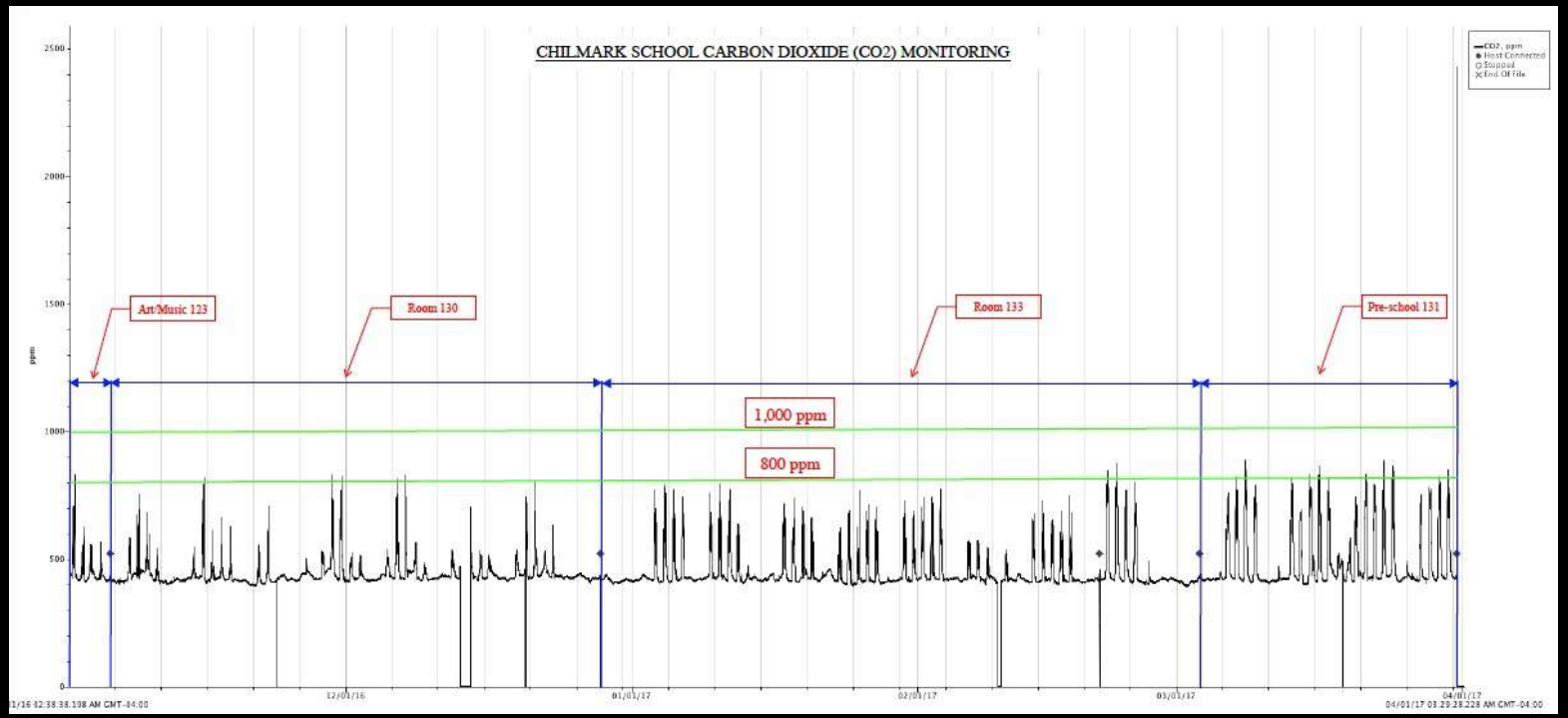
Monitoring Mechanicals

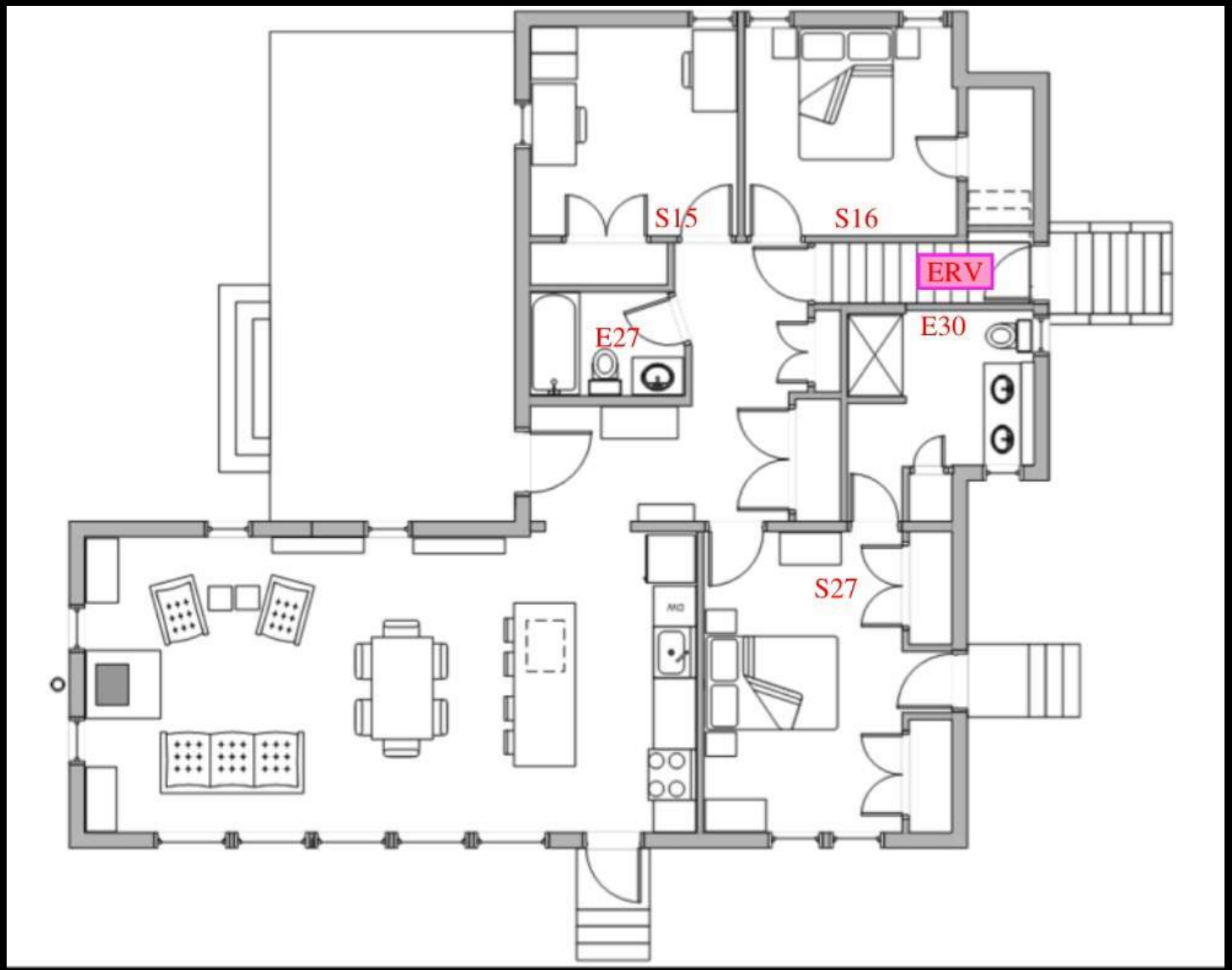


Marc Rosenbaum, P.E. South Mountain Company

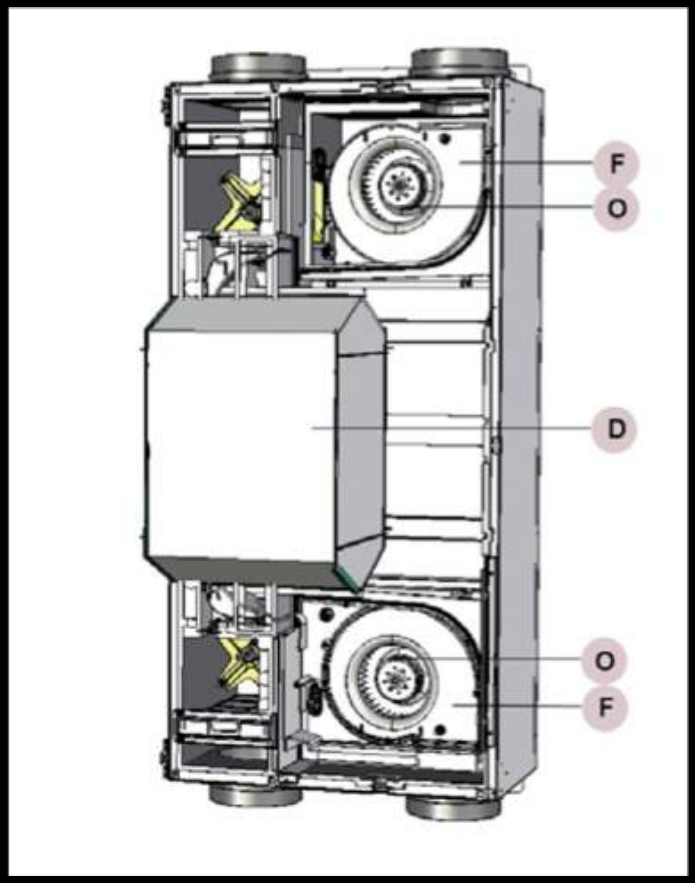
Zehnder CA200ERV

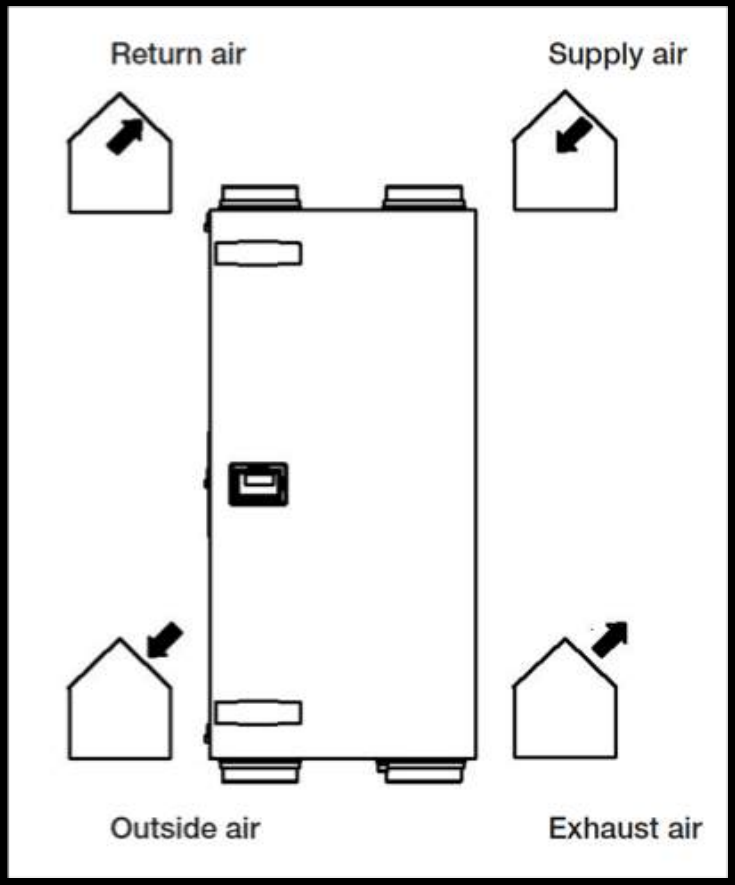
- ERV: Zehnder CA200 ERV
- 3 supply locations (BRs) 2 exhaust locations (baths)
- Balanced to 58 CFM supply and 57.3 CFM exhaust with powered flow hood (Flow Finder) at interior
- No boost – constant flow – 17-18W
- 176 kWh total energy in 2017; 18 kWh preheat
- 5 minute interval temperature monitoring on all four air streams at the unit connections (sensors calibrated within 0.2˚F)

Ventilation Layout

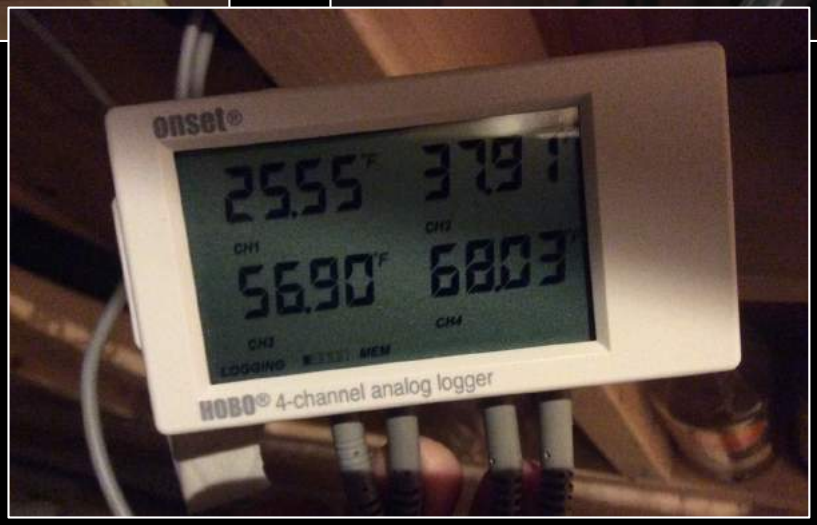


Zehnder CA200 ERV





Temperature Measurement



