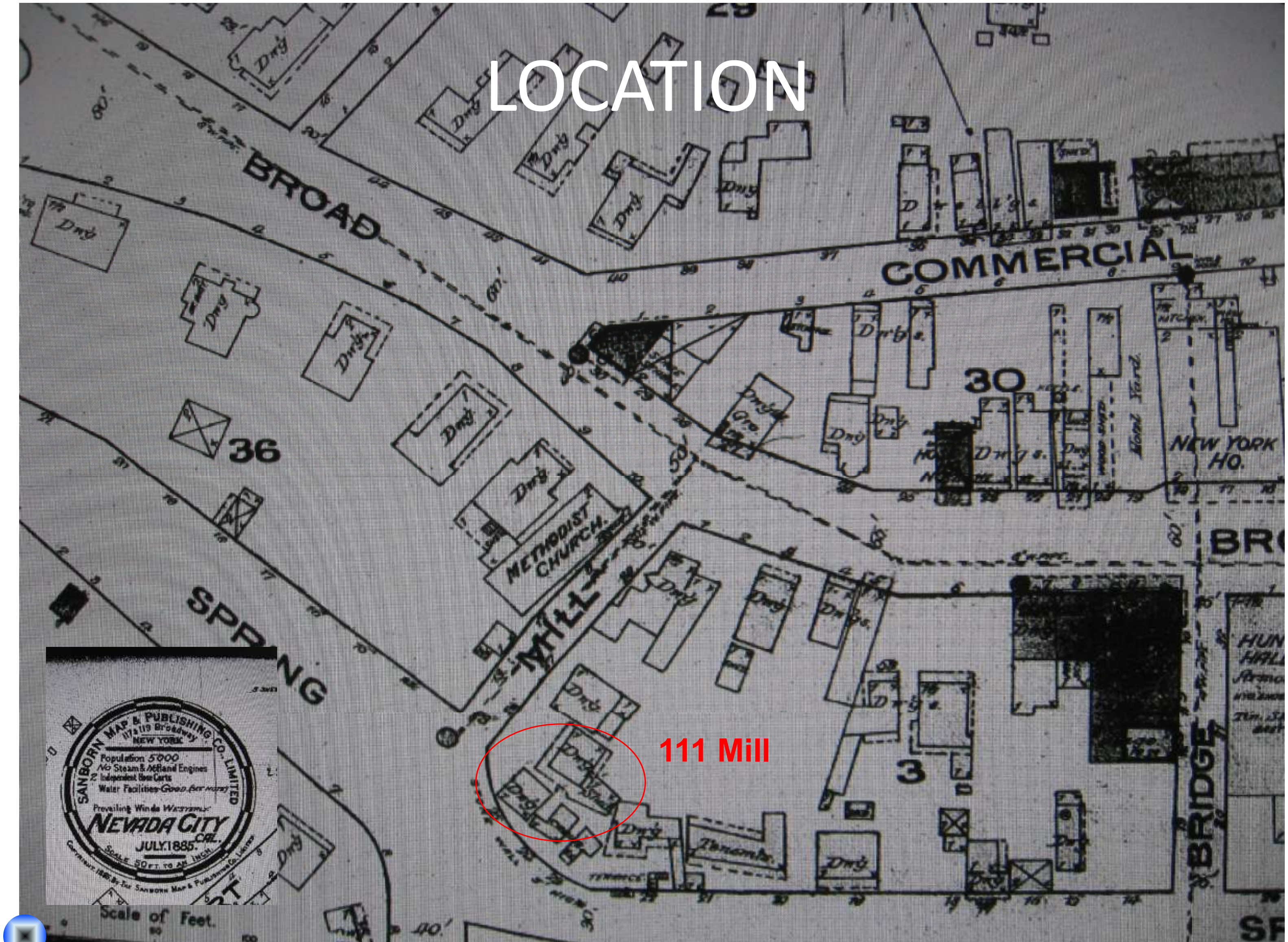

POS
DREAM HOUSE
NO
PARKING
ANY
TIME

POS DREAM HOUSE

- Located Sierra Nevada foot hills California , 5600 HDD, Poor site for PV due to shading , roof orientation, and historic commission.
- Pretty good house (not a passive house) .
- 1700 Ft^2 two story, 1880 Victorian plank frame, Rebuilt 2009-2015, no change to exterior building shape.
- .53 ACH50, Above grade walls advance frame 2x6 wall spray cellulose + 1.5" R-max foam continuous exterior sheeting. Below grade walls ICF, 3" continuous sub slab insulation (except for a big rock). Vented attic, R70+ cellulose, Windows double hung wood frame typical north American U .28 & SHGC .18
- Total site energy in 2014 (pre CO_2 water heater) Kwh: 7219Kwh, $492.29

LOCATION



BROAD
COMMERCIAL
MILL
SPRING
BRIDGE
METHODIST CHURCH
NEW YORK HO.
36
30
3
111 Mill
SANBORN MAP & PUBLISHING CO. LIMITED
NEW YORK
Population 5000
NEVADA CITY CAL.
JULY 1885.
Scale of Feet.

Purchased house in 2006 Just your typical California fixer



Combustion safety problems

Evolution of a porch

Wildland fire safety concerns

Step one establish an air barrier

They don’t build them like they use to

The building was out of plumb, out of level and some rooms felt unsafe to stand in.

(BEFORE) TYPICAL CALIFORNINA CRAWL SPACE

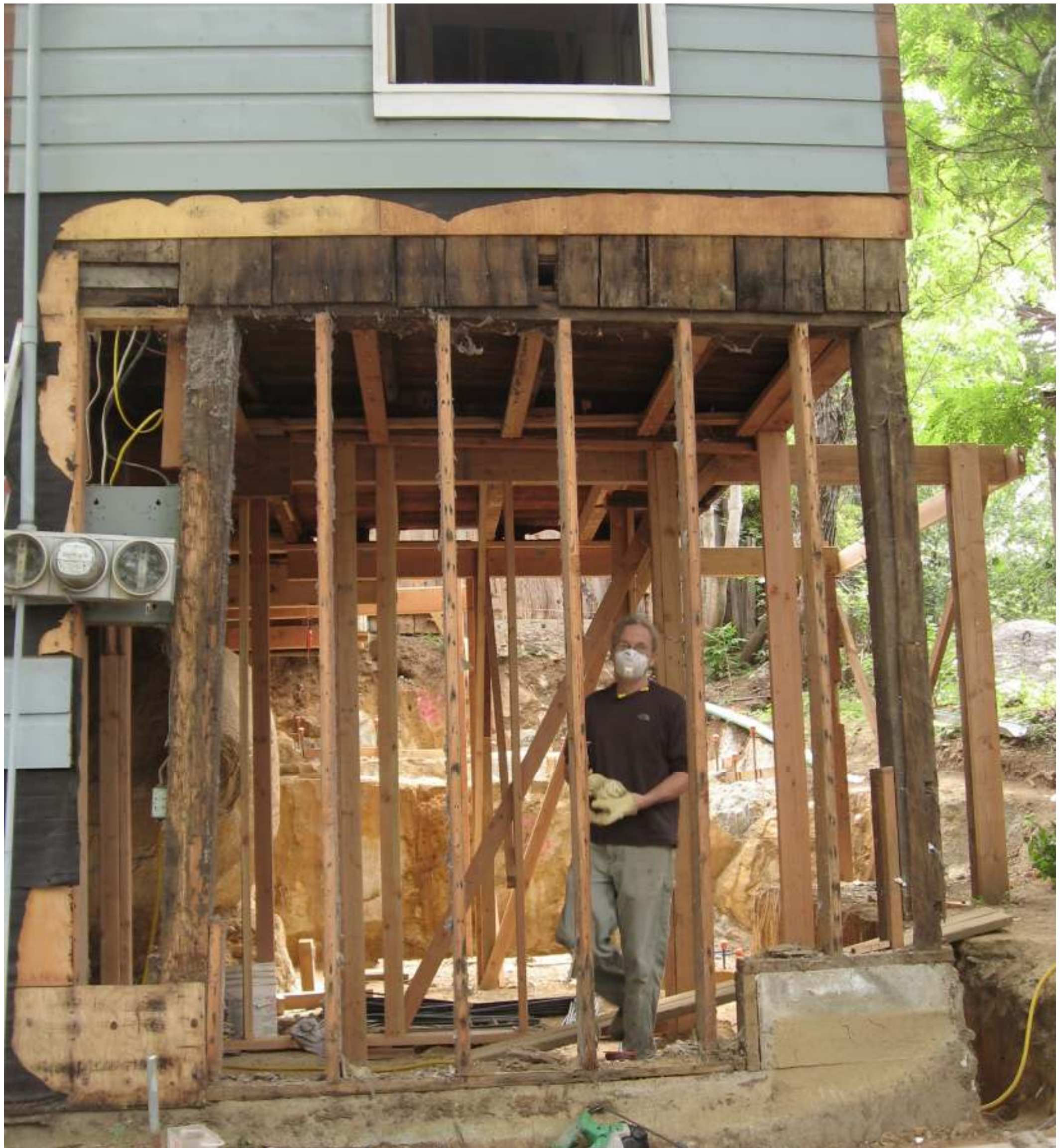

(BEFORE) NOT SO TYPICAL CRAWL SPACE

Termites and wood bees

Replace existing failed and missing foundation

ICF used due to proximity to proximity to neighbors houses, zero lot lines in historic town resulted in potential encroachment issues.

140 yards of dirt and rock hand excavated from under the building for the foundation upgrade.



Raise the Building

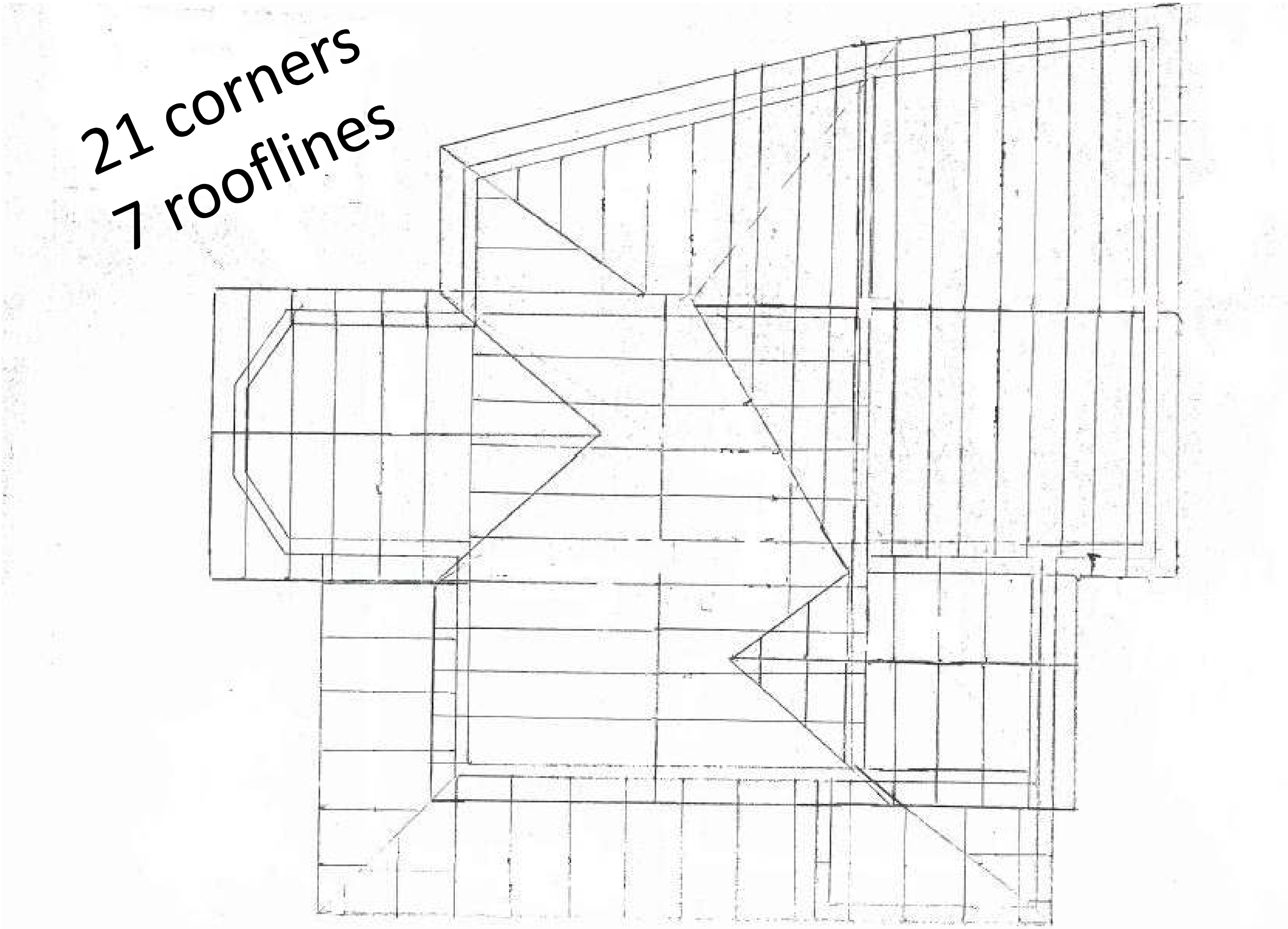
One key benefit to raising the building is the opportunity to add an effective capillary break between an existing or new concrete foundation and wood framing of the building. This capillary break can be a building gasket to create a more pliable air barrier at a critical joint.

CAN THE BUILDING BE LIFTED, OR DO WE HAVE TO WORK WITH IT AS IS?
If the foundation is shallow, buckled, or unsound it might be time to replace it.

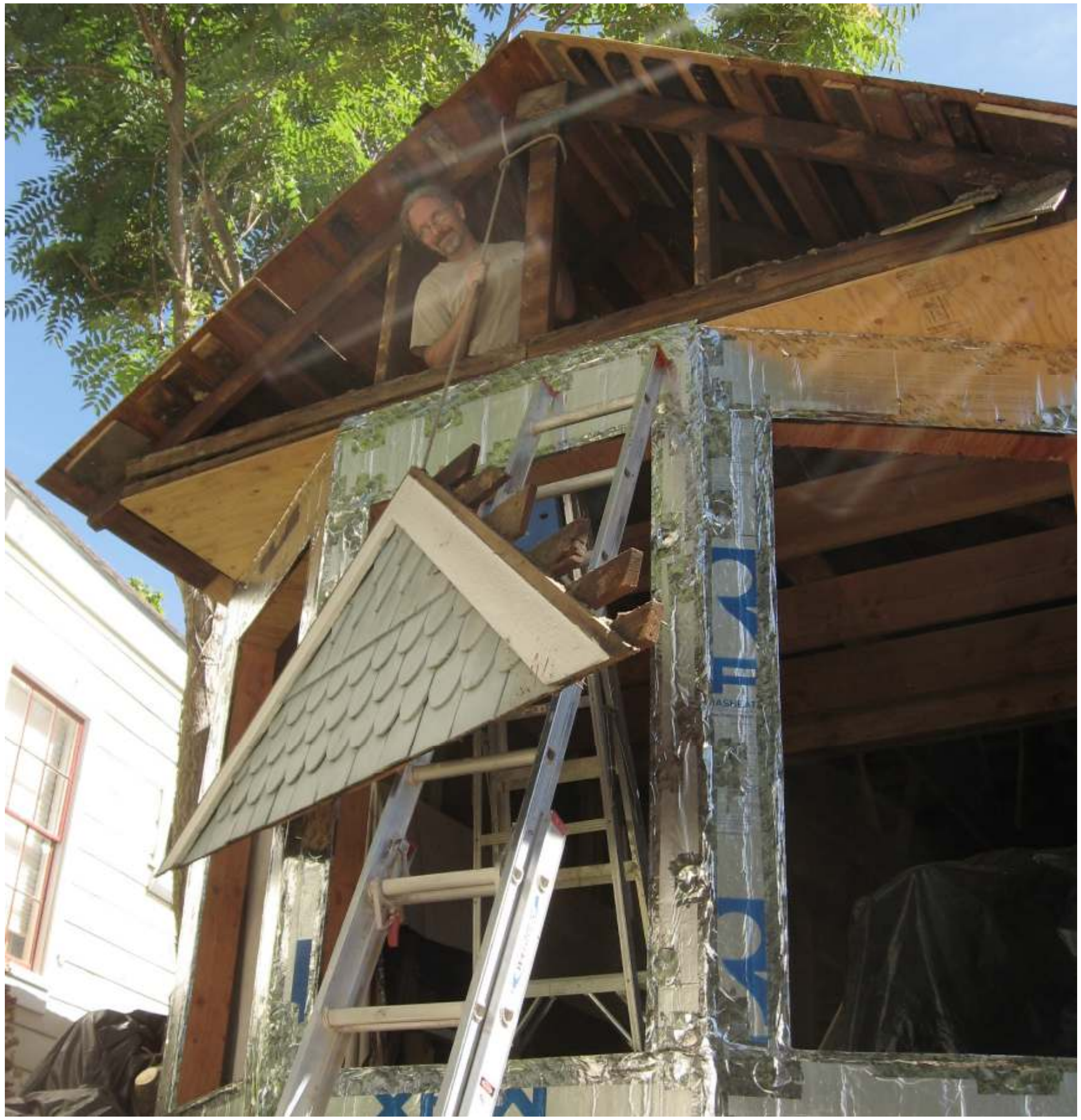
Below grade applications

XPS foam board on grade crawl space/basement 3 inches over vapor barrier

FOAMULAR 600
R-7.5
1½ inch Thickness
ZERO OZONE DEPLETION


21 corners
7 rooflines

Save what ever we could for reuse.




MAX
R MAX
R MAX


Death-Road
Survivor
MADNESS


TYPAR
HouseWrap

MADE


Wall spray Cellulose application

Cellulose behind netting at rim joists

FIRST BLOWER DOOR TEST .59 ACH 50

Evolution of the mechanical systems

Original Mechanical Systems

12 year old back drafting natural draft water heater vented to the attic

15 year old natural draft furnace installed with no return air duct, return siting directly on dirt, and a single supply duct with booster fan.

wood fire place all kinds of problems

New Mechanical systems

First Co hydronic air handler with ECM motor and low total external static pressure, paired with a condensing tank water heater rated at 97% efficient.

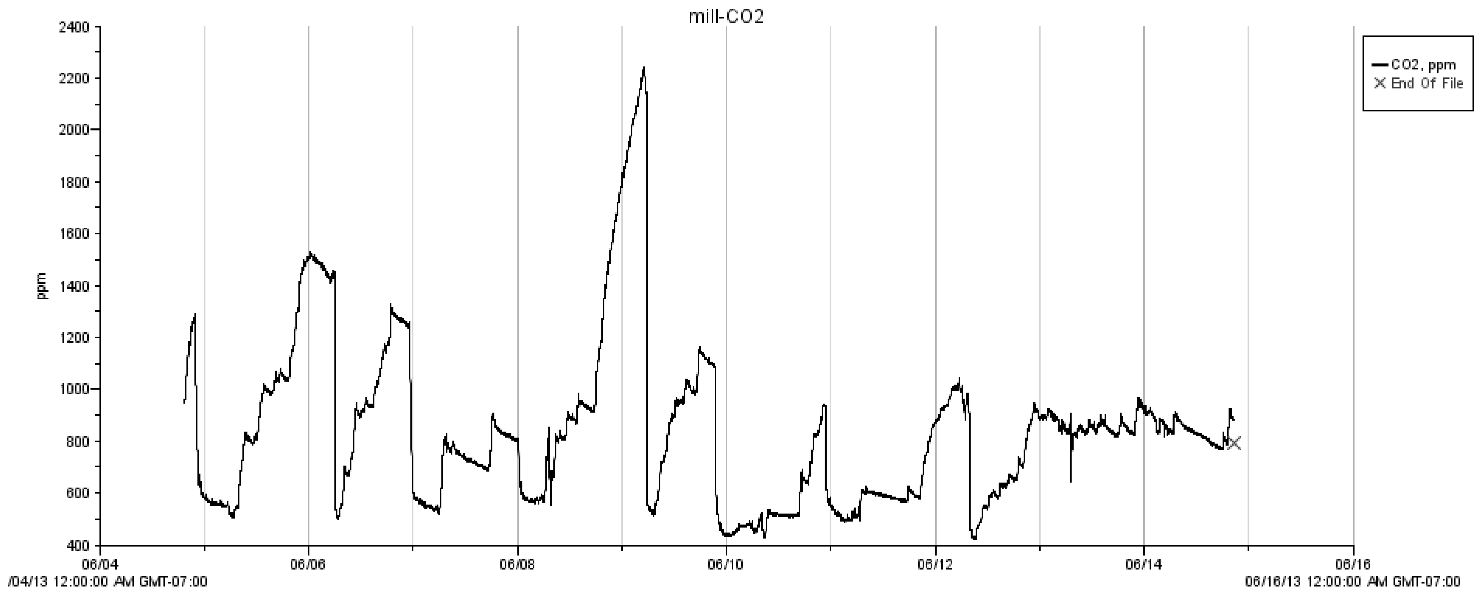
Supply and return water delivered through 1/4 “ mini-split line set tubing. Open loop system for system simplicity. All water run at 120F, controlled BTU output through restricted flow to hot water coil

Average Site Characteristics
5 minute data average Dec 15 2012-Jan 31 2013
This is indicative of the baseline condition of the house

	Inexpensive ways to gather data
37 ^{0}F outdoor temperature	wifi T-stat
67.3 ^{0}F indoor temperature	wifi T-stat
System run time 745 out of 1104 hours (67%)	wifi T-stat
Water heater inducer fan energy 13.32Kwh ($1.73)	smart plug
Air handler fan and pump energy 71.66Kwh ($9.32)	smart plug
total daily gas consumption 1.15 therm/day (81% space heat, 19% DHW)	PGE smart meter
Average 92,000 BTUS heat per day	PGE smart meter
Average run time 16 hours, Max run time 22 hrs, minimum run time 11 hrs	wifi T-stat
3400-4600 BTU/hr output depending on water heater efficiency.	onset data loggers: water flow and two external temp sensors

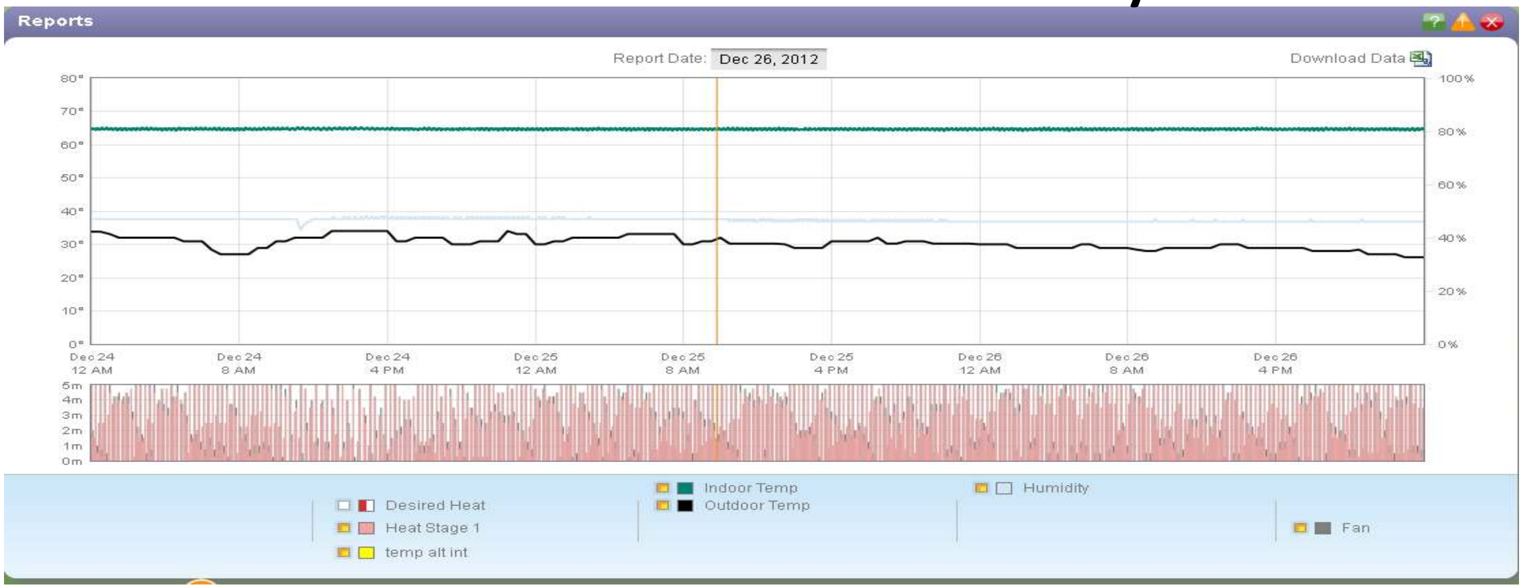
HEAT RECOVERY VENTILATOR with low static high performance distribution and site built filtration of out door and indoor air.

Ventilation Rate Proxies



Monitored CO2 rates for a year after initial occupancy: Chart above represents typical peaks in closed house conditions when the ventilation system is off. Note this is based on primary strategy of summer time night cooling with no mechanical ventilation during the day, house closed conditions.

