Performance of Ductless Heat Pumps in the Northeast

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BE2014 / High Performance Mechanicals

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Amended 6/3/2014

Titles/details in RED indicate significant changes

Conservation Services Group

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Learning Objectives:

- Better understand specifying and installing heat pumps in cold climates
- Address occupant concerns
- Understand drivers of cold climate performance
- Learn to interpret manufacturers' specifications for cold climate applications

Overview

- Measured
  - DHP Installation: Stamford, VT   July, 2012
  - 2 units, 3 zones
  - Moderately efficient 2400 SF ~20,000 btu/h @ 2F
  - Monitored 9/2012-10/2013
  - Results and anecdotes; application insights

Residential Heat Pumps – *Brief* History

- 1980s – lots of ASHPs in northern climates
  - Duct leaks, air flow/charge problems
  - “blowing cold air” complaints
- Electric resistance heat compensates
  - Leading to very low average system efficiency
- People *believe* ASHPs don’t work in cold climates *because of the climate*

Ductless Split Heat Pumps ("Mini-Split")

- 40+ years of mass-production
  - Originally single-point cooling, replace wall/window
- Steady advances:
  - System size – wider range
  - Flexibility (heat pump, multi-head, mini duct, other)
  - Efficiency increase - variable speed "inverter drive"
  - Climate (***optimizing for cold weather heating***)
    - Google "low temperature refrigeration": -60F to -80F

Use Cases for Residential DHP

- Offset existing heating source
  - Oil, LP, Electric resistance
- Exclusively heat low-load homes
  - Deep retrofit, new near-zero
- Add HVAC to addition or new zone

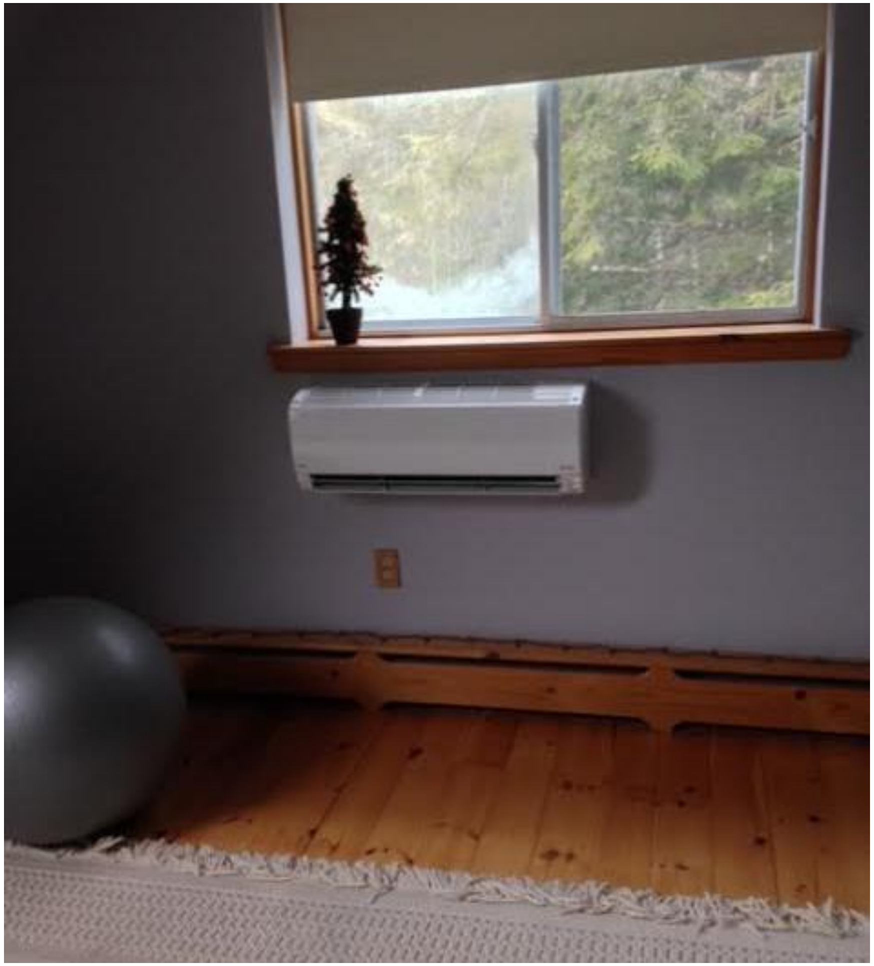
- No built-in electric resistance backup heat

1st Floor Unit (12 HSPF)

A bit of recirculation…

Outdoor Unit

Attic room - 2^{nd} floor



2-head, 9 HSPF

2nd Floor Air Handler

COP and HSPF

- Coefficient of performance
  - COP = Energy out / Energy in (kWh/kWh)
- Heating Season Performance Factor
  - Standardized test based on *specific climate*
  - HSPF = Energy out / Energy in (**kbtu/h** / kWh)