Onset Computer UX120-006M and (4) TMC20-HD sensors – 5 minute sampling

Effectiveness

- Effectiveness is the measure of how much of the temperature differential between outdoor and indoor air is recovered by the ventilator
- Effectiveness is affected by motor heat; heat transfer through the case; and internal condensation
- In this case (17-18W total power; well insulated case; ERV core) these effects are modest

Data

Data points selected for no preheater energy; Texh > 32˚F; new filters

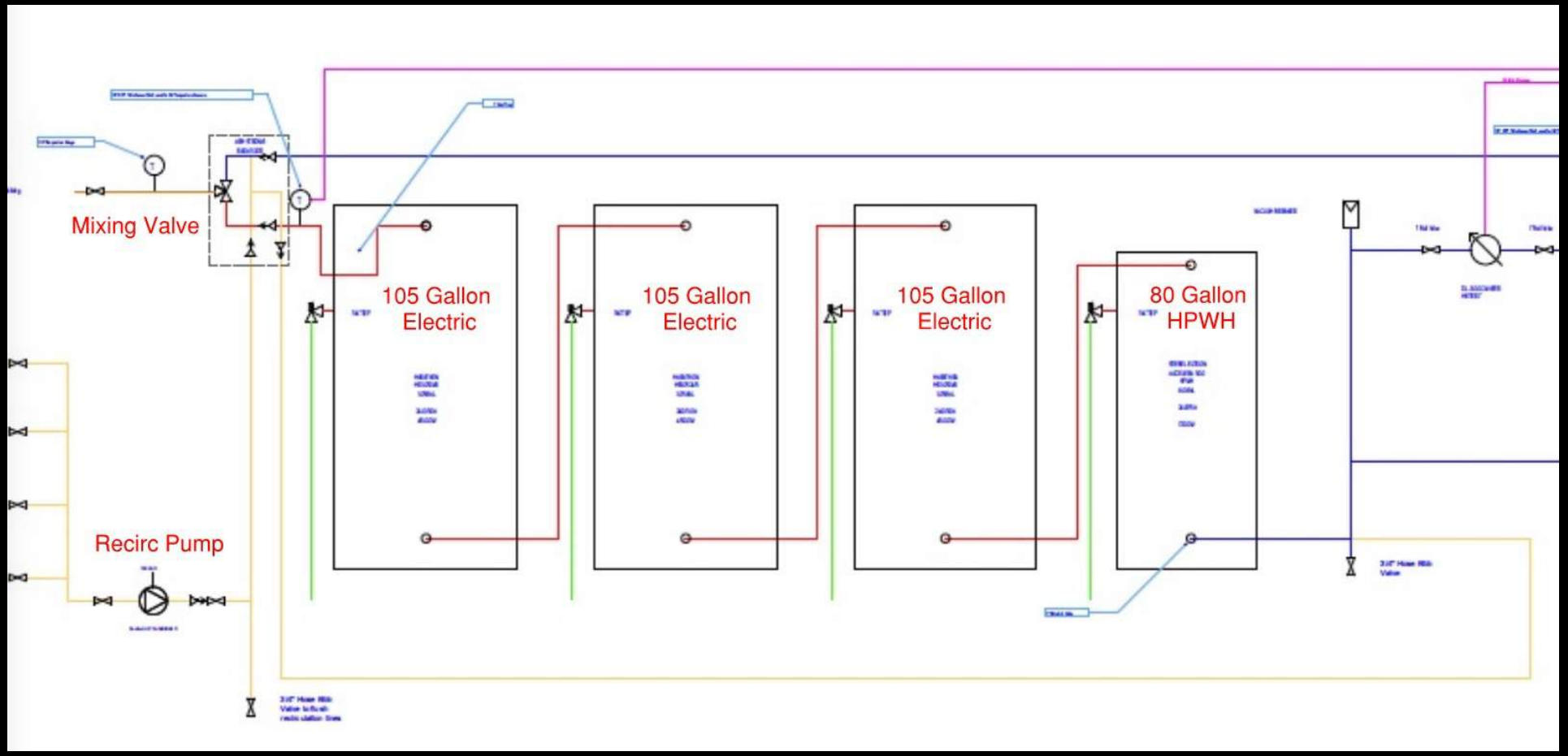
New Filters	Tout	Texh	Tsup	Tret
3/4/17 8:15	23.0	33.1	63.9	71.1
3/4/17 8:20	22.9	32.8	63.9	71.0
3/4/17 8:25	22.8	32.8	63.8	71.0
3/4/17 8:30	23.1	32.8	63.9	71.0
3/4/17 8:35	23.2	32.8	63.9	71.0
3/4/17 8:40	23.3	32.9	63.9	71.0
3/4/17 8:45	23.8	33.0	63.9	71.0
Average	23.2	32.9	63.9	71.0

