Vision to Validation: the Payoff of Passive Design

Design and Performance for Pipsqueak passive house in Salt Lake City, Utah

Dave Brach

- registered architect
- Principal at Brach Design Architecture, Salt Lake City Utah
- Phius certified CPHC
- Phius certified Rater
- RESNET certified HERS Rater
- Architect of the first Phius certified passive building west of the Mississippi in 2009
- Architect, rater, or CPHC on 9 Phius Final Certified projects

Today's Presentation

- Planning and Design of Pipsqueak
- Construction and Mechanical system
- 6 years of select performance data
- Indoor air quality
- What worked and what did not
- My preferred Passive Building kitchen and bathroom ventilation strategy

The Hook: heat your house with a hair dryer

- 1500 Watts Peak Heating Load
- 1 Watt/ square foot
- 3.412 Btu/hr-sf
- Deliver all the heat with the ventilation system
- This only works in ~Central Germany (no cooling!)

Actual peak loads = ~6kBtu/sf heat ~7kBtu/sf cool

Rhvac Online			**Elite Software Development, Inc.**
Brach Design			Pinkowski
Salt Lake City, Utah			Page 3

Check Figures

Supply CFM:	653	CFM per Square ft.	0.379
Square ft. of Room Area:	1,722	Square ft. per ton:	1,246
Volume (ft³) of Cond. Space:	16,126	Air Turnover Rate (per Hour)	2.4

Building Loads

Total Heating Required Including Ventilation Air:	10,525 Btuh	10.525	MBH
Total Sensible Gain:	12,440 Btuh	100	%
Total Latent Gain:	-236 Btuh	0	%
Total Cooling Required Including Ventilation Air:	12,440 Btuh	1.04	Tons (Based On Sensible + Latent)
		1.38	Tons (Based On 75% Sensible Capacity)

Notes

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Notes

Core idea is sound: design the building around the heater/cooler and not the other way around.

Hair dryer = 9k Btu/hr single split.

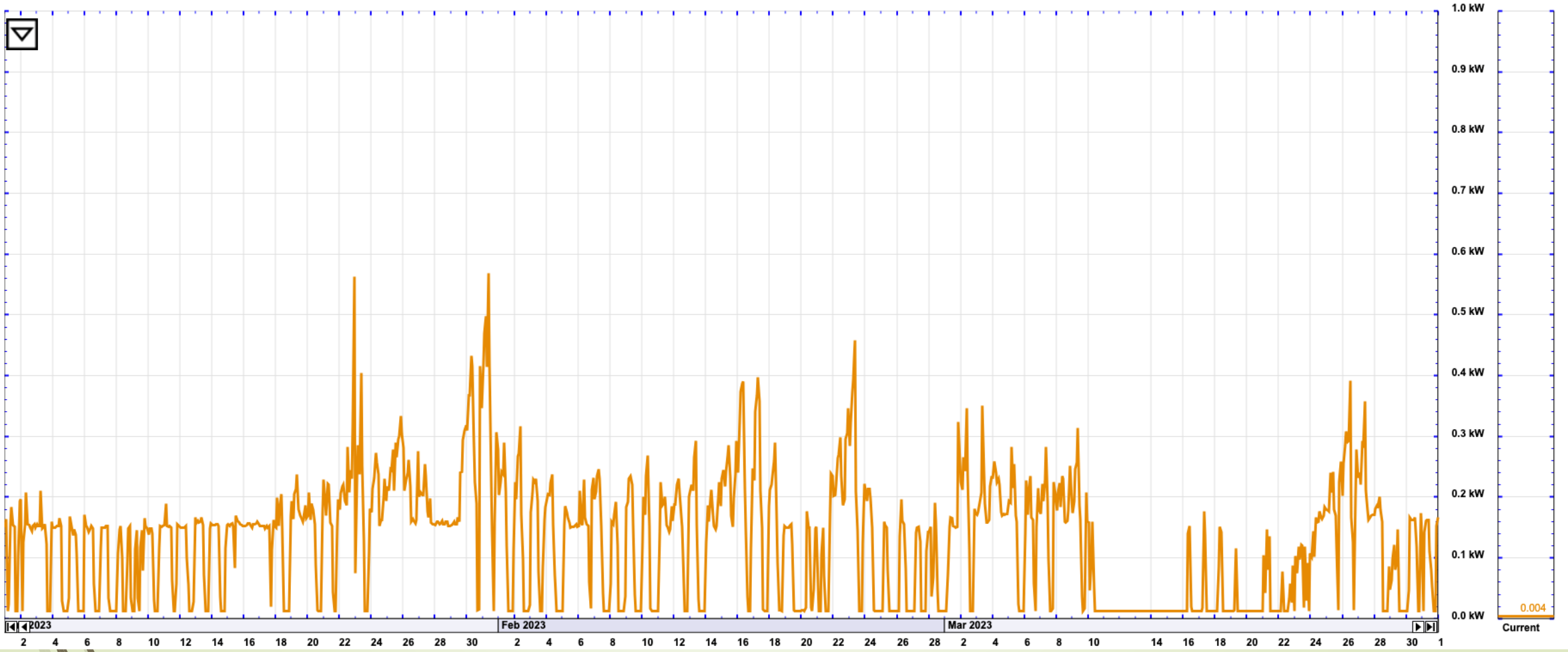
Definitely not a hair dryer

Energy Used	2.27 MWh	(approx. $294.53 used)
Energy Generated	1.19 MWh	(approx. $155.04 saved)
Net	1.07 MWh bought	(approx. $139.49 spent)

Energy Used	497 kWh	(approx. $64.58 used)
Energy Generated	784 kWh	(approx. $101.93 saved)
Net	287 kWh sold	(approx. $37.35 earned)

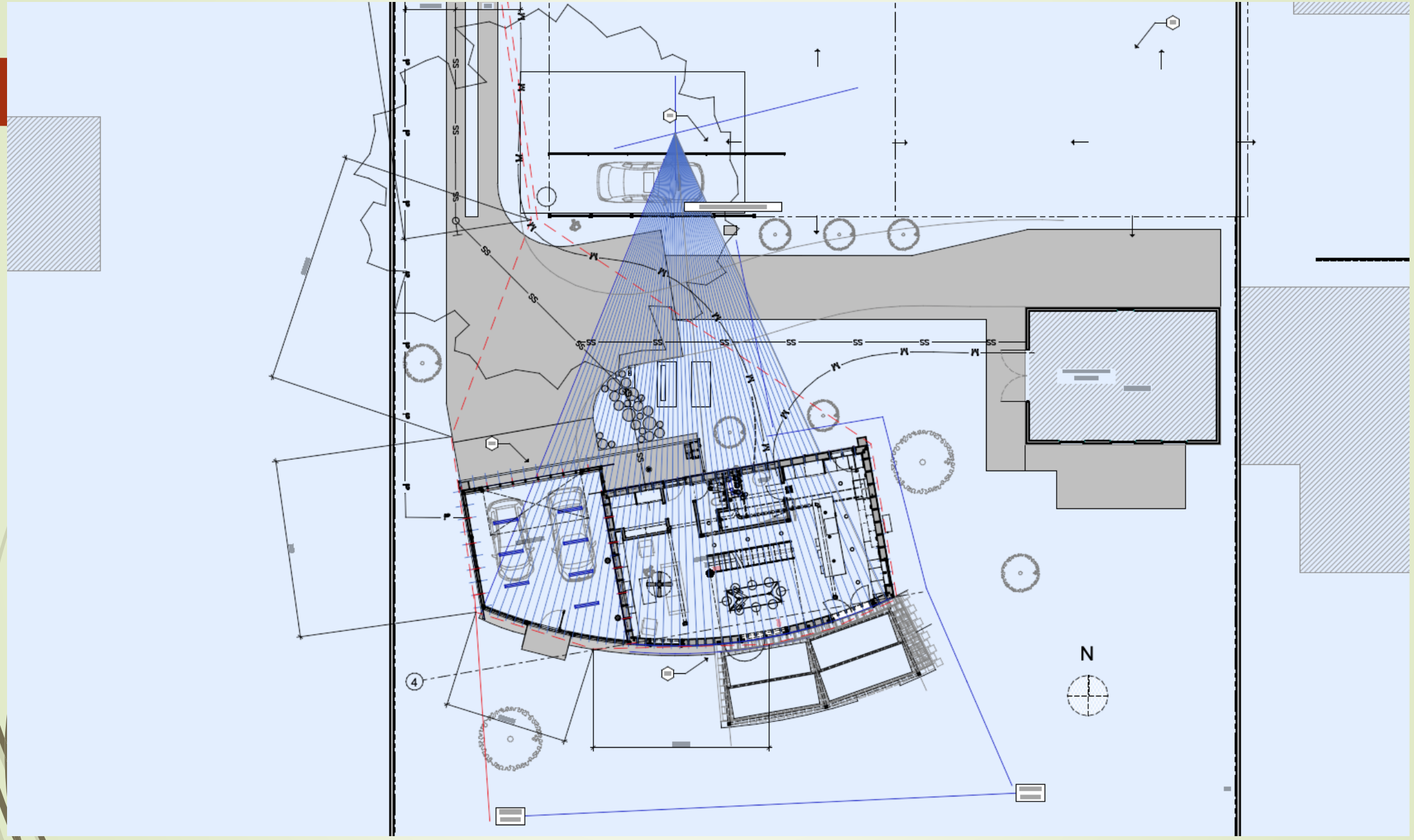
All | 1y | 6M | 3M | 1M | 3w | 1w | 3d | 1d | 12h | 6h | 3h | 1h | 10m

Auto | 500kW | 100kW | 50kW | 10kW | 5kW | 1kW | 500W | 100W | 50W



ARCHITECTURE

- Heating degree days: ~5800
- Cooling degree days: ~2000
- Very dry, ~15" rain per year, low RH
- Historically cool nights in summer
- Very sunny, heating with the sun is easy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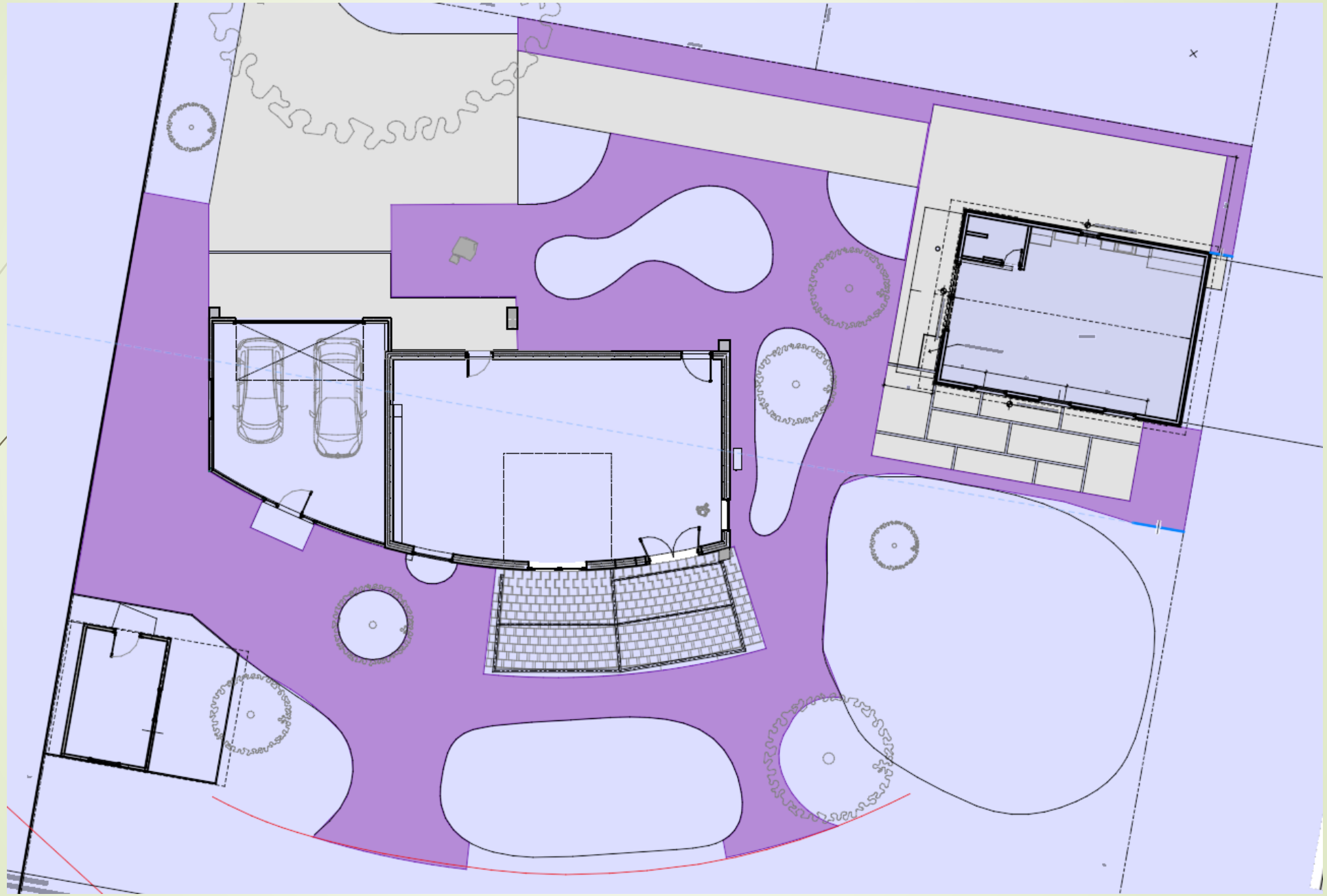
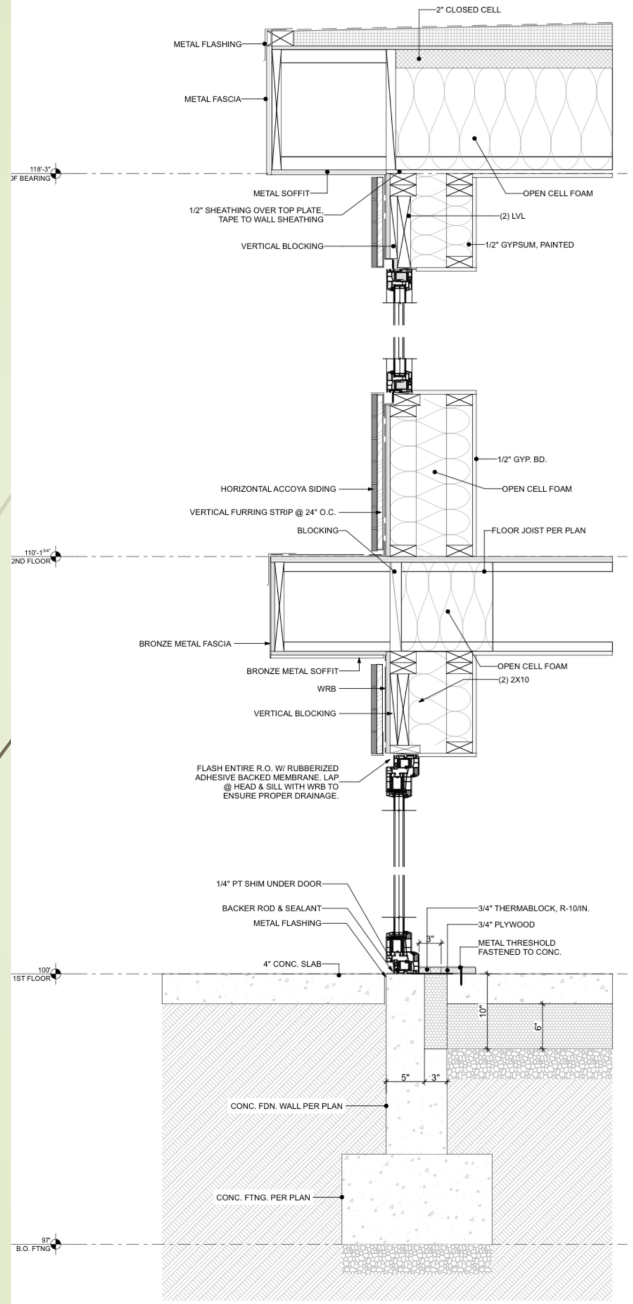


