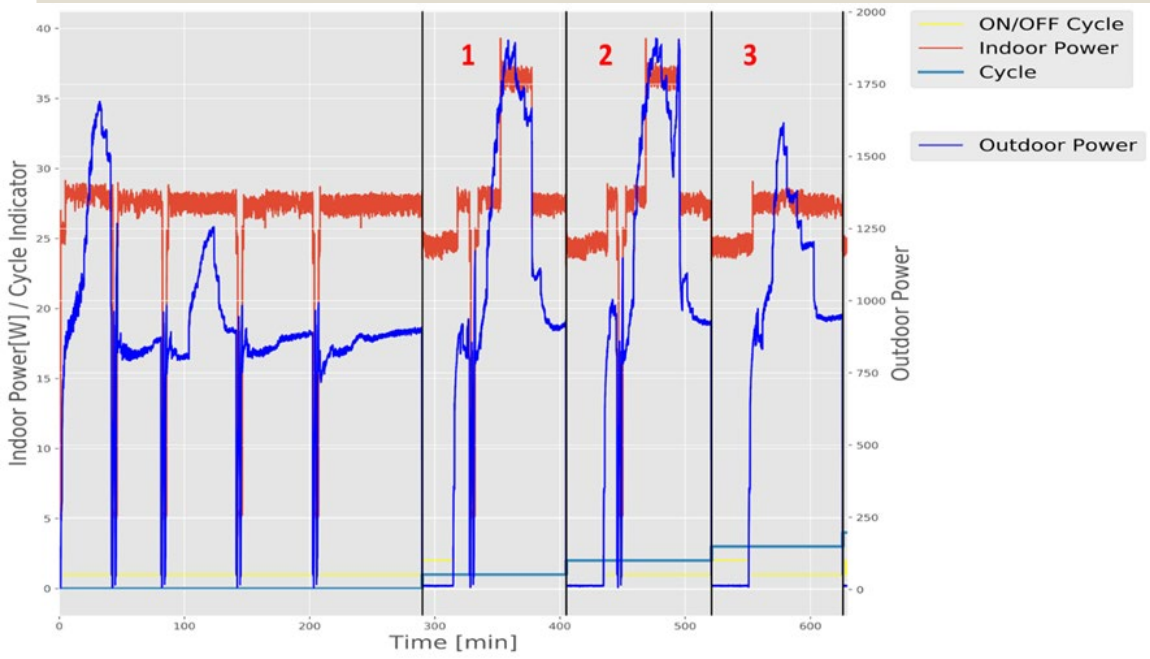
Home Efficiency Forum

October 2018

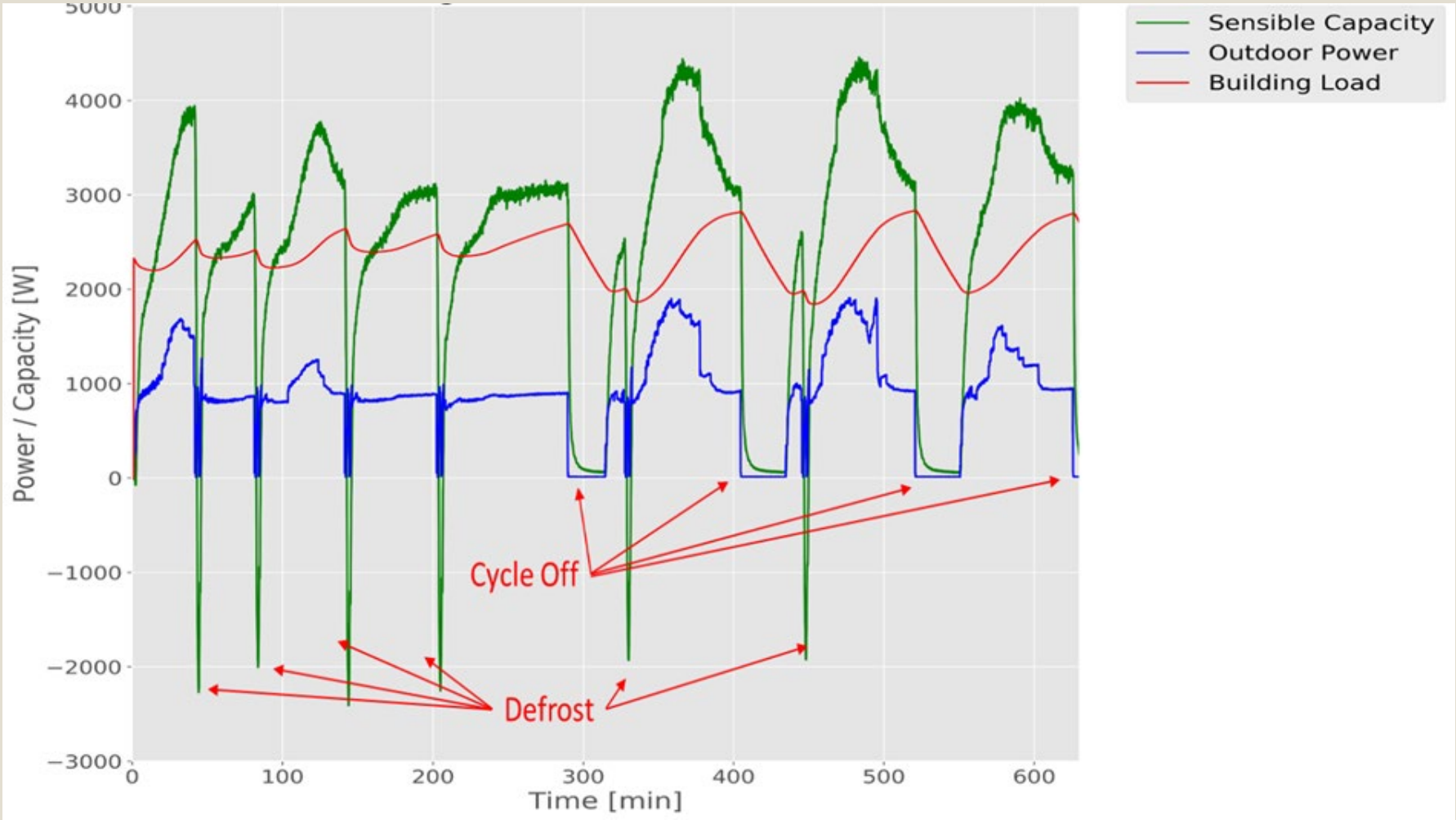
Load-based Testing of HVAC Systems

Charlie Stephens

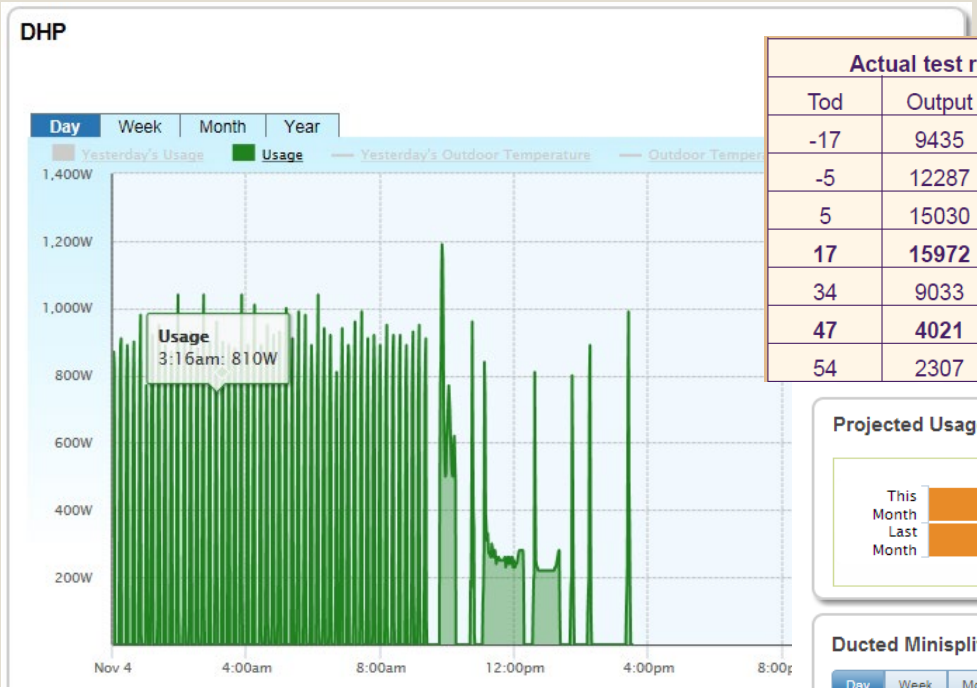
Senior Energy Codes & Standards Engineer



CSA EXP-07: Energy Performance of Split-System and Single-package Air Conditioners and Heat Pumps



Why is this important?