- 87% Sensible Effectiveness
- 56% Latent Effectiveness

Projected Annual Performance

HDD 70	7,392
Gross ventilation load @ 58 CFM, BTU/yr	11,112,837
Net ventilation load @ 87% effectiveness, BTU/yr	1,398,467
Avoided ventilation load, BTU/yr	9,714,370
Avoided ventilation load, kWh/yr	2,847
kWh used ERV	176
ERV COP	**16.2**
HP COP	3.0
HP kWh saved by ERV	949
ERV COP, HP	**5.4**

DHW Recirculation



Data From Unoccupied Periods

RECIRCULATION OFF; NO DHW USAGE					
	HPWH 24HR USE KWH	ELECTRIC WH 1 24HR USE KWH	ELECTRIC WH 2 24HR USE KWH	ELECTRIC WH 3 24HR USE KWH	TOTAL DAILY KWH
2/23/16	1.27	1.2	1.08	0.2	3.75
2/24/16	1.36	1.3	1.32	0	3.98
2/25/16	1.69	1.23	1.18	0	4.1
2/26/16	1.05	1.18	2.21	0	4.44
2/27/16	1.12	1.17	1.08	0	3.37
2/28/16	1.42	1.14	1.08	0	3.64
2/29/16	1.1	2.26	1.08	0	4.44
Average	1.29	1.35	1.29	0.03	**3.96**

Data From Unoccupied Periods

RECIRCULATION ON; NO DHW USAGE					
	HPWH 24HR USE KWH	ELECTRIC WH 1 24HR USE KWH	ELECTRIC WH 2 24HR USE KWH	ELECTRIC WH 3 24HR USE KWH	TOTAL DAILY KWH
1/25/16	12.21	0	0	0	12.21
1/26/16	12.24	0	0	0	12.24
1/27/16	12.46	0	0	0	12.46
1/28/16	12.16	0	0	0	12.16
1/29/16	12.32	0	0	0	12.32
1/30/16	12.4	0	0	0	12.4
1/31/16	12.31	0	0	0	12.31
Average	12.30	0.00	0.00	0.00	**12.30**

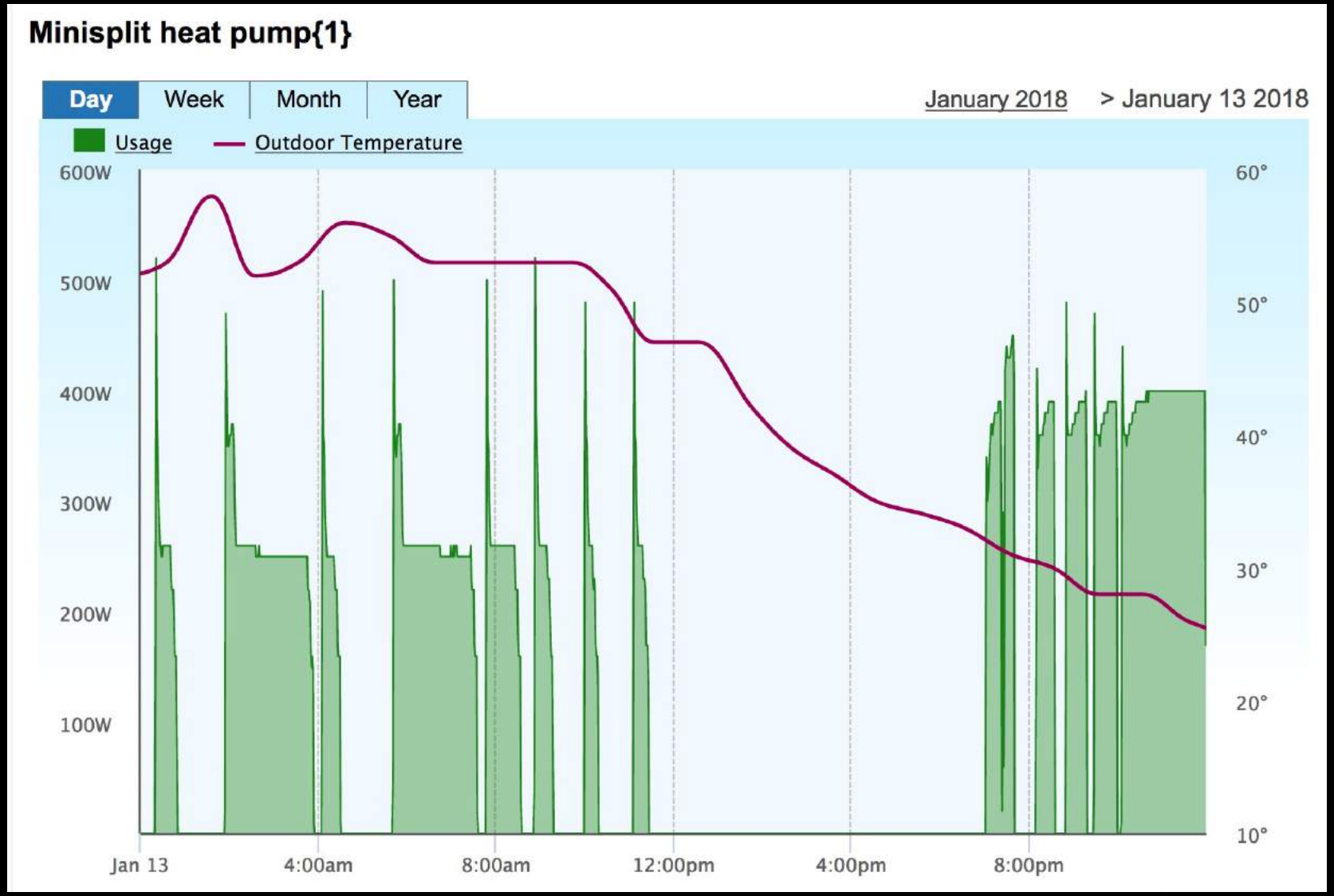
Annual Implications

- Energy use difference is 8.34 kWh/day
- Annualized this is 3,044 kWh/yr
- If the HPWH has a COP of 2.5, this amount of energy could make +/- 100 gallons/day of DHW

Air Source Heat Pump Monitoring

- Single zone ducted Fujitsu AOU/ARU9
- Past 3 year average usage 1,097 kWh/yr
- This is 0.82 kWh/sf/year based on GSF above grade – 0.142 Wh/sf/HDD65/yr
- Data point at -7˚F:
- Input of 2.09 kW; 368 CFM at 39.8˚F rise across the air handler is 15,750 BTU/hr, or 4.62 kW; COP = 2.21
- Fujitsu claims 13,500 BTU/hr at -5˚F, with an input of 1.92 kW; COP of 2.09

Single Zone Fujitsu Through a Day



Multi-zone ASHP Monitoring

- All multi-zone units monitored are Mitsubishi Hyperheat units
- No measured delivered energy data ☹

