



## **THE OLD HINESBURG POLICE STATION - COMPLETING THE ZERO ENERGY PROJECT - THE SEQUEL...**

**Better Buildings by Design - February 7, 2018**

Richard Faesy, David Pill, Chuck Reiss, Andy Shapiro

# Presentation Overview

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1. Project Team
2. Session Goals
3. Project Overview
4. Design Overview
5. Energy Focus to Achieve Net Zero
6. Construction Overview
7. Cost-Effectiveness
8. Lessons Learned and Next Steps

# Project Team

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- Richard Faesy (Chris Neme & Glenn Reed)
  - Energy Futures Group
  - Engaged Owners
- David Pill
  - Pill-Maharam Architects
- Chuck Reiss
  - Reiss Building and Renovation
  - General Contractor
- Andy Shapiro
  - Energy Balance, Inc.
  - Energy Modeling, Mechanical Systems and Envelope Commissioning



# Session Goals



1. Understanding the process of getting an old building to zero net energy
2. Design decisions and details
3. Preliminary performance analysis
4. Cost-effectiveness of building to zero net energy
5. Lessons learned





# Project Introduction

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- Energy Futures Group (EFG)
  - Hinesburg-based energy consulting firm since 2010
  - Ran out of room in former rental space
- Project Goals
  - Stay in Hinesburg
  - Private offices
  - Room to grow
  - Investment property
  - Energy showcase building to match firm's values and serve as an model for others

# The Old Police Station



Reiss Building  
& Renovation

pill-maharam architects

**PMa**

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- ❑ Vacant building
- ❑ Commercial use only
- ❑ Small lot (footprint + 10')
- ❑ Deconstruction restrictions
- ❑ Eliminate on-site parking
- ❑ For sale with no permits
- ❑ Closed October 2016

Page 1 of 1

10296 VT Route 116 Hinesburg

\$125,000



MLS: 4419358

Property Type: Residential	Year Built: 1900	Total Rooms: 7	Garage: Attached
School District: Champlain Valley UHSD 15	Total Fin SqFt: 1,467	Bedrooms: 2	Waterfront:
Gross Taxes: \$ .00	Approx. Acres: .10	Total Baths: 2	Water Type:
Taxes TBD: Yes	Basement: Yes / Interior	Apz Ttl Below Grd: 700	

Style: Cape, Farmhouse	Construction: Existing, Wood Frame	Foundation: Stone
Exterior: Wood	Roof: Shingle-Other	Basement: Crawl Space, Dirt, Gravel, Interior Stairs
Electric: Circuit Breaker(s)	Heating/Cool: Baseboard	Water Heater: Other
Heat Fuel: None	Sewer: Public	Water: Public
Disability: 1st Floor Full Bathrm, 1st Fir Hard Surface Flr, Zero-Step Entry/Ramp		

APPROXIMATE ROOM DIMENSIONS

Full Bath	1/2 Bath	3/4 Bath	Den	18.5x11.5
Dining Rm	Family Rm	Kitchen	Living Rm	
Master BR	2nd BR	3rd BR	4th BR	
Other Rm 1	Other Rm 2	Other Rm 3		

**Public Remarks:** High visibility opportunity to run a small business in the Heart of Hinesburg with over 11,000 automobiles passing by daily. Formerly used as the town's police station and prior to that, the Lyman estate, this historic farmhouse cape offers over 1400 square foot of space awaiting your customization. Building is situated on a corner with future plans to preserve the open space direct behind as the Hinesburg Town Common. With village location, pedestrian traffic and surrounding successful businesses, this is the perfect opportunity for light service industry.

**Directions:** In the heart of Hinesburg Village, across from Commercial Park and adjacent to the Bristol Bakery.

PREPARED BY

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# The Process

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- Extensive permitting process
  - ▣ May 2015 – October 2016
- Integrated design approach
  - ▣ Architect, builder, energy consultant, owner
  - ▣ Weekly meetings with daily interactions (2600 emails)
- Construction process
  - ▣ November 2016 – September 2017



# Energy Goals

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- All-electric
  - Avoid the natural gas line that runs out front and all fossil fuels
- Model project:
  - Tight: 1.0 ACH50 (440 CFM50) (vs. 4000+ CFM50 to start)
  - R-5 windows
  - R-20 foundation
  - R-40 walls
  - R-60 ceilings
  - Cold climate heat pumps
  - Energy recovery ventilation, high efficiency, EC motors
  - On-site renewables
  - Green, healthy and re-used materials
- Participate in Efficiency Vermont's Commercial New Construction Program and achieve Net Zero standard

