Air source

Designing with ^ Heat Pumps in Cold Climates

Energy Design Conference

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Duluth, MN

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Session Description

"For decades people have been hesitant to trust air-source heat pumps in cold climates, based on lessons learned from 1980s technology and dismal installation practices. With a current focus on low-load homes/buildings and increasing interest in strategic electrification to meet carbon reduction goals, heat pumps can be a powerful tool that delivers in both categories. This session will focus on design and application of cold climate heat pumps to maximize comfort, efficiency and value to the customer and the environment, focusing both on pro-active approaches and pitfalls to avoid."

Learning Objectives

- Understand:
  - how cold-climate heat pumps work and how they differ from typical heat pumps
  - pitfalls in design, application and installation that can lead to trouble
  - how to specify heat pumps for low-load buildings
  - when / how to use multi-zone systems
    - and when to avoid them

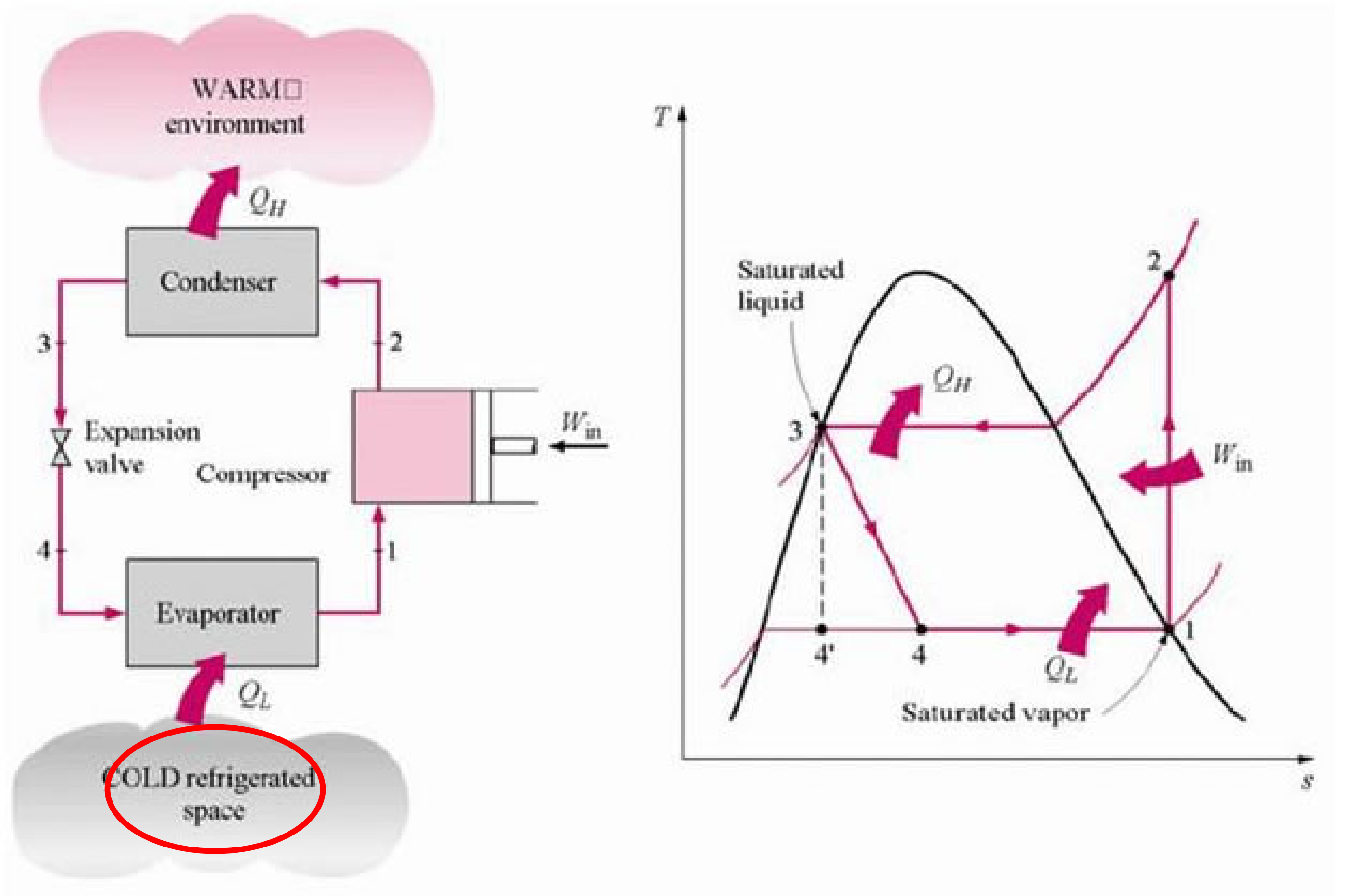
Outline

- Heat pumps explained – what and why
- Brief history, summary of some field results
- A few case studies
- Design, application, and installation insights
  - Particular focus on low-load buildings
  - Multi-zone systems – unique issues
  - Some discussion of retrofit (heating displacement)

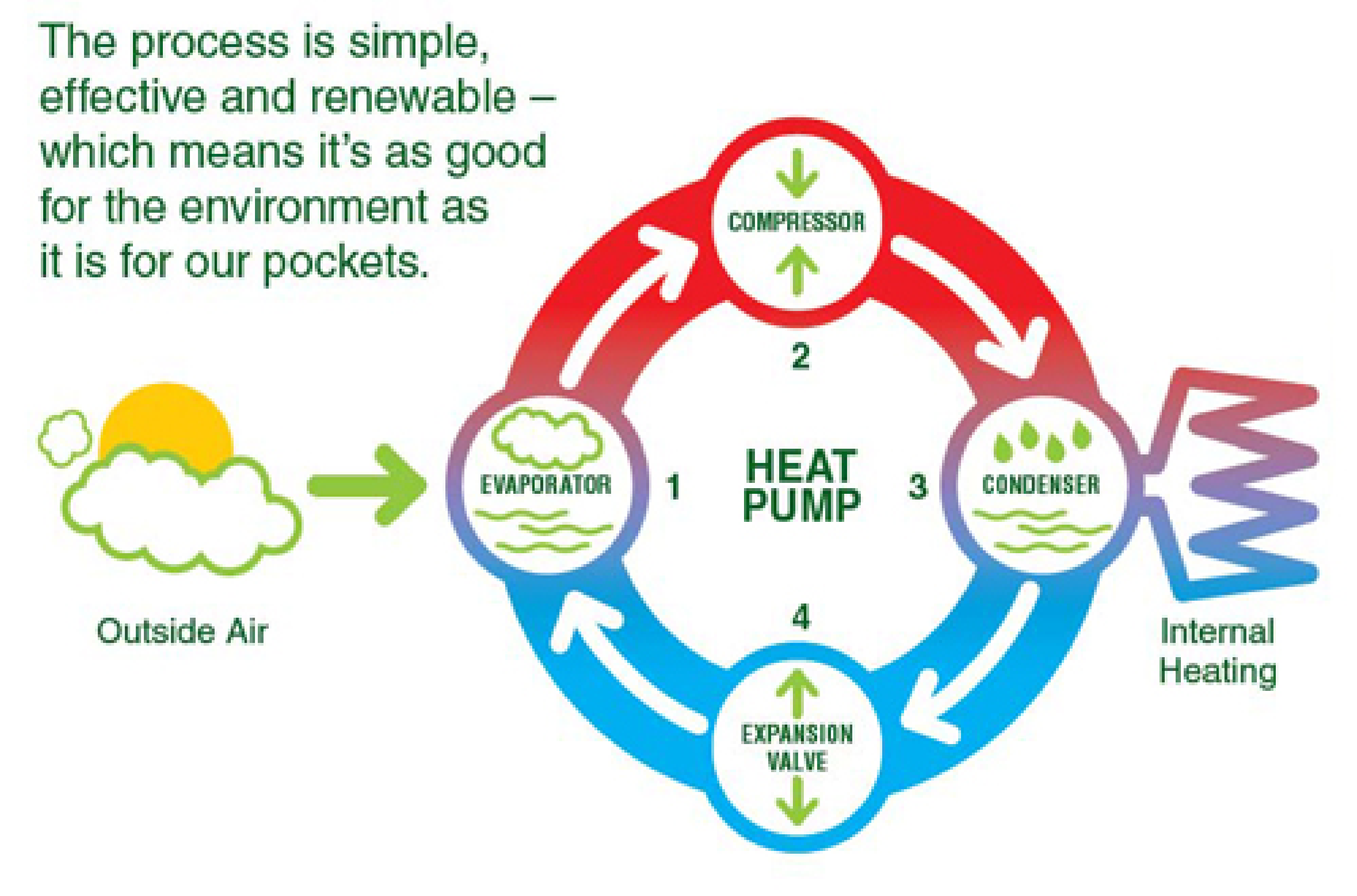
Disclosure

- My experience & this discussion based mostly on ductless and other mini-split heat pumps (e.g. compact-ducted, and mixed) systems
- Mostly residential, some small commercial
- Some of this also applies to cold-climate, central ASHP units
  - Except low-load homes would typically not have a conventional central-ducted system – too big!

Heat pumps explained



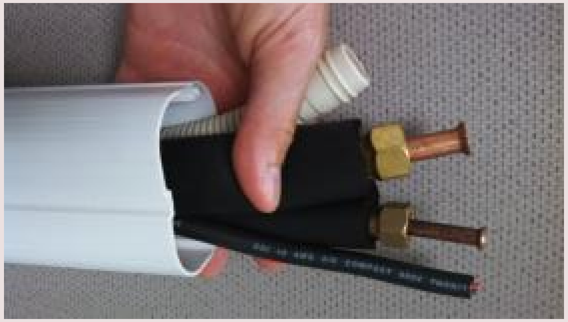
Fluffy marketing…



The real explanation…

1. Indoor unit

2. Outdoor unit



3. Line set

4. Control

Courtesy Andy Meyer, Efficiency Maine

Efficiency Terms

- **COP** = Coefficient of Performance

  = Energy Out / Energy In (like units)

  typical range 2~6 depending on conditions
- **HSPF** = rating of heating efficiency

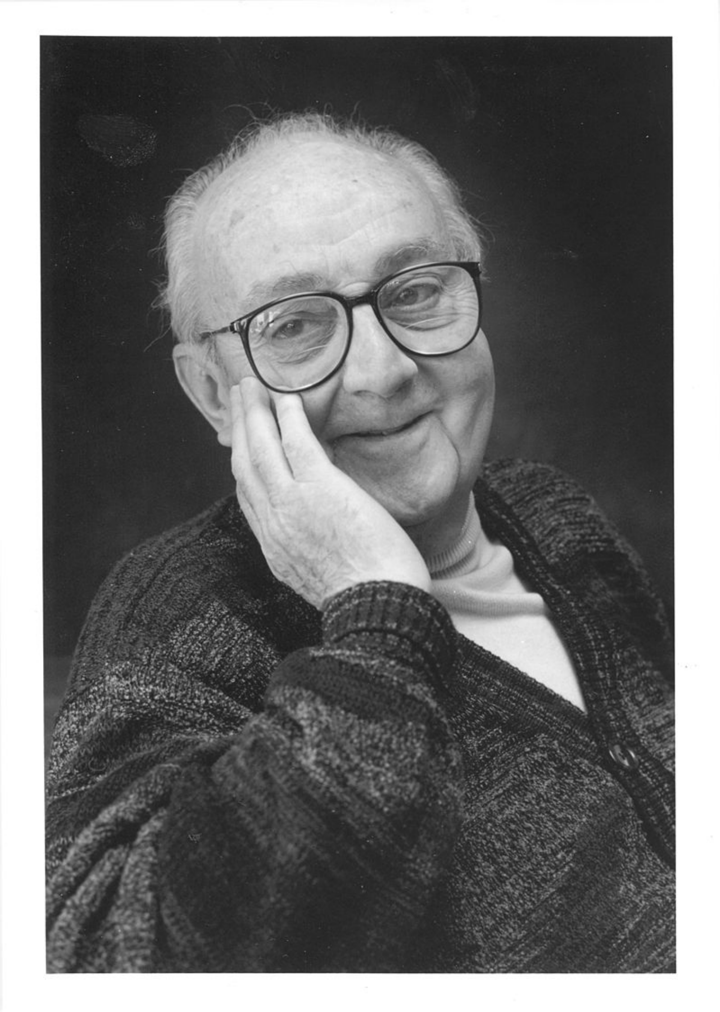
  = Energy Out / Energy In (btu/watt)
  - this is a *seasonal model* based on lab test
  - *Like* a COP * 3.41 but it’s *not measured*
  - *Many baked-in assumptions, minimal test points*

George Box (1919-2013)

“All models are wrong, but some are useful”

All **ratings** are wrong, but some are useful

CSA: Load-based test procedure coming soon (EXP07)



Other terminology

- ccASHP – cold climate air source heat pump
- DHP – ductless heat pump
- Capacity – heating or AC “output” delivered
  - kBtu/h – thousands of btu/hour
  - 1 Ton – 12,000 btu/hour
  - kW – kilowatt – 1000 watts = 3412 btu/h
- “Inverter” – fancy term for “variable speed”
  - VCHP = Variable speed heat pump

Residential Air Source Heat Pumps

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

Buying a DHP in 2012:

- 2 Local contractors I tried to get bids from:
  - “It won’t heat your house in Vermont… maybe if you were in Texas or Oklahoma”
  - “You should really get a ‘geothermal’ system… my dad and I installed lots of heat pumps in the ‘80s and they don’t work that well...”
  - Old myths die hard!

Ductless Split Heat Pumps

- 40+ years of mass-production
  - Originally designed as single-point cooling
- Steady advances:
  - System size: wider range
  - Flexibility: heating, zoning, compact ducts, etc.
  - Efficiency increase - variable speed “inverter drive”
  - Climate: optimize for cold weather
- Most have no electric resistance backup
- … these devices are *not* idiot-proof!

Hidden in soffit or above ceiling

DHP Residential Use Cases

- Offset existing heating source
  - Oil, LP, Electric resistance
  - 1-2 zones –through– complete replacement
- Exclusively heat low-load homes
  - Deep retrofit, new near/net zero
- Add HVAC to addition or new zone

Why heat pumps?

- Strategic electrification
  - Carbon reduction needs buildings off fossil fuels
  - The grid can get "greener" over time
  - Heat pumps can get more efficient over time
  - PV on- or off-site can provide electricity for individual heat pumps (annually)
  - Fossil fuel combustion will never get more efficient or have lower carbon emissions

What is a cold-climate heat pump?

- NEEP (Northeast Enery Efficiency Partnerships) ccASHP spec and listing
  - Best we have for now
- Requirements:
  - Variable speed (compressor and fans)
  - HSPF > 10 (>9 ducted or mixed)
  - COP@5°F >1.75 (at maximum capacity operation)
  - SEER > 15
  - Include min/max operating data @5, 17 & 47°F*
    - Optional low temp heating, often reported -13°F
    - Also min/max cooling at 82 & 95 °F

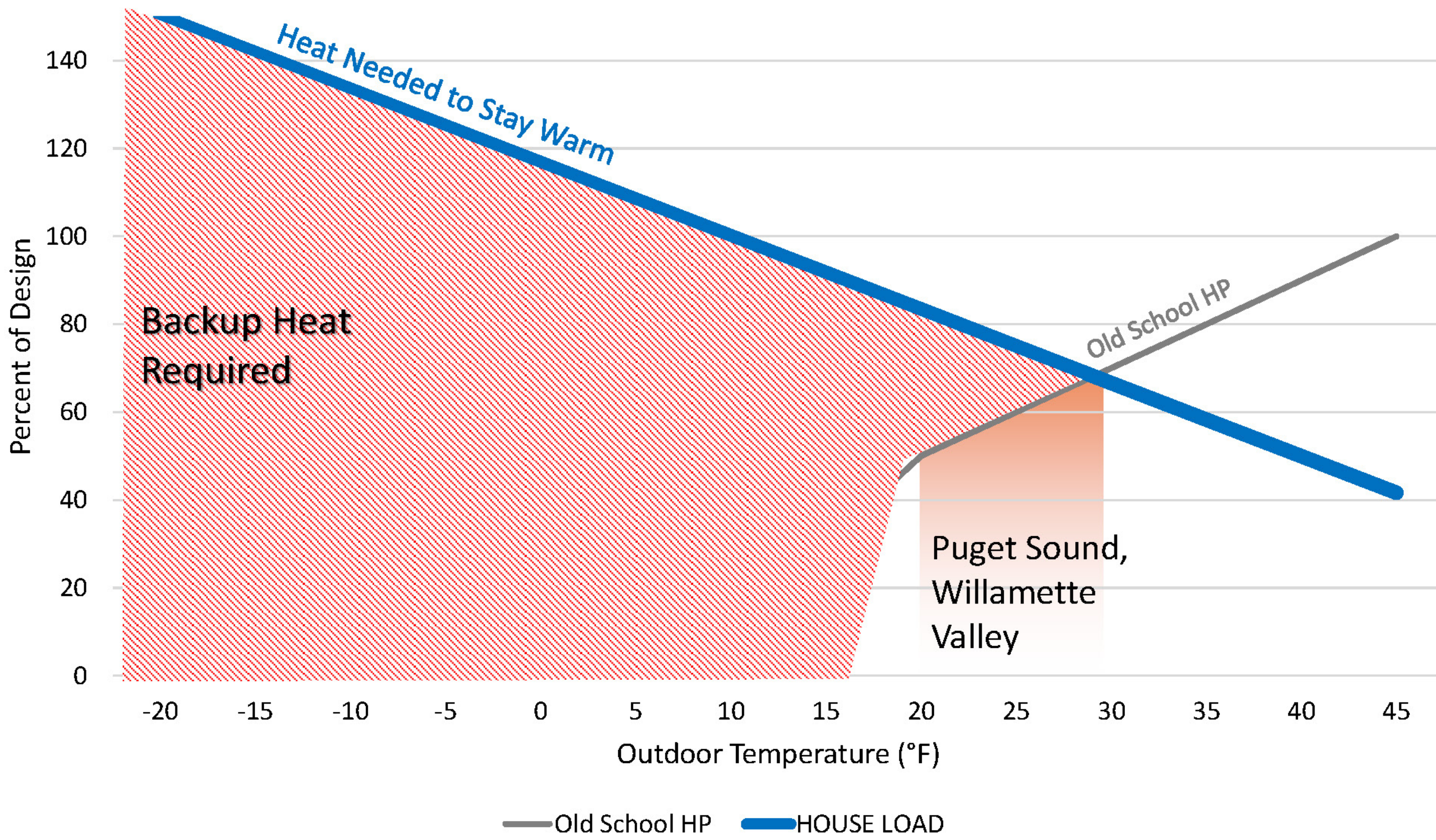
*more on this later

Why heat pumps in low-load homes?

- It's (practically) the only technology with small enough capacity for low design loads

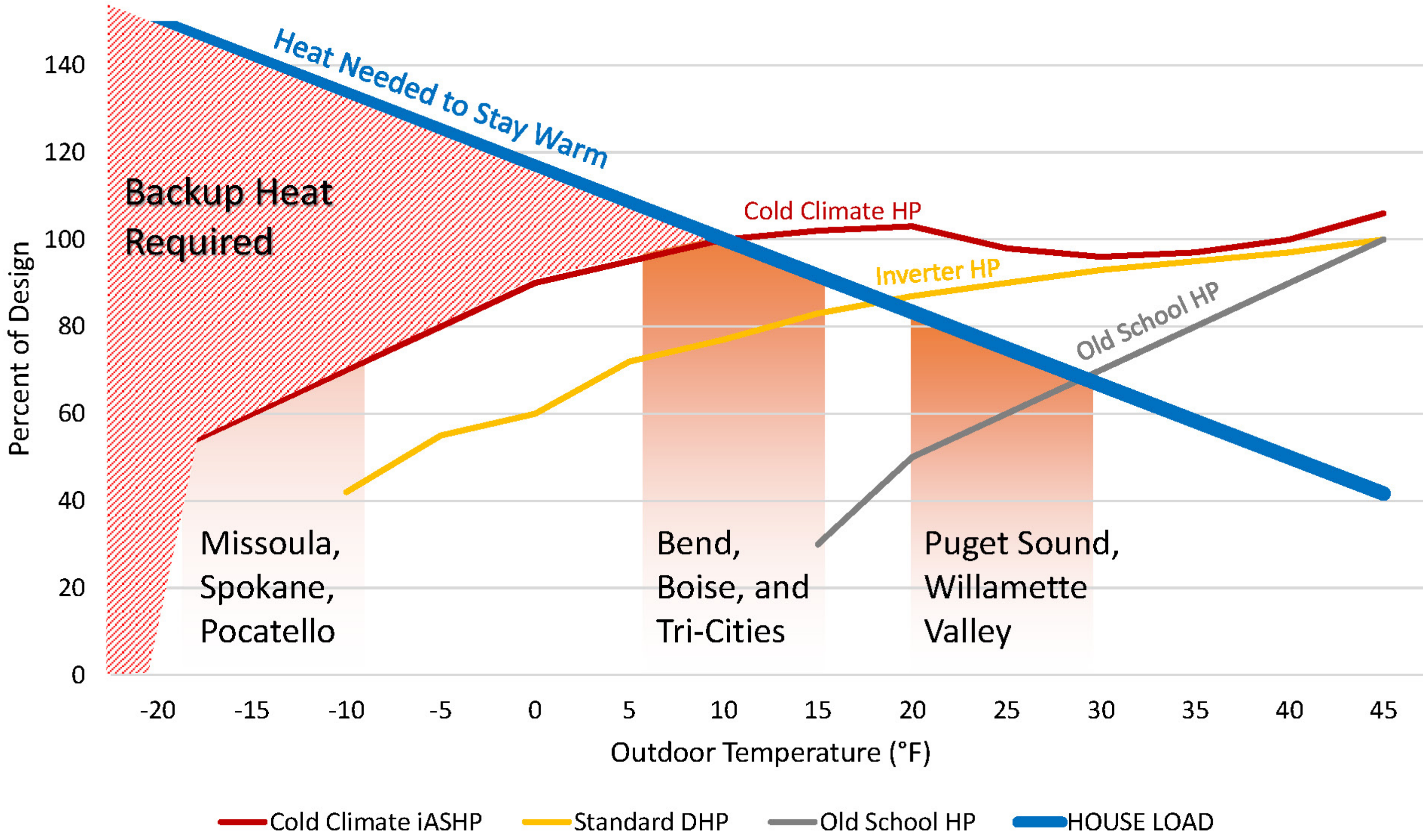
  (e.g. < 20,000 btu/h at design temps <0F)
- With some forethought, a well-planned combination can save $ on the HVAC
  - Compared with a conventional system
  - But doing it right may not be cheap…

Old School Heat Pumps



Note: these are representative curves, not a specific product

Cold Climate Heat Pumps



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neea

What makes a ccASHP tick?

- Typically variable-speed allows "overspeeding" compressor in cold weather to increase capacity
  - Other refrigerant-cycle "tricks" help optimize for cold-weather performance
  - Little or no need for auxiliary heat
  - Some units rated to full, or nearly full, rated capacity down to -22°F
- Capacity / COP still drop at low temperatures

Why is Variable Speed more Efficient?

- Variable-speed ("inverter") means when loads are small, the compressor and fans slow down
  - The heat exchangers are thus "oversized" for the needed refrigerant flow, which improves the heat transfer (more surface area = more efficiency)
  - And eliminates cycling losses by modulating to lower heating (or cooling) capacities*
- Some people think variable speed means you don't have to be very careful about sizing…
  - The reality seems to be the opposite!

