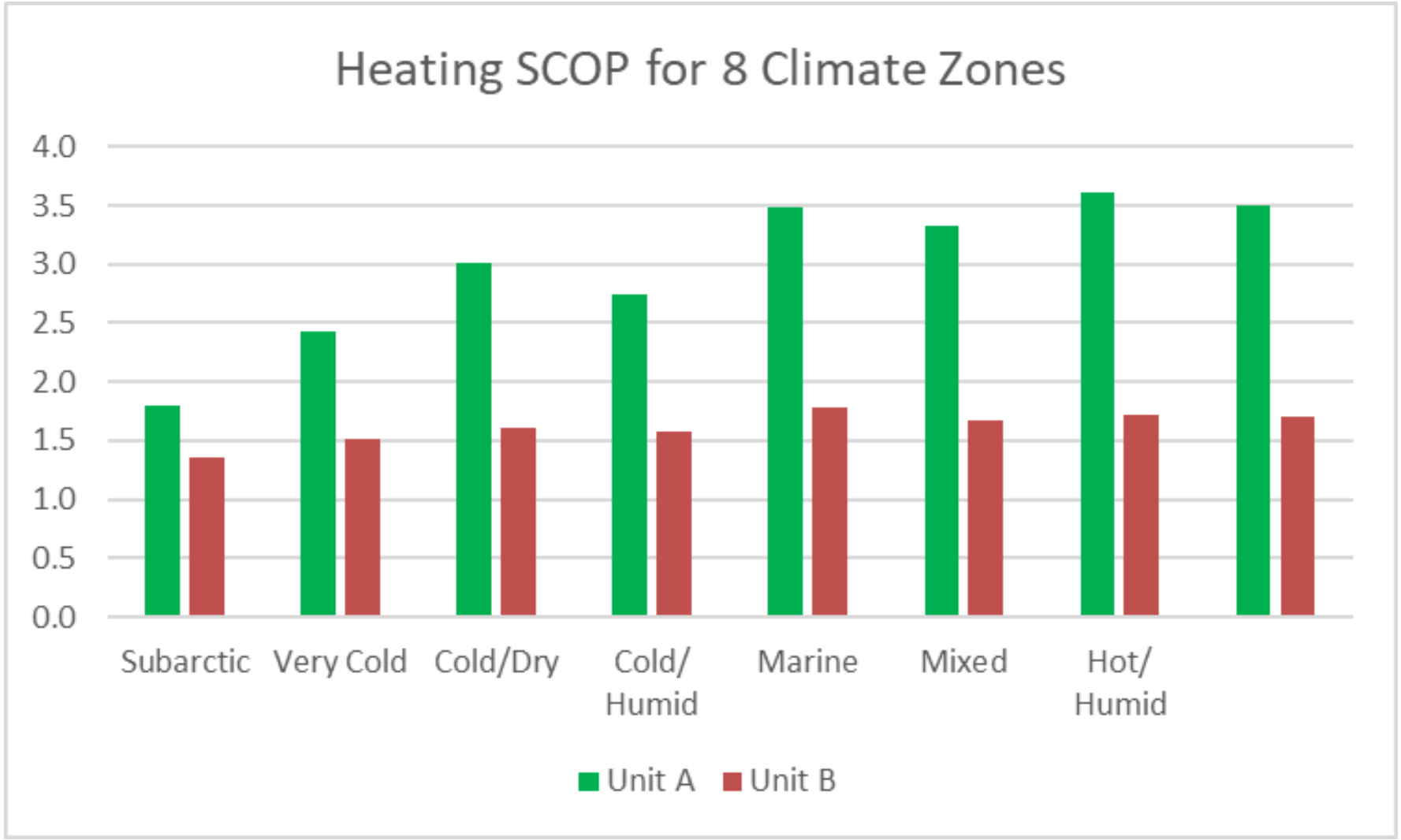
Unit B has slightly *higher* SEER, otherwise identical:

	Capacity	HSPF	SEER
Unit A	1 Ton	12.0	20.0
Unit B	1 Ton	12.0	**25.0**

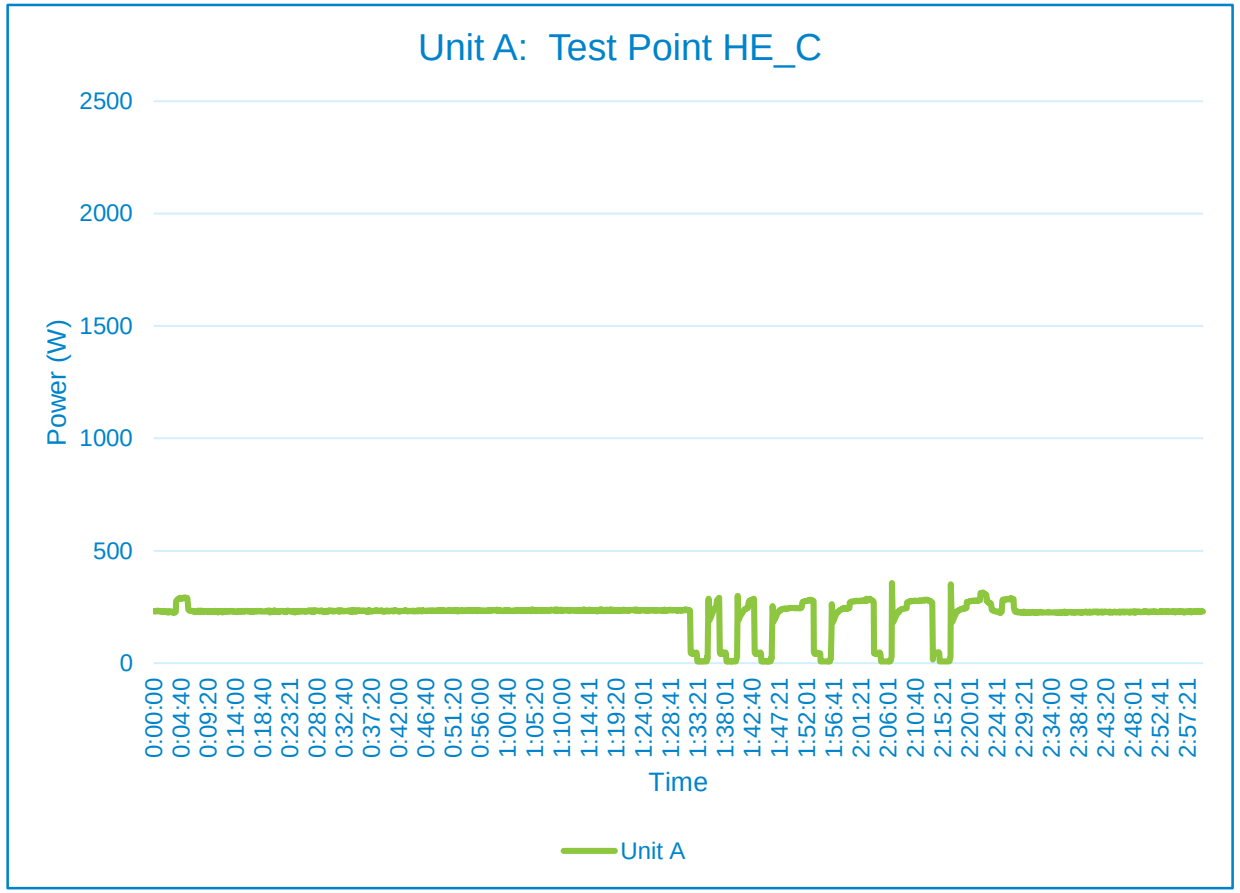
Heating Mode COP vs. Outdoor Temp

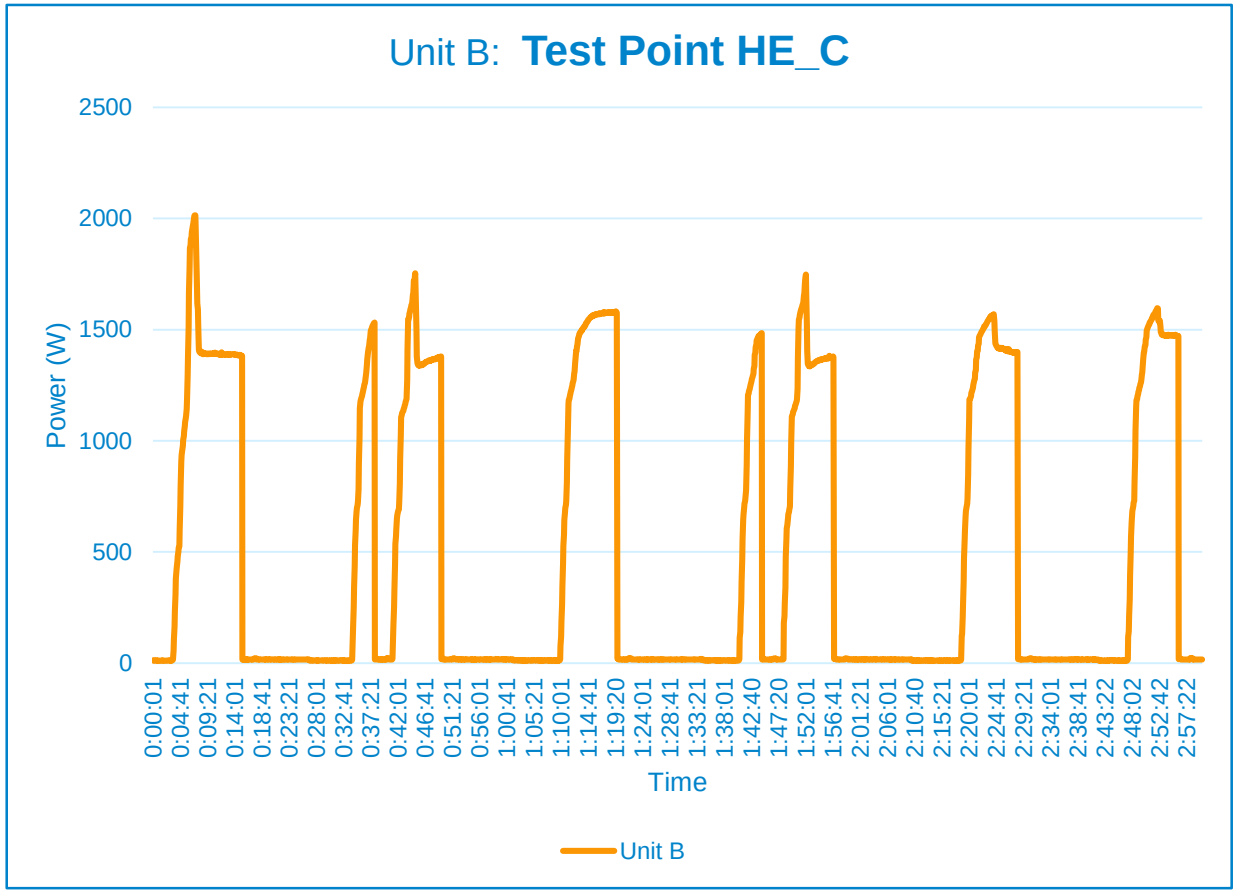


Heating SCOP Comparison

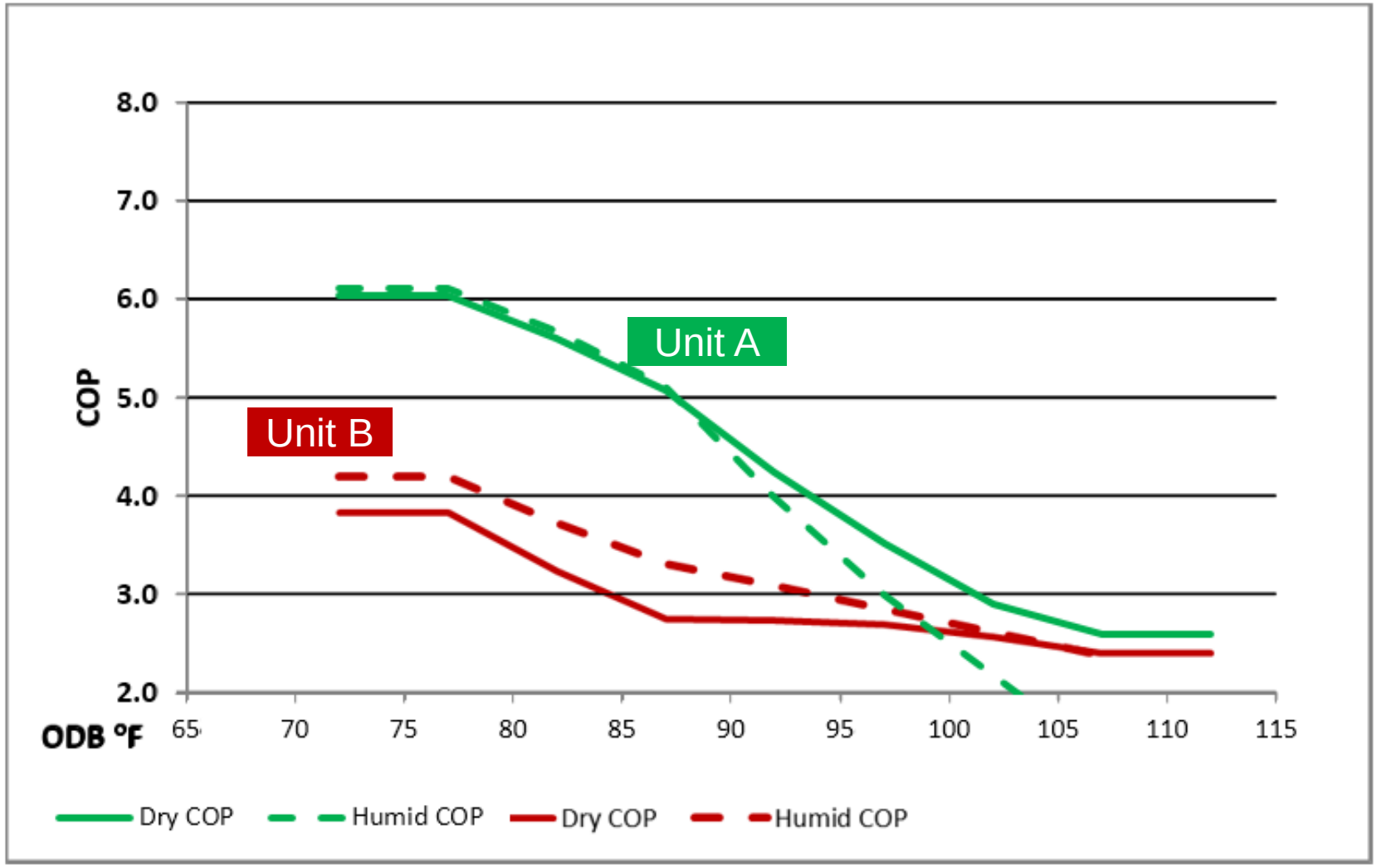


Heating Mode – Operation @ Part Load