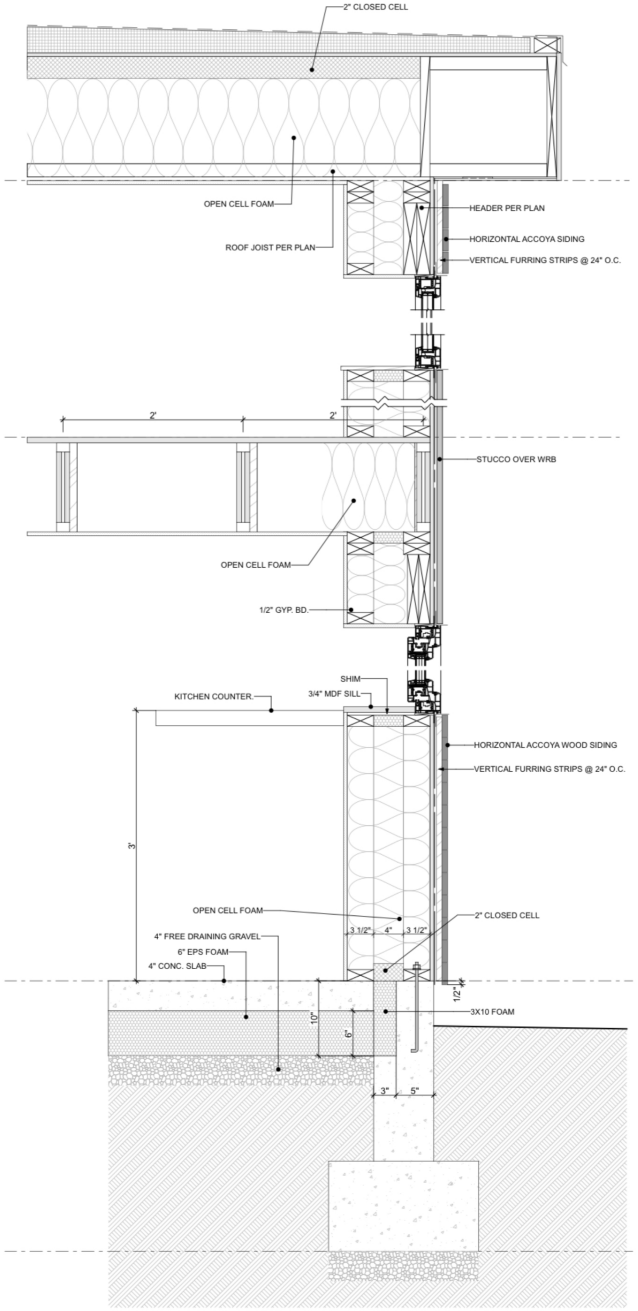
Compact simple shape, small size, good orientation

North Elevation

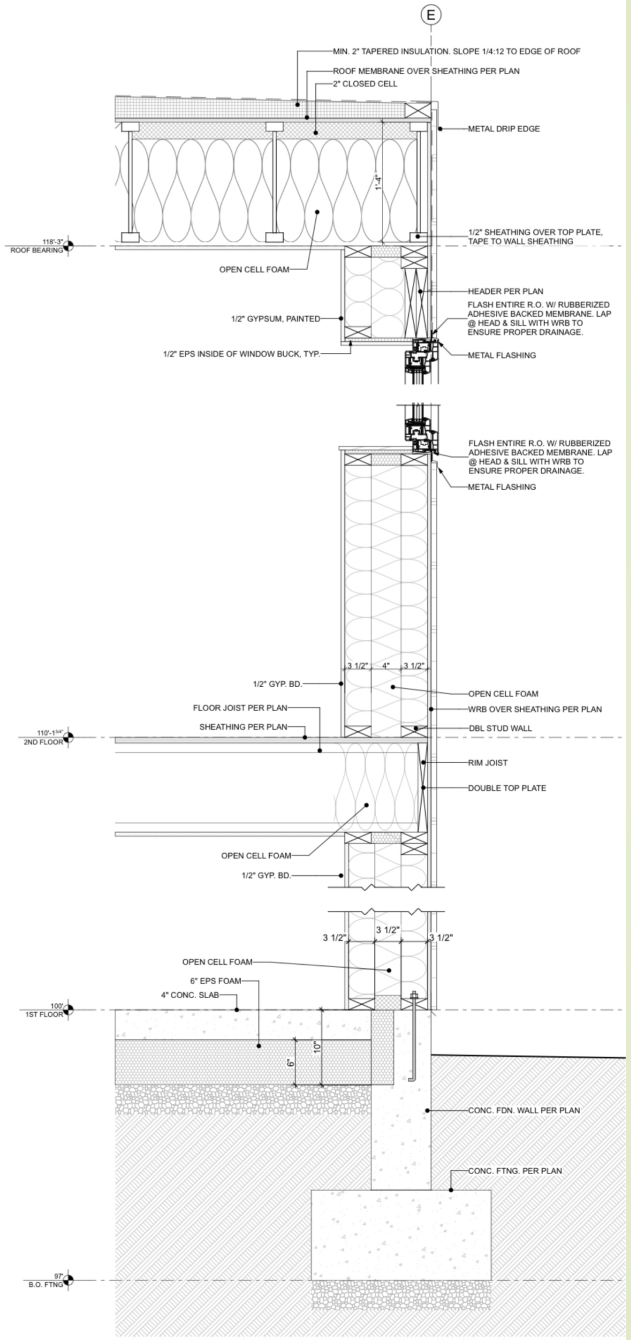

LO
GAIN
LOW
GAIN
LOW
GAIN
HIGH
GAIN
HIGH
GAIN
HI
GAIN



5 SOUTH WALL
SCALE: 1 1/2"= 1'-0"



8 NORTH WALL
SCALE: 1 1/2"= 1'-0"



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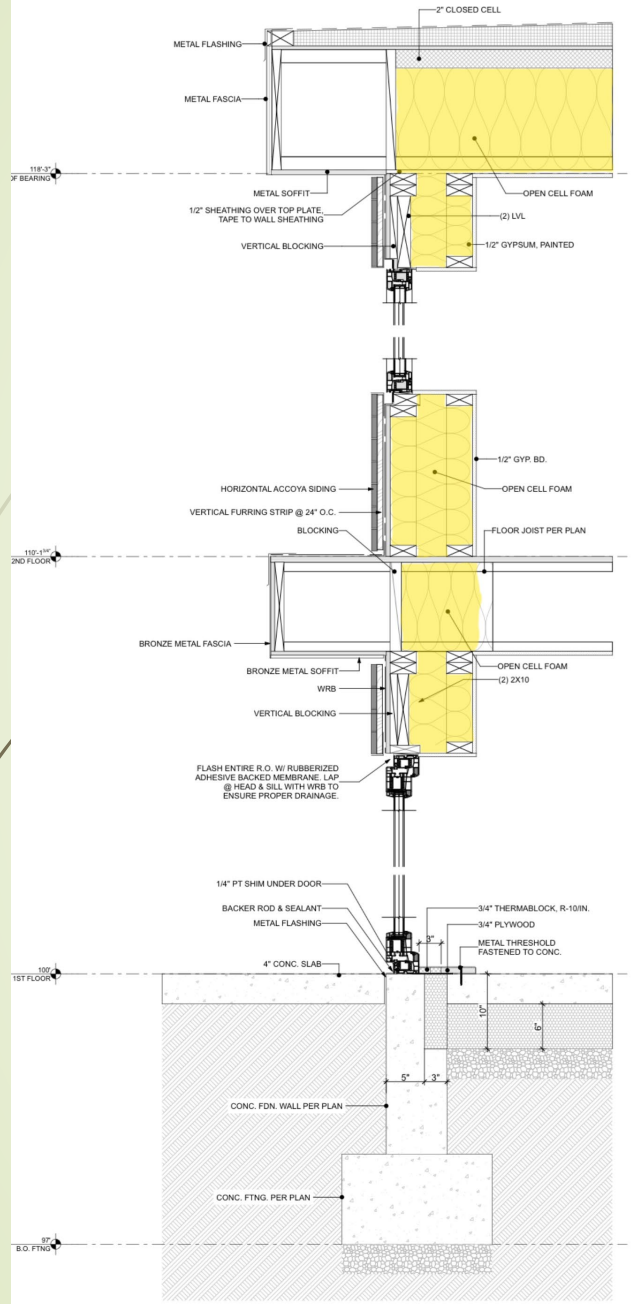

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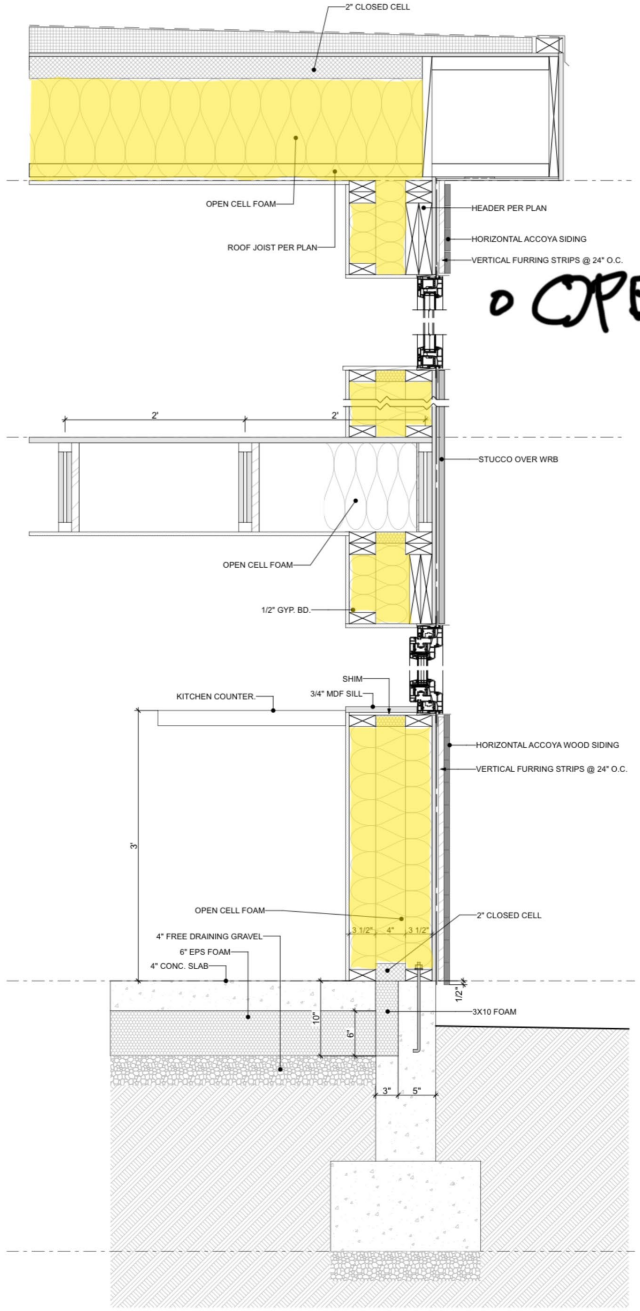

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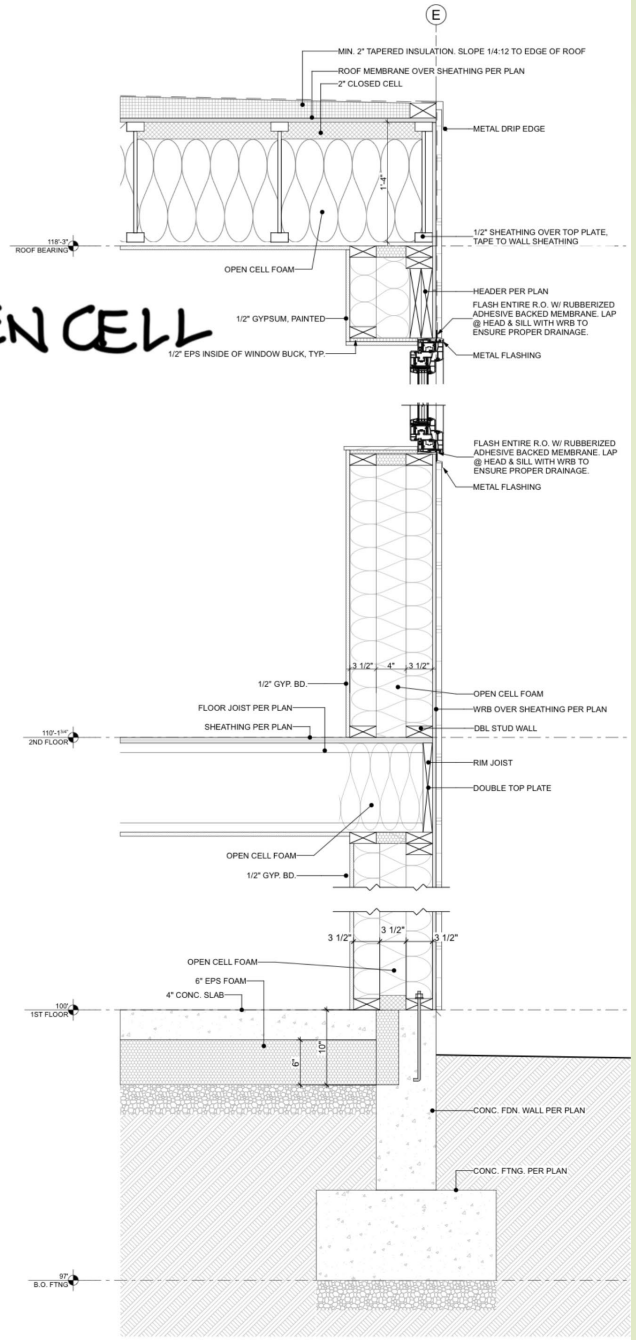