*more on this later

Field Studies -some highlights

- 1990s, Ecotope (WA):
  - ASHPs used *more* energy than electric baseboard
  - But less than electric furnaces
  - Big losses in ductwork, lack of zoning contributed
  - Also other installation problems
- 2003 (Ecotope):
  - 14 electric heat homes retrofitted
  - Single-zone, “standard” mini-splits
  - Saved average of 40% (range was *very* wide)

NEEP Meta-Study (EFG, 2014)

- BHE-EMT Heat Pump Interim Report 2013
- BPA- ACEEE Performance of DHP in the Pac. NW 2010
- BPA DHP Engineering Analysis (Res) 2012
- BPA DHP Retrofits Comm. Bldgs. 2012
- BPA Variable Capacity Heat Pump Testing 2013
- Cadmus DMSHP Survey Results 2014
- CCHRC ASHP Report 2013
- CSG DHP Performance in the NE 2014
- CSG Mini-split HP Efficiency Analysis 2012
- DOE DHP Expert Meeting Report 2013
- DOE DHP Fujitsu and Mitsubishi Test Report 2011
- DOER Renewable Heating & Cooling Impact Study 2012
- DOER Renewable Thermal Strategy Report 2014
- Ductless Mini-Split Heat Pump Customer Survey Results
- Eliakim's Way 3 Year Energy Use Report 2013
- EMaine Case Study (Andy Meyer) 2014
- Emaine EE Heating Options Study 2013
- Emaine LIWx Program Checkup 2014
- Emera Maine Ductless Heat Pump Pilot Program 2014
- KEMA Ductless Mini Pilot Study & Update 2009-2011
- Mitsubishi Heat Pump Market Data 2011
- Mitsubishi Indoor Unit Brochure 2011
- Mitsubishi M-series Features & Benefits 2011
- NEEA DHP Billing Analysis Report 2013
- NEEA DHP Evaluation Field Metering Report 2012
- NEEA DHP Final Summary Report 2014
- NEEA DHP Impact Process Eval Lab Testing Report 2011
- NEEA DHP Market Progress Eval 2 2012
- NEEA DHP Market Progress Eval 3 2014
- NEEP DHP Report Final 2014
- NEEP incremental cost study
- NEEP Strategy Report 2013
- NREL Improved Residential AC & Heat Pumps 2013
- Rocky Mountain Instit. DHP Paper 2013
- SCEC DHP Work Paper 2012
- Synapse Paper 2013 Heat-Pump-Performance
- VEIC Mini Split Heat Pump Trends 2014
- VELCO Load Forecast with Heat Pumps 2014

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Some Recent Studies

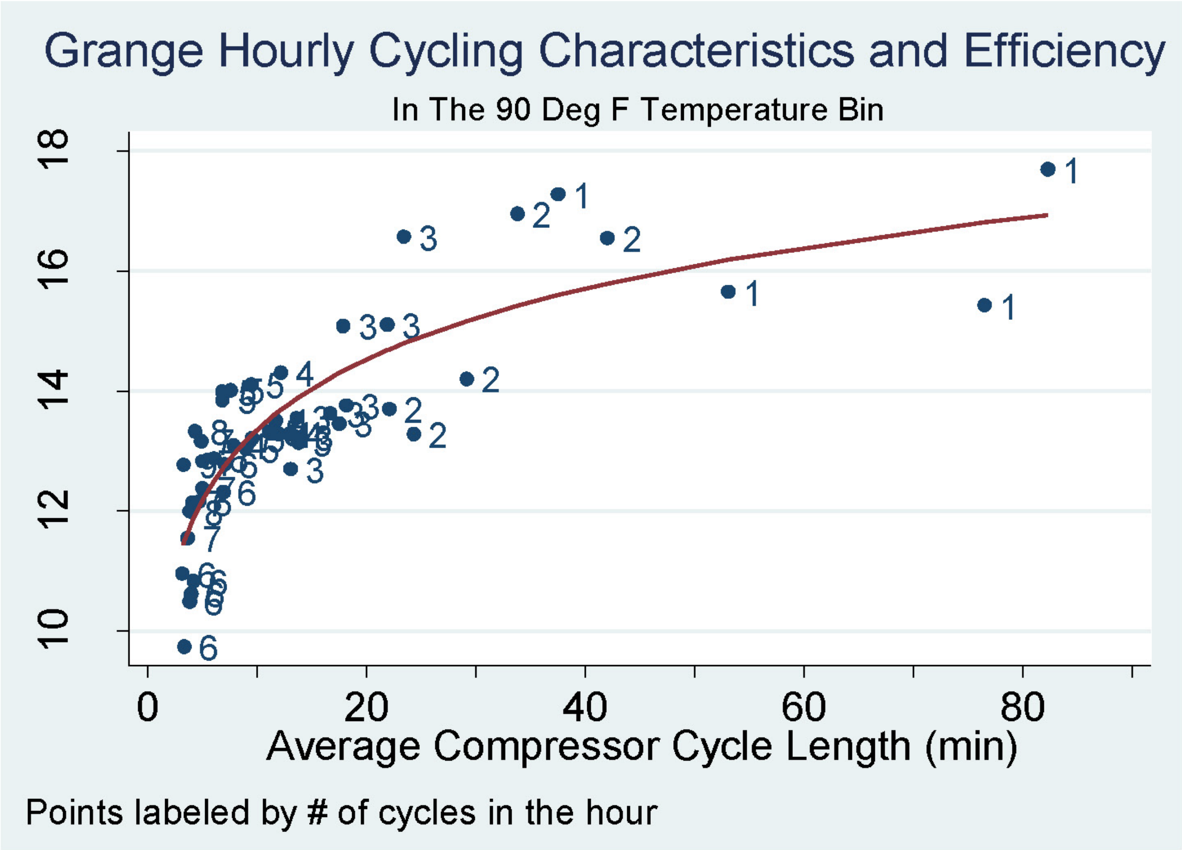
- Building Science Corp (Building America) 2014
  - Long term monitoring in *8 low-energy homes*
  - Predictable issues with indoor distribution
  - Big issue with “on/off” (*deep* setback = poor eff.)
- Steven Winter (Building America) 2015:
  - Measured 7 mini-splits retrofitted in homes
  - COP range from **1.1 – 2.3**
  - Issues: low air flow, high inlet temperature, poor integration with central heat

Recent Studies

- Cadmus 2016 MA/RI impact evaluation:
  - 152, CC/NonCC, average rated HSPF 9-11
    - Operating hours much lower than expected (only ran 19-27% of the time in winter!)
    - Efficiencies somewhat lower than ratings
    - Net result: savings pretty small
  - Issues: lack of use (many installed w/AC focus)
    - need better controls/thermostat placement
    - multi-zone had lower efficiency
- Cadmus 2017 VT evaluation:
  - Better efficiencies, more run time (still/ not optimal), more owner awareness as heating appliance, generally better installation quality

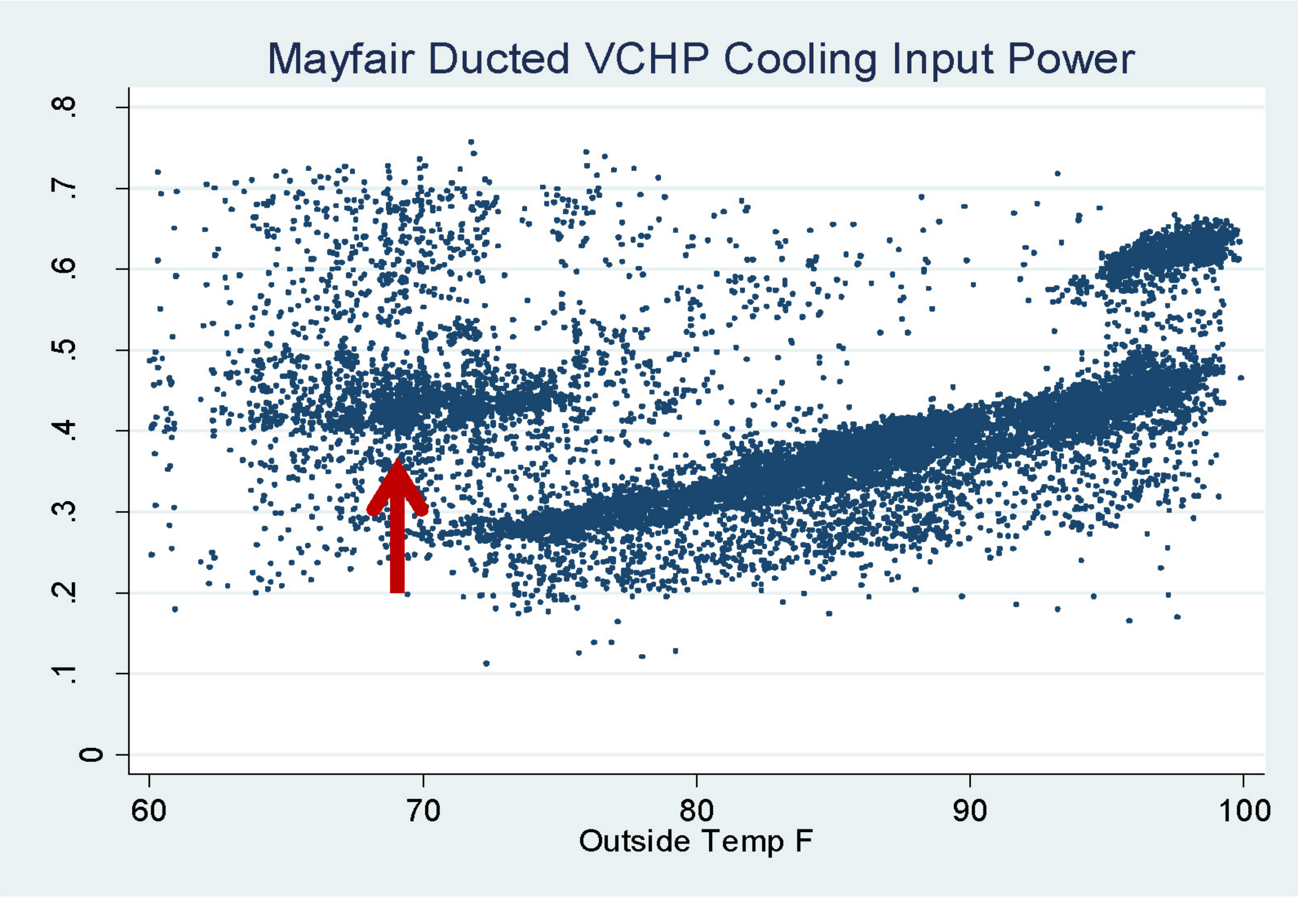
Stockton, CA Field Research

Cycling Losses



Stockton, CA Field Research (AC)

Unexpected Controls Behavior



My Own Home

- Summary:
  - DHP Installation: Stamford, VT   July, 2012
  - Modestly efficient, 2400 SF house
  - 2 units, 3 zones
  - Monitored 9/2012-4/2014,
  - Co-heat test: resistance heat, 14 days

1st Floor Unit - 12 HSPF

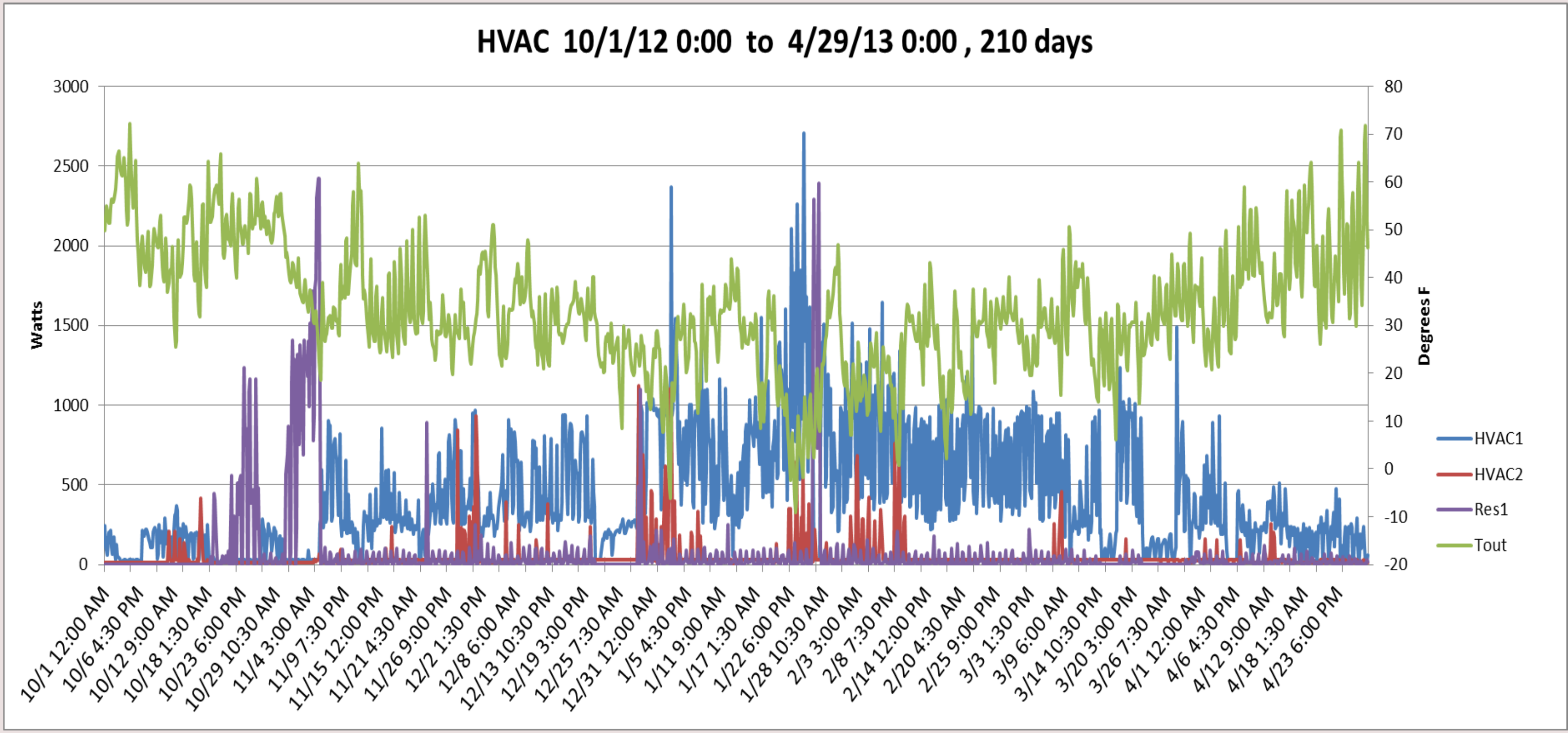
Outdoor Unit

Attic, 2nd floor, VS but NOT ccASHP

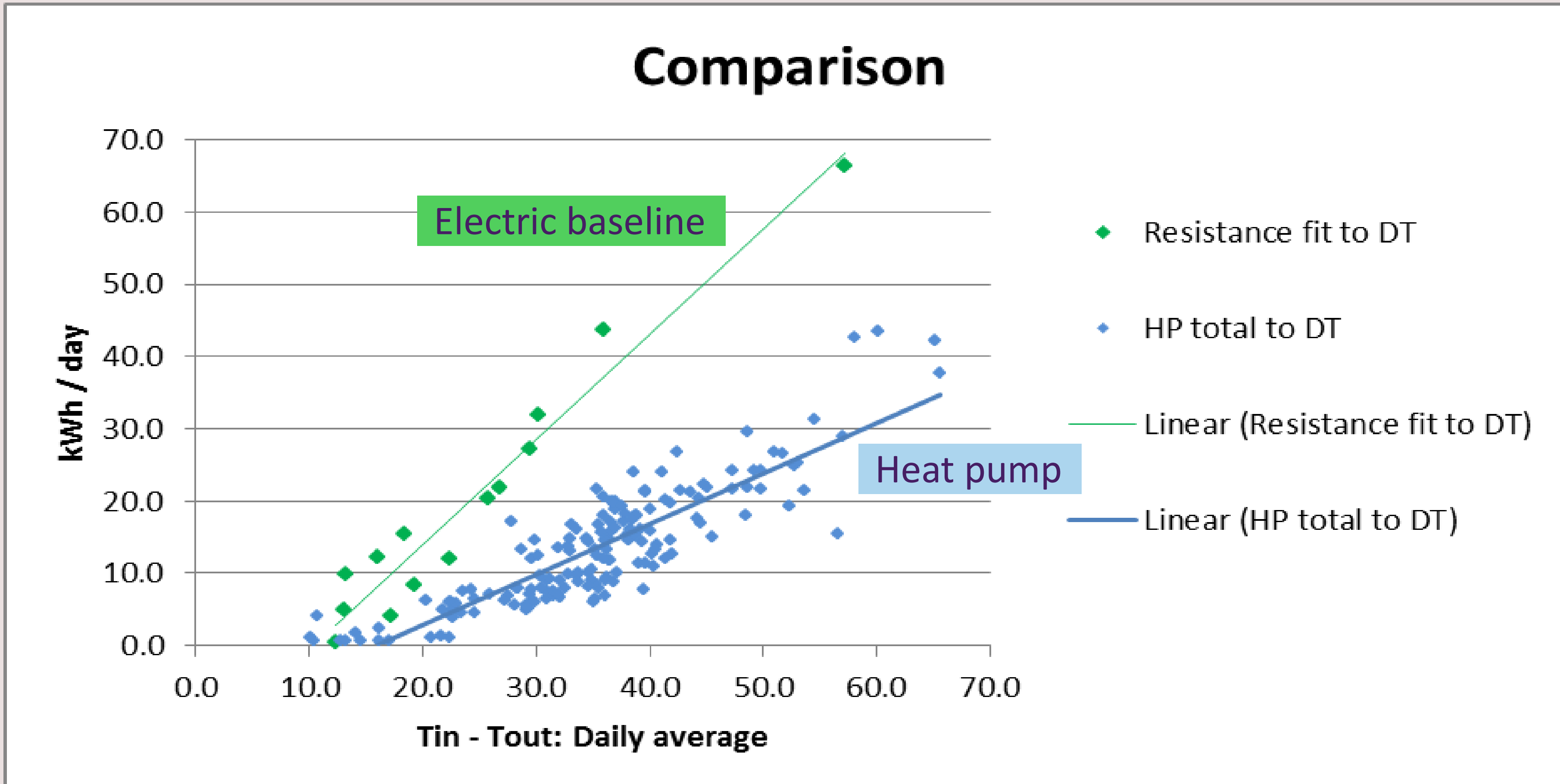
2-zone, 9 HSPF

2nd Floor Air Handler

HVAC kWh and Tout



Resistance vs DHP



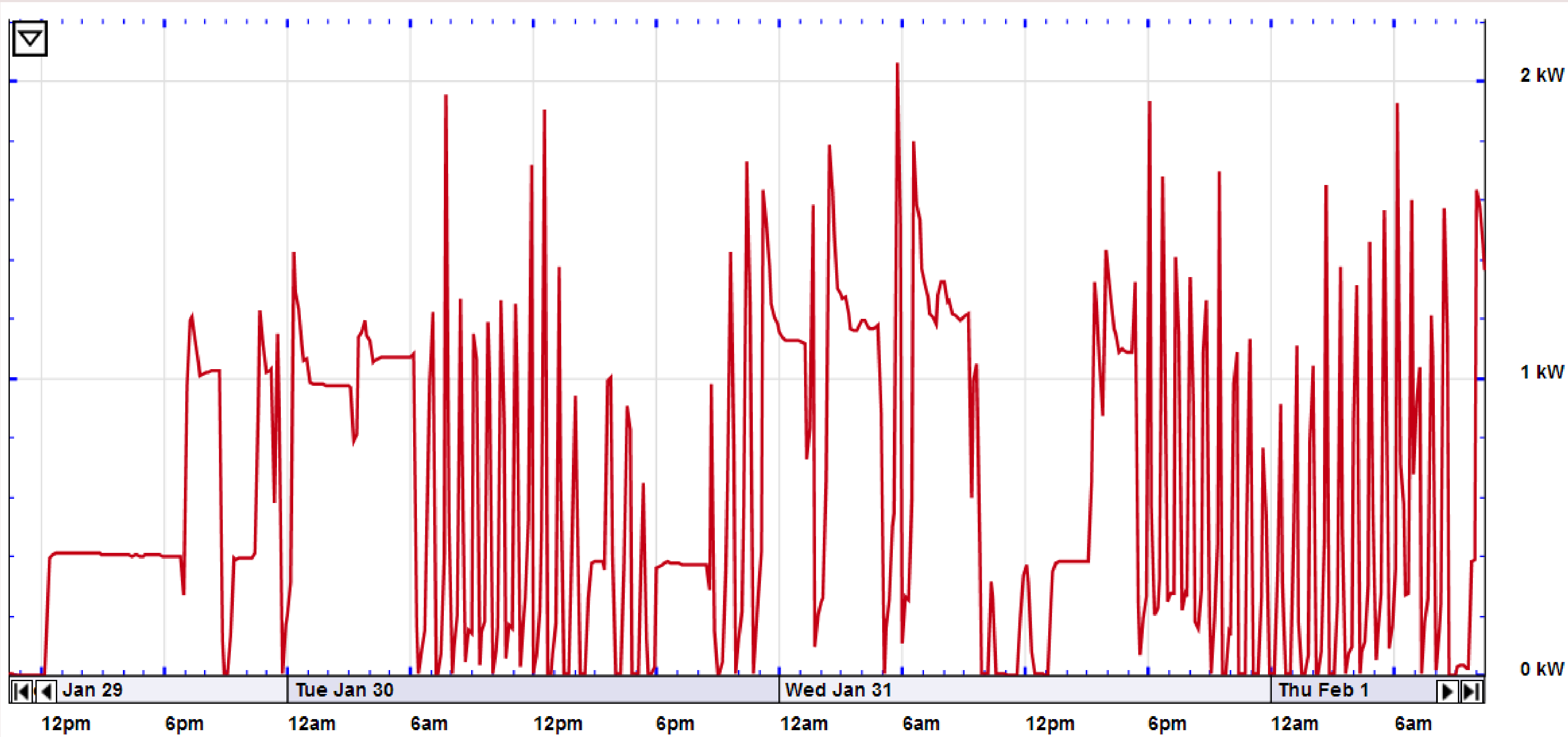
My house: Projected vs. Actual

	Projected	**Actual**
Load	7740 kWh	7358
Consumption	3067 kWh	2794
Cost	$460	$419
COP	**2.5**	**~ 2.8**

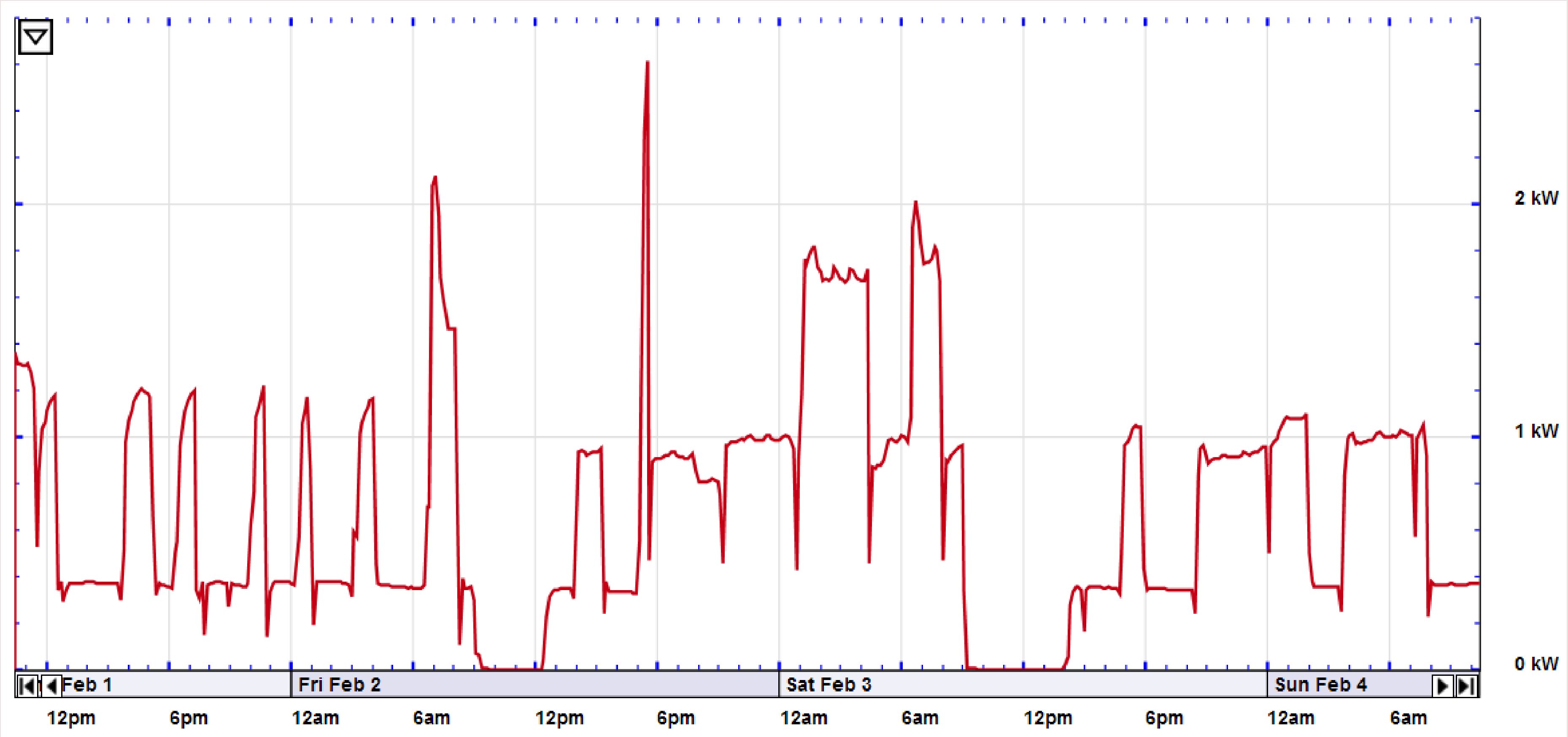
Installer settings

- Need to override setting that reverts to factory default on power outage
- Fujitsu – need to select “high insulation” setting in installer menu… (somewhat tricky)