Actual test result				210/240 values (approx)			
Tod	Output	Watts	COP	Tod	Output	Watts	COP
-17	9435	1827	1.5	-17	2347	733	0.9
-5	12287	1884	1.9	-5	4907	785	1.8
5	15030	2160	2.0	5	7040	828	2.5
17	**15972**	**2128**	**2.2**	**17**	**9600**	**880**	**3.2**
34	9033	1212	2.2	34	13227	954	4.1
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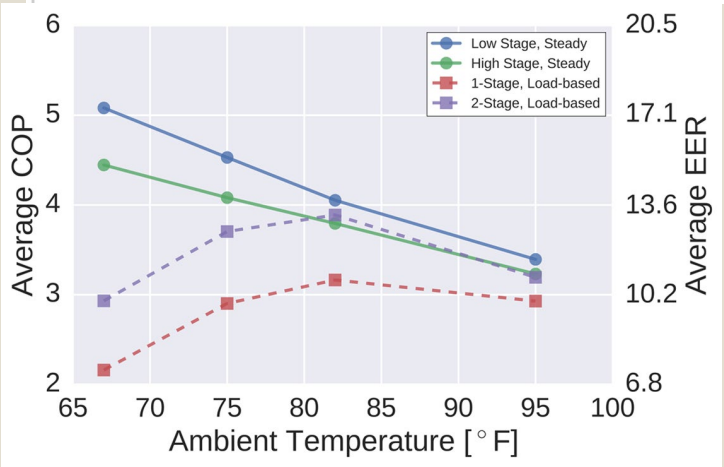
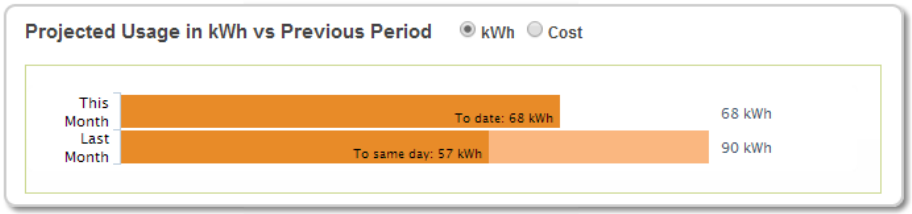
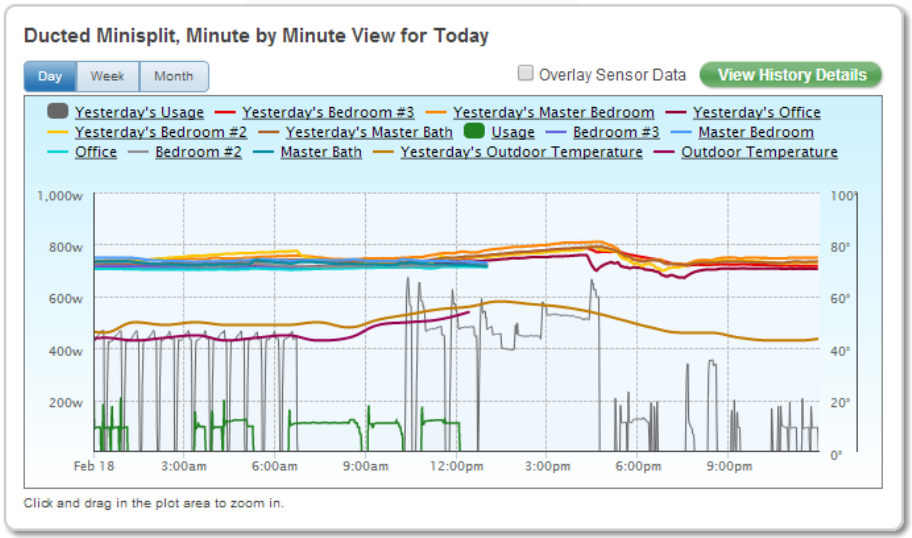
54	2307	211	3.2	54	17493	1040	4.9







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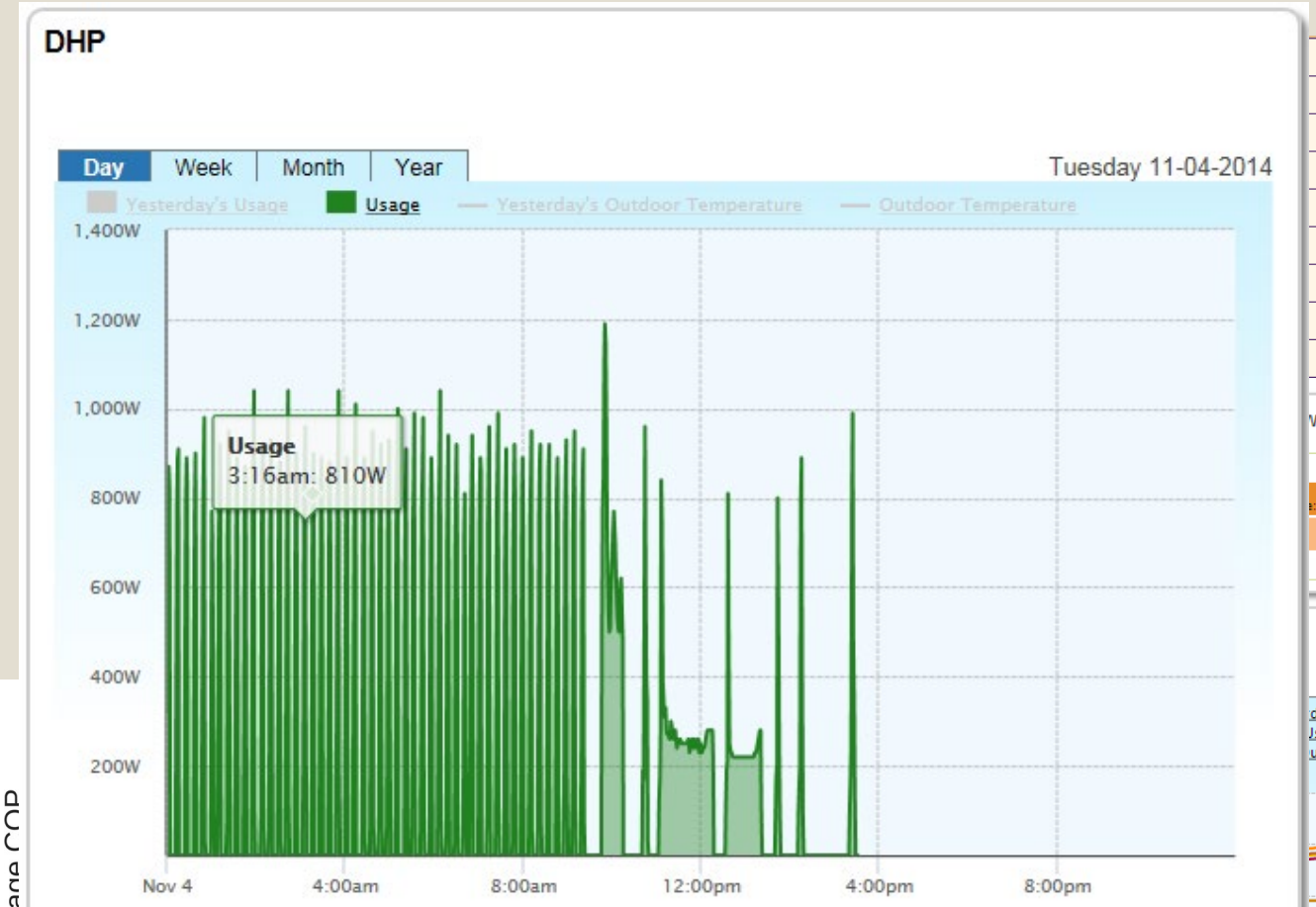

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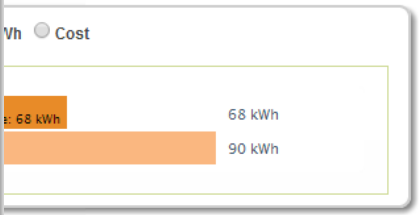

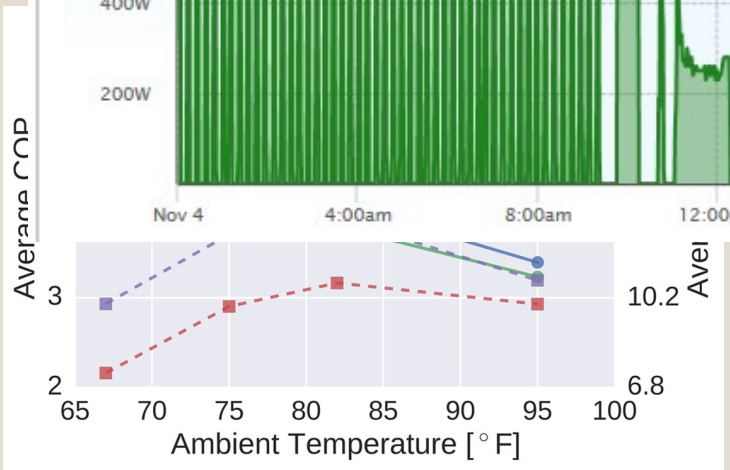

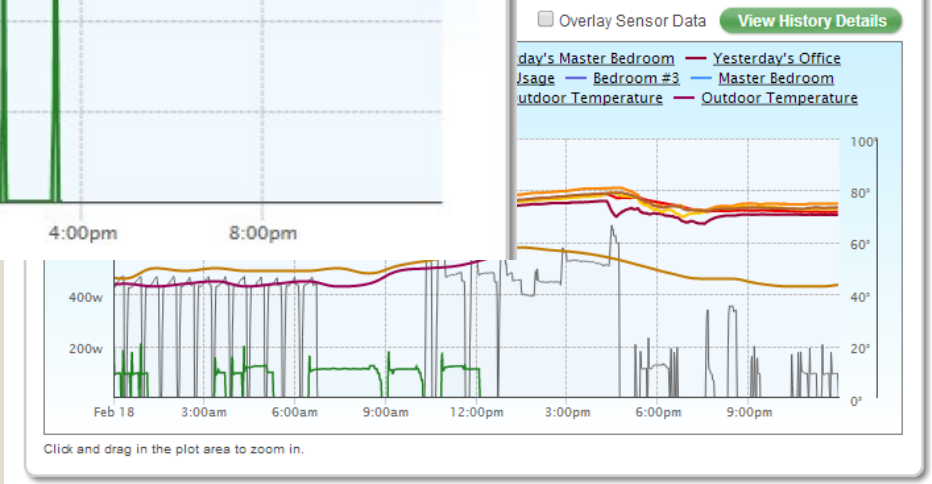

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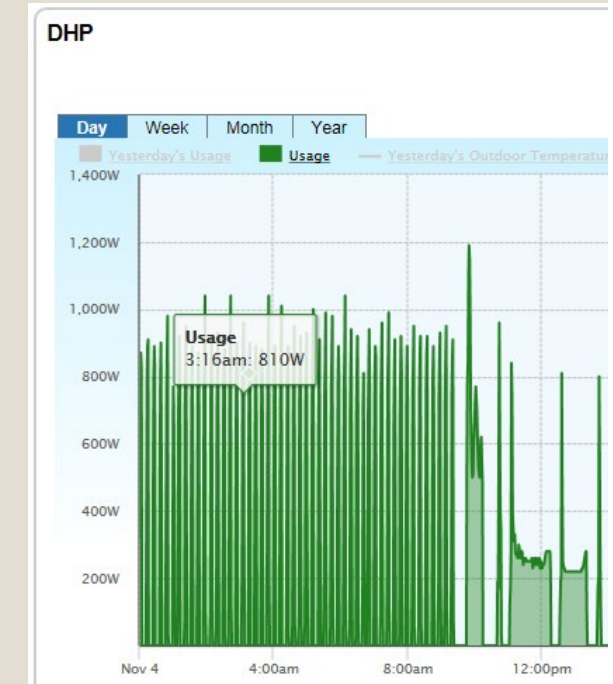