10 HSPF =~ 2.93 COP = 293% efficient

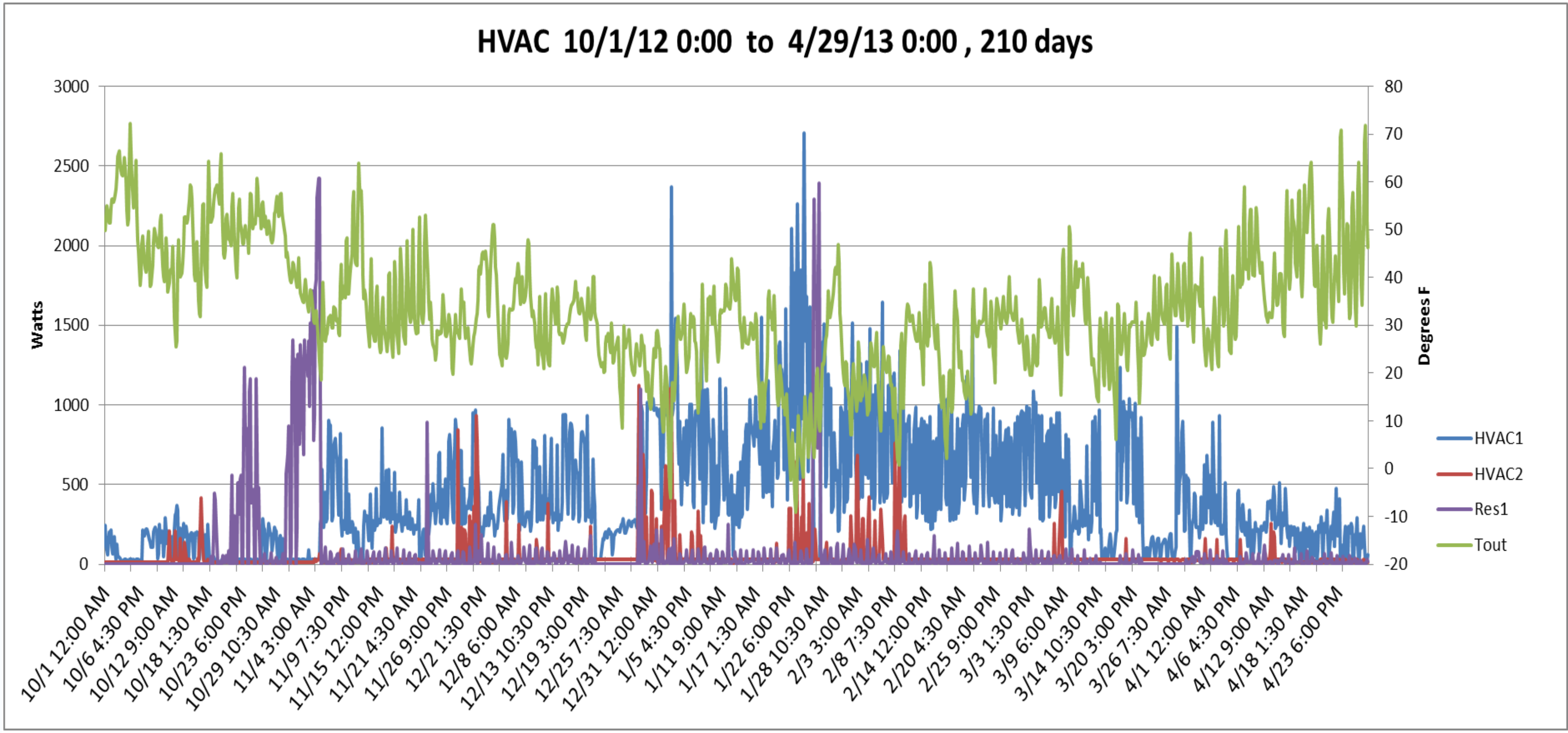
How can COP be > 1?

- “Energy in” is defined only as only the energy we pay for (electricity)
- So in heating mode:

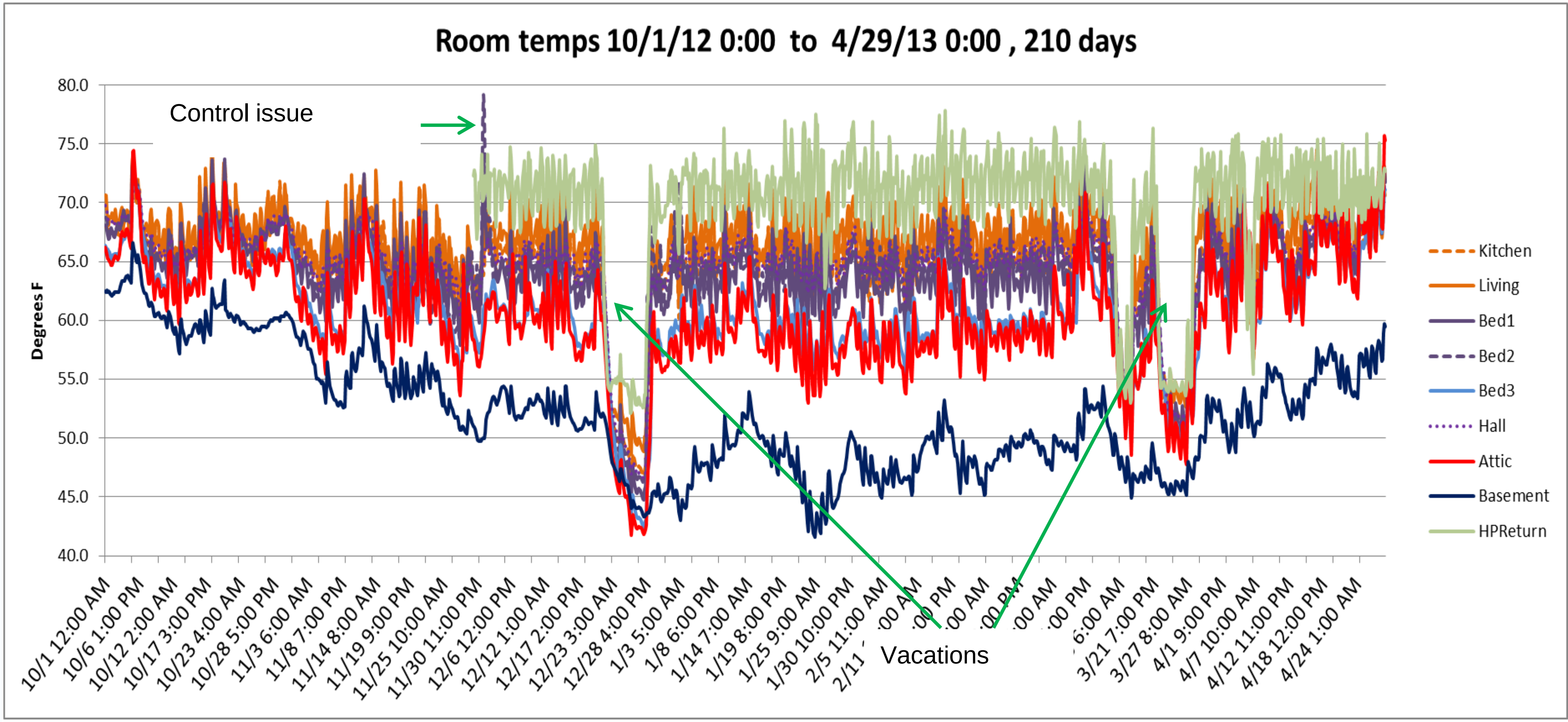
Energy (meter) + Energy (air) = Energy delivered