My heat pump, Jan 2018:



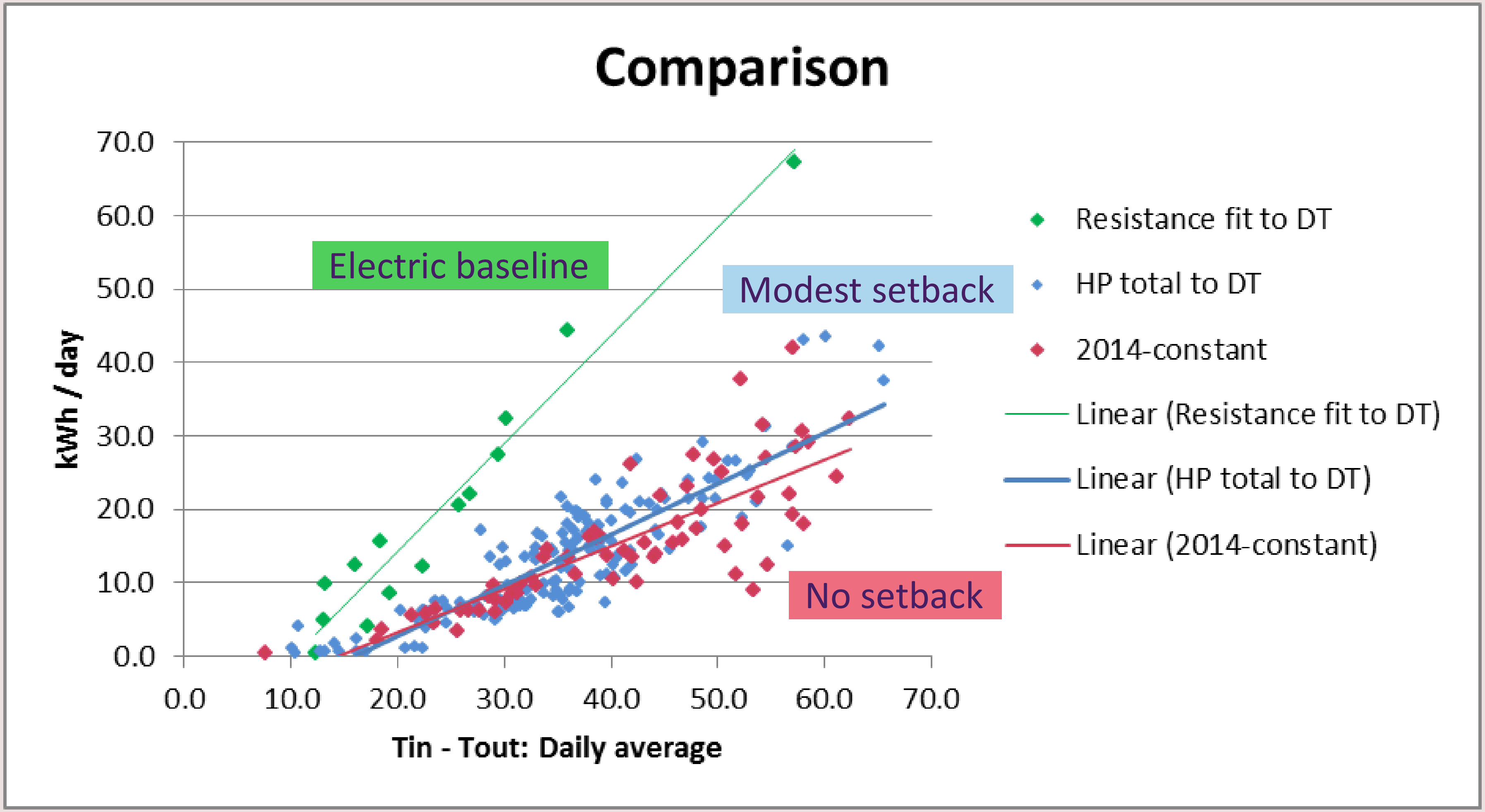
Next Day: “high insulation” setting



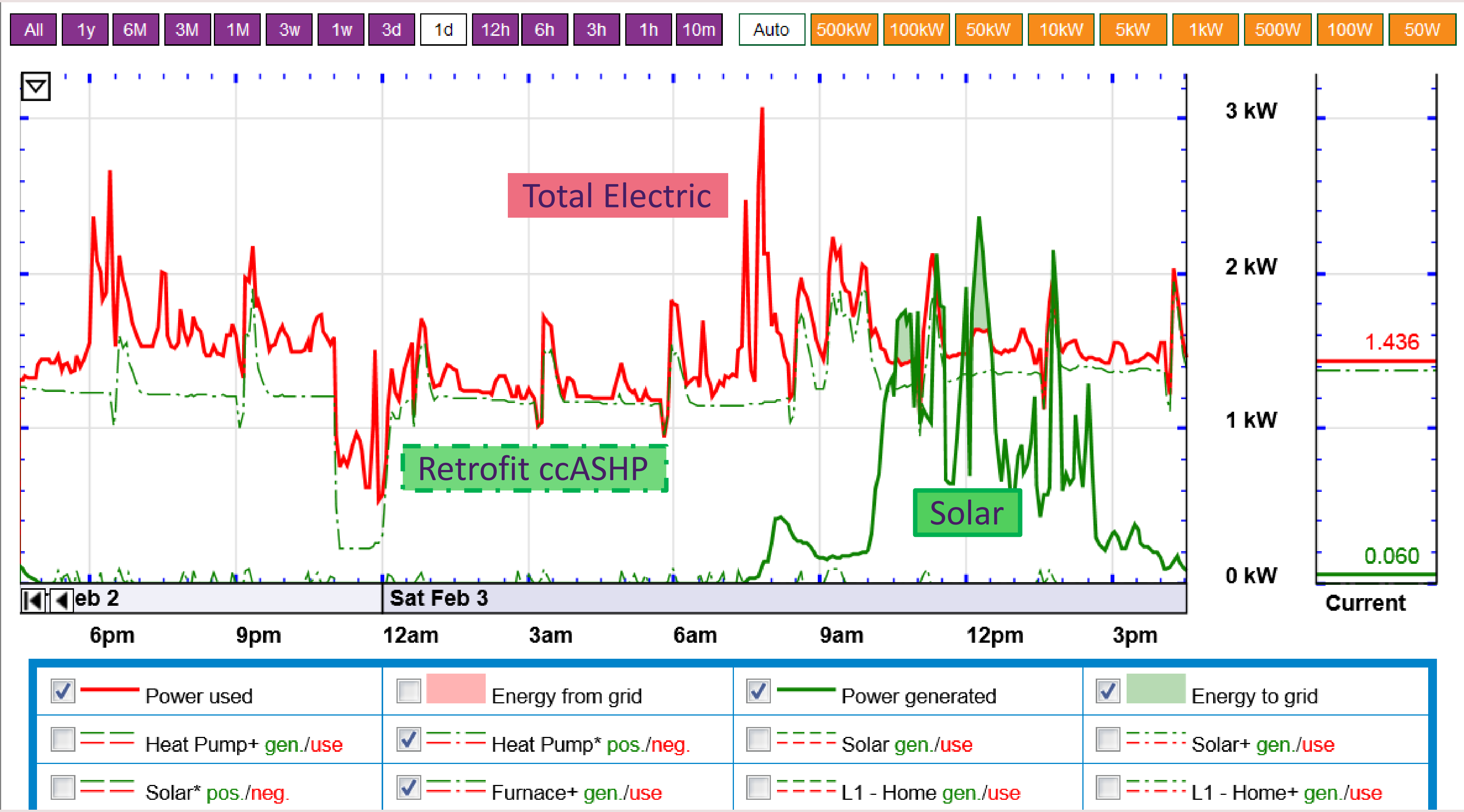
Temperature Setbacks

- For VCHP, setbacks don’t save much
  - Deep setback = high speed mode during recovery
  - Early morning recovery = lowest outdoor temps
  - Both of these = least efficient operation
- Better to “set it and forget it”
  - Adjust modestly for comfort, as needed
  - Use setback for > several days away
  - Don’t expect fast recovery! Not a lot of excess capacity

My house Setback vs. Constant



1 recent retrofit NY State



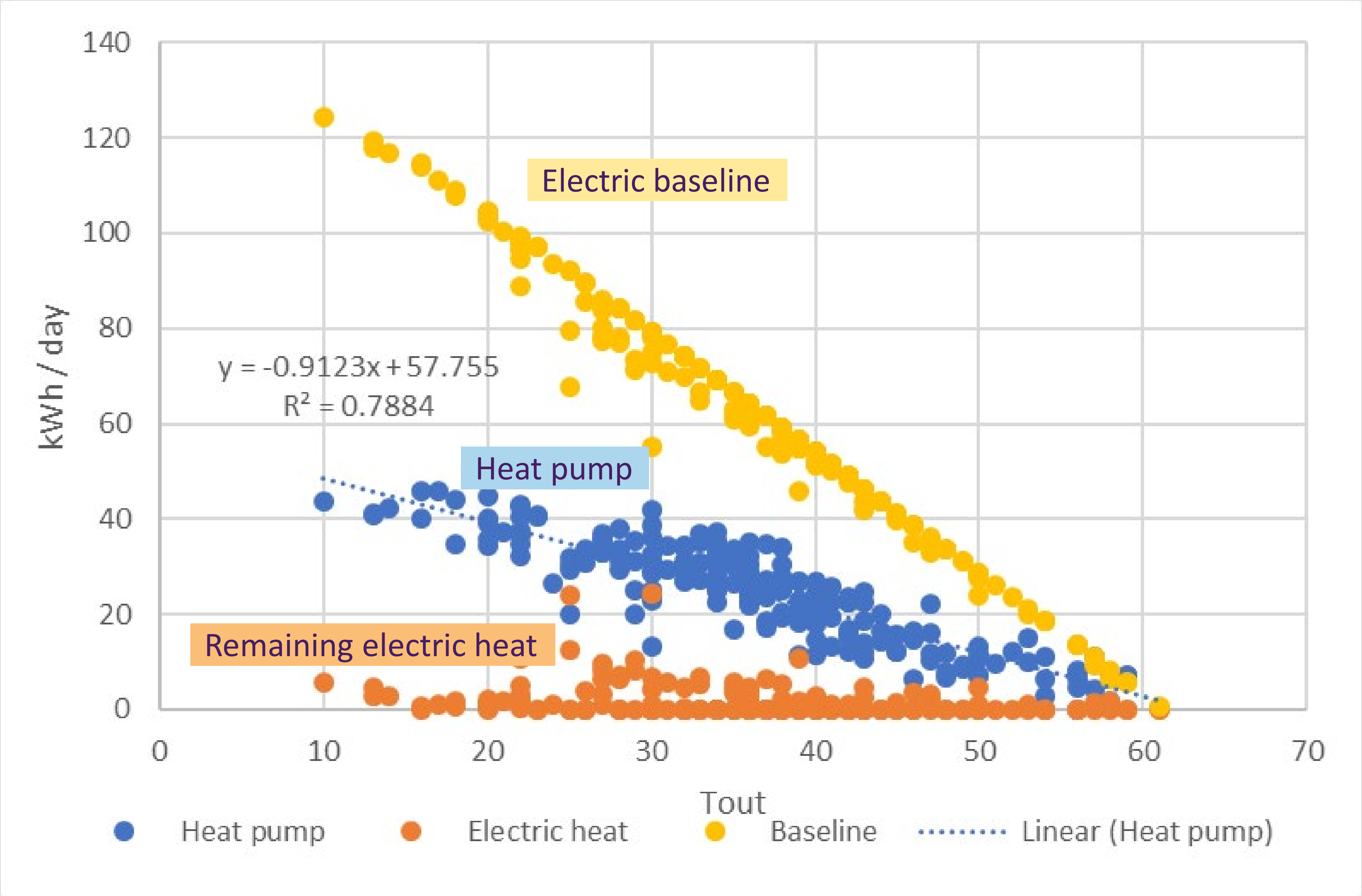
Gas Boiler, 1.5 Ton Cold Climate HP

- 1500 SF ranch, 3 bedroom. Open floor plan
  - Separate gas DHW – conventional tank (new)
  - Moved boiler thermostat to master bedroom
  - Installed wall-mount thermostat opposite HP
- Savings: **approx. 65% of gas heating**
- Savings: approx. 46% of all gas
  - Preliminary results, will get official M&V later

2^{nd} NY site: Electric Resistance Heat

- 2-story, 1 ½ bedroom
- Pre-heat pump billing data is baseline
- Based on logger data 1/13/18 - 1/10/19:

Net COP (incl. "aux")	**2.6**
COP - HP only	**2.7**
Heating Savings	**61%**
would have used kWh:	13847
Actually used kWh	8449



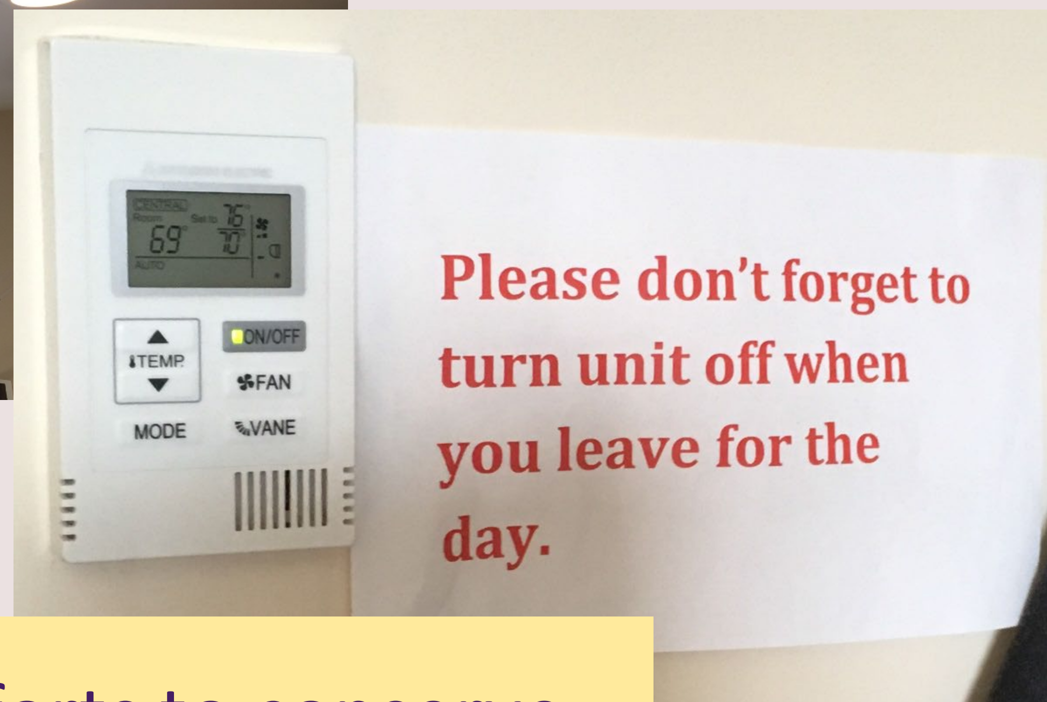
140
120
100
80
60
40
20
0
kWh / day
0
10
20
30
40
50
60
70
Tout
Electric baseline
y = -0.9123x + 57.755
R² = 0.7884
Heat pump
Remaining electric heat
Heat pump
Electric heat
Baseline
Linear (Heat pump)

7000 SF – new office/classroom (NZ-A*)

"Service disconnect" (manual switch): used as "on-off" in meeting/classroom spaces to control noise/blowing air

*Net Zero - Aspirational

Discomfort, noise: “fan-on” overrides occupant settings



Misguided efforts to conserve

Fixes…

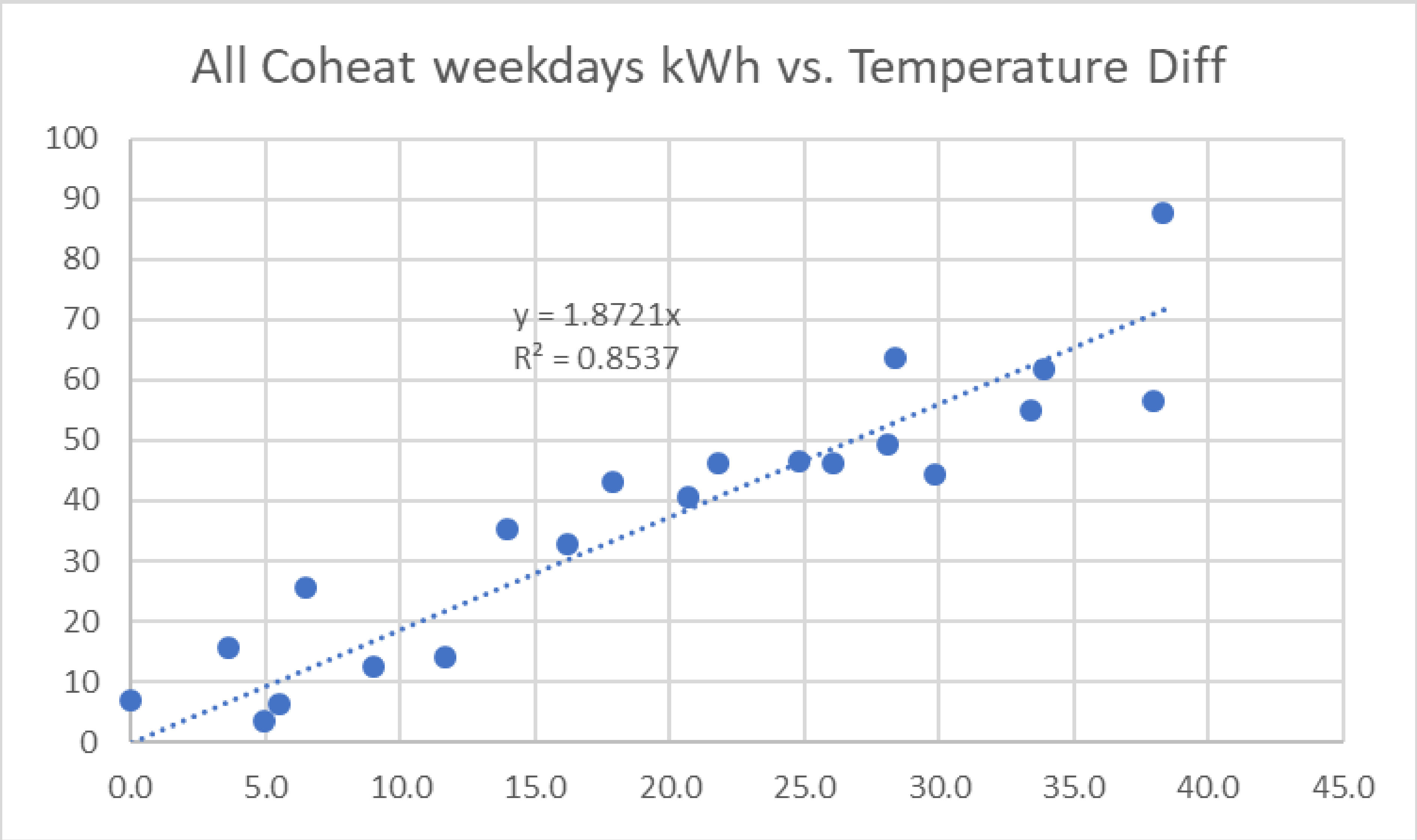
- Programmed to allow occupant fan control
- Memo: leave temp settings steady
  - Manual setbacks, if done, are overridden late PM
- Results:
  - Base energy: modest decrease (1kW -> 600W)
  - Heating energy: virtually the same
  - Happier, more comfortable people!

