Heat Pump
Rating Representativeness Project - Update

NEEA Product Council
August 15, 2023

Presented by

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Outline

- Introduction and Reason for Project
- Phase 1 – Field Testing
- Phase 2 – Lab Testing
- Preliminary Observations
- Summary and Next Steps
- Questions and Discussion

Desired Outcome

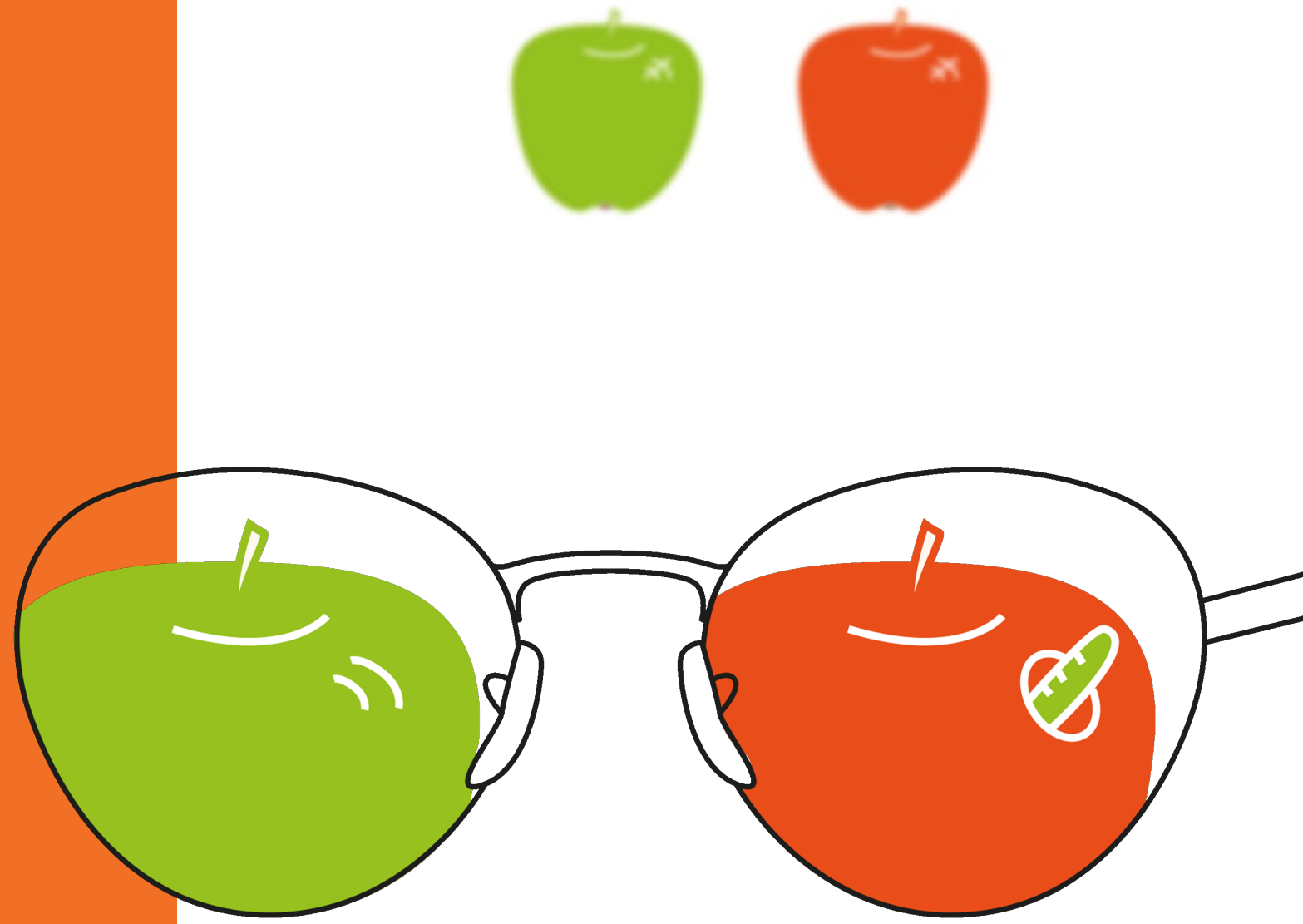
(of this presentation)

- Provide you with a progress update on the Rating Representativeness Project
- Provide general context and details about how the research was conducted
- Inform about possible updates to heat pump test procedure

Introduction
And Reason for Project

Accurate ratings …

… let us see key details we otherwise might have missed.

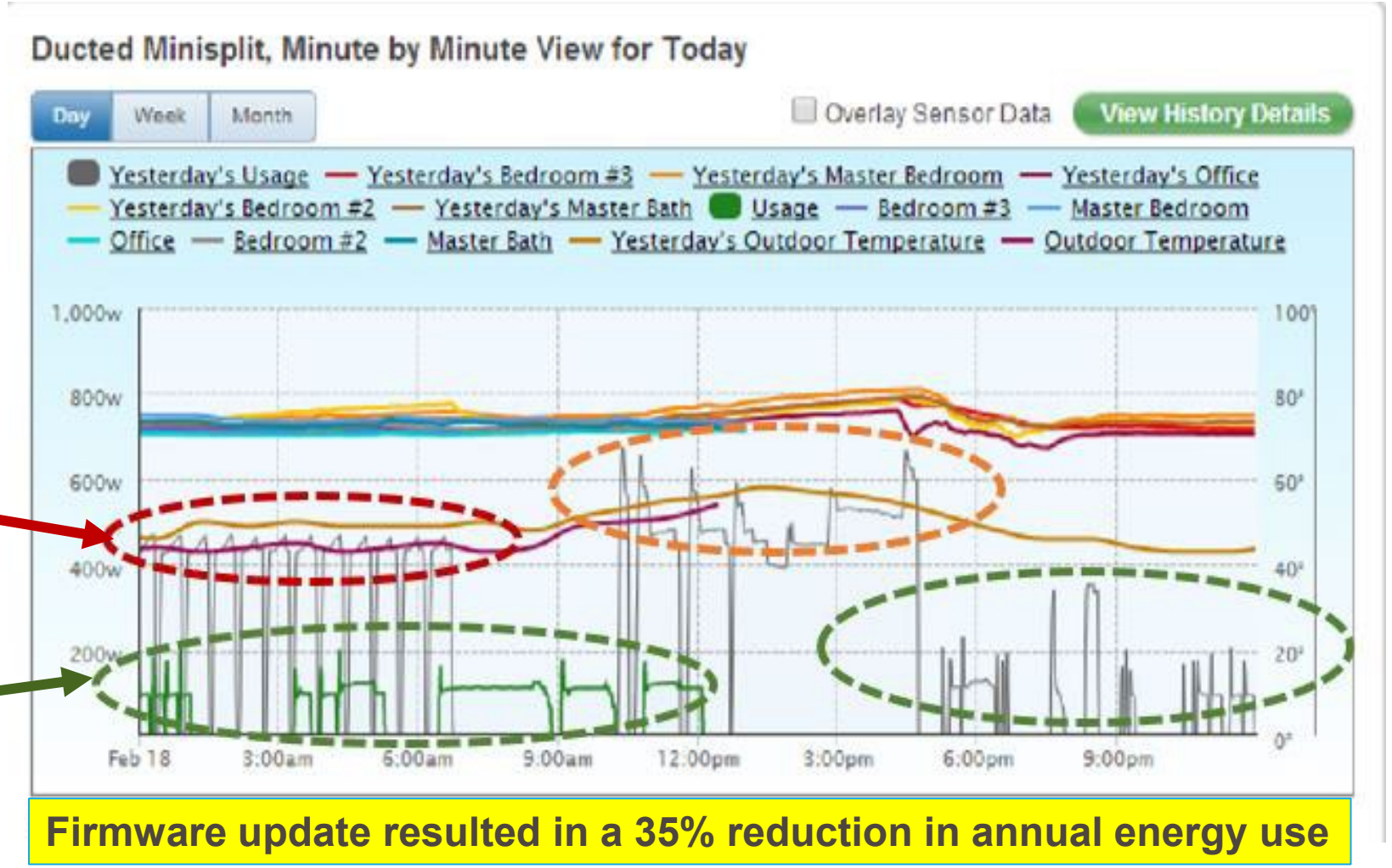


Field Data over past decade revealed:

Ratings were inconsistent with how VSHPs operate in the field

Graphs shows a ductless HP over 36 hours – the firmware was updated 6-11AM on first day

(grey traces show “previous day” power)



Power before update

(Grey traces)

Power after update

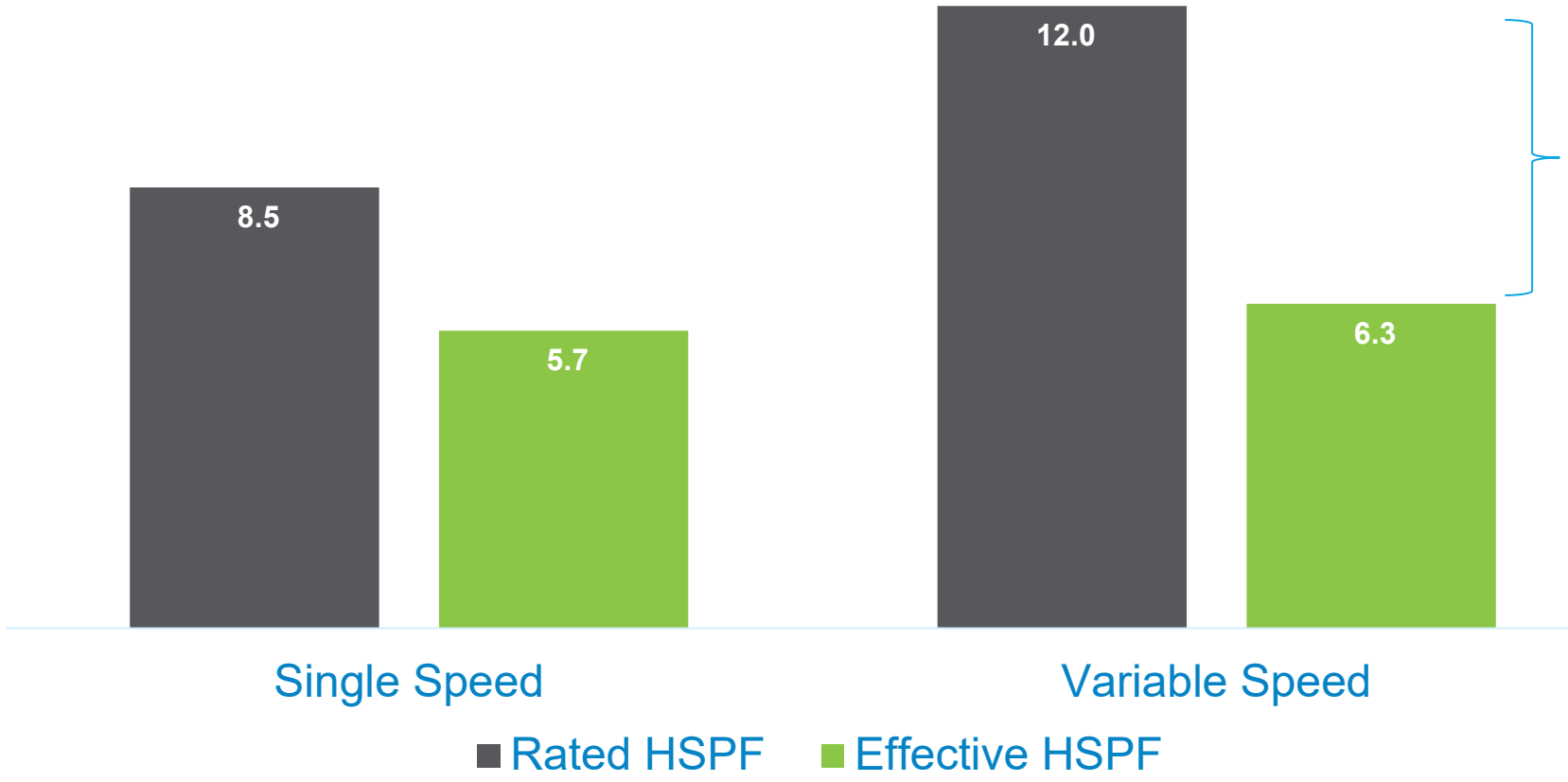
(Green traces)