Winter test with ventilation system off



This graph shows run time on hydronic system set for 65 degrees 24/7 during a vacation period at design day temperatures with no ventilation system running, house closed tight and very limited miscellaneous plug loads that would add heat to the builing (no lighting).

Low load hydronic heat

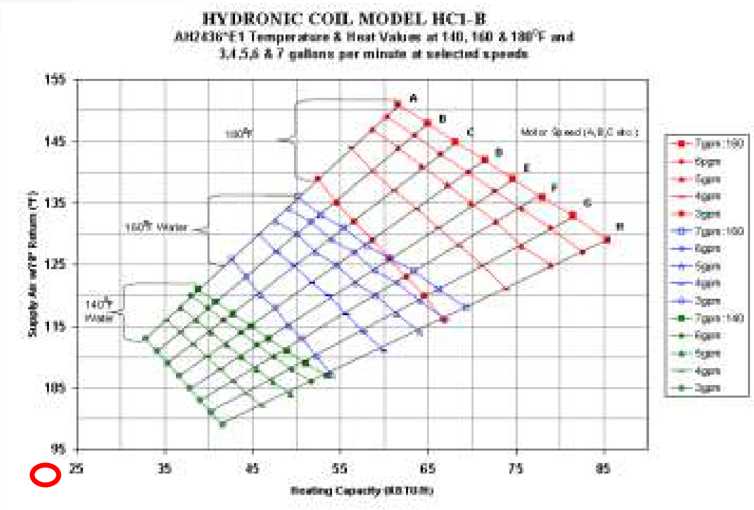
Retrofit Application Pre condition Dec-4-2012 to Nov 13, 2014

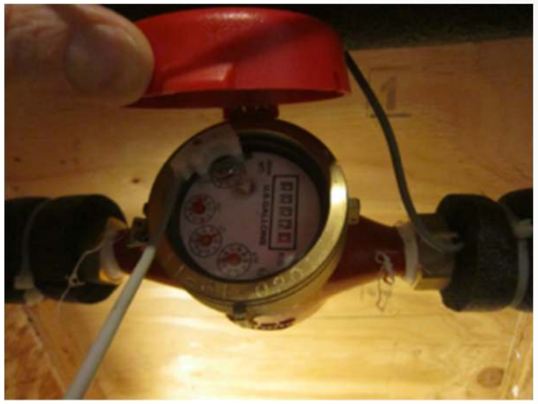
- Two years of monitoring performance, energy consumption, comfort and responsiveness.
- First Co 24VHBQB hydronic air handler, configured in an open loop. Equipment modified to run circulation fan as single speed heat only.
- Pluming loop ¼" refrigerant tube for open loop circulation system to regulate the flow and control the BTU output to 3500-4500 BTU/hr.
- Original water heating plant: AO Smith GDHE-50 Power Direct Vent, 50-gallon tank, 100,000 BTU gas burner, **rated** thermal efficiency of 96%, and a recovery rate of 129 gallons per hour.

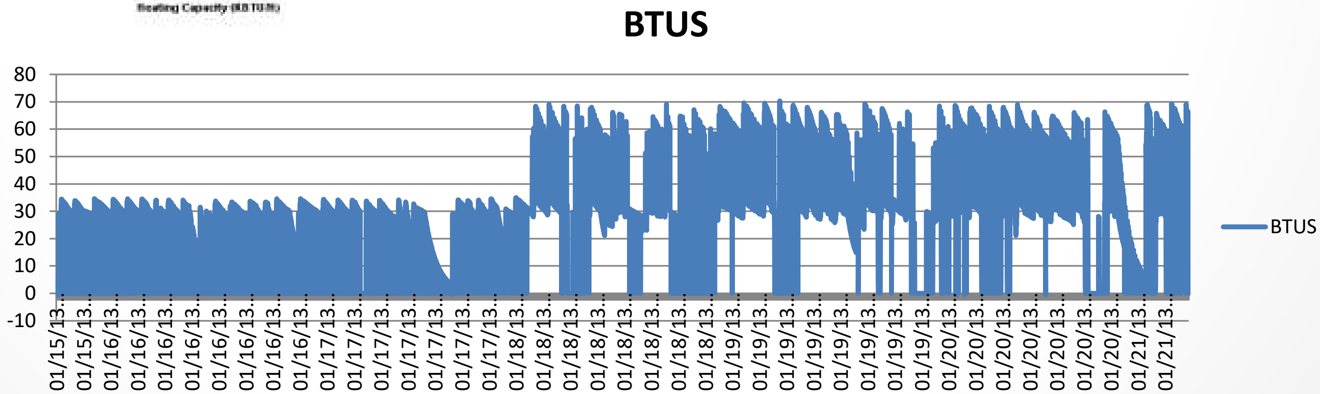
Combi heating lessons:

- Lower water flow rates (.3GPM-1GPM) are a method of achieving low load heat delivery.
- Lowest possible water temperature (particularly return water temperature, particularly with condensing equipment.)
- Low resistance for variable speed pumps means lower watt draw (and higher out put)
- High resistance for single speed pumps can be used to reduce watt draw and restrain output.
- Large unrestricted coil surface area for low fan energy
- Heat only systems allow greater freedom in design airflow
- Don’t let manufactures engineering charts dictate design for high performance
- Cold air blow is not a problem for well designed high performance systems.
- Combi systems can be used as a battery to extract heat during more efficient operation hours.
- Combi systems are best for heat only applications, but can be tuned more granularly to meet specific heat outputs, particularly low load outputs.

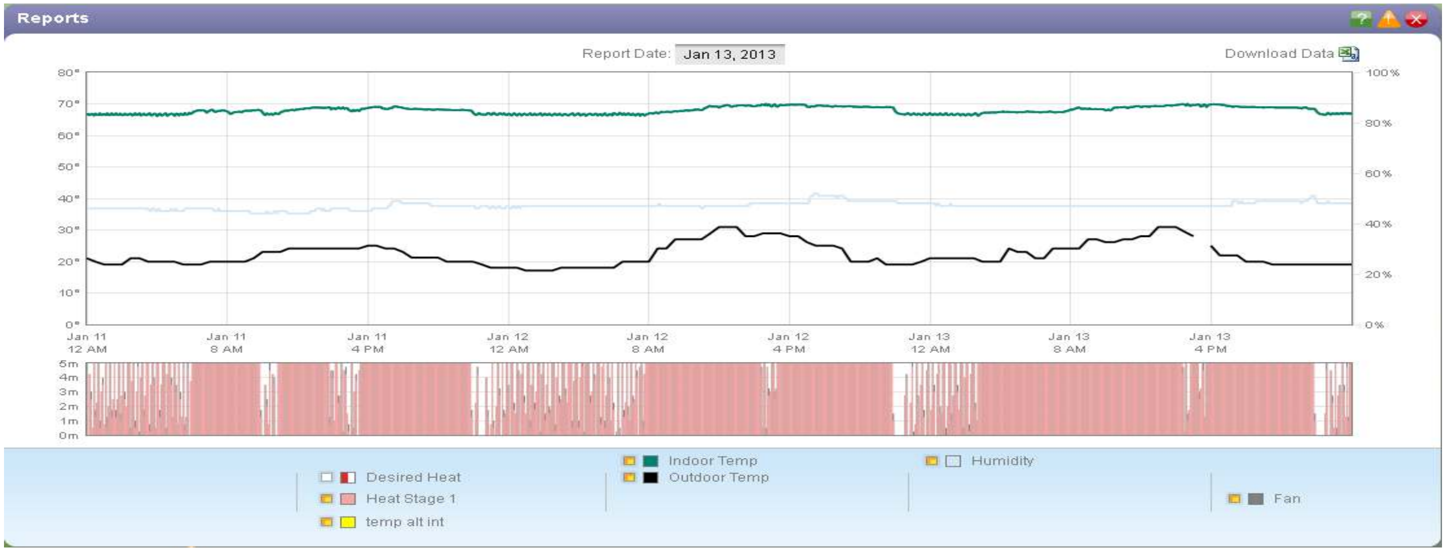
Commissionable Heating systems





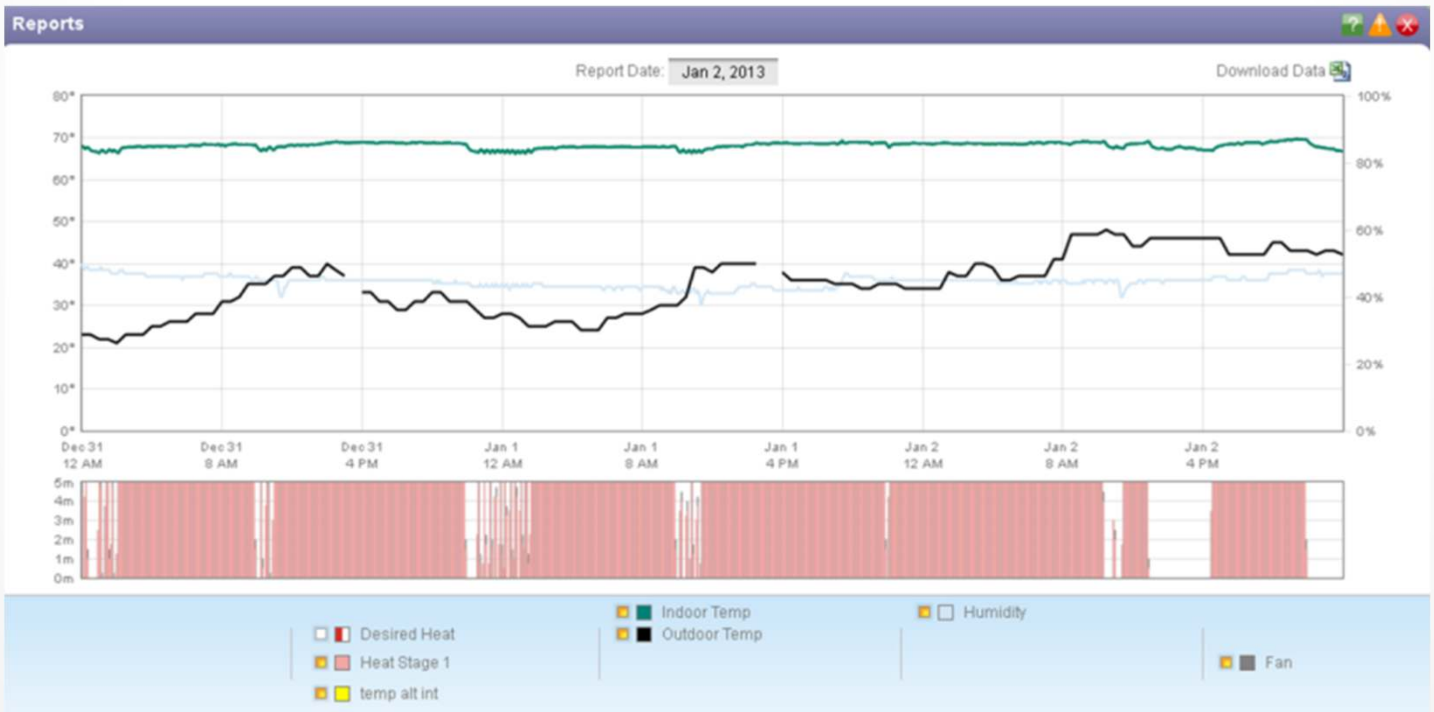


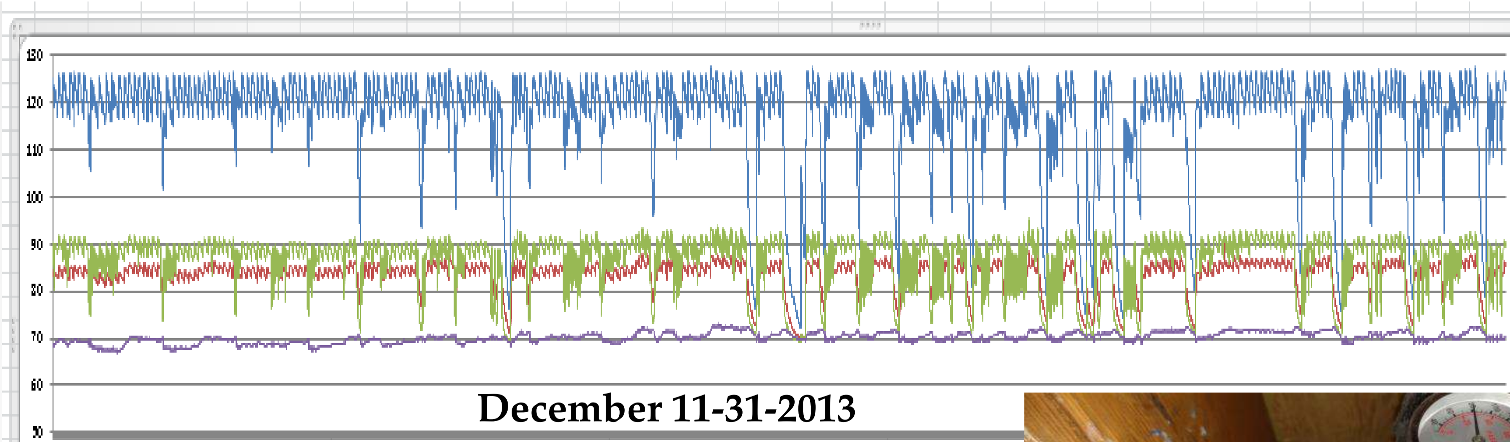
Design day run time



Notice the pink bars at the bottom of the graph this system is well sized, and has smooth run times that correspond with the users set temperatures.

temperature set backs not useful for this enclosure



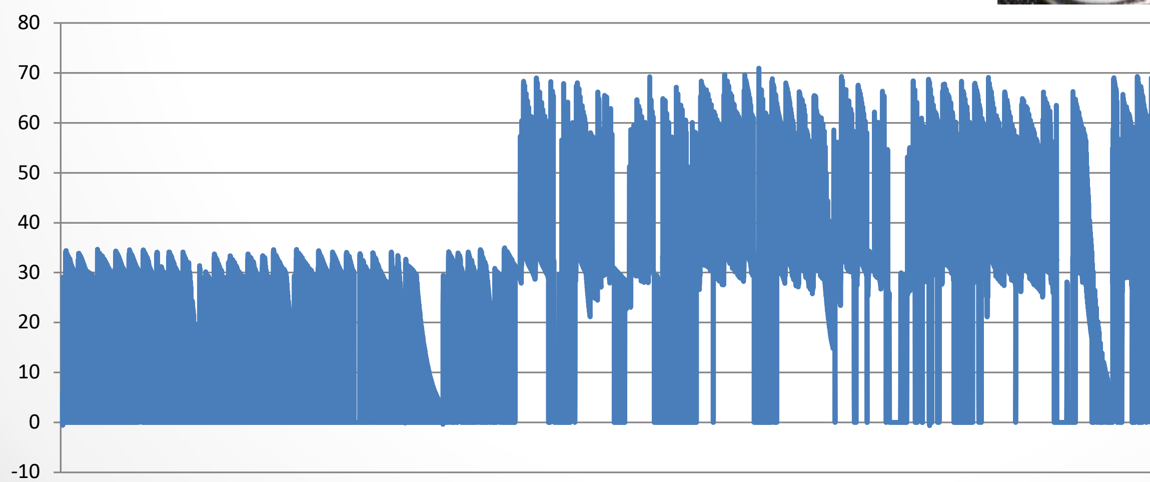


Average water supply temperature 117.5^{0}F

Average water return temperature 83.49^{0}F

Average air temp supply air 86.32^{0}F

Average air temperature return air 70.21^{0}F



Average hourly BTUs from gas heated water 1800-4200 BTU/ hr.

Average hourly BTU from fan and pump 229 BTU/hr

UPDATE TO HEAT PUMP

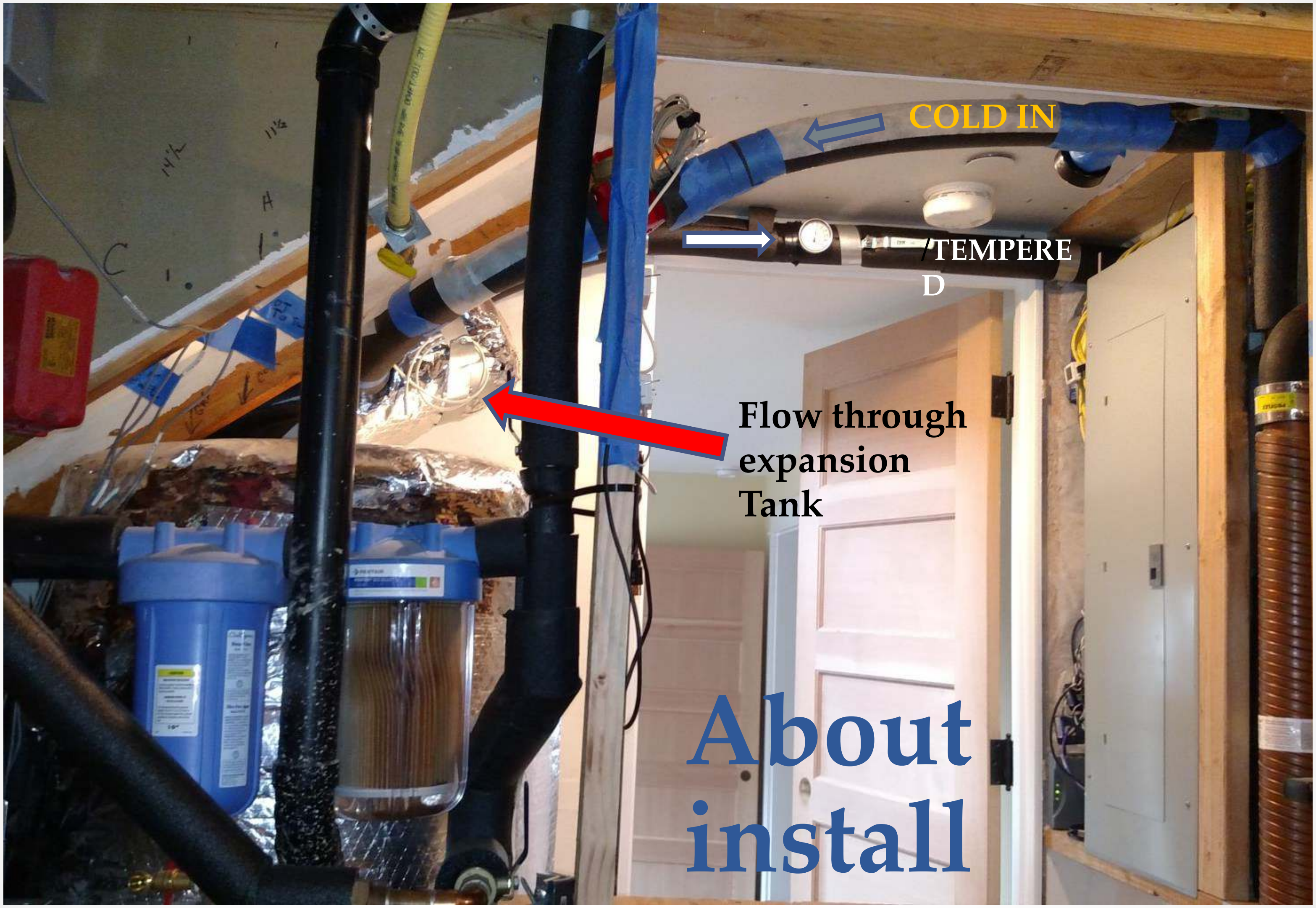
WATER HEATER

Retrofit Application Initial Condition
Nov 13, 2014 to Dec 29, 2014

- AO Smith Vertex removed, Sanden split system CO_2 Heat pump water heater (GAU-A45HPA) and matching 80 gallon stainless steel tank (HP31555D)installed on Nov 13, 2014.

- First Co 24VHBQB hydronic air handler remains (no airflow adjustments) manufacture's taco 006 pump (35W) removed and replaced with Grundfos Alpha Pump, set on constant flow low speed, water loop upsized to 3/8 inch pex to reduce friction for variable speed pump.

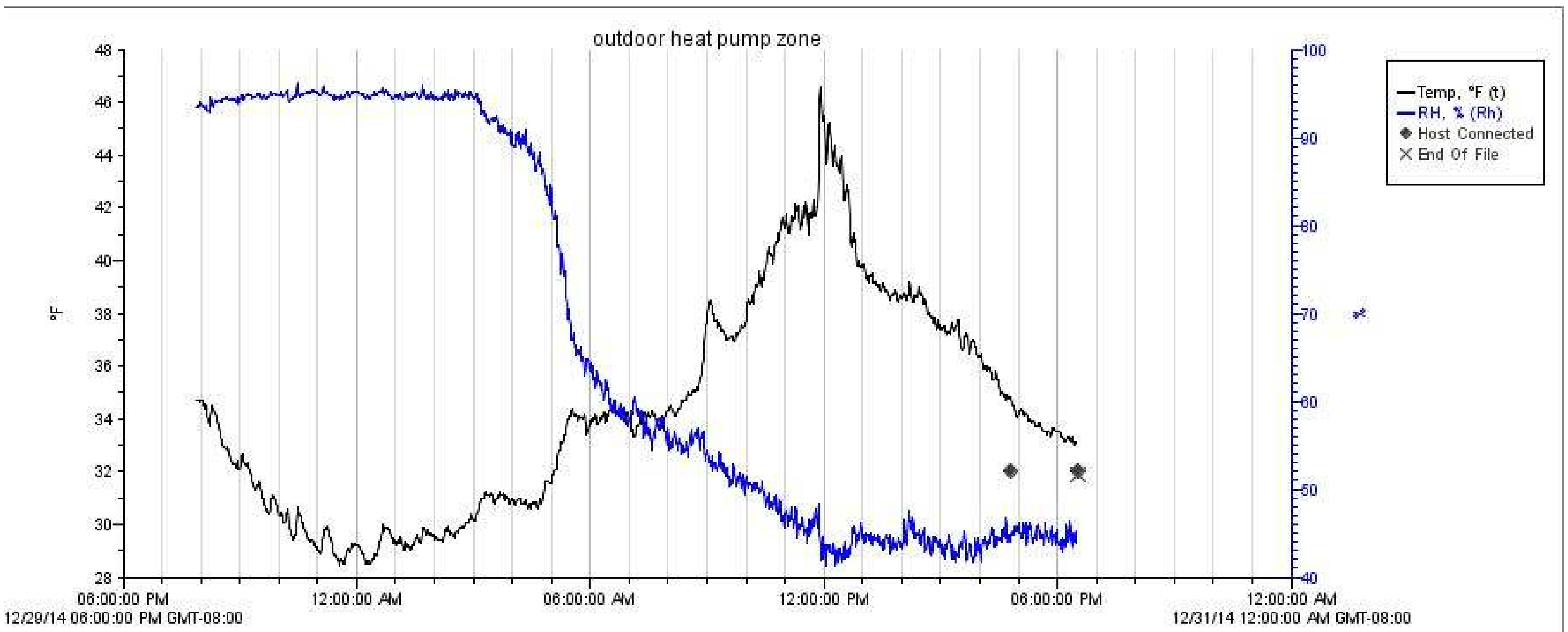
Open Loop hydronic system


COLD IN
TEMPERED
Flow through expansion Tank
About install

Tempered
hot

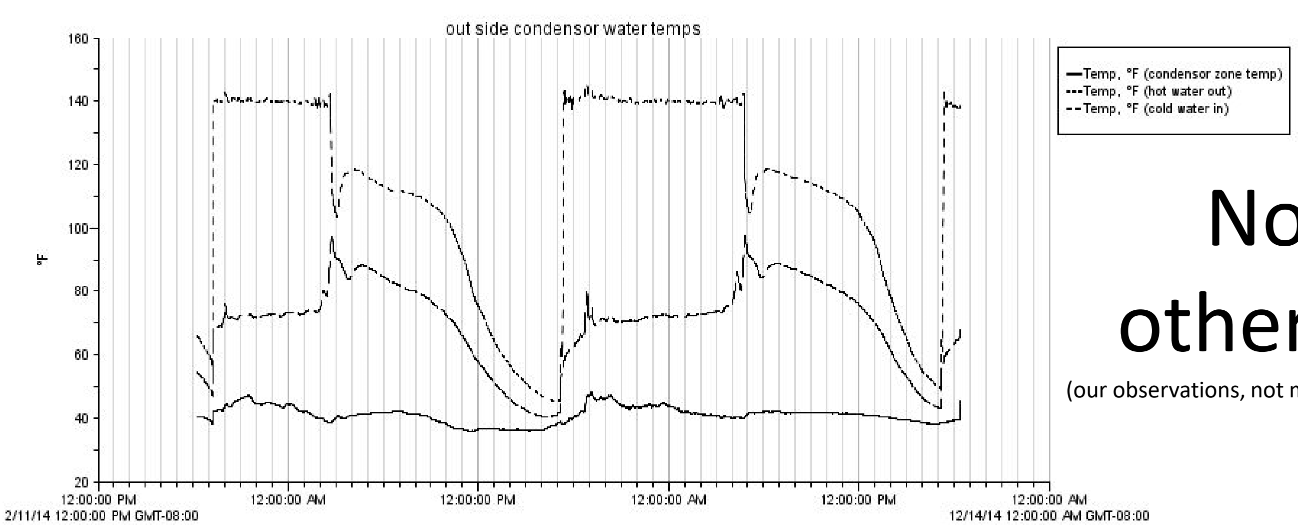
Tempering
valve (not
visible

Goal: Optimize CO2 heat pump for climate



Typical 20-50F Delta T between Day time highs and night time lows

- Run heat pump at optimal day time hours (highest outdoor temps)
- Lock out and use tank capacity as a storage battery for colder evening hours.