Cooling Mode COP vs. Outdoor Temp



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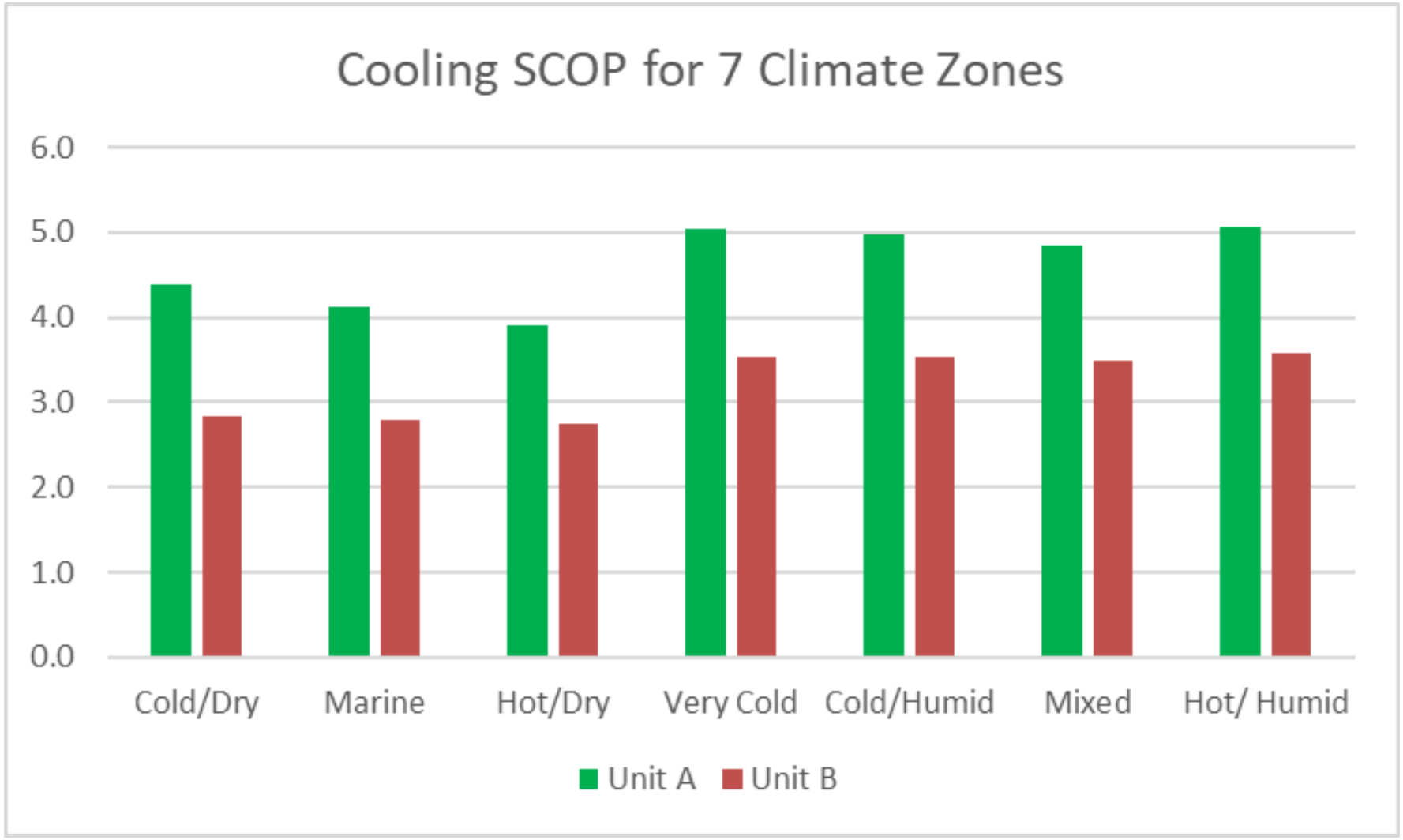

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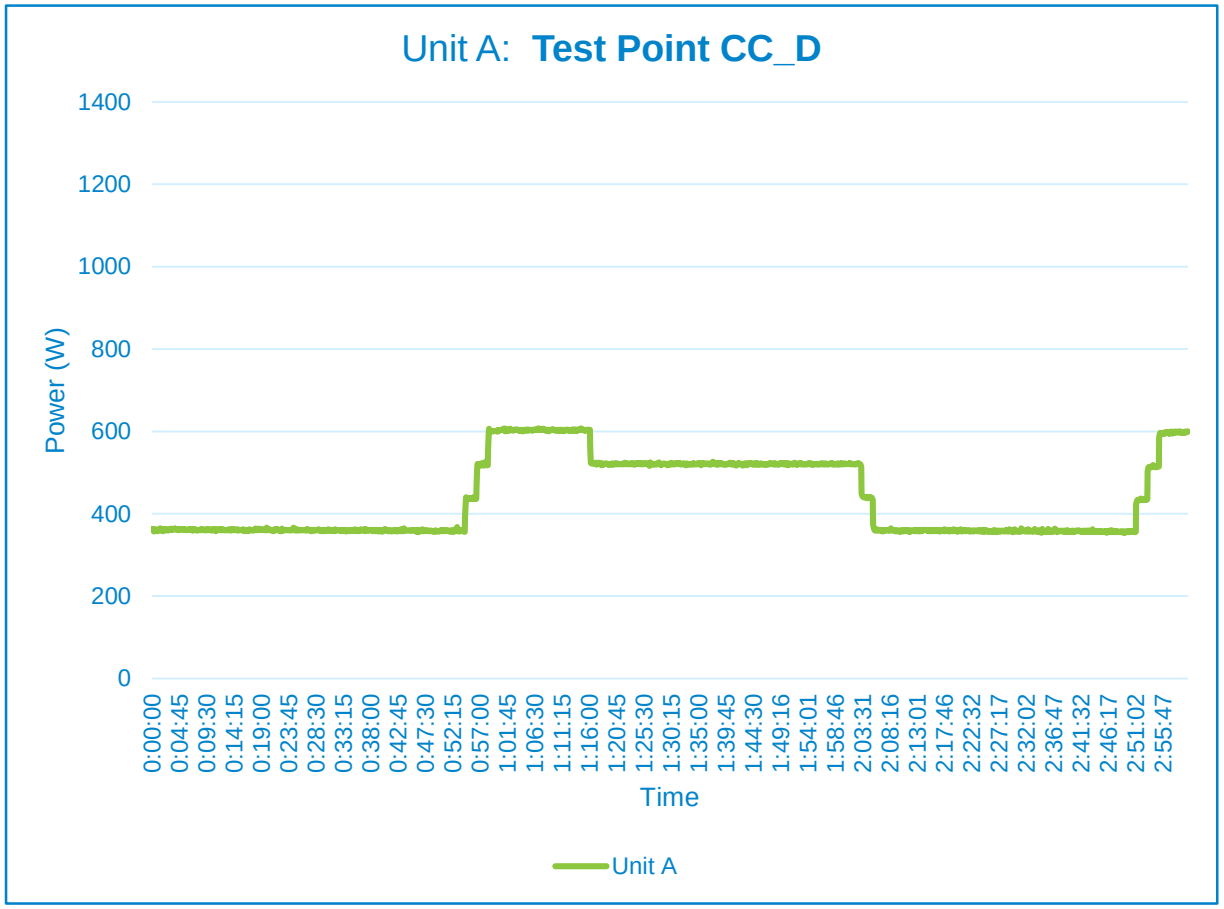
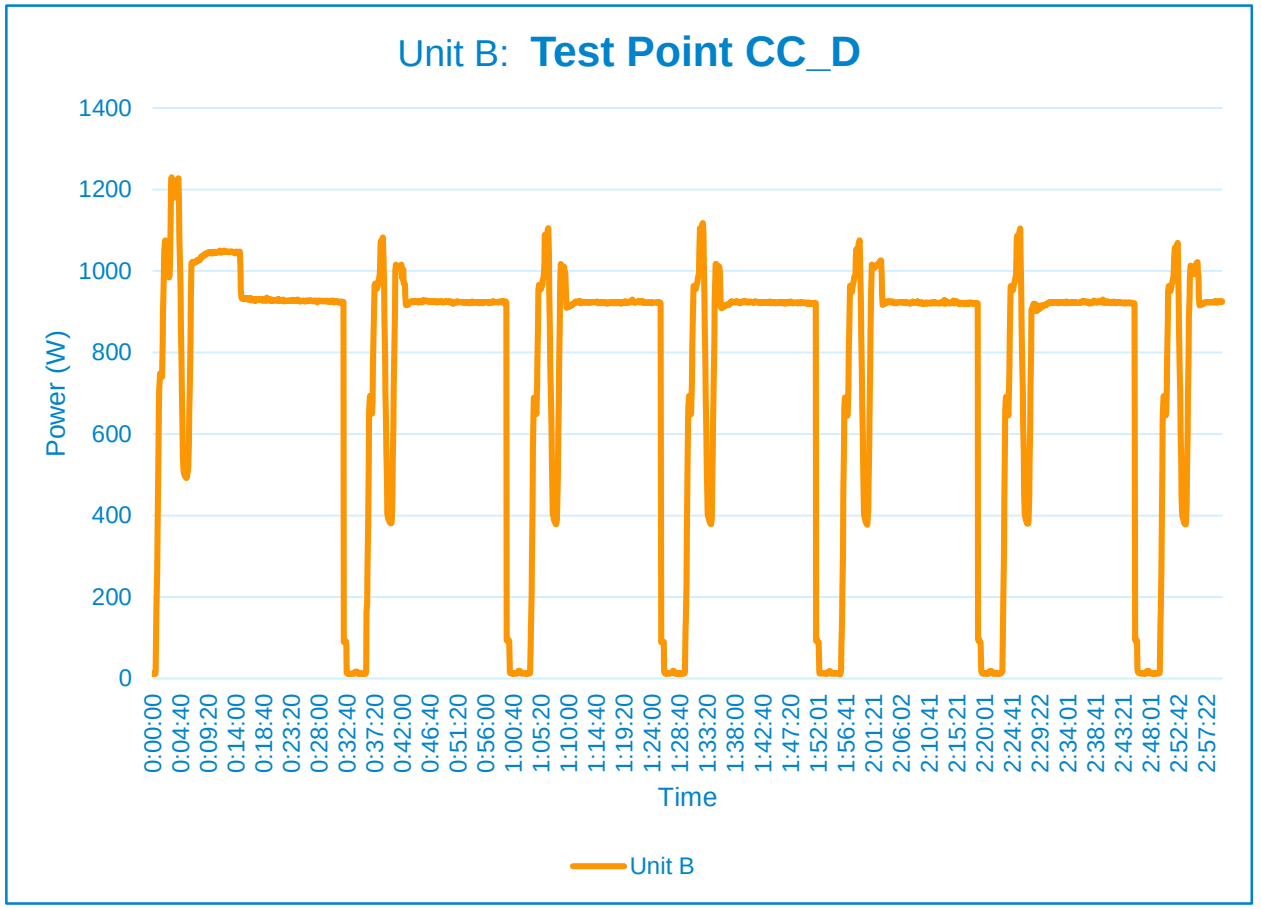