Firmware update resulted in a 35% reduction in annual energy use

Orange circle/gray trace: “yesterday” power after firmware change (learning and recovery period)

Utility Programs Derate Equipment Performance

(based on program evaluation studies of thousands of program participants)

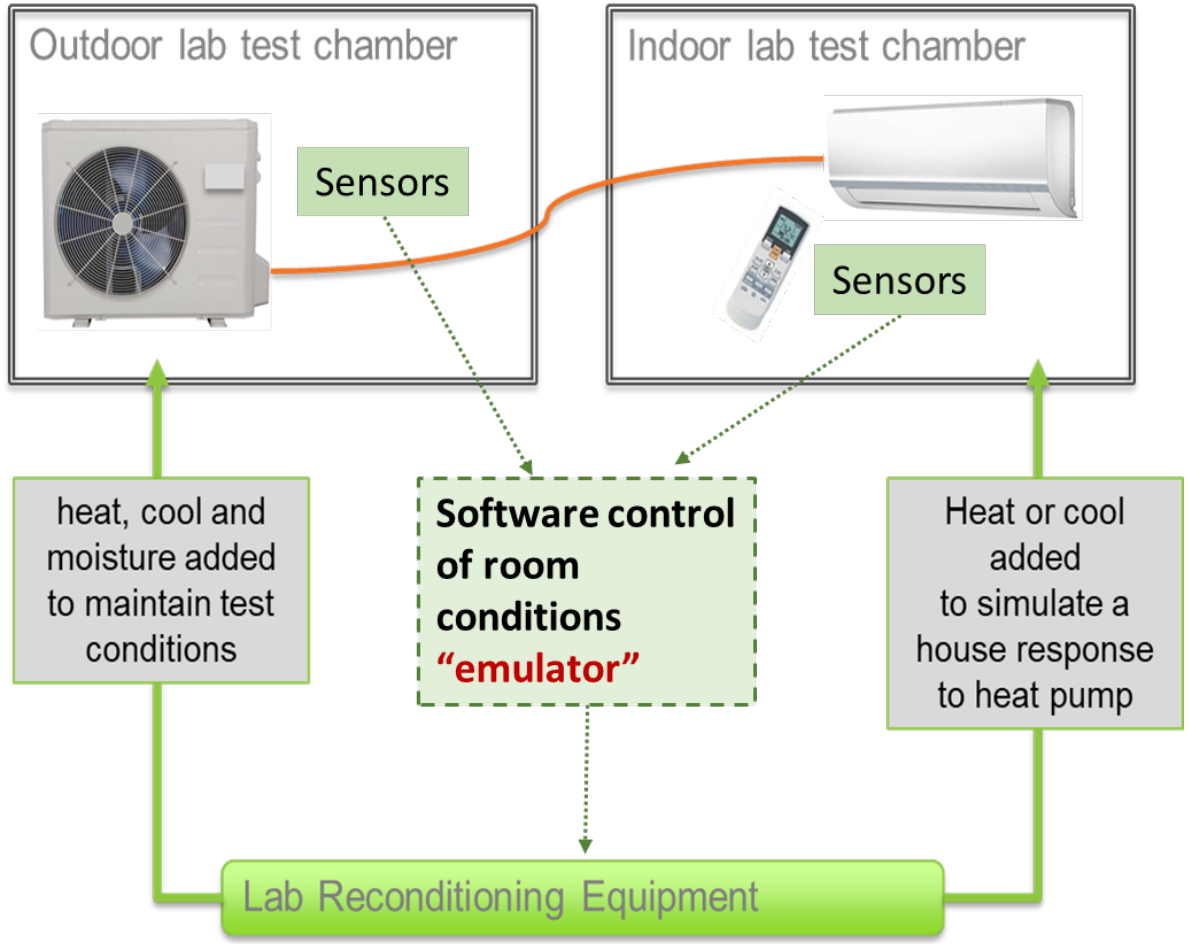


most of the performance reduction is because of duct leakage, supplementary heat controls and design impacts,

but some of this difference is because ratings are not representative

Load Based Test Method Was Developed (2017-19)

- Unit operates under its own native (default) controls based on thermostat setpoint
- Outdoor chamber temperature is held constant for each test condition
- Indoor chamber temperature is allowed to modulate based on real time heat/cool from unit
- Software control of indoor conditions are based an emulated virtual building load for a house exposed to outdoor chamber conditions



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Load Based Testing Revealed Slightly Lower Performance and Rank Order Changes

5 systems with same AHRI rating

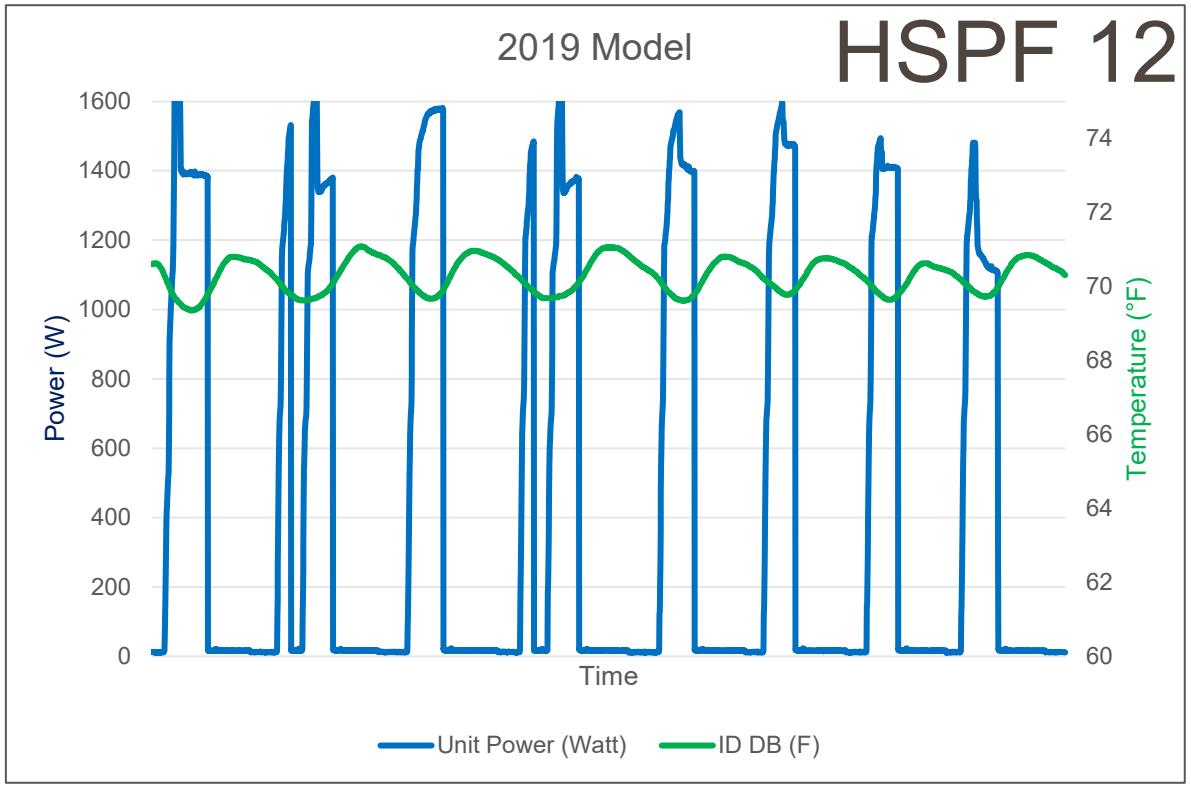
Results vary when tested with EXP07

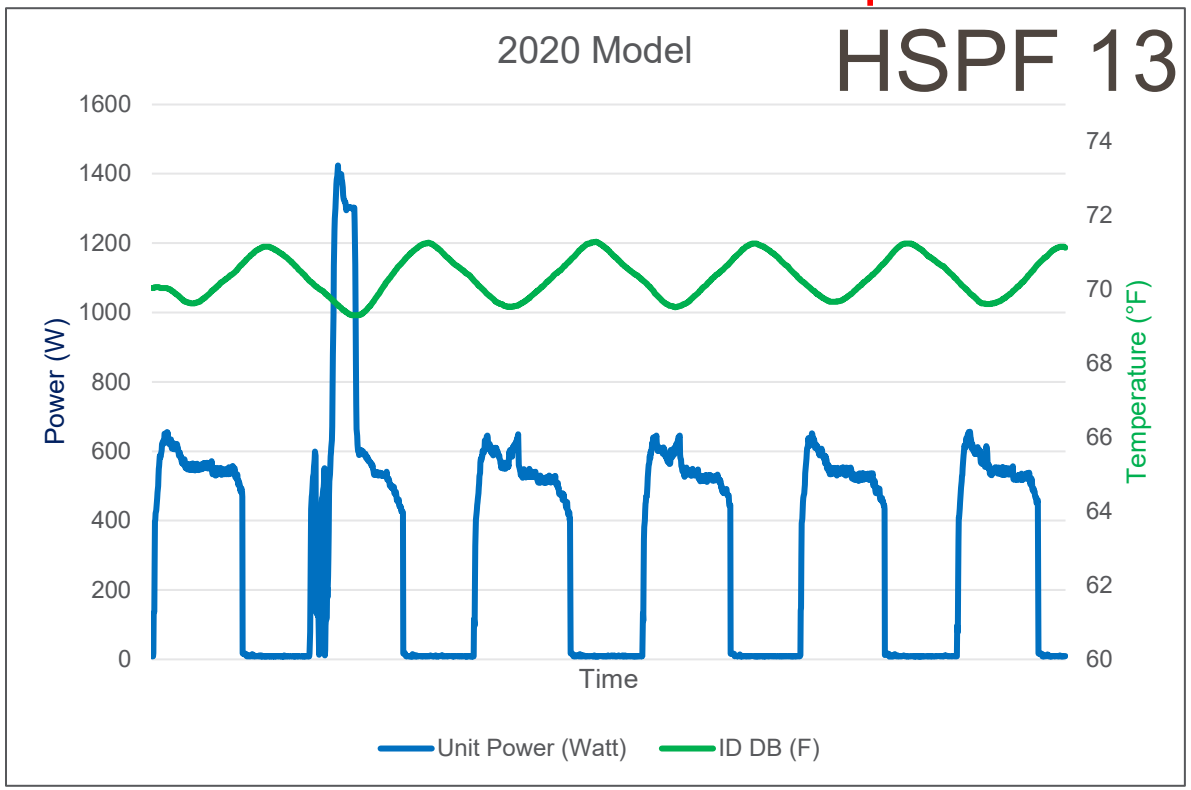
Better ways of predicting and confirming installed system performance enable accurate product differentiation and increased utility support

Load Based Testing revealed that Controls have a big impact on performance of variable speed systems

graphs of same make, model, and size, different model-year

+8% Improvement





COP = 2.03

COP = 3.37

+66% Improvement

  These are graphs of 47F heating test point, all other test points showed similar difference with 40-80% improvement in COP