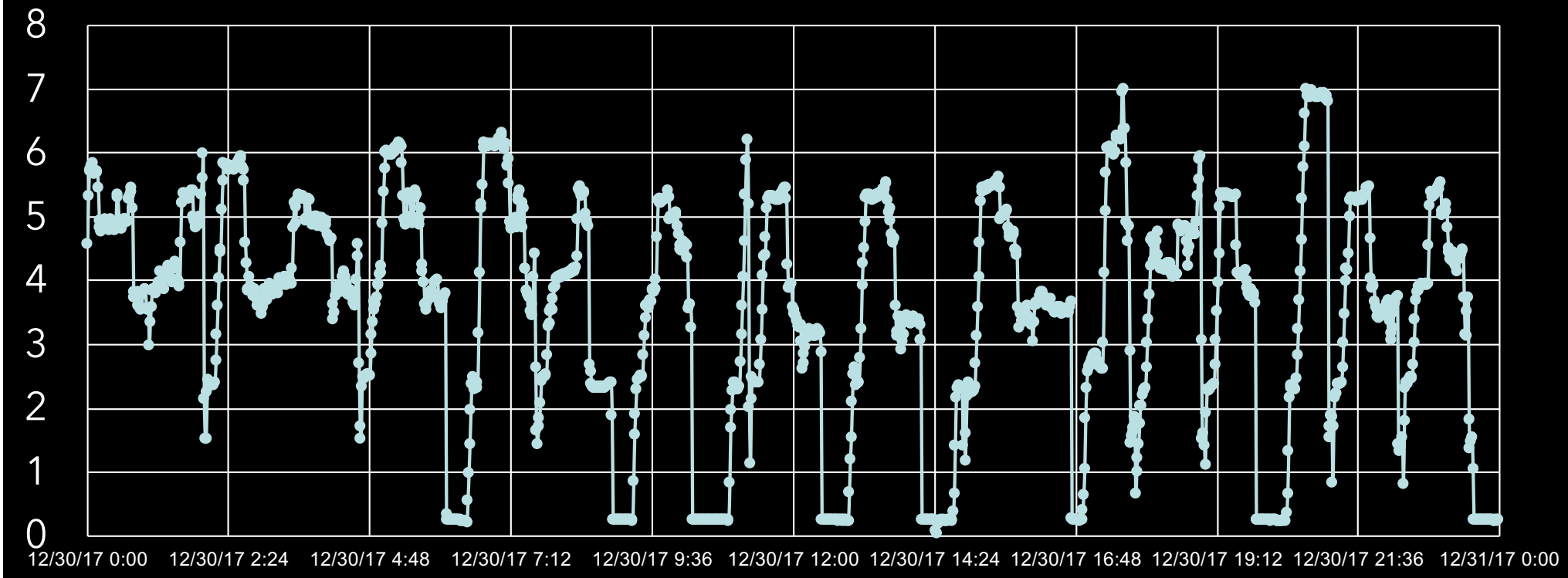
Three Zone on MV

- Three zones:
  - Ducted SEZKD12
  - Ducted PEAD-A24
  - Wall Cassette MSZ-GE06
- MXZ-8C48NAHZ outdoor unit
- MHK1 web accessible controls
- 2,800 sf house over crawl space, DER
- Very windy location
- Unoccupied now, controls set to 70˚F, running at 73˚F – shades drawn, minimal IGs
- Data is from 12/30/17 through 1/12/18

Three Zone on MV Data

Tavg = 17.5˚F; 85 kWh; 1.53 kWh/HDD;
0.549 Wh/HDD/sf

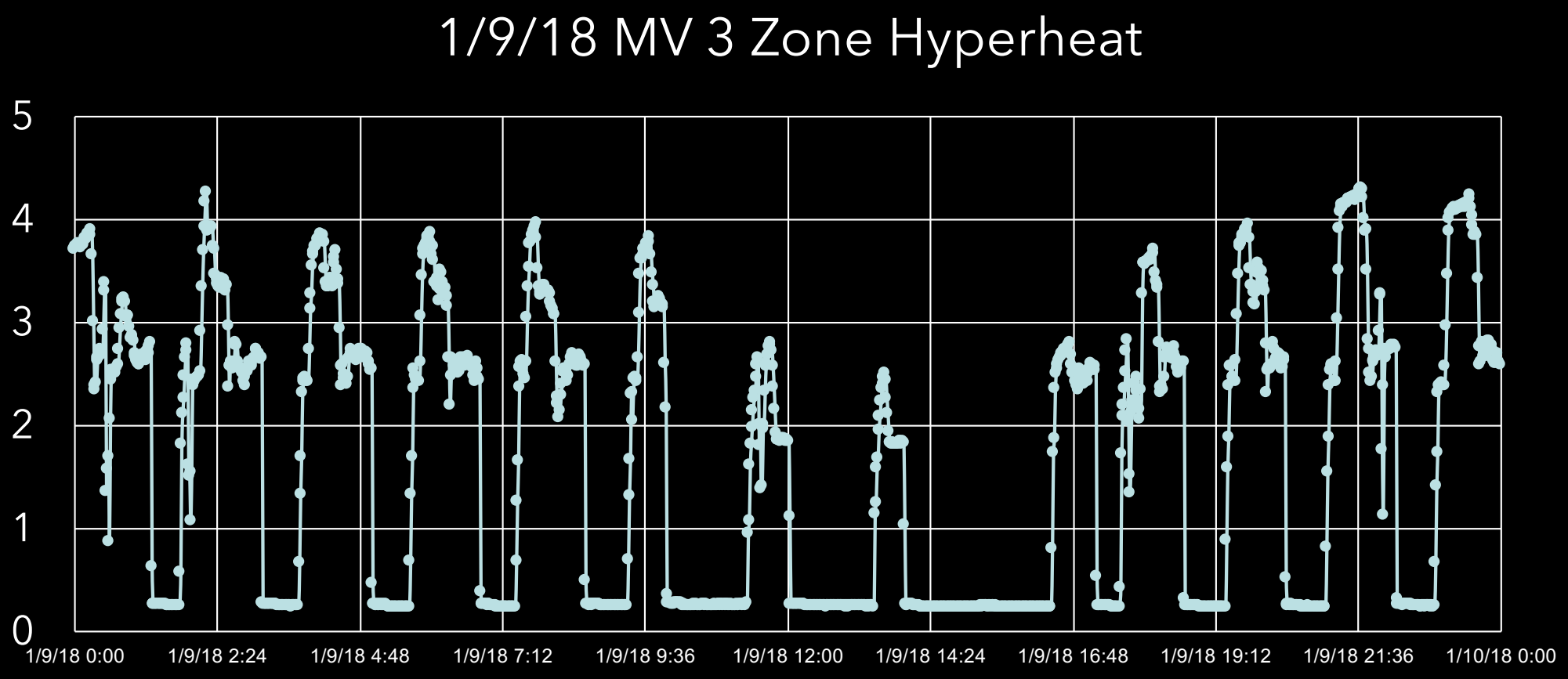
14 14 14 13 14 13 13 13 17 18 19 21 21 20 20 19 19 20 20 20 19 20 19 19



Three Zone on MV Data

Tavg = 36.1˚F; 40 kWh; 1.09 kWh/HDD;
0.391 Wh/HDD/sf

34 34 35 35 35 35 35 35 36 37 38 39 41 41 41 40 39 37 36 35 33 33 31 31

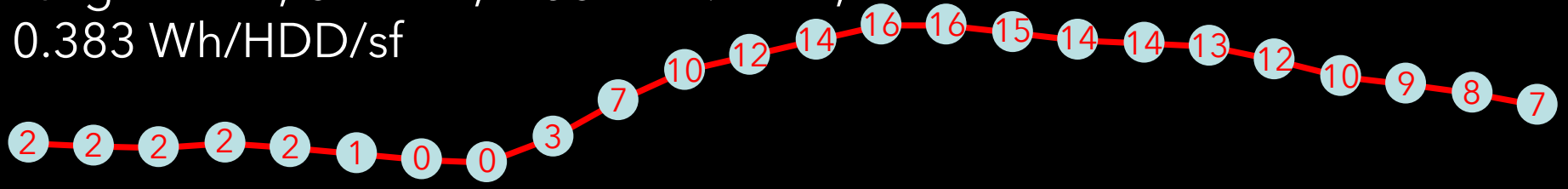


5 Zone Metro Boston

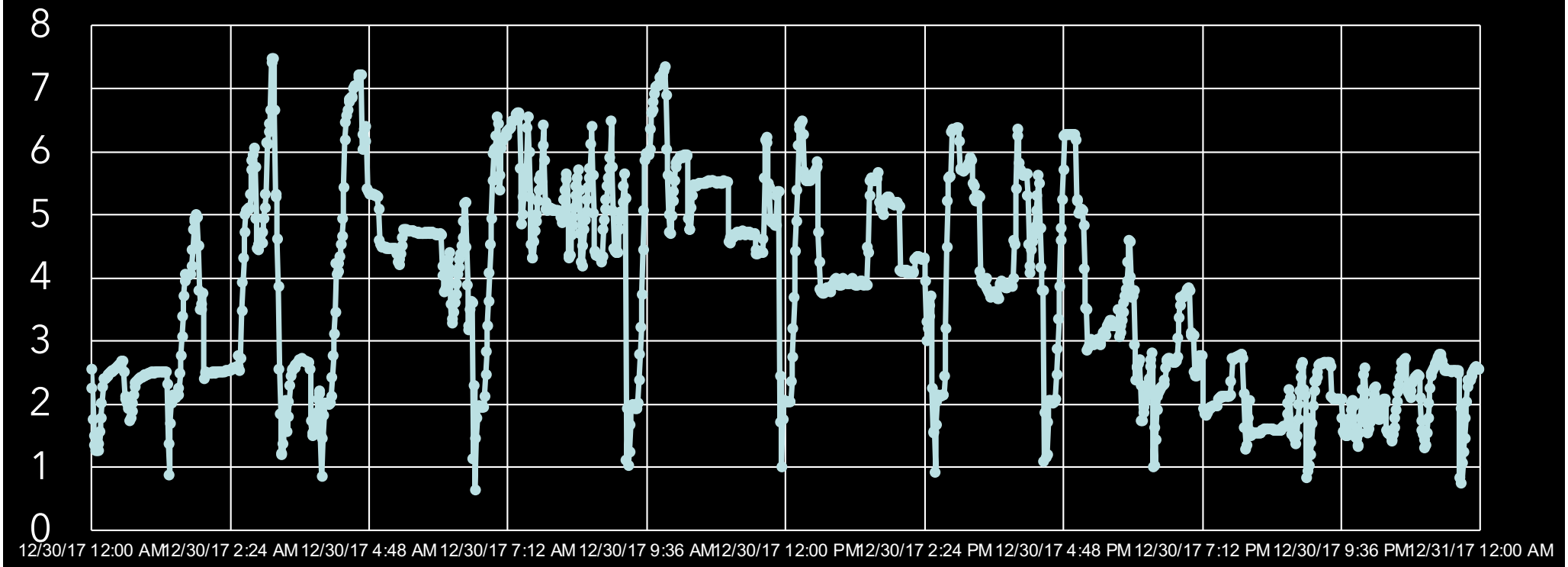
- Five zones:
  - Ducted SEZKD12 plus (2) ducted SEZKD09
  - Ducted MVZ-A18
  - Wall Cassette MSZ-GE06
- MXZ-5C42NAHZ outdoor unit
- MHK1 web accessible controls
- 3,600 sf house over full basement, PH
- Occupied now, running at 71˚F – significant IGs
- Data is from 12/30/17 through 1/12/18