Office Building, Northern VT

- 2-story, 2700 SF NZE remodel
- Equipment
  - Outdoor: (2), 2-ton (nominal), multi zone
  - Indoor wall units
    - Owner’s half has 15 kBtu + 12 kBtu
    - Rental spaces have 15 kBtu + (2x) 6 kBtu

Coheating Test

- Heated building with electric resistance heaters (3 week+ long periods)
  - Monitored with dataloggers
- kWh vs. outdoor temp -> heat loss
- Heat loss of whole building: about 20 kbtu/h
- Compare actual heat pump energy, results:
  - COP_H for 1 Oct, 17 to 1 May, 2018 is **1.4**
  - *Not* counting resistance heat periods


All Coheat weekdays kWh vs. Temperature Diff
y = 1.8721x
R² = 0.8537
100
90
80
70
60
50
40
30
20
10
0
0.0
5.0
10.0
15.0
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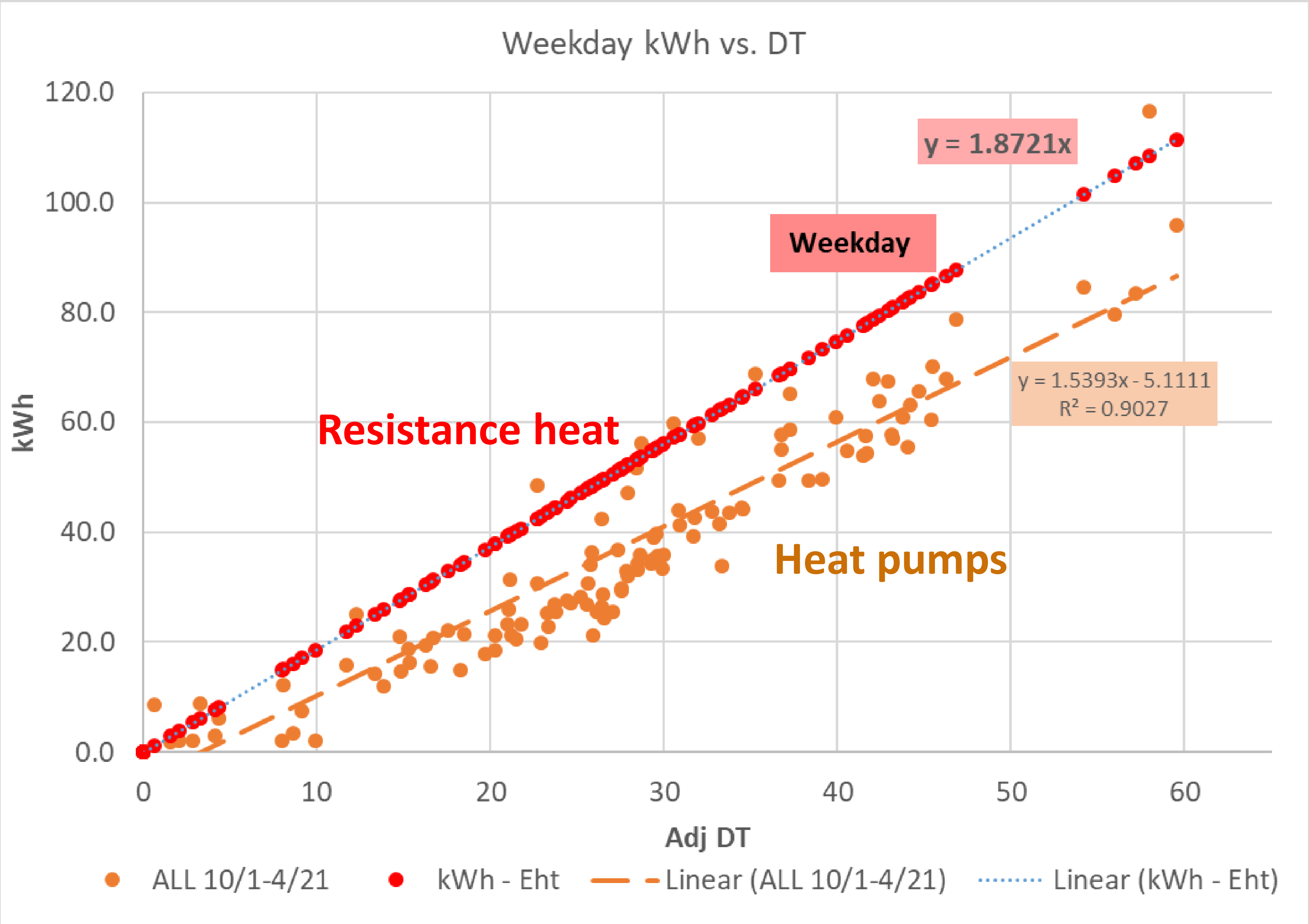
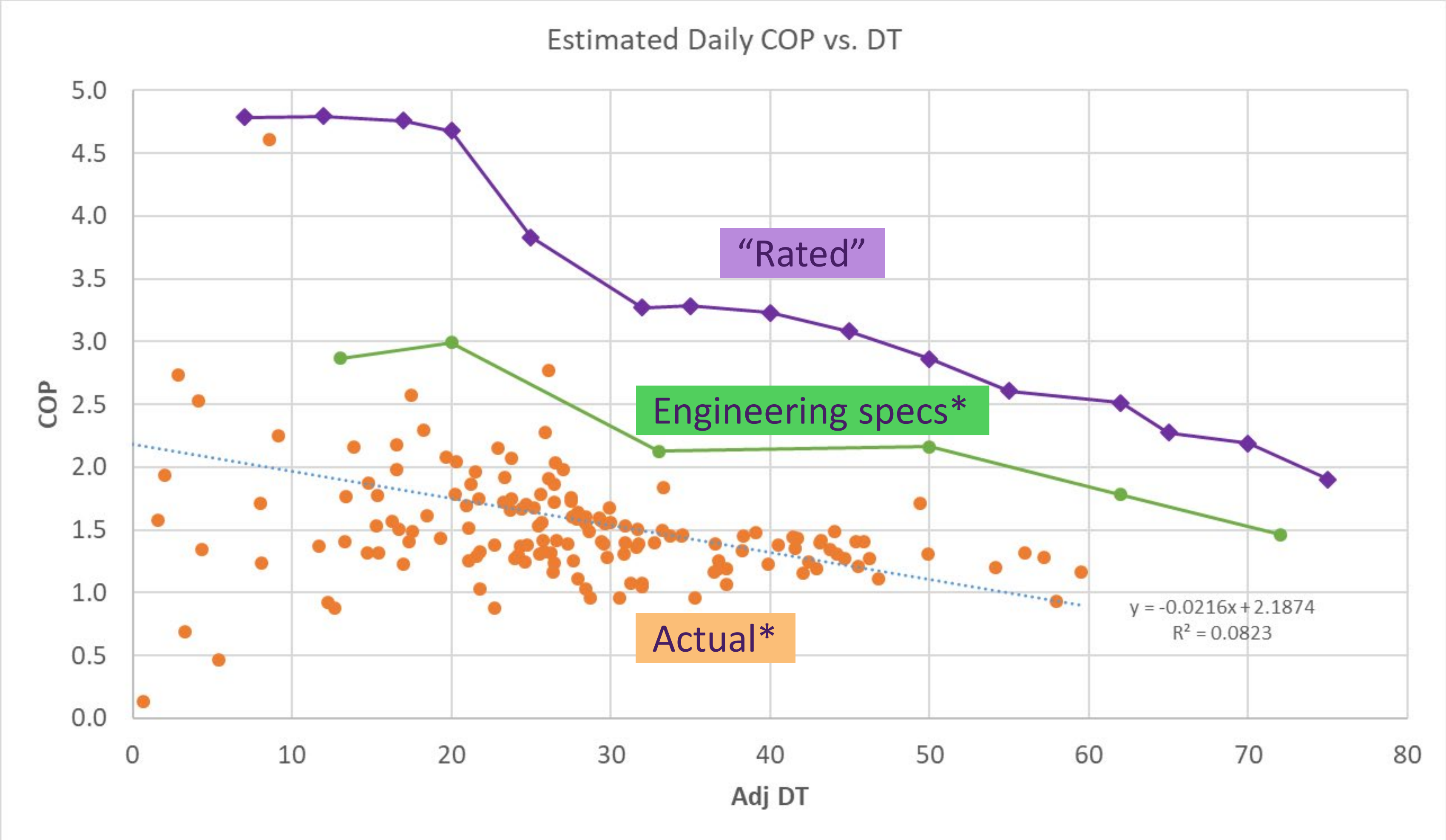
25.0
30.0
35.0
40.0
45.0


Weekday kWh vs. DT
120.0
100.0
80.0
60.0
40.0
20.0
0.0
kWh
0
10
20
30
40
50
60
Adj DT
y = 1.8721x
Weekday
Resistance heat
y = 1.5393x - 5.1111
R² = 0.9027
Heat pumps
ALL 10/1-4/21
kWh - Eht
Linear (ALL 10/1-4/21)
Linear (kWh - Eht)

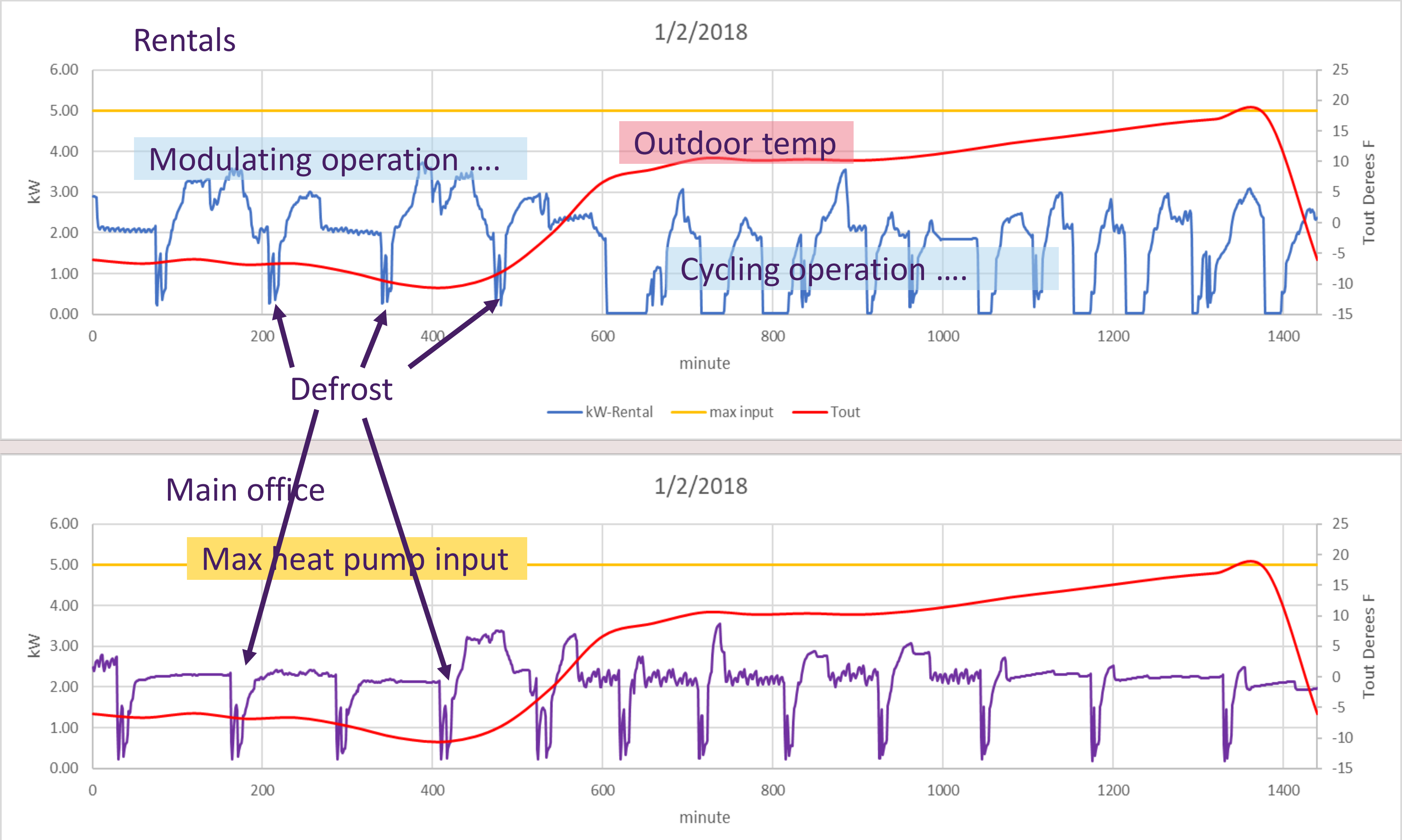
Compare to rated & engineering:



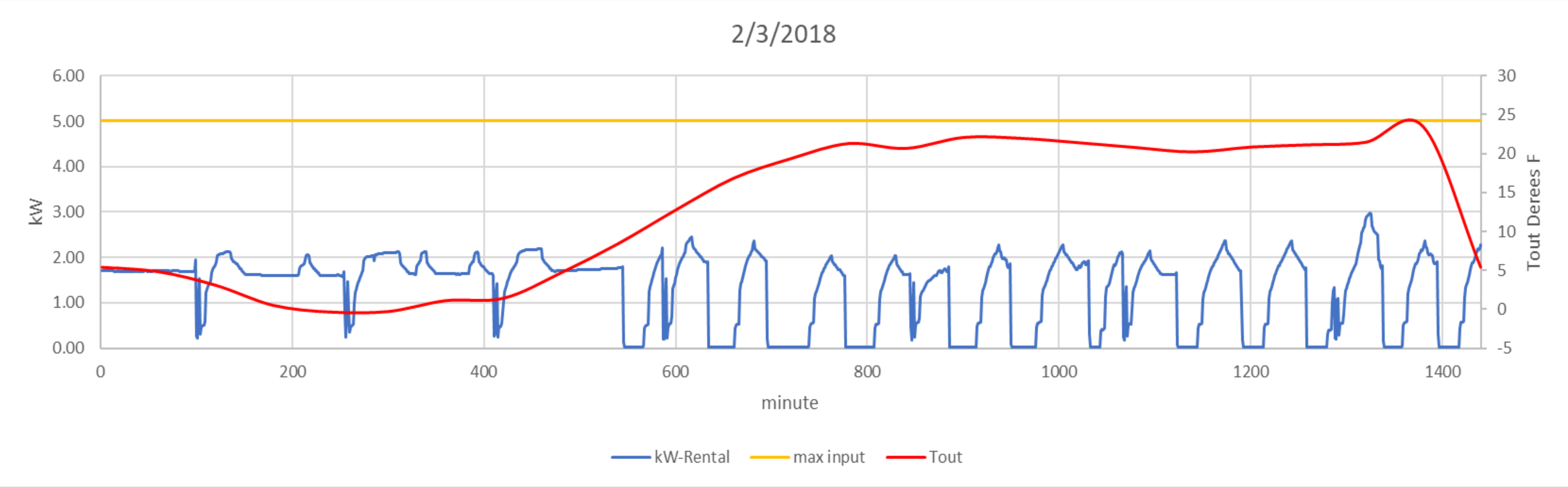
*Not an exact comparison; engineering specs are steady state, not daily; and don't include defrost

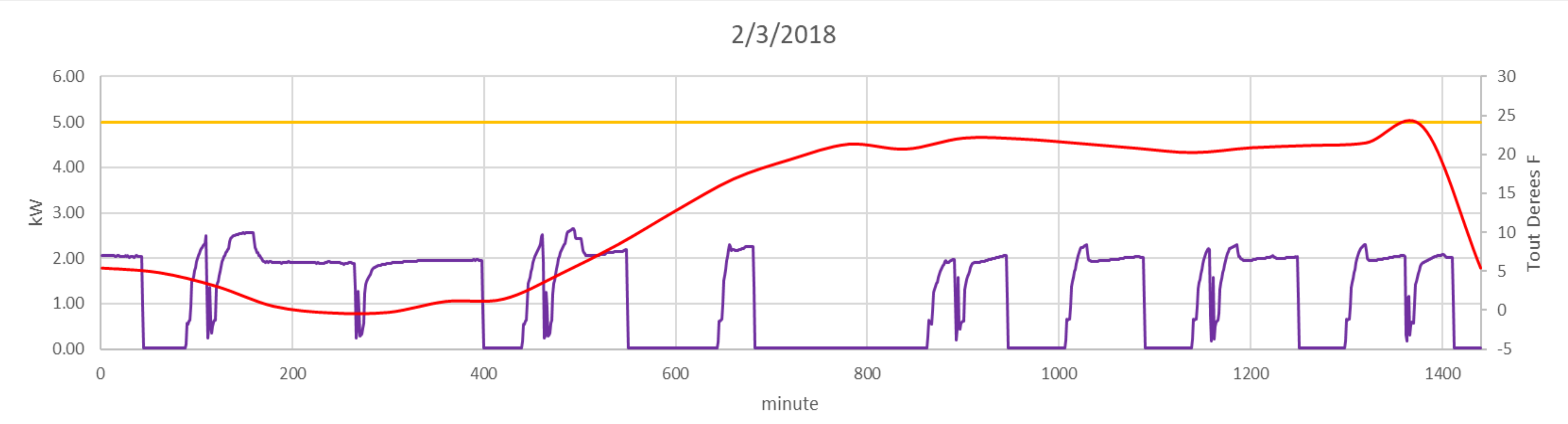
Design day, modulates ~50% COP=1.2 (*1.8**)

**COP should be*

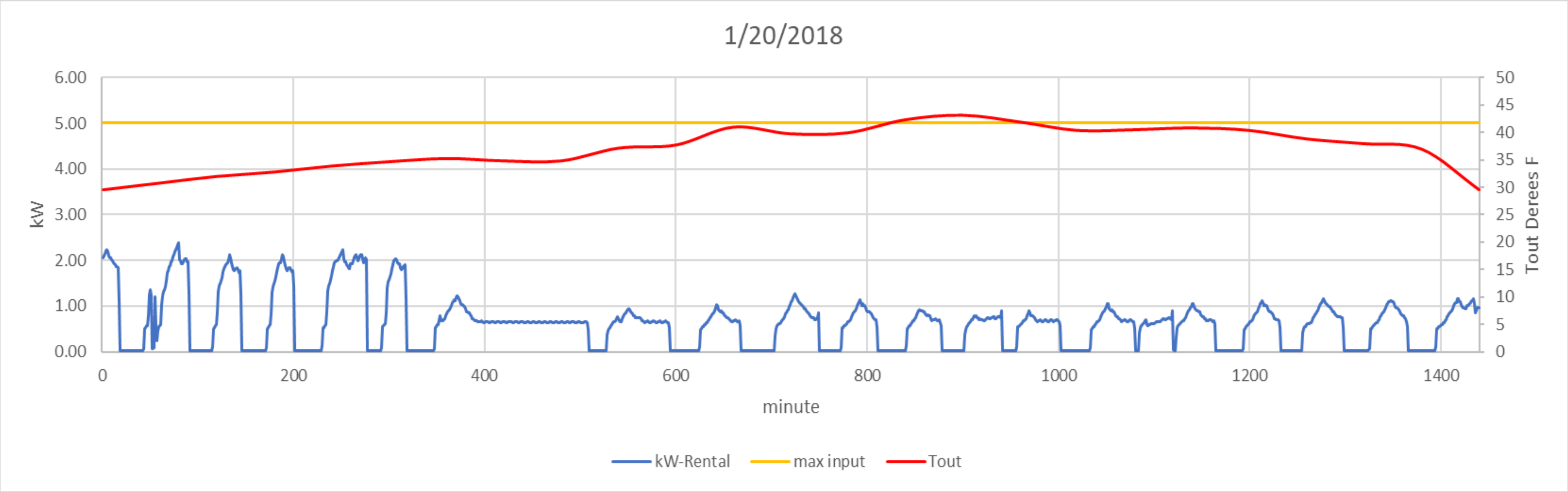


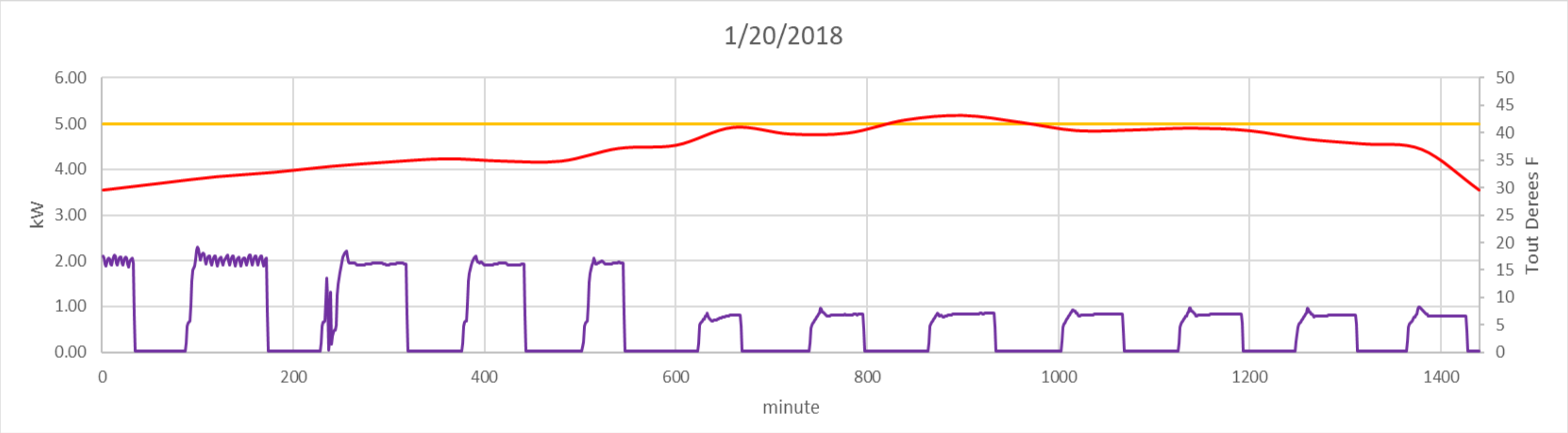
Cold day, cycling starts >10F



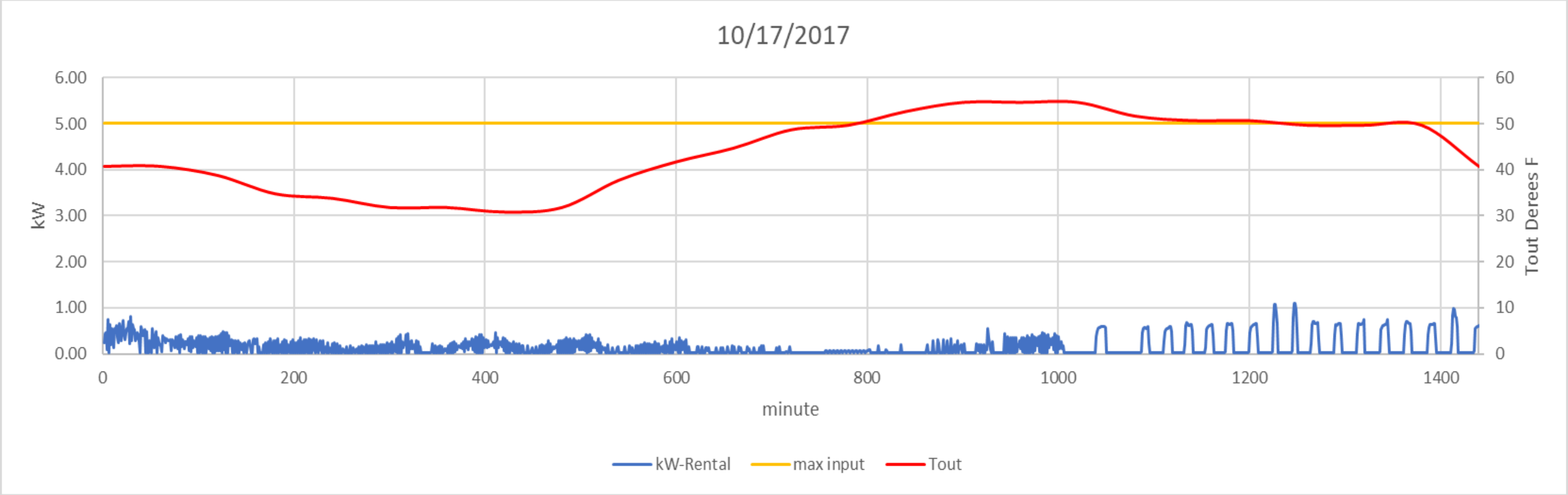


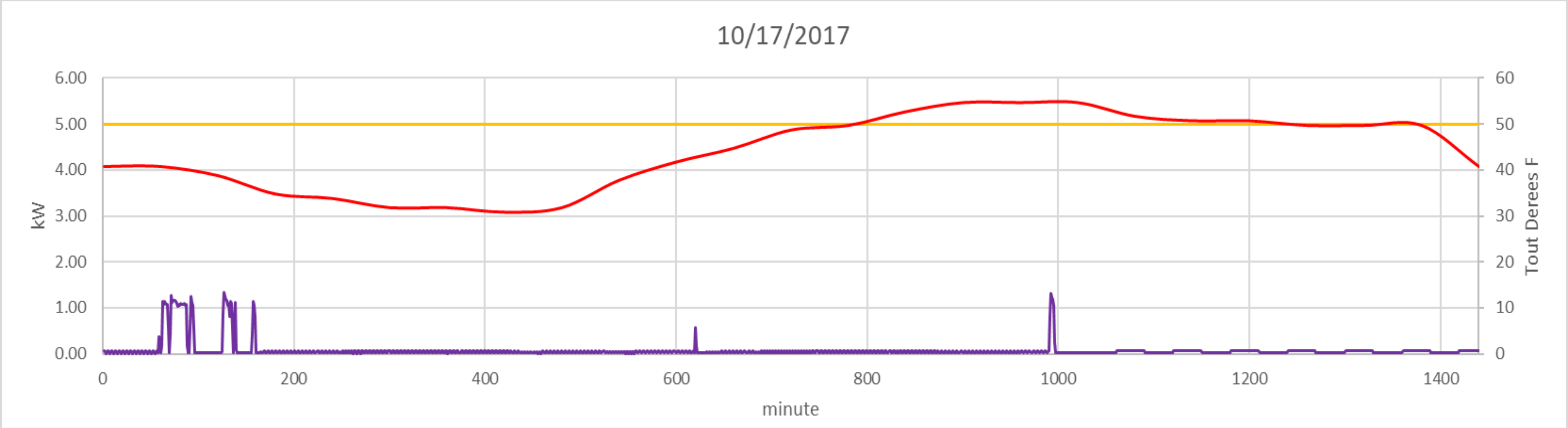
35F day, cycles ~0.6 to 2 kW COP=1.3 (2.9)





50F, cycling (rental) COP 2.2 (3.2)