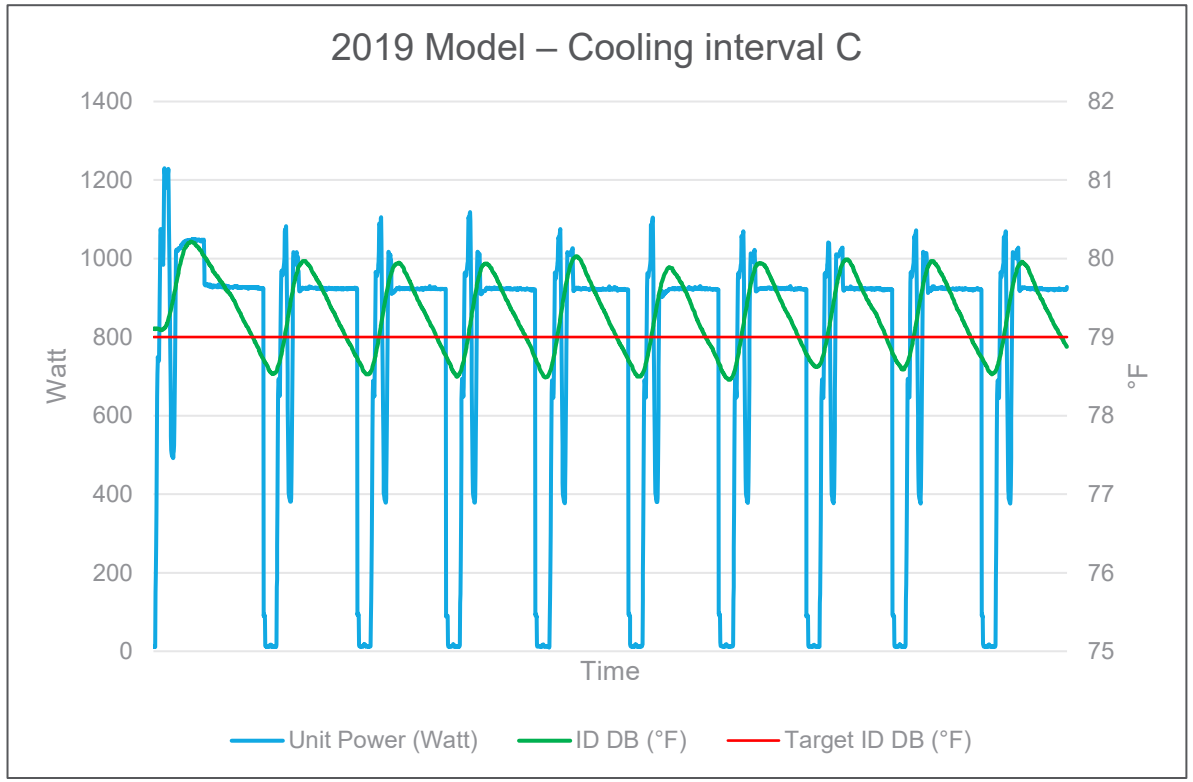
Controls have a big impact on performance

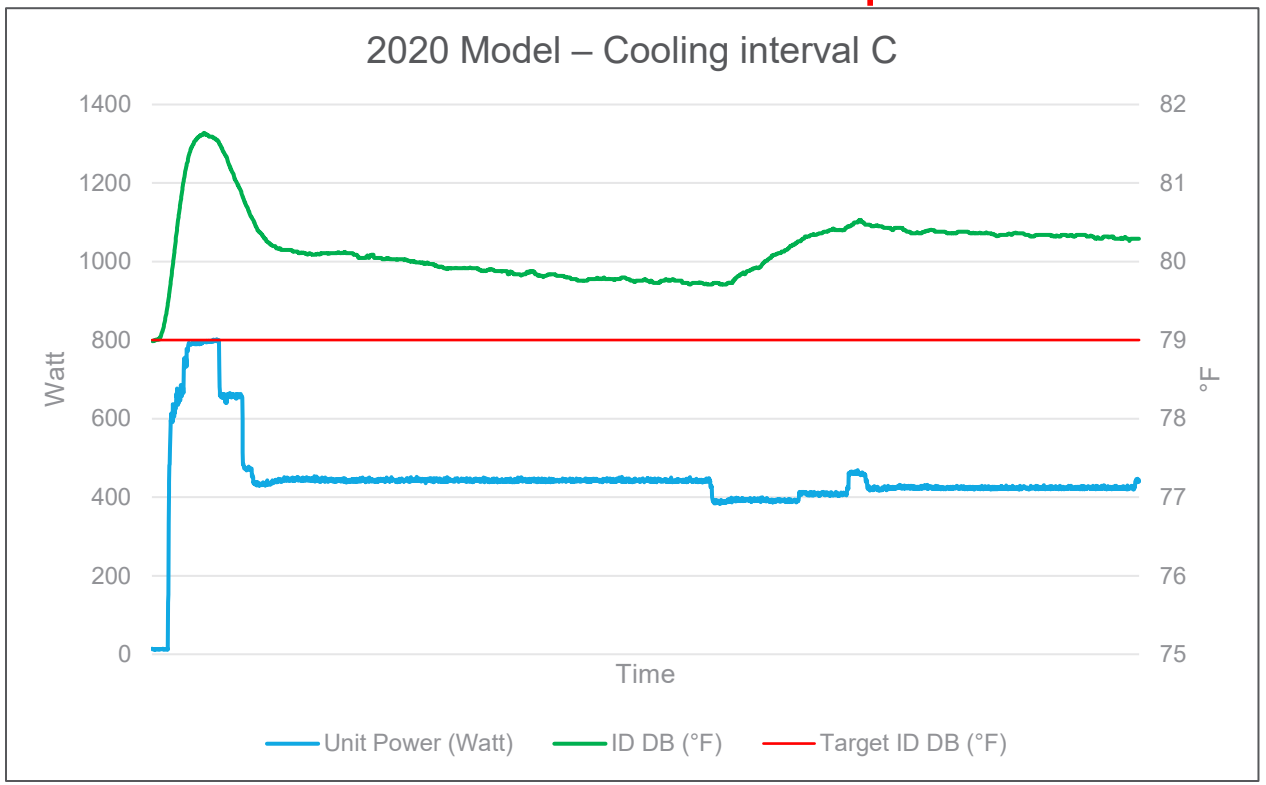
Same make, product line, and size; new model-year

SEER 25

SEER 27

+8% Improvement





Interval COP = 2.73

Interval COP = 4.36

+60% improvement in interval COP

Cooling COP improved +80%

Representativeness Project Inception

- We knew the load-based test results were different
- They looked reasonably consistent with field data
- We did not know if they were more accurate
  (or if the test burden effort would be worthwhile to implement)

We needed a study that evaluated the representativeness of heat pump test procedures

Project Objectives

- Establish trusted field measurement data on ducted and ductless HPs to allow detailed comparison between field results and two major lab test procedures
  - CSA SPE07:23
  - AHRI 210/240-2023 (2020)
- Determine representativeness of test procedure results compared with field operation
- Validate the test methods
  (we were not testing equipment performance)
- Investigate what are the most important test conditions to get right

Project Teams

• Contracts and Partner Manager	NEEP
• Prime Contractor and Project Manager	DNV
• Field Testing Research	University of Nebraska
• Technical Leadership and Support	Bruce Harley Energy
• Lab Testing Research	UL
• Partner Recruitment and Scope of Work	NEEA

Project Details

- Timeline
  - Scoping, Recruitment, RFP 6/22 – 12/22
  - Work planning & Dev 1/22 – 5/22
  - Field Testing 6/22 – 3/23
  - Lab Testing 6/23 – 9/23
  - Analysis & Reporting 7/23 – 12/23
- Total Project Budget ~$1.1M
- Advisory Groups
  - Project Partners Monthly Meetings
  - Technical Workgroup Bi-weekly Meeting

Project Partners

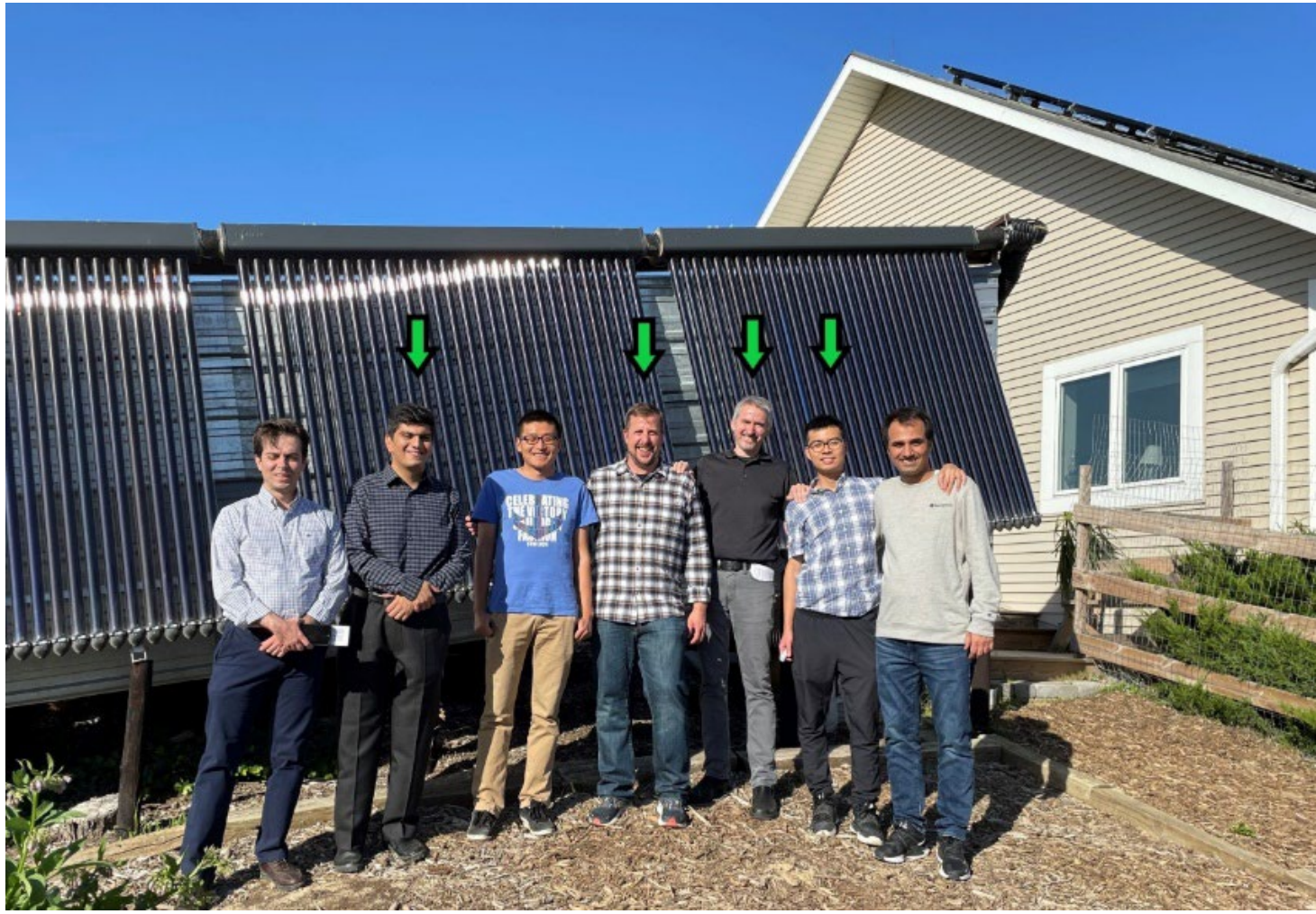
(financial or in-kind contributions)

- Northeast Energy Efficiency Partnerships
- Northwest Energy Efficiency Alliance
- BC Hydro
- The Air-conditioning, Heating and Refrigeration Institute
- Xcel Energy
- Southern California Edison
- Pacific Gas and Electric
- New York State Energy Research and Development Authority
- ComEd
- Illume Advising
- American Public Power Association
- 4 Equipment Manufacturers

Phase 1
Field Testing

UNL Team

- Jim Butler
- Yuxuan Chen
- Mehrdad Poursadegh
- Dr. David Yuill



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DNV Team

- Jennifer McWilliams
- Vivek Jaiswal
- Chris Williams

Test Houses

- Lincoln, NE from Aug 2022 – Apr 2023
- 3 homes x 2 heat pumps
  - 1 ducted, 1 ductless
  - 3-4 days/week for each HP
  - Scheduled internal gains