5 Zone Metro Boston

Tavg = 7.9˚F; 89 kWh; 1.38 kWh/HDD;
0.383 Wh/HDD/sf

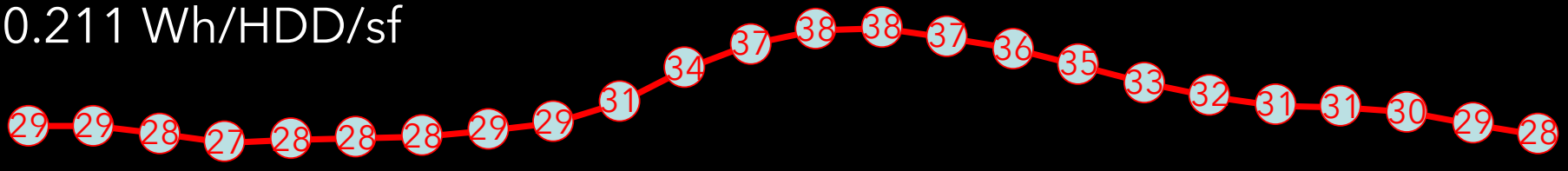


12/30/17 5 Zone Metrowest Boston

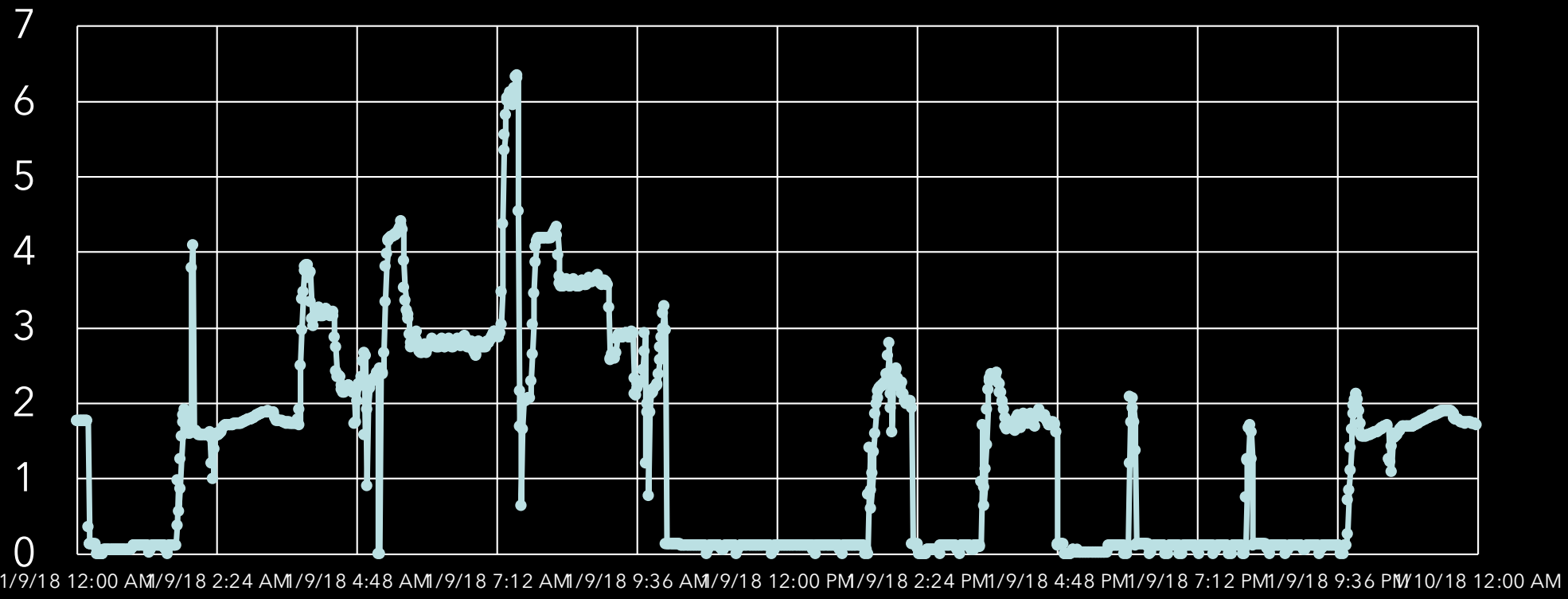


5 Zone Metro Boston

Tavg = 31.5˚F; 32 kWh; 0.76 kWh/HDD;
0.211 Wh/HDD/sf



1/9/18 5 Zone Metrowest Boston



Turndown

	Max/Min Output; kW Input		
Unit	47˚F	17˚F	5˚F
Fujitsu AOU/ARU09	18/3.1; 0.15	16.1/2.7; 0.14	15/2.6; 0.15
Mitsubishi MXZ-5C42NAHZ	48/24; 1.17	48/24; 1.66	48/24; 1.91

Source: NEEP Cold Climate Heat Pump Directory

Heat Pump Energy Use Through 1/15/18

Unit	House SF	HDD65	kWh	Wh/SF /HDD
Fujitsu AOU/ARU09	1334	2544	471	0.14
Mitsubishi MXZ-5C42NAHZ	3600	2278	2647	0.32

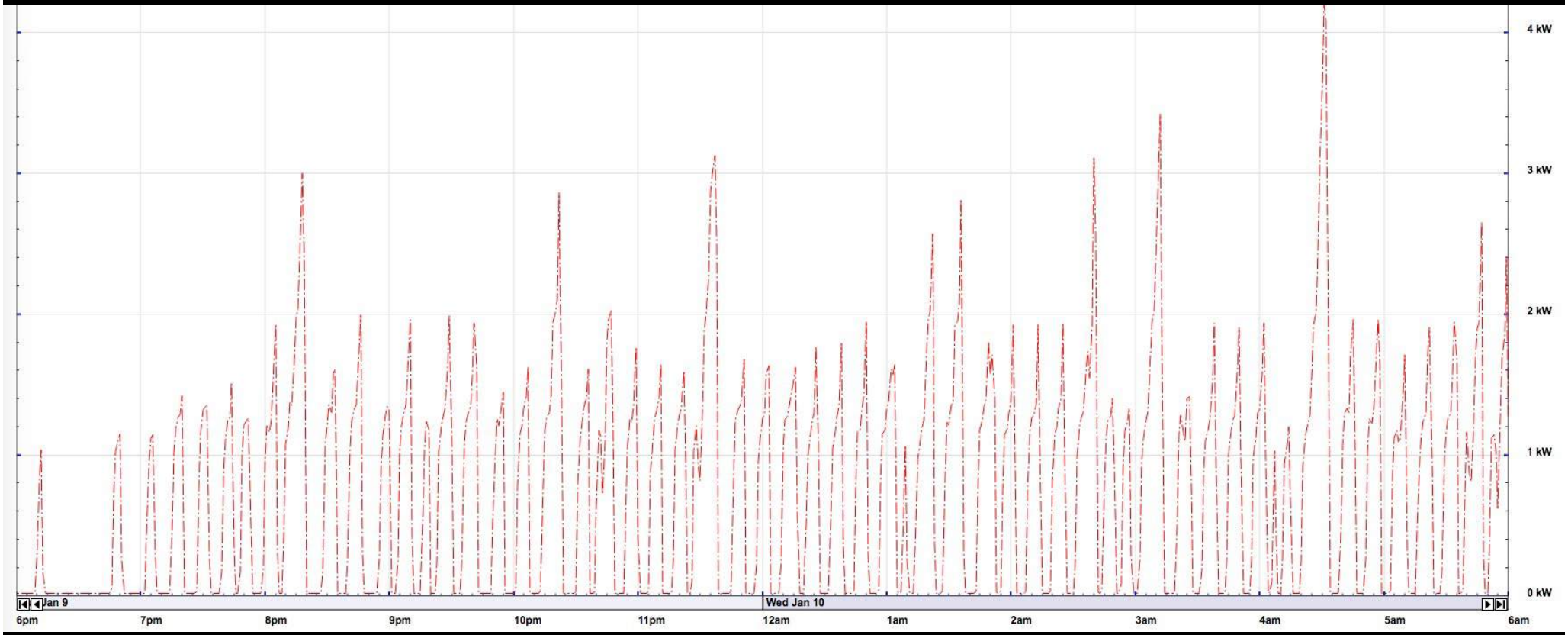
SMC HQ

- (2) PUMY P60NKMU City Multi S Series
- (7) zones, (4) wall, (3) floor cassettes
- 3,350 sf office over wood shop
- Occupied now, running at 71˚F – significant IGs
- 2x6, 2x10, double low-e – nothing special
- Data is from 12/30/17 through 1/12/18
- 12/30 – 16˚F, 129 kWh, 2.32 kWh/HDD, 0.691 Wh/HDD/sf
- 1/9 – 35˚F, 56 kWh, 1.54 kWh/HDD, 0.459 Wh/HDD/sf