Not like other HPWH

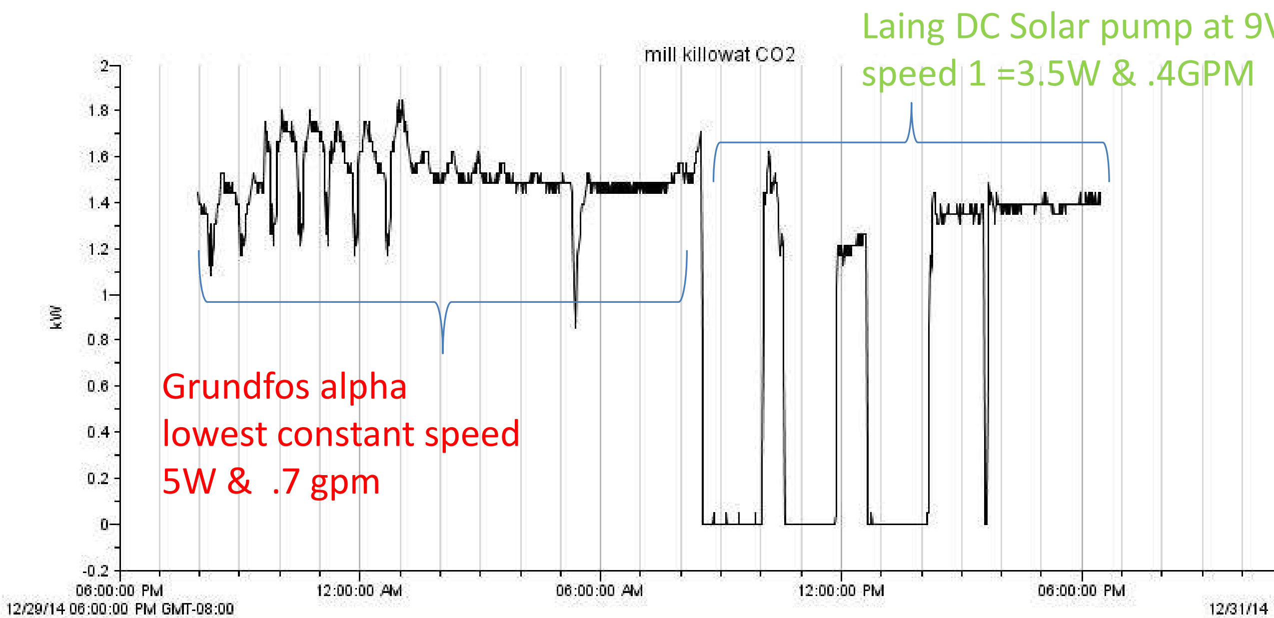
(our observations, not manufactures recommendations)

- Despite no back up heat extremely fast recovery of useable water, due to tank stratification.
- Does not impact interior air temperature or sound.
- Compressor is more quiet than the combustion vent it replaced.
- Starts producing 140F+ water within five minutes of cold start regardless of outdoor temp. (lowest monitored in this study period 20F)
- From full cold (80gallons) hot showers can be taken within 30 minutes of start up. (the tank is not satisfied but is sending out 120 after the mixing valve with in this timeframe.
- Recovers from being shut off overnight, even when starting at subfreezing outdoor temperatures.
- Has a built in time of use lock out which can be used to control one on off in a 24hr period.

Built in time of use clock

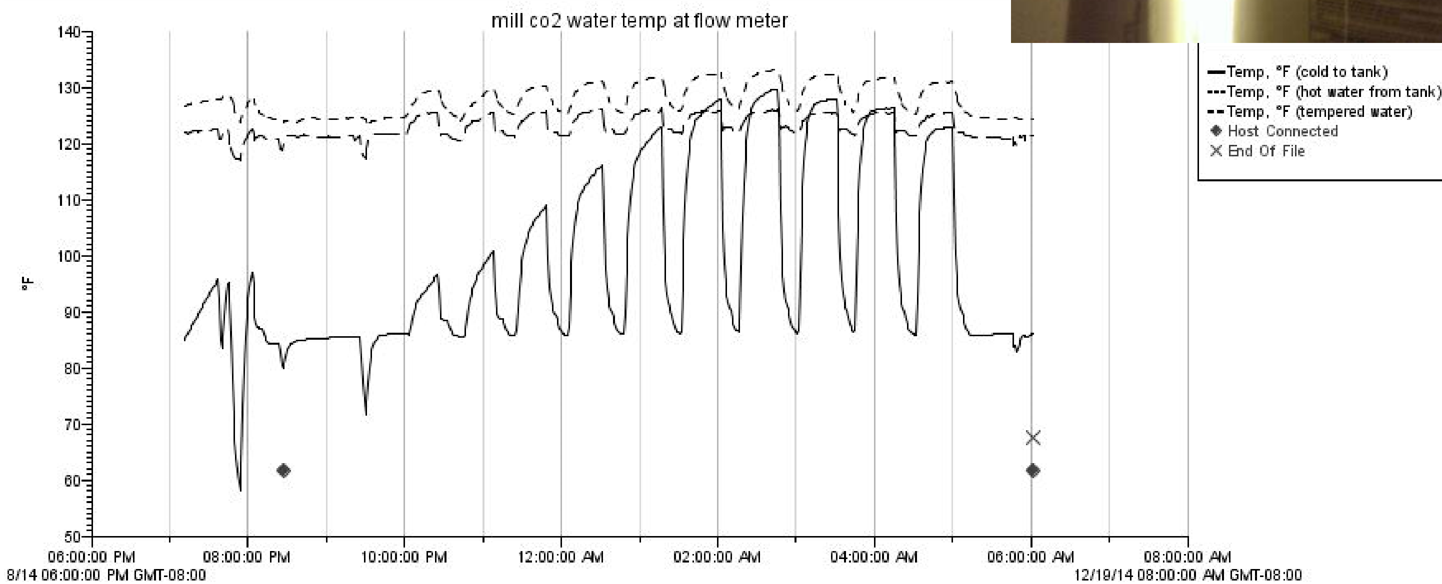
Blocked out from 11pm-9am

Pump change out impact on heat pump cycling energy



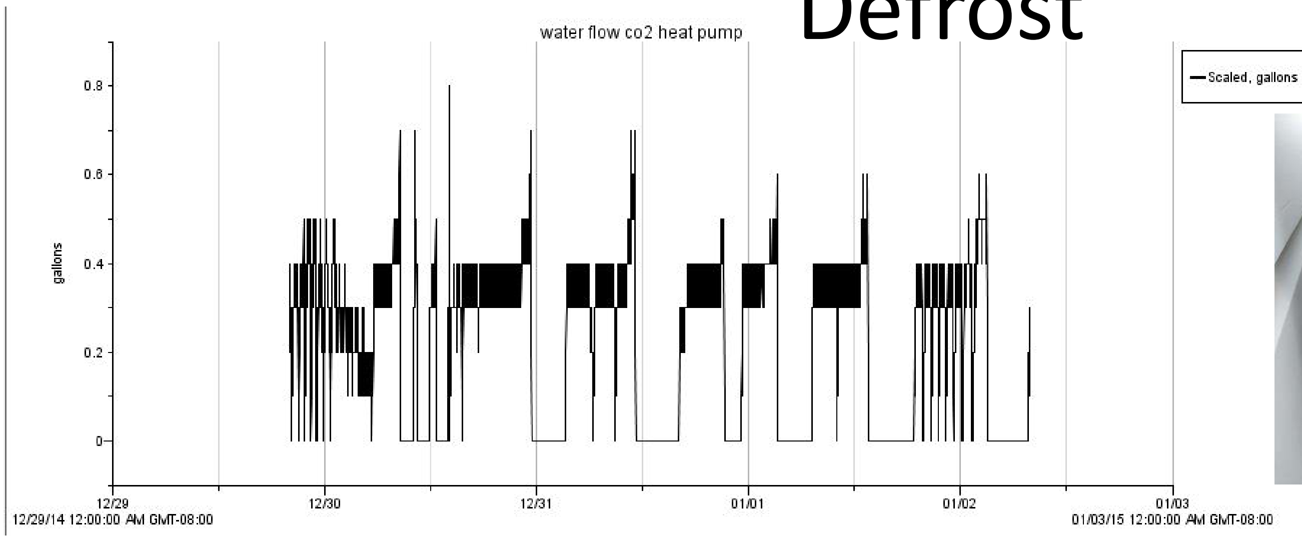
Smart equipment would decide how to recover During optimum time frames. Left to it's own devises the heat pump satisfies tank temp at the worst time frames for efficiency. A simple control can override this decision.

Tempering Valve

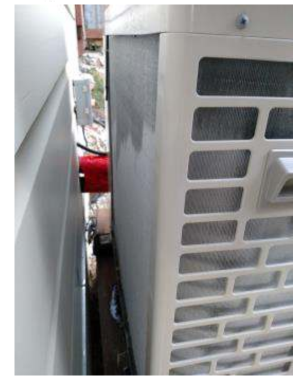


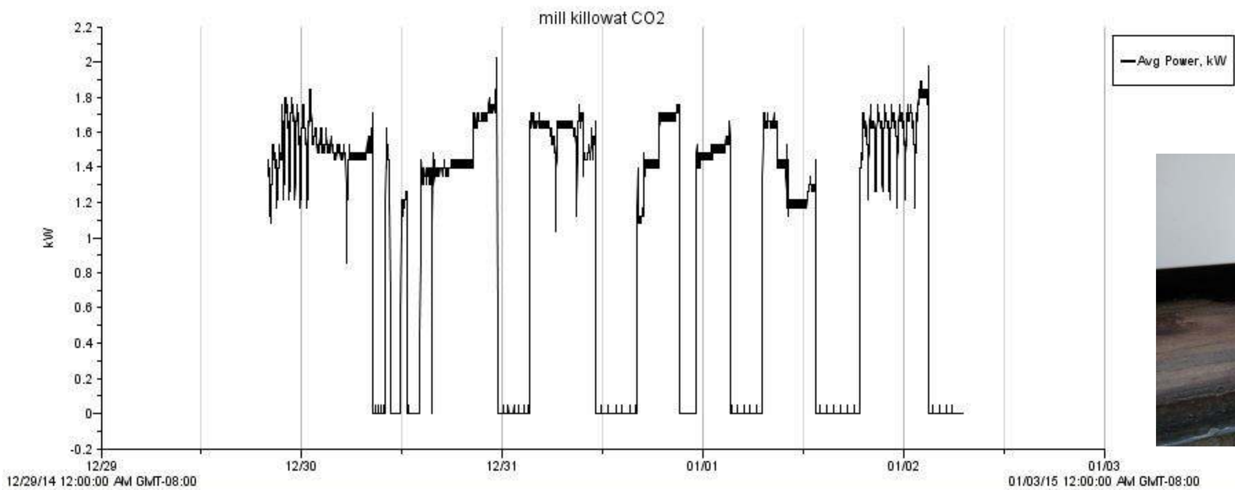
While there are solutions for tempering valves that are better regulated it is difficult to do with out creating a closed loop system which has pumping energy consequences.

Defrost



water flow co2 heat pump
Scaled, gallons
gallons
0.8
0.6
0.4
0.2
0
12/29
12/29/14 12:00:00 AM GMT-08:00
12/30
12/31
01/01
01/02
01/03
01/03/15 12:00:00 AM GMT-08:00



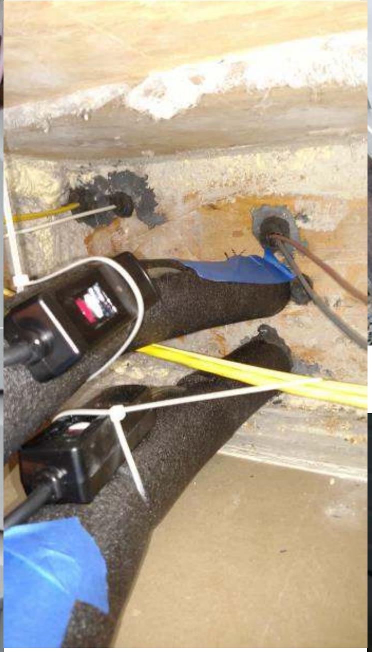


mill killowat CO2
Avg Power, kW
kW
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
12/29
12/29/14 12:00:00 AM GMT-08:00
12/30
12/31
01/01
01/02
01/03
01/03/15 12:00:00 AM GMT-08:00

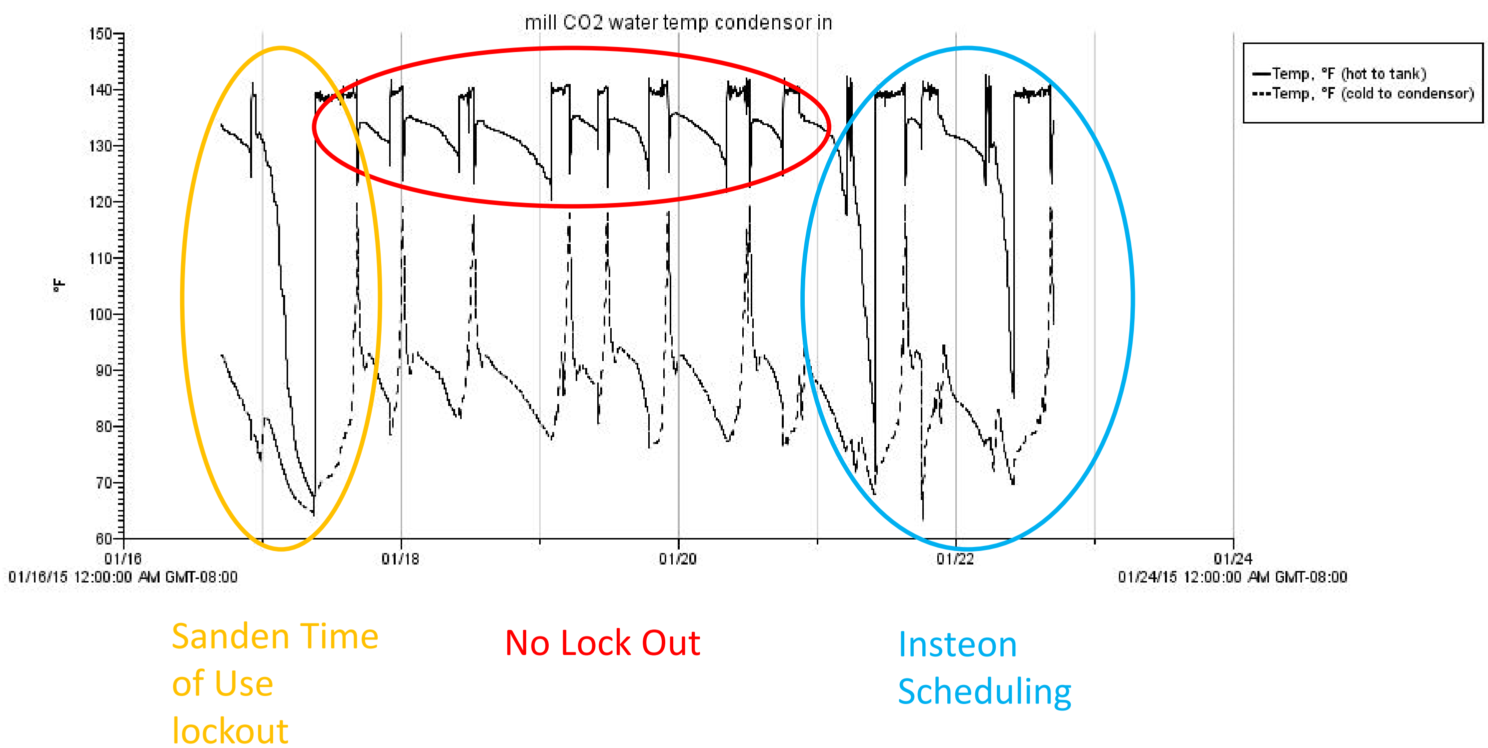
WARNING: OVER PRESSURE

WHAT WE WOULD ADD…

Heat Trace



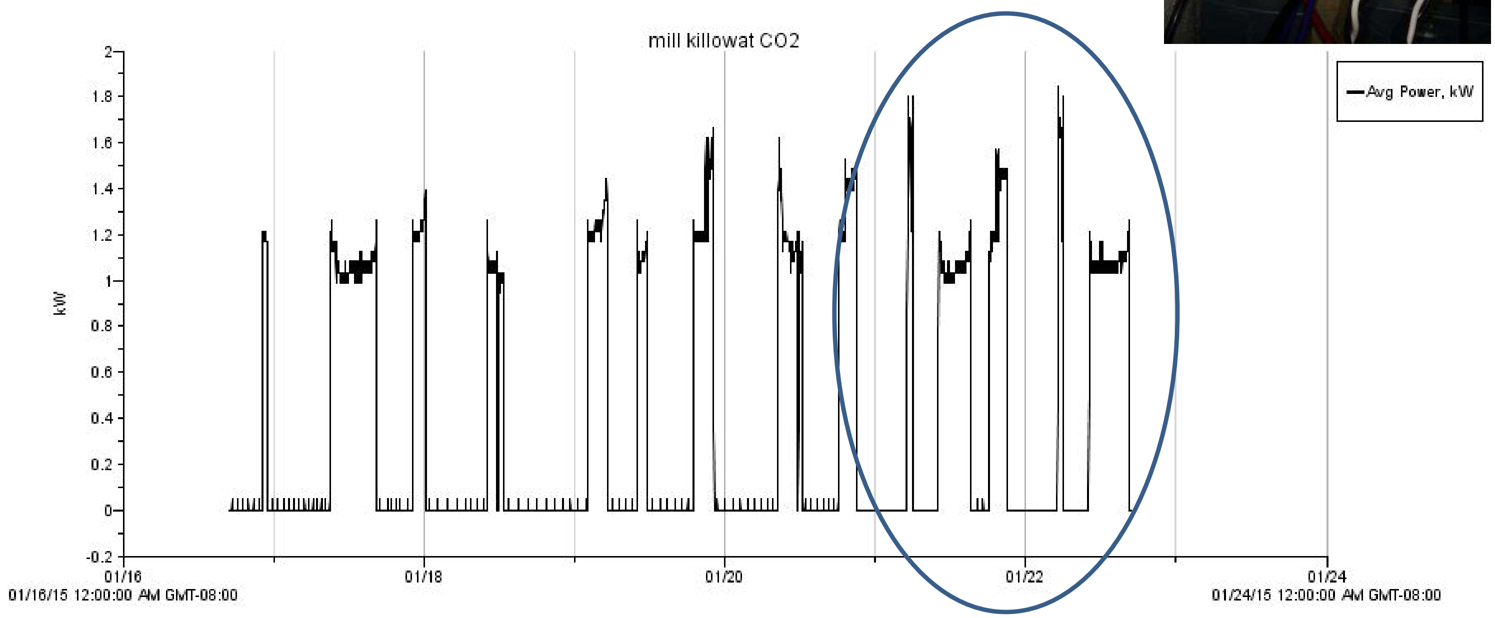
240V scheduler



New lock out pattern

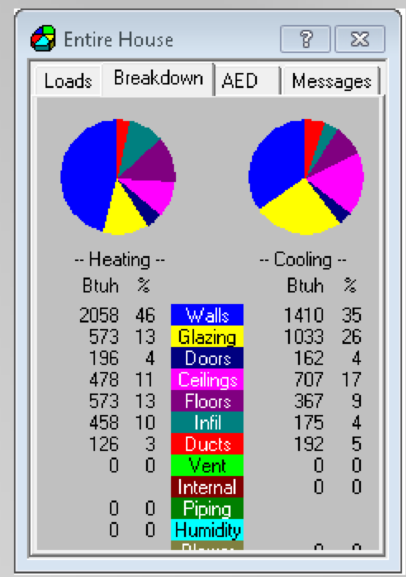
1 hr morning recovery 5am-6am

allowed to run between 10am-9pm



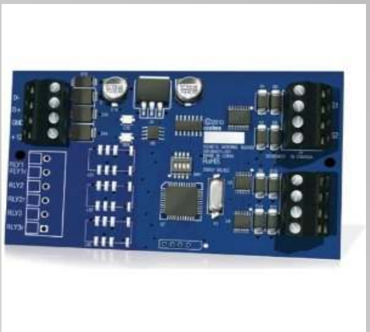
Using a Thermostat to check your manual J and other interesting things

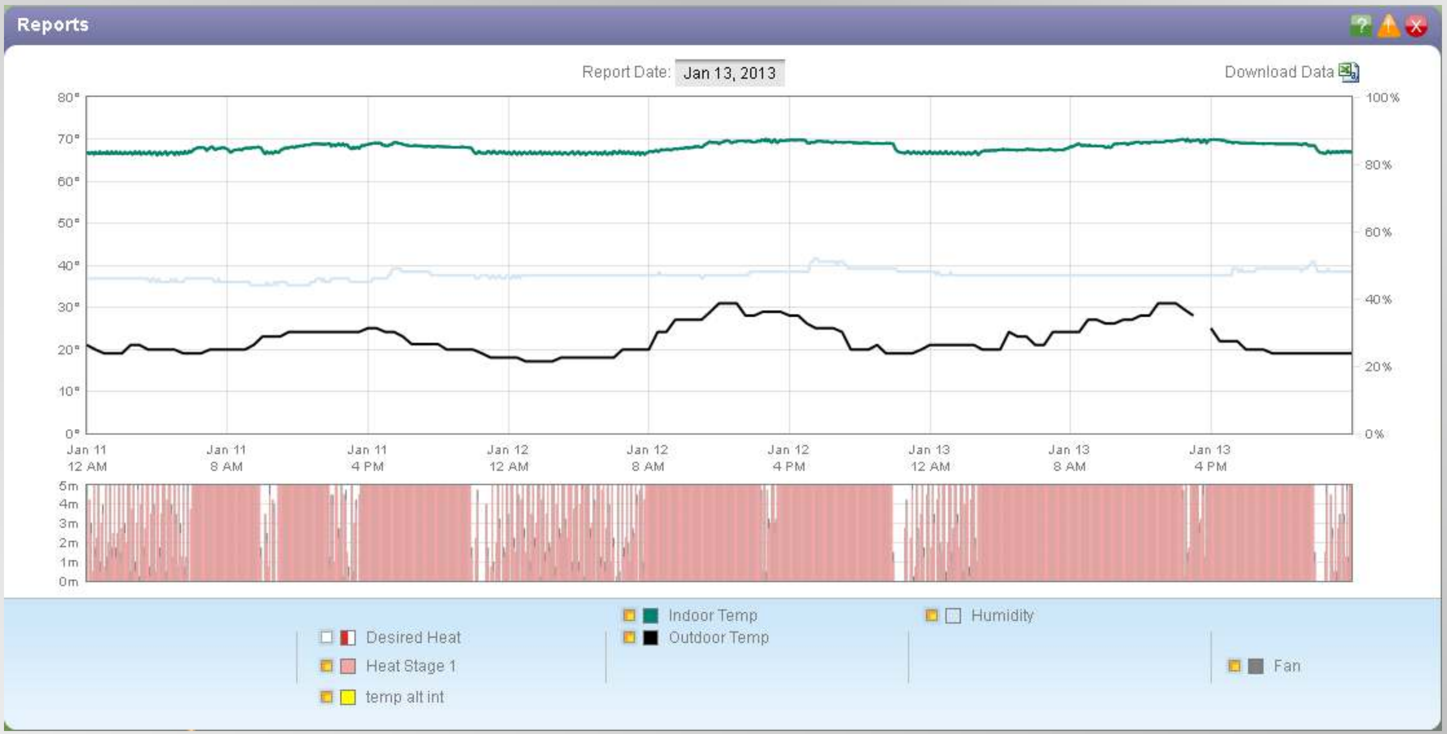
“Rutskowski estimates that only 10% of heating and cooling equipment sizing decisions are based on some type of Manual J calculation and that less than 1% of the jobs are based on an aggressive implementation of the recommended design procedures.”
Holliday