1 EAST WALL
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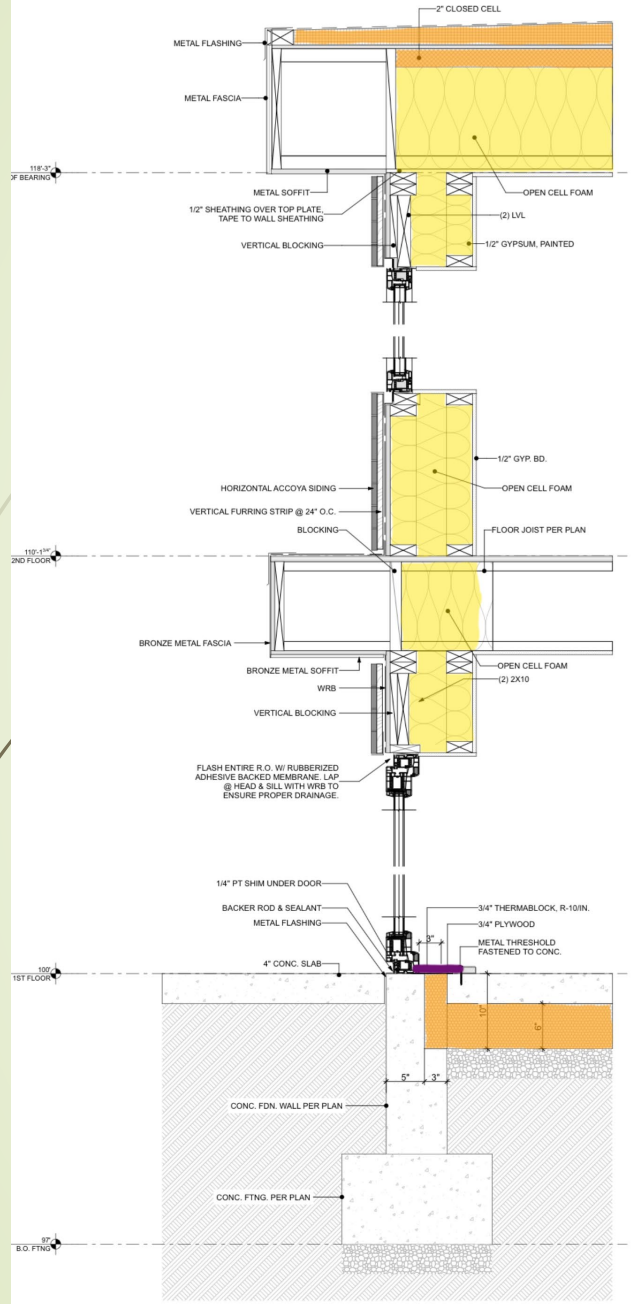
o OPEN CELL



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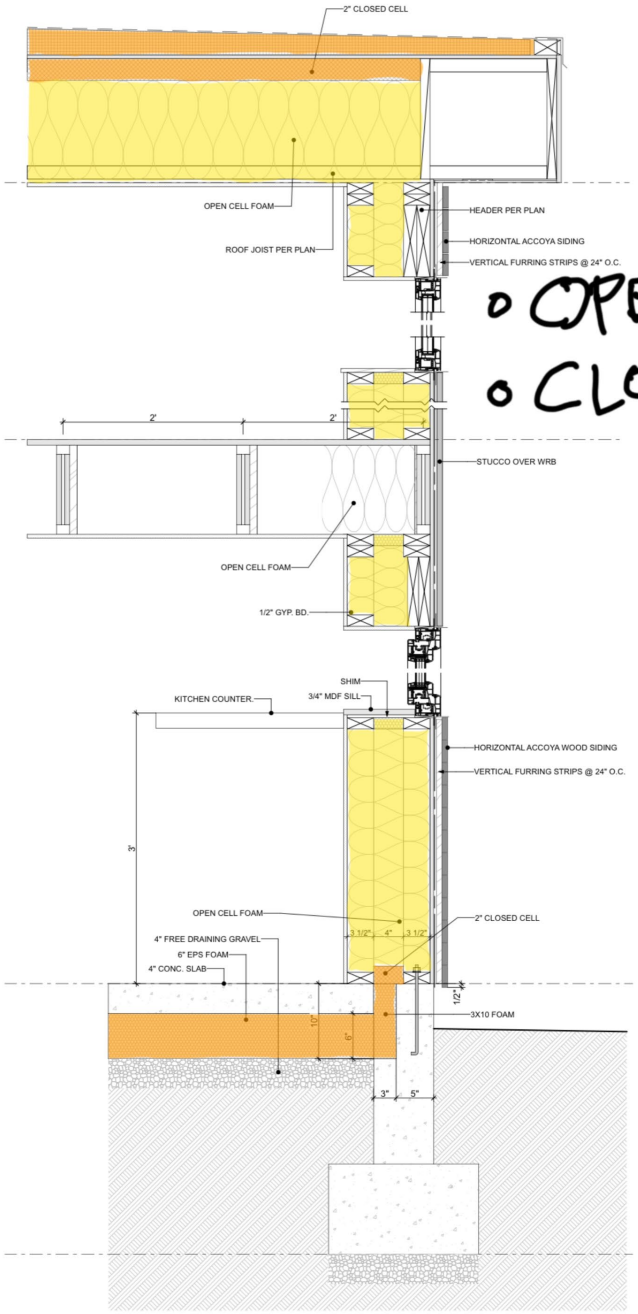

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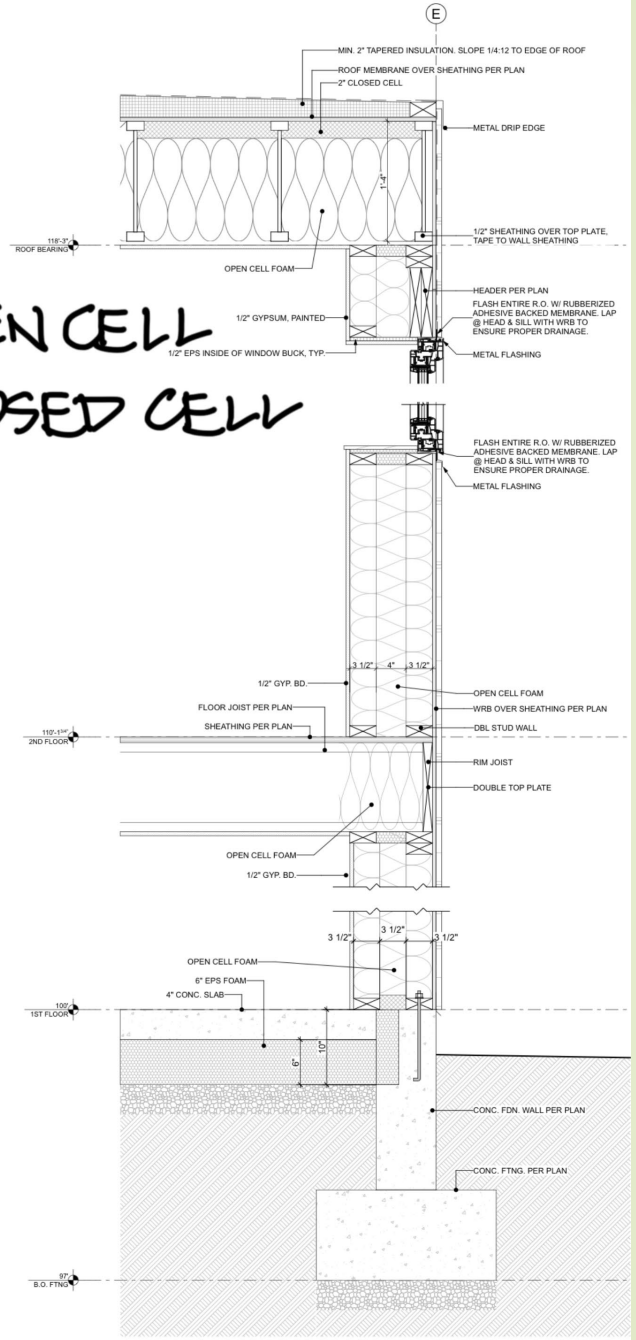
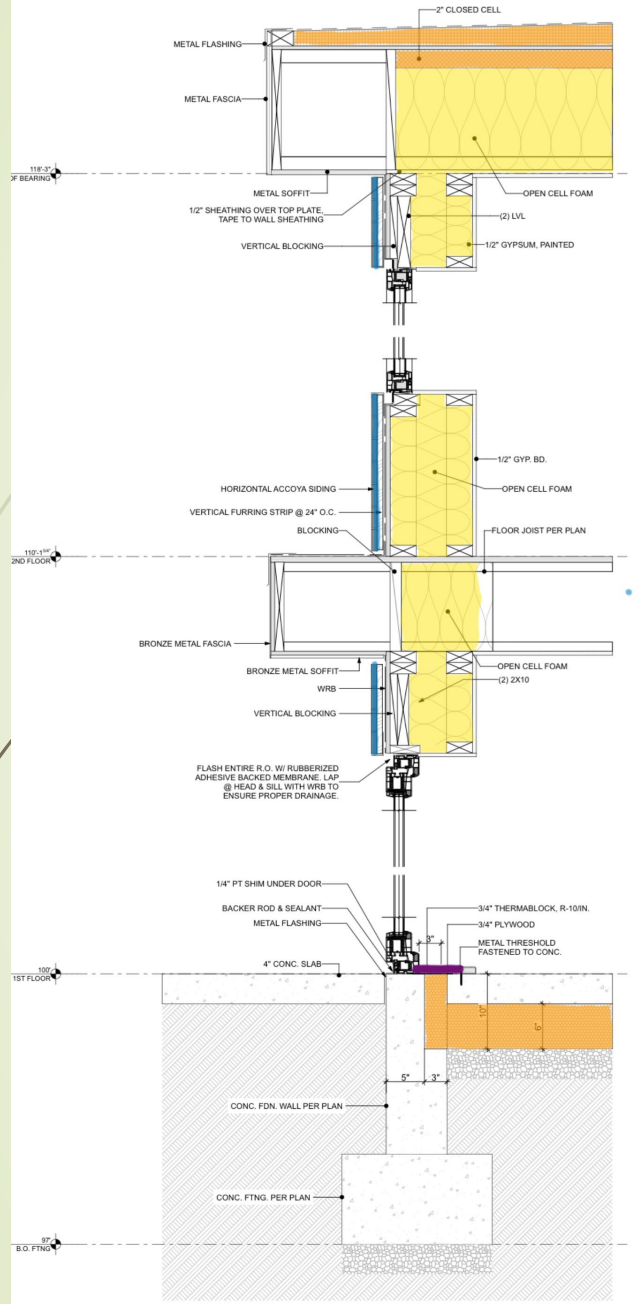


1 EAST WALL
SCALE: 1 1/2"= 1'-0"

- OPEN CELL
- CLOSED CELL



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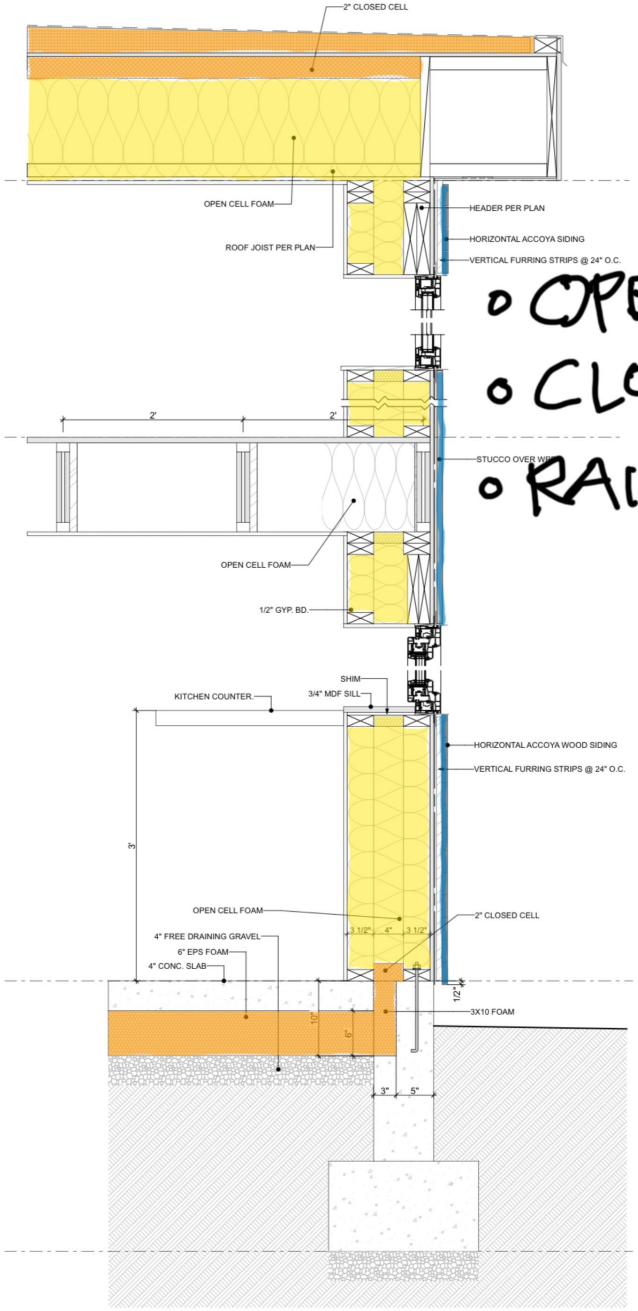

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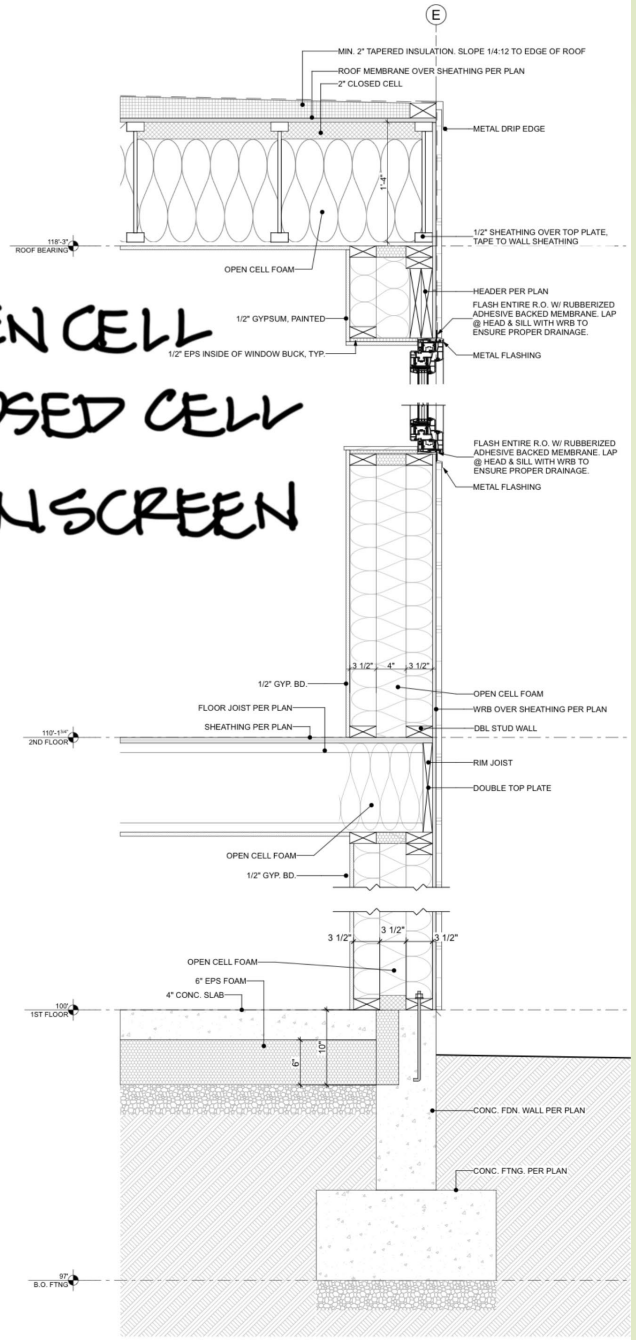
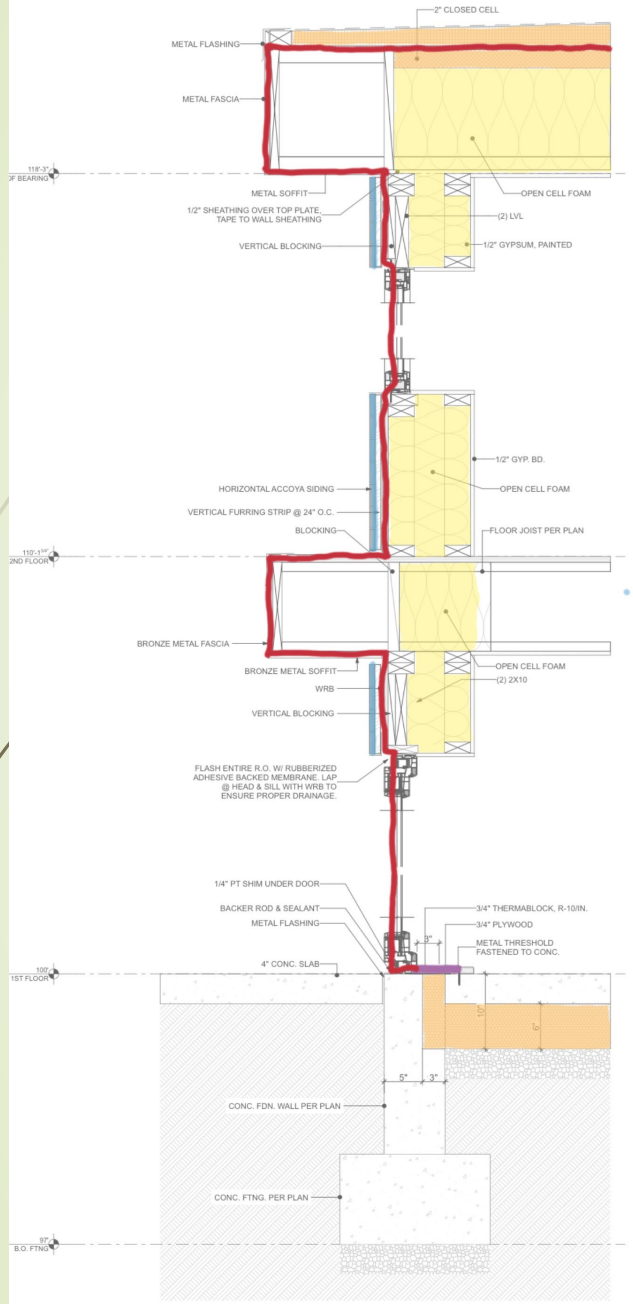