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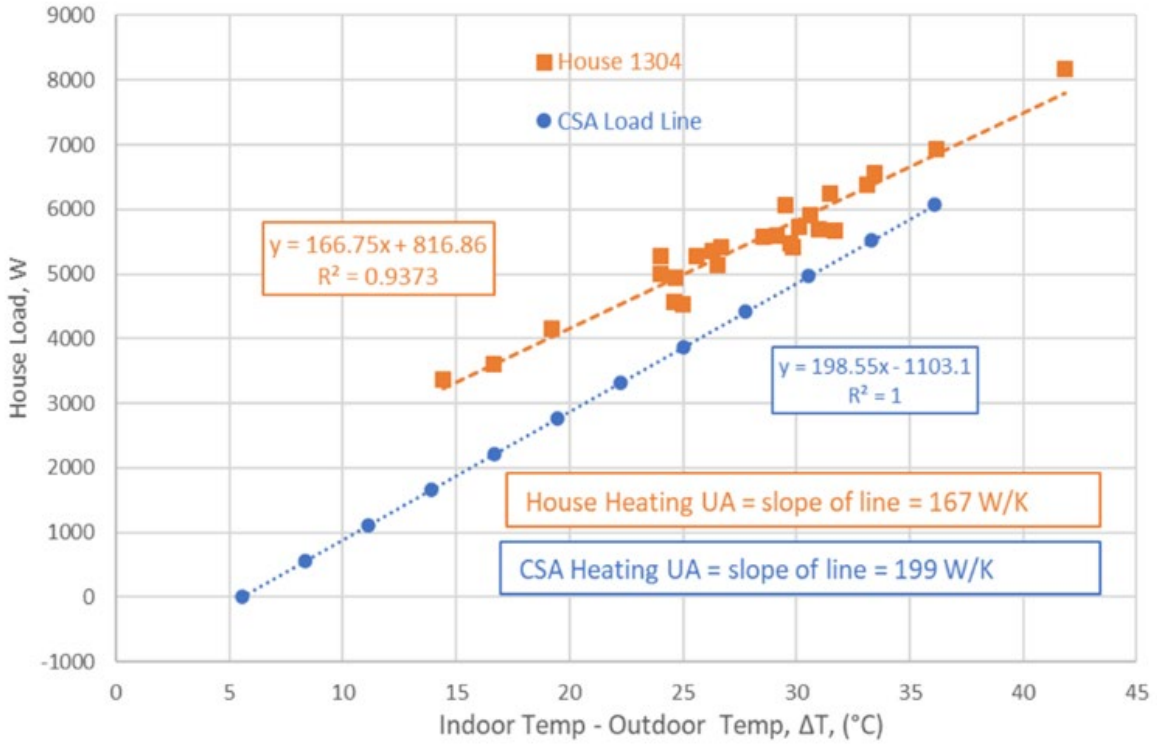
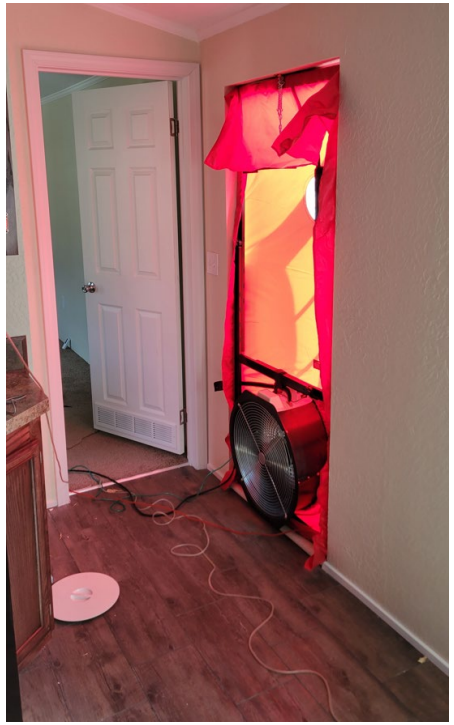
House Characterization and Tuning

- UA tested and adjusted
  - Modest adjustments to get close to SPE07
  - Indicated system capacity (~1.5 tons, but selected for heating)





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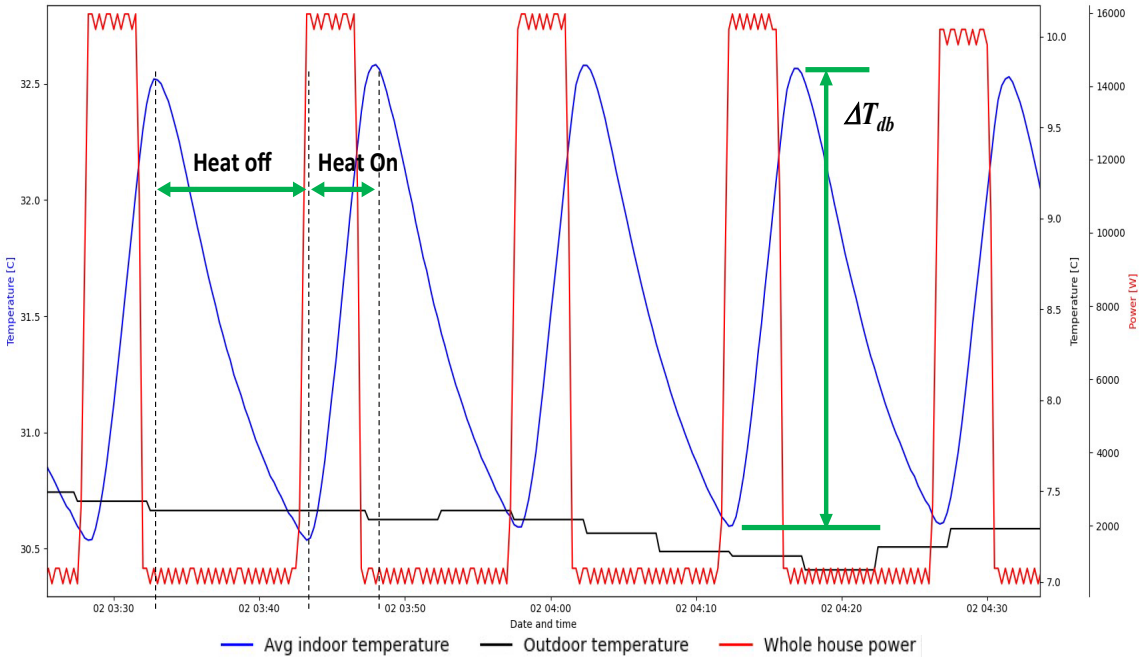
House Characterization and Tuning

- Thermal capacitance tested and adjusted
  - Dynamic pulse method
  - Added shallow mass (drywall) in several rooms



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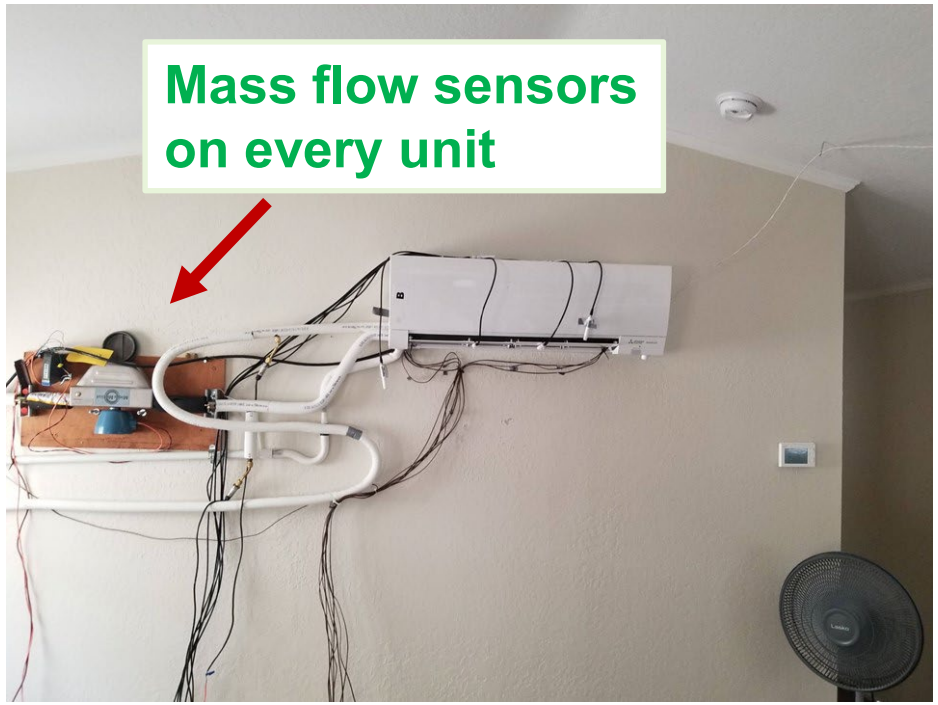
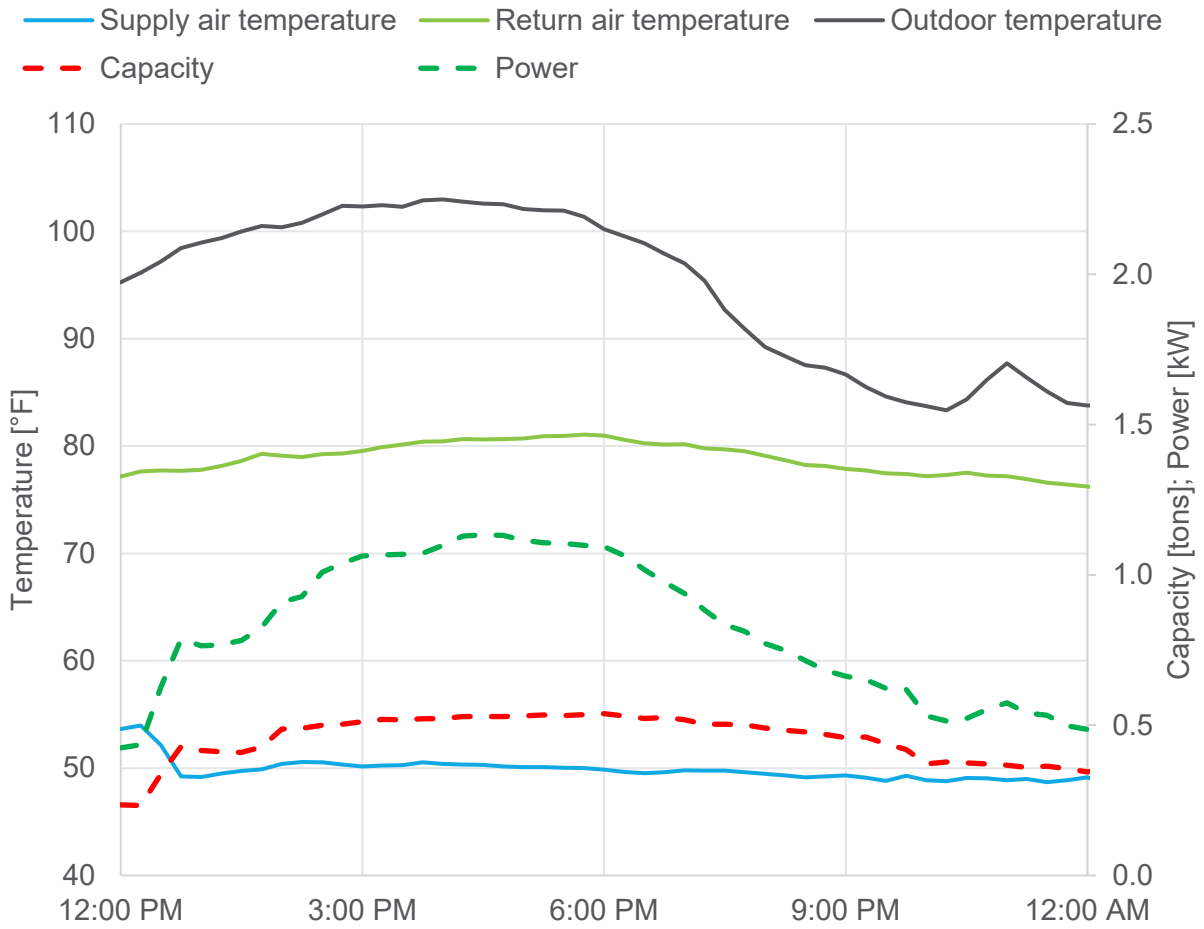
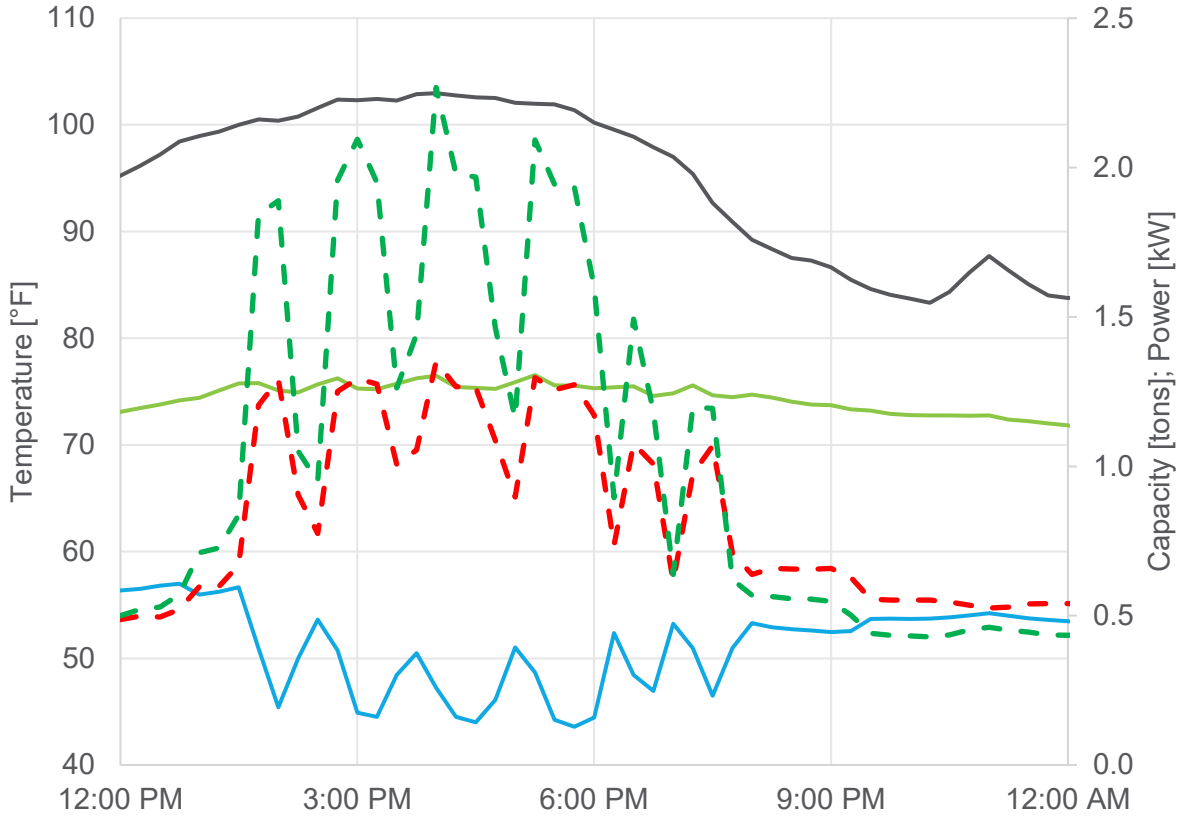
System Installation and Instrumentation