# Efficiency Vermont's Commercial N.C. Program – Net Zero

Energy Balance, Inc.  
High Performance Buildings



Reiss Building  
& Renovation

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PMa

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- Equipment incentives
- Energy charrette (\$2500)
- Energy simulation (50% of cost)
- Energy monitoring equipment (50% of cost)
- Commissioning (25% of cost)
- Performance goals, standards & incentives (up to 25% of equipment incentives, based on building operation for one year)
- Incentives worth > \$7000 for EFG, but costs are quite a bit more (>\$20,000) to achieve net zero
- Recognition Pre- and Post-occupancy



# Building Movie

<http://www.energyfuturesgroup.com/zero-energy-project/>

Or

<https://vimeo.com/222866137>



# Design Elements

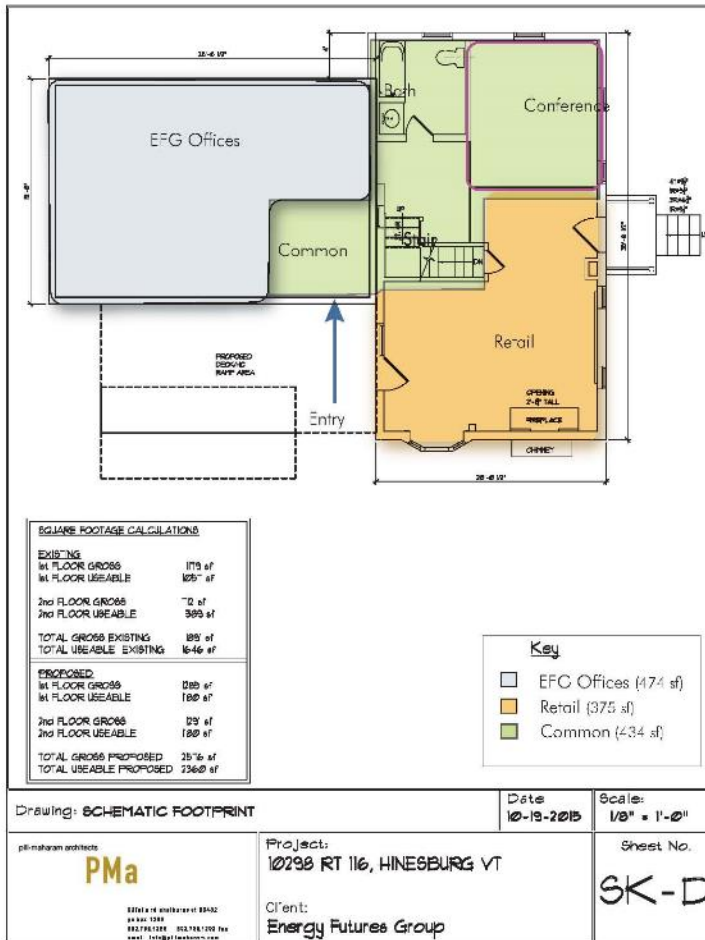
11

- Design process based on client goals
- Integrated design process
  - ▣ Involvement of the builder in the design and decision process
    - ▣ Slab foundation vs. basement or crawlspace
    - ▣ Roof trusses vs. working with the existing rafters
- Challenges and opportunities
- Plans and specs...