Data

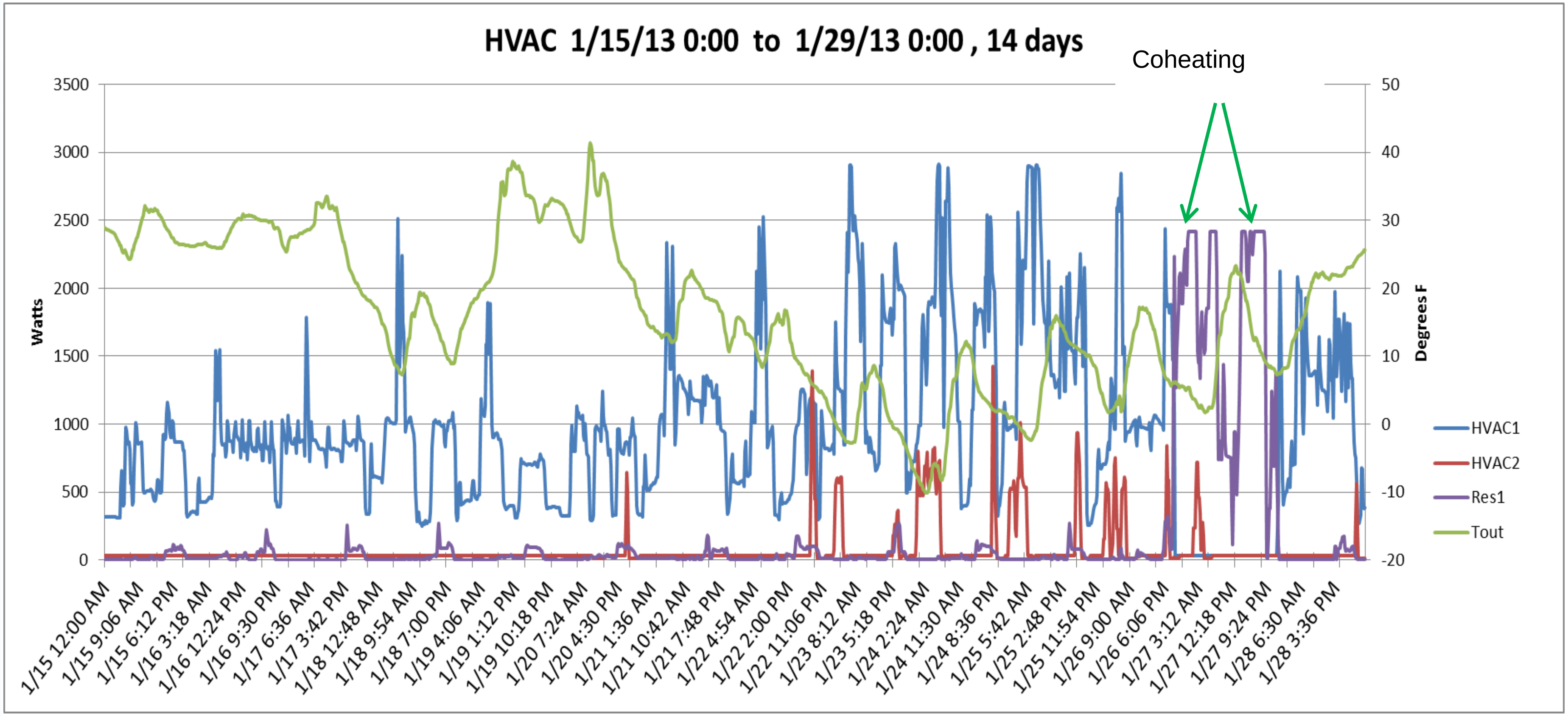
HVAC kWh and Tout



Room Temperatures