- Field tested, but like a lab installation
  - Over 100 sensors per house, including $\dot{m}$



Example Results - Two Heat Pumps, Same (Hot!) Day





"F" (left) uses 8.4 kWh while "D" (right) uses 11.3 kWh (34% more energy)

Phase 2
Lab Testing

Test Lab

UL lab in Plano, TX

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Thermostat Environment Emulator

- Ensures the thermostat is exposed to indoor temperature (RAT) as defined by virtual building load calculation in real time
  - Using consistent air velocity and temp control
- Developed by Purdue University to improve repeatability of load-based testing

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Lab Testing

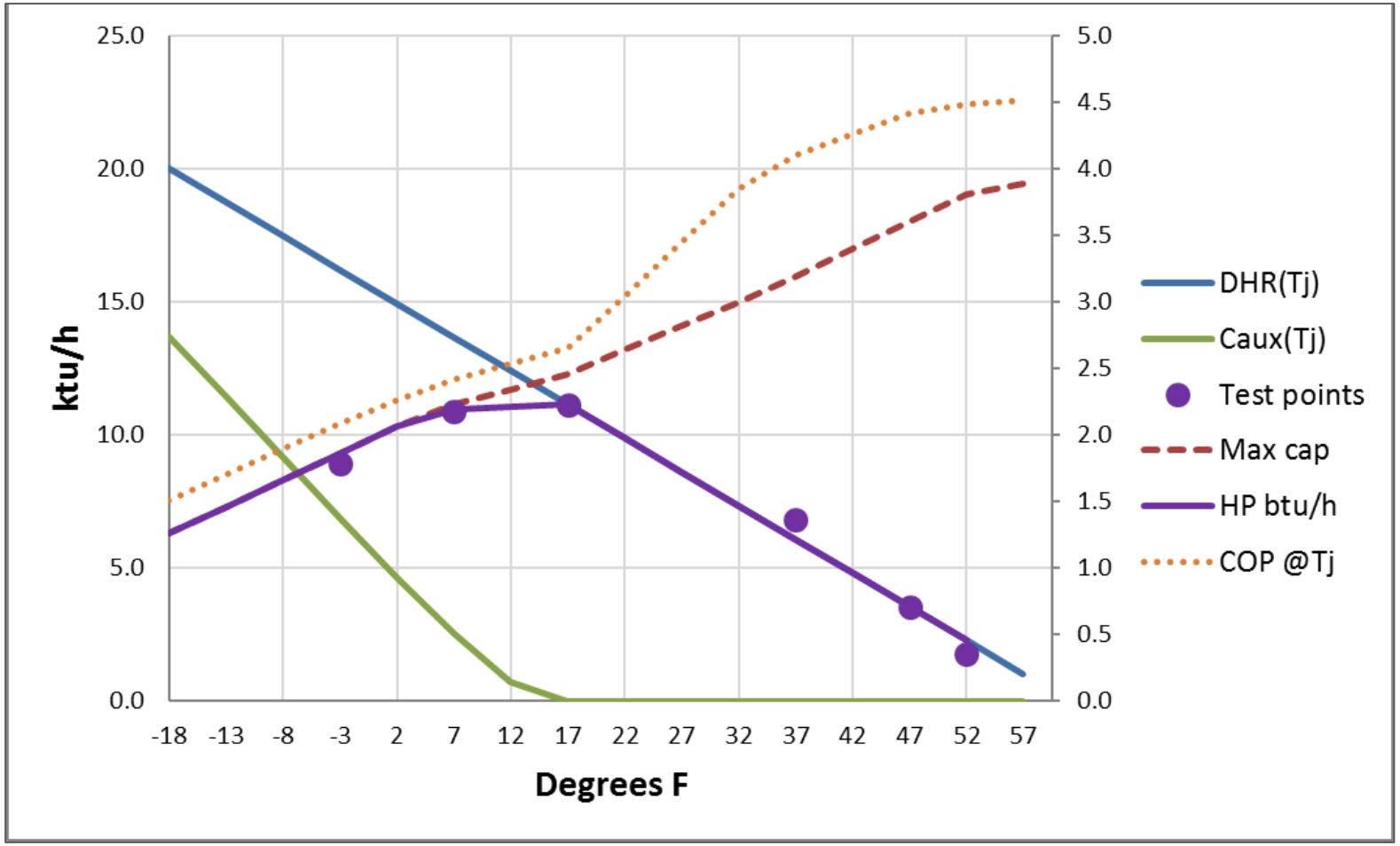
- Each Unit Tested with SPE07
- Followed by Appendix M1
- 2 units will have additional repeat SPE07 testing
  - Addition to original project scope

Schedule as of Aug 1

SUN	MON	TU	WED	THU	FRI	SAT
23-Apr	24-Apr	25-Apr	26-Apr	27-Apr	28-Apr	29-Apr
30-Apr	1-May	2-May	3-May	4-May	5-May	6-May
7-May	8-May	9-May	10-May	11-May	12-May	13-May
14-May	15-May	16-May	17-May	18-May	19-May	20-May
21-May	22-May	23-May	24-May	25-May	26-May	27-May
28-May	29-May	30-May	31-May	1-Jun	2-Jun	3-Jun
4-Jun	5-Jun	6-Jun	7-Jun	8-Jun	9-Jun	10-Jun
11-Jun	12-Jun	13-Jun	14-Jun	15-Jun	16-Jun	17-Jun
18-Jun	19-Jun	20-Jun	21-Jun	22-Jun	23-Jun	24-Jun
25-Jun	26-Jun	27-Jun	28-Jun	29-Jun	30-Jun	1-Jul
2-Jul	3-Jul	4-Jul	5-Jul	6-Jul	7-Jul	8-Jul
9-Jul	10-Jul	11-Jul	12-Jul	13-Jul	14-Jul	15-Jul
16-Jul	17-Jul	18-Jul	19-Jul	20-Jul	21-Jul	22-Jul
23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul
30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug
6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug
13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug
20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug	26-Aug
27-Aug	28-Aug	29-Aug	30-Aug	31-Aug	1-Sep	2-Sep
3-Sep	4-Sep	5-Sep	6-Sep	7-Sep	8-Sep	9-Sep
10-Sep	11-Sep	12-Sep	13-Sep	14-Sep	15-Sep	16-Sep
17-Sep	18-Sep	19-Sep	20-Sep	21-Sep	22-Sep	23-Sep
24-Sep	25-Sep	26-Sep	27-Sep	28-Sep	29-Sep	30-Sep
1-Oct	2-Oct	3-Oct	4-Oct	5-Oct	6-Oct	7-Oct
8-Oct	9-Oct	10-Oct	11-Oct	12-Oct	13-Oct	14-Oct

UNIT 1 (B)
UNIT 2 (A)
UNIT 3 (E)
UNIT 4 (F)
UNIT 5 (C)
UNIT 6 (D)
HOLIDAY

SPE07:23 – Heating Test Conditions



Test	Toutdoor (drybulb °F)	Max Humidity
HL	LCT	
HB	5	0.0008
HC	17	0.0013
HD (dry)	34	0.0031
HD (marine)	34	0.0035
HE	47	0.0042
HF	54	0.0045