# Design



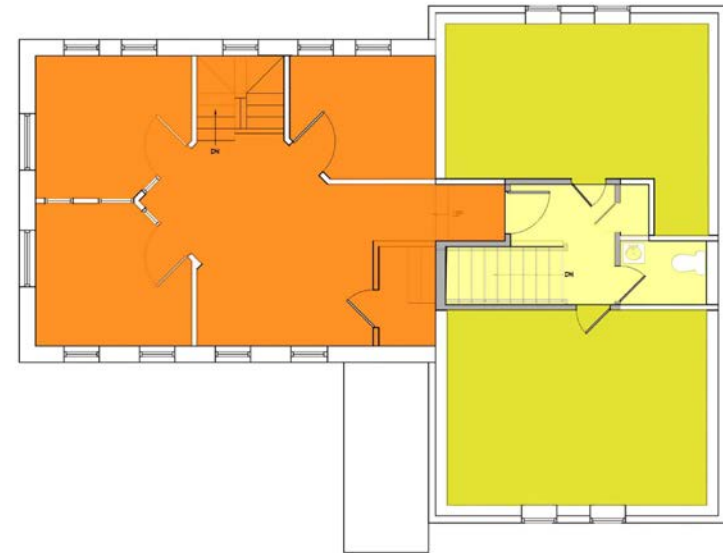
# Design



# Design



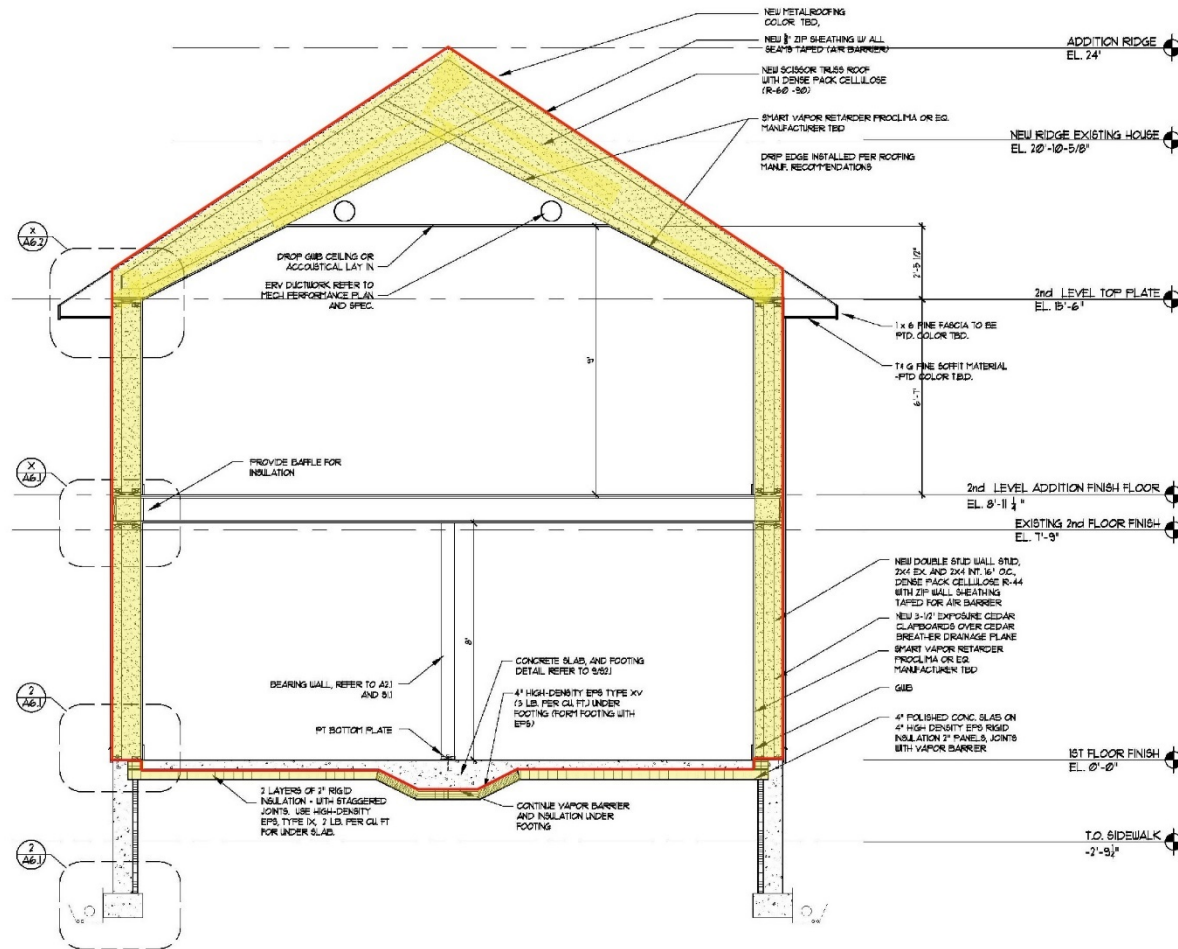
First floor



Second floor

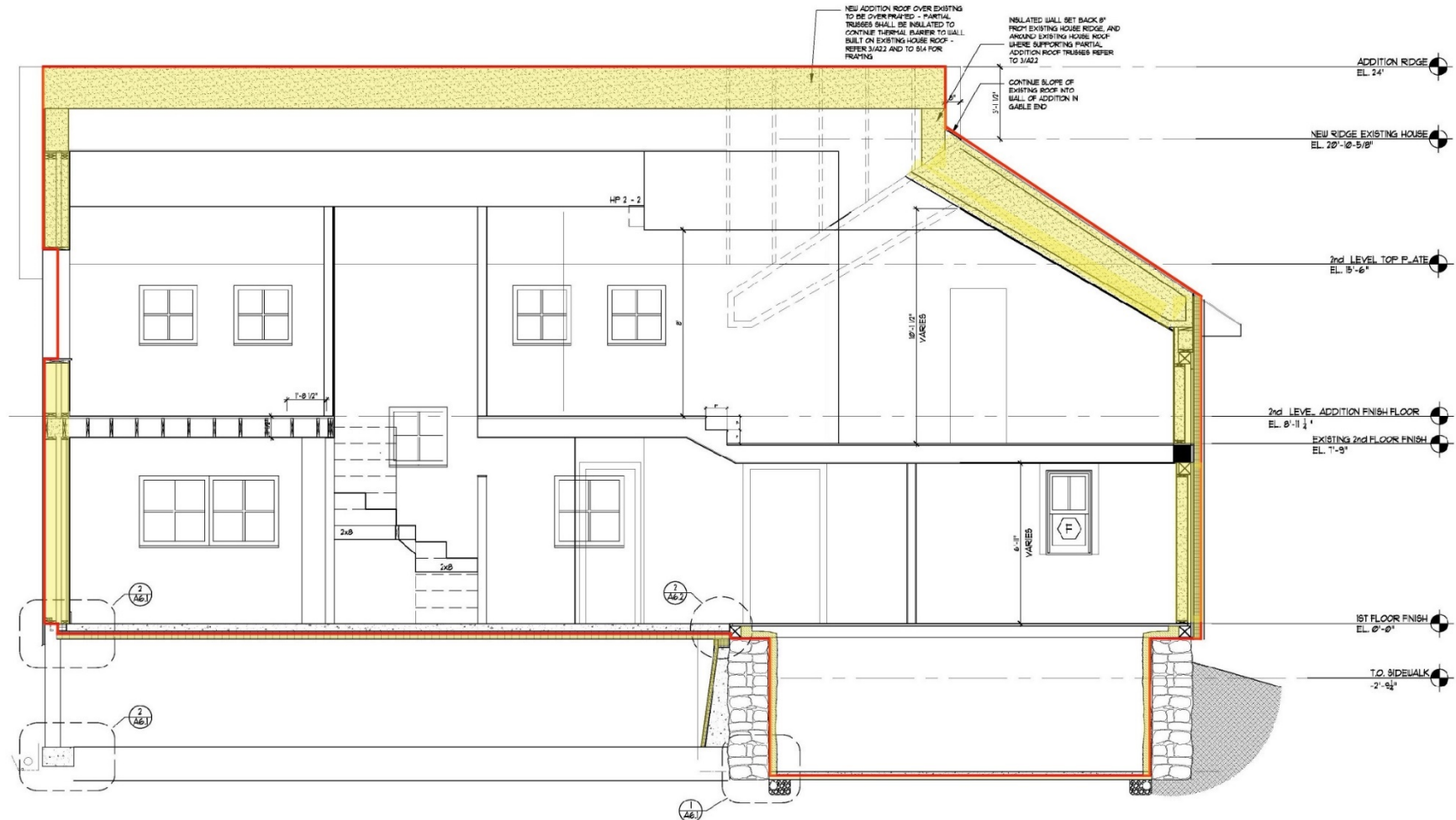


# Construction Details



1 BUILDING SECTION @ ADDITION  
SCALE: 1/2" = 1'-0"