MV School HVAC Retrofit

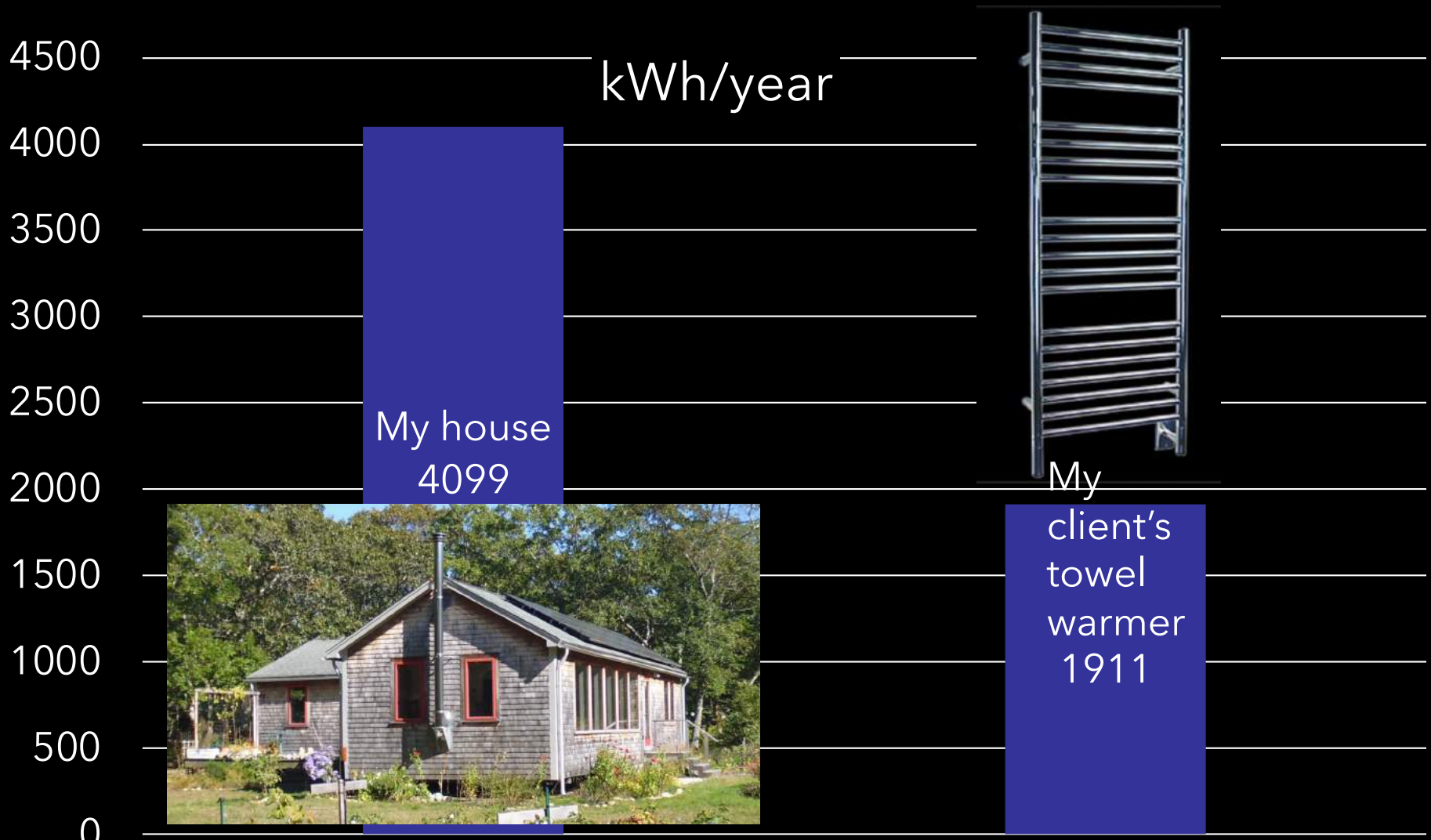
- (2) MXZ-4C36NAHZ Hyperheat
- (4) MSZ-GE18 (one in each 568 sf classroom)
- Timber frame, SIPS, double low-e, over crawl space – leaky
- Data is from 12/30/17 through 1/12/18
- 12/30 – 16˚F, 106 kWh, 1.95 kWh/HDD, 0.858 Wh/HDD/sf
- 1/9 – 35˚F, 52 kWh, 1.48 kWh/HDD, 0.651 Wh/HDD/sf

Interface with Other Controls

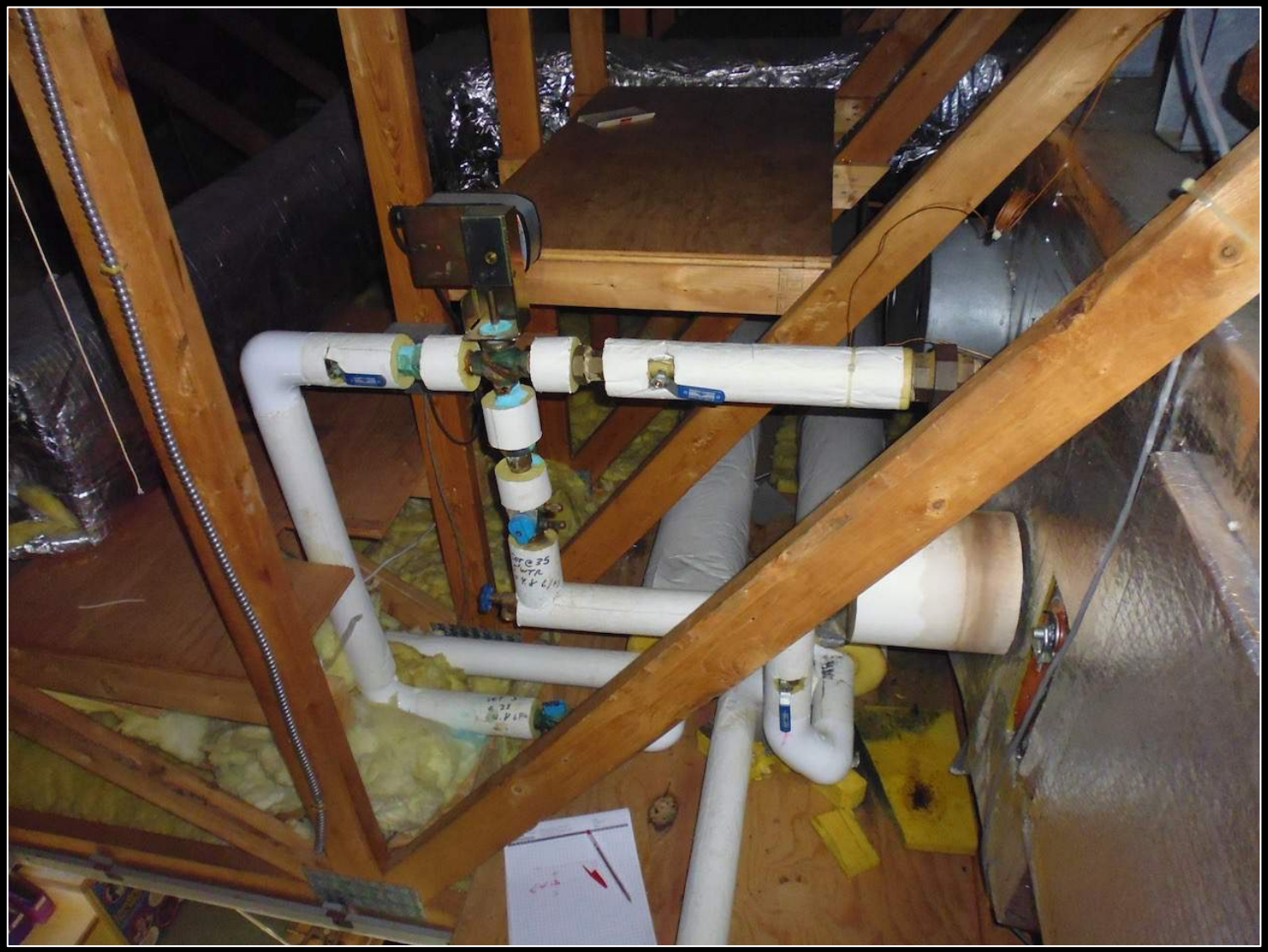


- Many after-market controls cause the heat pumps to change from variable speed to on-off
- Cool Automation and Control4 are promising but $$