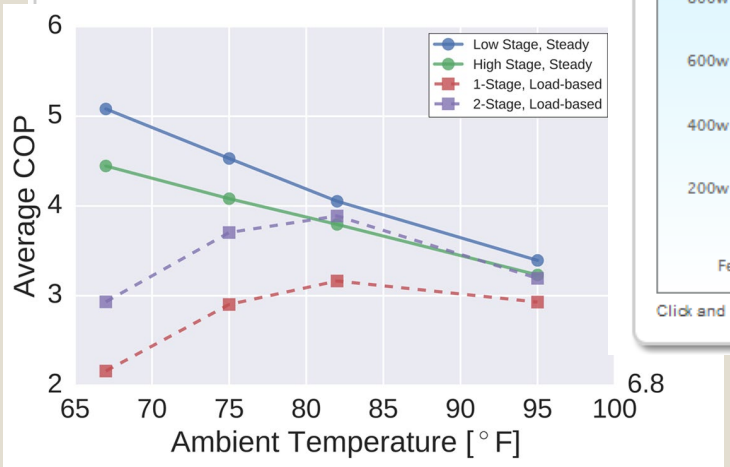

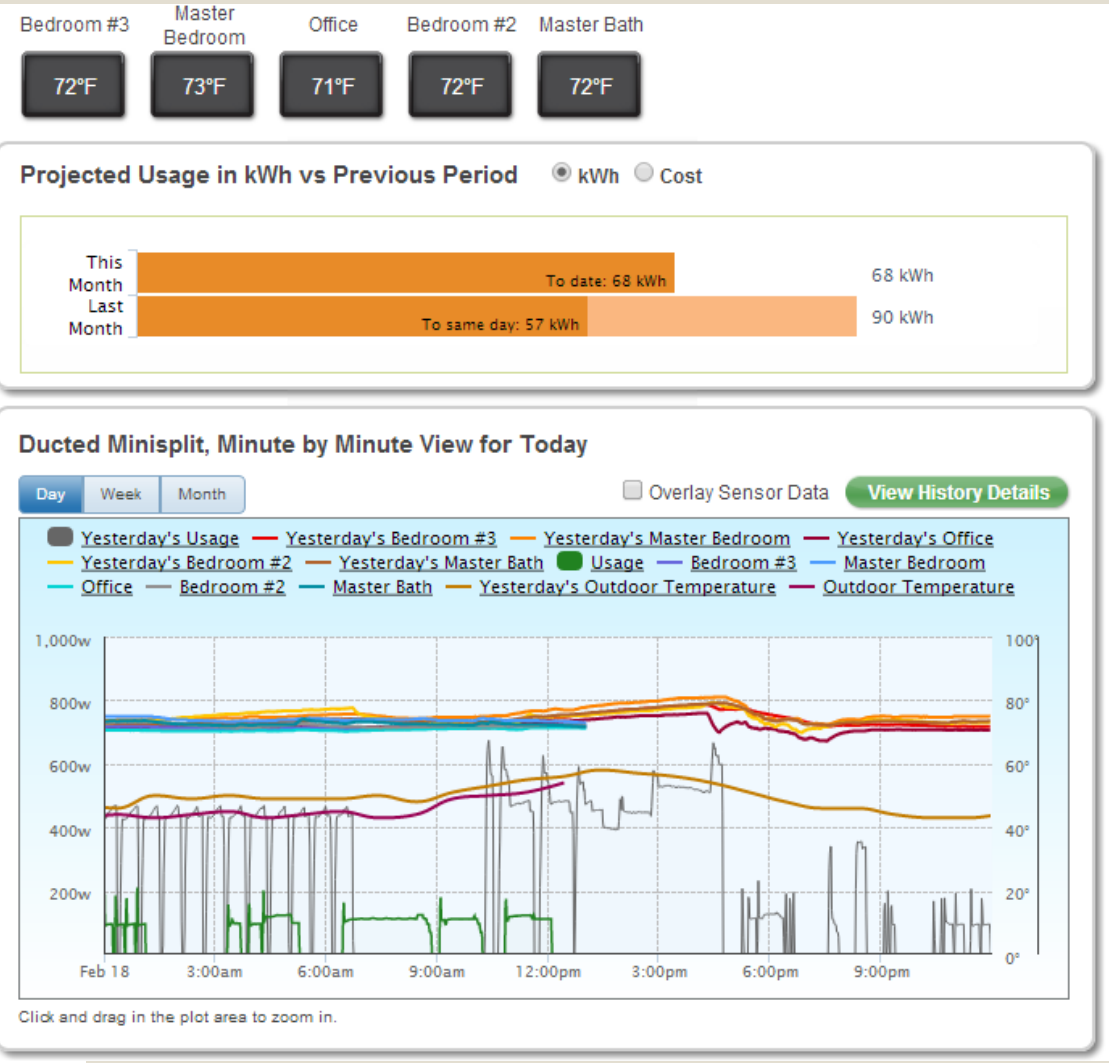

Why is this important?

DHP

Day | Week | Month | Year

Yesterday's Usage — Usage — Yesterday's Outdoor Temperature — Outdoor Temper

1,400W

1,200W

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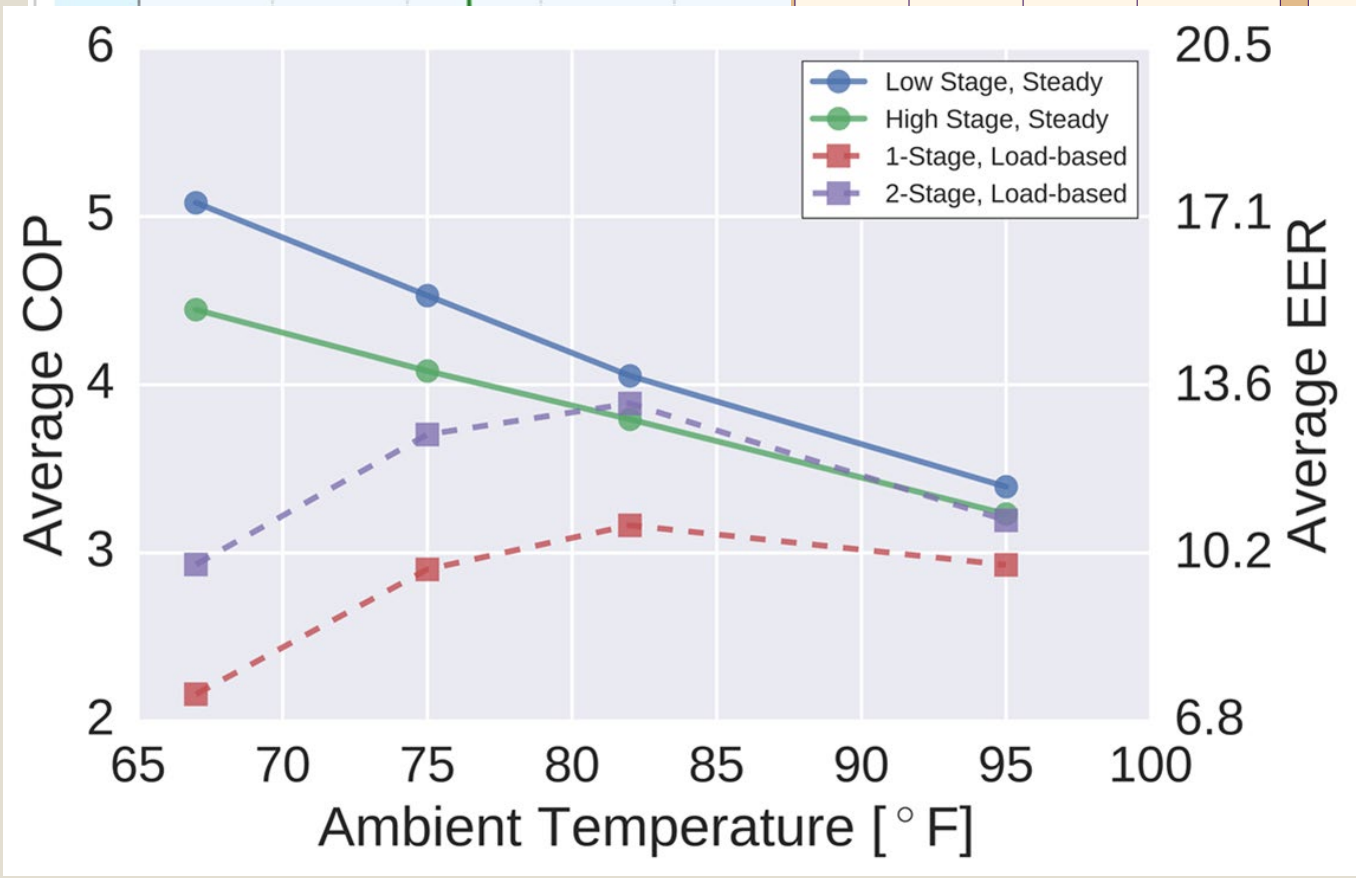