1 EAST WALL
SCALE: 1 1/2"= 1'-0"

- OPEN CELL
- CLOSED CELL
- RAINSCREEN



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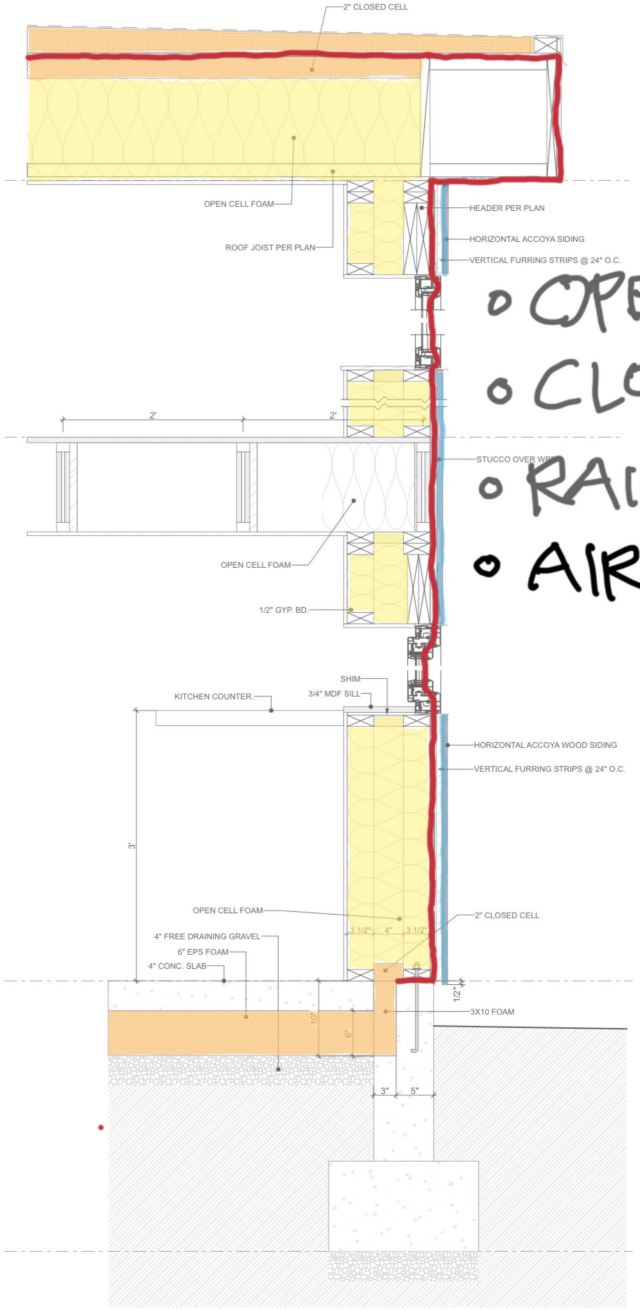
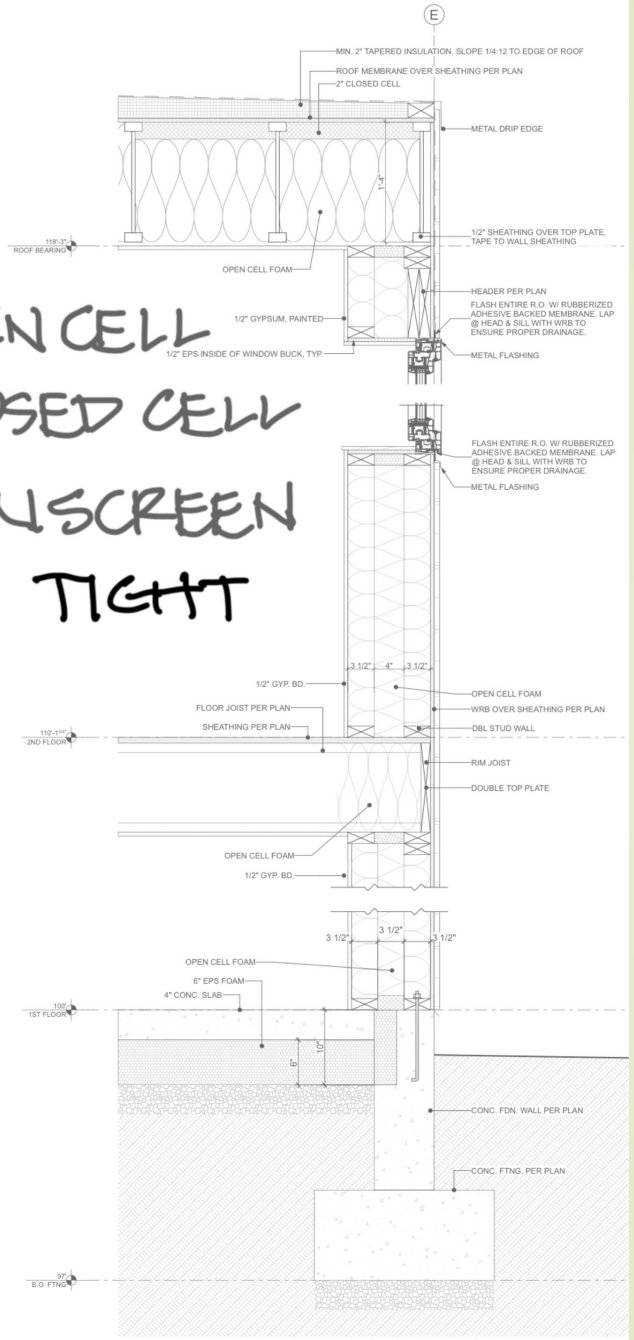