Gavin Healy, Balance Point Home Performance

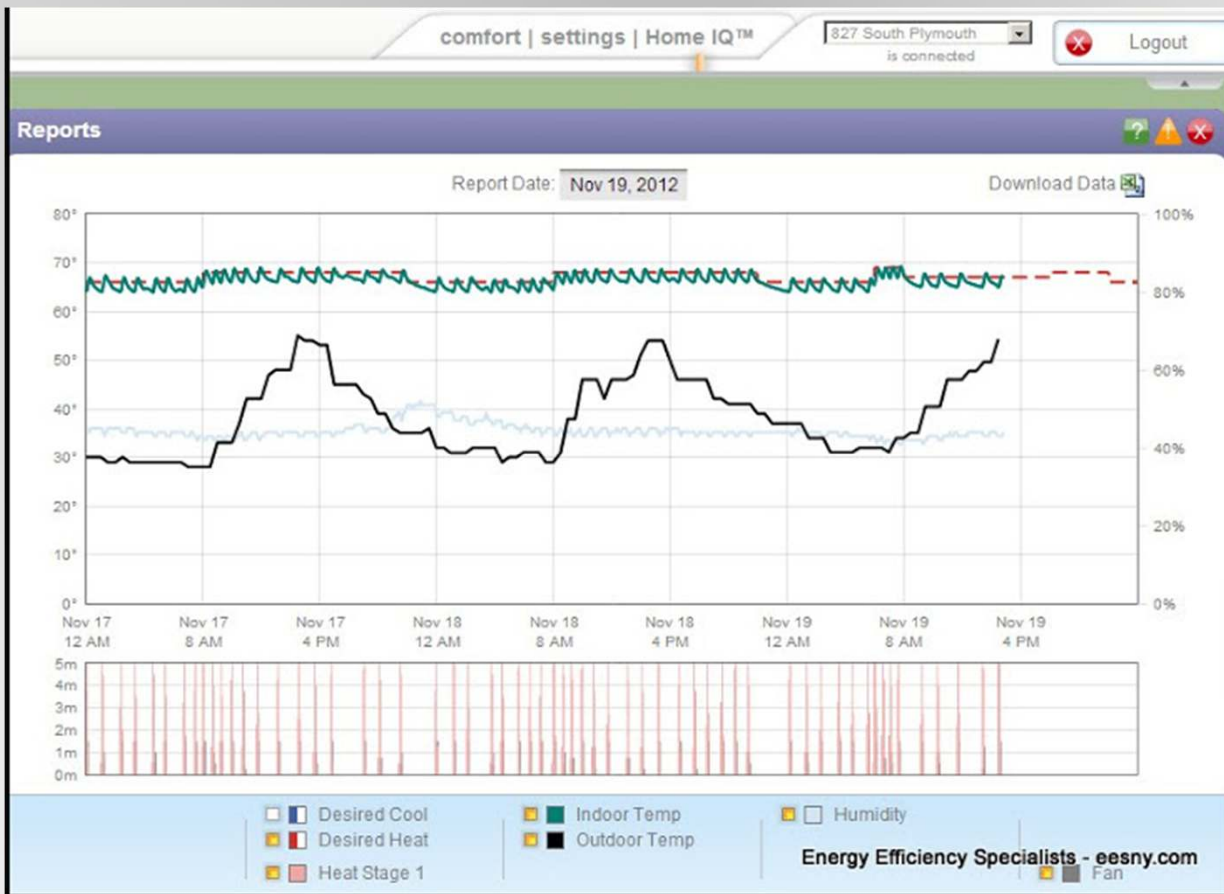
Thermostats evolve into data loggers



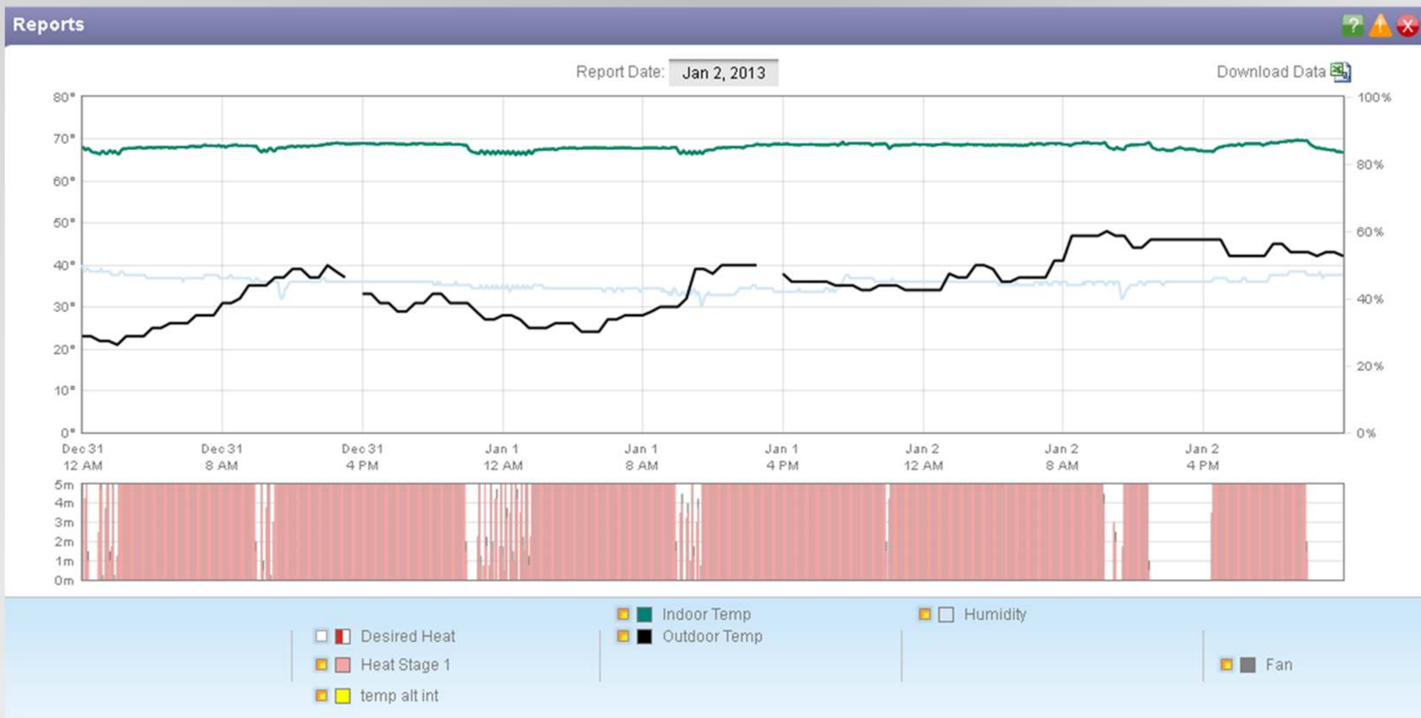


This graph shows run time on hydronic system set for 70 degrees with evening and afternoon 3 degree set backs and exhaust only ventilation system with a single window open 1.875 square inches normal house operation.

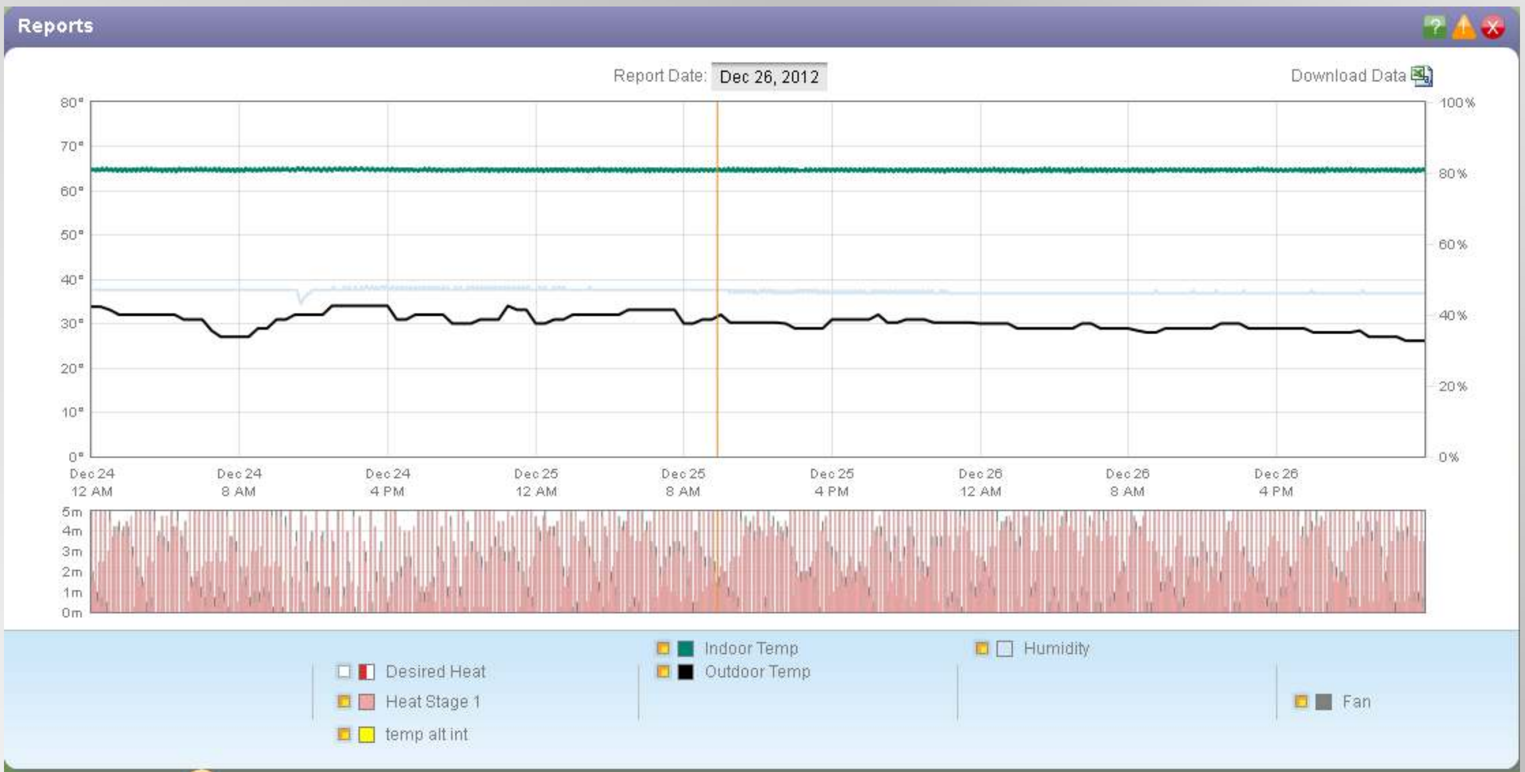
What does it look like when the heat is mismatched to the load.



Short cycling becomes more evident when the outdoor temps clime

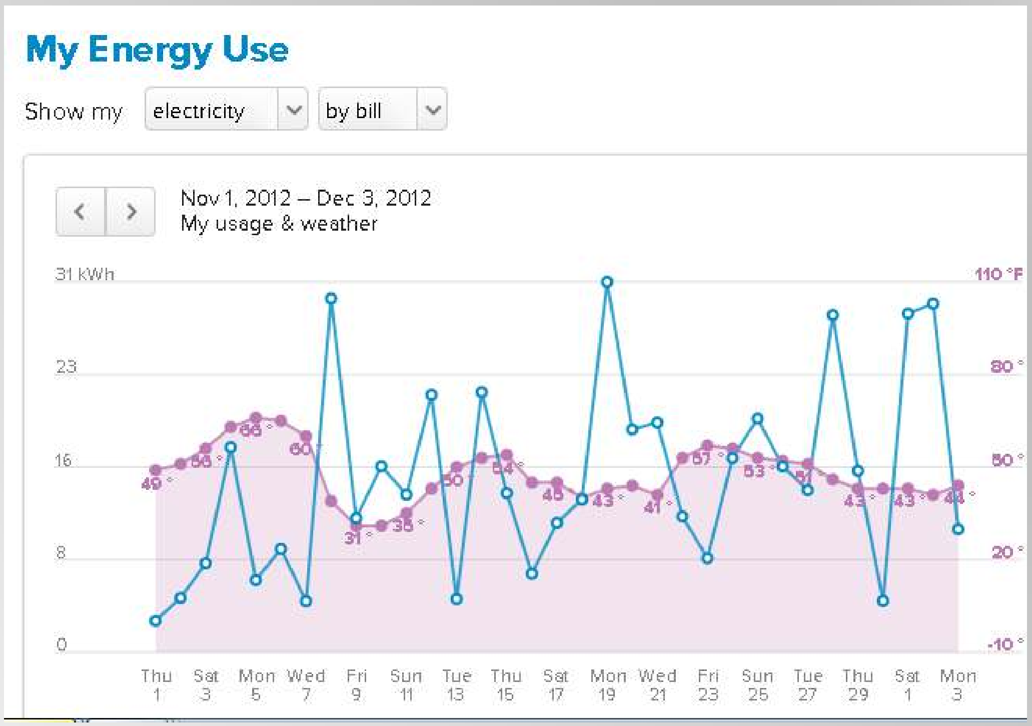


Some heating systems can be locked into manage comfort better. Since the loads are low but consistent on this house, the hydronic air hander allows us to restrict the heat output. One shortfall of better equipment is that you may not be able to override proprietary manufactures controls.

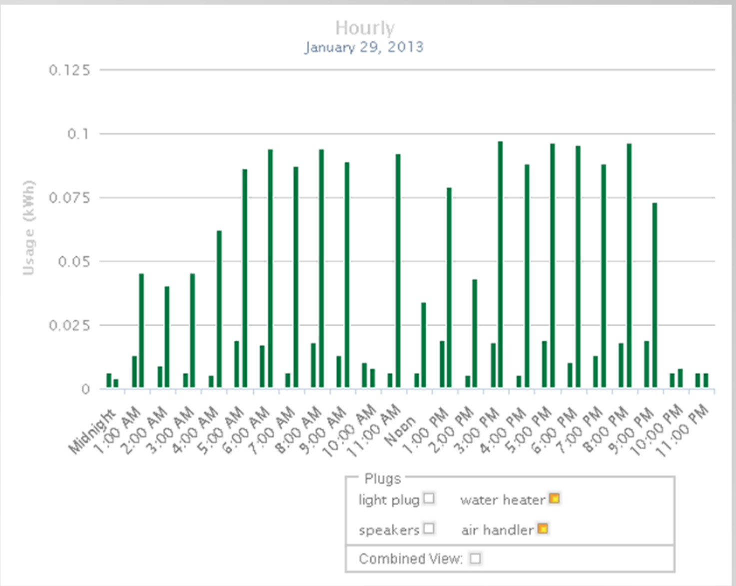


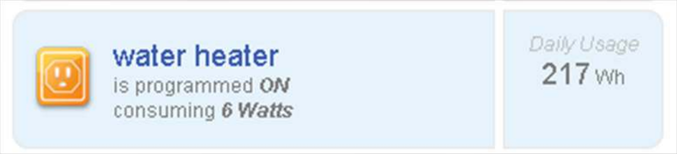
This graph shows run time on hydronic system set for 65 degrees 24/7 during a vacation period at design day temperatures with no ventilation system running, house closed tight and very limited miscellaneous plug loads (no lighting).

Point source heating is sometimes offered as a solution, it is rare that this option is compared in the same house to evaluate the quality of heat provided, when it is compared it often compared to a previous system that was poor at delivering comfort. Prior to turning on the ducted heating system, two thermostatically controlled 1500W space heaters were use to provide heat, with the same thermal enclosure these systems lacked uniformity in delivered temperatures.



Watt draws from smart plug for air handler fan and pump

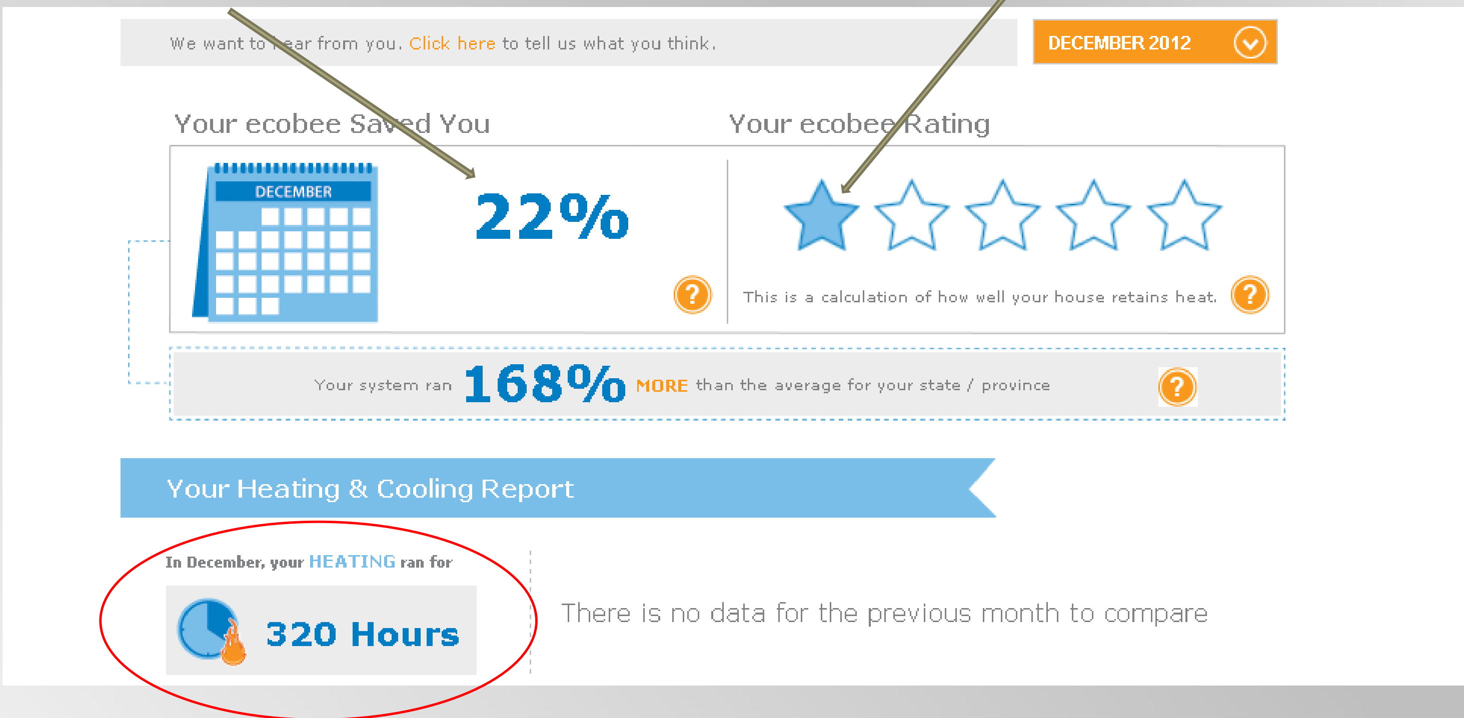




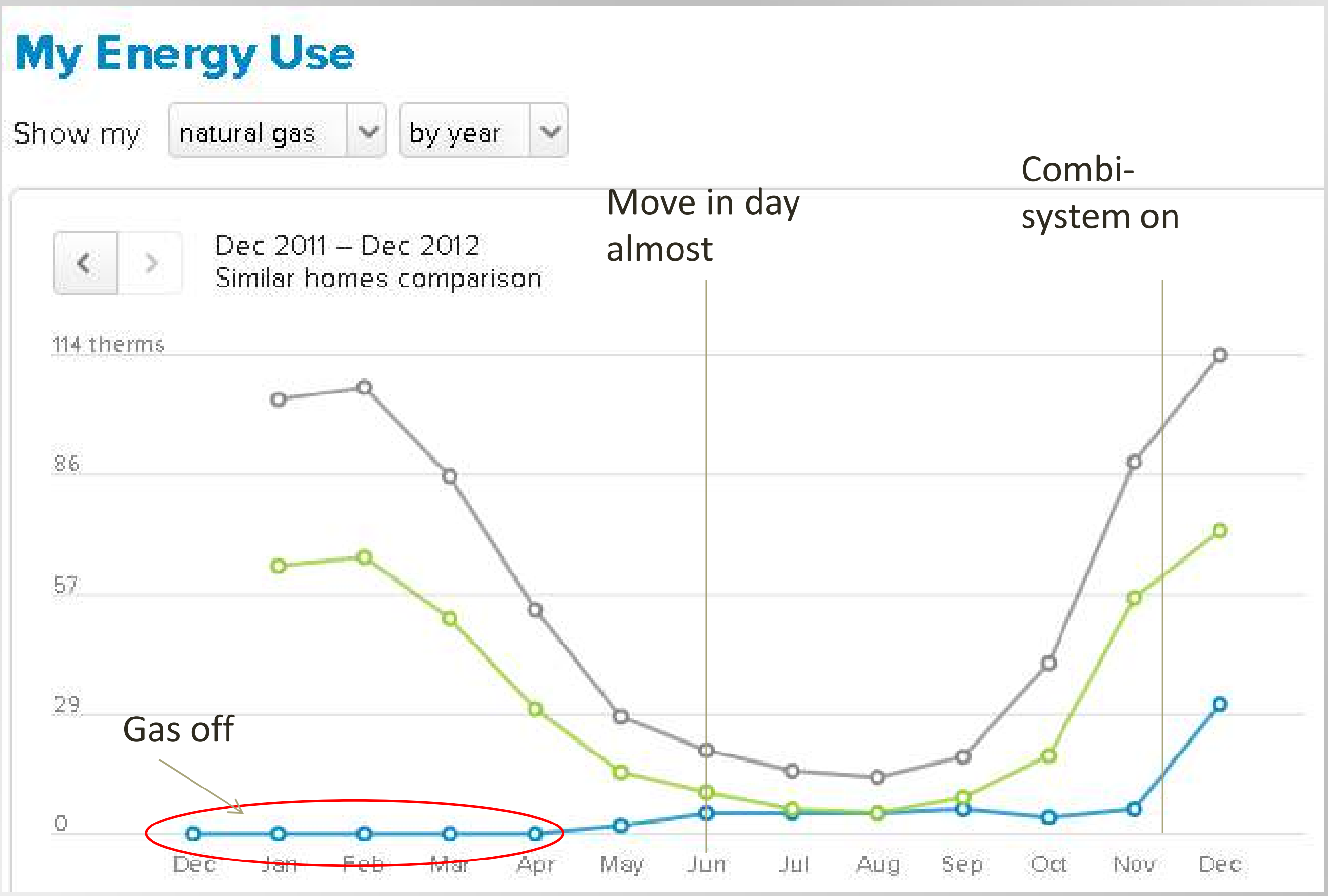
Watt draws from
vertex combustion fan

Funny I don't remember the thermostat doing this

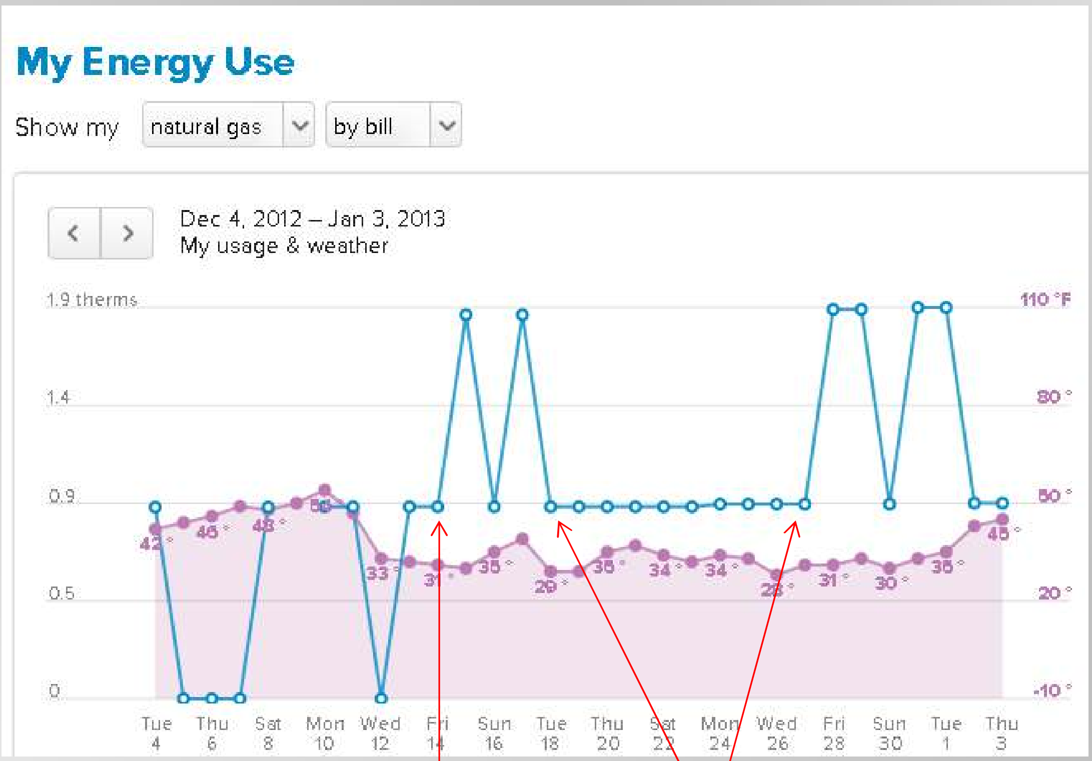
Is my house really this bad?



- Generic advice on energy performance given by ecobee and emonitor consistently rate the energy performance of my house as poor. Lesson feedback is good so long as it is accurate.