Some Perspective…



Ventilation Retrofit CO2 Monitoring



Ventilation Retrofit

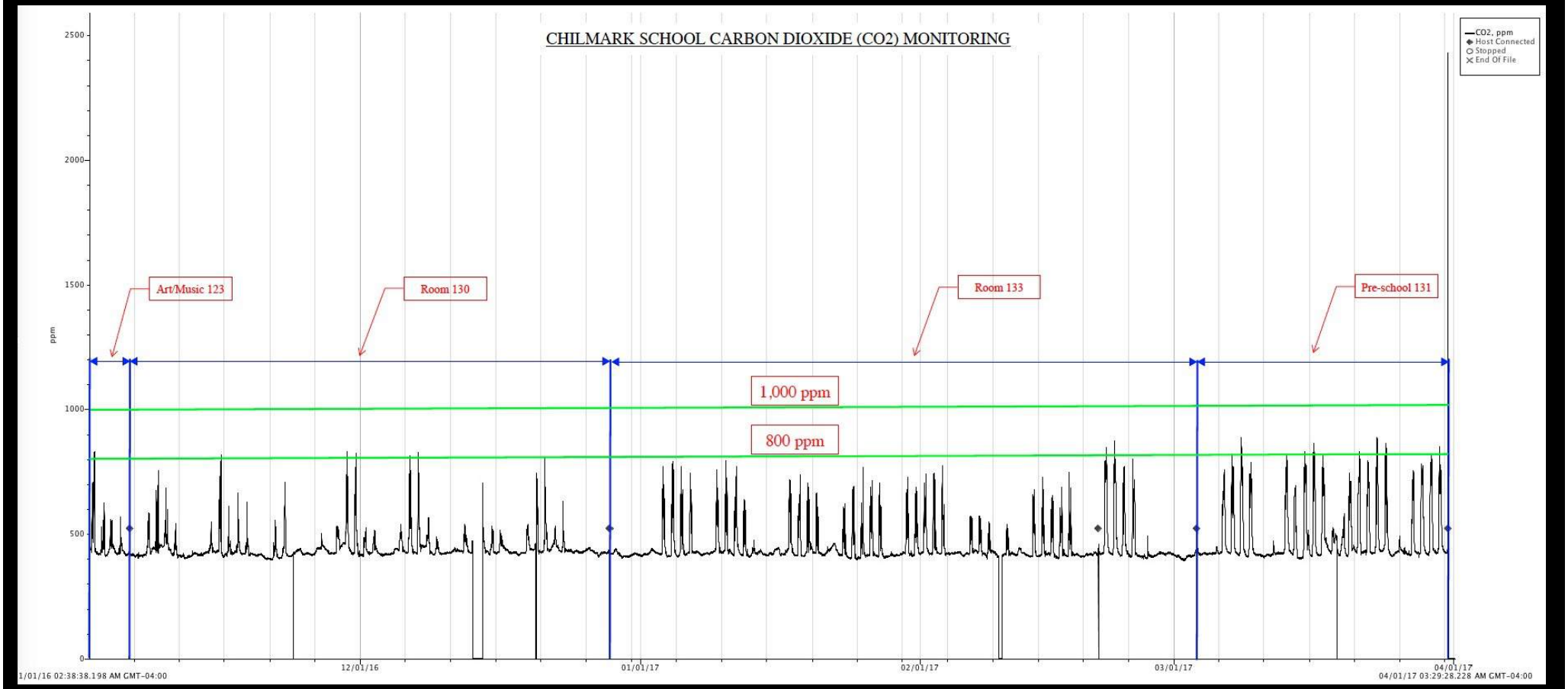
- Project is a retrofit of ERVs to a small K-5 school
- Each of 7 classrooms has a Renewaire EV450 ECM
- Lobby/offices/reception has a Renewaire HE1XINH ECM
- Classroom distribution is via a fabric duct
- Control is a dual-technology occupancy sensor
- Classrooms have up to 18 occupants
- Flow rates balanced to slightly below ASHRAE 62
- Four classrooms were logged at 5 minute intervals with a Telaire T7001 carbon dioxide monitor connected to an Onset Computer UX120-006M logger