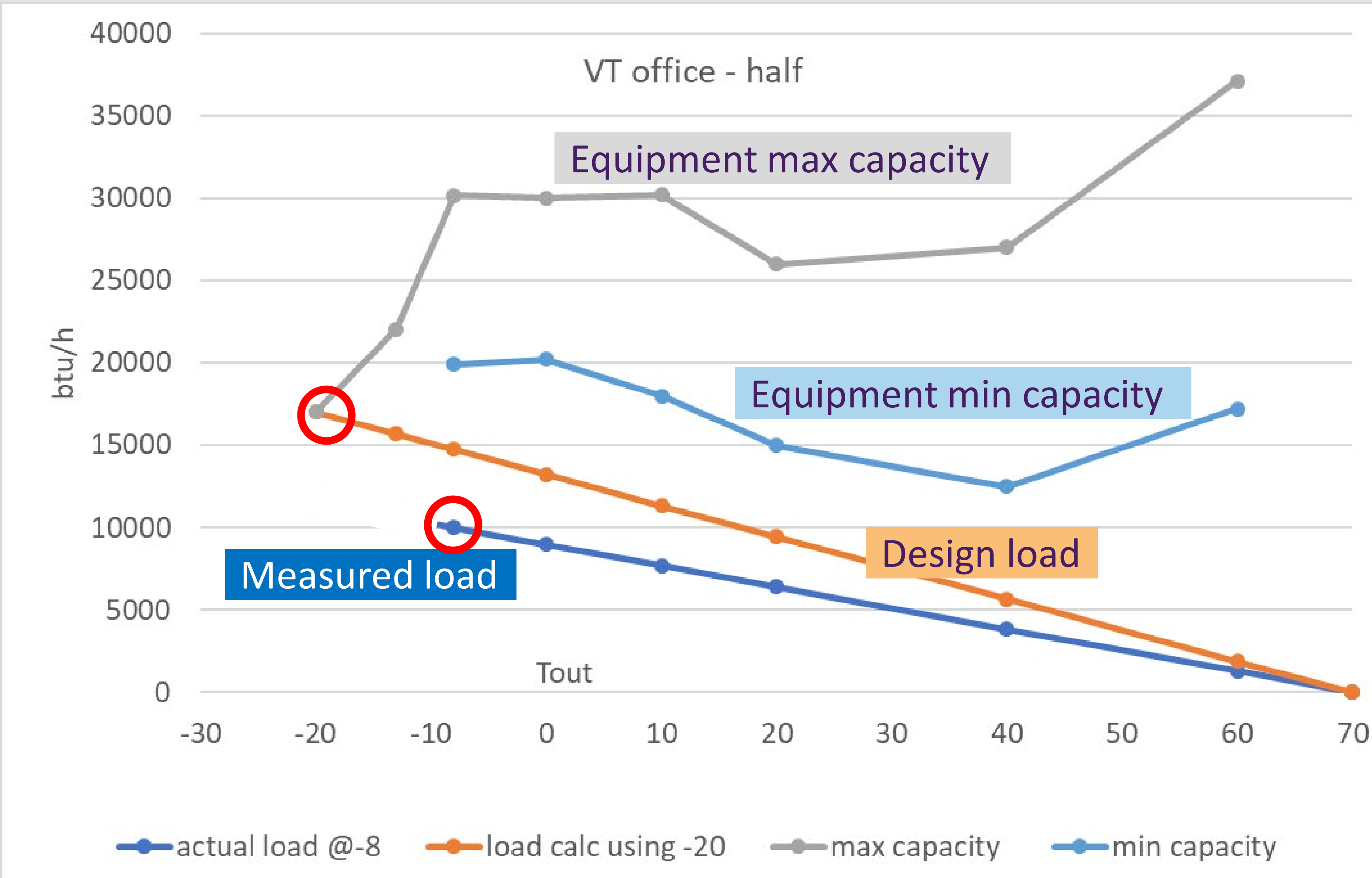




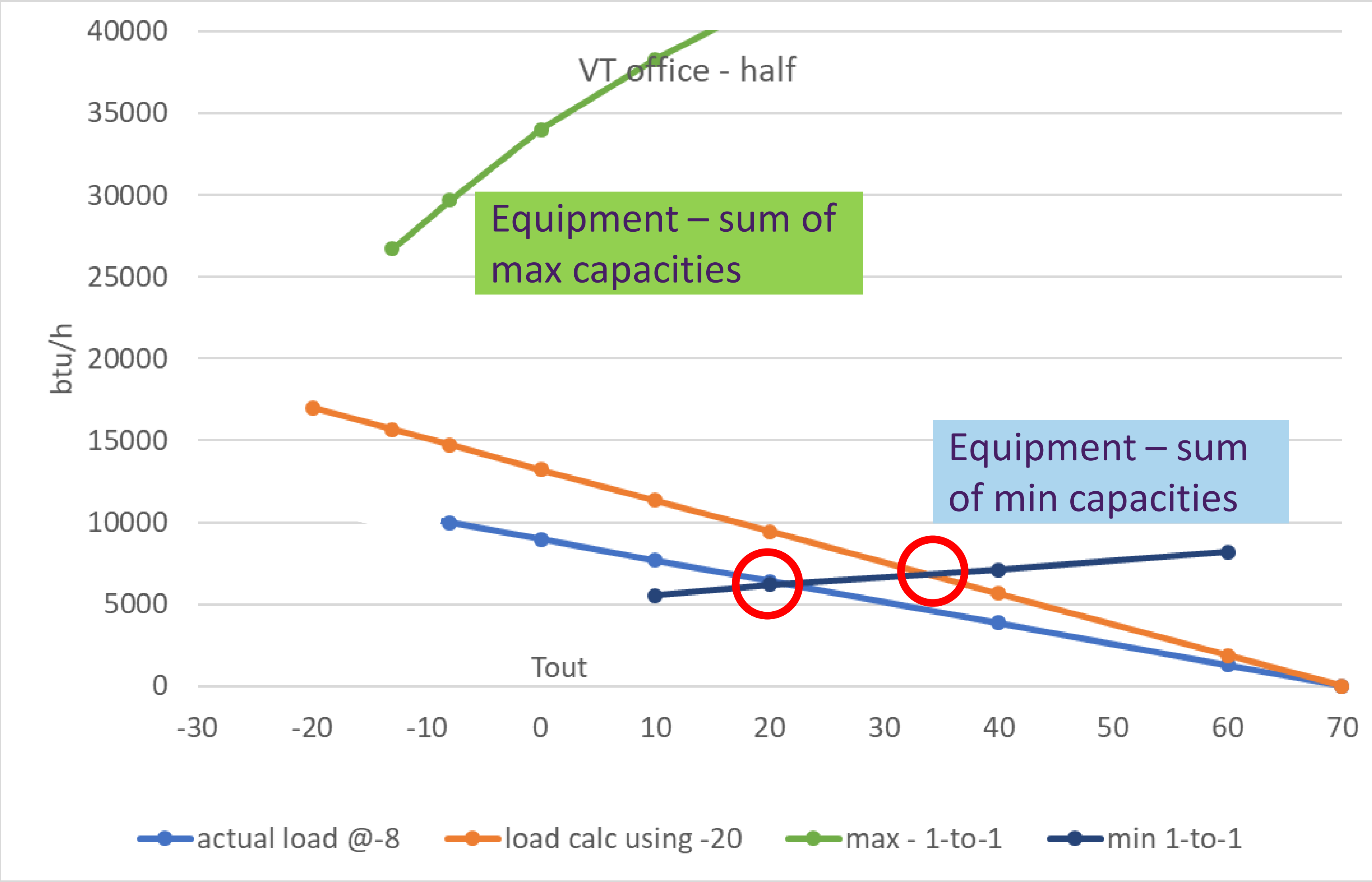
Tentative conclusions

- Oversizing leads to underperformance
  - Very little of heating season is in modulating mode
  - Controls affect this too – built in firmware doesn’t help
- Cycling behavior starts at colder temperatures than it should
  - Rental does cycle more, presumably due to extra zone/smaller terminals upstairs (asynchronous calls for heat)

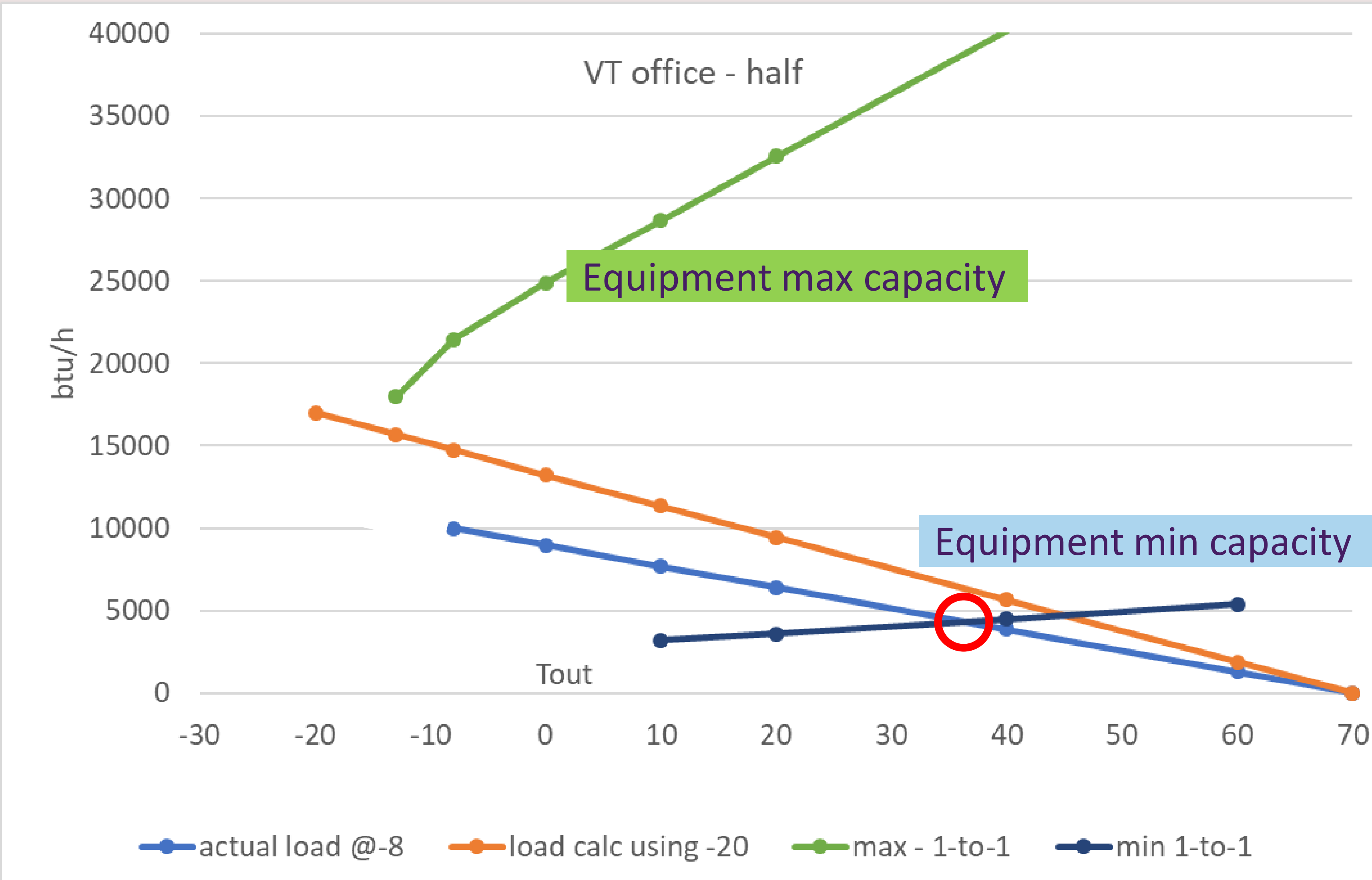
What they got (equipment specs)



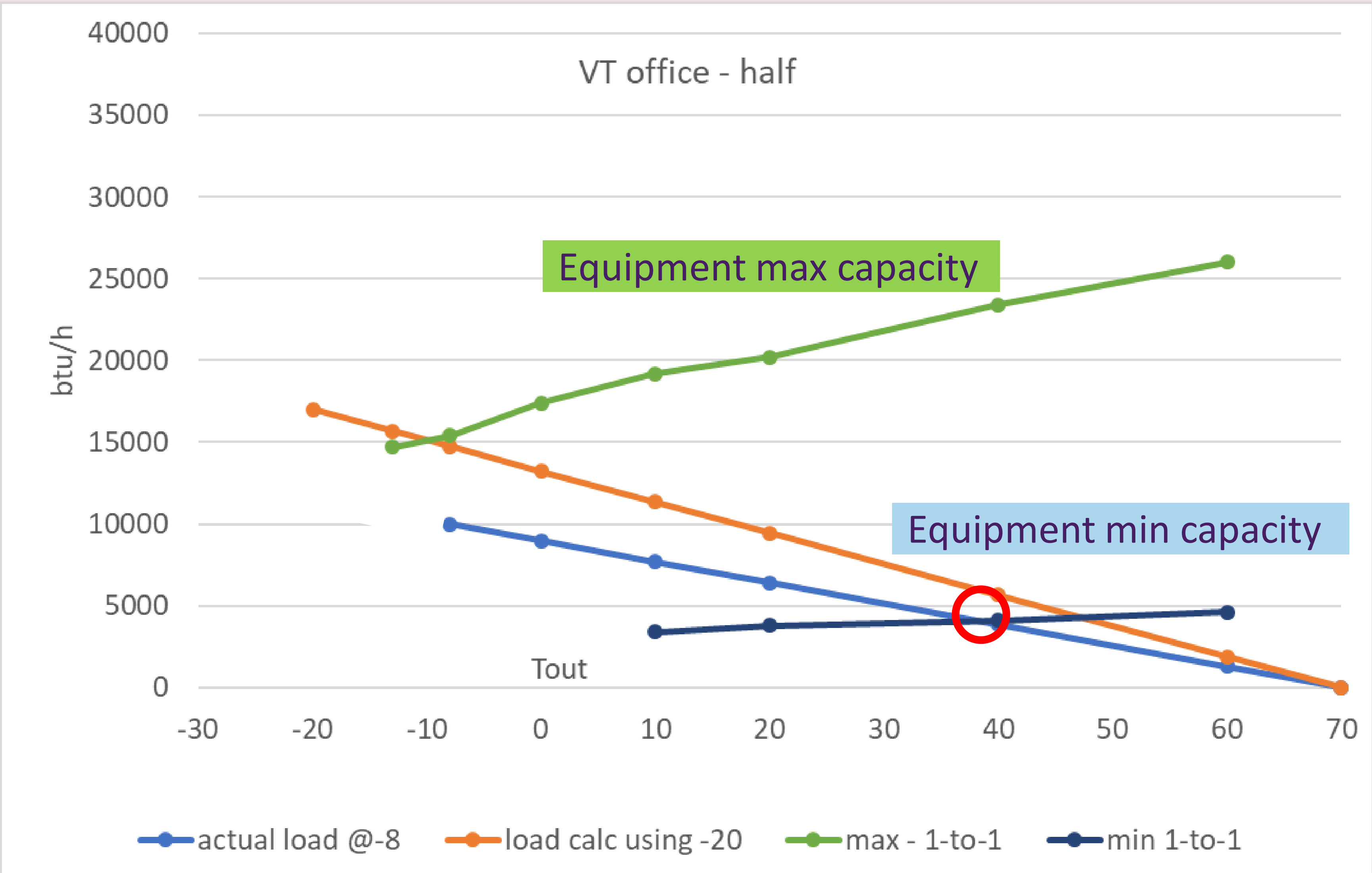
If rental was 6+6+15 single zone



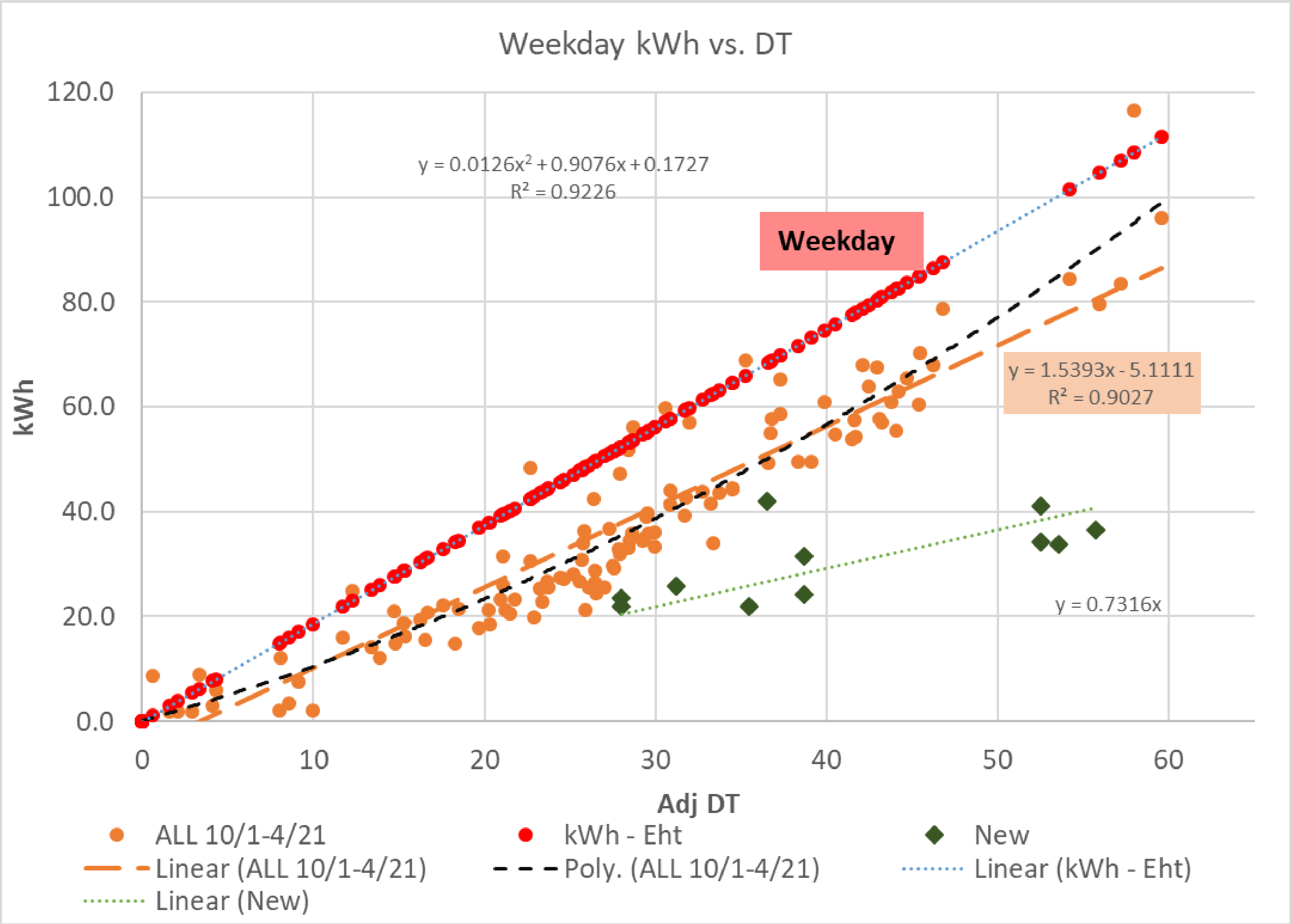
Better match: 6+6+6



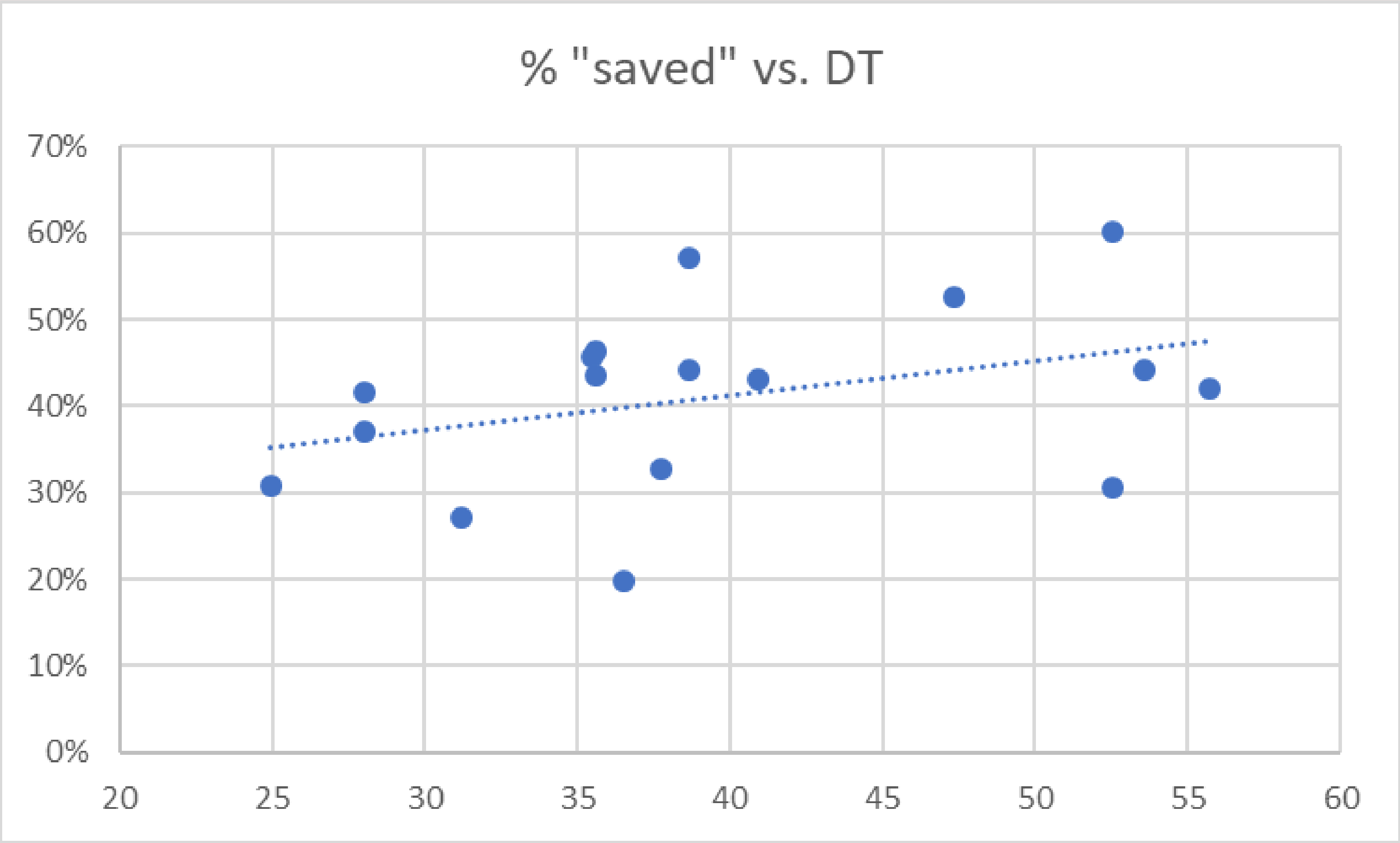
Even better: (1) 15k, ducted:



Success: new 1-to-1 outdoor units

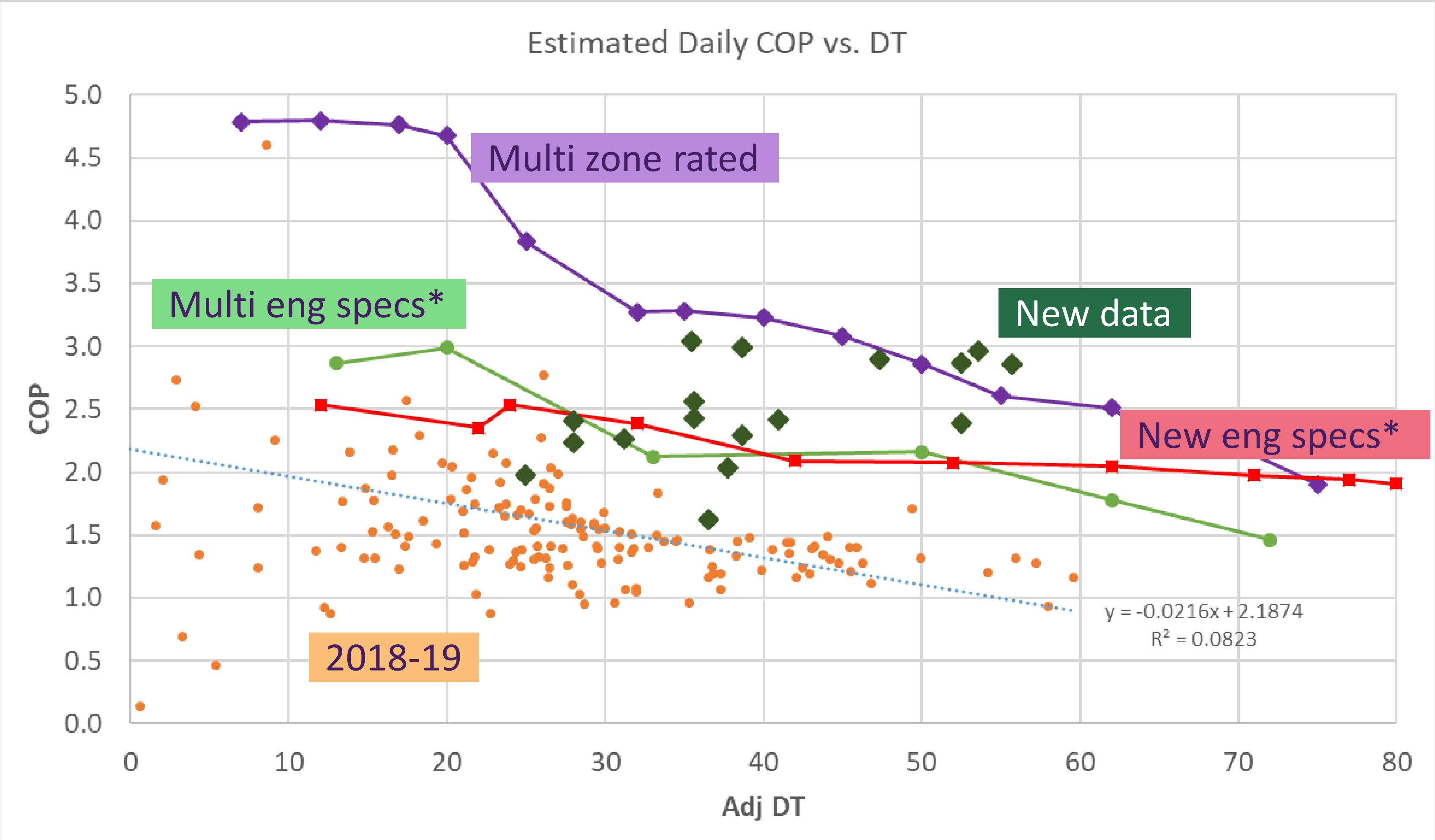


“Savings” (compared w/ prev trend line)



Very preliminary! …and promising

New: rated vs. engineering:



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Design - Sizing

- Focus on the application
  - Sole heating source: cold weather performance/ capacity is critical
  - Retrofit to offset oil/LP/resistance heat: overall performance matters more
- Conventional sizing may not be relevant for some uses
  - Smaller seems to be better – as long as load is met

Multi-zone Guidance

- *Don't* choose a ductless zone for each room, and then choose an outdoor unit that can supply that number of zones!
  - Most bedrooms *in existing homes* have loads too small for a ductless zone: *1500-3000 btu/h at design*
- *Strongly recommended:*
  - Maximum of three zones / outdoor unit
  - Smallest indoor unit <= 1/3 of outdoor capacity
- Use multiple outdoor units (similar cost; redundancy is good) – even multiple 1-to-1's

Design – Sizing/Application

- Distribution – where needed:
  - Use ducts vs. multiple heads
  - Or, multiple heads in 1-to-1 systems
  - Or, a hybrid:
    - 1 or 2 single-head DHPs for main living space(s), and
    - 1 compact-ducted for bedrooms
  - Easier for new, low-load homes

Proper Equipment selection

Outdoor units

Outdoor units should first be selected by the proper load done for the structure. The outdoor unit should not be selected based on how many indoor units are desired. If the outdoor unit is oversized just to provide a certain number of indoor units for each of the zones, overheating, humidity issues and higher than expected energy usage can occur. If the proper size outdoor unit doesn't provide enough indoor units/zones, the best option may be to combine some zones as needed with a ducted unit. Or, if there are only 2 or 3 small zones to condition, combining them and using a one to one system may be a better choice.

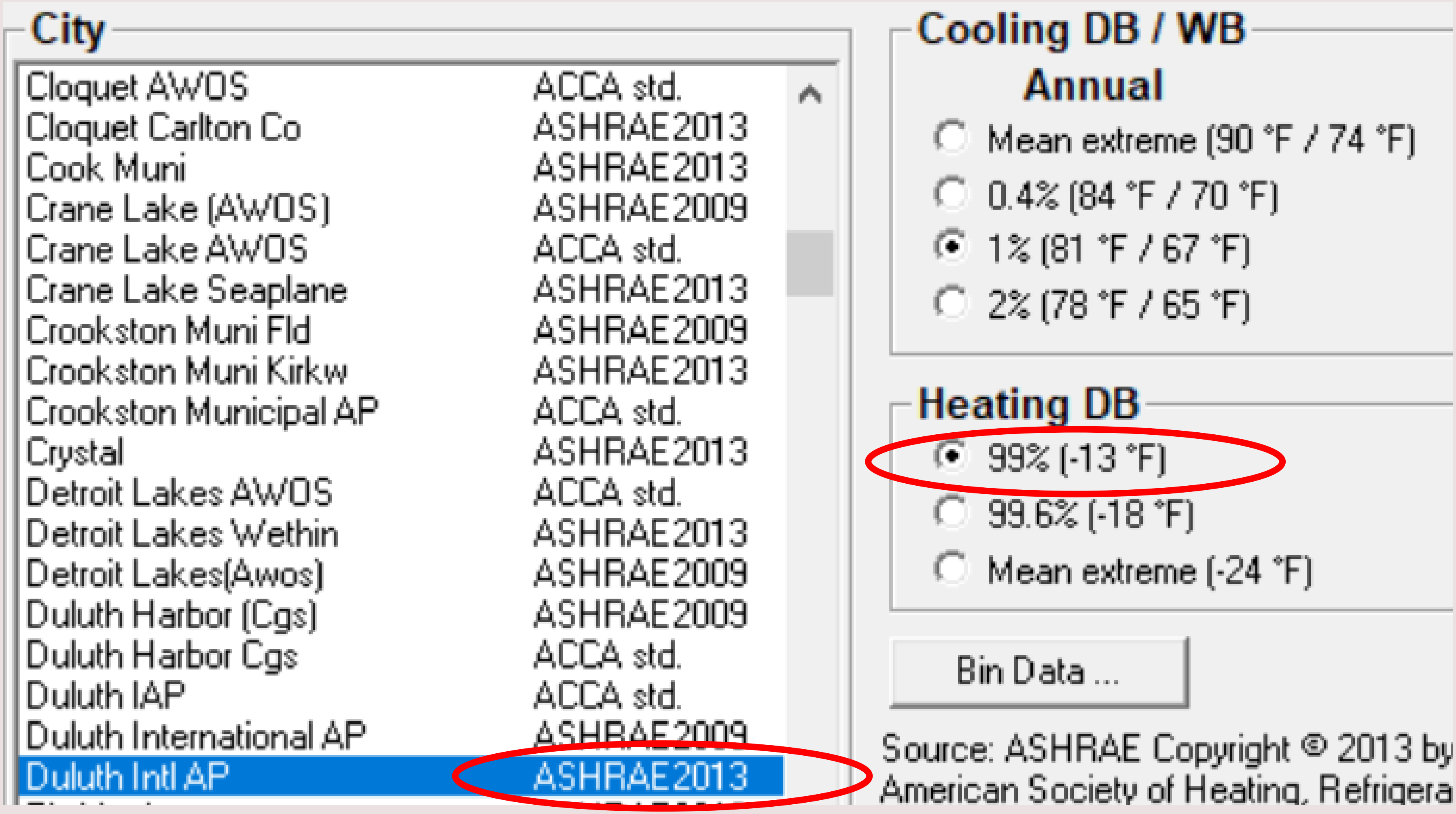
Indoor Units

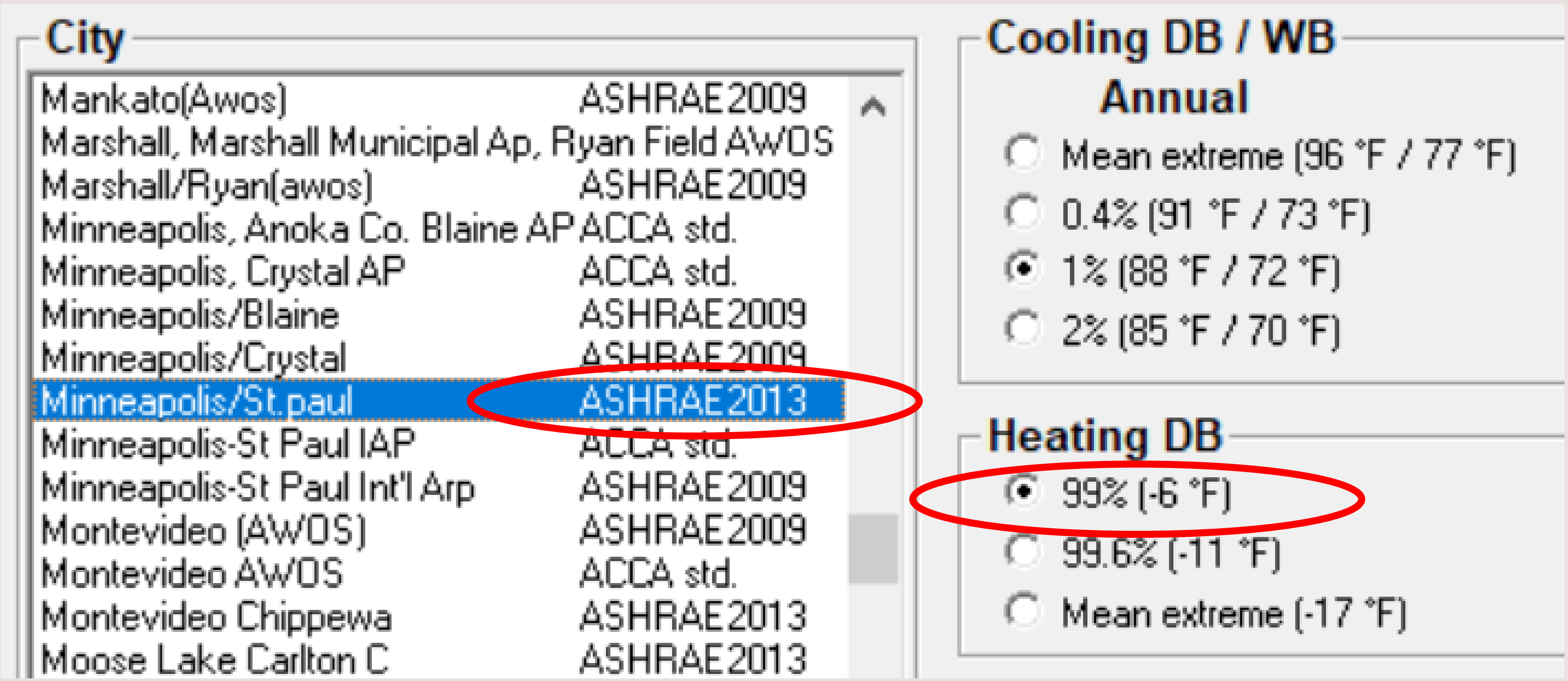
Proper indoor unit sizing and selection is probably the most important part of applying an MXZ-C system. Too often the indoor units are used because a homeowner wants to have their own control without regard for oversizing. If an indoor unit nominal capacity is more than 50% higher than the maximum heating or cooling load in a space, it will be oversized and humidity, overheating and higher than expected system energy usage can occur. This space should not have its own indoor unit.

Sizing – Efficient New Con / DER

- Do load calculations
- Use equipment spec's *at design conditions*
  - Never base on nominal capacity e.g. "1 ton"
- Consider sizing at 75-80%
  - Installing *just* enough aux heat (resistance, or fan coil, or gas fireplace) to make up difference
  - Think, electric radiant underfloor in bath/kitchen…
  - Best to control so aux is disabled until needed
    - Need better options for this… still under development
    - Or shut the breakers off, probably rarely or never used

Design Conditions




City
Mankato(Awos) ASHRAE2009
Marshall, Marshall Municipal Ap, Ryan Field AWOS
Marshall/Ryan(awos) ASHRAE2009
Minneapolis, Anoka Co. Blaine AP ACCA std.
Minneapolis, Crystal AP ACCA std.
Minneapolis/Blaine ASHRAE2009
Minneapolis/Crystal ASHRAE2009
Minneapolis/St.paul ASHRAE2013
Minneapolis-St Paul IAP ACCA std.
Minneapolis-St Paul Int'l Arp ASHRAE2009
Montevideo (AWOS) ASHRAE2009
Montevideo AWOS ACCA std.
Montevideo Chippewa ASHRAE2013
Moose Lake Carlton C ASHRAE2013
Cooling DB / WB
Annual
Mean extreme (96 °F / 77 °F)
0.4% (91 °F / 73 °F)
1% (88 °F / 72 °F)
2% (85 °F / 70 °F)
Heating DB
99% (-6 °F)
99.6% (-11 °F)
Mean extreme (-17 °F)

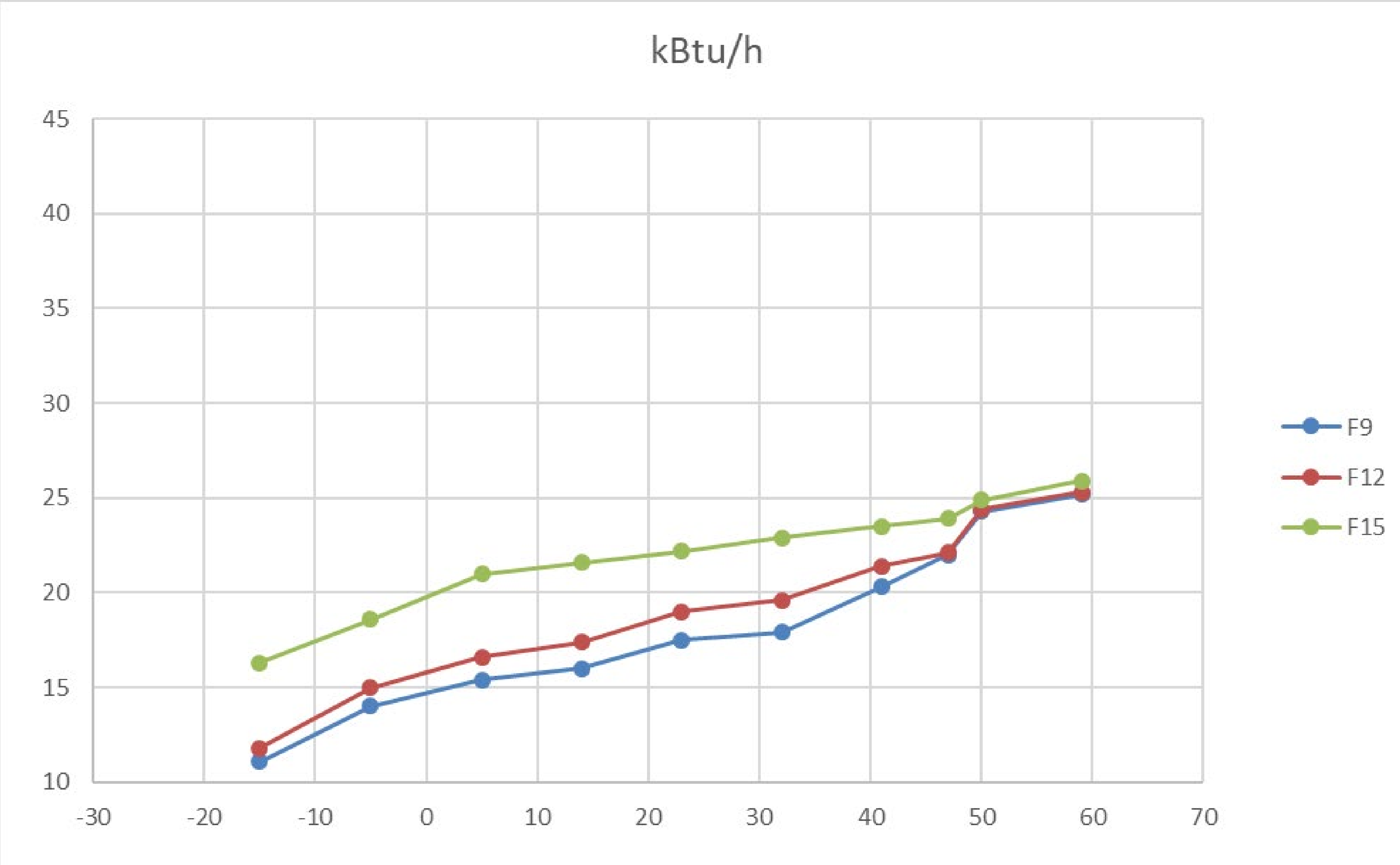
Design Conditions

- Use the 99% design temperature
  - Based on the most recent data (typ. ASHRAE 2013)
- Range for MN:
  - Minneapolis: -6
  - Duluth: -13
  - International Falls: -20
- These may not seem low enough
  - But, even careful calcs tend to be too high

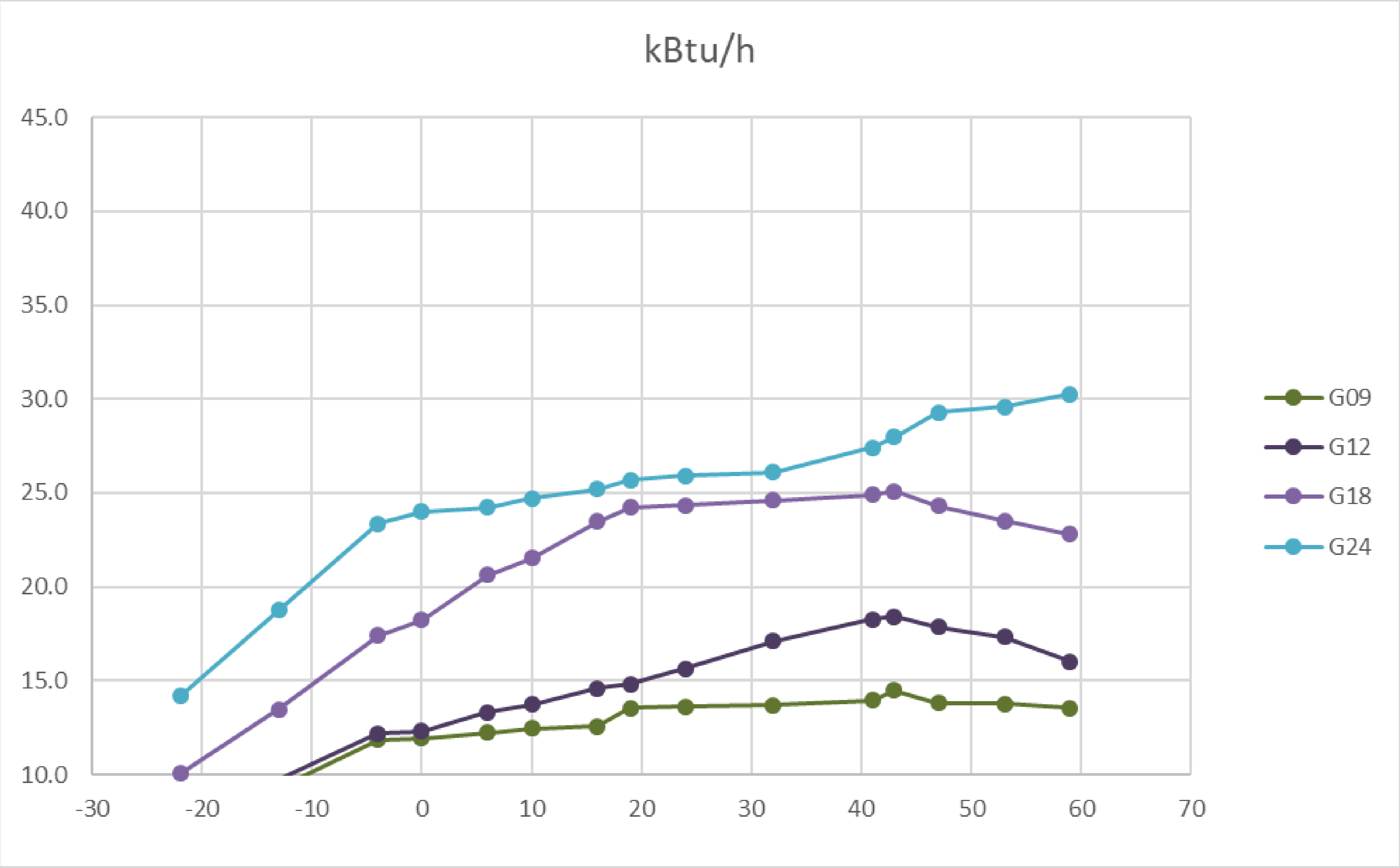
Objective with VCHP

- Match the operating range with as much of the heating season as possible
- Don't exceed the load at design temperature
- Maximize the turn-down (min speed as low as possible) to cover the range of loads
- This gets harder at lower design temperatures
  - Heat pump capacity drops, or equipment not rated
  - There is always a load at 50-60F, no matter how low the design temperature – so spread is increased.