8 NORTH WALL
SCALE: 1 1/2"= 1'-0"

- OPEN CELL
- CLOSED CELL
- RAINSCREEN
- AIR TIGHT



1 EAST WALL
SCALE: 1 1/2"= 1'-0"


3M
All Weath
Flashing


SIGA-Wigluv
www.siga.ch


3M


Tape 8067
3M
SIGA-Wigluv

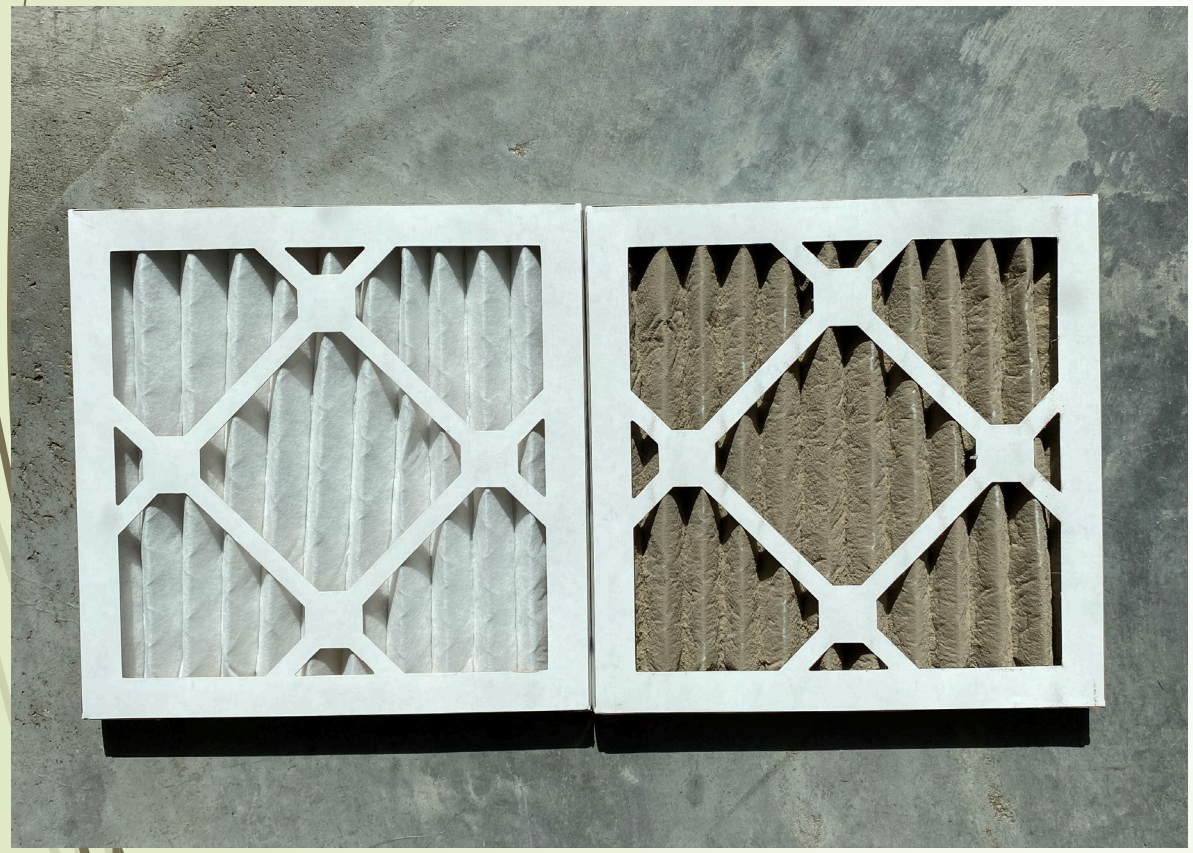

3M


STIEBEL ELTRON


MITSUBISHI ELECTRIC
INVERTER

Use the CERV2 to distribute conditioned air

MERV 8 in kitchen:
$8 filter

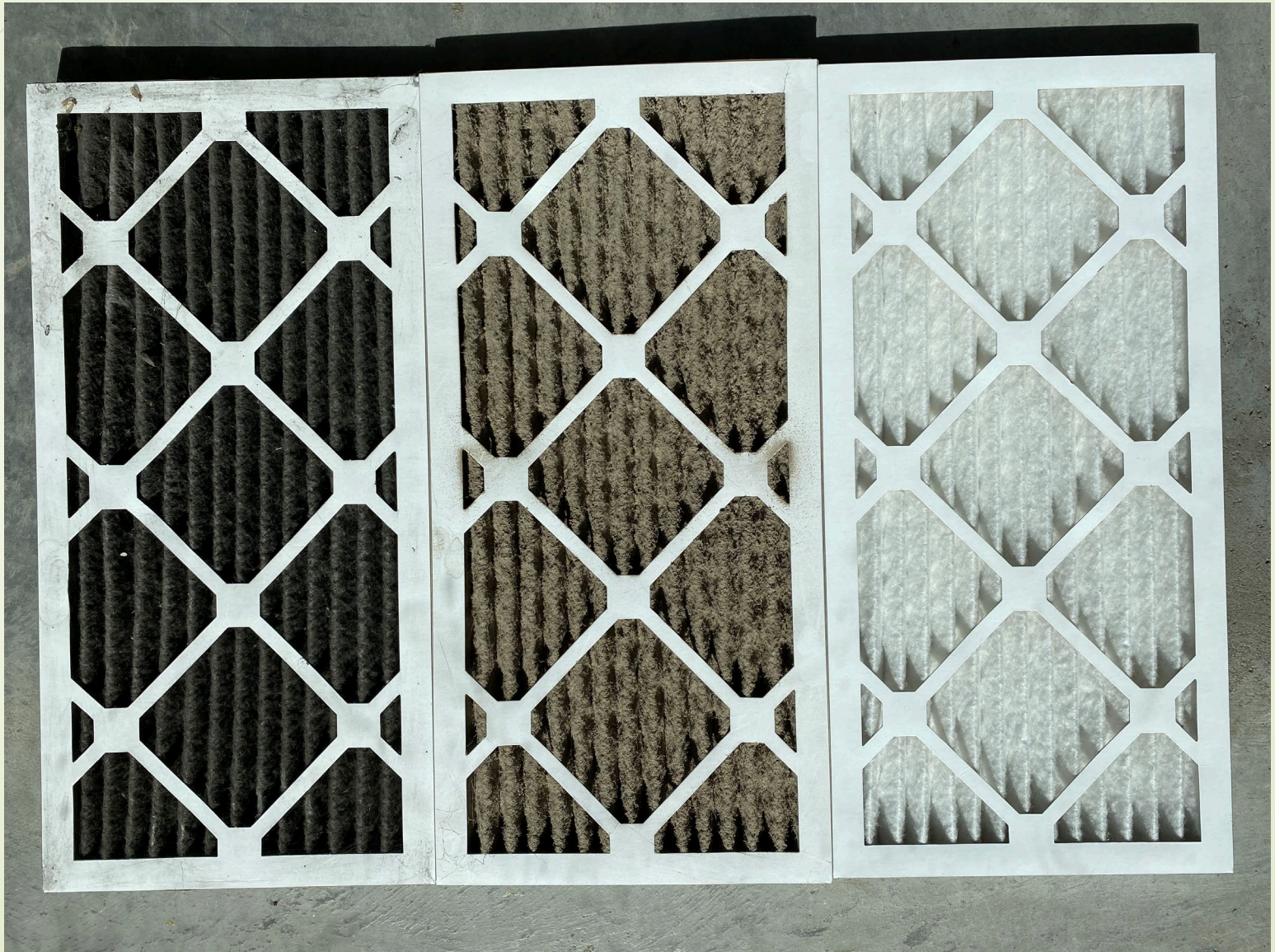


Clean healthy indoor air is paramount

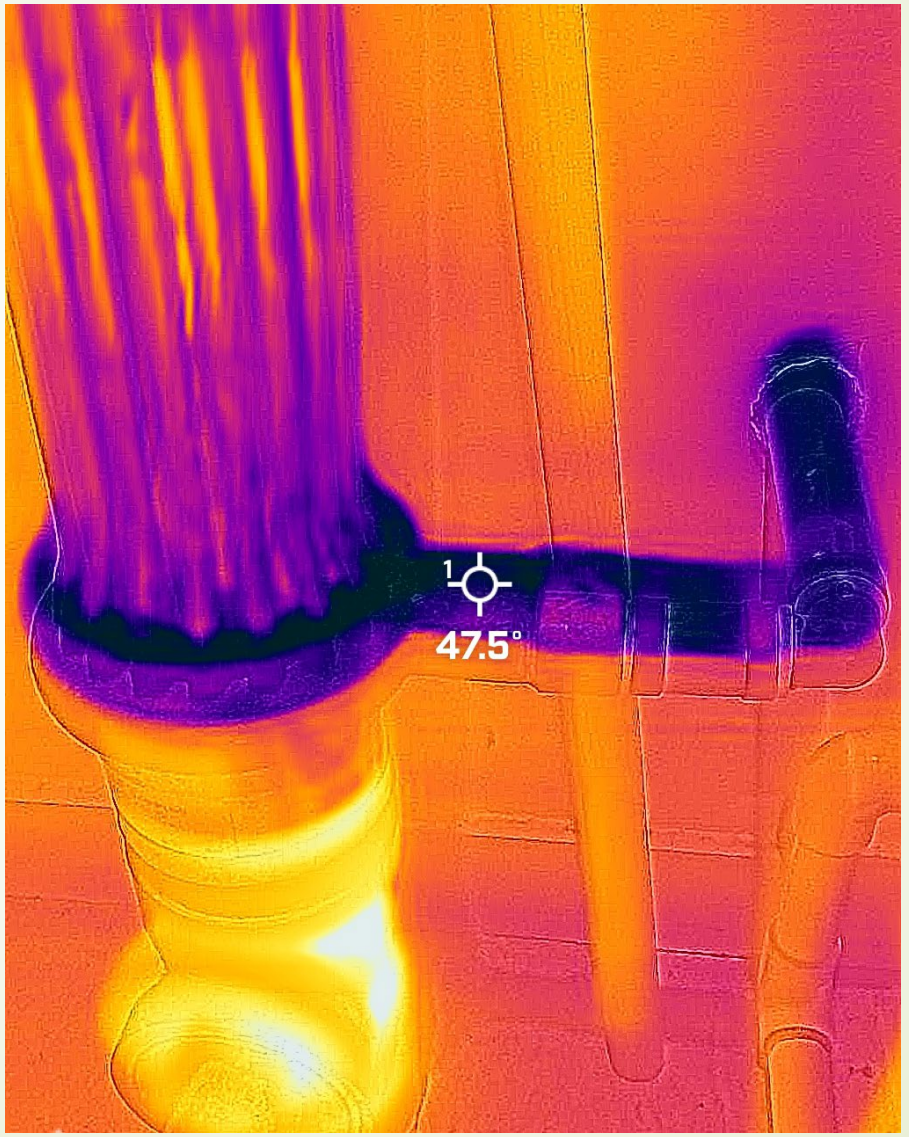
Inversion

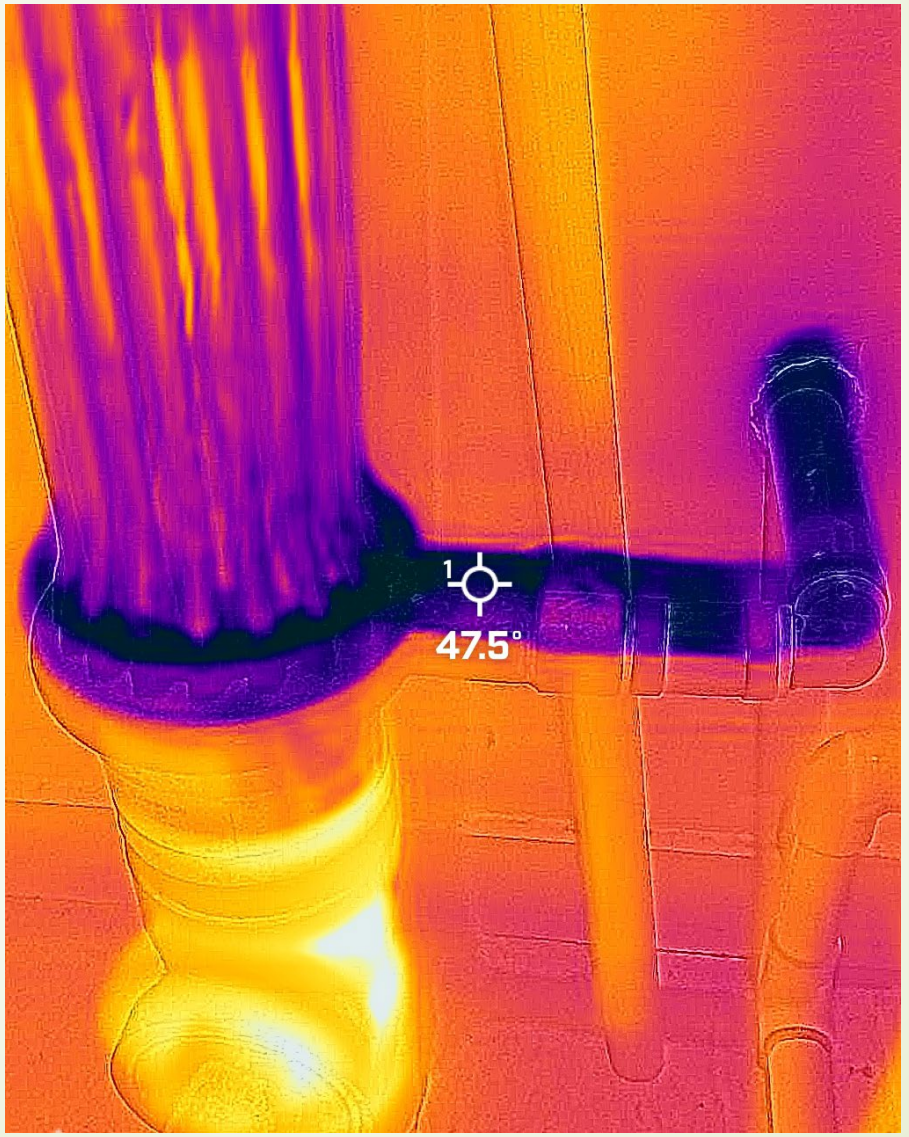
Dust Storm, Wildfires…..

Standard 10 x 20 MEV13 filter: ~$10



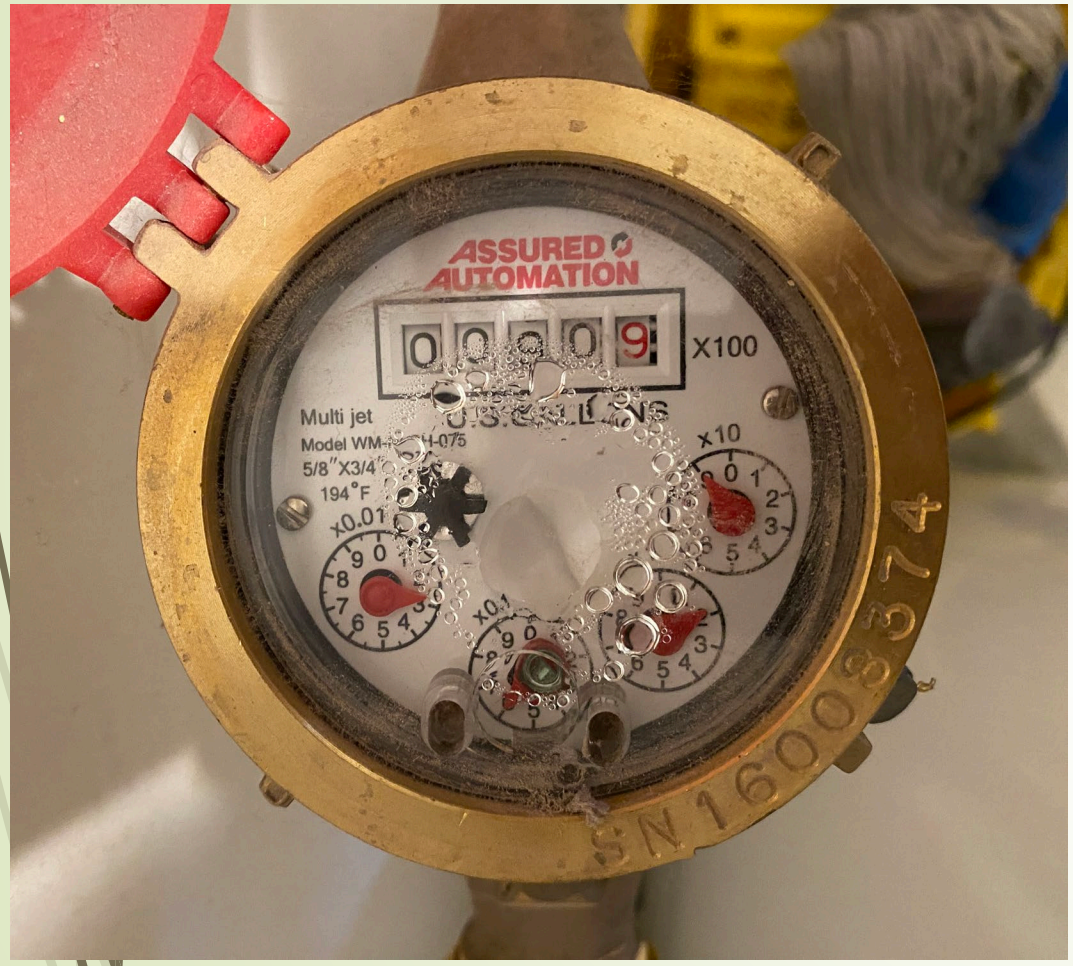
HPHW with drain water heat recovery




1
47.5°


1
73.4°
FLIR

5 Years of hot water = 88,500 gallons
kWh used by HWH = 4,520
output = 51,697 Btu
Temperature delta = 70F°
total COP = 3.5



$$\Delta T \cdot gal.$$

$$E = m \cdot c \cdot \Delta T$$

$$= (gal \cdot 8.345)\, 1 \cdot \frac{BTU}{lb \cdot {}^{\circ}F} \cdot 70$$

Performance

Modeled

ANNUAL HEATING DEMAND

4.96 kBTU/ft².yr

ANNUAL COOLING DEMAND

2.78 kBTU/ft².yr

PEAK HEATING LOAD

3.88 kBTU/ft².yr

PEAK COOLING LOAD

2.77 kBTU/ft².yr

SITE ENERGY USE INDEX (EUI)

13.12 kBTU/ft².yr

SITE ENERGY USE INDEX (W/RENEWABLES)

8.54 kBTU/ft².yr

COMPLIANCE SOFTWARE

WUFI Passive

SOURCE ENERGY (RESIDENTIAL)

5279 kWh/person.yr

SOURCE ENERGY (RESIDENTIAL W/ RENEWABLES)