Typical Classroom

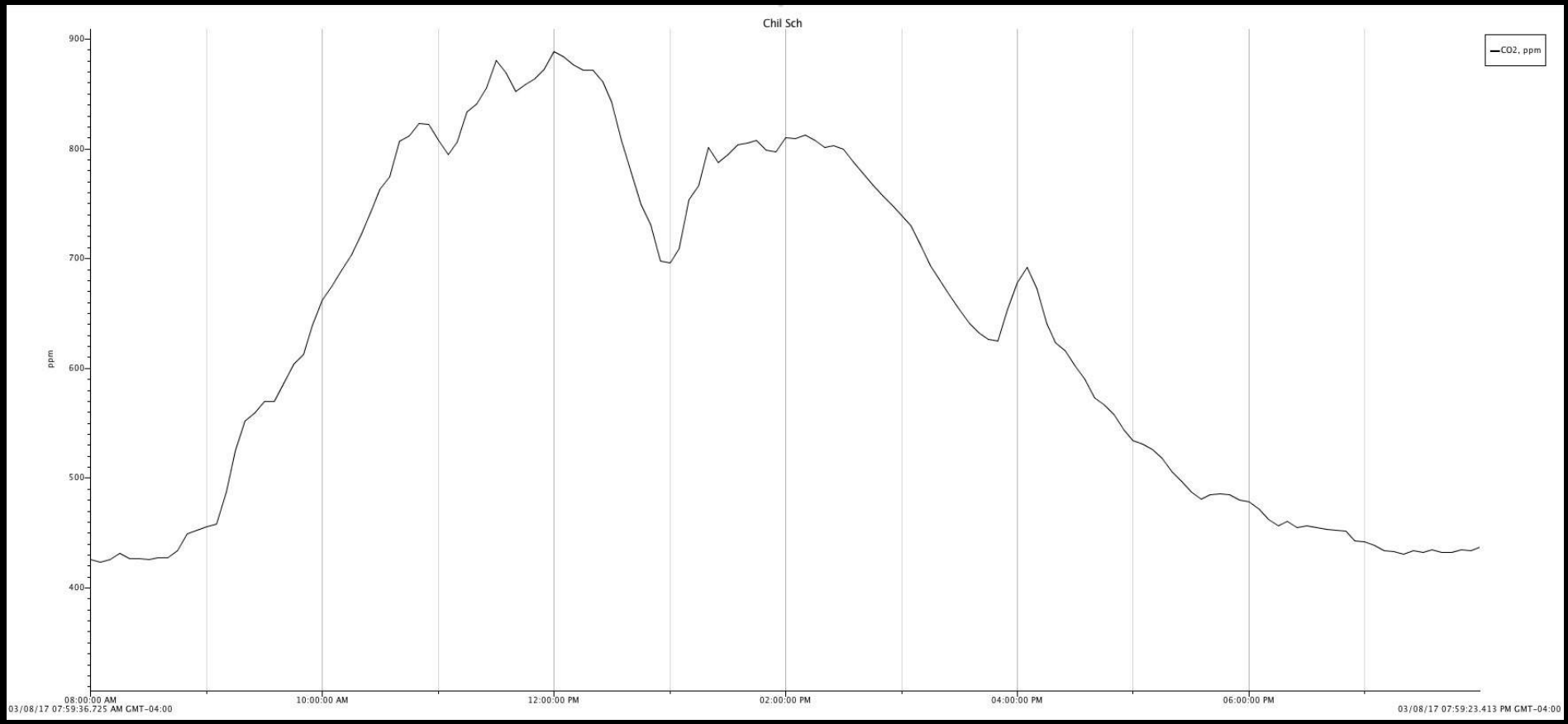
Lobby System

Balancing

CO2 Measurements



One Day CO2 Levels



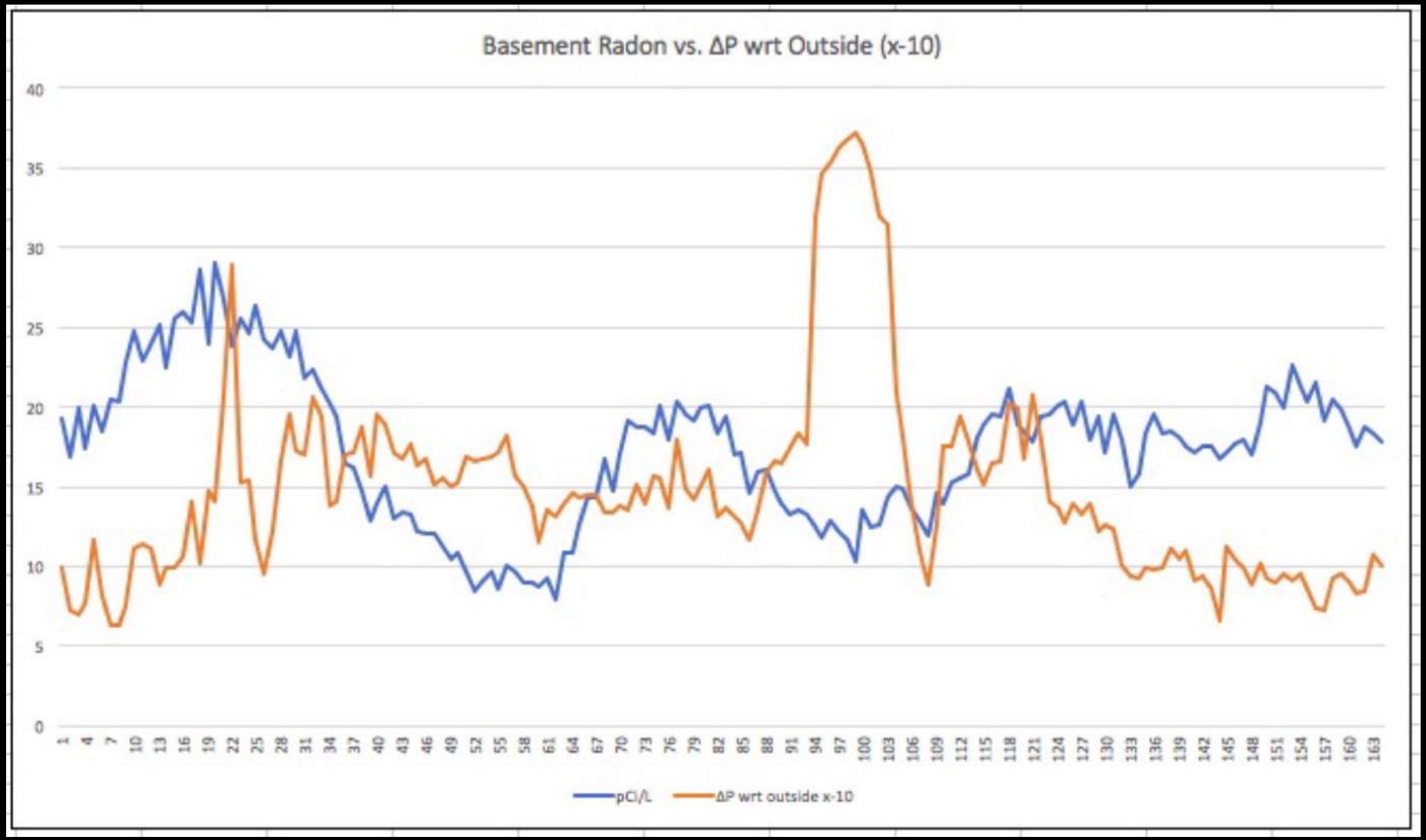
- CO2 peaks at 889 ppm
- 30 minute time delay off on the occupancy sensor

Resourcefulness

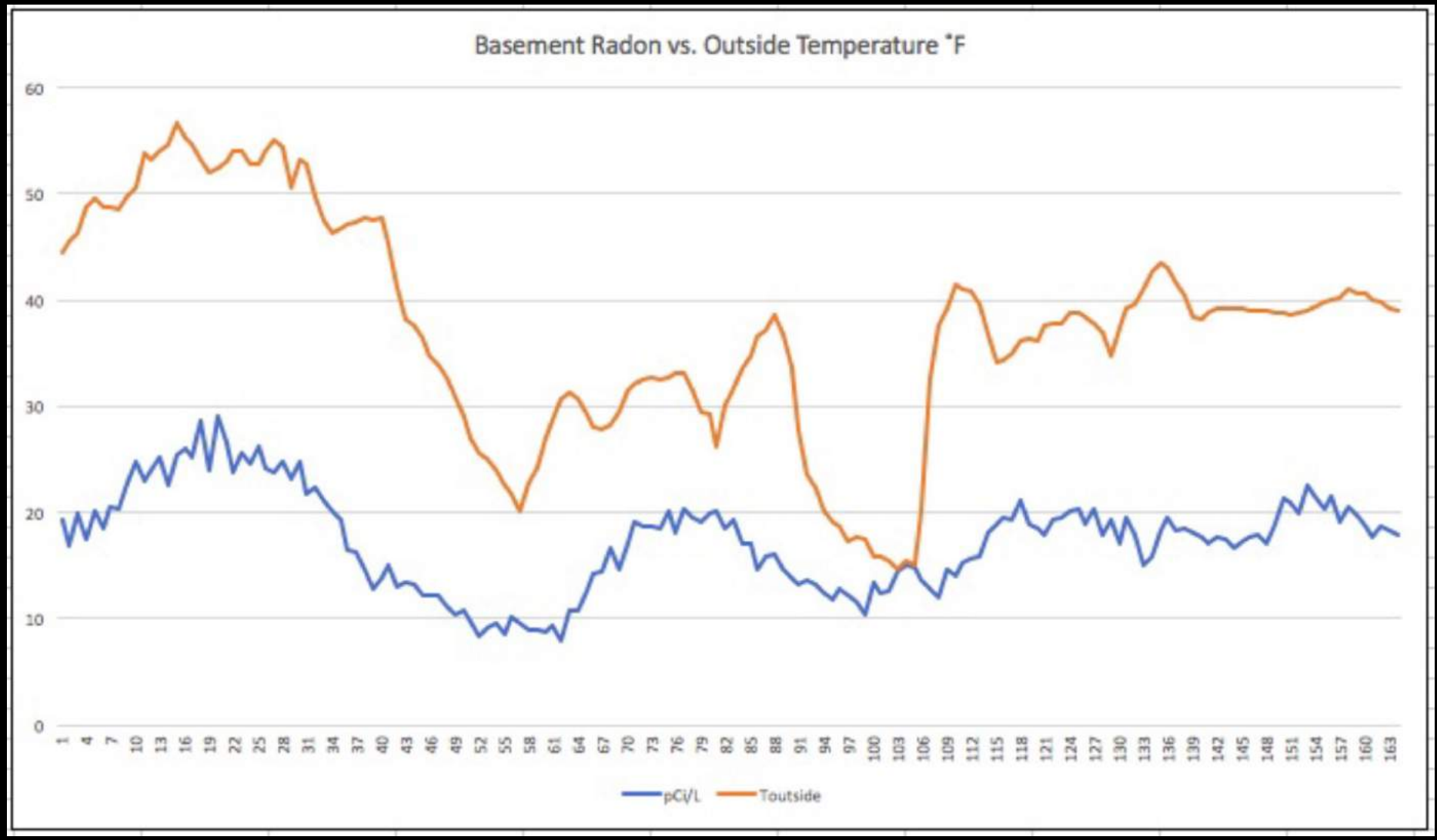
Radon in Tight Houses

- The flow rate of a gas across a resistance is affected by pressure
- In tight houses (let's say, under 200 CFM50), small flow imbalances can impose measurable pressure differentials (my range hood and my dryer running simultaneously brings my house 38 Pascals negative wrt outdoors)
- I measured basement radon with a Radstar RS300 (hourly measurements) and basement pressure wrt outdoors with a DG-700 digital manometer.

Radon vs. ΔP


Basement Radon vs. ΔP wrt Outside (x-10)
40
35
30
25
20
15
10
5
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91 94 97 100 103 106 109 112 115 118 121 124 127 130 133 136 139 142 145 148 151 154 157 160 163
pCi/L
ΔP wrt outside x-10

Radon vs. ΔT


Basement Radon vs. Outside Temperature °F
60
50
40
30
20
10
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91 94 97 100 103 106 109 112 115 118 121 124 127 130 133 136 139 142 145 148 151 154 157 160 163
pCi/L
Toutside

Anecdotal observations

- Experienced radon researchers have told me that a guideline is that the radon concentration on the first level of the house over the basement is about ½ the concentration in the basement
- My experience is that tight houses have a larger ratio – my basement level is about ten times higher than my bedroom
- A friend is monitoring radon in his older house and is seeing high levels when it's very windy outdoors

Thank You!

Marc Rosenbaum, P.E.
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