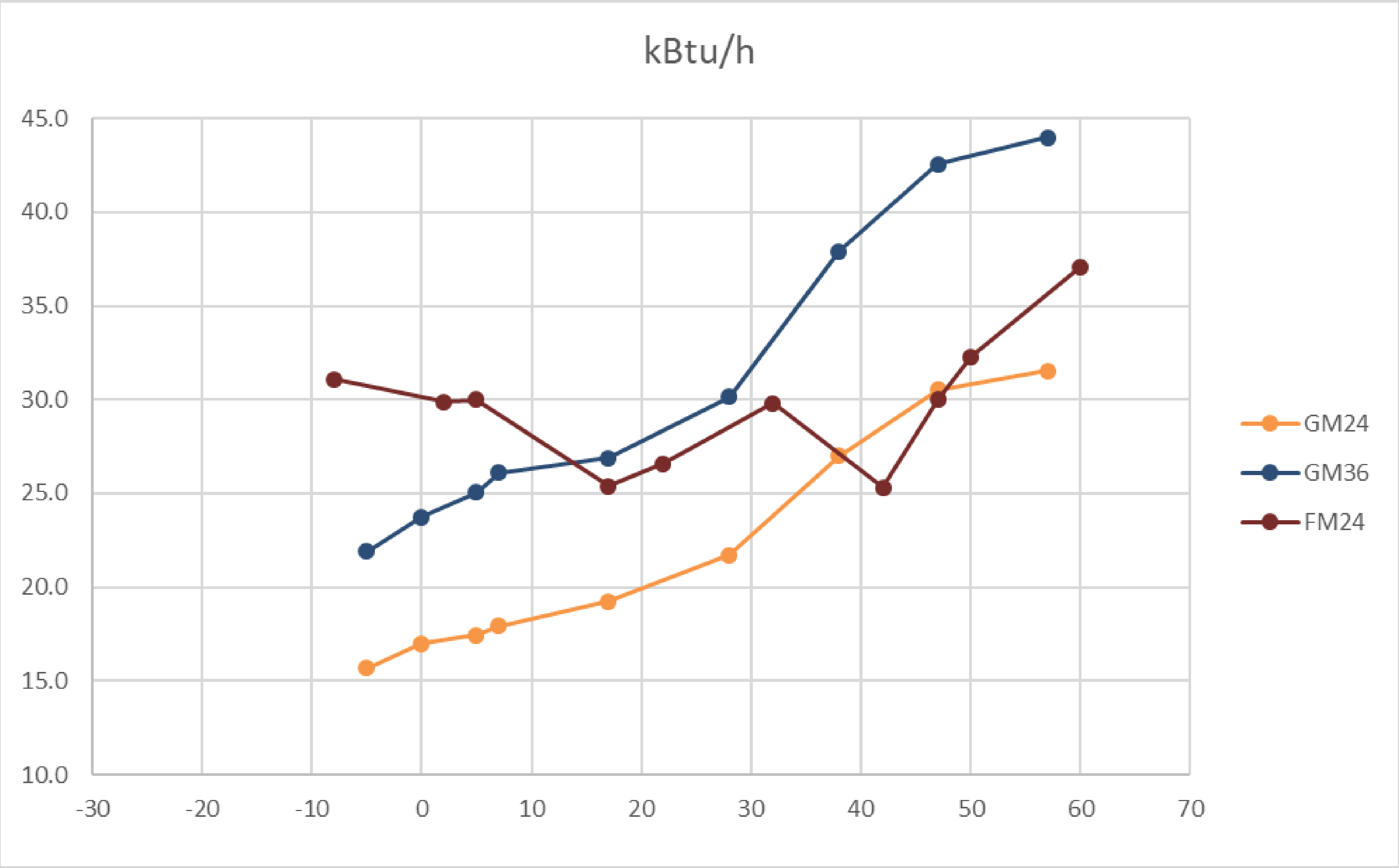
Some 1-to-1 models – capacity vs. Tout



Other 1-to-1 models – capacity vs. Tout

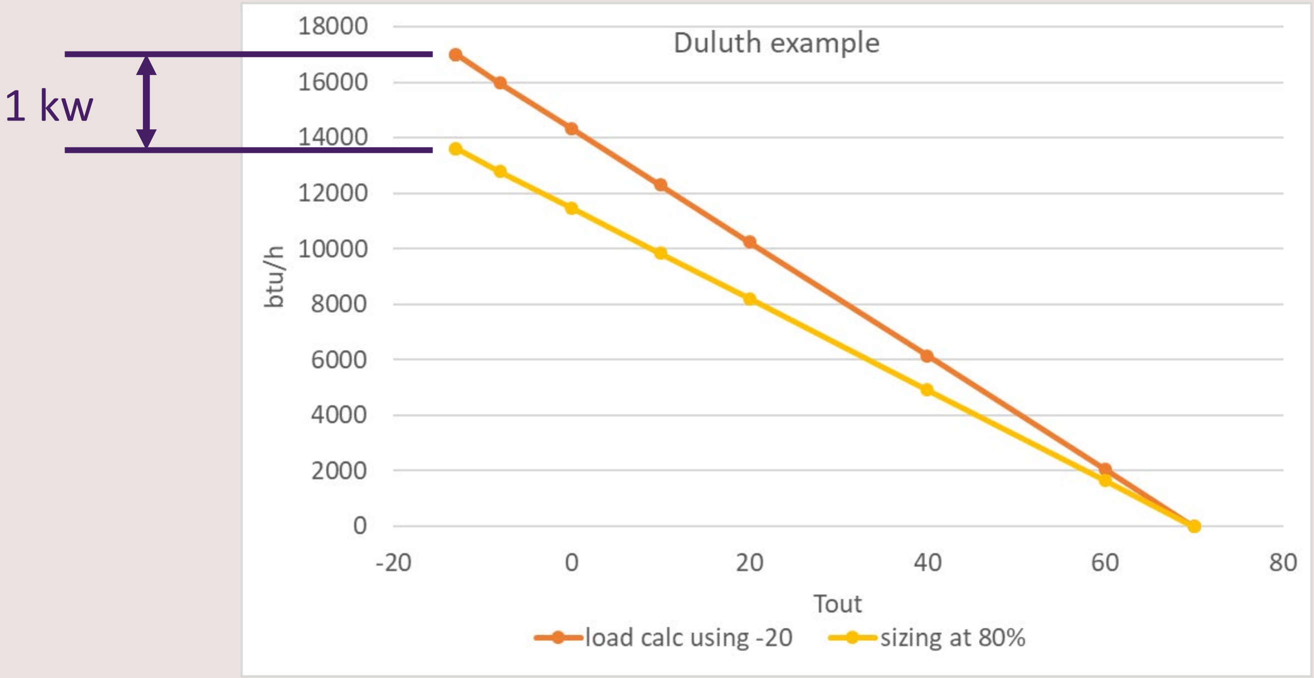


2 types of multi-zone

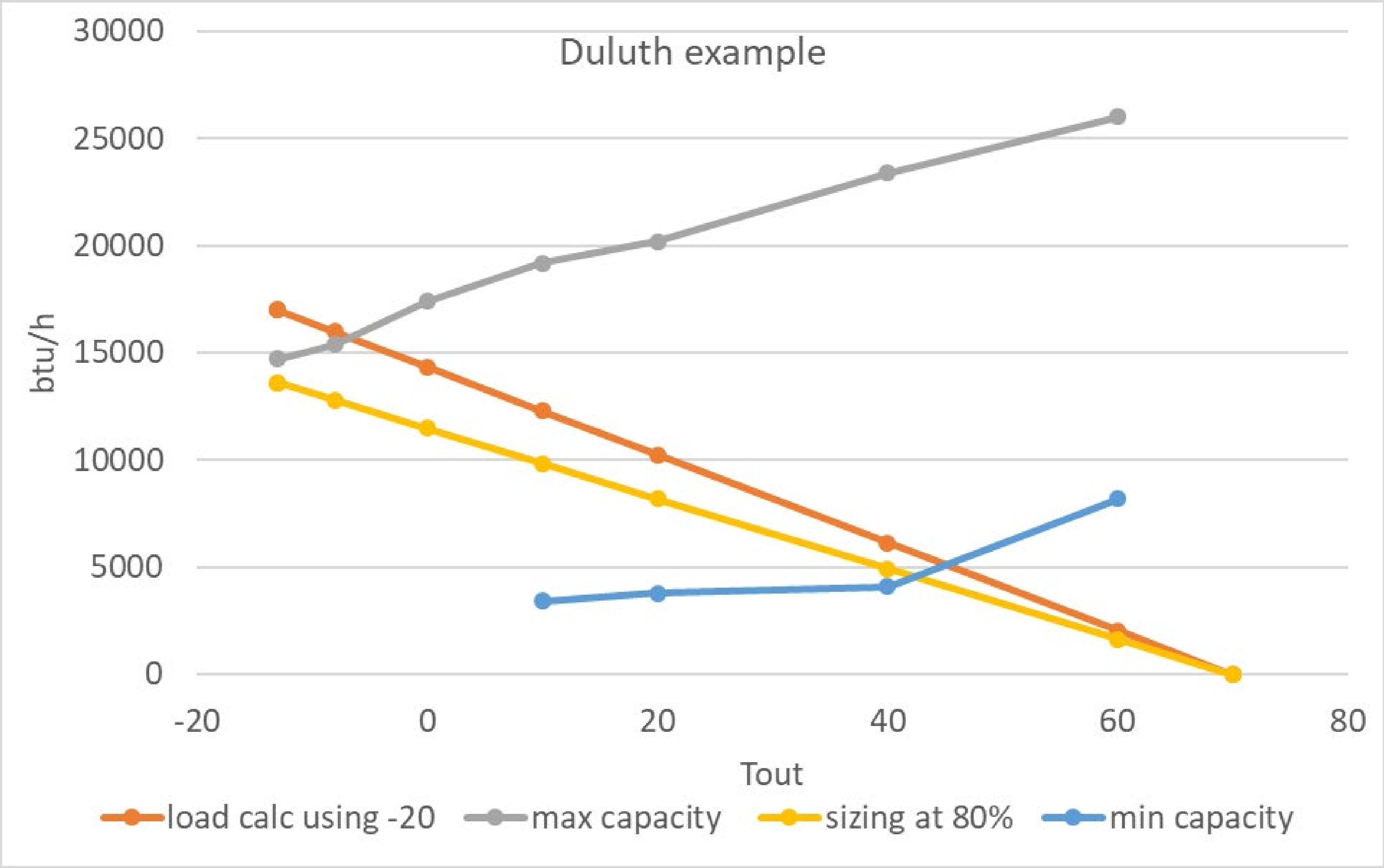


Duluth Example

- 17,000 btu/h at -13
- 80% of 17,000 = 13,600 – heat pump design
  - 20% of auxiliary = 3,400 btu/h = 1 kW

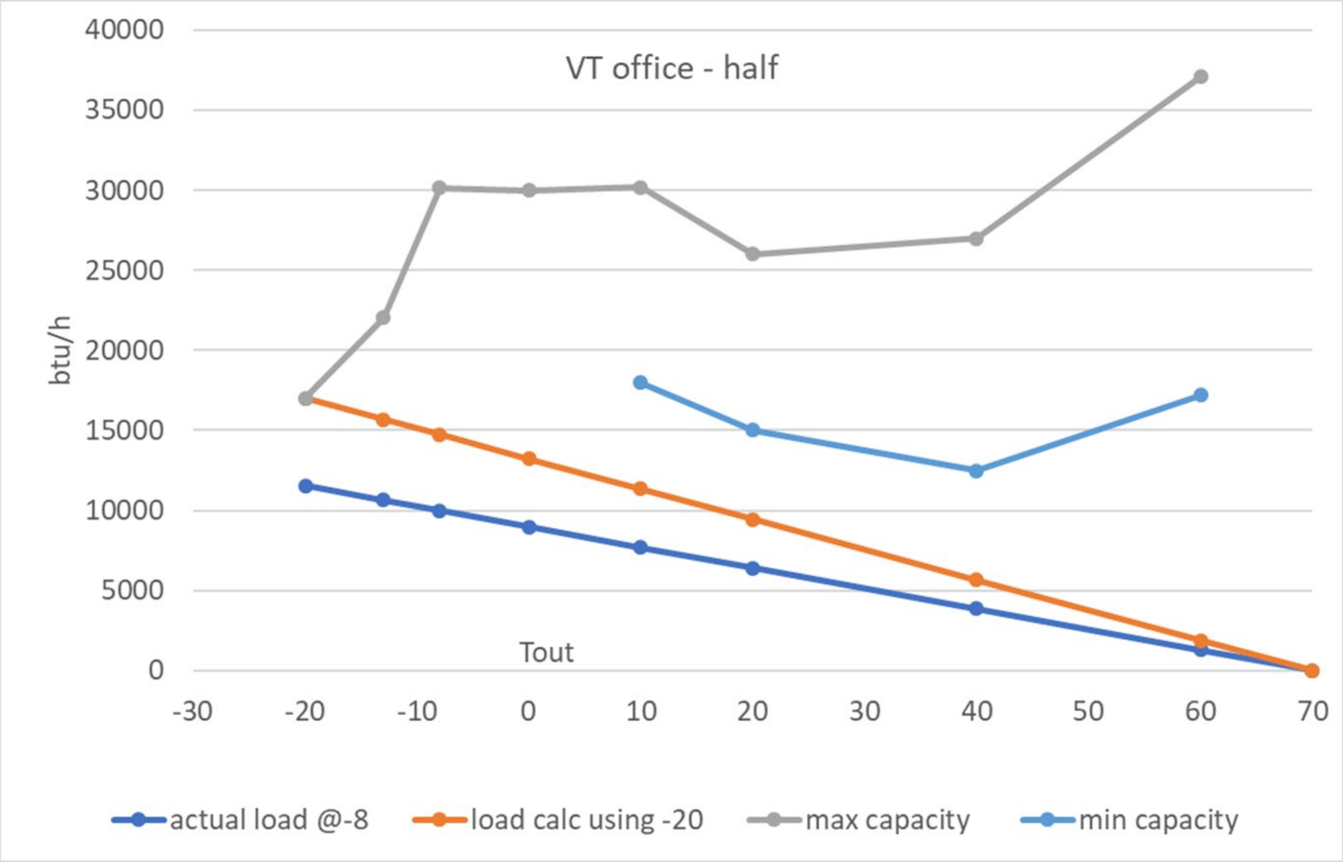


15k, 1-to-1 unit:



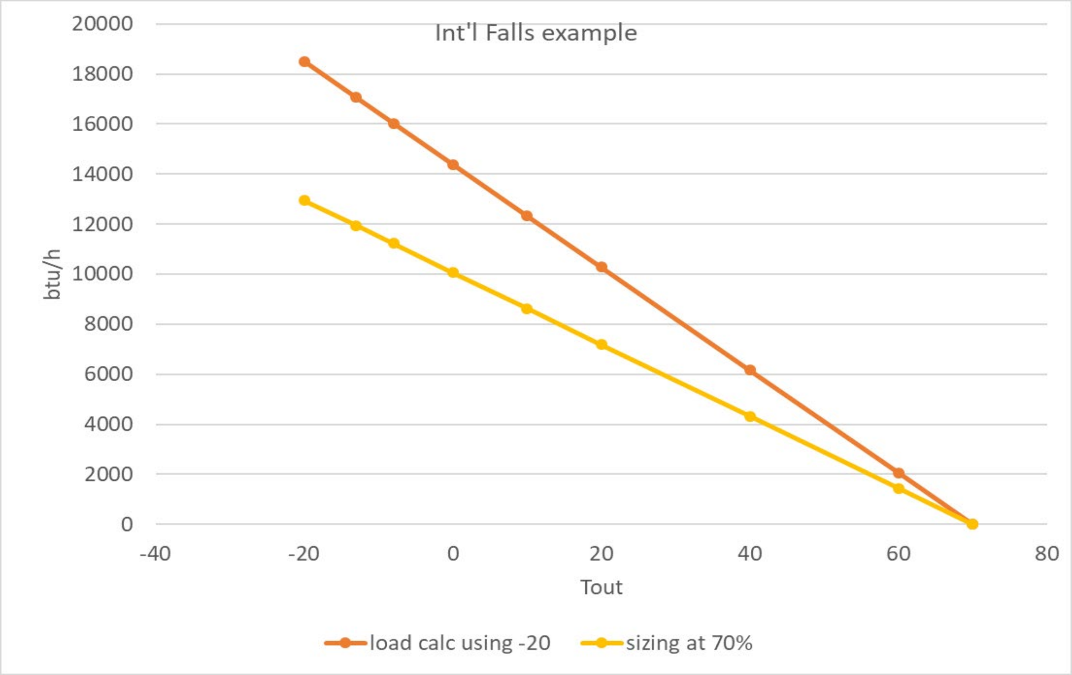
Same house, using -24F design (mean extreme)

Load -> 19,200 @ -24; sizing for 100% would look similar to this:



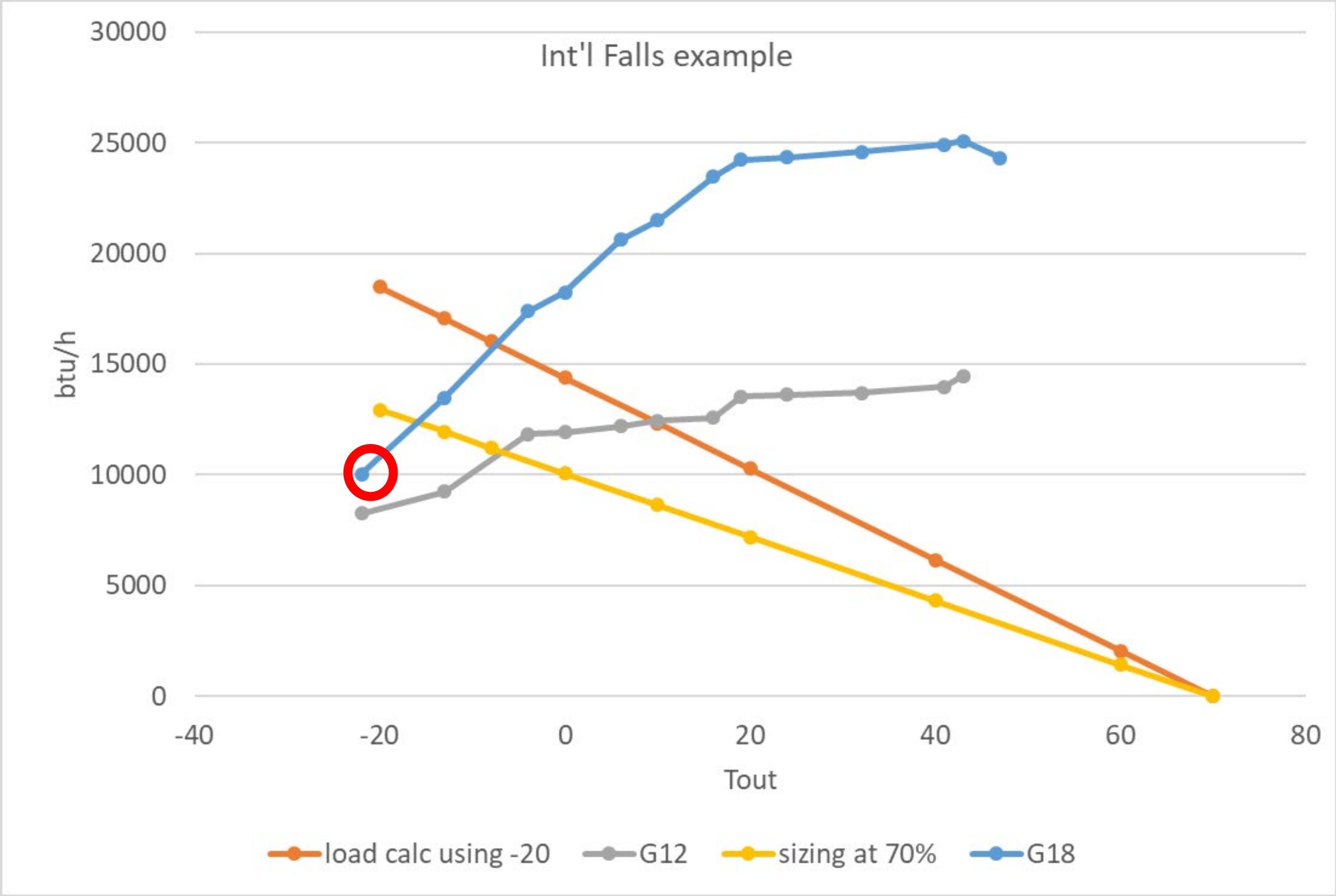
International Falls

- 18,500 btu/h at -20
- 70% of 18,500 = 12,950 – heat pump design
  - 30% as auxiliary = 5550 btu/h = 1.6 kW



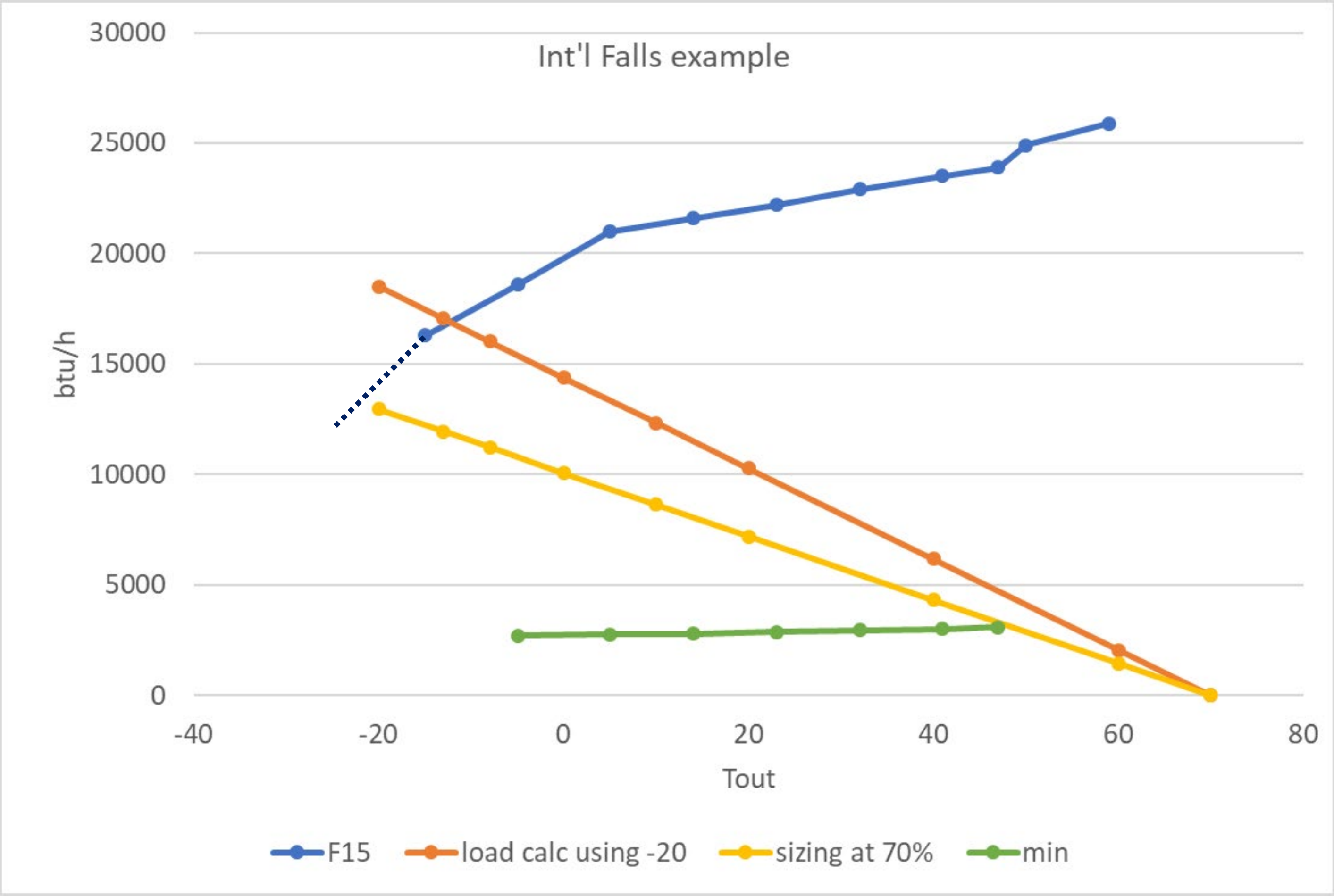
International Falls

- Try this: 18,500 - 10,000 = 8500 = 2.5 kW



International Falls

- Or…



Important

When planning auxiliary heat "backup"

- Don't use enough to meet total heat load
  - If multiple outdoor units: only the difference, or up to the difference x 1.5
  - If one outdoor unit: enough to keep house from freezing (> half the design load: 54% Minneapolis to 61% International Falls)
- Plan for it not to be needed
  - Have an easy way to turn it off/disable
- Spread it out
  - 2-3 small heaters in most distant corners
- Or use small hydro-air coil
  - Not from heat pump water heater

1 more case study:

- Minneapolis, 1907 house w/2017 addition
  - Superinsulated retrofit, was heated w/ 18k Polaris
- Used ducted single zone rated 18k at -5F
  - No data below that in manual…
  - “I would have felt more comfortable getting a 2T heat pump, but the 2T unit required 2 indoor units and I decided to take a chance on the 1.5T… I decided not to get the unit rated to -15 because the extra condensate pan heater causes its published performance to be quite a bit poorer.”

Minneapolis….

- "It works! We had a couple nights when it got to -15 last winter and the house seemed to not lose any temperature. I did turn the HPWH to resistance mode. "
- However:
  - Cycling seems to happen when not necessary
  - Not happy with dehumidification (sensible load is so low the unit barely runs).
- And …. Disconnected the gas meter!

Equipment Selection

- NEEP Cold Climate Listings
  neep.org/ASHPInstallerResources
  - High heating efficiency rating: HSPF >10
  - High efficiency in cold weather: COP > 1.75
    - at 5°F outdoor temperature
- Also look for
  - High capacity (output) at low outdoor temps
  - **Rated operation at -5°F, -15°F, or lower**
  - Max capacity is expected when it's cold!