HVAC kWh and Tout



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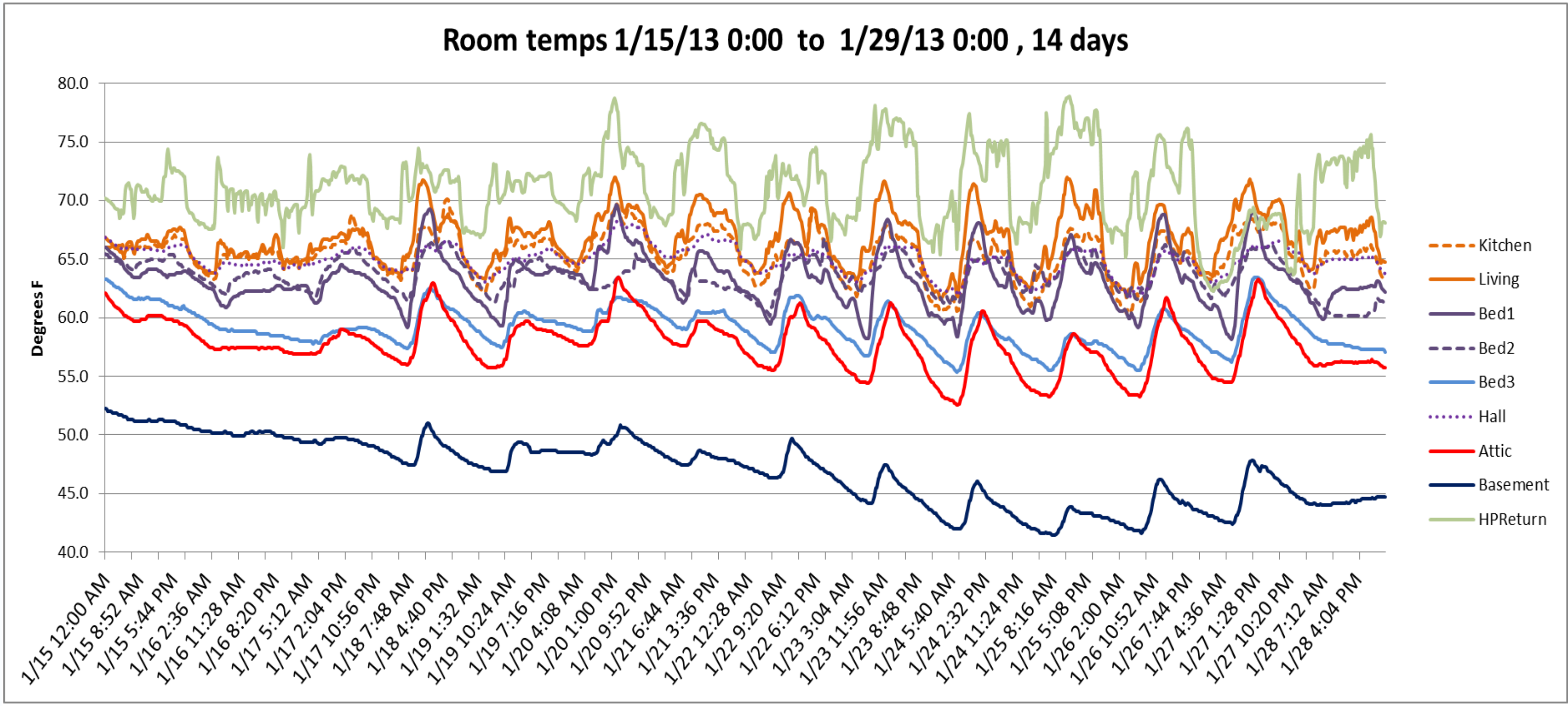