Potential Benefit of Load-Based Testing

Better Differentiation of real-world performance

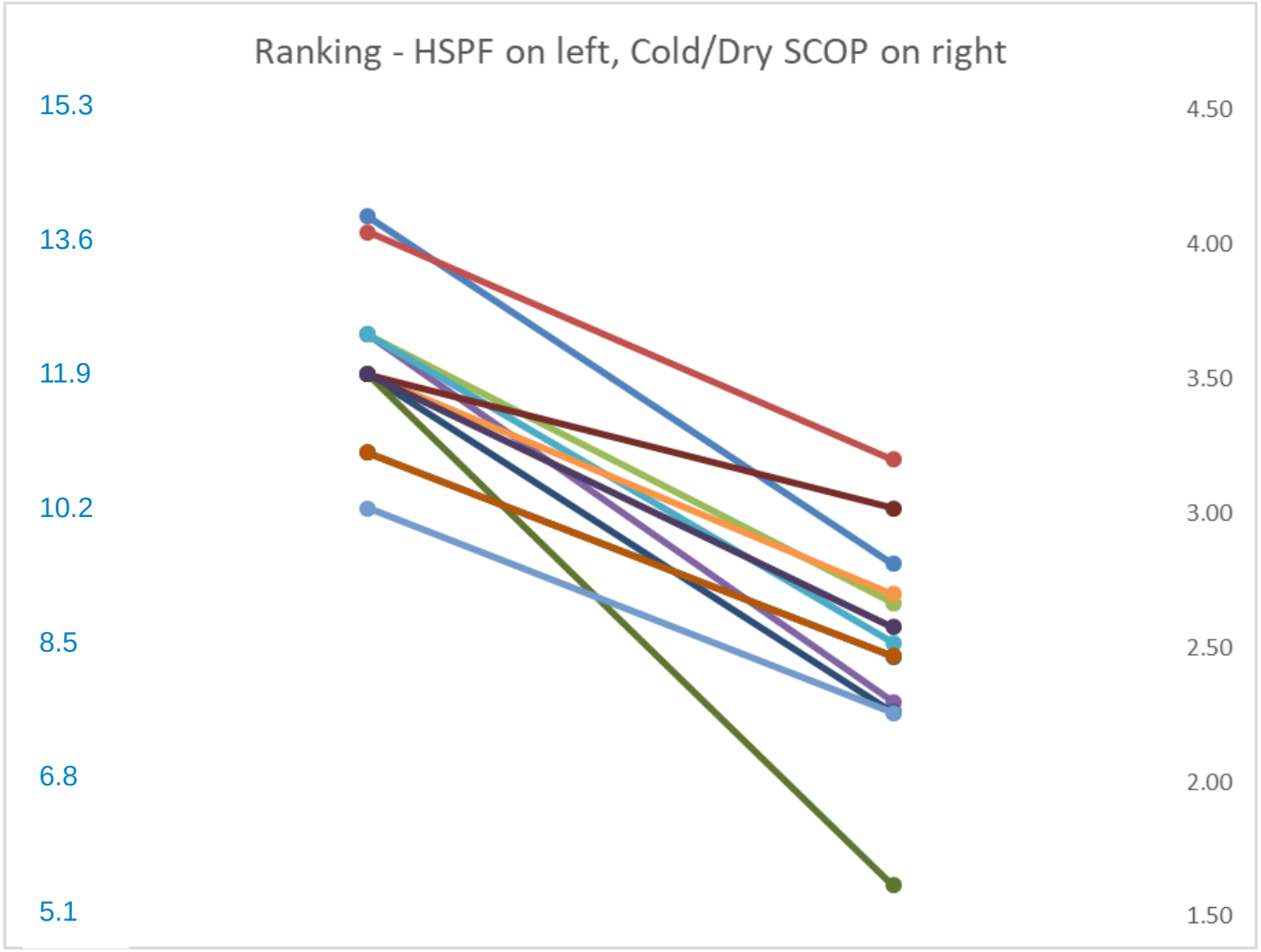
- Climate differences
- Low-load differences
- More accurate qualified product lists (QPL)
- Increased savings estimates of top performance equipment

	Capacity	HSPF	SEER	SCOPH	SCOPC
Unit A	1 Ton	12.0	20.0	**3.0**	**4.8**
Unit B	1 Ton	12.0	25.0	**1.6**	**3.5**