# Construction Details



# Construction Details

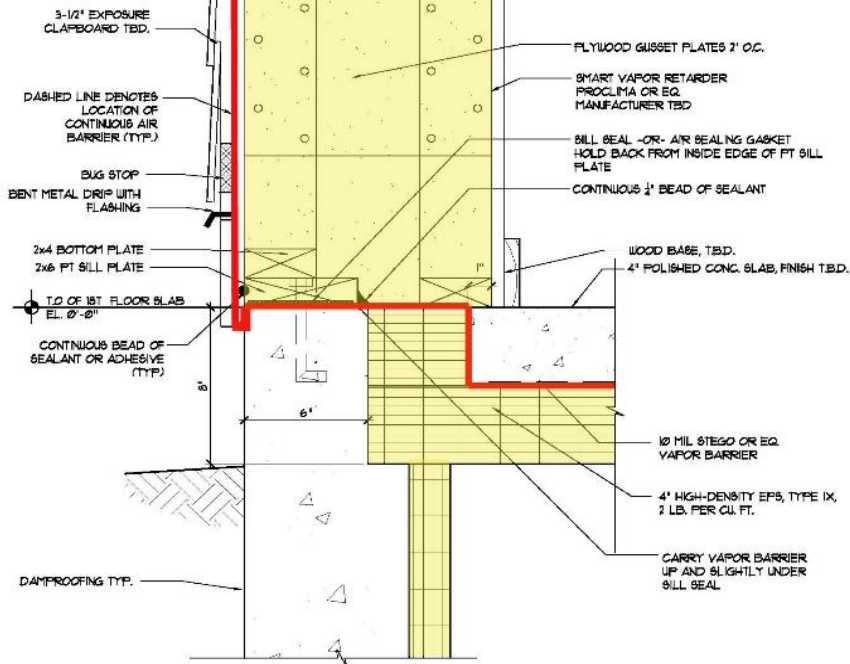




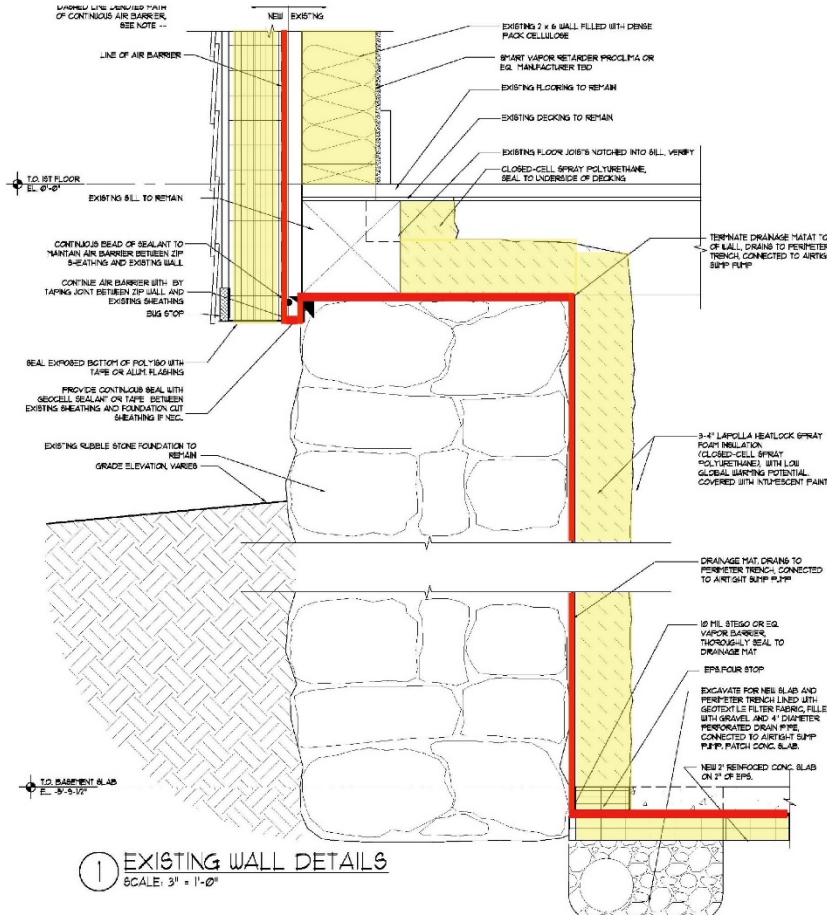
# Construction Details



**TYPICAL EXTERIOR WALL CONSTRUCTION:**  
 3-1/2" EXPOSURE CLAPBOARD MATERIAL TBD OVER CEDAR BREATHER -OR- MEBC GALVALUME CORRUGATED METAL SIDING -COLOR AND PROFILE TBD  
 HUBER ZIP SYSTEM 1/2" WALL SHEATHING, ALL SEAMS TAPED WITH MANUFACTURER'S RECOMMENDED TAPE  
 2x4 DOUBLE STUD WALL WITH 1'-0" CAVITY, STUDS @ 16" O.C. CAVITY FILLED WITH DENSE-PACK CELLULOSE INSULATION OVER 5/8" GYPSUM WALLBOARD -OR- OTHER INTERIOR FINISH AS NOTED IN SCHEDULE OR ELEVATIONS