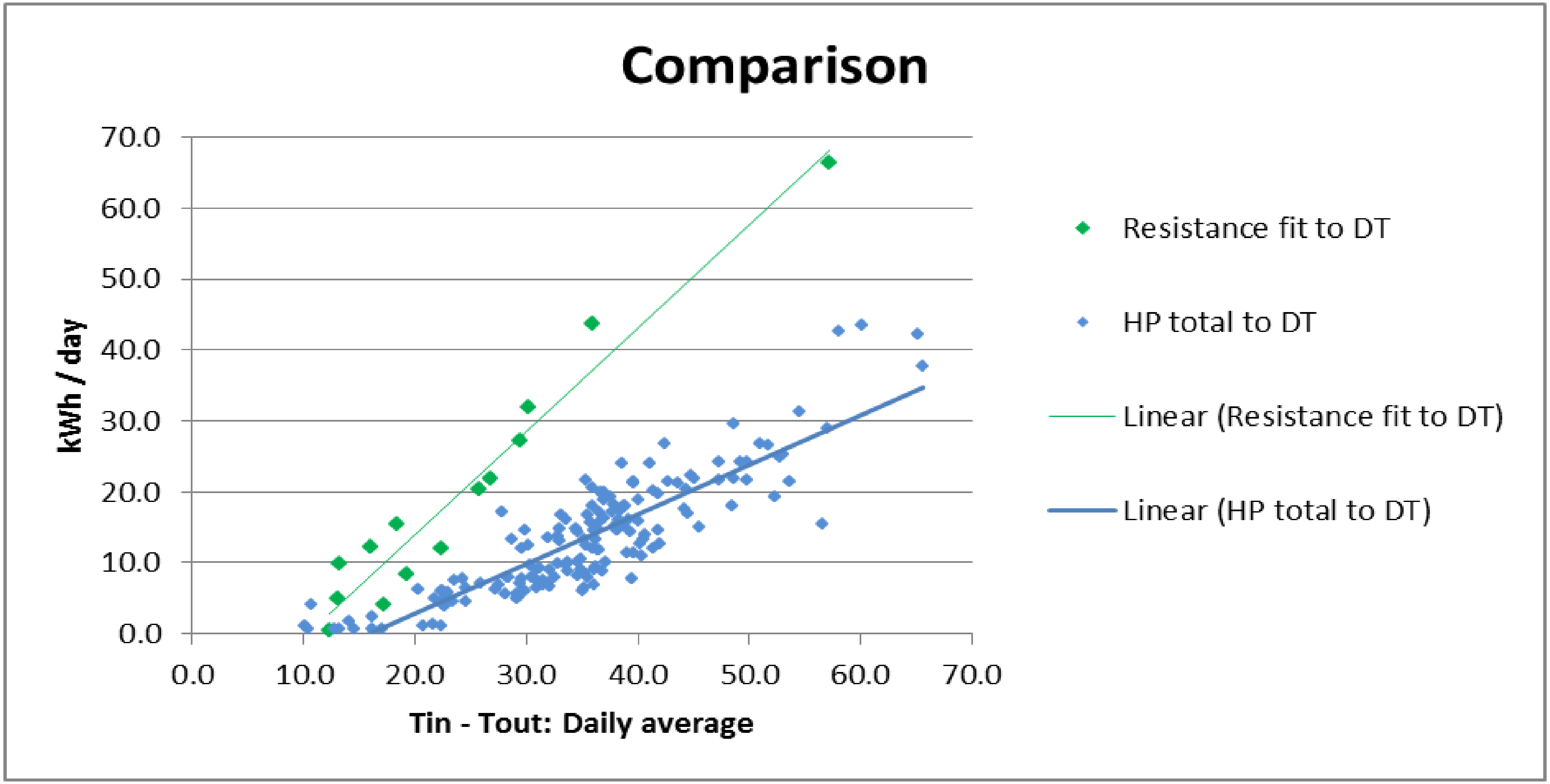
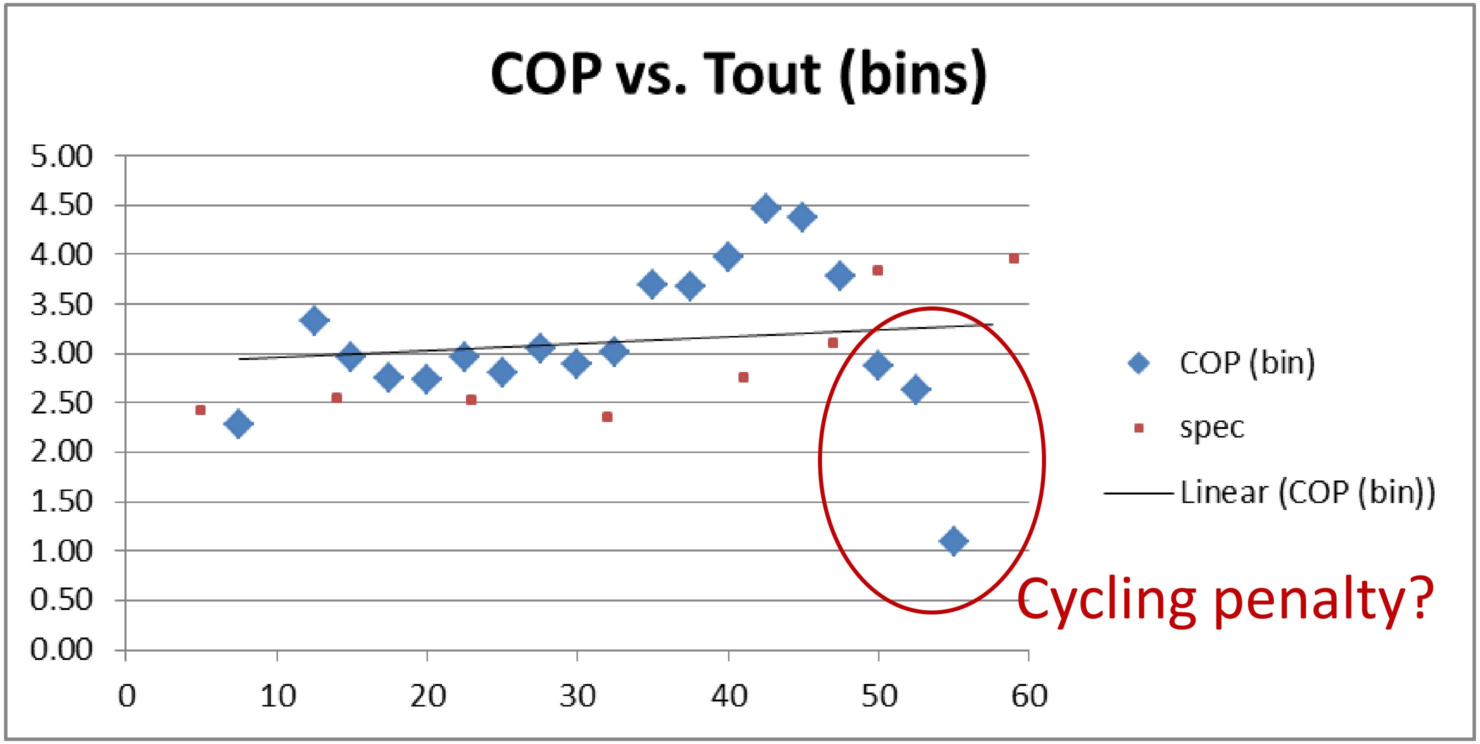