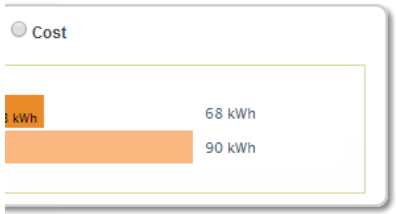

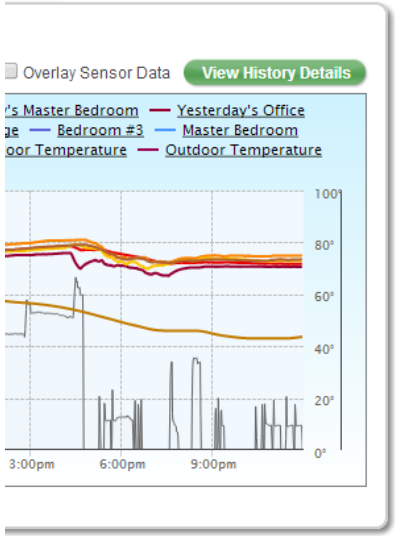

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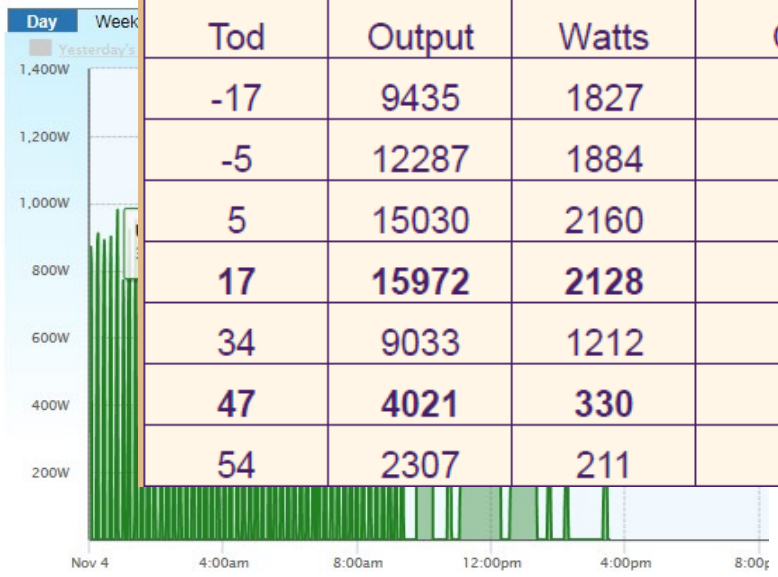
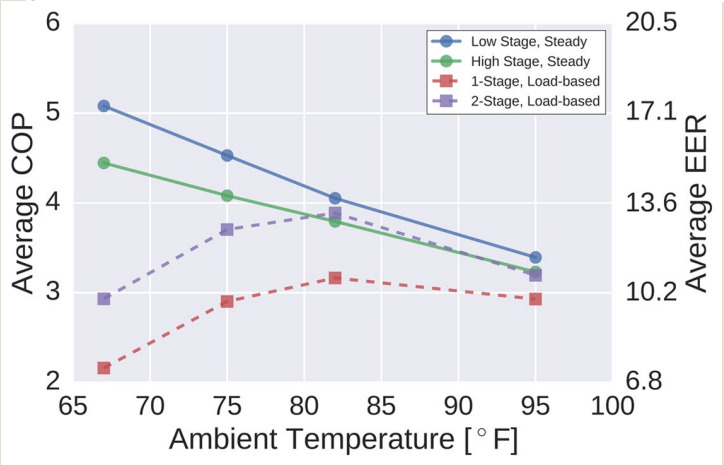
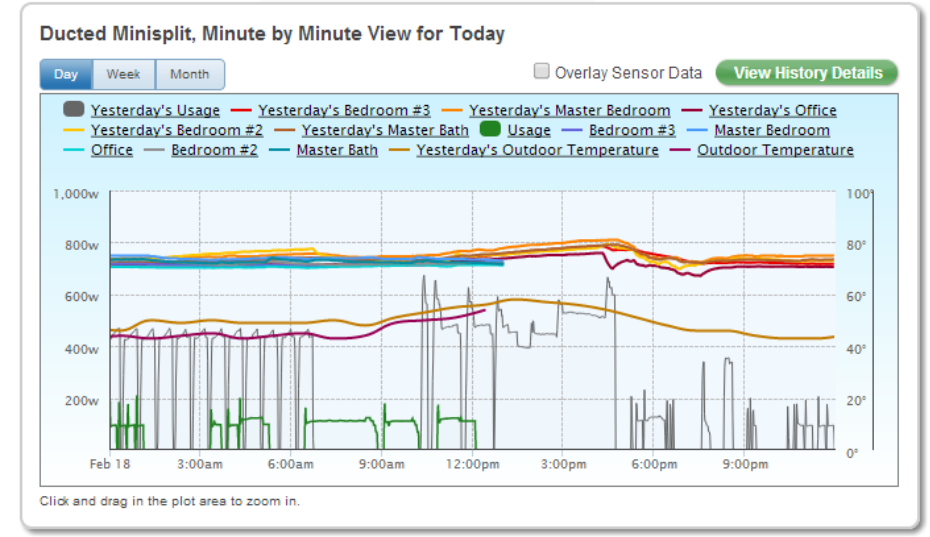


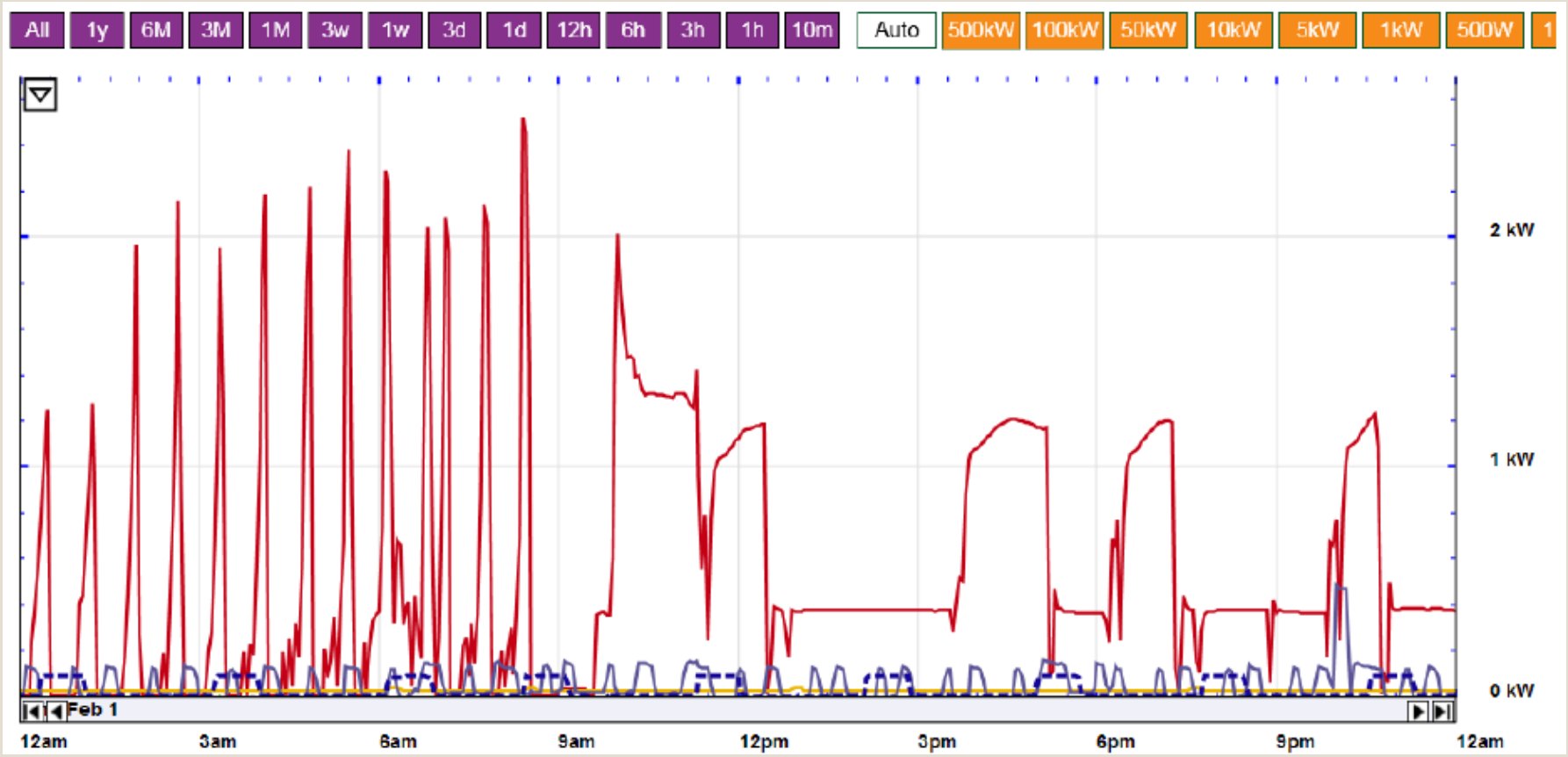




Harley Residence Heat Pump

Before and after firmware adjustment

An example of why this matters



Conventional DOE/AHRI Testing

- Fixed fan and compressor speeds
  - High fan speeds used in test aren't available in normal operation
  - Boosts rated efficiencies
- Doesn't include low-load cycling behavior
- Manufacturer's reps install equipment and monitor testing using proprietary test modes
  - Can't be independently duplicated
- Rating extrapolates performance over a wide range of conditions from two test points (with some adjustments)

Stakeholder Needs - Accuracy

- Climate-specific ratings
  - Seasonal heating and cooling performance
- Include standby energy
  - Can be significant during shoulder seasons
- DOE ratings (HSPF/SEER) not consistently representative of actual performance
  - Based on **two data points** (with adjustments), **in one climate**
  - **Savings** based on HSPF **not predictive**
  - Meaningful **performance comparisons impossible**
  - Leads to **modeling inaccuracies**

EXP-07 Development Objectives

- Respond to stakeholder needs:
  - Realistic rating, especially for variable speed systems
  - Seasonal efficiency (heating & cooling) reported for a range of climate zones
  - Detailed data for hourly computer simulation
- Voluntary – *not intended as regulation*
  - Marketplace differentiation of high-performance products
  - Qualified product lists for market support

Scope

- *Single-stage, multi-stage, and variable speed heat pumps and air conditioners*
- Residential equipment sizes (<65,000 Btu/hr)
- Ducted/ductless (including central ducted)
- Air-to-air, single-zone
  - Multi-zone and air-to-water planned
- Use dynamic, load based testing rather than lab-induced fixed-speed and fixed-condition, tested under the system's own controls, as shipped