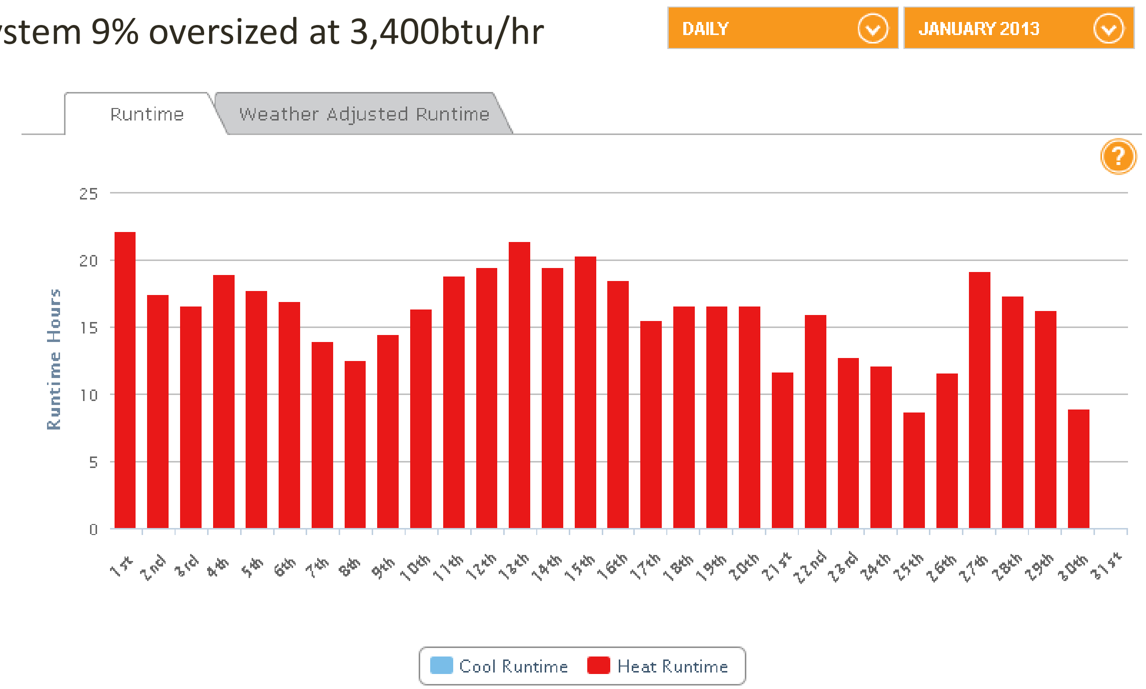
Blue line is my house, and this graph shows initial occupancy compared to other houses in the area of the same size, and efficient houses in the area of the same size.



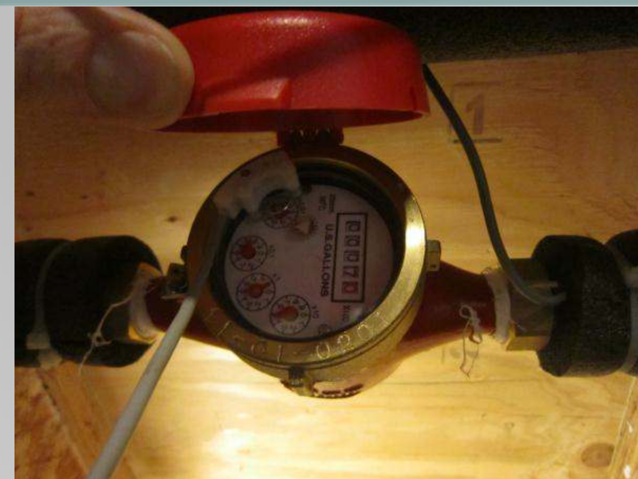
Air handler hooked up here

Vacation combi-heat only no domestic hot water draws

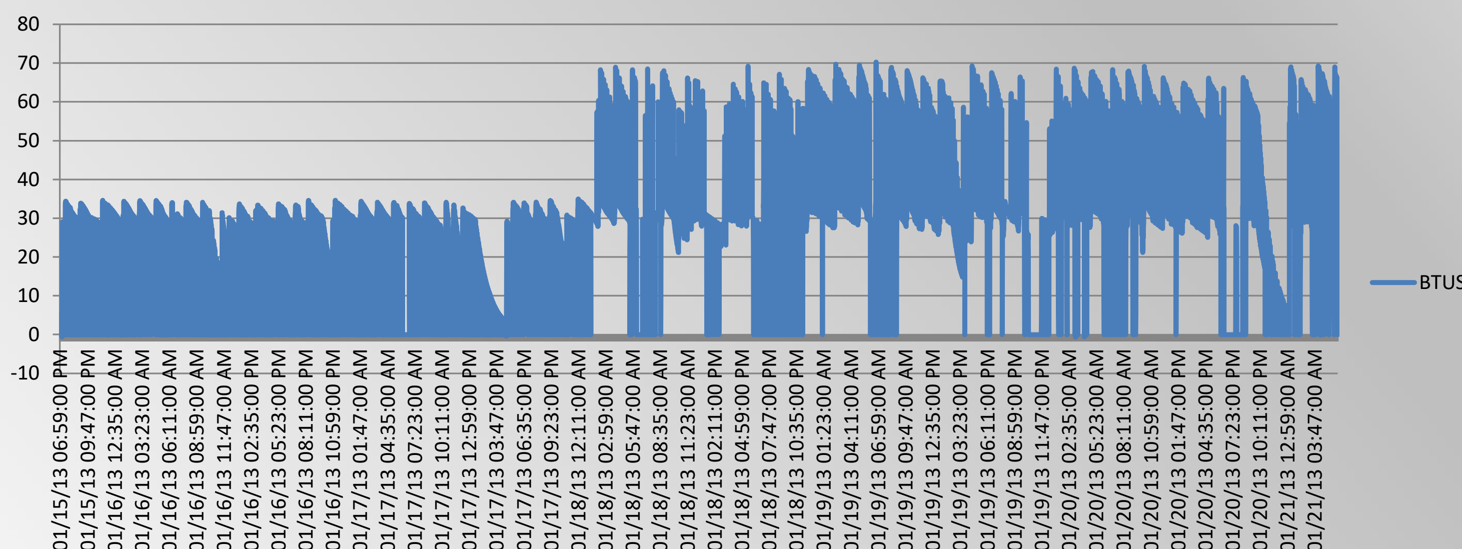
System 9% oversized at 3,400btu/hr

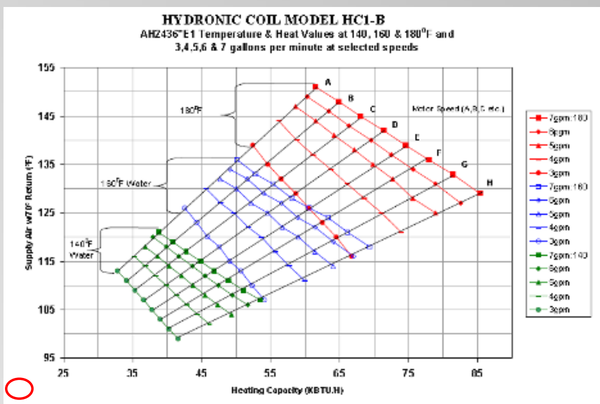


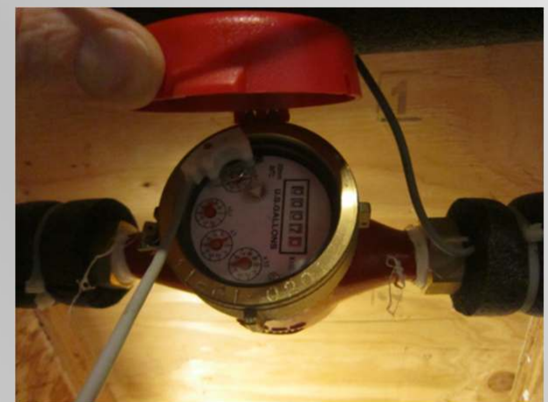
A low flow hot water meter is needed to commission a hydronic air handler effectively

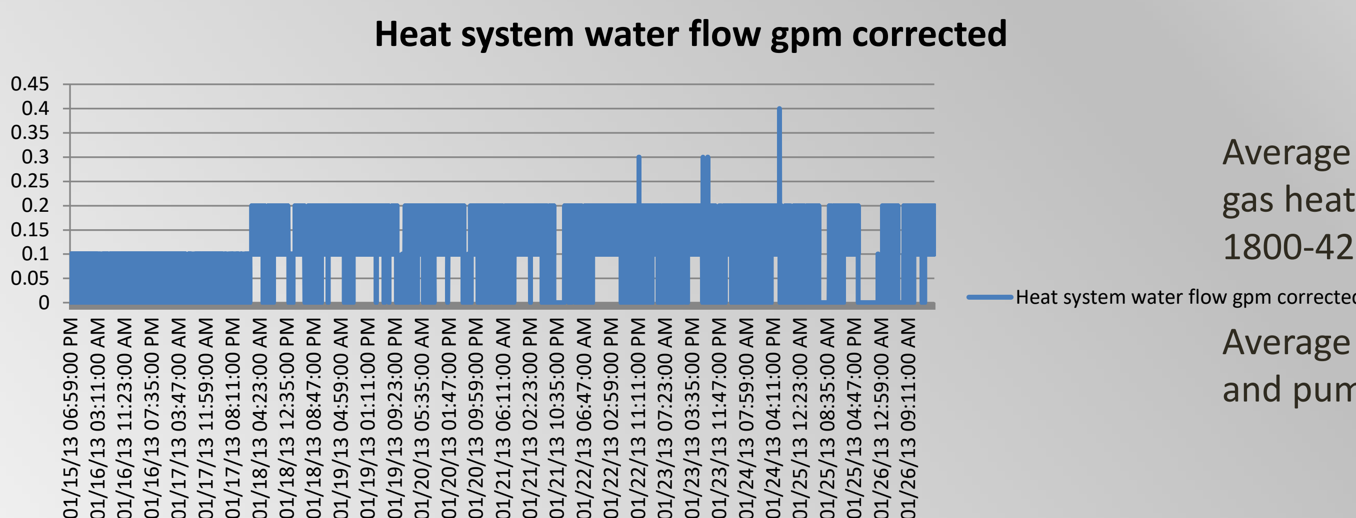


BTUS









Average hourly BTUs from gas heated water 1800-4200 BTU/ hr.

Average hourly BTU from fan and pump 229 BTU/hr

Your Services

◉ Current billing period ○ Previous billing period

7812578279

111 MILL ST
NEVADA CITY , CA 95959
Meter Number: 410234A
Usage history
View Nearby Gas Transmission Pipelines

7812578809

111 MILL ST
NEVADA CITY , CA 95959
Meter Number: 1007739141
Usage history
View Nearby Gas Transmission Pipelines

Total billing days: 31

Total billing days: 31 PDP Event Days: 0 ?

Average cost per therm: $1.03 ?

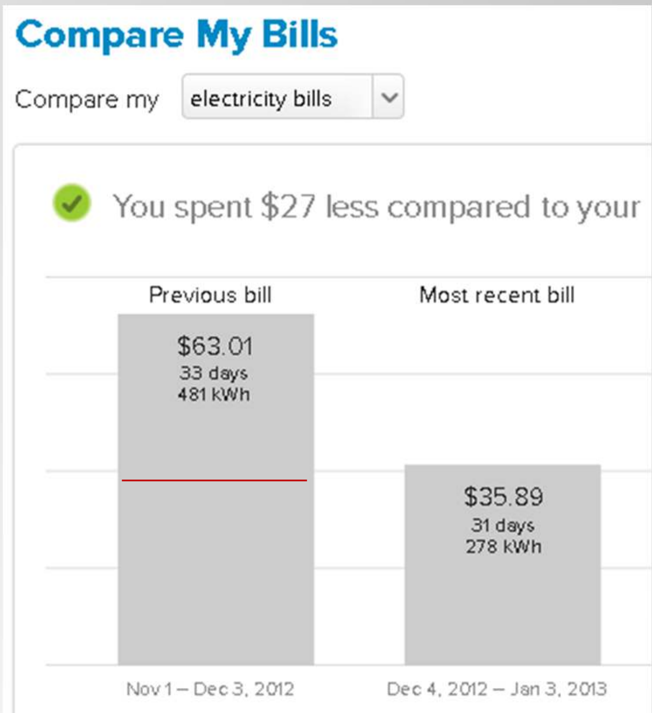
Average use per day: 1.00 Therms ?

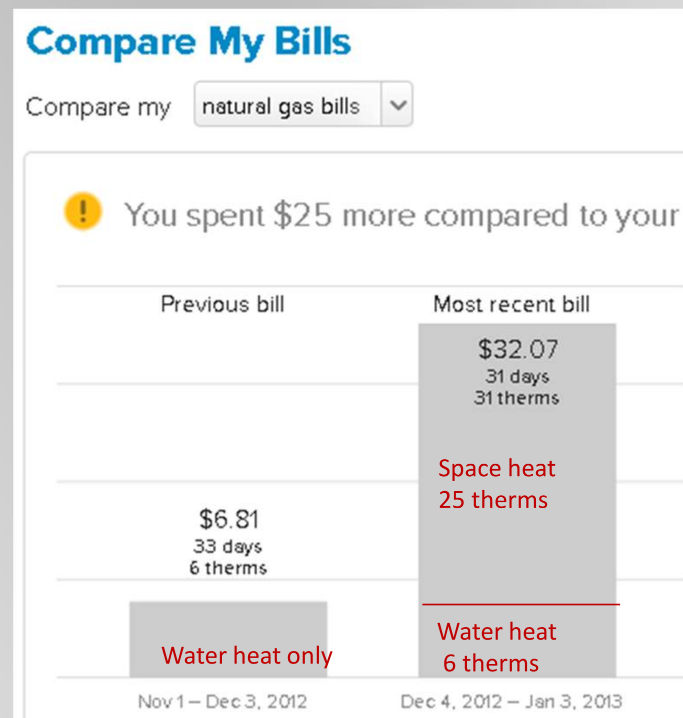
Average cost per kWh: $0.13 ?

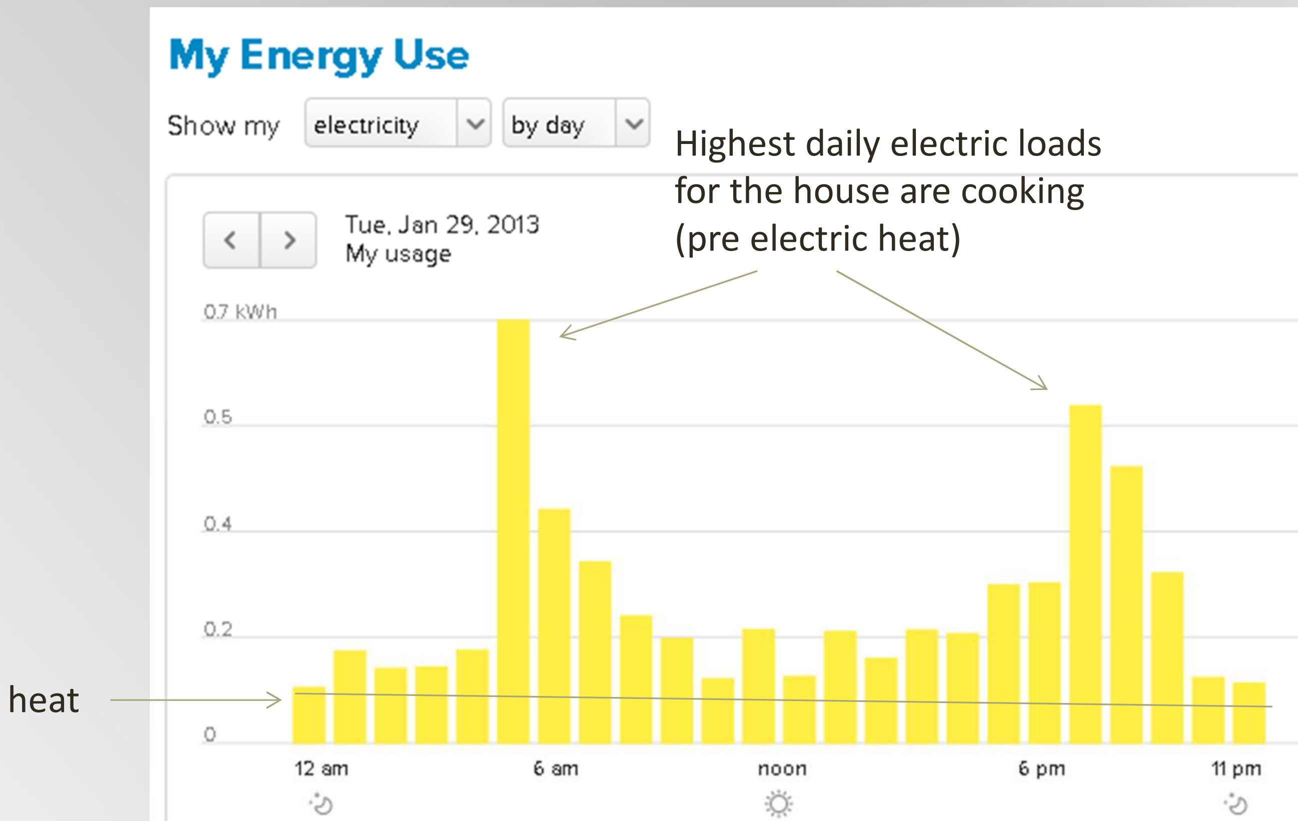
Average use per day: 8.97 kWh ?

TYPE	DATE	USAGE	UNITS	COST
Natural gas usage	12/4/2012	0.93	therms	$0.89
Natural gas usage	12/5/2012	0	therms	$0.00
Natural gas usage	12/6/2012	0	therms	$0.00
Natural gas usage	12/7/2012	0	therms	$0.00
Natural gas usage	12/8/2012	0.93	therms	$0.89
Natural gas usage	12/10/2012	0.93	therms	$0.89
Natural gas usage	12/11/2012	0.93	therms	$0.89
Natural gas usage	12/12/2012	0	therms	$0.00
Natural gas usage	12/13/2012	0.93	therms	$0.89
Natural gas usage	12/14/2012	0.93	therms	$0.89
Natural gas usage	12/15/2012	1.86	therms	$1.78
Natural gas usage	12/16/2012	0.93	therms	$0.89
Natural gas usage	12/17/2012	1.86	therms	$1.78
Natural gas usage	12/18/2012	0.93	therms	$0.89
Natural gas usage	12/19/2012	0.93	therms	$0.89
Natural gas usage	12/20/2012	0.93	therms	$0.89
Natural gas usage	12/21/2012	0.93	therms	$0.89
Natural gas usage	12/22/2012	0.93	therms	$0.89
Natural gas usage	12/23/2012	0.93	therms	$0.89
Natural gas usage	12/24/2012	0.94	therms	$0.90
Natural gas usage	12/25/2012	0.94	therms	$0.90
Natural gas usage	12/26/2012	0.94	therms	$0.90
Natural gas usage	12/27/2012	0.94	therms	$0.90
Natural gas usage	12/28/2012	1.89	therms	$1.80
Natural gas usage	12/29/2012	1.89	therms	$1.80

Daily gas consumption when running vertex as combi-system.


Compare My Bills
Compare my
electricity bills
You spent $27 less compared to your
Previous bill
Most recent bill
$63.01
33 days
481 kWh
$35.89
31 days
278 kWh
Nov 1 – Dec 3, 2012
Dec 4, 2012 – Jan 3, 2013


Compare My Bills
Compare my
natural gas bills
You spent $25 more compared to your
Previous bill
Most recent bill
$6.81
33 days
6 therms
$32.07
31 days
31 therms
Space heat
25 therms
Water heat only
Water heat
6 therms
Nov 1 – Dec 3, 2012
Dec 4, 2012 – Jan 3, 2013


My Energy Use
Show my
electricity
by day
Tue, Jan 29, 2013
My usage
0.7 kWh
0.5
0.4
0.2
0
12 am
6 am
noon
6 pm
11 pm
Highest daily electric loads for the house are cooking (pre electric heat)
heat

Case study
Radon in a .58 ACH50 home

OUR Goal is to under stand this and lower our levels not to 4Pci/L but as closed to outdoor ambient as possible. Preliminary Radon test is 44 Pci/L

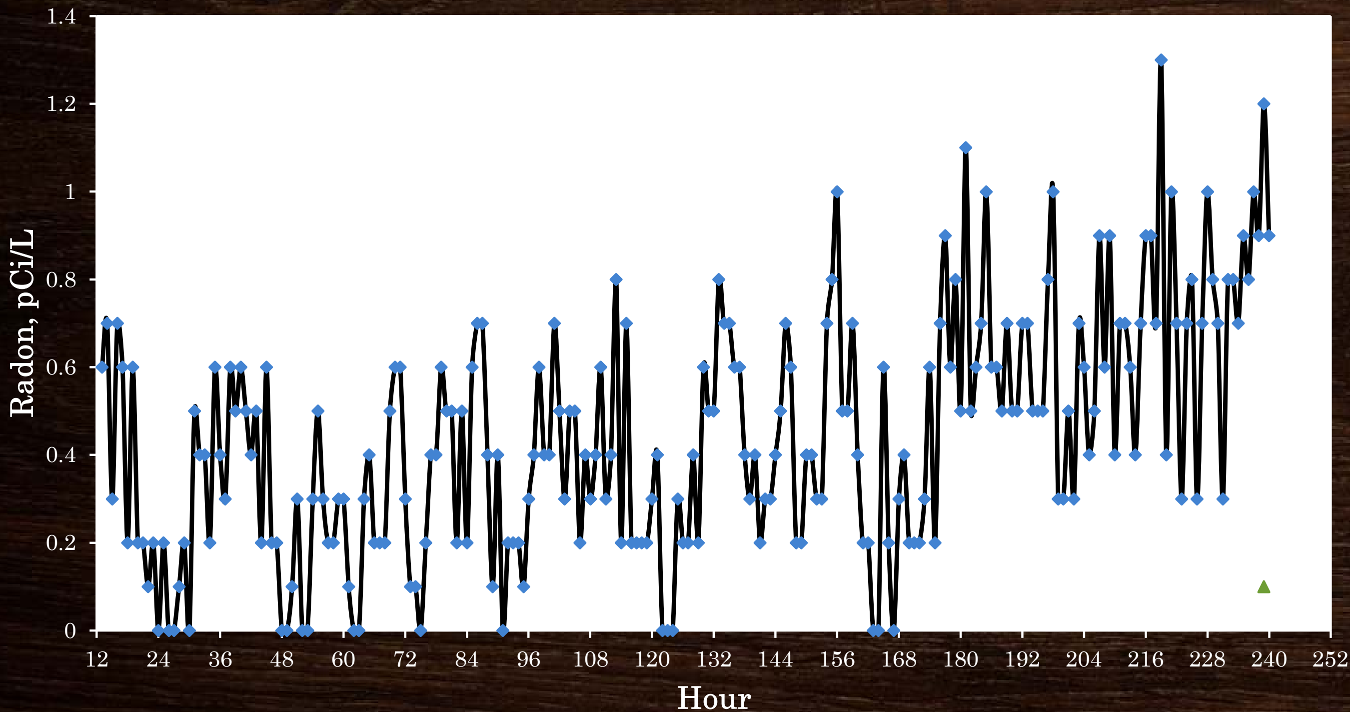
Initial test

GAVIN HEALY

Test Conditions June 2013-Feb 2014

- Summertime no daytime ventilation (no active cooling), nighttime passive ventilation, active sub-slab depressurization
- Summertime no daytime ventilation (no active cooling), nighttime passive ventilation, passive sub-slab depressurization
- Summertime exhaust only ventilation (no active cooling), nighttime passive ventilation, active sub-slab depressurization with fan cycler house closed condition.
- Wintertime closed house condition 24/7, no ventilation, point source heat, active sub-slab depressurization.
- Wintertime closed house condition 24/7, no daytime ventilation, central forced air heat, no active sub-slab depressurization, unoccupied.
- Wintertime closed house condition 24/7, HRV on Medium Speed, central forced air heat, no active sub-slab depressurization.
- Wintertime closed house condition 24/7, HRV on Low Speed, central forced air heat, no active sub-slab depressurization.
- Wintertime closed house condition 24/7, HRV on Low Speed, central forced air heat, active sub-slab depressurization.
- Wintertime closed house condition 24/7, HRV on Low Speed, central forced air heat, active sub-slab depressurization with variable speed controller.