Analysis

Resistance vs DHP

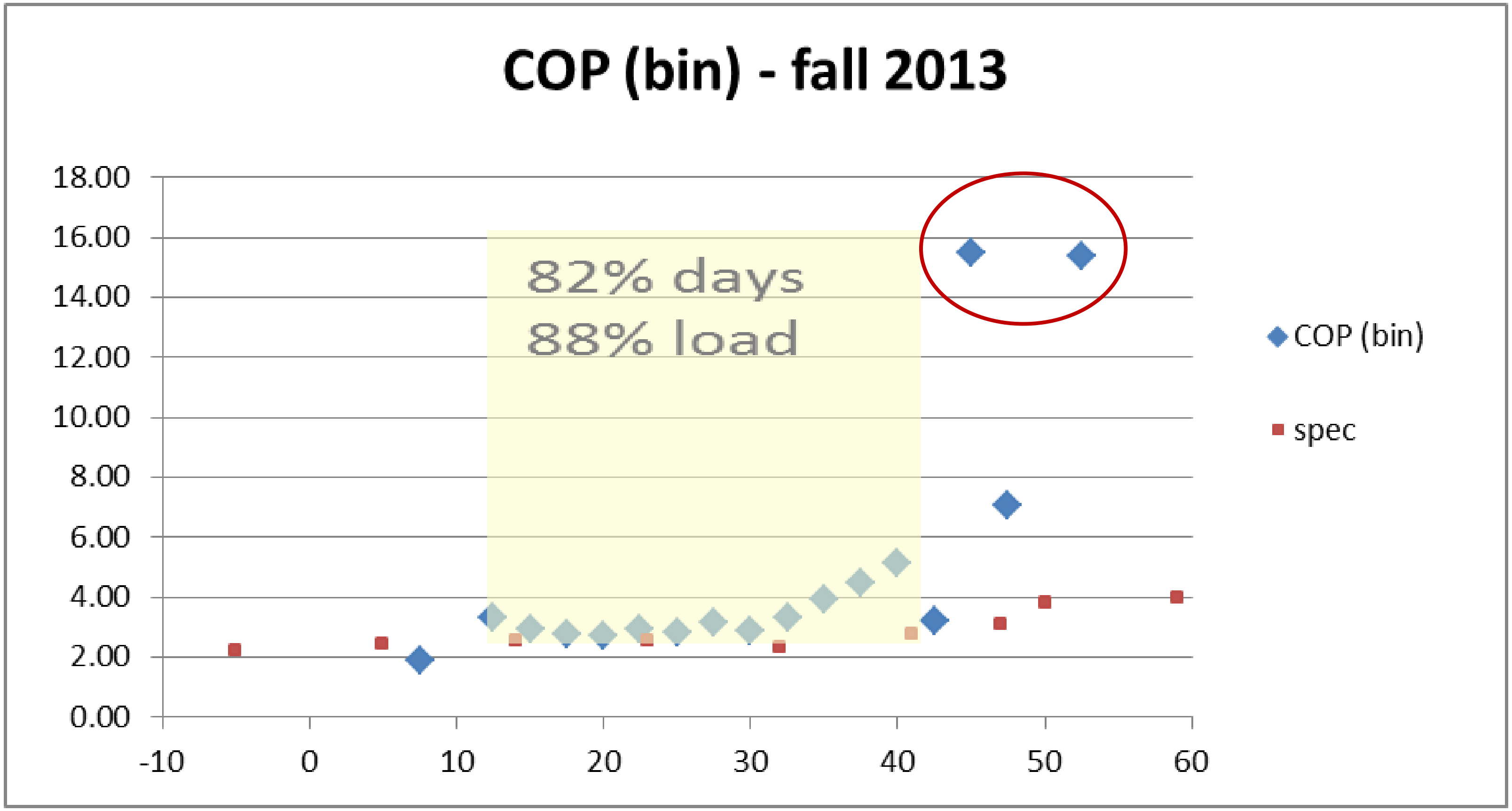


COP Variation with Tout



Tout

COP Variation with Tout



Tout

Projections….

- Load: 26 Mbtu / 7740 kWh
  - actual **7358**
- Consumption: 3067 kWh / $460
  - actual **2022 (2245) / $303 ($337)**
- COP: 2.5
  - actual **2.6 – 2.8**

Methodology, Discrepancies

- (Adjusted for power factor—inverter!)
- Removed days away, incl. recovery time
- Daily average Tout, not instantaneous
- Non-uniform indoor temp in house
  - Projection used estimated % of “full heating” load
- Solar gain contributed to heating
  - Projection used house UA, didn’t account for gains

RESULTS

"Heating-only" COP

	Both DHP monitoring period only	Both DHP Adj for full year, incl. all standby	1st Floor unit, no CC heater	1st no cc – no sunny days
COP	2.75	2.63	3.04	2.88
"HSPF"	9.5	9.0	10.4	9.8
Total cost:	*$332*	*$419*		
kWh:	*2211*	*2794*		

2-system COP

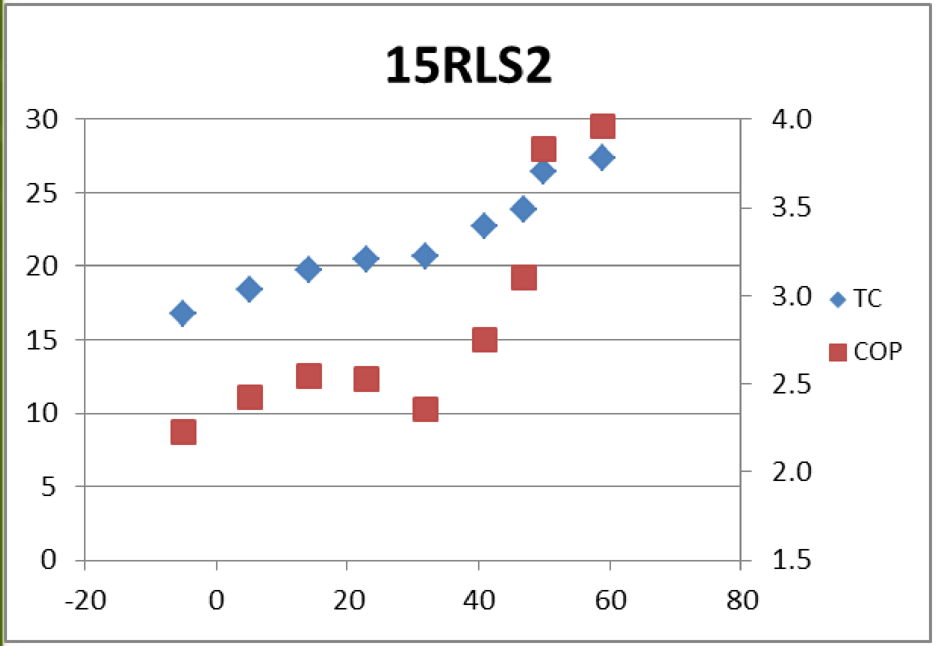
Cooling: 5.5 kWh/day max, typical AC 2 kWh/day