# Construction Details





# Basement Details



# Wall Details



# Roof Details



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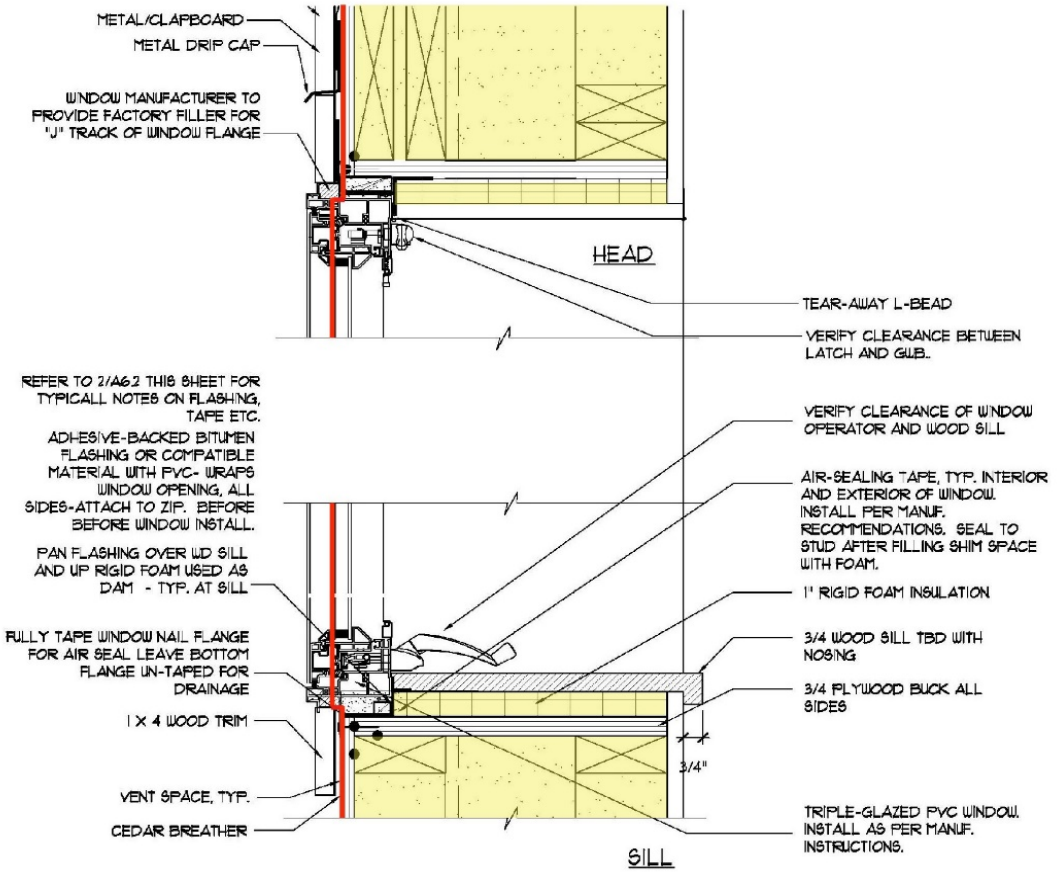
# Window Choices

23

- Wood vs. vinyl vs. fiberglass
  - Performance
    - Similar
  - Cost
    - \$12k vs. \$21k
    - White vs. color
  - Wood vs. sheetrock returns
- European, NY, ME
- Local availability and service
- Paradigm Windows
  - Portland, ME
  - U-.22
  - SHGC .22



# Window Details



① TYPICAL WINDOW HEAD AND SILL DETAIL FOR CLAPBOARD/METAL IN ADDITION

SCALE: 3" = 1'-0"



# Window Details



# Mechanical System Challenges



- Zoned approach
- Heating and cooling
- All-electric cold climate heat pumps
- Ducted vs wall mount – cost difference and comfort difference and uncertainties
  - Ducted System for new offices
  - Wall-Mount system for new offices
- Cost Savings - \$5k-\$10k (mechanical + construction)
- Less transfer fan costs  $\sim \$400 \times 6 = \$2400$