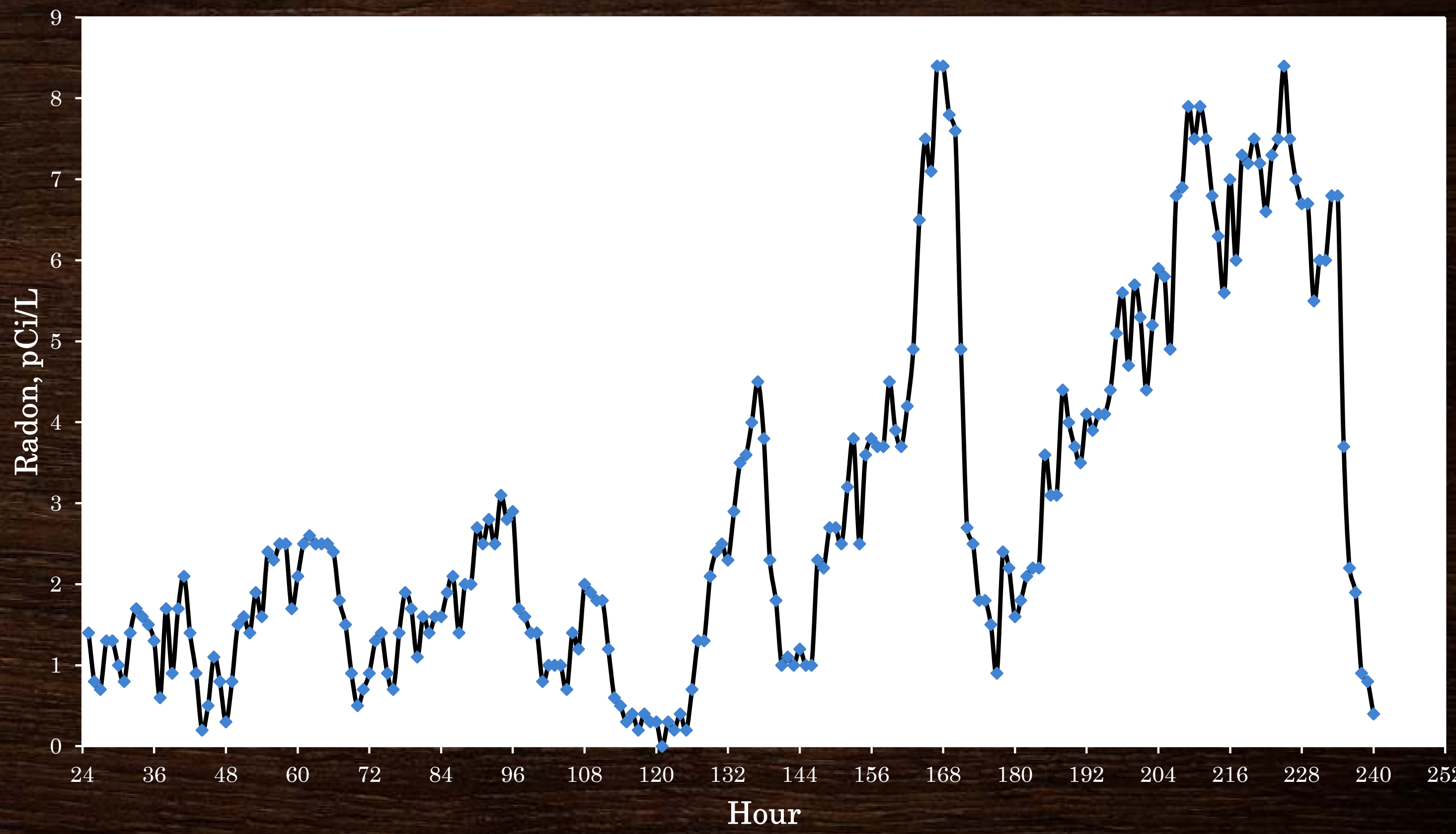
AVERAGE RADON LEVEL PCI/L .4



Continuous Radon Monitor

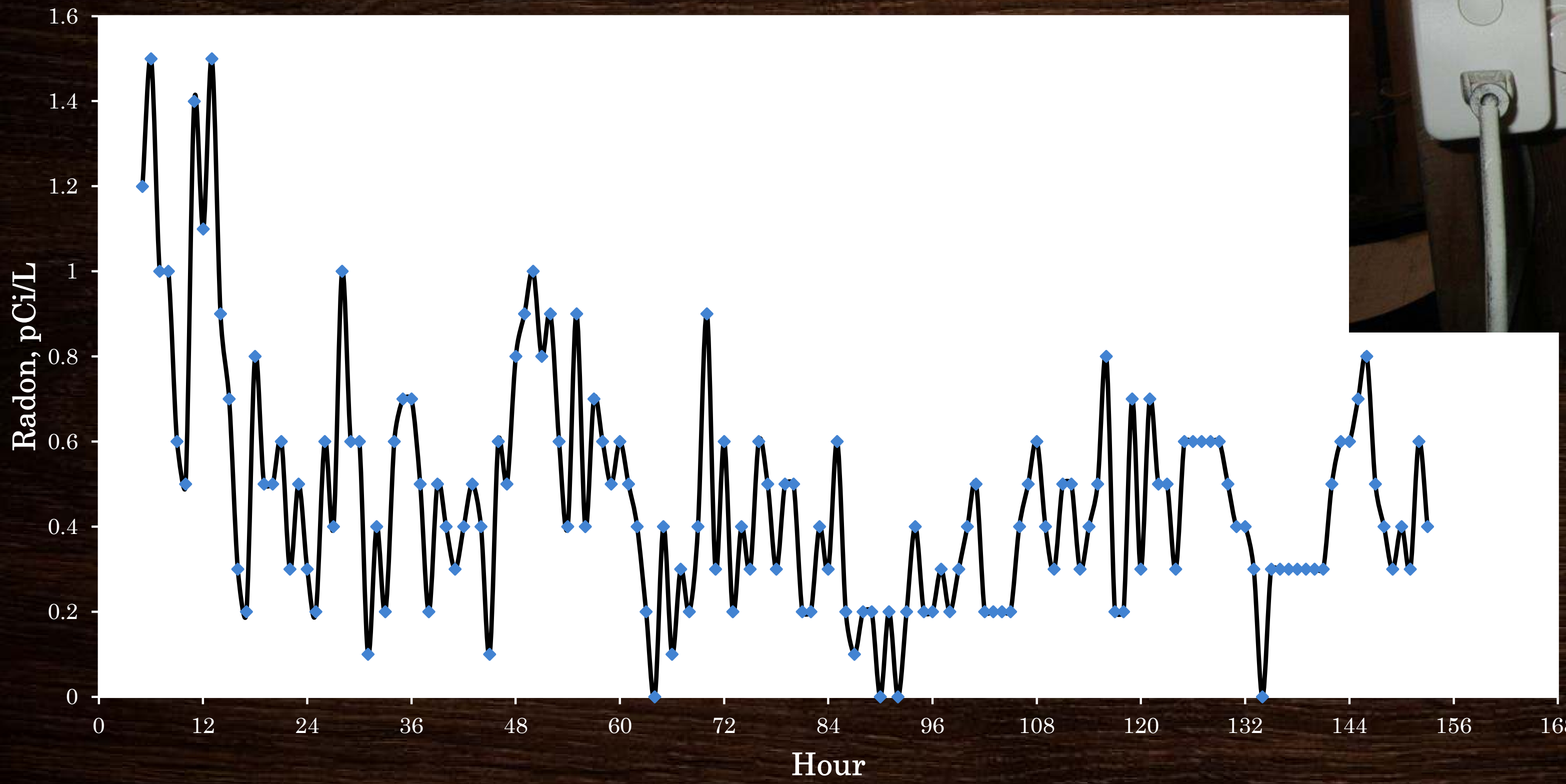
RADON FAN ON, NO DAYTIME VENTILATION, NIGHTTIME OPEN WINDOWS (SUMMER)

AVERAGE RADON LEVEL PCI/L 2.9



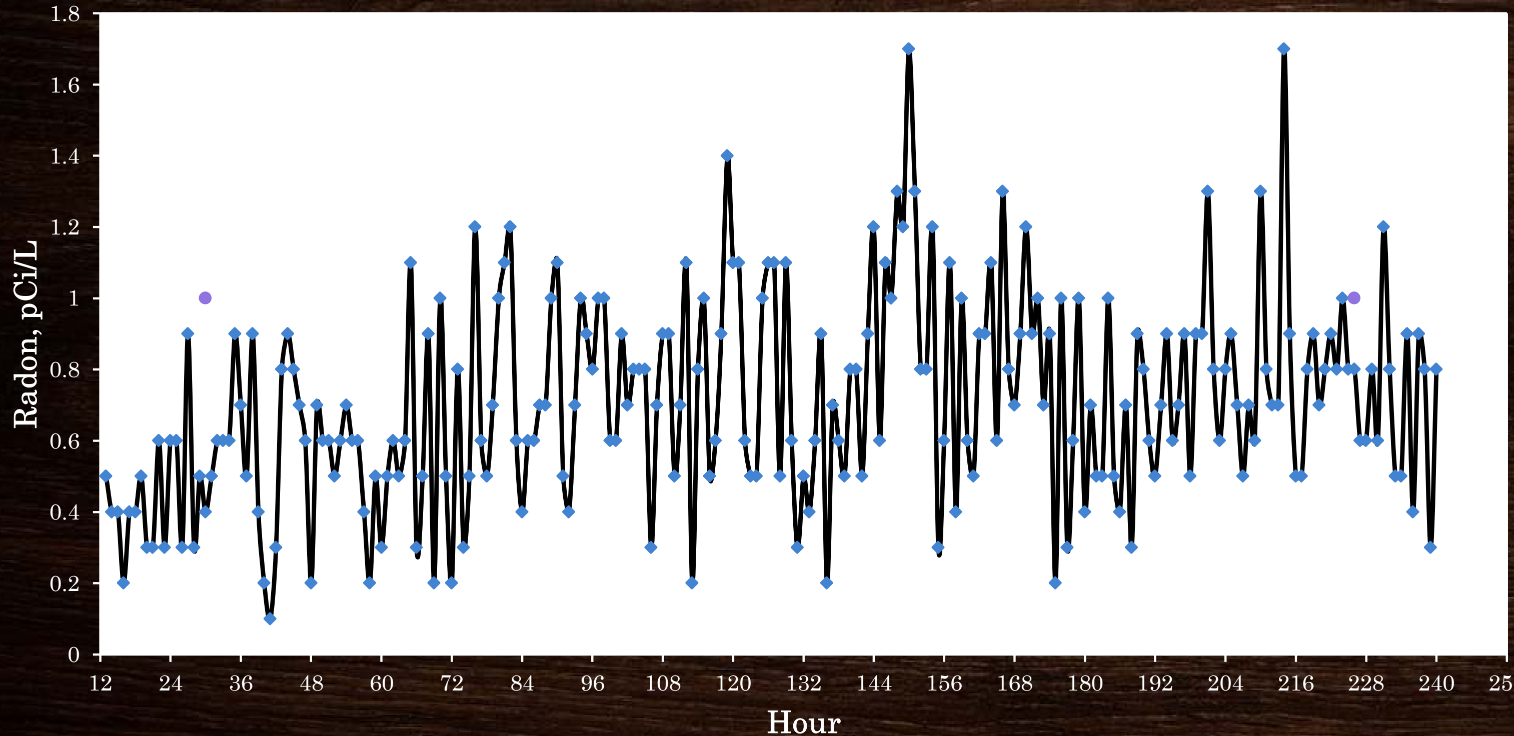
RADON FAN OFF, NO DAYTIME VENTILATION, NIGHTTIME OPEN WINDOWS (SUMMER)

AVERAGE RADON LEVEL PCI/L .4



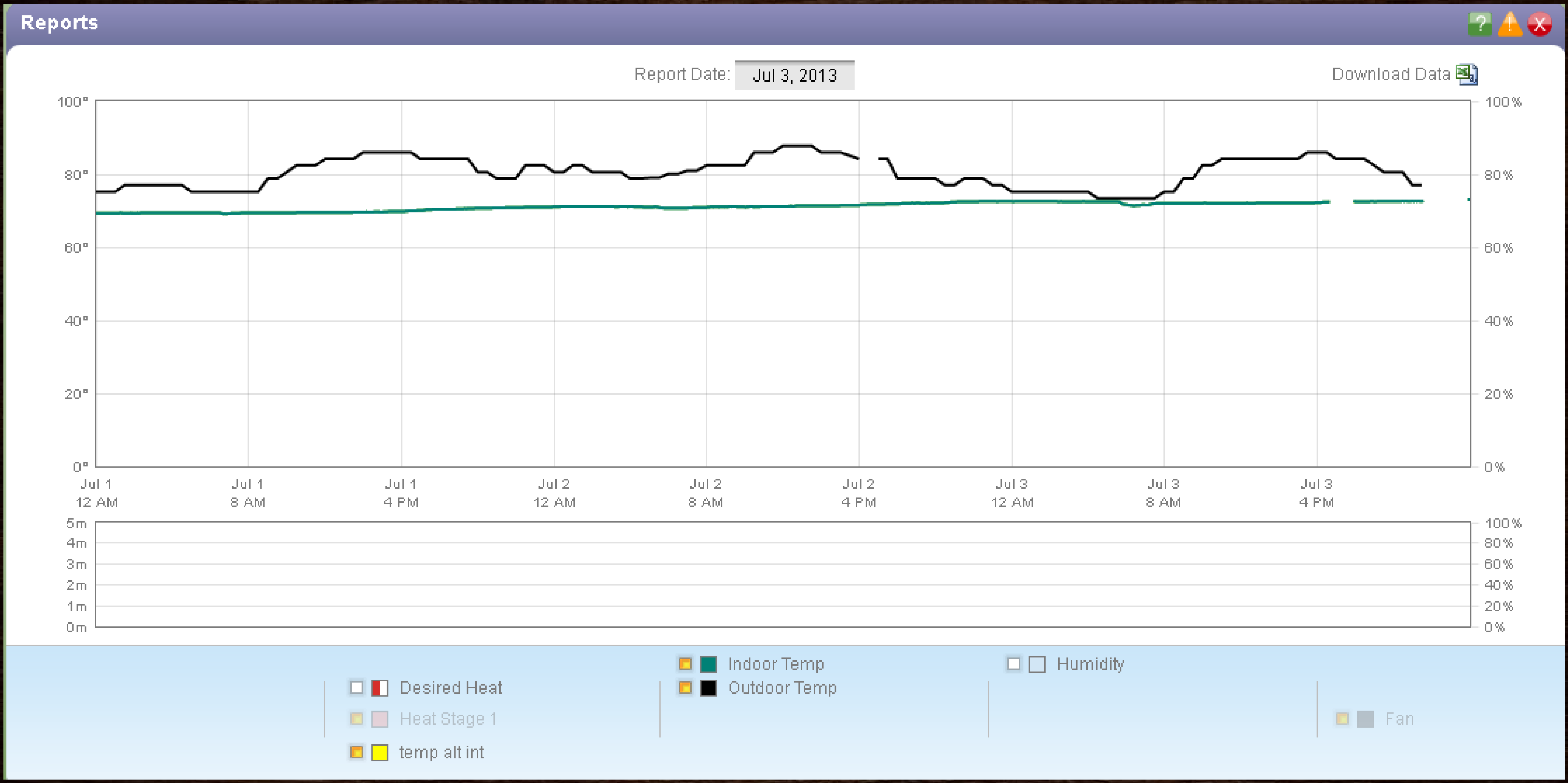
CYCLING RADON FAN, WINDOW OPEN @ NIGHT
RADON FAN SCHEDULED TO RUN DAYTIME,
HOUSE CLOSED NO OTHER VENTILATION