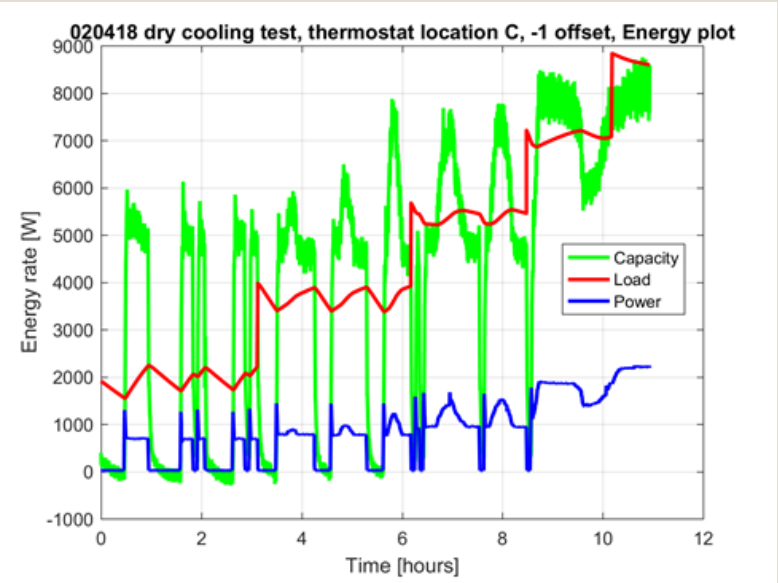
Task Group

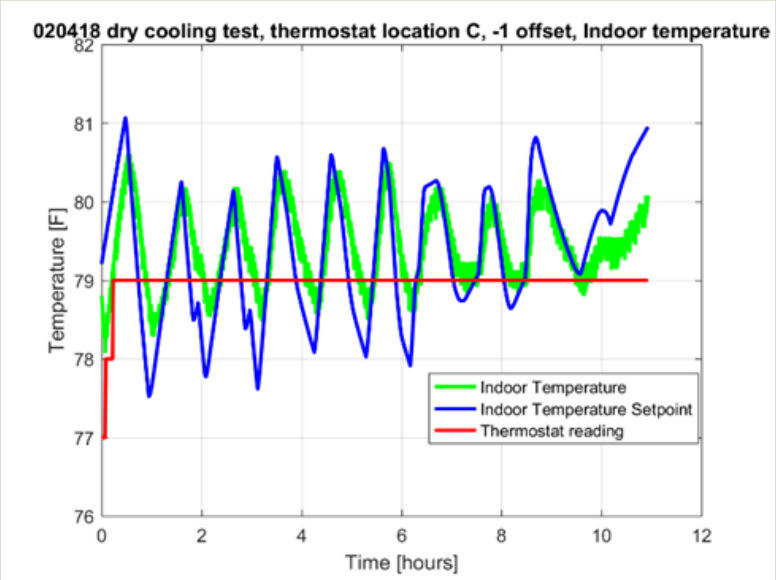
- Working group convened by CSA in 2015
  - Project manager: Jovan Cheema
- Comprised of:
  - Canadian utilities (Chair: Gary Hamer – BC Hydro)
  - Natural Resources Canada (NRCan) / CanMetEnergy
  - Northwest Energy Efficiency Alliance (NEEA)
  - Pacific Gas and Electric (PG&E)
  - Electric Power Research Institute (EPRI)
- Tasked to develop a CSA "Express Document"
  - Not full ANSI process, but similar –standards language

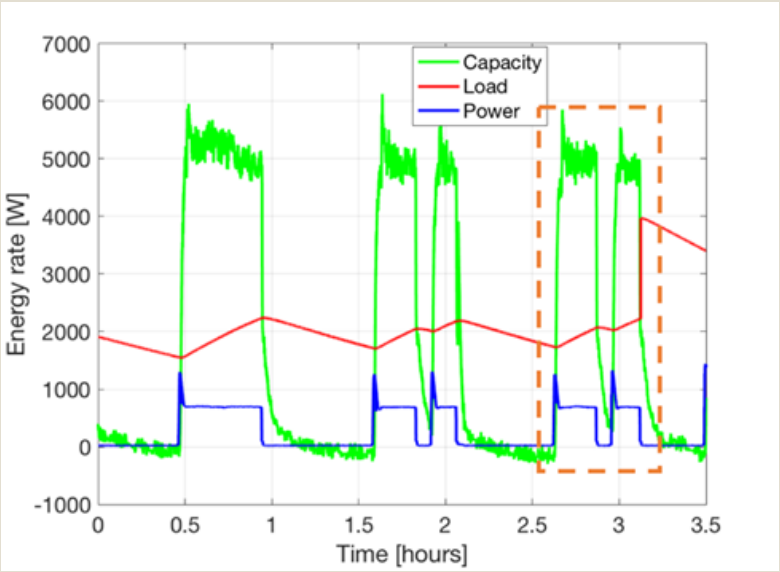
The New Procedures

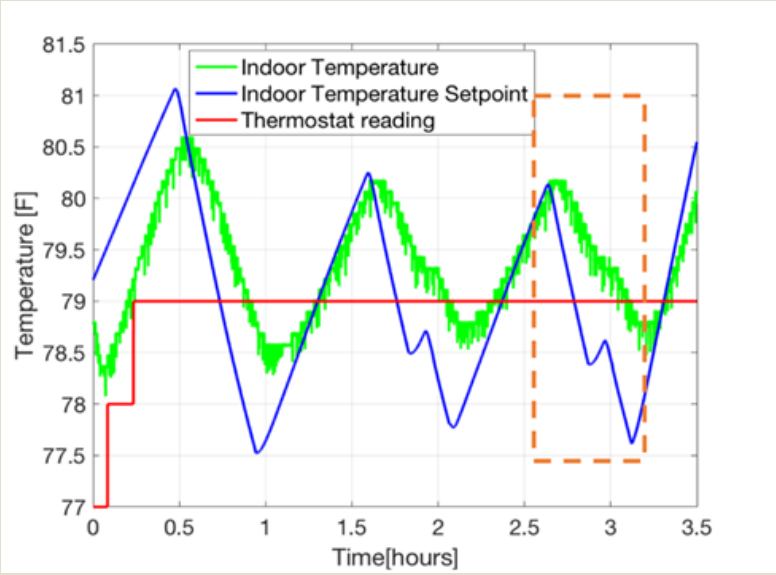
- Dynamic, load-based testing
- Tested under system's own controls
- Data reported for all test condition intervals
- 4 sets of tests – 2 for cooling, 2 for heating
- Ratings in 8 climate zones
- Bin hours for weighting not the same as DOE's
- Application ratings to be included