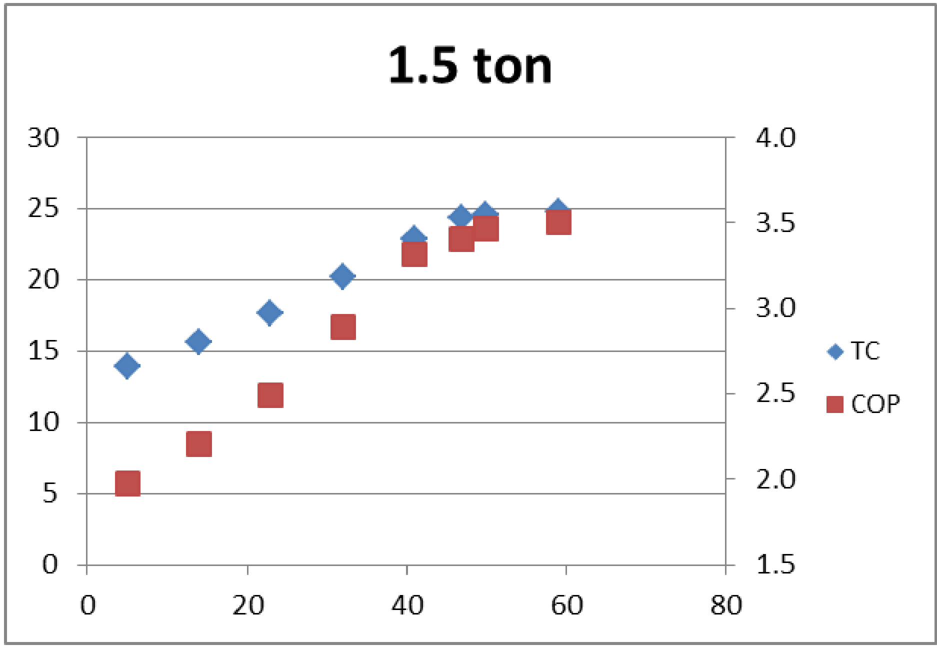
Hot week = 30 kWh

Insights

- Crankcase Heater: ~0.7 kWh/day in winter
  - Only below ~34F, when compressor isn't running
  - ~120 kWh annually (mostly for 2^{nd} system) - small
- "Higher efficiency" at lower temperatures is good, but depends one use case
  - May sacrifice performance in mid-range temps – if there's backup heat
  - Higher capacity in lower temps means more hours at part load / higher efficiency for sole heat source

Cold-Climate vs. "Standard" inverter





Thermostat / Controls

- Setup is NOT intuitive
- Ensure communication with remote
  - Or get wired unit
- Remote control is not temperature sensor!
  - Wired control, remote sensor or compensate
- Increase temperature for better comfort
  - Reduce use of existing /backup (oil, LP, electric)

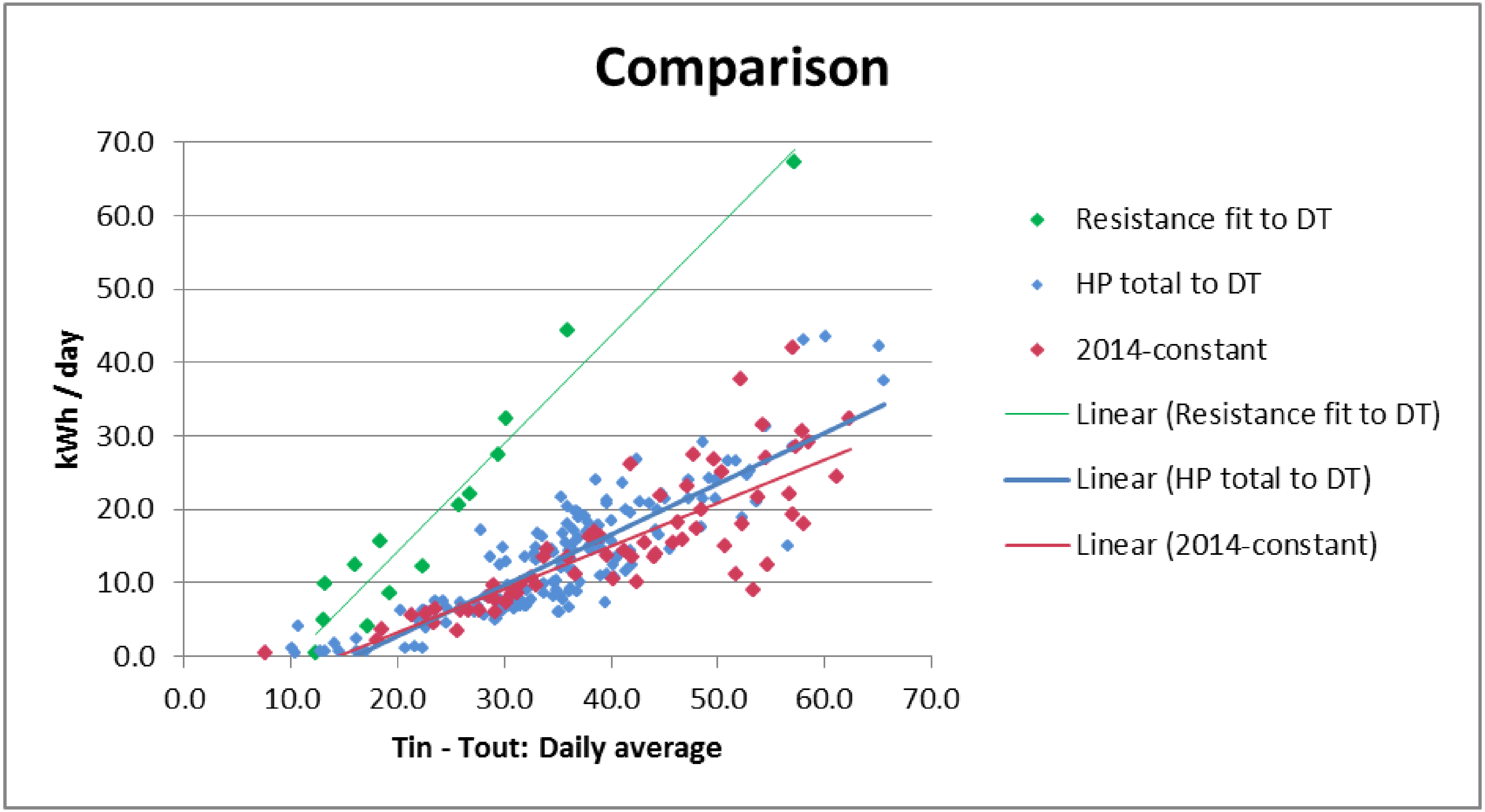
More Insights

- Fan Speed
  - Low is quiet; “Auto” boosts capacity when needed
  - Low seems to decrease efficiency slightly (?)
- In heating climate: indoor unit low on wall
  - Window sill height provides balance between heating and cooling performance