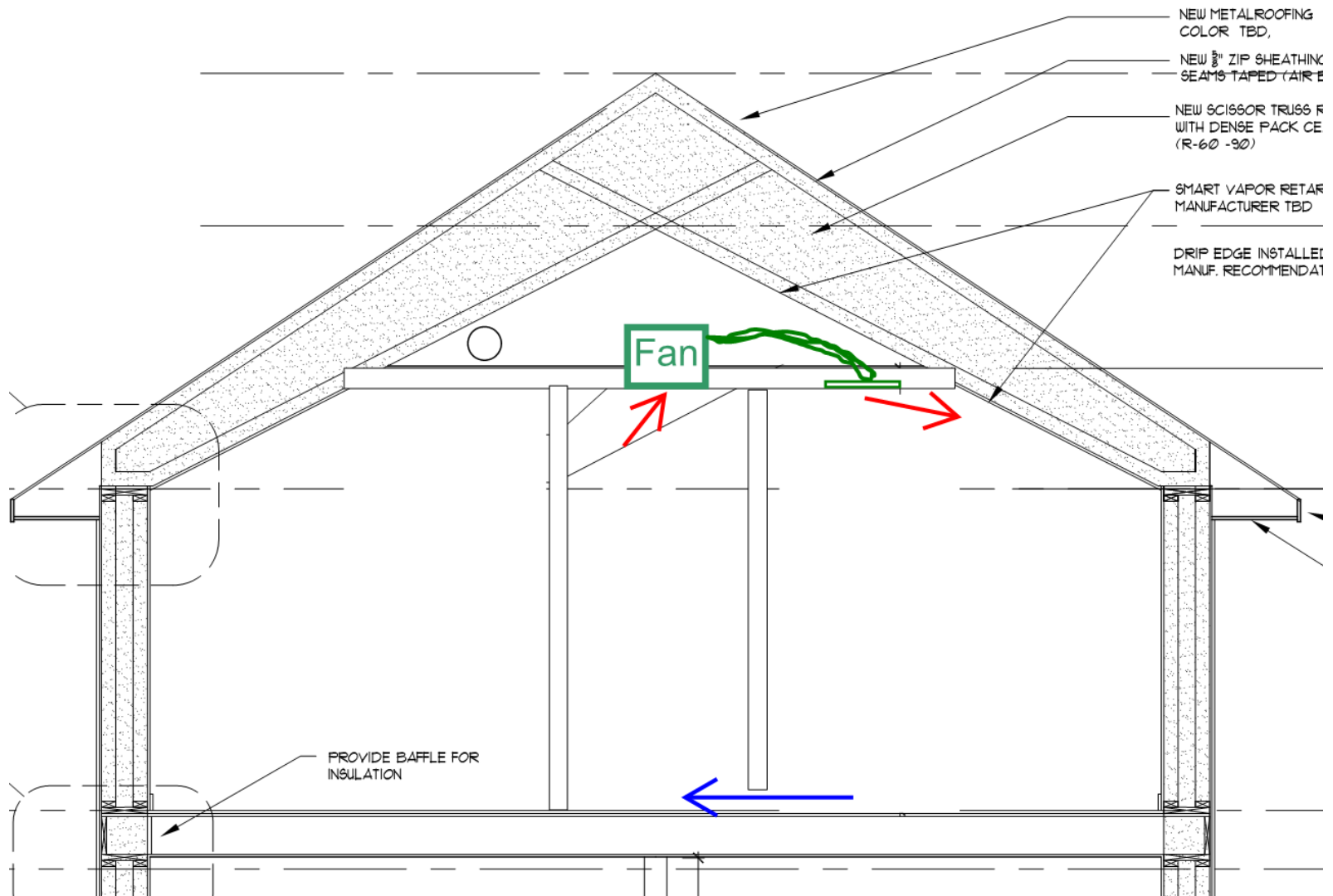
# Mechanical System Challenges



## Challenges with wall mount:

- Heating and cooling offices with doors closed
- Comfort difference and uncertainties
- Transfer fan solution and uncertainties
- Peak loads driven by cooling in some rooms and heating in others