3389 kWh/person.yr

Performance

Modeled

ANNUAL HEATING DEMAND

4.96 kBTU/ft².yr

ANNUAL COOLING DEMAND

2.78 kBTU/ft².yr

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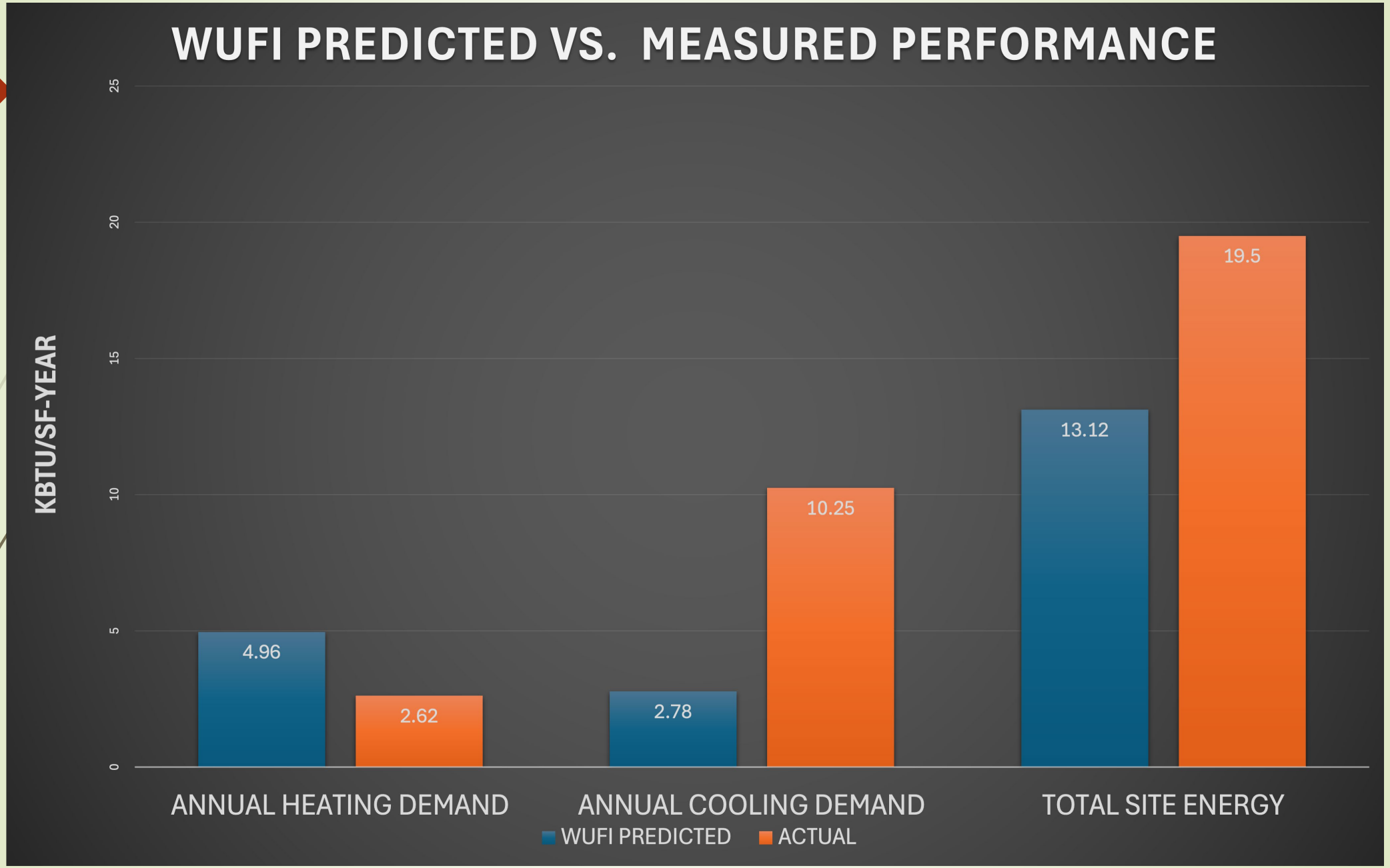
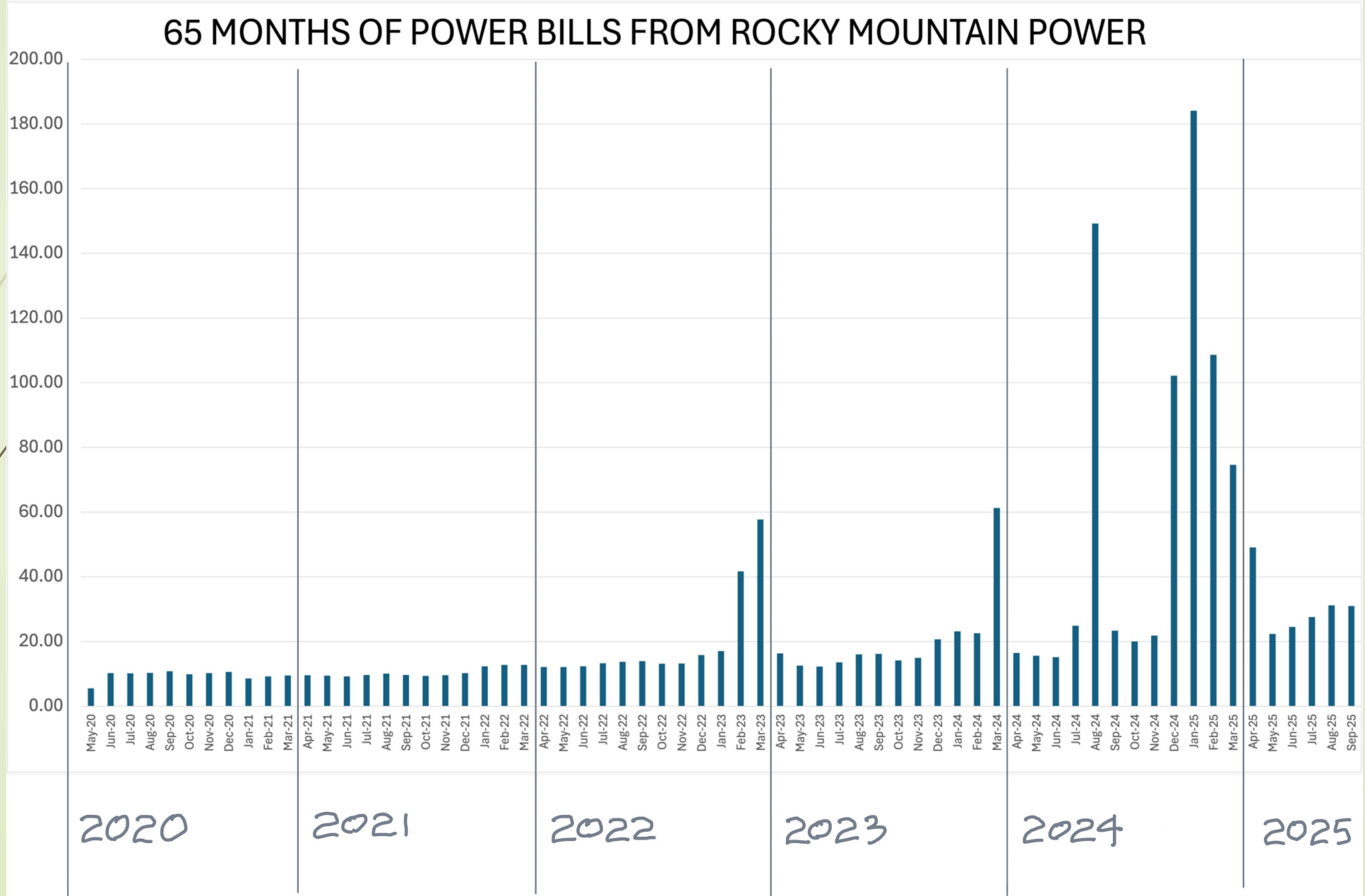
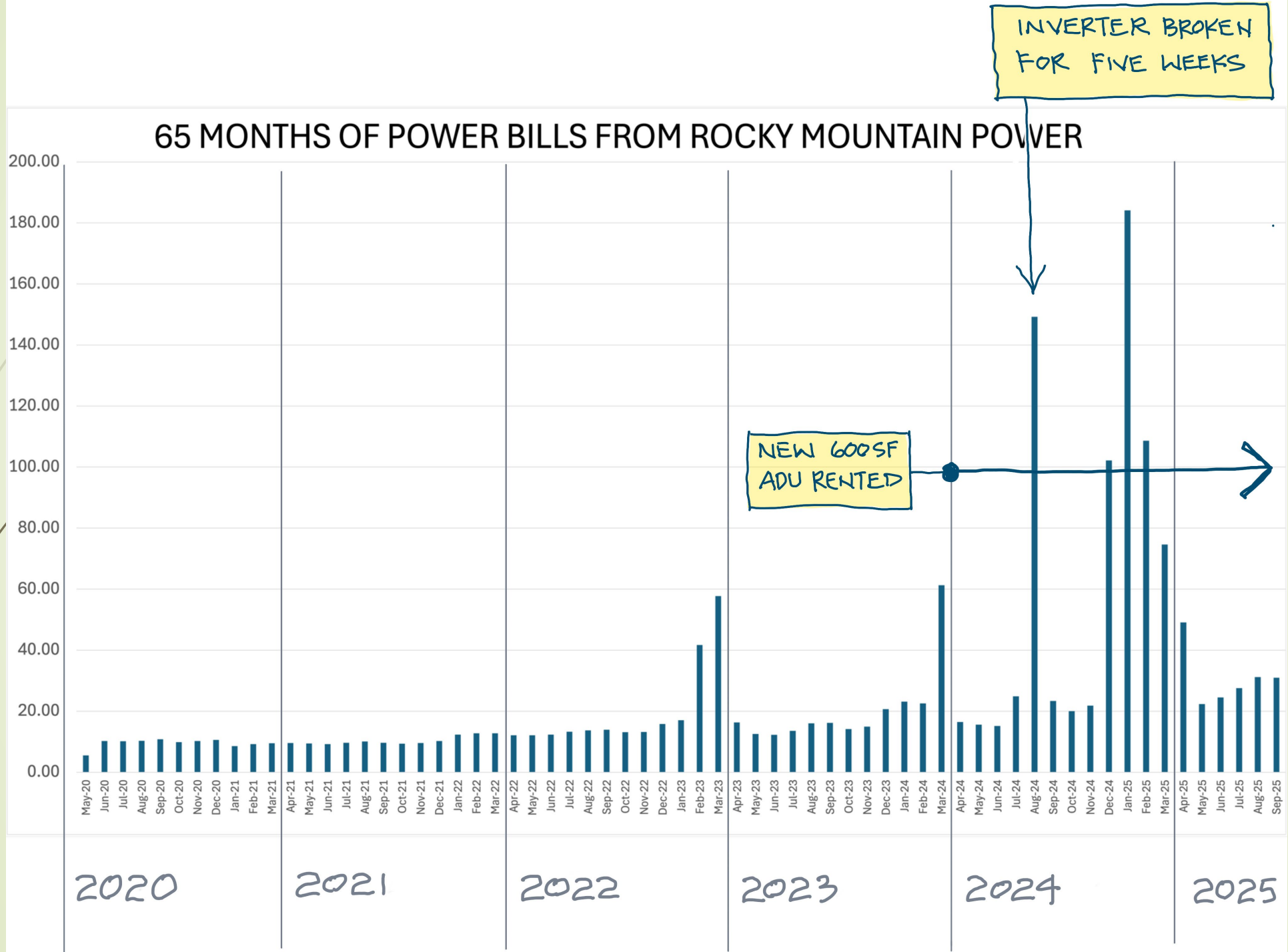
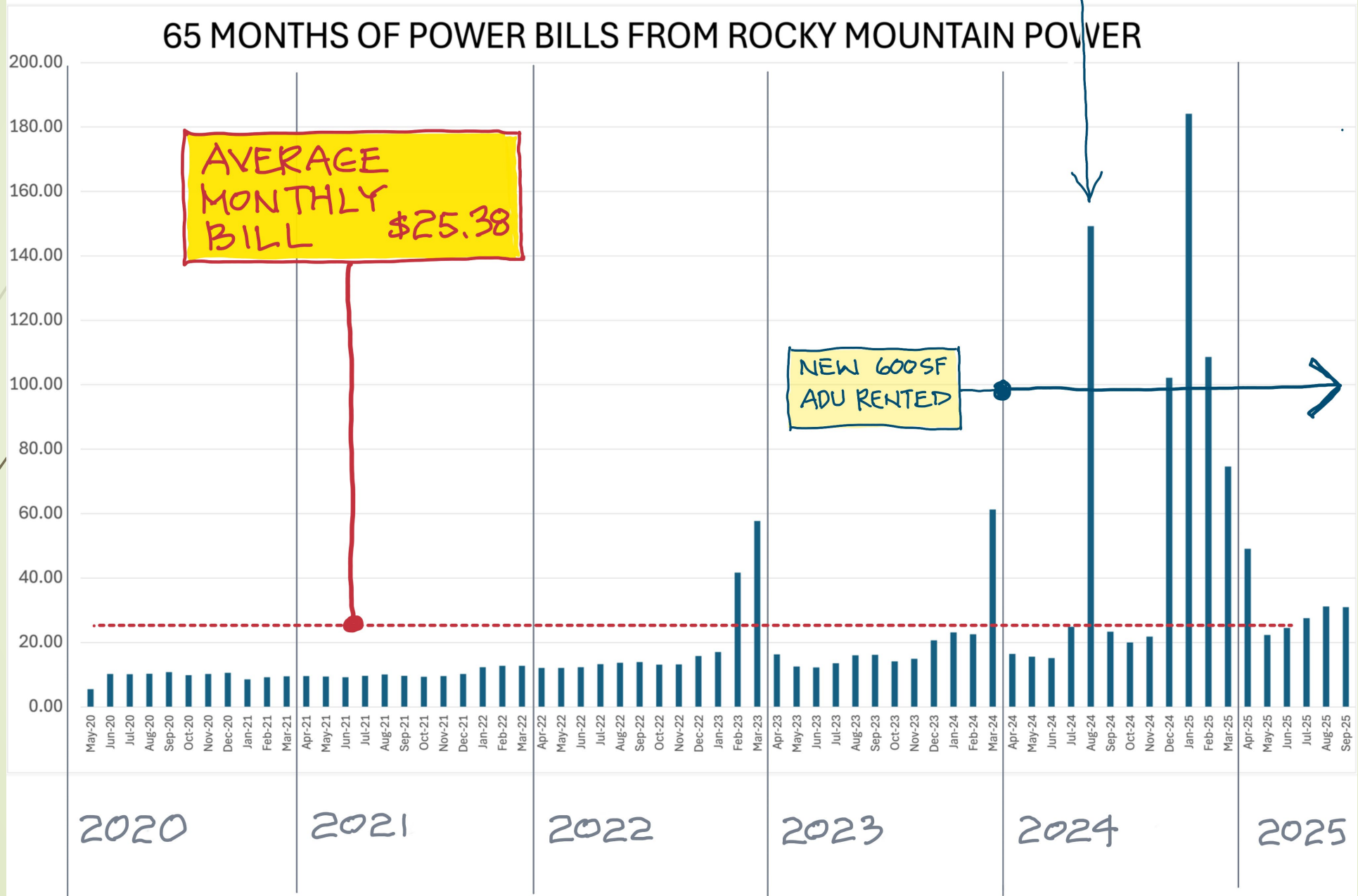
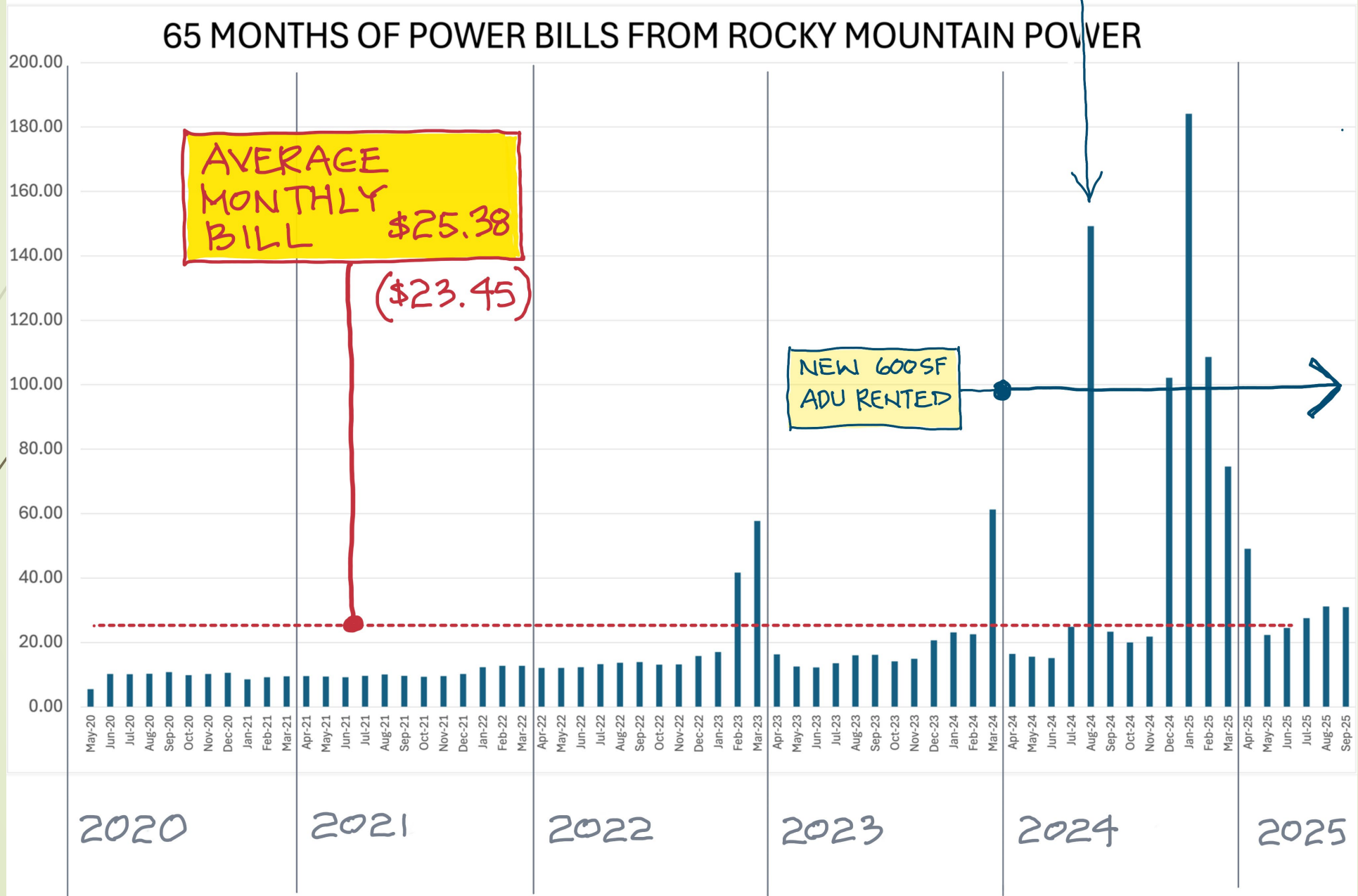

WUFI PREDICTED VS. MEASURED PERFORMANCE
KBTU/SF-YEAR
25
20
15
10
5
0
4.96
2.62
2.78
10.25
13.12
19.5
ANNUAL HEATING DEMAND
ANNUAL COOLING DEMAND
TOTAL SITE ENERGY
WUFI PREDICTED
ACTUAL

Pipsqueak power bills


65 MONTHS OF POWER BILLS FROM ROCKY MOUNTAIN POWER
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
May-20 Jun-20 Jul-20 Aug-20 Sep-20 Oct-20 Nov-20 Dec-20 Jan-21 Feb-21 Mar-21
Apr-21 May-21 Jun-21 Jul-21 Aug-21 Sep-21 Oct-21 Nov-21 Dec-21 Jan-22 Feb-22 Mar-22
Apr-22 May-22 Jun-22 Jul-22 Aug-22 Sep-22 Oct-22 Nov-22 Dec-22 Jan-23 Feb-23 Mar-23
Apr-23 May-23 Jun-23 Jul-23 Aug-23 Sep-23 Oct-23 Nov-23 Dec-23 Jan-24 Feb-24 Mar-24
Apr-24 May-24 Jun-24 Jul-24 Aug-24 Sep-24 Oct-24 Nov-24 Dec-24 Jan-25 Feb-25 Mar-25
Apr-25 May-25 Jun-25 Jul-25 Aug-25 Sep-25
2020
2021
2022
2023
2024
2025