AVERAGE RADON LEVEL PCI/L .7

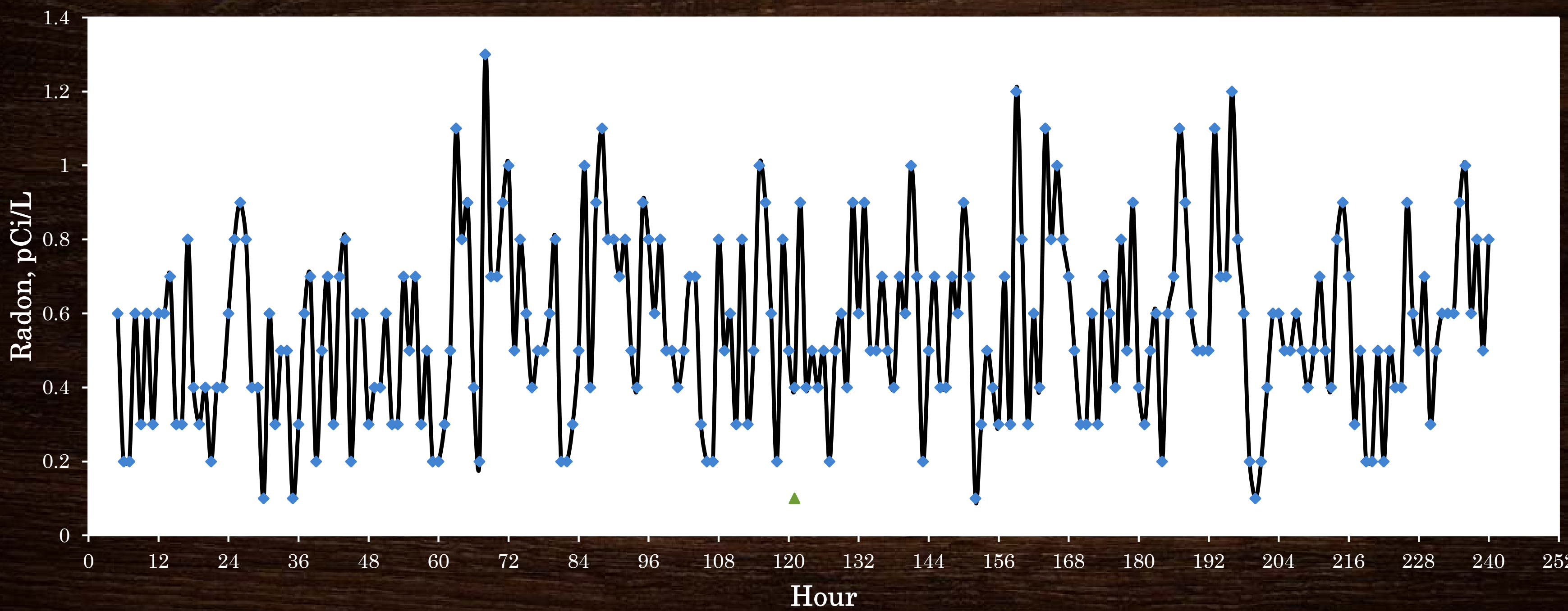


FAN CYCLING CONTINUED WINDOWS OPEN 7HRS DAILY

NIGHT LOW TEMPS CONSISTENTLY ABOVE 80F

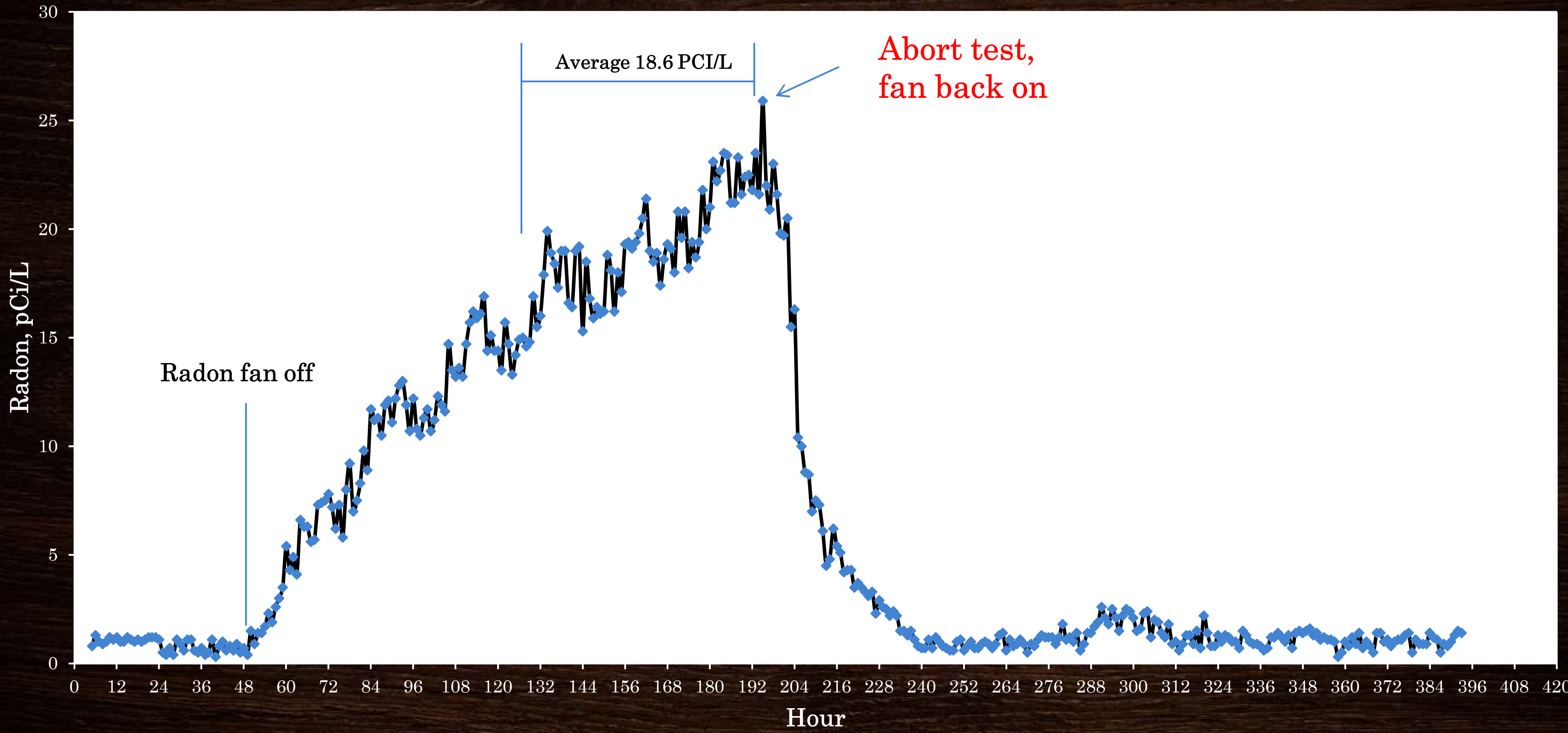


AVERAGE RADON LEVEL PCI/L .5



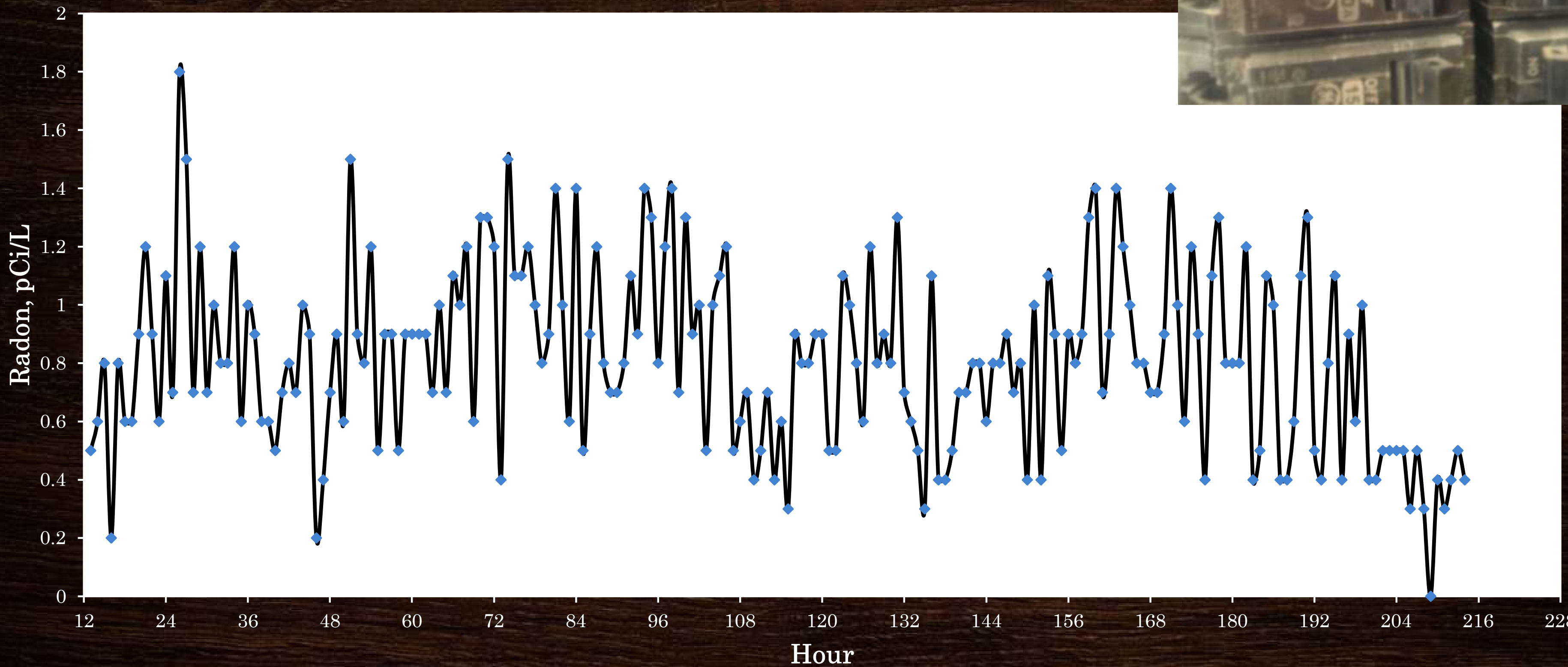
FAN CYCLING CONTINUED

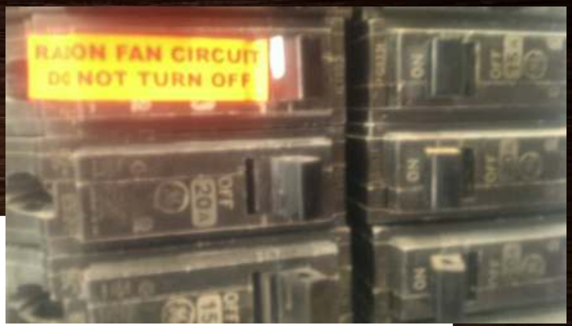
AVERAGE RADON LEVEL PCI/L 6.7



ALL SYSTEMS OFF VACATION UNOCCUPIED

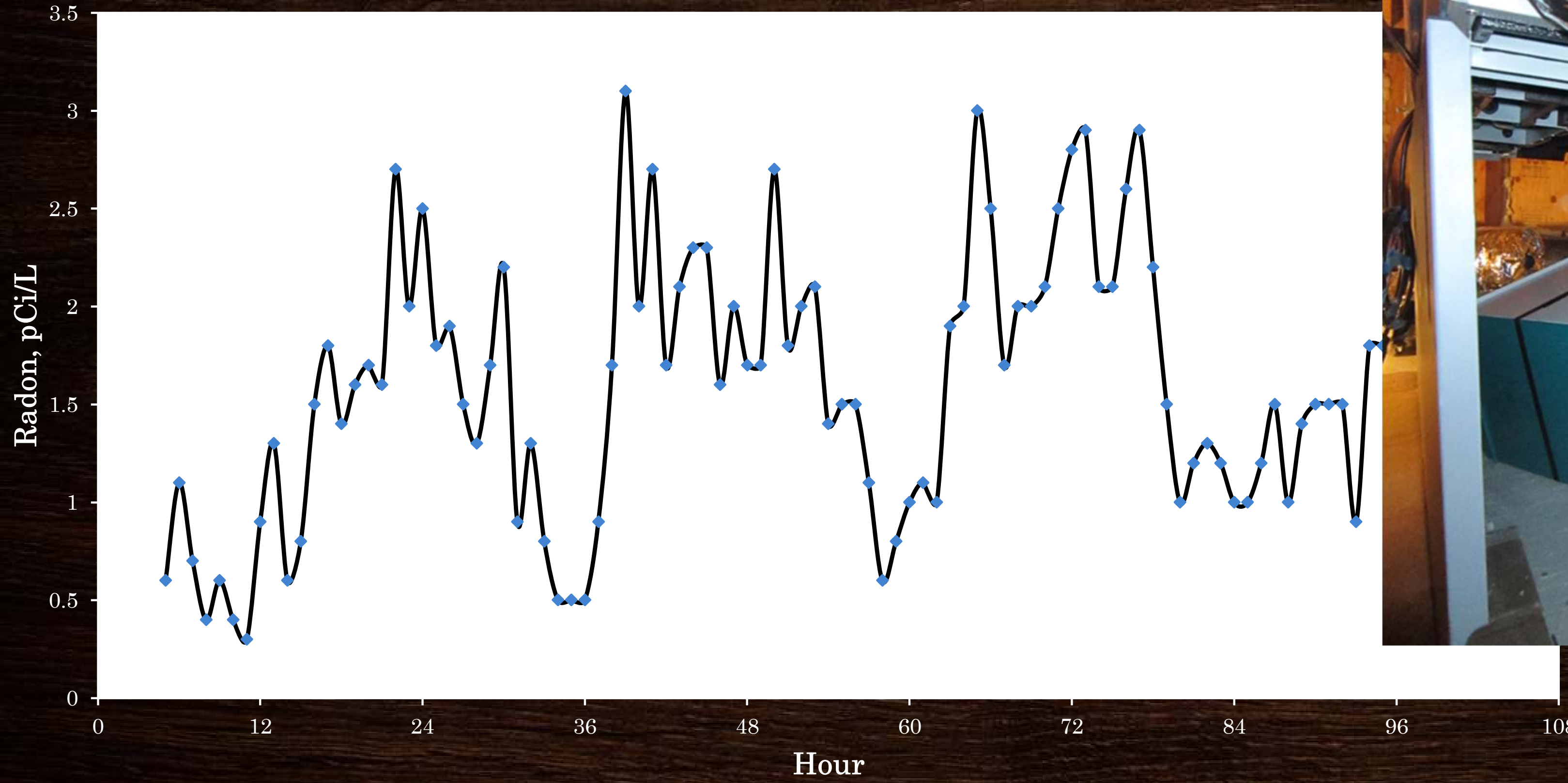
AVERAGE RADON LEVEL PCI/L .8





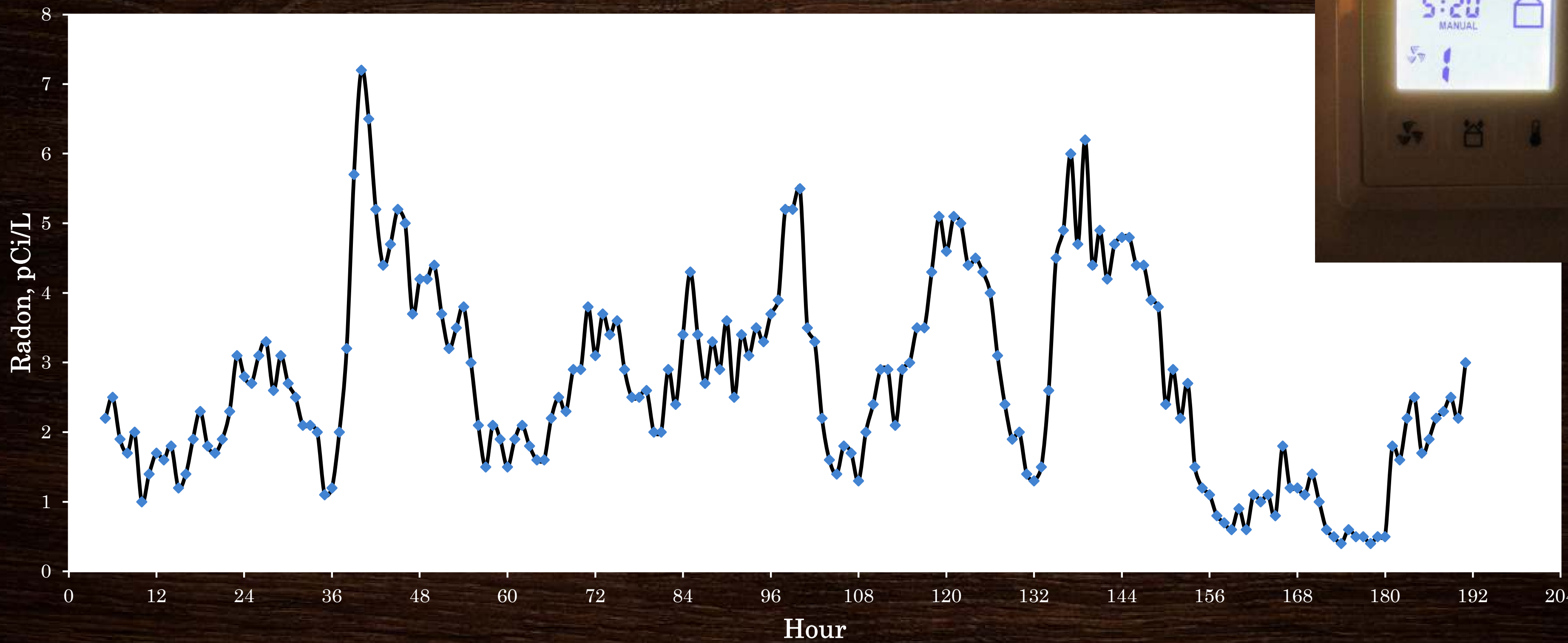
RADON FAN ON, NO VENTILATION, HOUSE CLOSED, WINTERTIME CONDITIONS

AVERAGE RADON LEVEL PCI/L 1.5



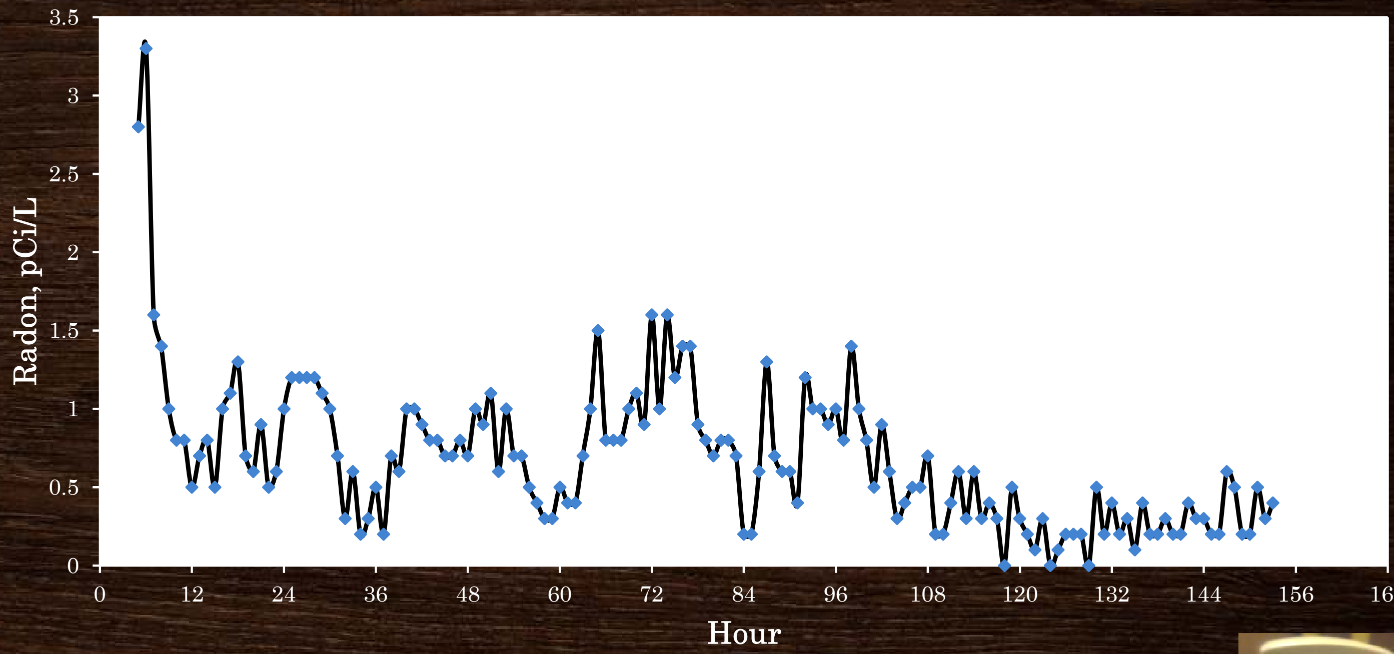
RADON FAN OFF, HRV MEDIUM (78CFM)

AVERAGE RADON LEVEL PCI/L 2.7



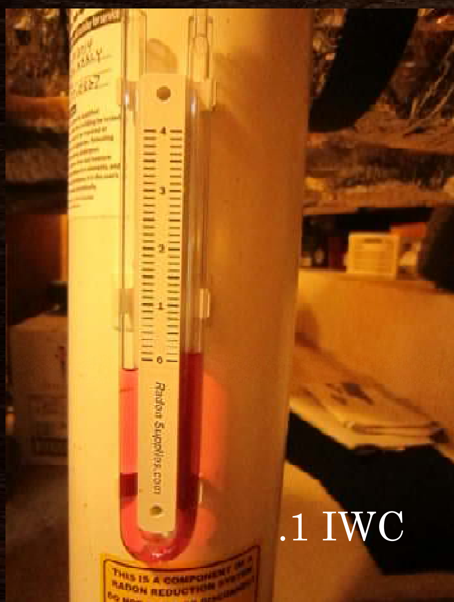
RADON FAN OFF, HRV LOW (53 CFM)

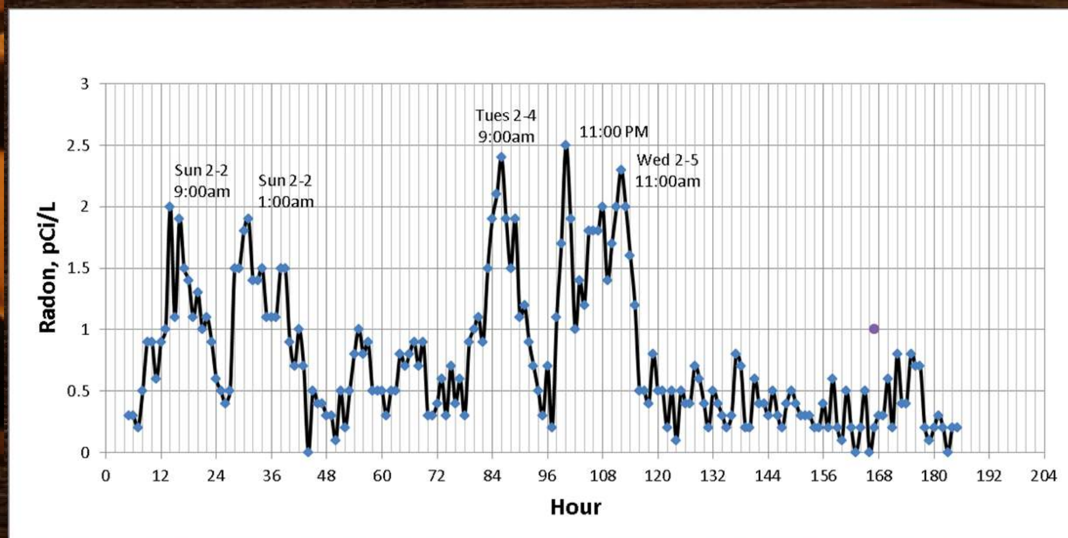
AVERAGE RADON LEVEL PCI/L .6



RADON FAN ON, HRV LOW (53CFM)

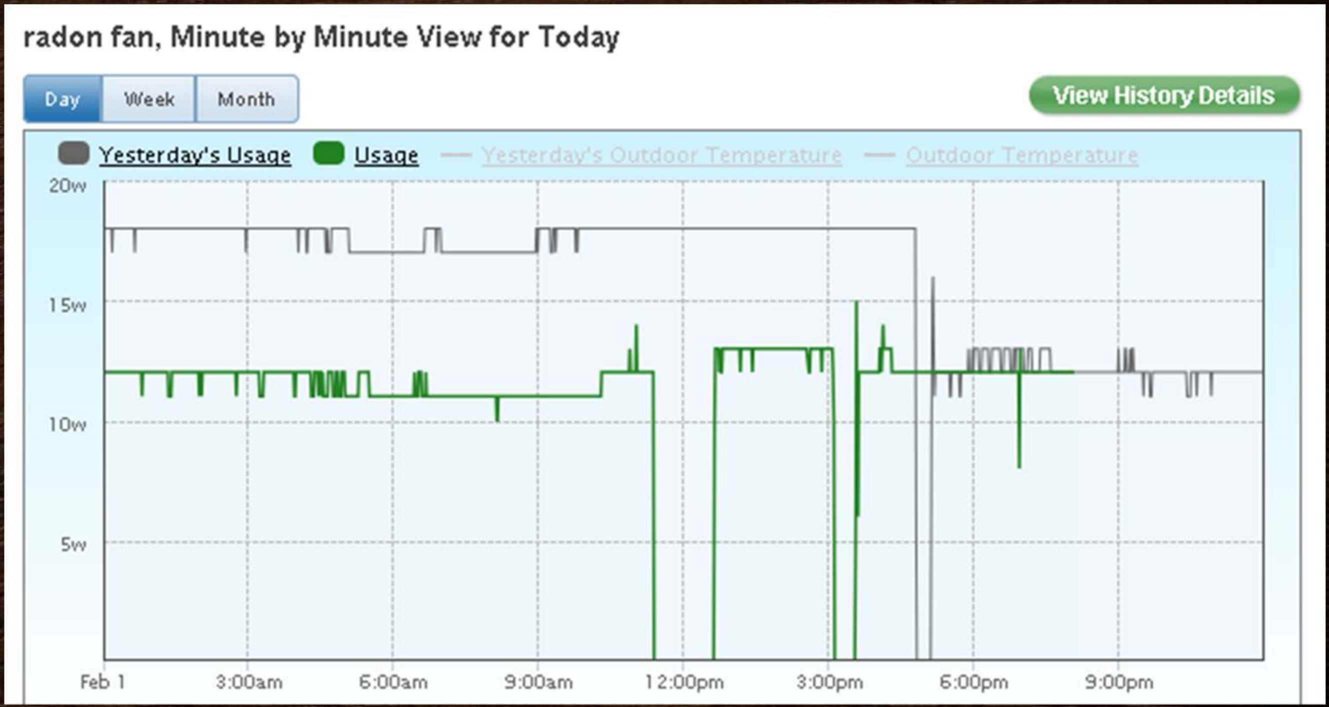
AVERAGE RADON LEVEL PCI/L .7
SYSTEM WITH VARIABLE SPEED CONTROL





LOW 32 CFM @ 11 WATTS OR 2.9CFM/WATT

SYSTEM WATT DRAW WITH VARIABLE SPEED CONTROL



HIGH 72 CFM @ 18 WATTS OR 4CFM/WATT

Radon fan consumption by fan speed.

QUANTIFYING HOUSE AIRFLOW FROM SUB-SLAB DEPRESSURIZATION

Initial results:

Radon fan on high is 38CFM from the house.

Radon fan on low is too low to measure, less than 10CFM with ring 3

RANGE HOOD TESTING

Gavin Healy, Balance Point Home Performance

RANGE HOOD CRITERIA

- Quiet (less than 1.5 sones at design)
- Airflows installer adjustable based on ACH of house and desired volume of make up air
- Target airflow 50-200CFM
- High CFM per Watt, low absolute watt draw.
- Effective range of capacities (controlled depressurization)
- A hood that we could recommend to a variety of customers doing a kitchen remodel (one that they would pick based on aesthetics, one that we would pick for performance.)
- An exhaust appliance rated for kitchen exhaust (grease) do not want to rely on HRV for kitchen exhaust.
- Capacity for effective damper to maintain house air tightness.

RATED FAN SPECS

ACT INTERNAL BLOWER with AIRFLOW CONTROL TECHNOLOGY™

Min.-Max. CFM	250 - 590	250 - 440	250 - 290
Min.-Max. Sones	0.8 - 4.5	0.8 - 3	0.8 - 1.2

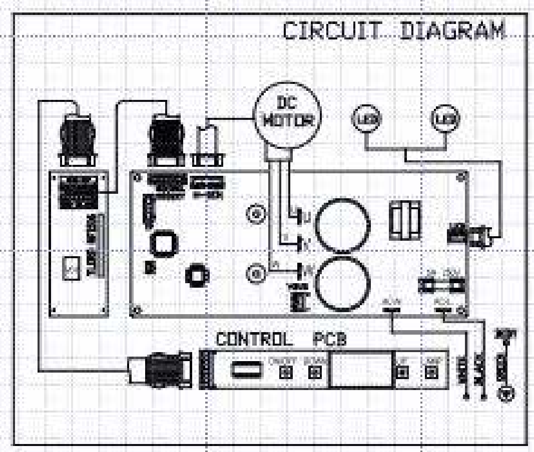
ACT 590 CFM - Fan Max. 130W @ 1.8A

ACT 440 CFM - Fan Max. 70W @ 1A

ACT 290 CFM - Fan Max. 35W @ .55A

Wiring Diagrams

Model: AK9428AS / AK9434AS	
Voltage: 120V 60Hz	
Power consumption	
Total: Max. 219W @ 3.5A	
Lamp:	Max. 6Wx2
Fan:	Max. 207W
Electronically	Protected



Power consumption shown for default 715 CFM blower configuration

The range hood airflow was measured at each of the five speeds to test the how effective different backdraft dampers are at time of installing the new range hood. Note because the house is substantially airtight the test method for determining range hood air flow is the use of a blower door to match the negative pressure produce at each speed (the house is a plenum).

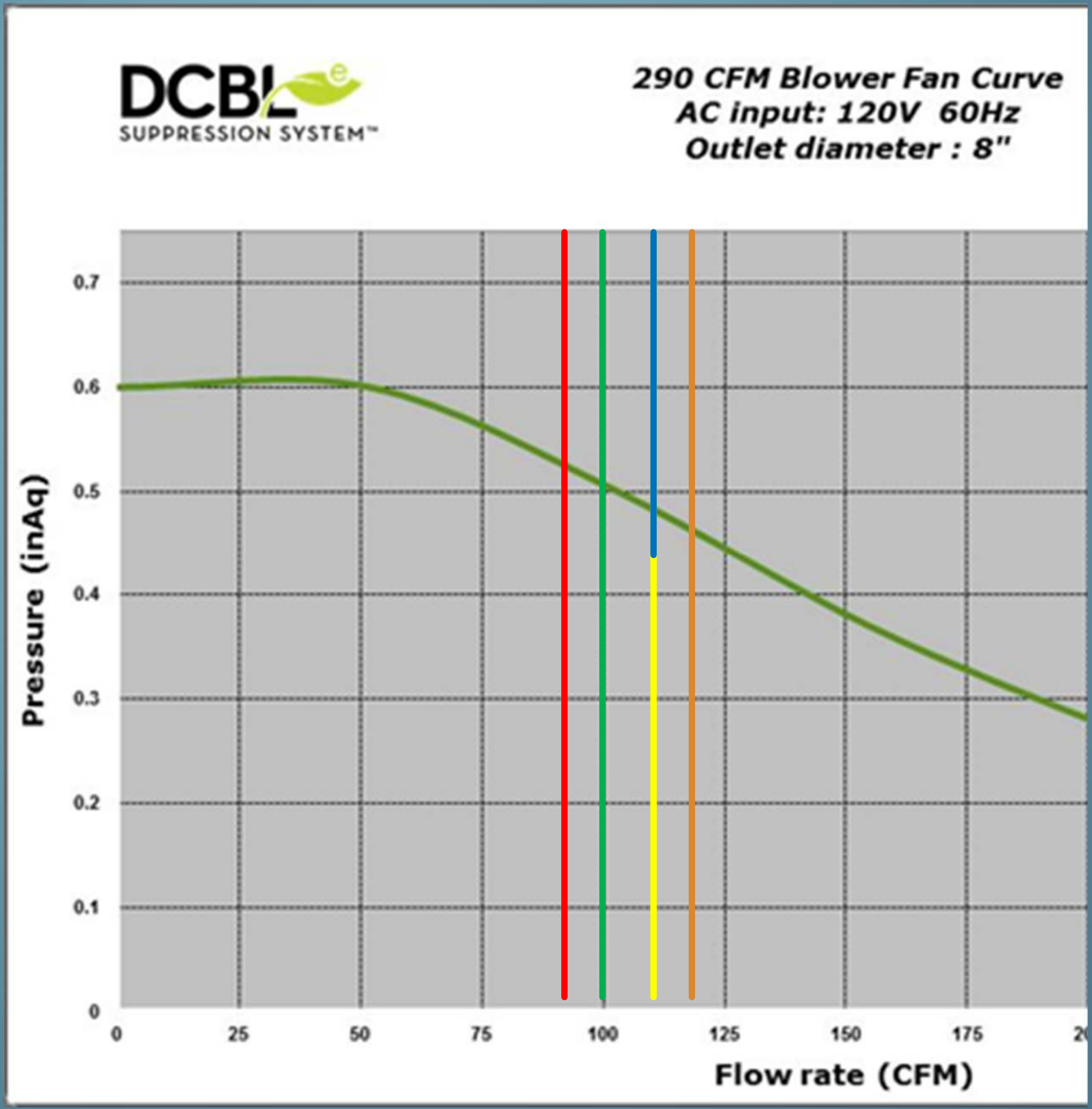
TEST 1
NO DAMPER OR CAP

NOTE: THE HOUSE AIR TIGHTNESS IS CREATING A MAJORITY OF THE BACK PRESSURE RESULTING IN FLOWS THAT ARE AT 30% OF RATED CAPACITY