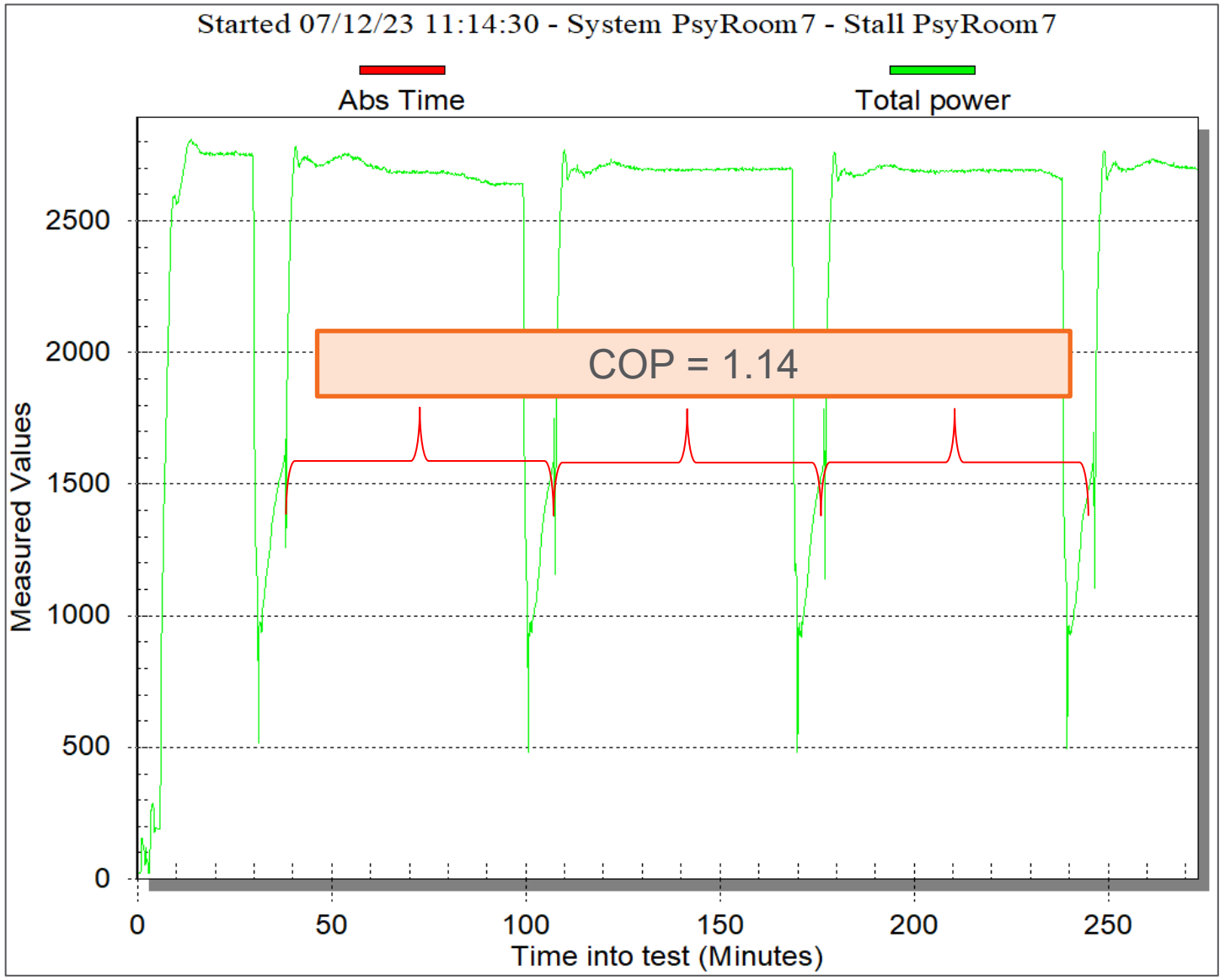
LCT = Lowest Cataloged Temperature

Tindoor = 70°F

Graph for illustrative purposes only

Example

Lowest Cataloged Temperature Heating Test
(below 0°F)