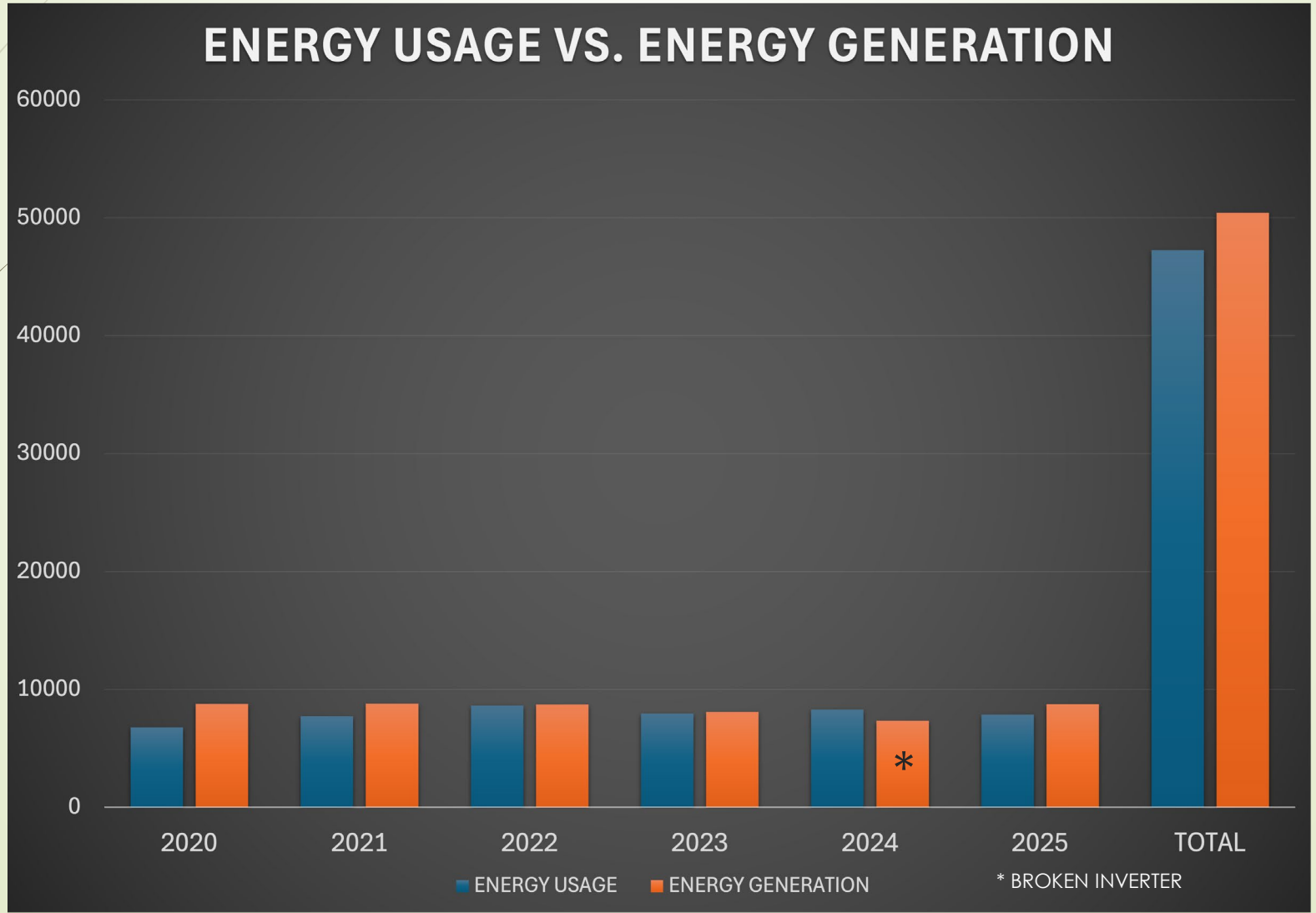

INVERTER BROKEN FOR FIVE WEEKS
65 MONTHS OF POWER BILLS FROM ROCKY MOUNTAIN POWER
NEW 600SF ADU RENTED
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
May-20 Jun-20 Jul-20 Aug-20 Sep-20 Oct-20 Nov-20 Dec-20 Jan-21 Feb-21 Mar-21 Apr-21 May-21 Jun-21 Jul-21 Aug-21 Sep-21 Oct-21 Nov-21 Dec-21 Jan-22 Feb-22 Mar-22 Apr-22 May-22 Jun-22 Jul-22 Aug-22 Sep-22 Oct-22 Nov-22 Dec-22 Jan-23 Feb-23 Mar-23 Apr-23 May-23 Jun-23 Jul-23 Aug-23 Sep-23 Oct-23 Nov-23 Dec-23 Jan-24 Feb-24 Mar-24 Apr-24 May-24 Jun-24 Jul-24 Aug-24 Sep-24 Oct-24 Nov-24 Dec-24 Jan-25 Feb-25 Mar-25 Apr-25 May-25 Jun-25 Jul-25 Aug-25 Sep-25
2020
2021
2022
2023
2024
2025

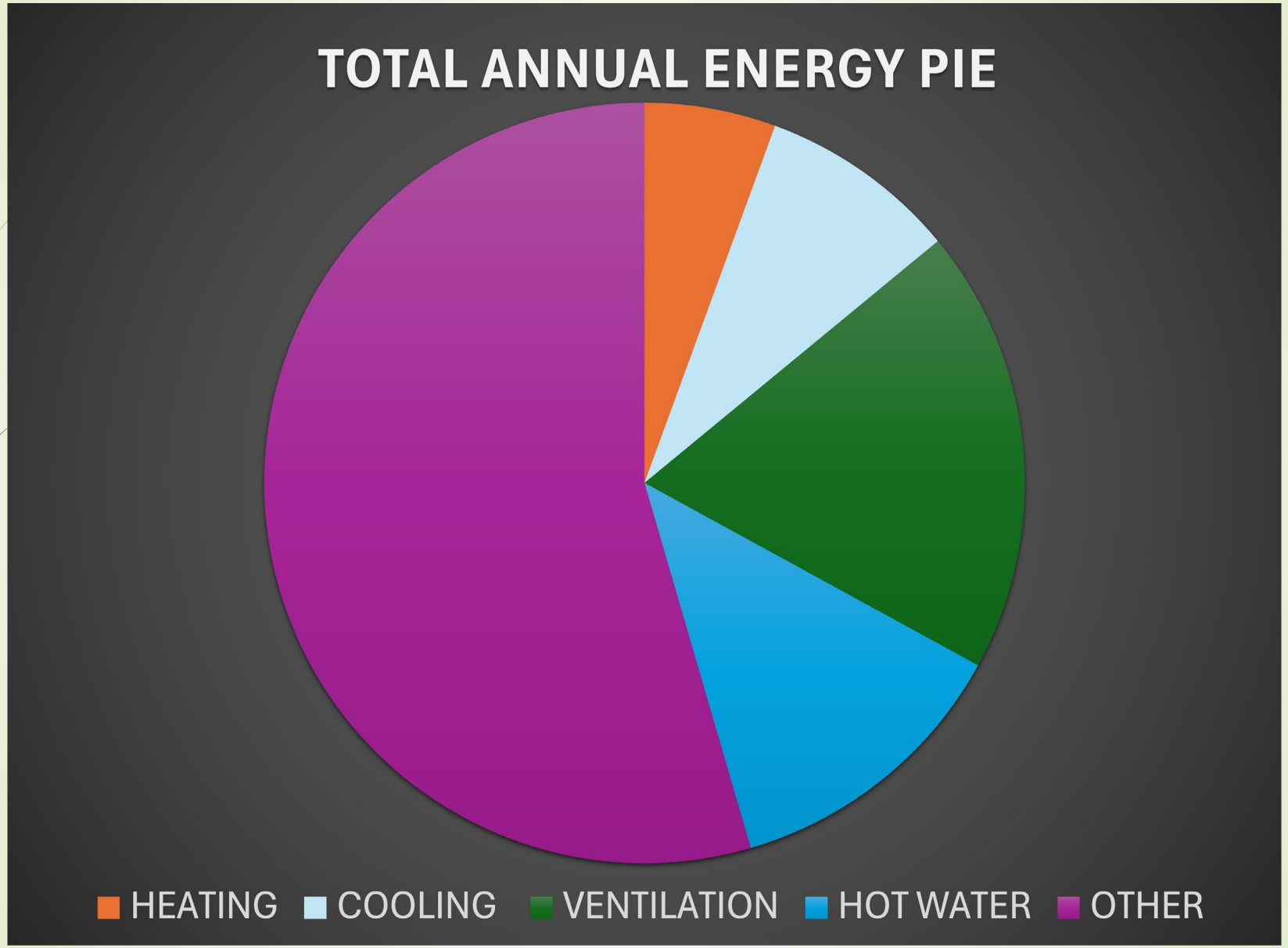

65 MONTHS OF POWER BILLS FROM ROCKY MOUNTAIN POWER
INVERTER BROKEN FOR FIVE WEEKS
AVERAGE MONTHLY BILL $25.38
NEW 600SF ADU RENTED
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
2020
2021
2022
2023
2024
2025


65 MONTHS OF POWER BILLS FROM ROCKY MOUNTAIN POWER
INVERTER BROKEN FOR FIVE WEEKS
AVERAGE MONTHLY BILL $25.38
($23.45)
NEW 600SF ADU RENTED
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
2020
2021
2022
2023
2024
2025

18 panels @325 W = 5.8 kW system

Generation: 49,000 kWh
Usage : 45,500 kWh
~7% overproduction

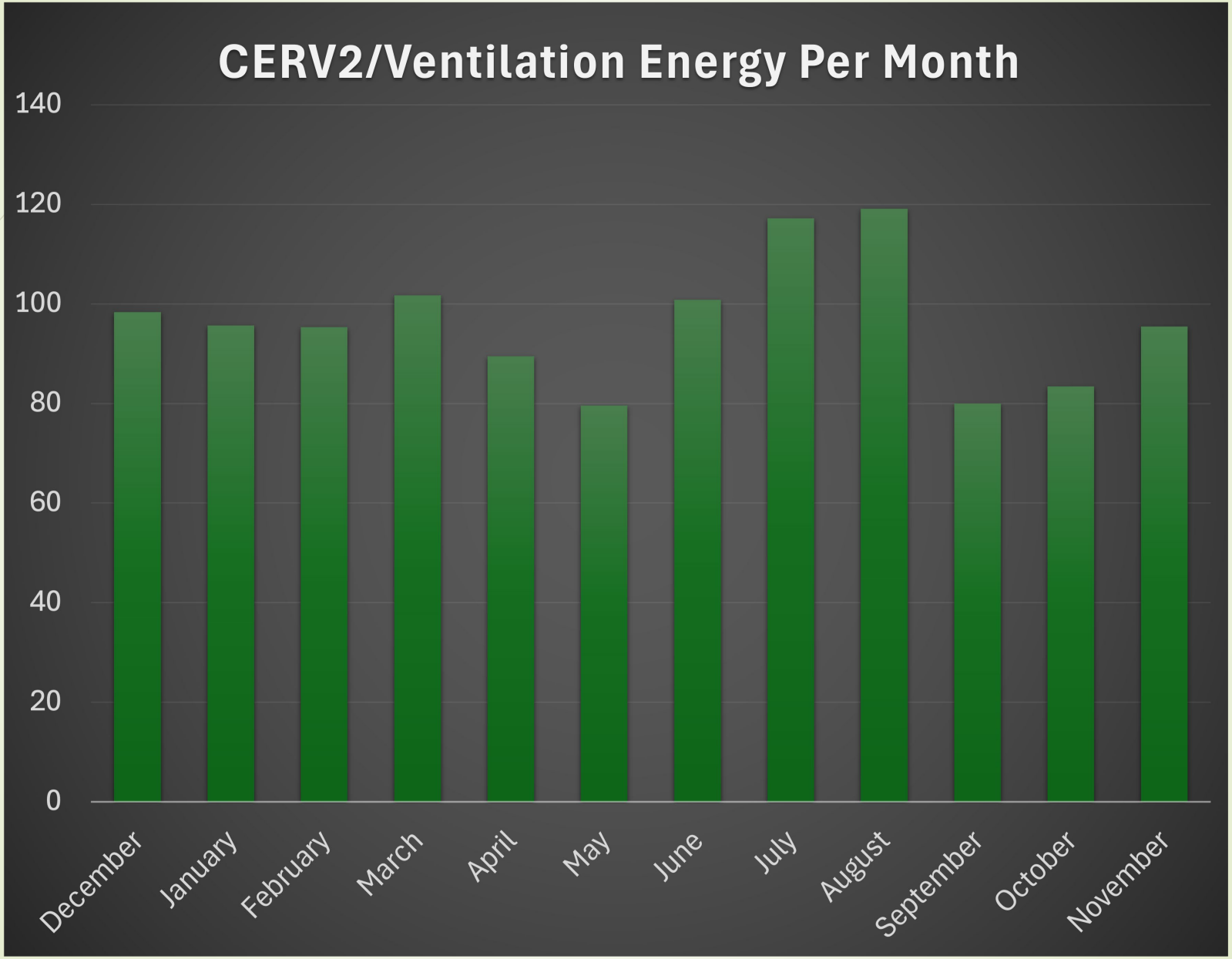



TOTAL ANNUAL ENERGY PIE
HEATING
COOLING
VENTILATION
HOT WATER
OTHER

Recirc 100% fan speed
227 W

Recirc cooling
440 W

Ventilation cooling
433 W


CERV2/Ventilation Energy Per Month
140
120
100
80
60
40
20
0
December
January
February
March
April
May
June
July
August
September
October
November

Total Construction Cost $390k

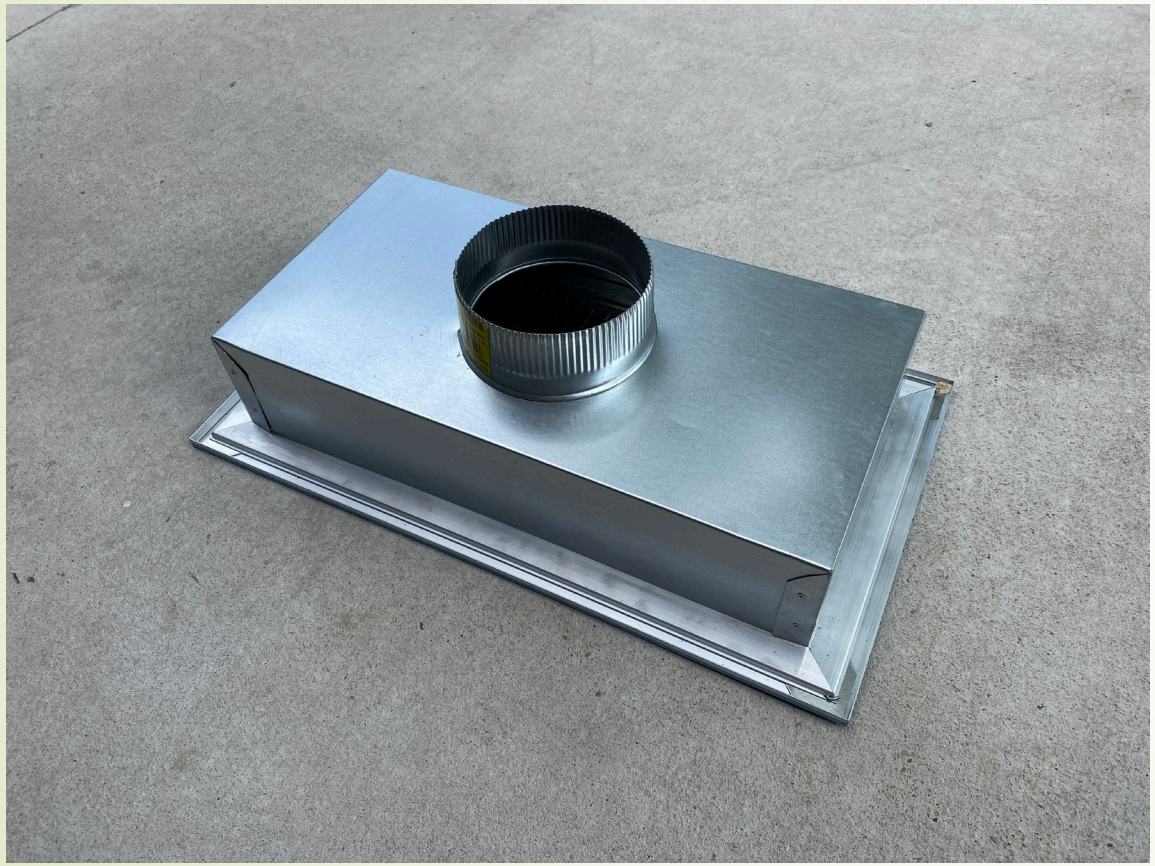
- Broke ground in 2018
- Not including solar PV system
- Not including air-tightness tape and labor
- 1800 square feet of living space
- 2-car garage
- $170/sf including garage
- $220/sf not including garage