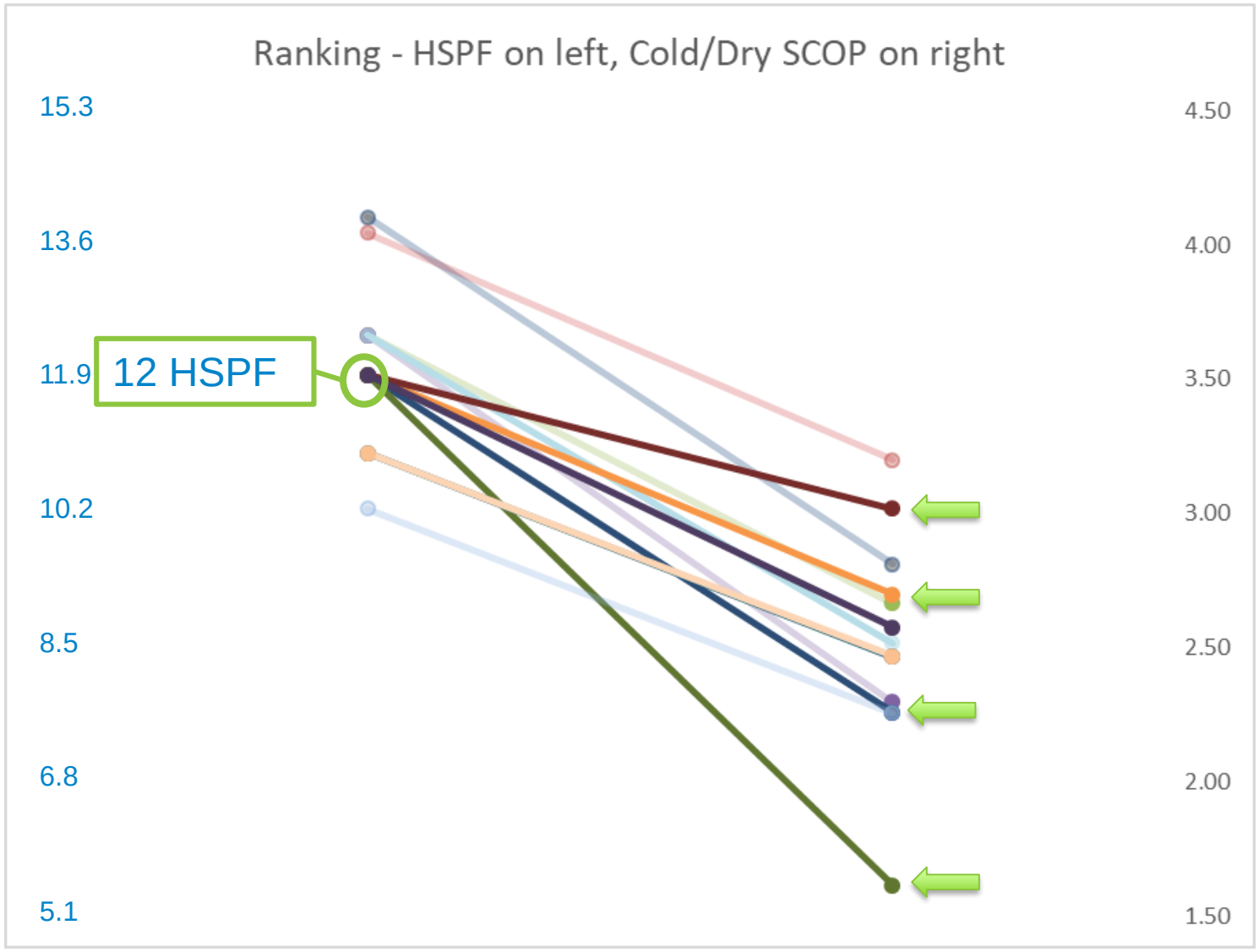
Performance Ranking - Heating

13 Units Tested
- 8 @ 1 Ton
- 4 @ 1.25 Ton
- 1 @ 2.75 Ton

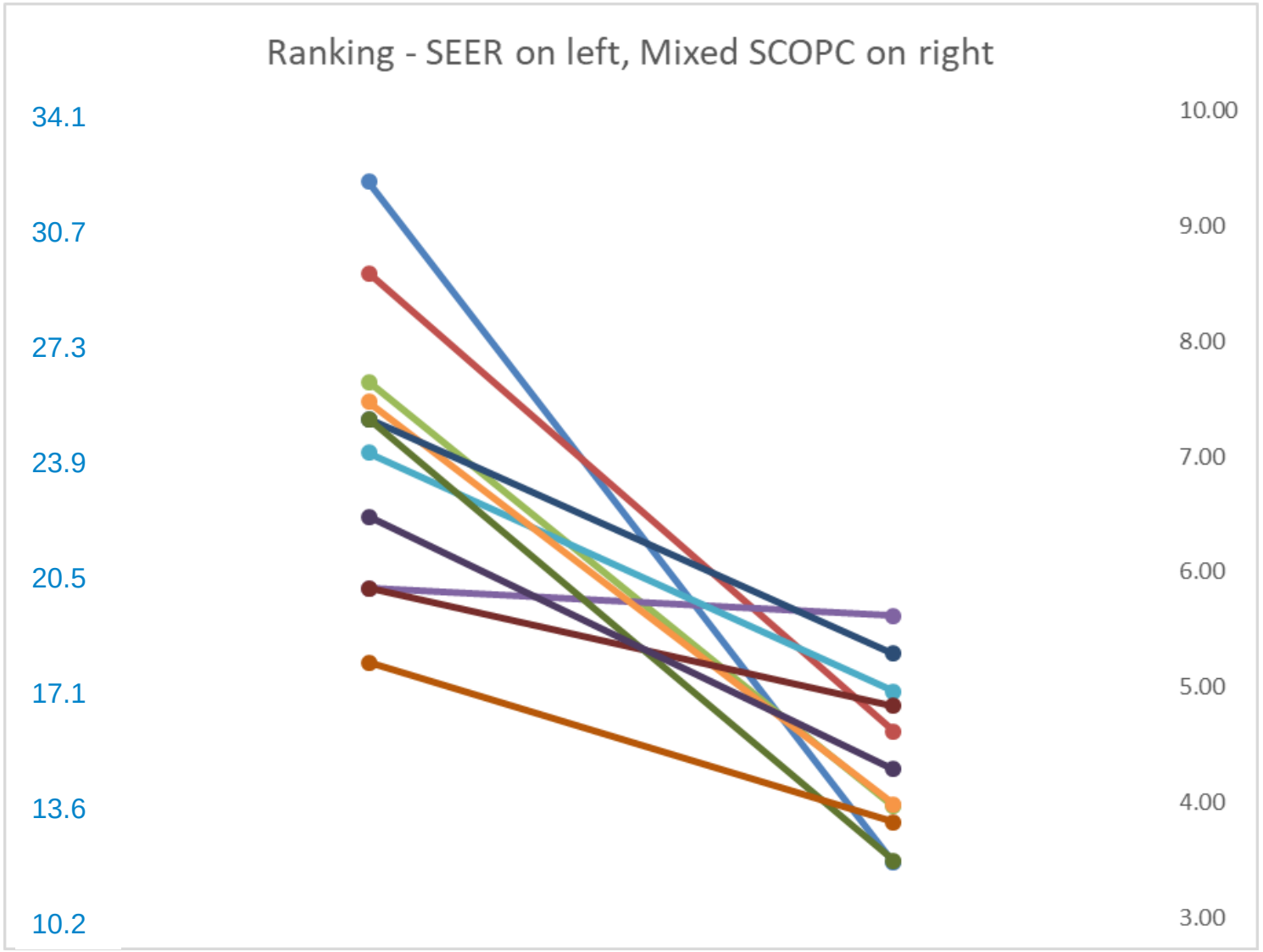
All on NEEP QPL



Performance ranking – 12 HSPF

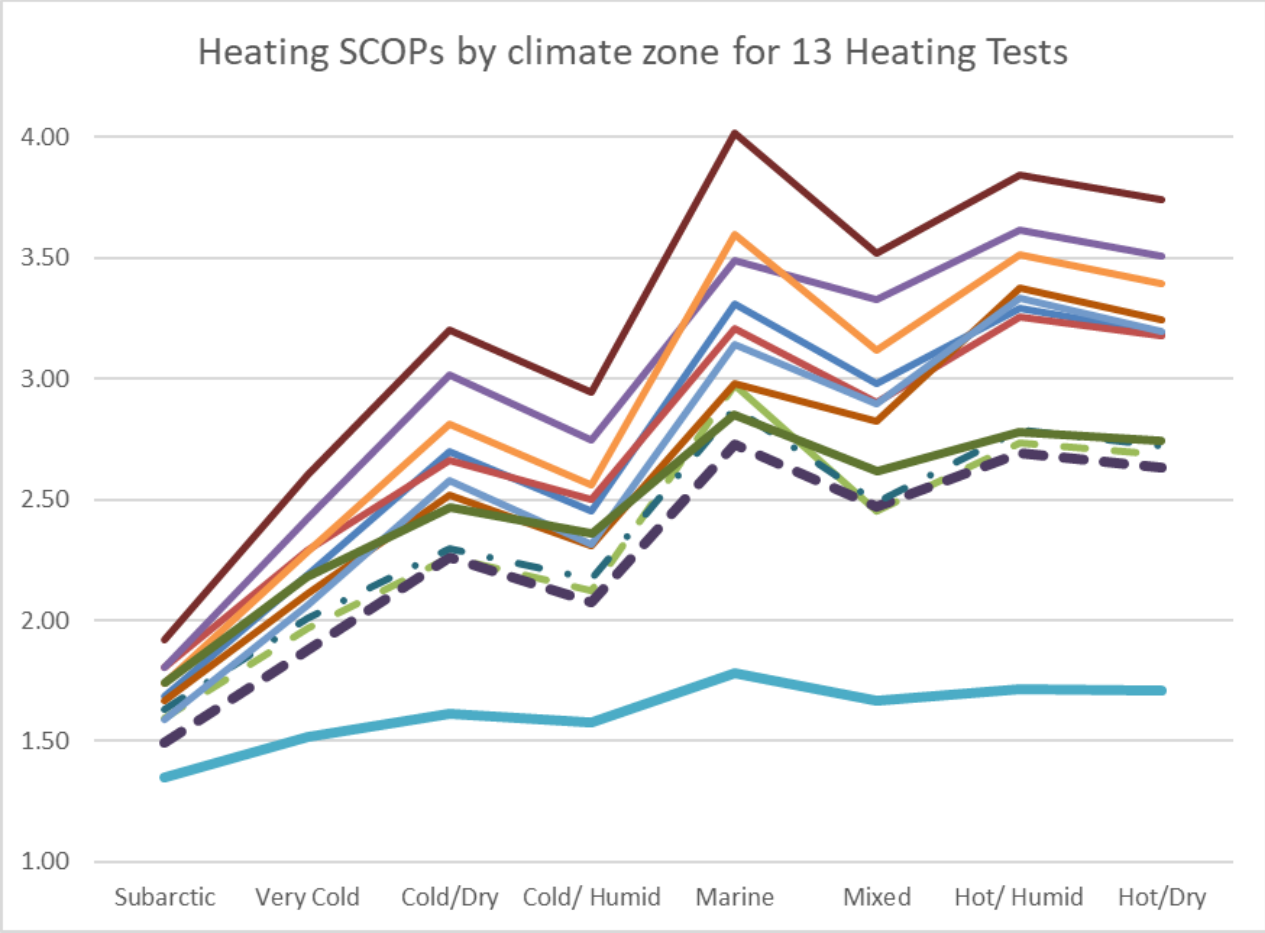


Performance Ranking - Cooling

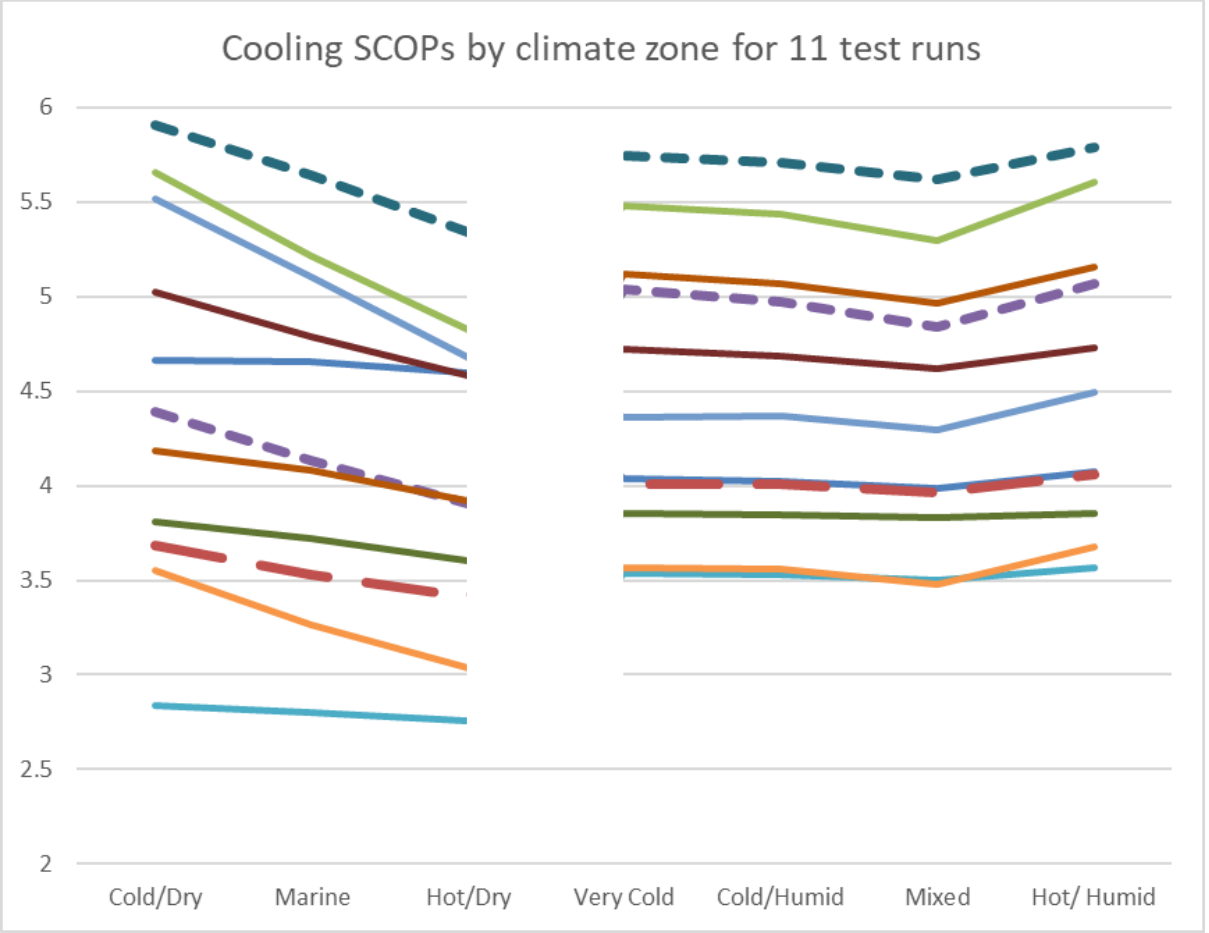


Range of tested SCOPs Grouped by climate