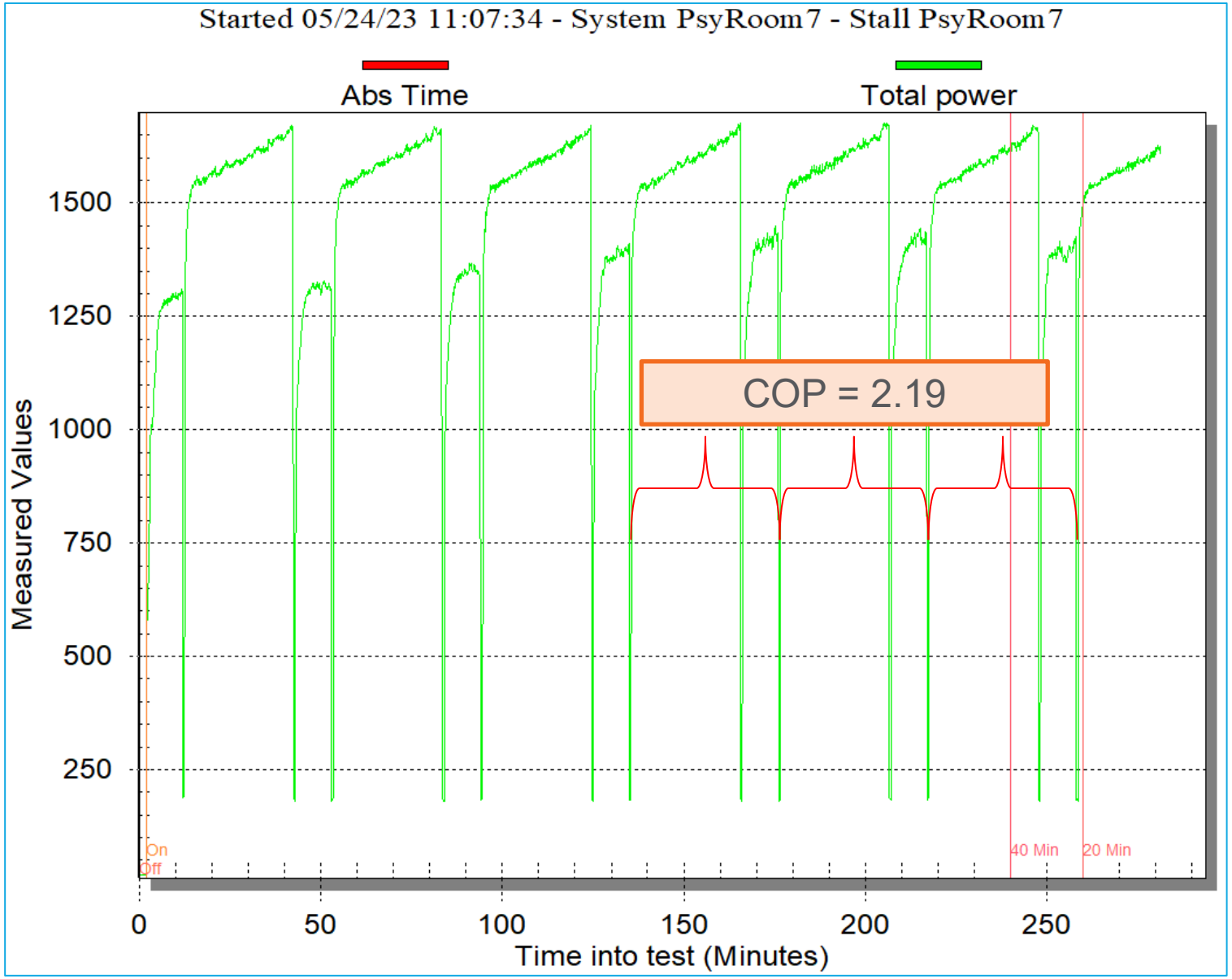


Examples are of different machines

Example

17°F

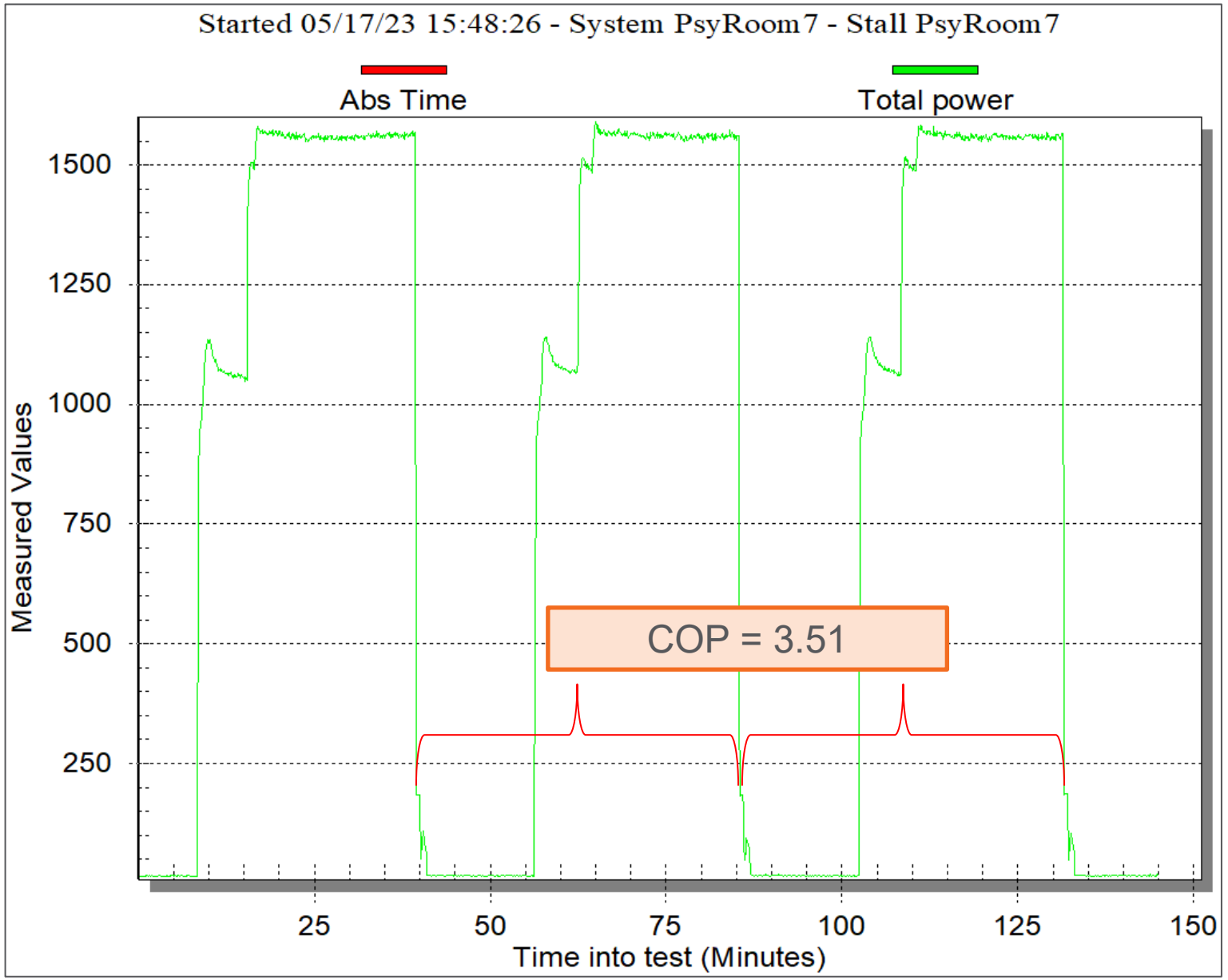
Heating Test



Examples are of different machines

Example

86°F Humid
Cooling Test



Examples are of different machines

Preliminary Observations

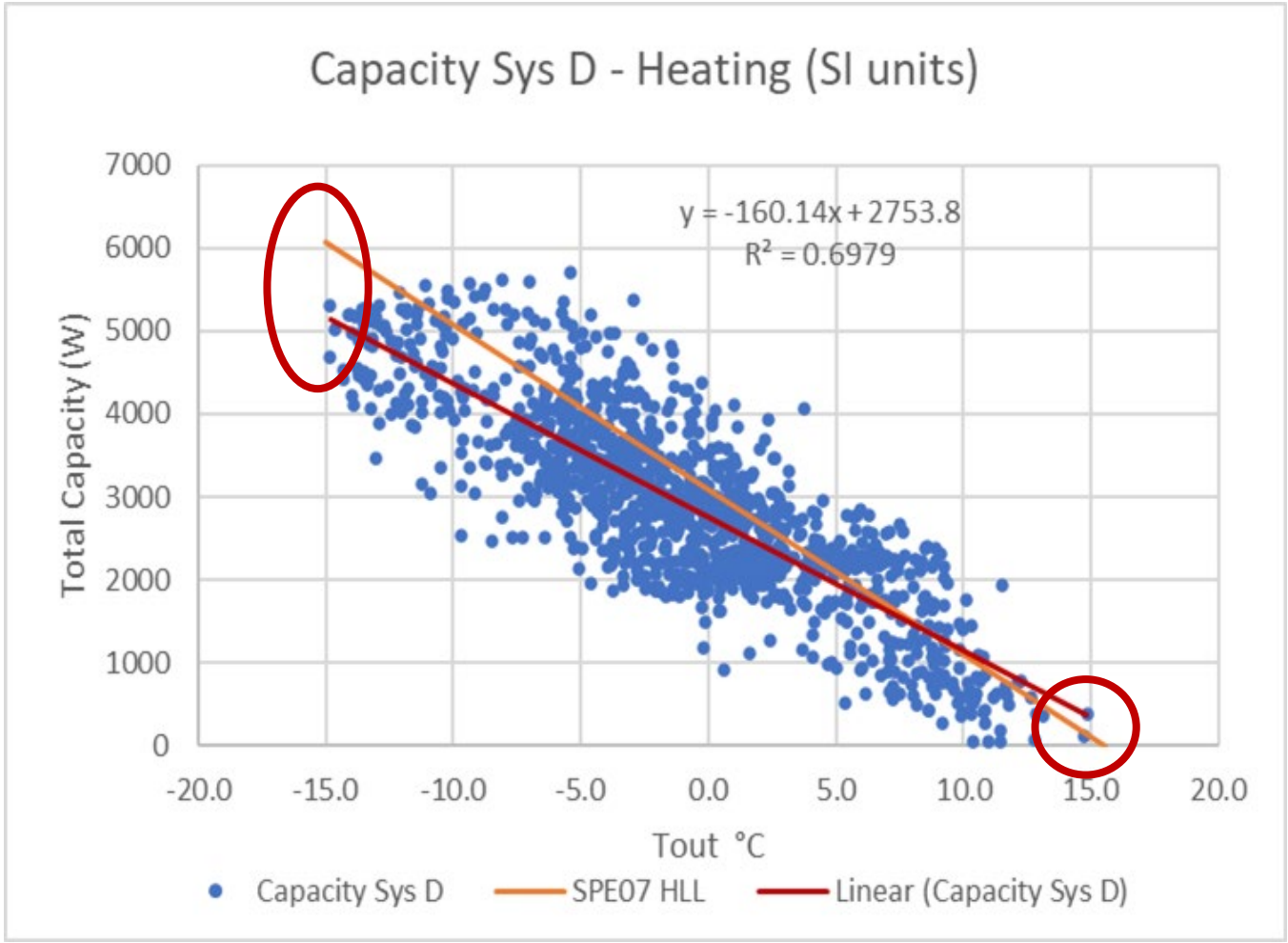
(final analysis not completed)

SPE07 specifies load line (1.15 * rated cooling capacity)

SPE07 load line (orange) is “prototypical”: assumes system sizing for home

For each system, we’re using the measured load line (red) from the field in lab tests

(Average = 78% H / 93% C)



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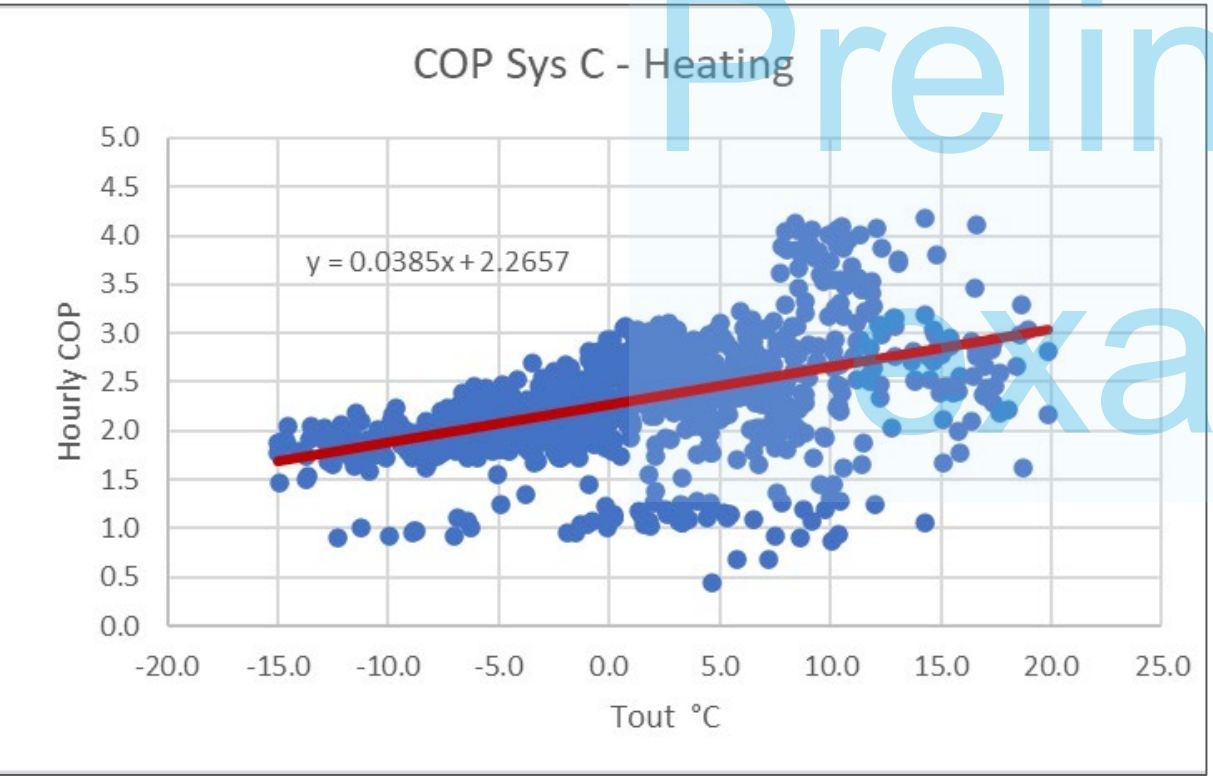
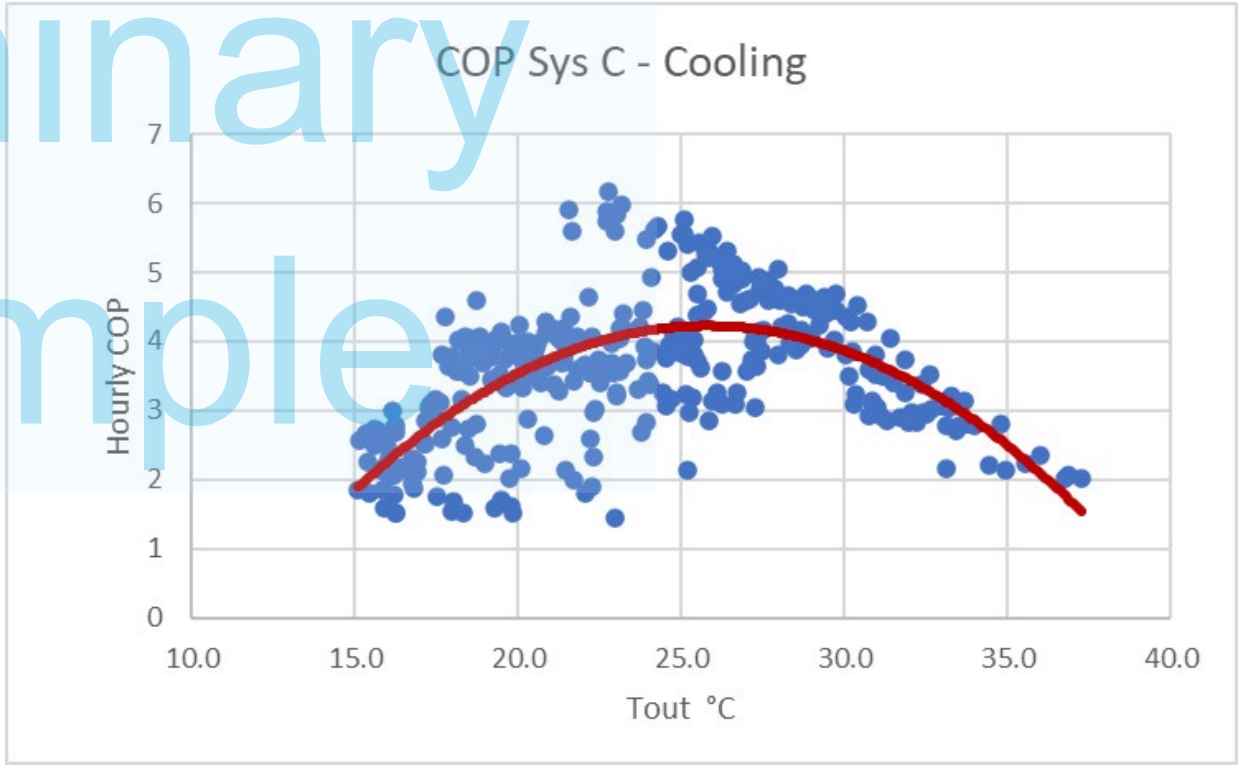
Hourly COP profile of system C