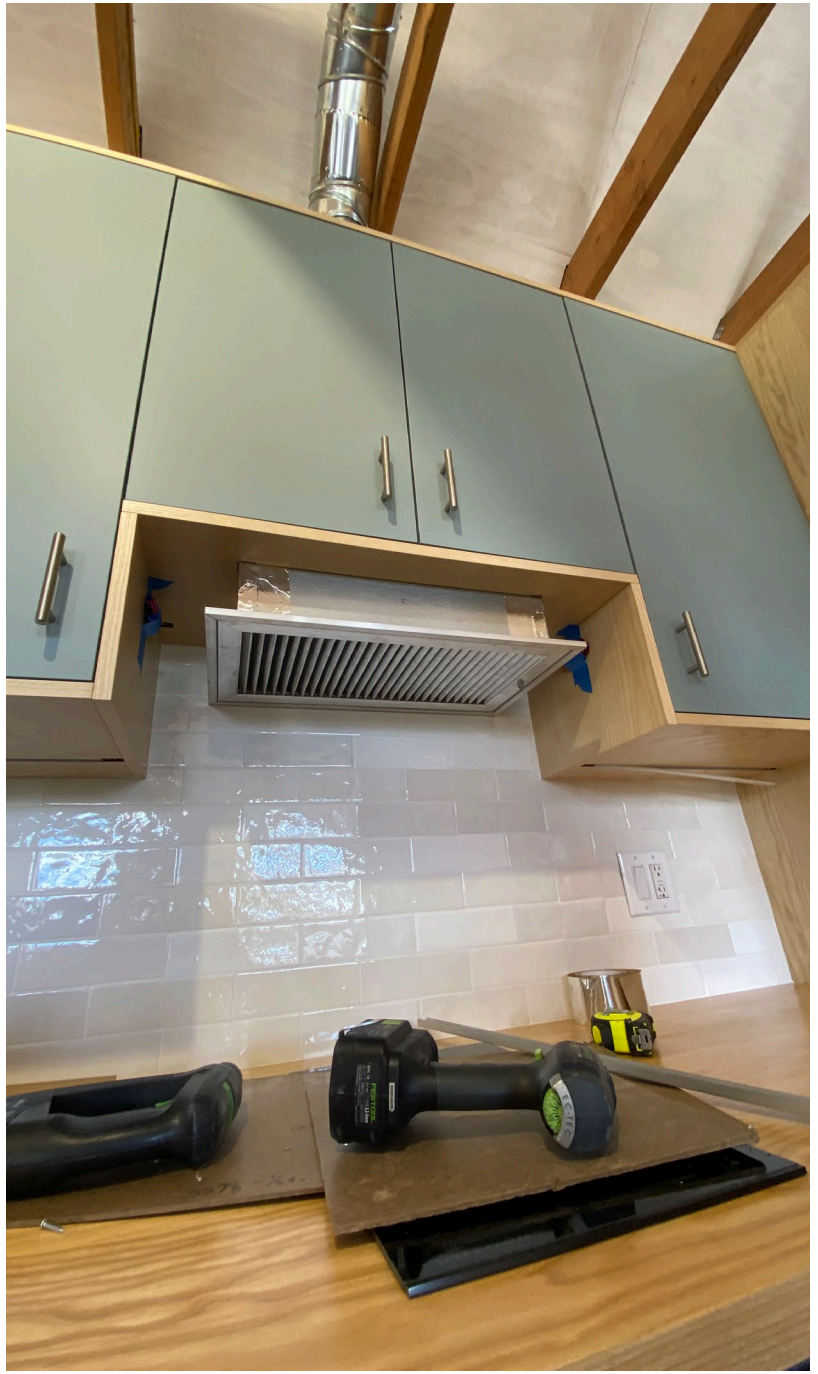
Used the ADU to testreferred Ventilation system design

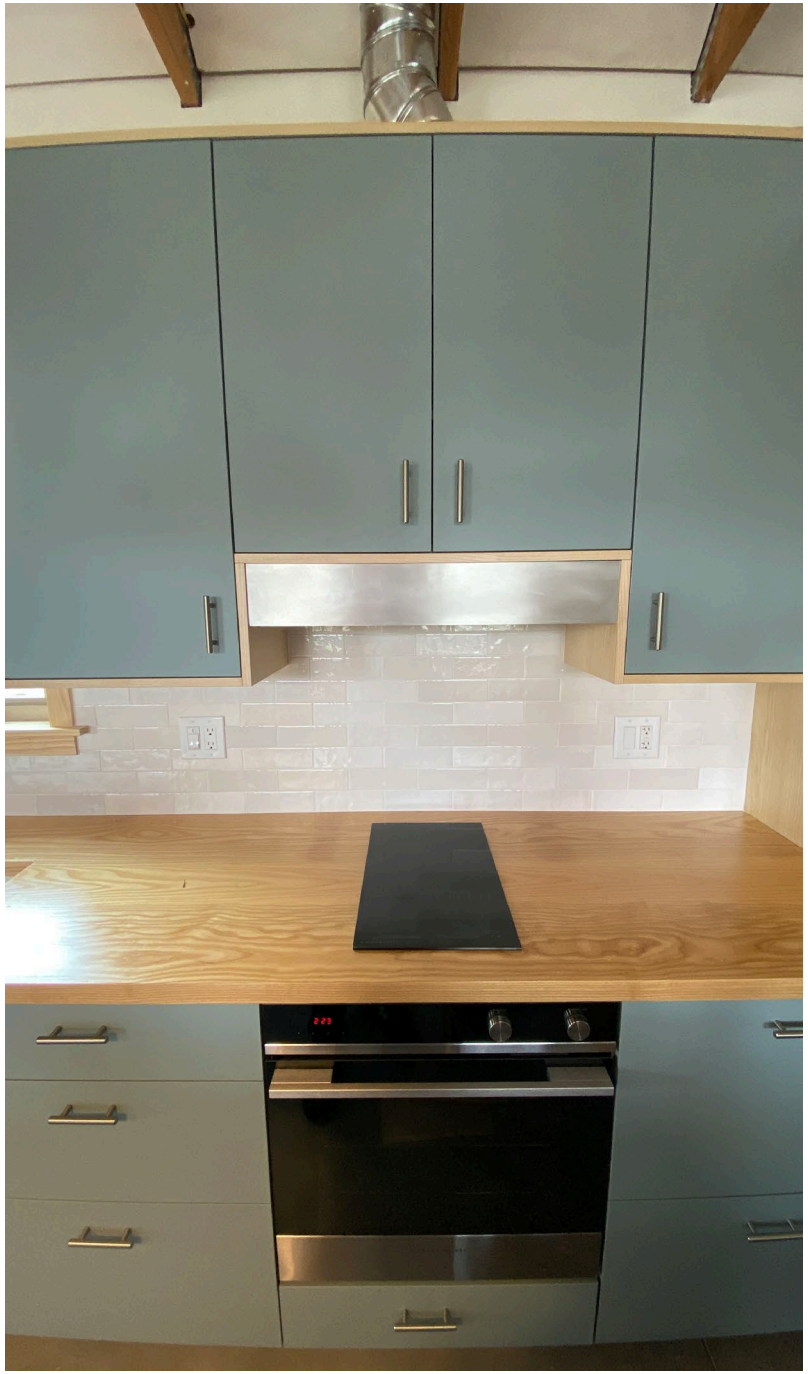
- Place vent hood directly over cooktop
- Vent directly to HRV with MERV8 filtration
- Trigger switches and Zone dampers to strategically increase exhaust flow to where it is needed

Kitchen ventilation hood directly over cooktop

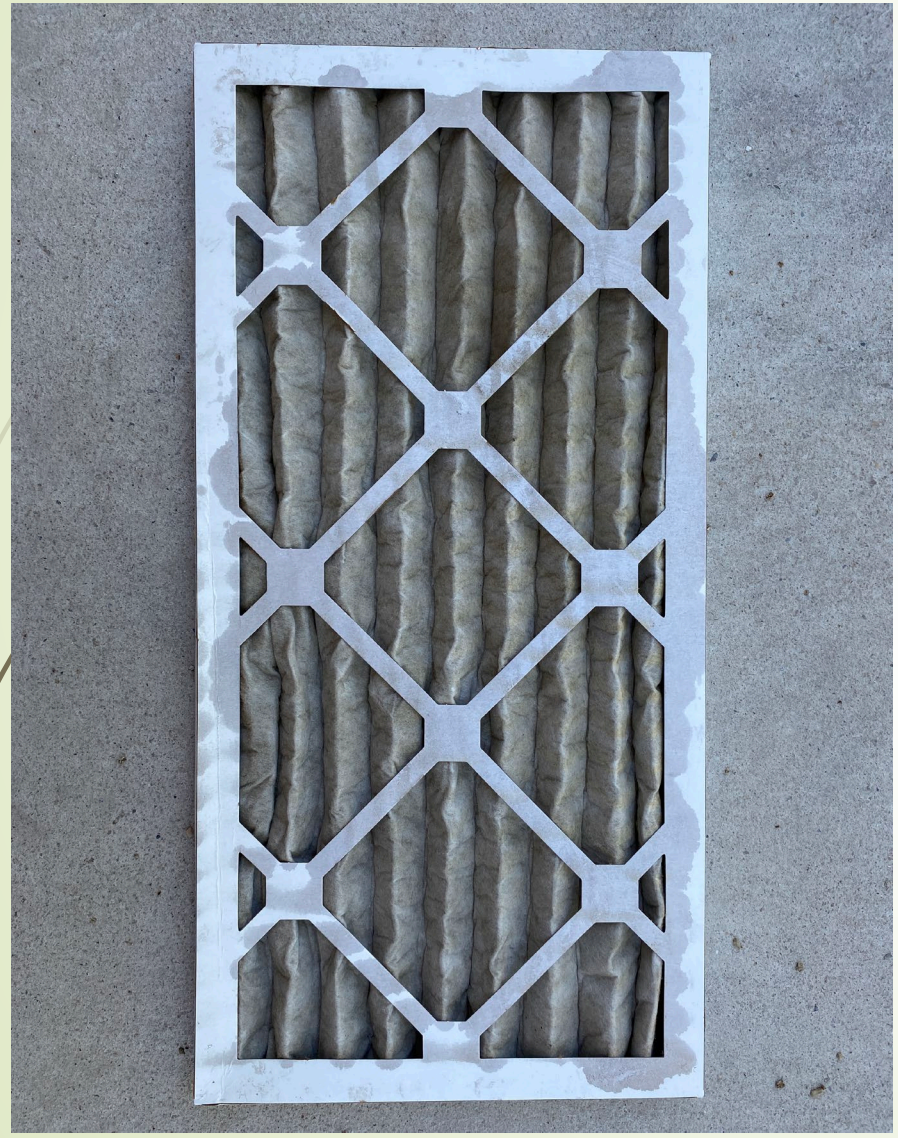
Standard 10” x 20” brushed aluminum filter box

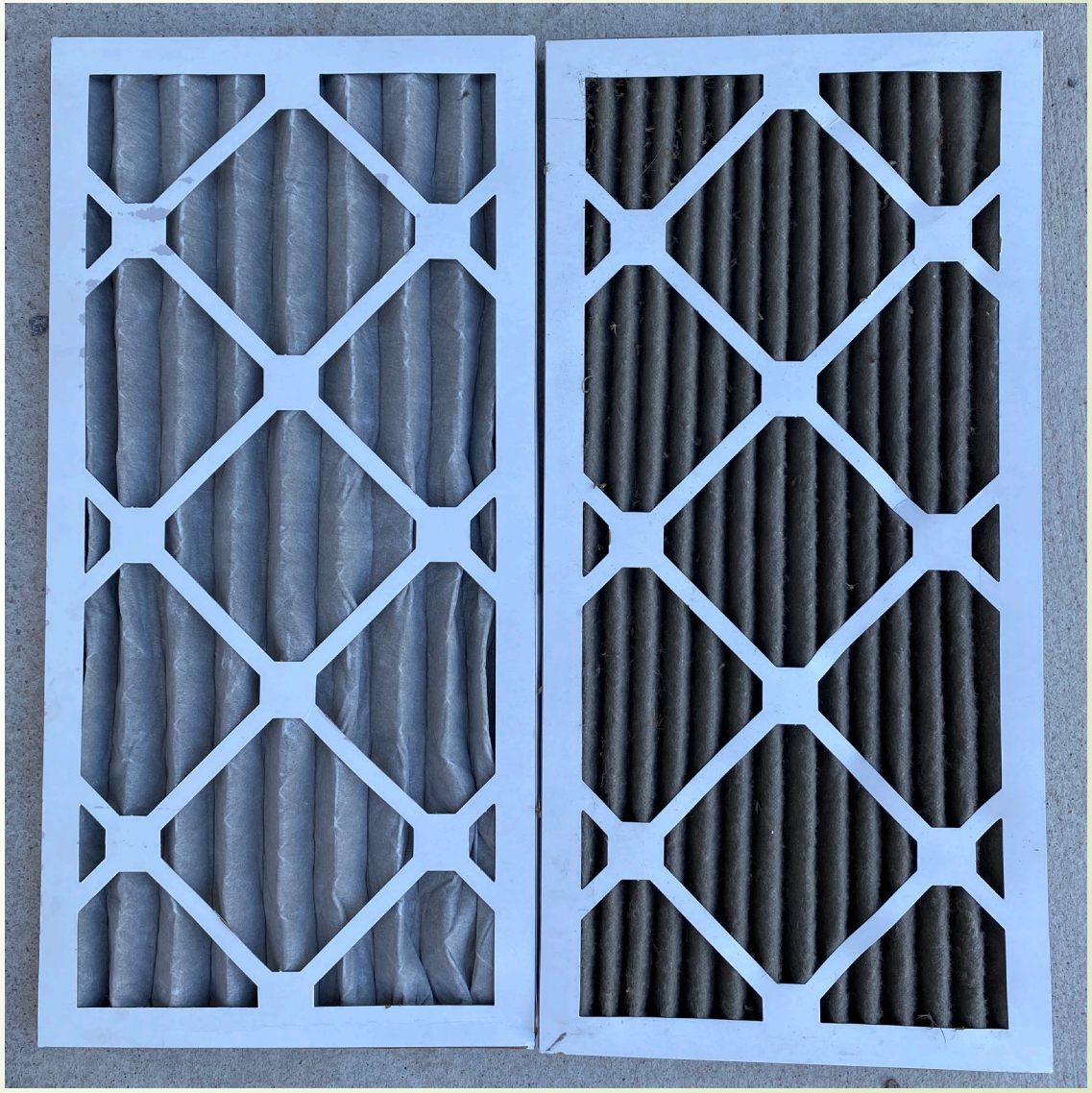






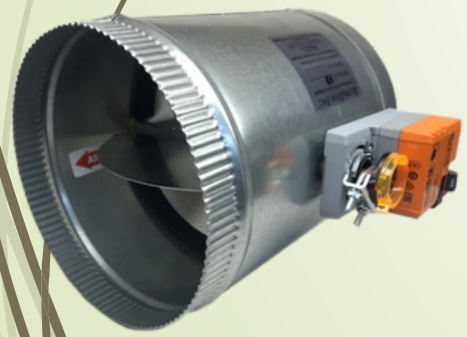
Used MERV 8 filters from the kitchen





But what about the HRV core?

Use the CERV2 zoned exhaust & dampers



Thank you for your kind attention.