Extensive Lab Work Involved

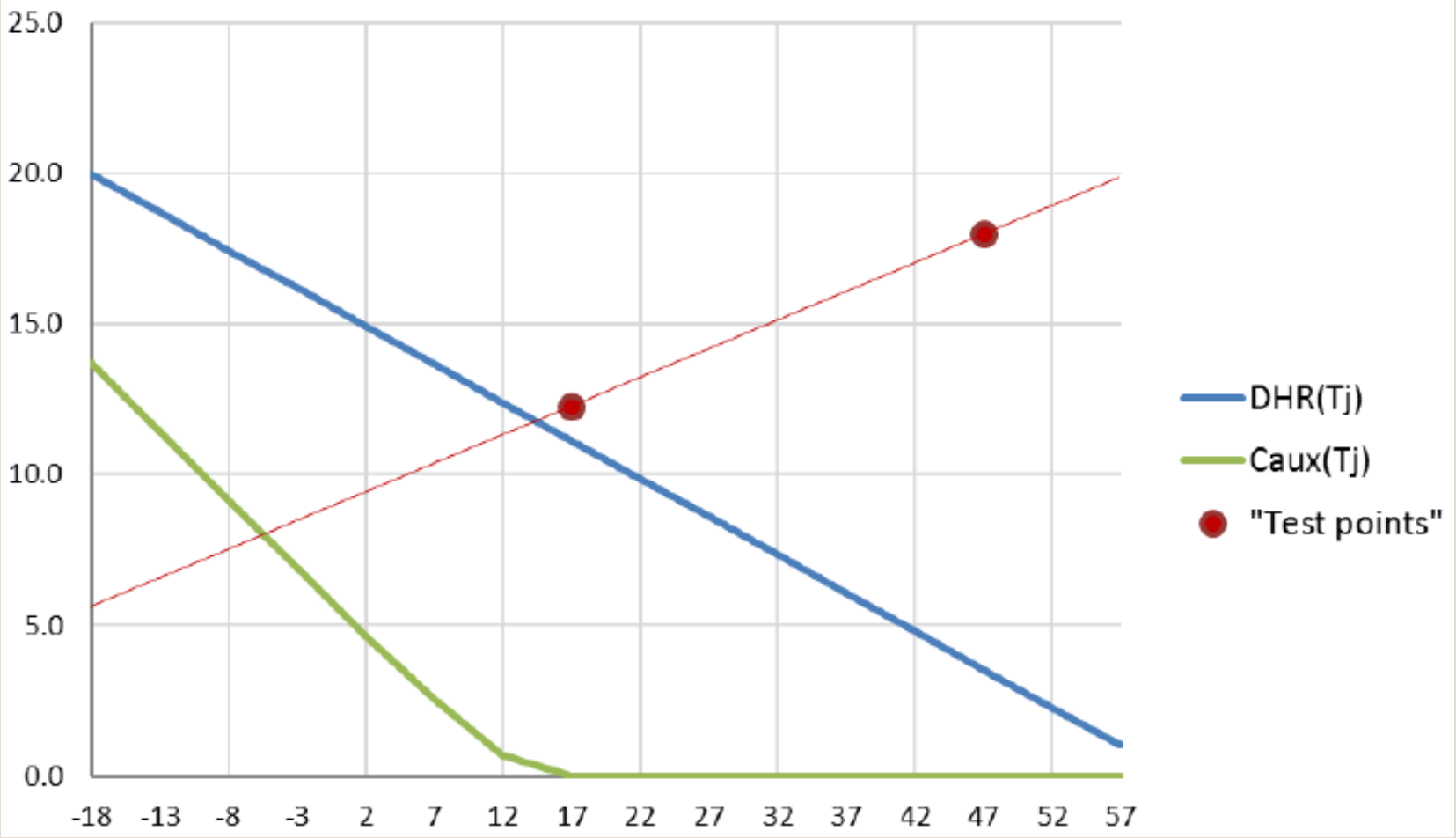




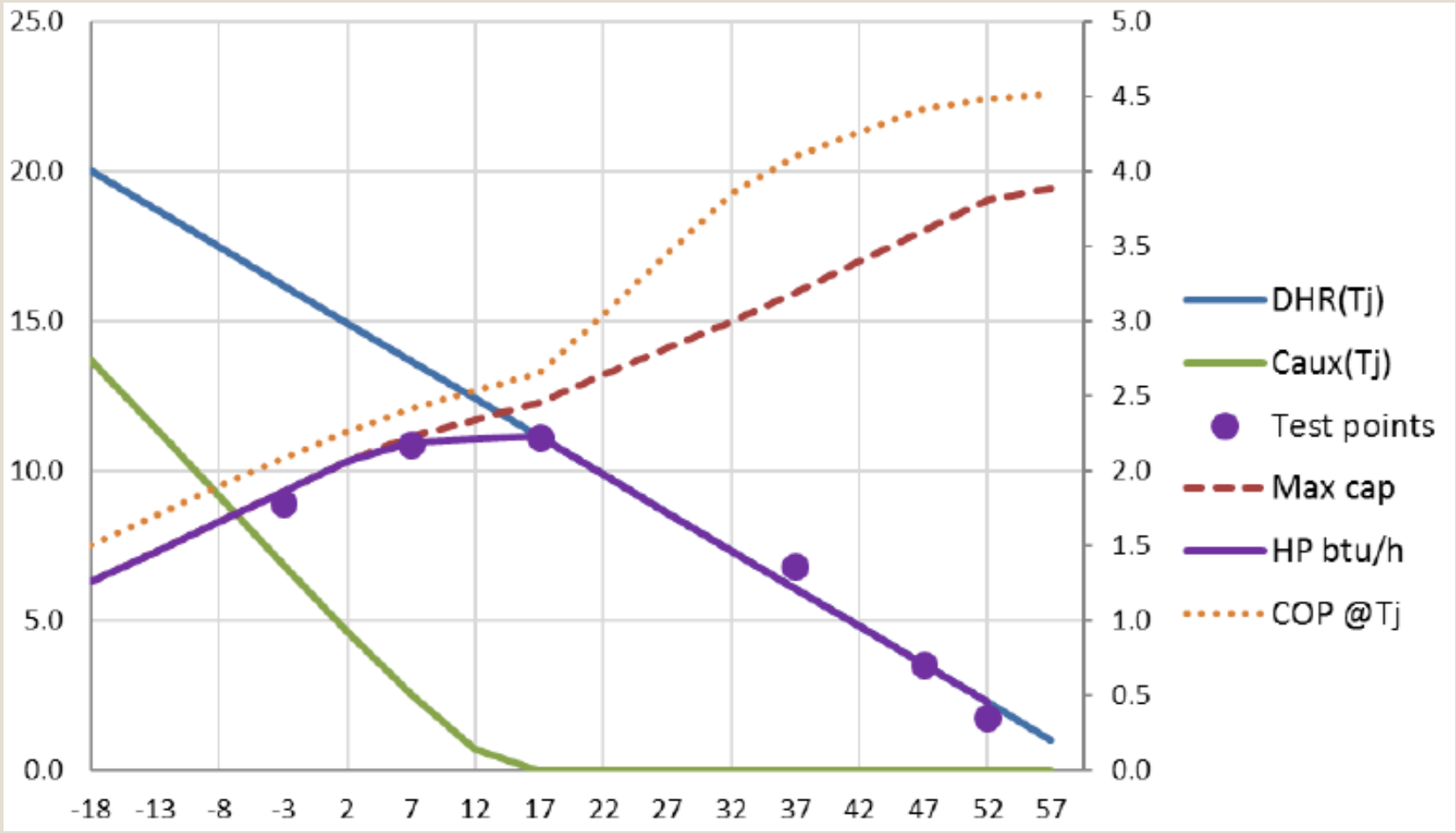




Conventional Test Method



Dynamic Test Method



Dynamic Load-based Testing

- Indoor room has simulated loads
  - Load is "imposed" by indoor room reconditioning equipment, programmed to mimic load
  - Load varies based on outdoor conditions
  - ***Includes dynamic moisture load for humid/cooling***
  - Equipment under test: on-board thermostat/ controls govern system operation as normally installed
- Includes native fan, cycling, defrost and latent removal in a single test procedure
- Tested as shipped

Data Reported

Test and report data under a wide range of outdoor conditions and building loads:

- Cooling: 5 outdoor room temperatures
  - From 77°F to 113°F (DOE test: 82 & 95)
- Heating: 6 outdoor room temperatures
  - From 54°F to -10°F (DOE test: 17 & 47)
- Report consistent performance data
  - Can be used in hourly building simulations or design

Test Conditions

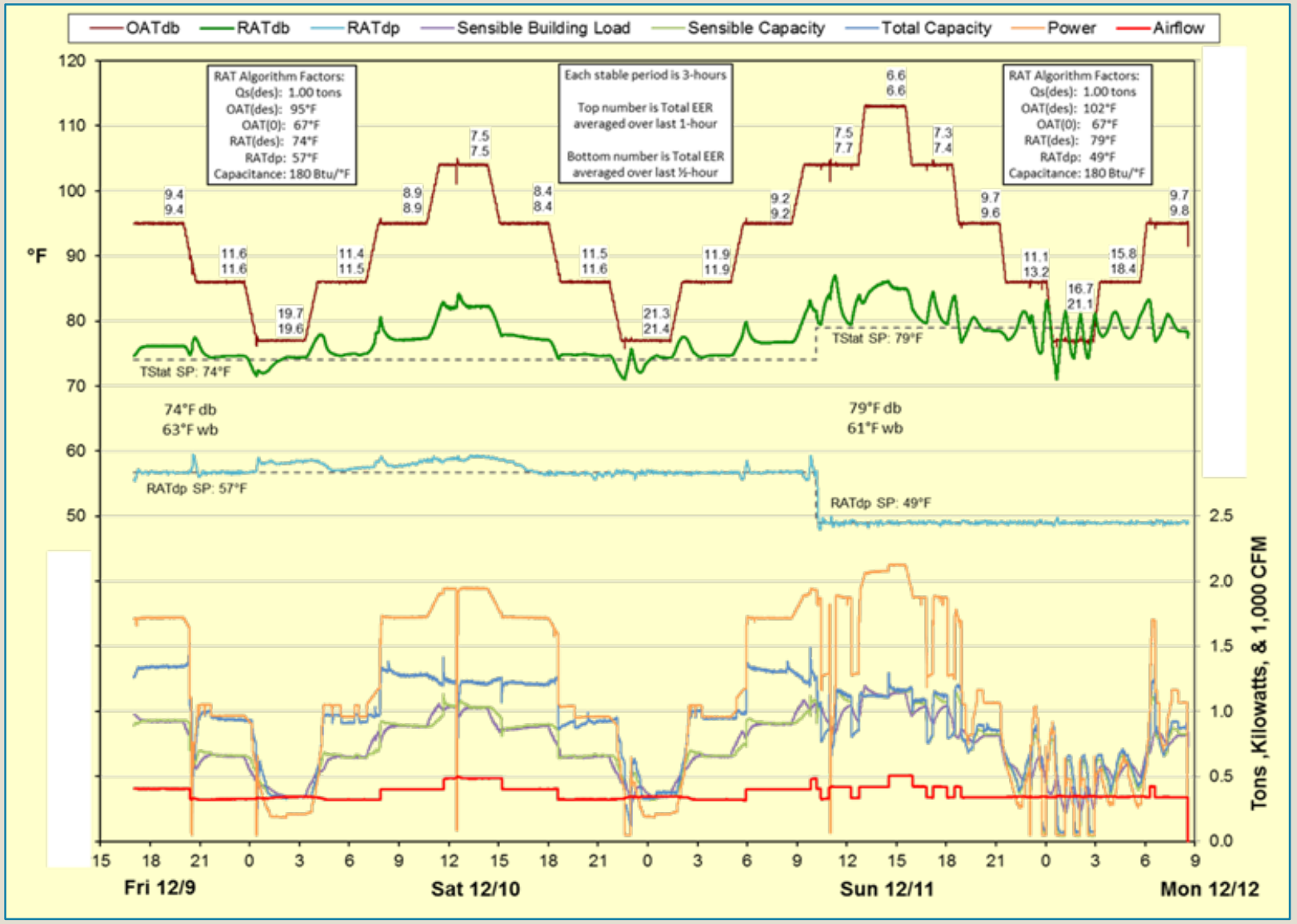
Cooling

	Humid Test Conditions			Dry Test Conditions		
	Outdoor Dry-Bulb Temperature, °F	Indoor Dry-Bulb Temperature[2], °F	Indoor Wet-Bulb Temperature[3], °F	Outdoor Dry-Bulb Temperature, °F	Indoor Dry-Bulb Temperature[2], °F	Indoor Wet-Bulb Temperature[3], °F
CA[1]	N/A	74	63	113	79	56 (maximum)
CB	104			104		
CC	95			95		
CD	86			86		
CE	77			77		