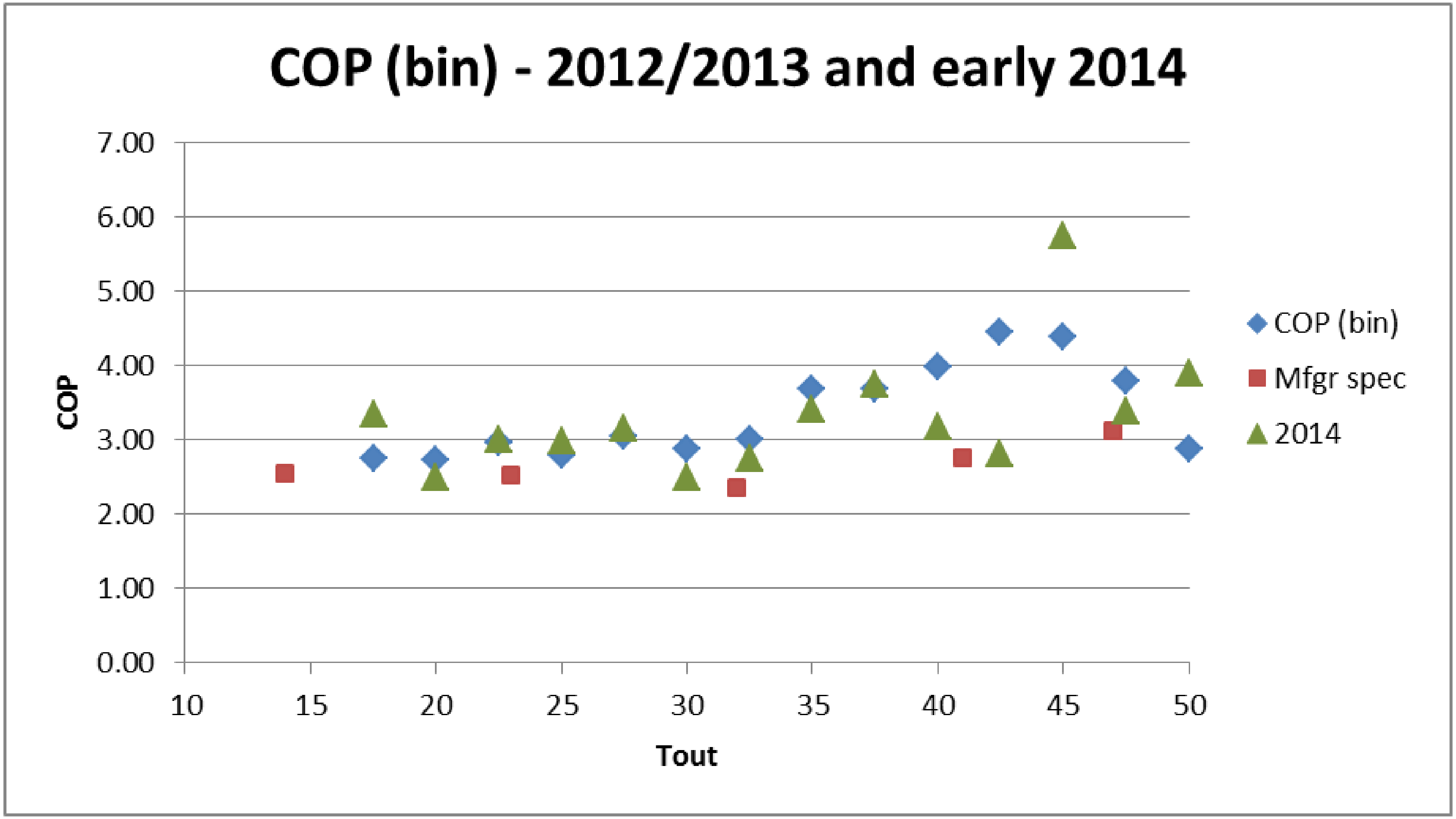
Night/Away setbacks

- For DHP, setbacks *don't* appear to save energy
  - Low capacity = long recovery, in high speed mode
  - Night setback = recovery at lowest outdoor temps
  - Both of these result in least efficiency operation
- Data from Feb-Apr 2014
  - Constant temp setting (Tin avg = 67.0 vs. 66.6)
- Better to "set it and forget it"
  - Use modest setback for several days away

Feb-Apr 2014 Performance



Feb-Apr 2014 Performance



Design thoughts: whole house retrofit

- 1st floor unit primary heating for 2-story house
  - 2nd floor unit great for cooling 2-story house
    - Ducts help—3 very low load rooms
- Most savings from first heating unit
  - Sometimes 2-3 heads for cut-up floor plans
- Any more will be for comfort, convenience
- Balance multi-head vs. multiple outdoor units
- What are client’s priorities/commitment?

Design tips:

- Don't use HSPF "as-is" to estimate or even compare performance
  - Adjust for climate using bin analysis for actual equipment
- Focus on the application
  - Sole heating source: cold weather performance/ capacity is critical
  - Retrofit to offset oil/LP/resistance heat: overall performance matters more

Insights

- Some benefits aren't limited to "ductless"…
  - Inverter drive variable speed, cold climate becoming available in central split systems
  - Better for replacement of central split systems
    - If ducts are OK, or accessible and can be fixed

Cold Climate Ductless Heat Pump

- Should provide significant cost/carbon savings
  - Compared with oil, LP gas, electric resistance
  - Most savings for biggest users
  - Most savings for first unit
- Fast payback
  - If heating bill >$2000: roughly 2-5 years

Thank you for your time!

QUESTIONS??

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