Heating (L) and Cooling (R) – COP profiles vs. outdoor temperature

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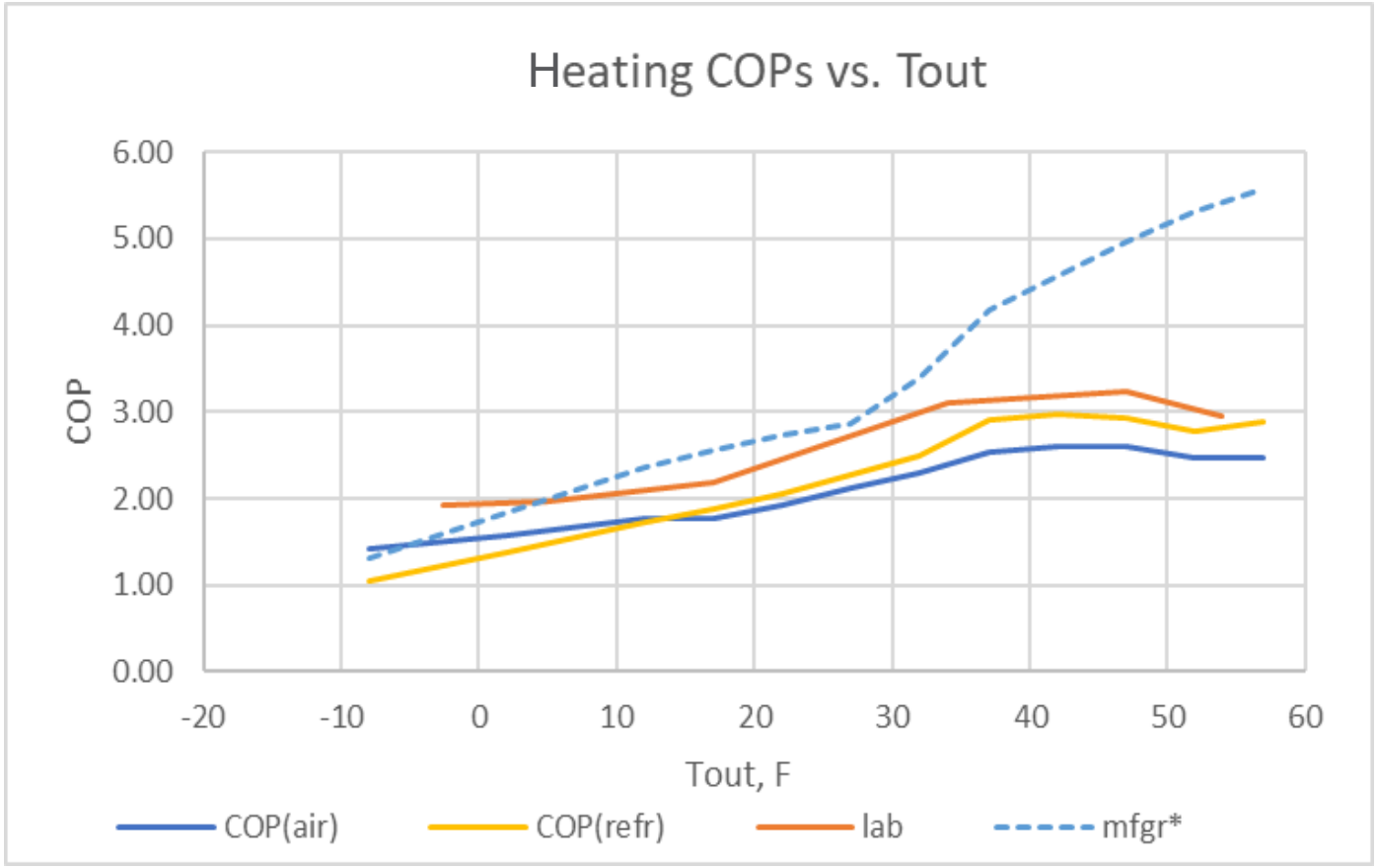
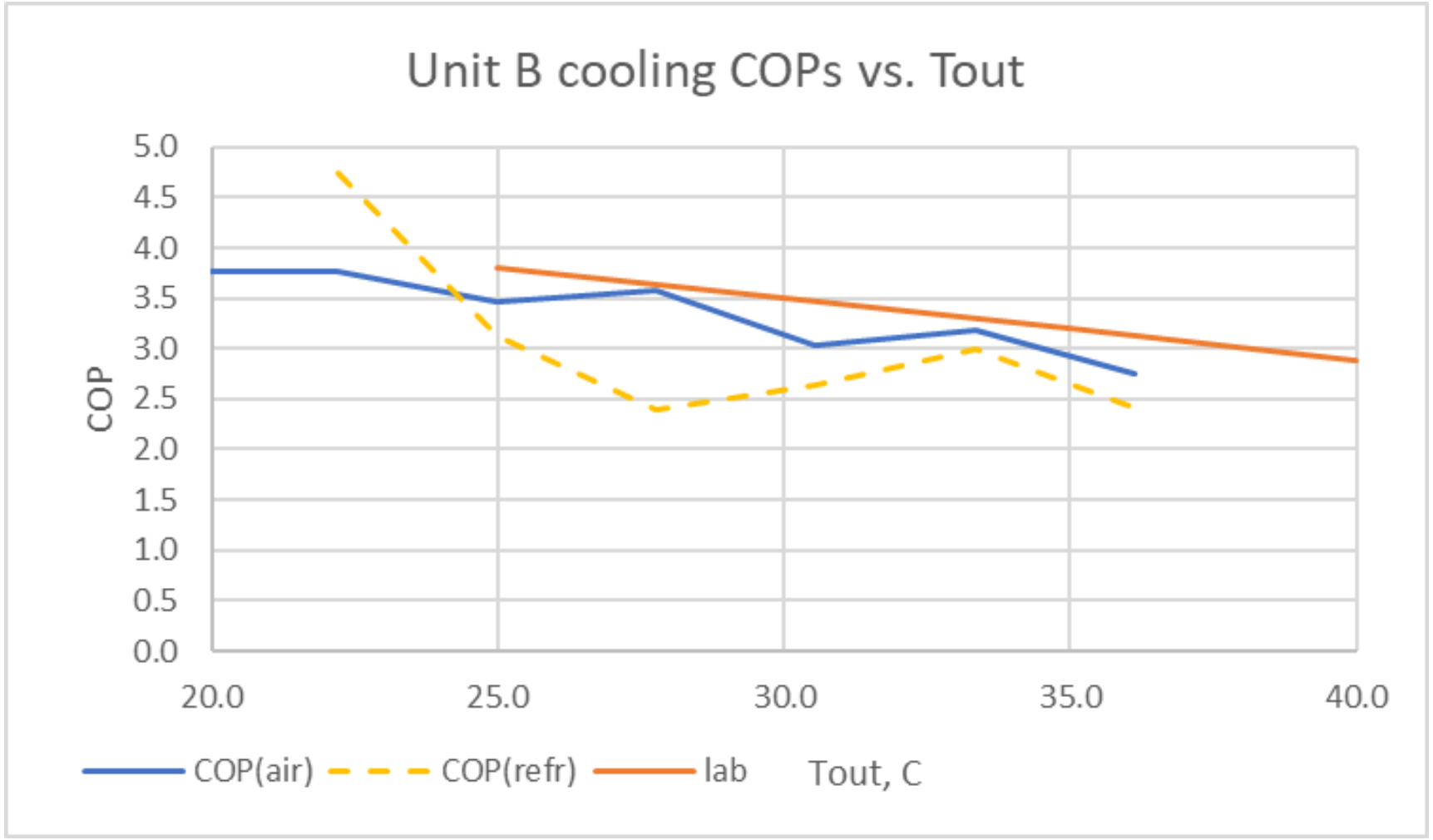
Analysis Objective:

Starting with field- and lab-measured efficiencies across outdoor temperature:

Need to normalize conditions in order to compare



First Unit Comparison – Cooling Performance



Note: COP(refr) from refrigerant mass flow sensor appears to be problematic for this unit and is under review

Normalizing Efficiency Metrics

- Field:
  - ~~Seasonal efficiency during test period~~
  - Actual efficiency profile vs. outdoor temperature (bins)
- Load-based test:
  - Lab-tested efficiency profile vs. outdoor temperature
- Fixed-speed test:
  - Lab-tested efficiency profile vs. outdoor temperature

End result: Equivalent seasonal efficiency metrics

- **Field-based** seasonal efficiencies calculated with:
  - SPE07 climate profiles
    Heat: cold dry, Cool: mixed
  - AHRI/M1 climate profiles
    Heat: Region IV, Cool

- **Load based** tests:
  - Cold/dry heating Seasonal COP
  - Mixed/humid cooling Seasonal COP
- **Fixed-speed** tests:
  - Region IV heating “HSPF2”/3.41
  - Cooling “SEER2”/3.41

Summary & Next Steps

Heat Pump Test Procedure Update

- DOE asked AHRI for help to update the test procedure
- Near Term
  - Update existing Appendix M1
  - Does not impact rating
  - Intended to address representativeness concerns and provide industry alignment on definitions, etc.
  - Potentially in effect in **2025**
- Long Term
  - Will require new rating metric
  - AHRI 210/240 will become AHRI 1600
  - Potentially in effect by **2030**

List of items being developed by STC

	Topic	Subtopic
NEAR	CVP	
	CCHP	
	"Minor"	Low static
	"Minor"	Cut-in / cut-out
	"Minor"	A2L fan power
	"Minor"	"Other"
LONG	HP	Strip heat dfst
		Strip heat supp
		Dem dfst credit
	Full season	Standby/off
		Shoulder fan pwr
		Bin weights
		Load lines
	CCHP	CCHEI
		Size for heating
	Coil only	Default watts
		Floor
	Hybrid	
	IDDB/IDWB	
	Dehumidify	
	"Minor"	"Other"

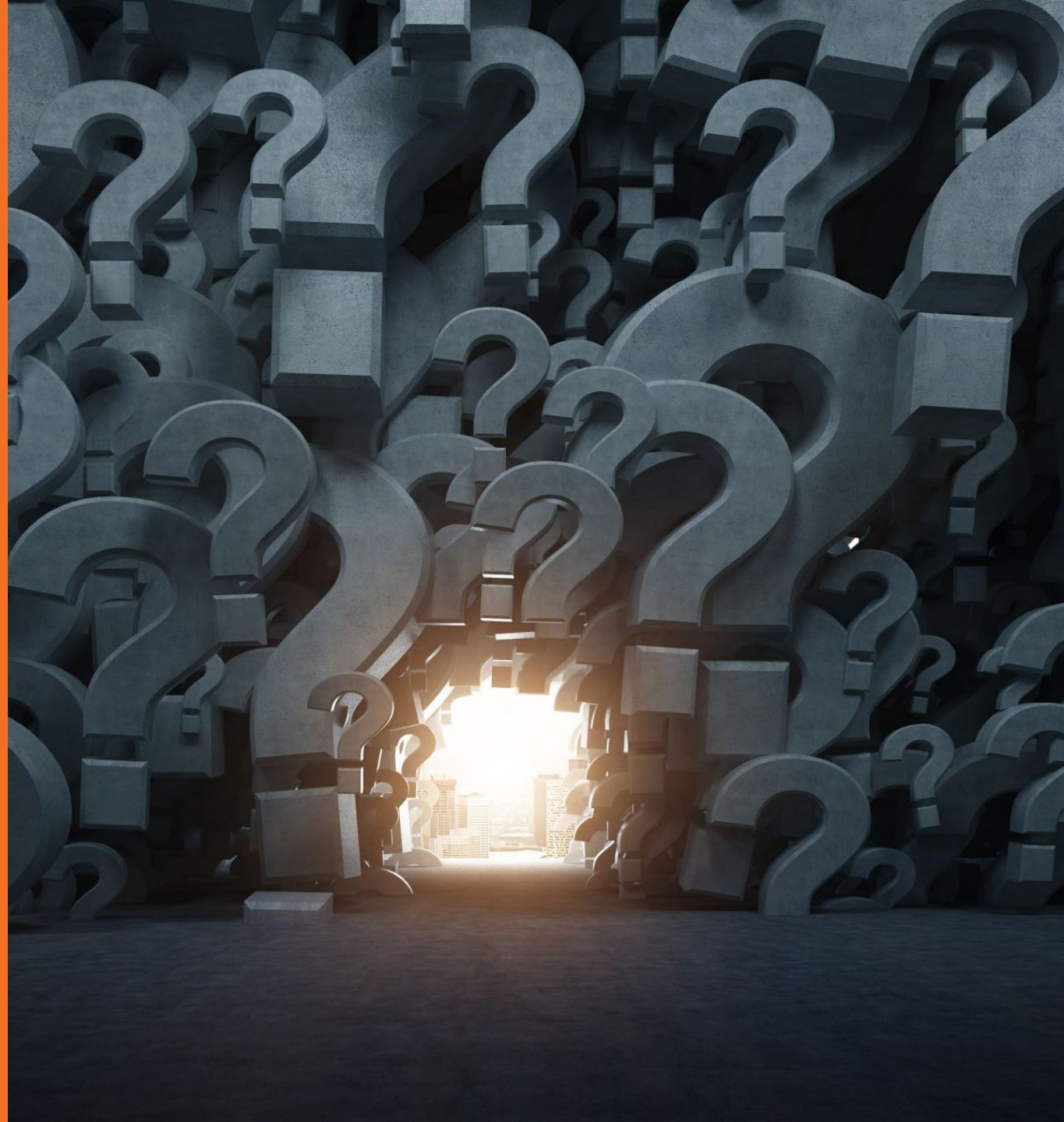
Proposed Controls Verification Procedure (CVP)

- Designed to verify if a variable capacity heat pump is operating as a variable capacity system and if the locked test settings used M1 are reflective of how the heat pump operates in the field
  - Appendix J section 4 – Variable Speed Operation
  - Appendix J section 5 – “Four Corners Test”
    - Verifies low load, and high load operation is consistent with fixed speed test

Final Thoughts

- AHRI and DOE have clearly recognized the need for better representativeness in the test procedure
- Changes in test procedures have such a big impact that data is essential to make the case for any significant changes
- In addition to CVP the future test procedure may include:
  - Cold Climate definition
  - Improved defrost energy methodology
  - Dual Fuel Rating ($AFUE_{hybrid}$)
  - Rating based on national average climate and use 8760 hour full season calculation method

Questions and Discussion



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Many thanks to all those involved

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Xudong Wang
Dave Podorson
Sean Gouw
Randall Higa
Rafik Sarhadain
Courtney Moriarta
Pauravi Shah
Jes Rivas
Marilla
Chad Kirkwood
John Bade
Marc Shkolnick
Nelson Stephens
Jay Stoa

Thank You

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