Heating

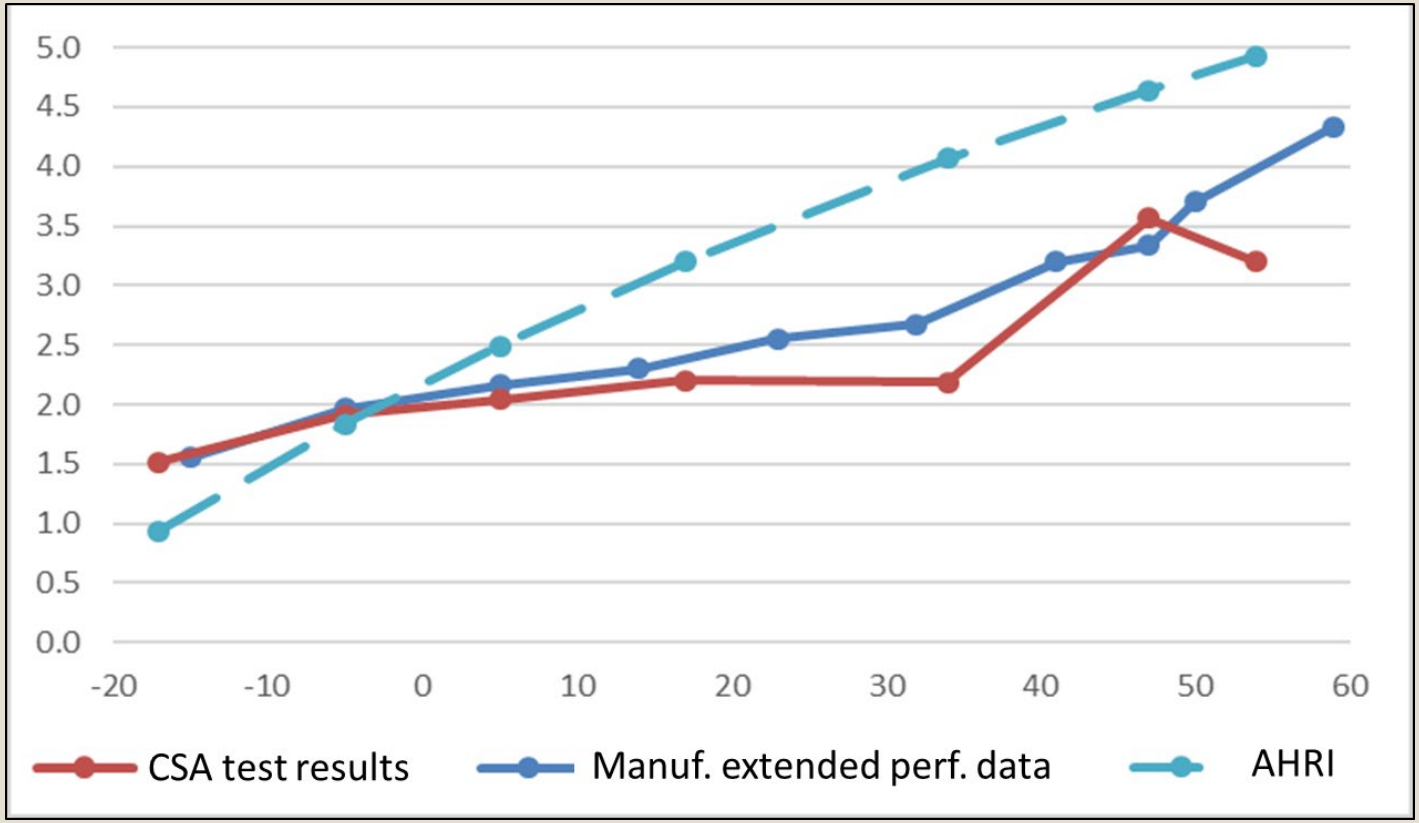
	Standard Outdoor Conditions		Marine Outdoor Conditions		Indoor Conditions	
	Dry-Bulb Temperature, °F	Wet-Bulb Temperature, °F	Dry-Bulb Temperature, °F	Wet-Bulb Temperature, °F	Dry-Bulb Temperature, °F[3]	Wet-Bulb Temperature, °F[4]
HA[1]	-10	-11.4			70	60 (maximum)
HB[1]	5	4				
HC	17	14.5	17	15.5		
HD	34	31	34	32		
HE	47	41	47	45		
HF	54	45	54	49		
HL[1,2]	TOL	TOL-1	TOL	TOL-1		

Typical Cooling Test Profile



Performance Data Comparison

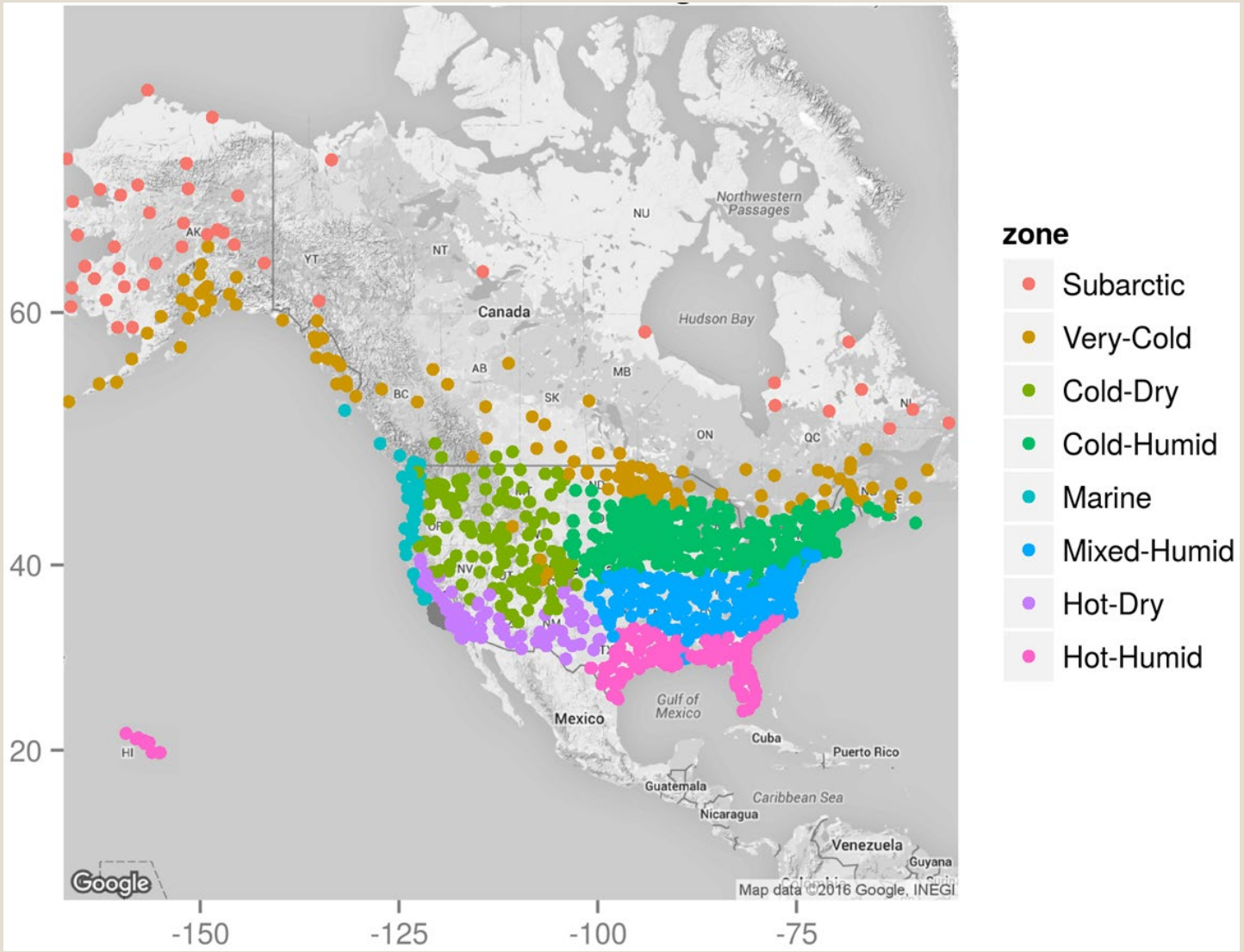
- Test COPs match manufacturer engineering data fairly well
  - AHRI shown for illustration purposes (From published values at 17/47; not including defrost, C_d)



Climate-based Ratings

- 8 North American climate zones
- Based on (simplified) Building America zones
  - Using a grouping analysis by Ecotope
- Test results used to create bin model for annual performance for each climate
  - Seasonal COPs for heating /cooling in each climate
- With and without standby, crankcase, pan heater