Speed	Air flow	Watt draw
1	91	11.2
2	98	16.2
3	109	23.2
4	109	26.7
5	119	30

331 CFM50

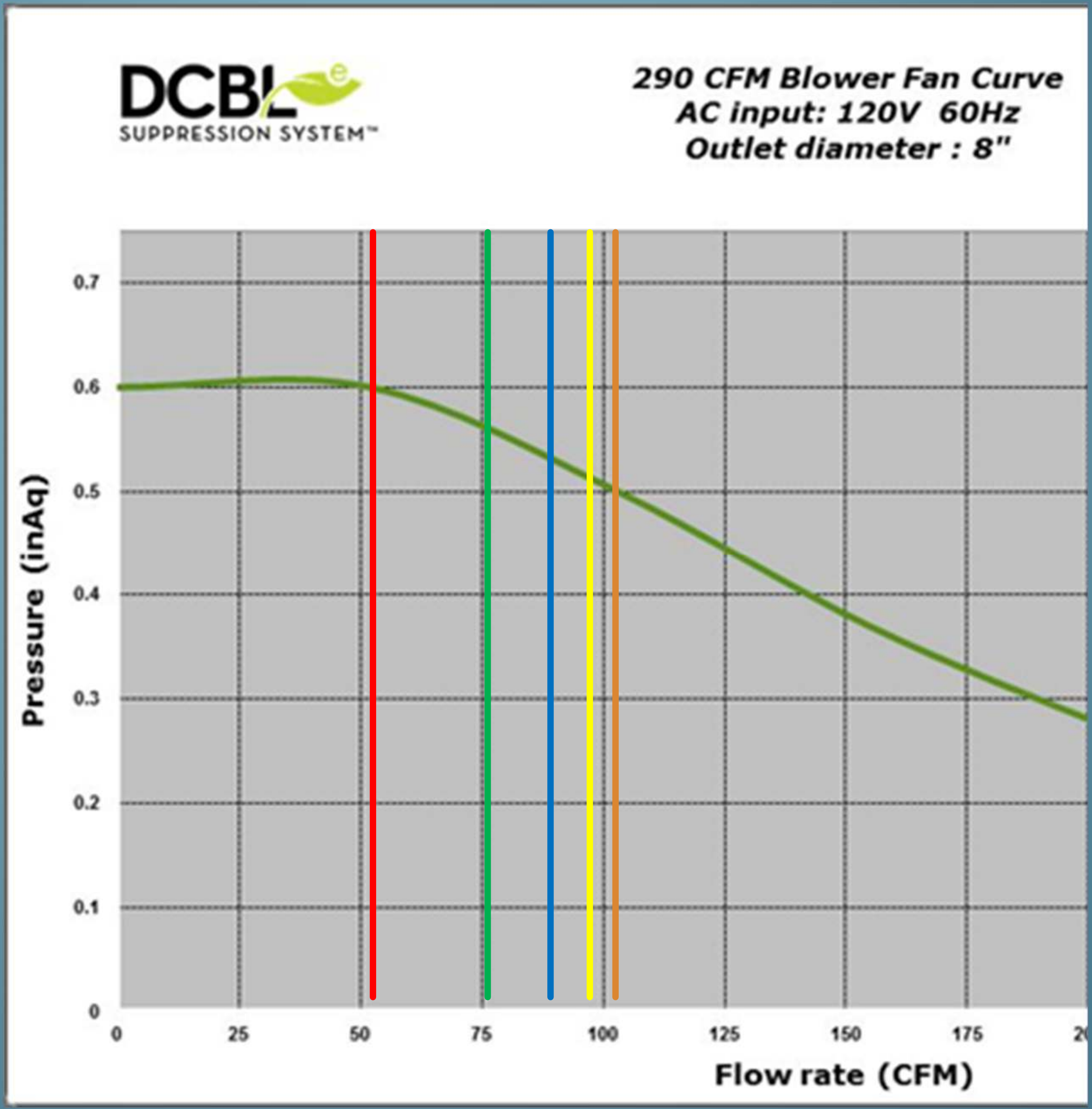
PRE TEST
125 CFM50



TEST 2
SPRING LOADED DAMPER
NO CAP

Speed	Air flow	Watt draw
1	53	12.3
2	77	17.8
3	94	24.6
4	98	27
5	103	30.6

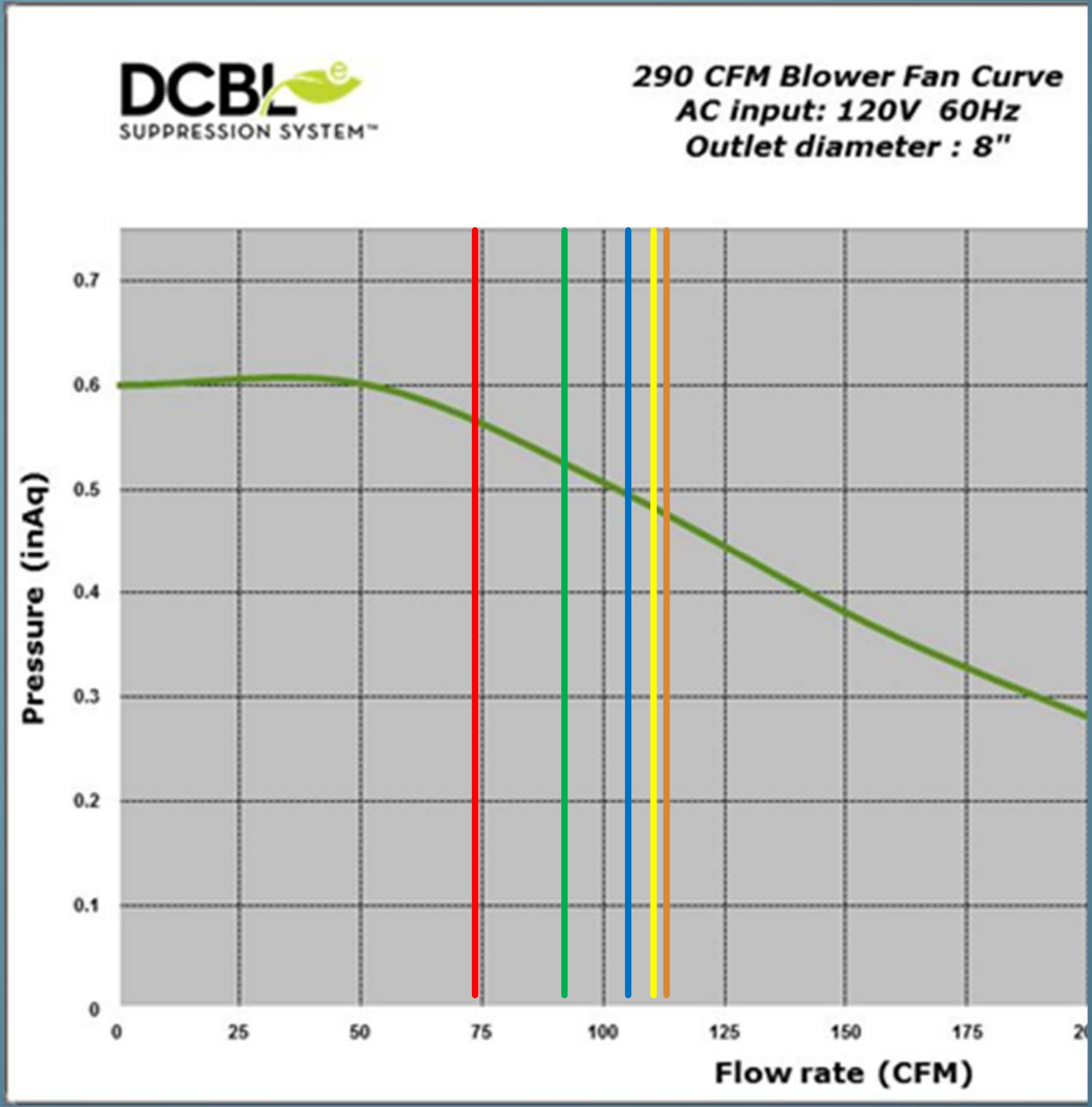
145 CFM50



TEST 3
BUTTER FLY
DAMPER NO
CAP

Speed	Air flow	Watt draw
1	75	11.3
2	91	16.4
3	104	23.2
4	111	26.3
5	114	30.3

135 CFM50

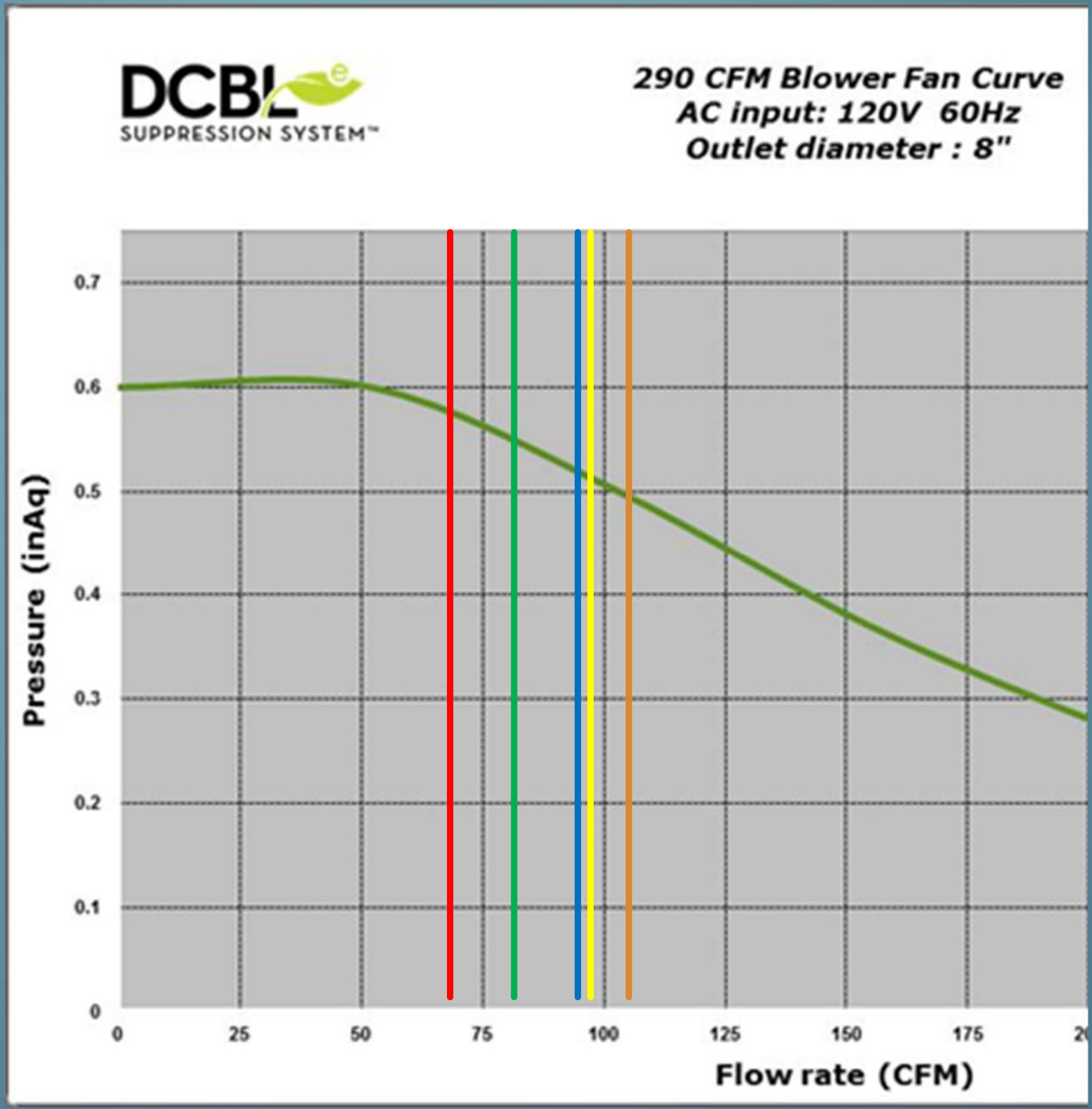


FINAL TEST (4) WITH CAP & BUTTER FLY DAMPER

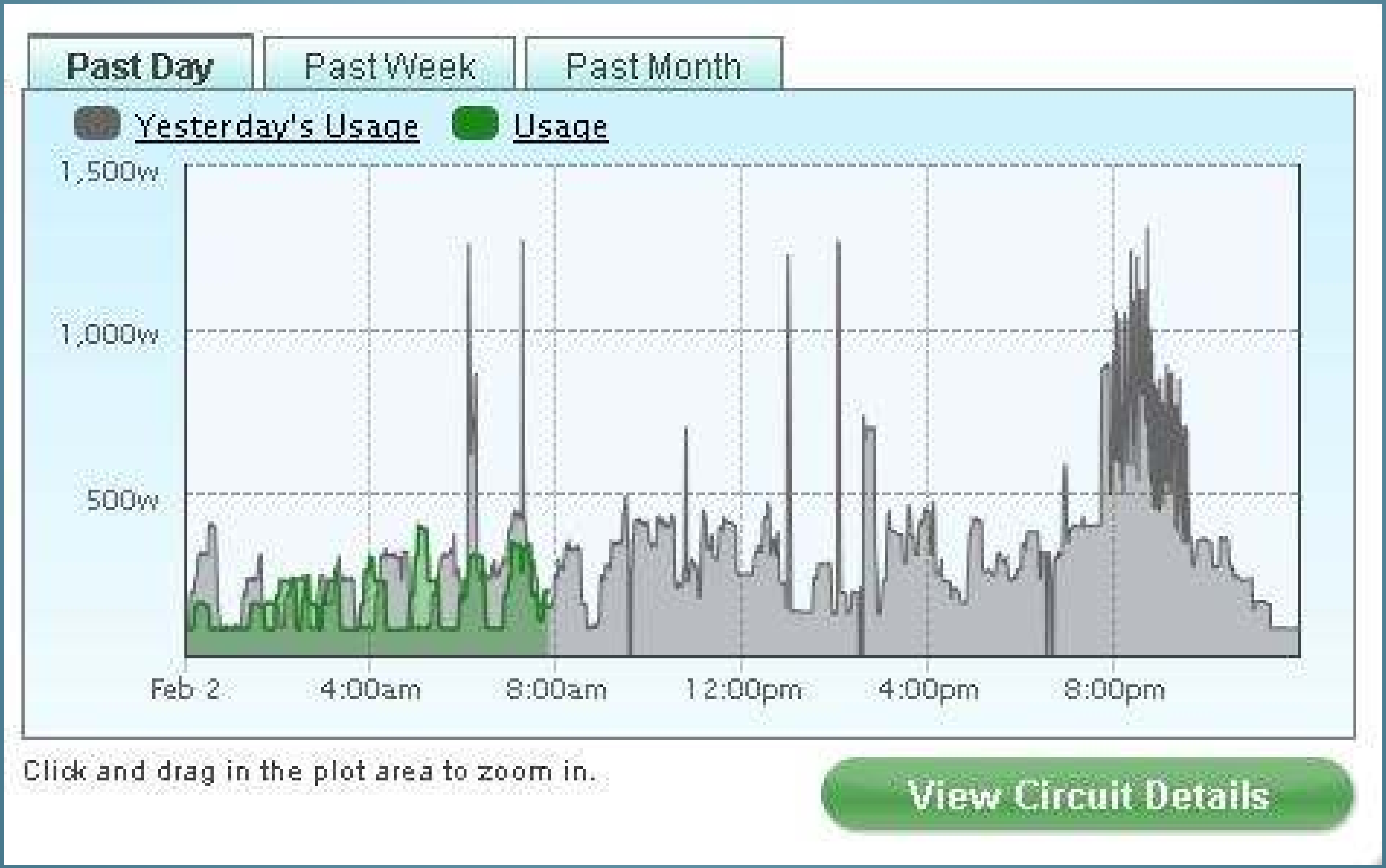
WHILE THE AIRFLOWS ARE LOW FOR THE LEVEL OF DUCT PERFORMANCE THEY ARE IN LINE WITH THE INTENDED DESIGN

Speed	Air flow	Watt draw
1	69	11.3
2	81	16.4
3	94	23.2
4	97	26.3
5	102	30.3

143 CFM50

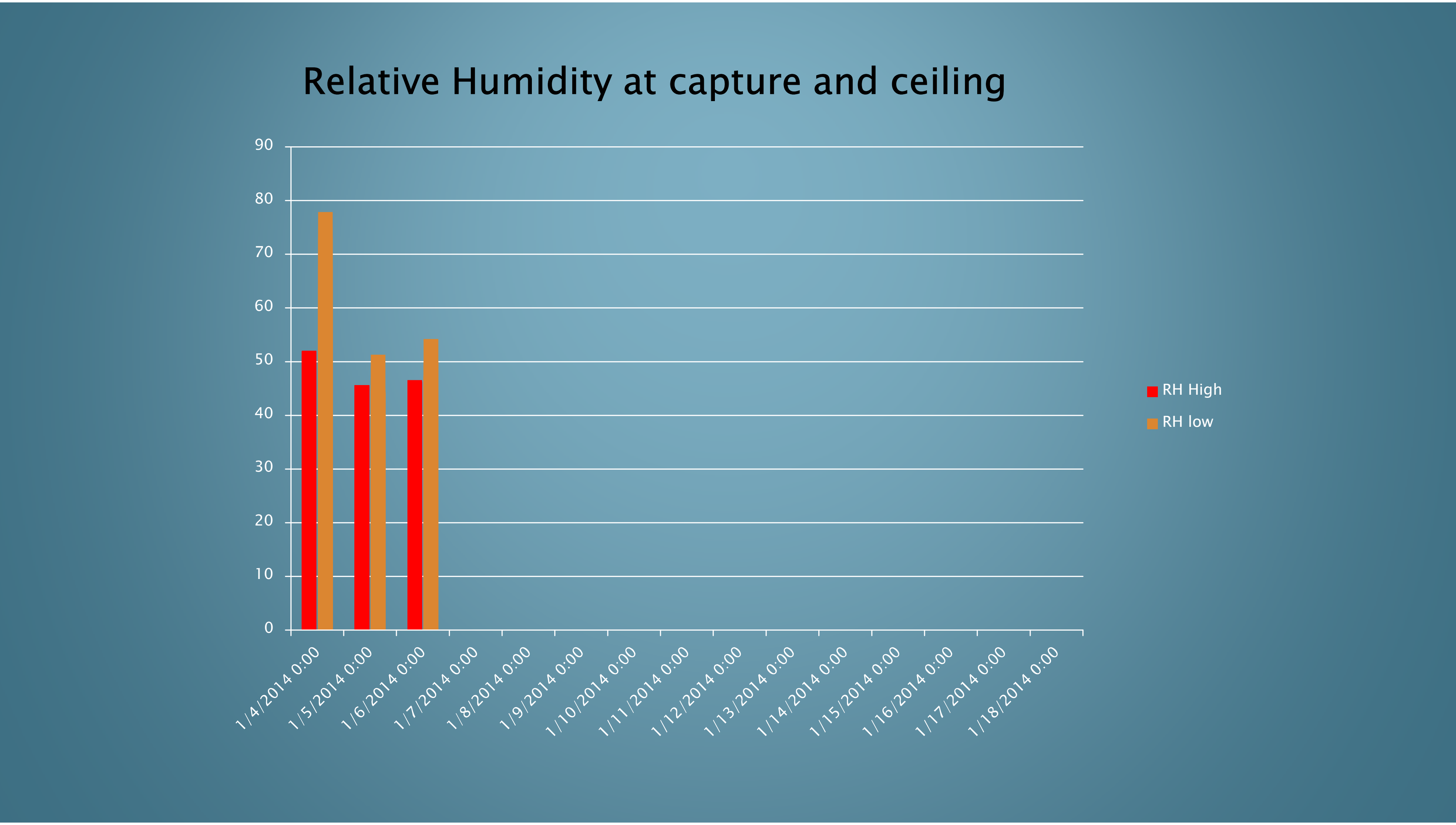


Cooking is the peak daily electric load prior to heat pump water heater

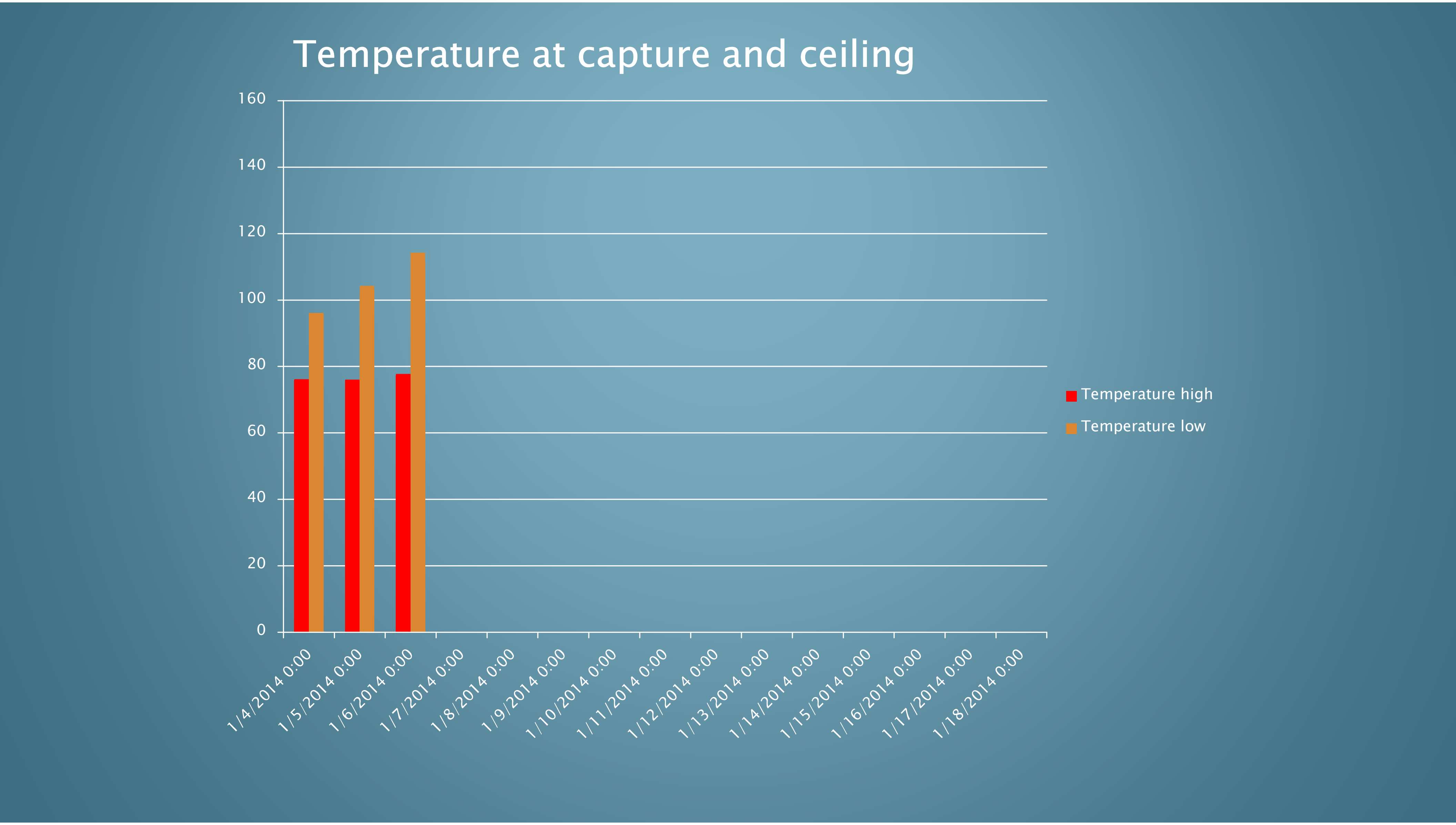


Internal Gain related to cooking with gas

DOES CAPTURE EFFICACY CHANGE BASED ON THE ENCLOSURE TIGHTNESS?



Relative Humidity at capture and ceiling
90
80
70
60
50
40
30
20
10
0
1/4/2014 0:00
1/5/2014 0:00
1/6/2014 0:00
1/7/2014 0:00
1/8/2014 0:00
1/9/2014 0:00
1/10/2014 0:00
1/11/2014 0:00
1/12/2014 0:00
1/13/2014 0:00
1/14/2014 0:00
1/15/2014 0:00
1/16/2014 0:00
1/17/2014 0:00
1/18/2014 0:00
RH High
RH low

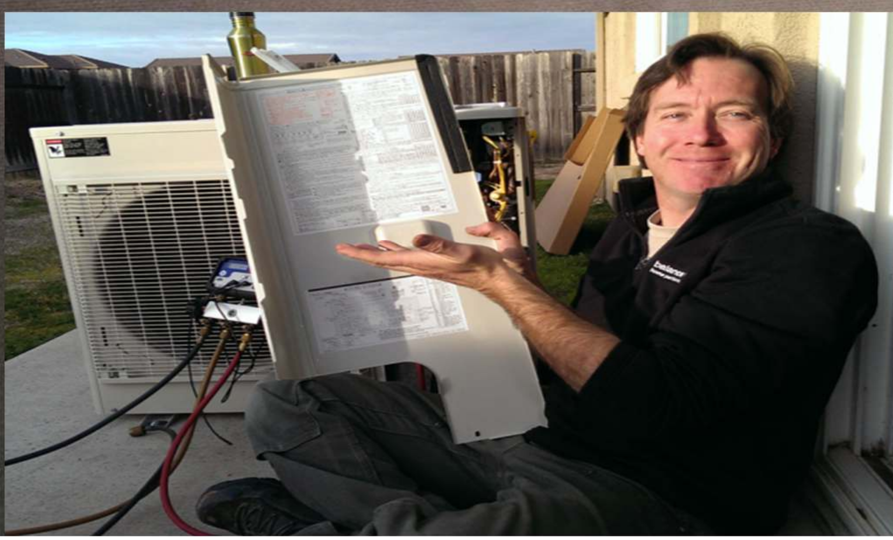


Temperature at capture and ceiling
160
140
120
100
80
60
40
20
0
1/4/2014 0:00
1/5/2014 0:00
1/6/2014 0:00
1/7/2014 0:00
1/8/2014 0:00
1/9/2014 0:00
1/10/2014 0:00
1/11/2014 0:00
1/12/2014 0:00
1/13/2014 0:00
1/14/2014 0:00
1/15/2014 0:00
1/16/2014 0:00
1/17/2014 0:00
1/18/2014 0:00
Temperature high
Temperature low

www.balancepointhp.com

balance point
home performance

Dan Perunko



Gavin Healy

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