NEEP ccASHP Listings

DISCLAIMER- Some of the performance values reported as part of the Cold-Climate ASHP Specification are NOT derived from industry standard test procedures or third-party tested/v

Products added to list since previous update highlighted in pink

General Information

Updated: March 9, 2017

Manufacturer	Brand (if applicable)	AHRI Certificate No.	Outdoor Unit Model	Indoor Unit Model(s)	HSPF (Region IV):	SEER	EER (@ 95°F)	ENERGY STAR Certifie	Ductless or Ducted	If Ductless, Multi-zone or Single-zone
Daikin		3208521	RXG09HVJU	FTXG09HVJU	11	26.1	15.8	Yes	Ductless	Single-zone
Daikin		3208522	RXG12HVJU	FTXG12HVJU	10.55	24.2	14	Yes	Ductless	Single-zone
Daikin		3208523	RXG15HVJU	FTXG15HVJU	10	21	12.9	Yes	Ductless	Single-zone
Mitsubishi		4217888	MUZ-FE18NA	MSZ-FE18NA	10.3	20.2	14.2	Yes	Ductless	Single-zone
Mitsubishi		4908219	MUZ-FE09NA	MSZ-FE09NA	10	26	15.5	Yes	Ductless	Single-zone
Mitsubishi		4934170	MUZ-FE12NA	MSZ-FE12NA	10.5	23	12.9	Yes	Ductless	Single-zone
Fujitsu		5063325	AOU9RLS2	ASU9RLS2	12.5	27.2	16.1	Yes	Ductless	Single-zone
Fujitsu		5063326	AOU12RLS2	ASU12RLS2	12	25	13.8	Yes	Ductless	Single-zone
Daikin		5265753	RXS09LVJU	FTXS09LVJU	12.5	24.5	15.3	Yes	Ductless	Single-zone
Daikin		5265755	RXS12LVJU	FTXS12LVJU	12.5	23	12.8	Yes	Ductless	Single-zone
Daikin		5265756	RXS15LVJU	FTXS15LVJU	11.6	20.6	14.4	Yes	Ductless	Single-zone
Daikin		5265757	RXS18LVJU	FTXS18LVJU	11	20.3	12.7	Yes	Ductless	Single-zone
Daikin		5265758	RXS24LVJU	FTXS24LVJU	10.6	20	12.5	Yes	Ductless	Single-zone
Nortek Global	Maytag	5597453	PSH4BG024K	B6VMAX024K-B	10	19	13.9	Yes	Ducted	N/A
Nortek Global	Maytag	5597457	PSH4BG036K	B6VMAX036K-B	10	19	12.9	Yes	Ducted	N/A
Fujitsu		5751311	AOU9RLFC	AUU9RLF	13	24	14.5	Yes	Ductless	Single-zone
Fujitsu		5751312	AOU9RLFC	ARU9RLF	12.2	21.5	14.5	Yes	Ductless	Single-zone
Fujitsu		5751313	AOU12RLFC	AUU12RLF	12.2	21.9	12.8	Yes	Ductless	Single-zone
Fujitsu		5751314	AOU12RLFC	ARU12RLF	11.5	20	12.8	Yes	Ductless	Single-zone
LG		5859619	LUU187HV	LCN187HV	10.1	20	15	Yes	Ductless	Single-zone
LG		6236101	LSU240HSV3	LSN240HSV3	10.2	20	12.5	Yes	Ductless	Single-zone
American Standard		6749789	4A6V0024A1	*AM8C0B30V21	10	19.25	13.75	Yes	Ducted	N/A
American Standard		6749791	4A6V0048A1	*AM8C0C48V41	10	19.25	12.5	Yes	Ducted	N/A
Trane		6749942	4TWV0024A1	*AM8C0B30V21	10	19.25	13.75	Yes	Ducted	N/A
Trane		6749944	4TWV0048A1	*AM8C0C48V41	10	19.25	12.5	Yes	Ducted	N/A
American Standard		6750232	4A6V8036A1	*AM8C0C36V31	10	18	13	Yes	Ducted	N/A
American Standard		6750233	4A6V8048A1	*AM8C0C48V41	10	18	12.5	Yes	Ducted	N/A

Current Product List (3.9.17) | Delisted (on 1.1.17)

What about hot water?

- Heat pump water heaters in conditioned space
  - Efficiency tends to be low unless used a fair bit
  - They do add to the space heating load slightly
  - Look at cold-climate rating (NEEA) for HPWHs
- Electric resistance for low-use scenarios
- (High efficiency fossil fuel?? Not best choice)

Design (Retrofit)

- 1st floor unit primary heating for 2-story house
  - 2nd floor unit great for cooling 2-story house
    - Ducts help upstairs—low load rooms in general
- **Most** savings from first heating unit
  - Sometimes 2-3 heads for cut-up floor plans
- More: increased comfort, convenience
  - Higher cost and (if multi-zone) lower efficiency
- If aiming for full replacement, too easy to oversize
  - But if there’s a backup/supplement, less risk

Design

- Don’t use HSPF “as-is” to estimate or even compare performance
  - Adjust for climate using bin analysis for actual equipment and application
  - Be careful about what manufacturer specs you use
    - Typically run at max capacity at low temperatures
    - The NEEP guide is really helpful as reality check
      - Not sole source for designing
      - *And,* minimum speed operation specs are not always accurate (trying to improve for 2019)

Other Issues (new & retrofit)

- Installation
  - Snow/ice / drip / drain pan heat etc
- Utilization (retrofit)
- Controls / firmware / settings
  - Wall mount thermostat
  - Temp sensing / air handler
  - Constant fan

Design / Install

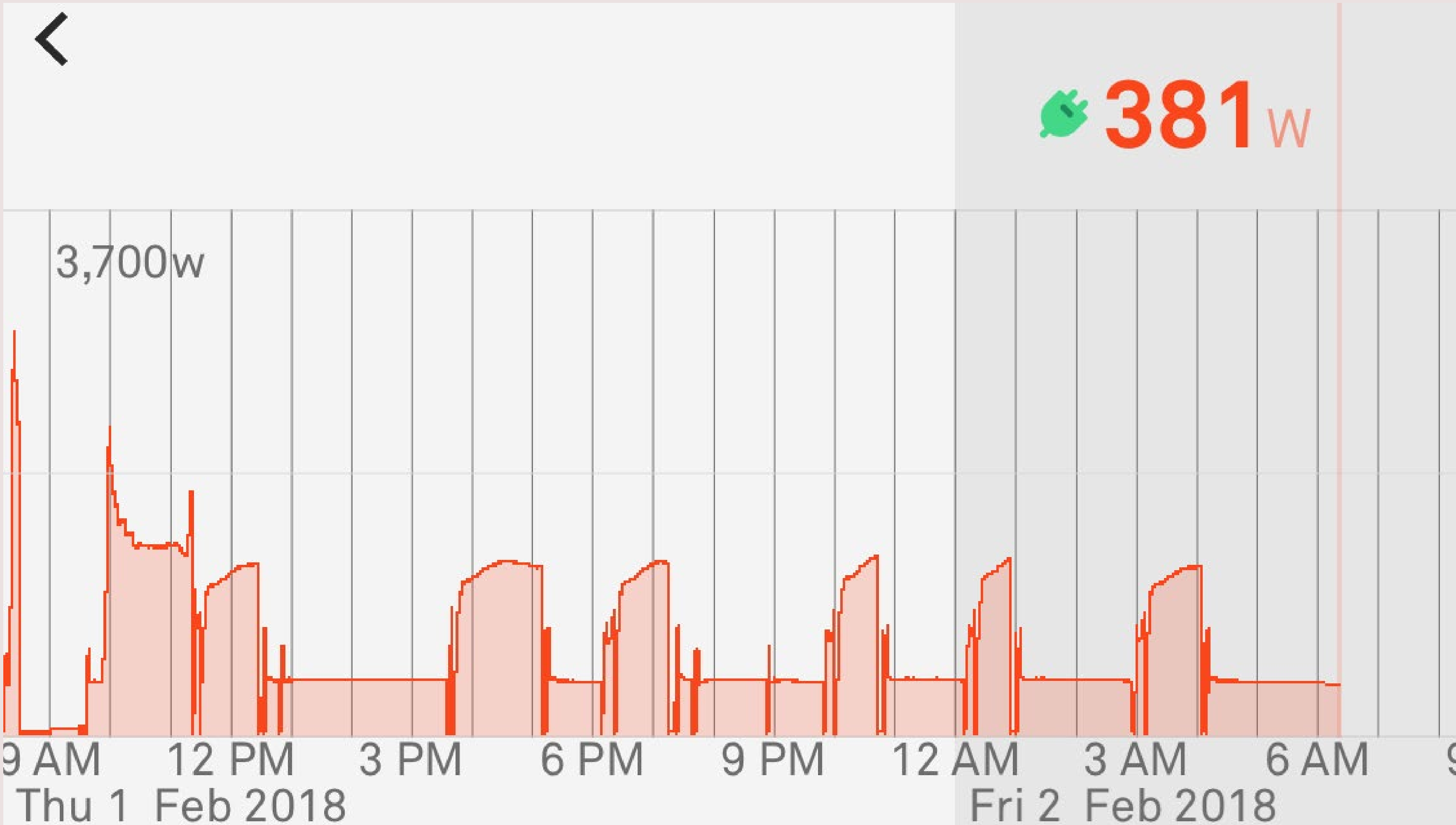
- In heating climate: indoor unit low on wall
  - Window sill height provides balance between heating and cooling performance in cold climate
  - Or use floor mounted system
  - Or ducted system with floor registers

“Floor mount” good for larger spaces

- Better heat distribution, esp. first/lower floor

- Or, ducted system with floor registers

Got Monitoring?



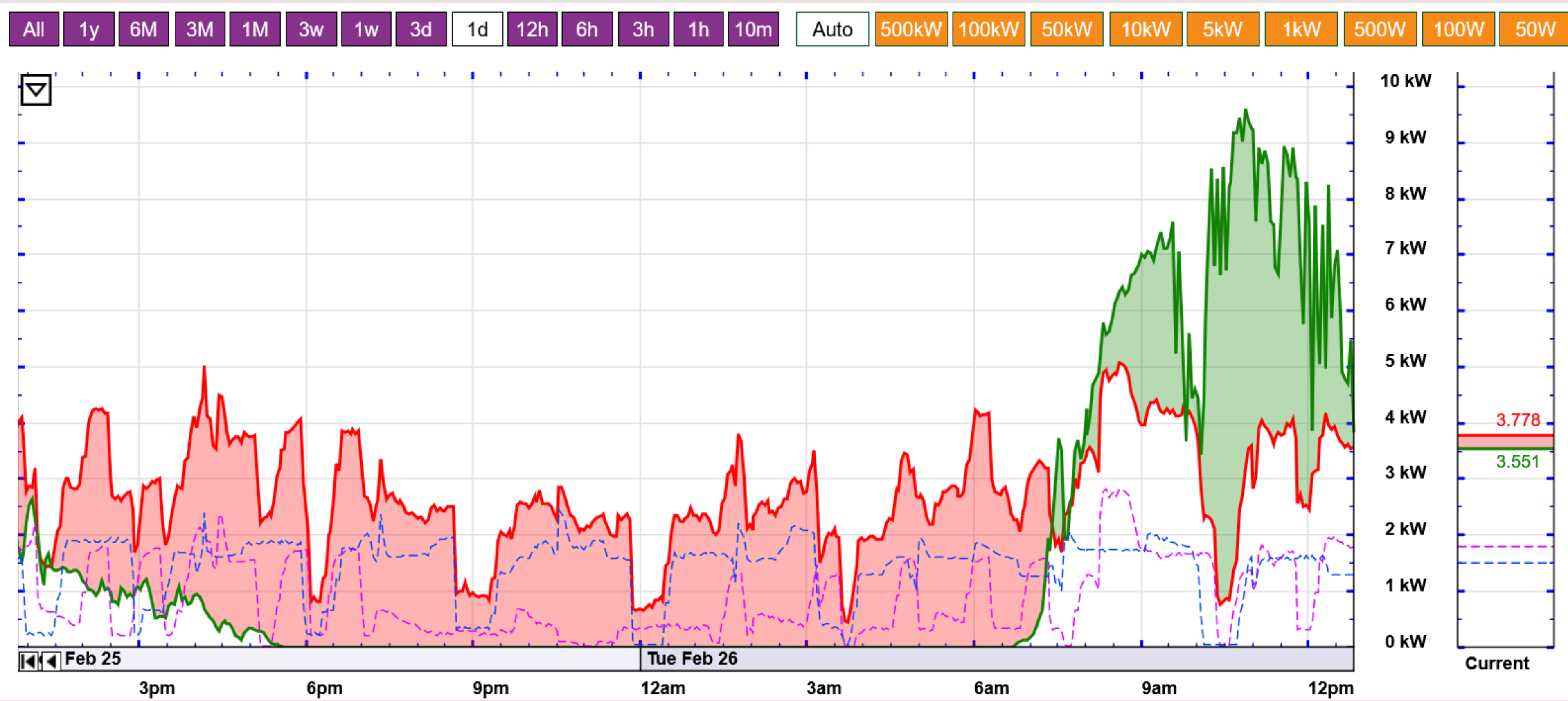
Monitoring is *really* good to have

- See what's happening… but adds $300-1500+
- eGauge – flexible, configurable, rather geeky
  - No subscription fee (need to backup data and configuration in case of failure)
- eMonitor – more consumer friendly
  - Have to pay for data storage
- Sense – Can't "sense" variable-speed heat pump unless you put it on JUST the HP circuit

Sense – cheaper, but imperfect:

Connect only to the heat pump(s)

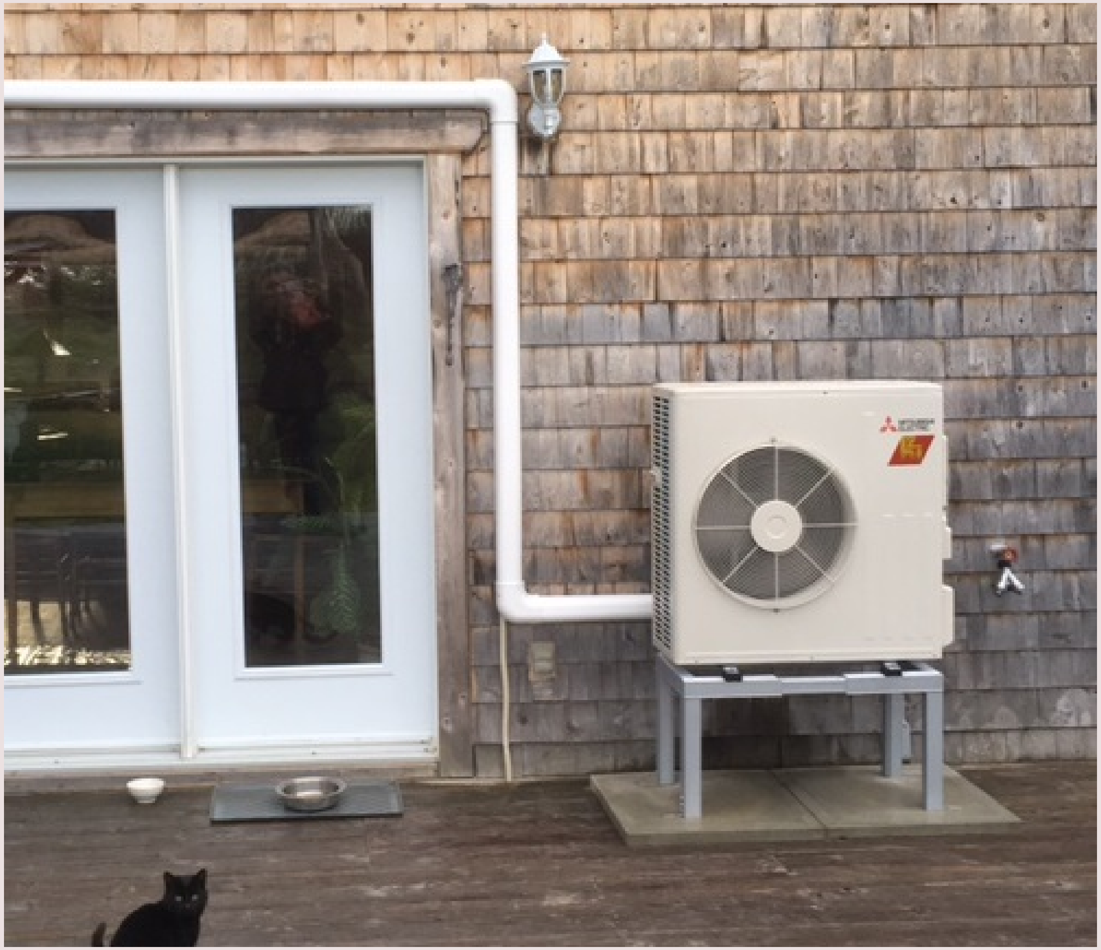
eGauge more $, lots more info



General: Care In Installation

- Follow manufacturers instructions carefully
  - Refrigerant charge adjustments if needed
  - Flare fittings – careful, or avoid (use crimp system)
  - Triple-purge refrigerant system; start-up process
- Keep above snow line – wall brackets
  - Best if mounted to foundation or on stand
- Surge protector at service disconnect
- Rodent-proof entry

Wall mount or stand:



Beware frost heave w/stands

Drip Diverter

- Avoid eave drip, or use diverter
- Sheltering from above is good – don’t obstruct air flow (follow instructions for clearances!)

Surge protector helps avoid this:

Rodent-proofing line set entry

Controls / Settings

- Use wall-mounted controls
  - Sense temperature *at control, not in return air*
  - Honeywell D-6 or IntesisHome for many DHPs
- Fan Speed: Auto; avoid constant-fan settings
  - High speed = more efficient and more capacity, but more noise
- Avoid “Auto” heating / cooling changeover setting
- Retrofit: the heat pump needs to operate
  - Set ASHP warmer than backup heat!
  - Control location – ASHP as primary, central as backup
  - Integrated control strategies, coming soon!

NEEP Guides

- Sizing/selection guide, and installation guide

neep.org/ASHPInstallerResources

Sizing and Selecting Guide

Application Sheets

Guide To Sizing & Selecting Air-Source Heat Pumps in Cold Climates

A companion to NEEP's Guide to Installing Air-Source Heat Pumps in Cold Climates

Heating (or Heating & Cooling) Displacement

Application Description	
Suggested ASHP System Configuration (Single/Multi-Zone Ductless, Mini-Duct, Centrally Ducted)	
Suggested Treatment of Existing HVAC System	
Sizing Strategy Overview	
Load Calculation	
Equipment Selection Considerations	
Oversizing Concerns / Tradeoffs	

Further Guidance

Guide To Sizing & Selecting Air-Source Heat Pumps in Cold Climates

A companion to NEEP's Guide to Installing Air-Source Heat Pumps in Cold Climates

Full Heating System Replacement

Application Description	
Suggested ASHP System Configuration (Single/Multi-Zone Ductless, Mini-Duct, Centrally Ducted)	
Suggested Treatment of Existing HVAC System	
Sizing Strategy Overview	

Isolated Zone

Application Description	One room or zone that is otherwise thermally isolated a newly finished basement room, build out above gara had poor thermal comfort.

Installing ASHPs in Cold Climates

General Equipment Selection Guidance

ACCA Manual S[3] (or equivalent), when combined with the recommendations in this guide, is an acceptable method to ensure equipment meets the heating and cooling load requirements. The general guidance below may be combined with the application-specific recommendations to inform the selection process:

- Generally, use manufacturer's extended performance tables to determine heating and cooling capacity as applicable, at the actual design conditions for the local climate.
- Although extended performance tables are recommended for sizing equipment to heating loads (whether 100% of load, or based on some use of available backup heat source), be cautious because not all published performance data is consistent. Some tables may not show maximum capacity at colder temperatures, when variable-speed equipment may reasonably be expected to operate at high speeds. The information in the Cold Climate Air Source Heat Pump (ccASHP) Specification tables (minimum and maximum heating capacities reported at 5°F) may be used to corroborate extended performance tables and help ensure the right equipment selection.
- For homes where systems are installed with a heating focus, cooling capacity may be estimated for sizing purposes as allowed in the various application sections below, as an alternate to manufacturer's performance tables.
- The step of adding the heating and cooling air flow needed for each room to estimate total system air flow applies to centrally ducted heat pump systems, and may be omitted for single- or multi-zone ductless distribution systems.

Heating (or Heating & Cooling) Displacement

Application Description	Customer primarily desires to reduce heating (and/or cooling) cost for central area of home. Heating is supplemental when the existing heating equipment is not at or near the end of its service life. The main tradeoff is between initial cost vs. savings and comfort in remote zones.
Suggested ASHP System Configuration **(Single/Multi-Zone Ductless, Mini-Duct, Centrally Ducted)**	For this application, typical configurations include 1-zone ductless, or 1-3 room mini-duct located to serve central living space (for reduced installed cost). Alternatively, larger 2-5 zone system, ductless and/or mini duct, can be configured to serve home widely for better comfort and savings (higher installed cost). In some cases, a new single-zone central heat pump may make sense but that is more likely a whole-house replacement.
Suggested Treatment of Existing HVAC System	Left in place, provides heat only as needed. A centrally ducted system may also provide mixing of house air for improved comfort.
Sizing Strategy Overview	Place first zone where heat will cover most central living area. Establish any additional zones (as appropriate) to strategically cover key living areas per customer needs. Size each zone to heating load of area(s) to be served (block load): total will be undersized for whole-house design heating load. If cooling comfort is desired by customer, size to larger of heating or cooling load for each zone.
Load Calculation	See "Getting Load Calculations Right" to ensure accurate load calculations.
Equipment Selection Considerations	Heating capacity of system at or near outdoor design temperature is a secondary concern. Undersizing somewhat for heating should improve efficiency and reduce overall heating costs, even though central system may be used slightly more. High efficiency at predominant winter outdoor temperatures will reduce operating cost.
Oversizing Concerns / Tradeoffs	Cooling oversize is mitigated by variable-speed equipment; if minimum speed cooling capacity is over 130% of design cooling load, look for equipment with a higher ratio of heating to cooling capacity, or a larger turn-down ratio (a lower minimum capacity), or both.

Installation Guide

Guide To Installing Air-Source Heat Pumps in Cold Climates

A Companion to NEEP's Guide to Sizing & Selecting Air-Source Heat Pumps in Cold Climates

Introduction

High-quality installations of air-source heat pump (ASHP) systems generate referrals, increase sales, reduce callbacks and improve customer comfort and satisfaction. Installation practices also have a major impact on efficiency and performance of an ASHP system. Efficient ASHPs have seen significant sales growth in colder climates in recent years. The recent generation of cold-climate ASHPs, combined with insights from large-scale installation programs and installers, has led to a better understanding of the full range of practices to ensure maximum system performance and customer satisfaction. This guide provides a list of these best practices, as well as homeowner education and system setup guidance, to help ensure efficient air-source heat pumps and happy customers in cold climates.

Heat pumps should always be installed by licensed, trained professionals. Always follow manufacturer's specification and installation instructions, and all applicable building codes and regulations. All installers should attend a manufacturer's training or preferred installer program.

ASHPs come in a number of configurations, and in some cases the following guidance may be specific to one or more of those system types. There are many variations and terms used, but these guidelines will focus on the following broad categories: "ductless ASHP" refers to any non-ducted cassette type indoor unit (including wall-mount air handlers, floor mounted consoles, in-ceiling cassettes, etc.); "mini-duct ASHP" refers to remote air handlers that are typically designed for compact, concealed-ceiling or short-duct configurations; and "centrally ducted ASHP" refers to whole-house systems with central air handlers. The icons shown here are used below to indicate when guidance is specific to a certain system type. All items without icons are generally applicable to all ASHP configurations.

Applies to: Ductless ASHP | Mini-Duct ASHP | Centrally ducted ASHP

Access/Use of Guides

- Guides developed to be shared/used broadly
- Guides posted on NEEP's public website, available to download
- Guides available to co-brand
- Seeking opportunities to disseminate resource
- Please send ideas about key venues to share the Guides

Thanks!

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