Proposed Climate Zones

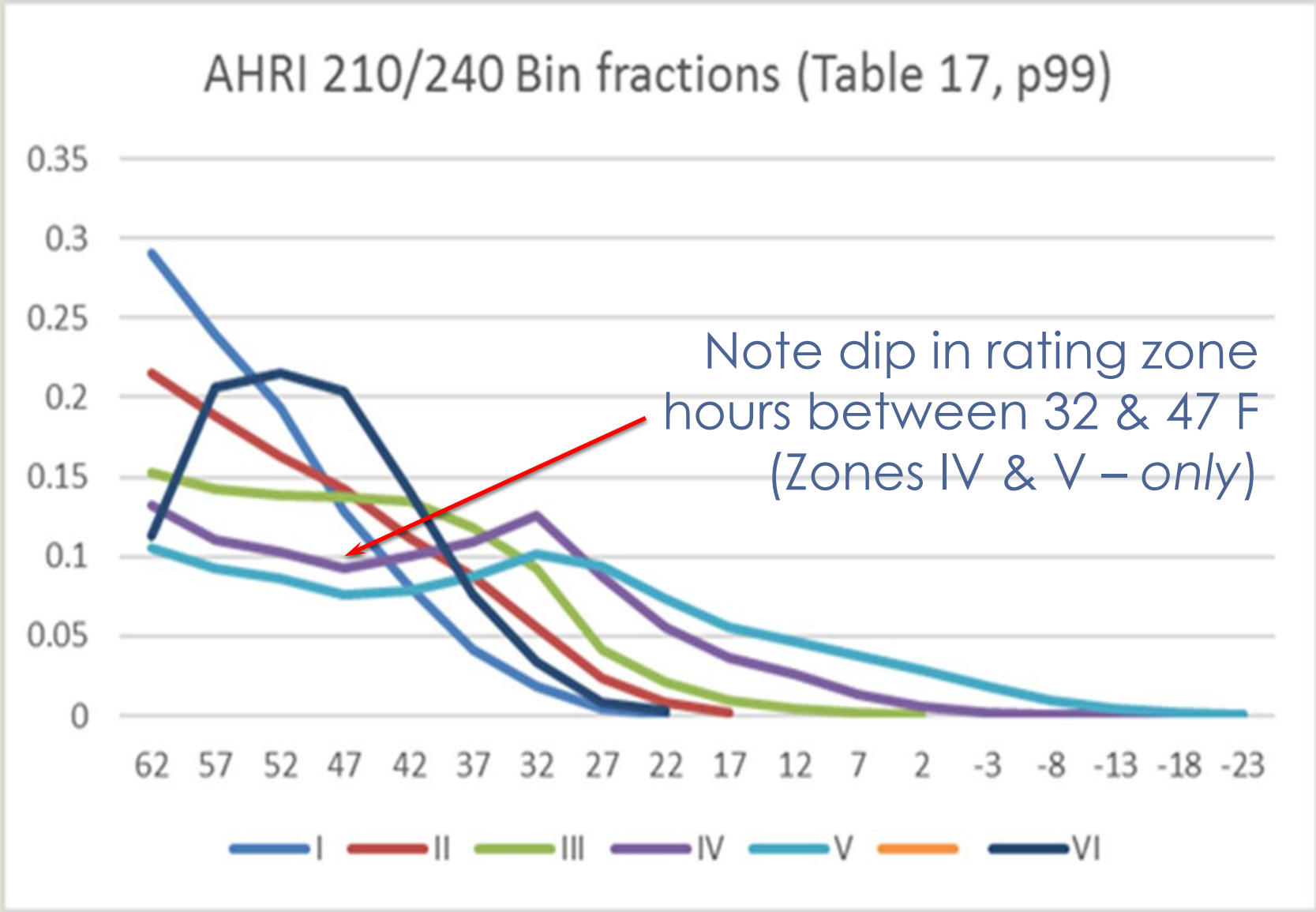


Two Sets of Heating & Cooling Tests

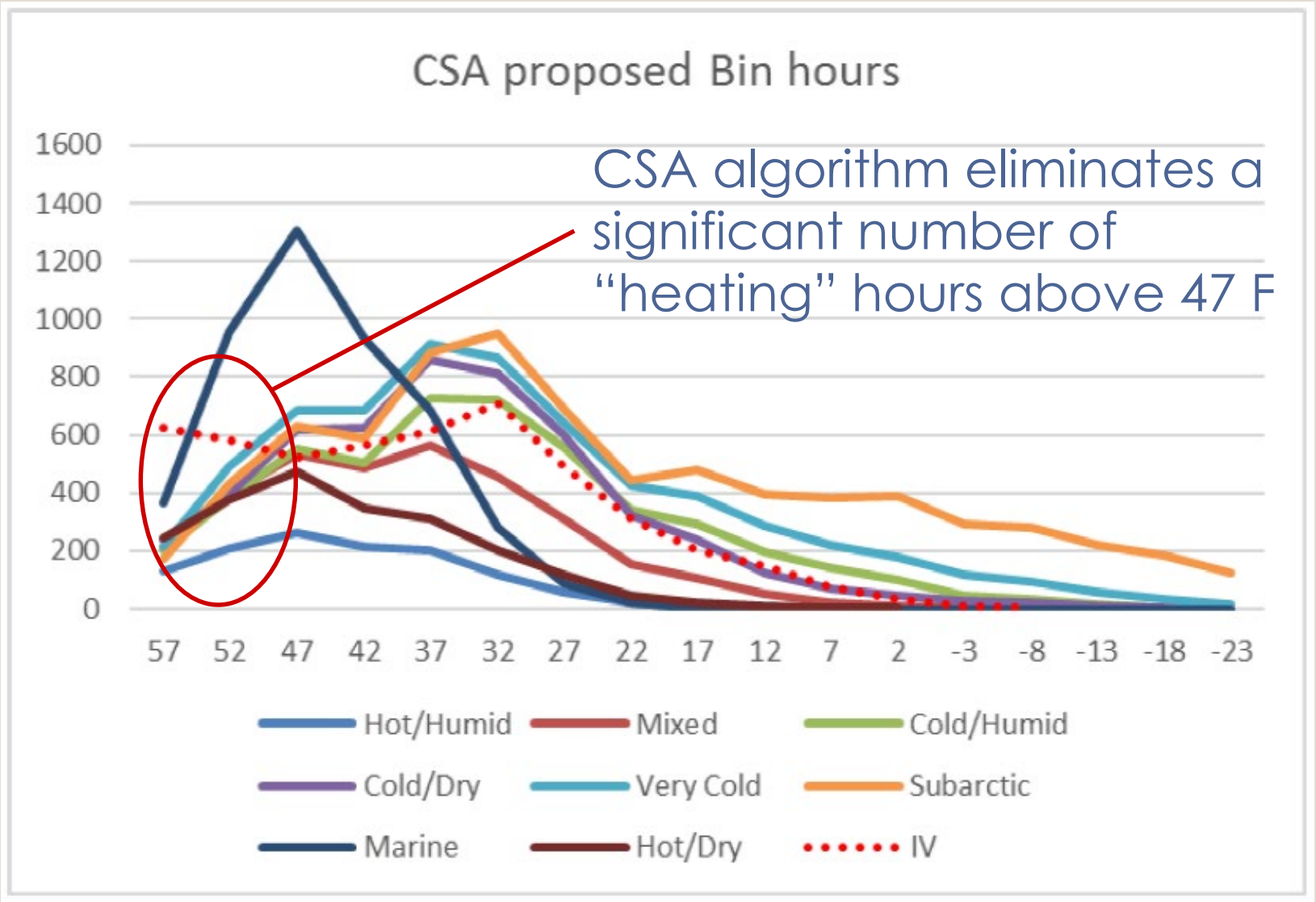
Heating	Cooling
Standard	Dry
Marine	Humid

Rating Climate	Heating	Cooling
Sub-Arctic	Standard	N / A
Very Cold	Standard	Humid
Cold / Dry	Standard	Dry
Cold / Humid	Standard	Humid
Marine	Marine	Dry
Mixed	Standard	Humid
Hot / Humid	Standard	Humid
Hot / Dry	Standard	Dry

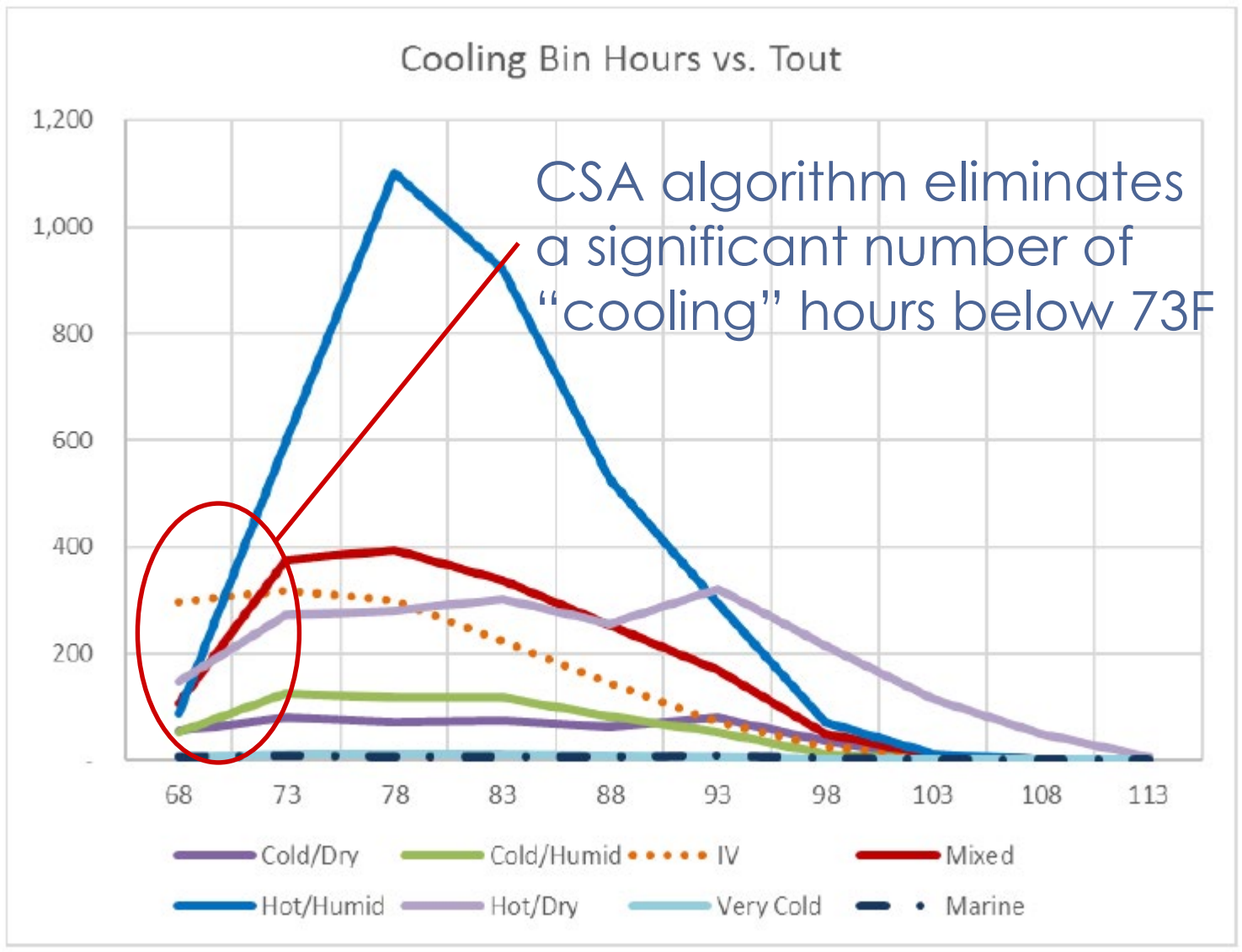
AHRI / DOE Bin Hours (Table 17, p.99)



EXP-07 Heating Bin Hours



EXP-07 Cooling Bin Hours - 6 Climates



Application Ratings

- Use the same set of lab test data as standardized ratings
- Customizable to specific building types and climates
  - In a way that is consistent with standard ratings
- Includes guidance for realistic use of auxiliary heating (e.g., boiler or electric resistance)

Progress / Next Steps

Lab testing so far:

- PG&E
- Purdue
- NRCan/ CanMetEnergy
  - NGTC
  - UL Plano
- EPRI
- SCE starting
- Many partial; details have varied over time
- Some focused on answering research questions (e.g., simulated loads, repeatability)

Time Line

- Public comments closed December 2017
- Lab testing will continue
  - Several key issues resolved since last winter
  - Controller apparatus & set-up - Purdue to finish summer 2018
- Stable version by fall 2018, for more lab testing and technical feedback
- Publish in late 2018 or early 2019
- Work starting on air-to-water, and multi-split (residential "VRF") system types

Interested Parties

- Canadian Utilities
- Natural Resources Canada
- Some NE Utilities / State agencies / NEEP
- Northwest Utilities / NEEA
- CA Utilities (PG&E, SCE at least)
- Some cities –decarbonization efforts

Contacts

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  503 688-5457
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  BC Hydro
  Vancouver, BC
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  604 453-6388