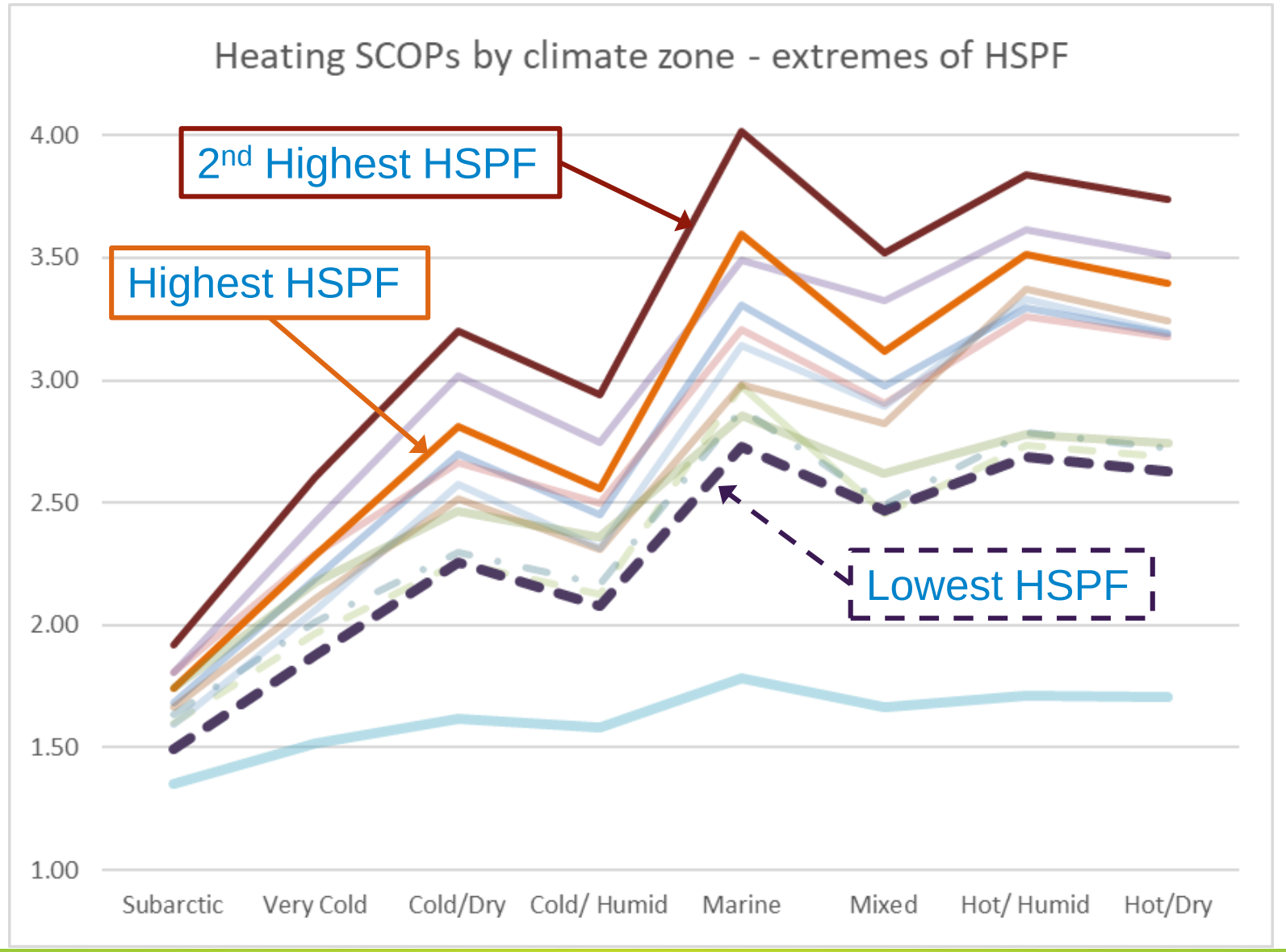
Heating



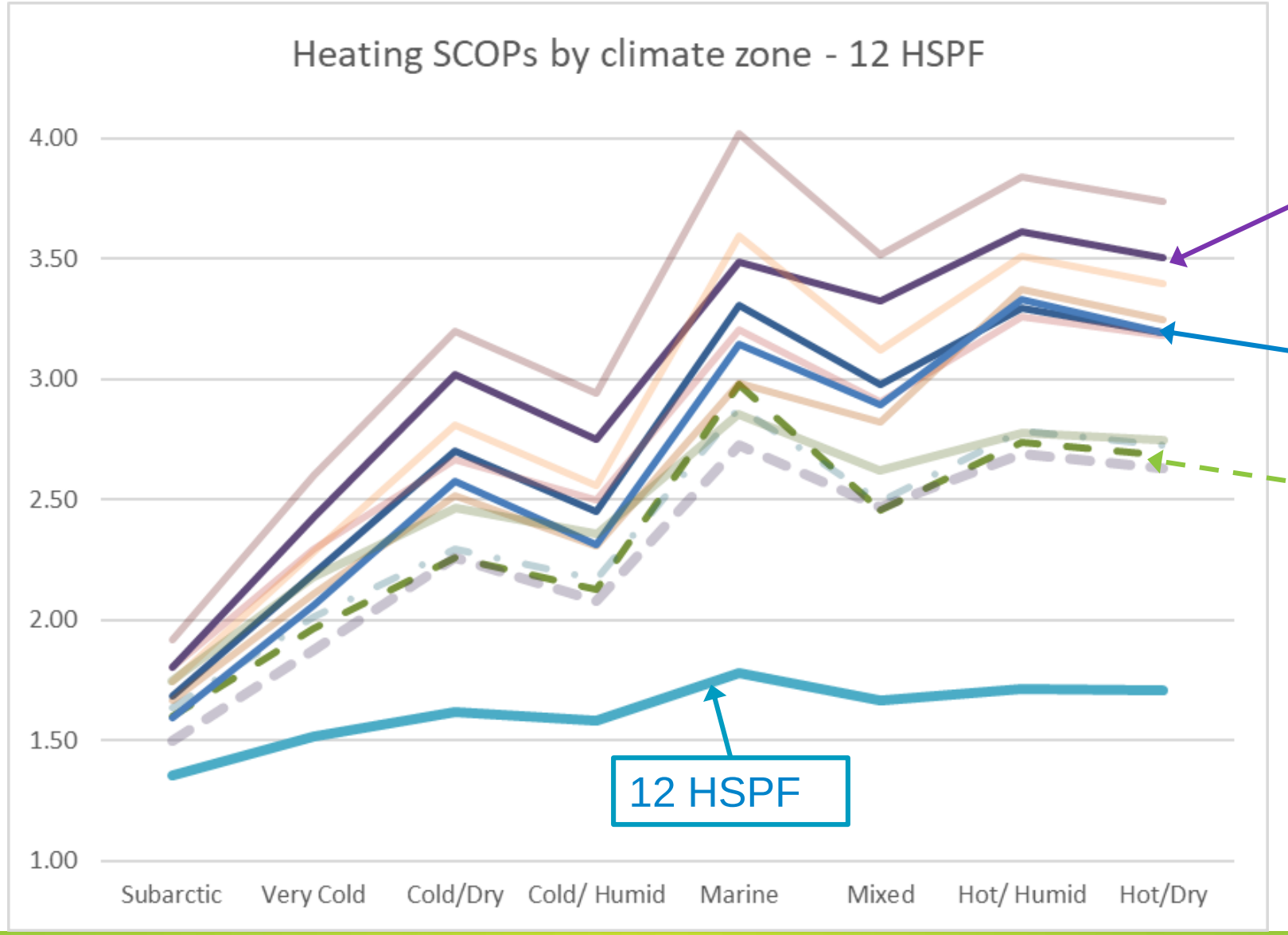
Cooling



Heating SCOPs – by climate

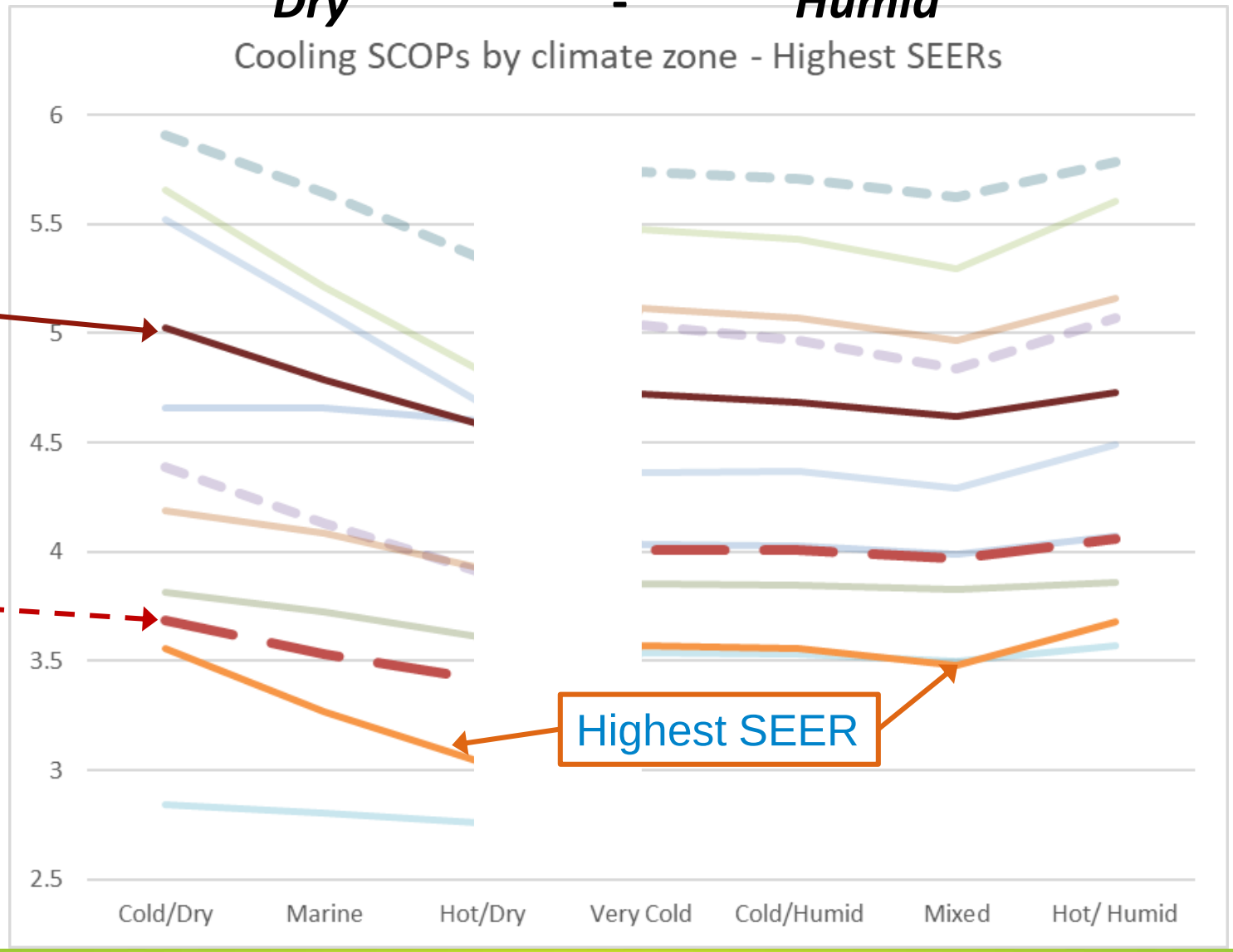


Heating SCOPs – by climate



Cooling SCOPs - Grouped

Dry - Humid



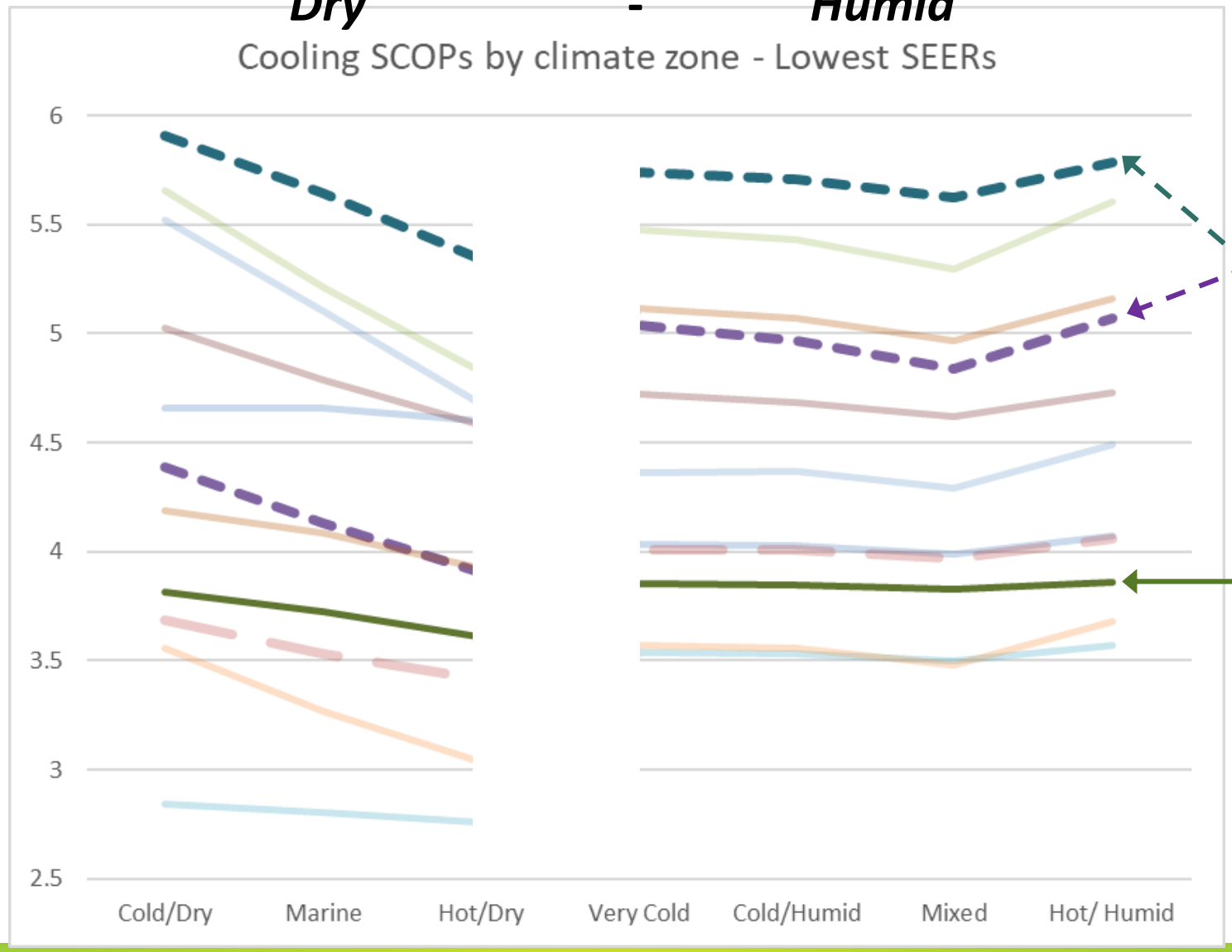
2nd Highest SEER

3rd Highest SEER

Highest SEER

Cooling SCOPs - Grouped

Dry **-** ***Humid***



Summary

Lab Experience

- More time consuming than 210/240 --- currently 3X, potential to reach 2X
- Cooling convergence is easier than heating convergence

Performance Findings

- Shows controls impact not observed in static testing – for example:
  - Defrost algorithms
  - Partial load efficiency
- Considerable changes observed in relative ranking
- Climate specific performance differences observed

Ongoing

- Prepare for March comment deadline (repeatability, reproducibility, representativeness)
- Improve operational efficiency --- process streamlining
- Preliminary findings report --- Due January 2020.

Questions?

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TOGETHER We Are Transforming the Northwest