# Heating and Cooling Transfer Fan



# Mechanical System Challenges

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- Very low peak loads

Btu/hour at -20F and 68F inside

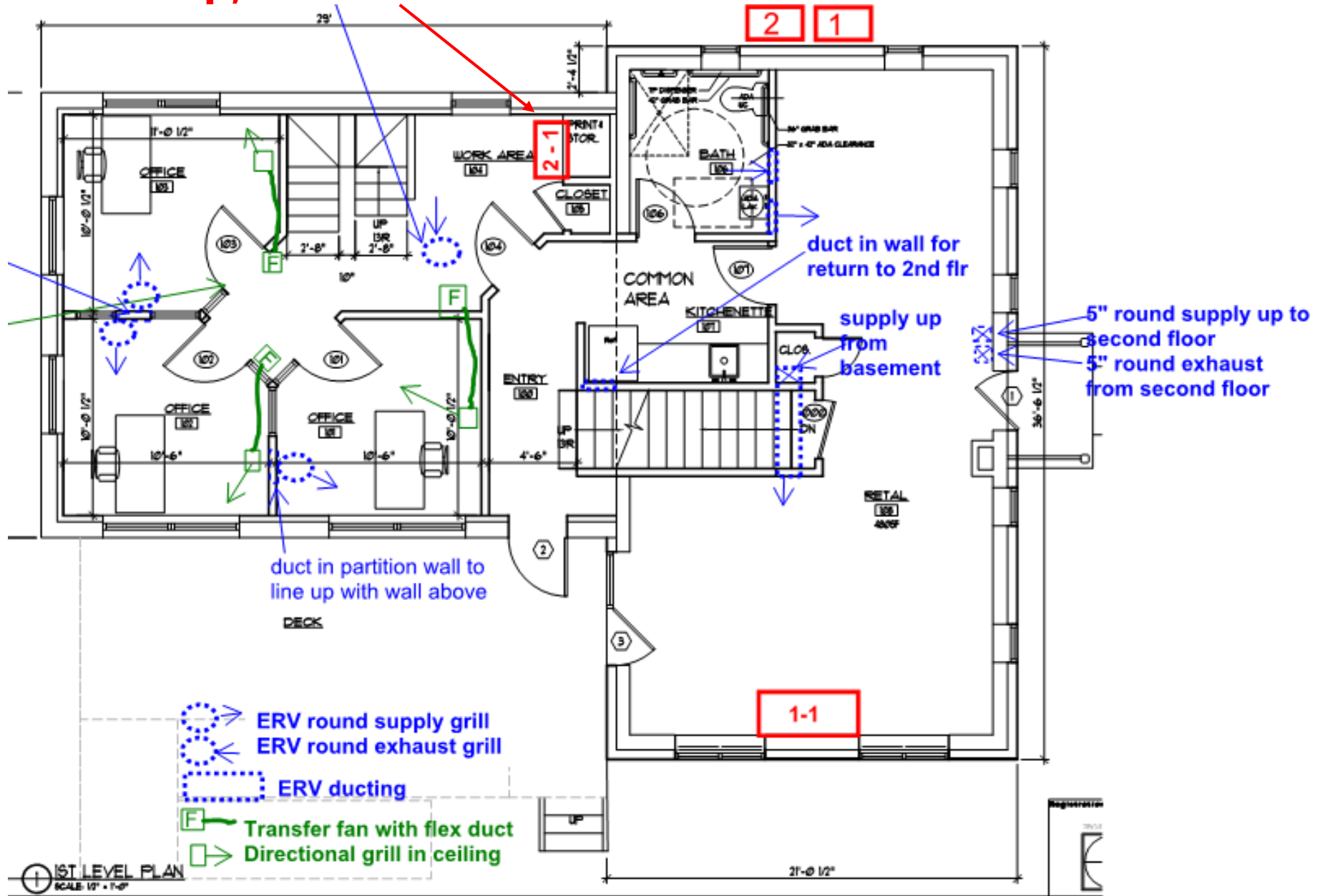
<b>EFG Office and Retail</b>			
<b>Indoor and Outdoor Unit Loads</b>			
Outdoor unit number		1	2
Total Peak Load Heating		16,410	16,575
Total Peak Load Cooling		8,880	16,627

# Mechanical System Challenges

EFG -- Peak Heating and Cooling Loads -- First Floor								19-Apr-16
<b>First Floor</b>								
Room	Retail 108	Bathroom 106	Common hall / kitchentte 107	Office SE 101	Office SW 102	Office NW 103	Work area/stair 104	
Heating	10,000	1,000	1,700	1,500	2,400	2,300	1,600	
Cooling	5,100	300	700	2,700	2,800	2,200	600	
<b>Second Floor</b>								
Room	Office rental S 207	Office rental N 204	Office Rental circ, storage 208/205	Office Rent Bath 206	EFG Common 200	Office SW 201	Office NW 220	Office NE 203
Heating	2,300	2,300	500	200	2,300	1,800	1,800	1,100
Cooling	2,100	1,000	200	200	2,600	2,100	2,100	900

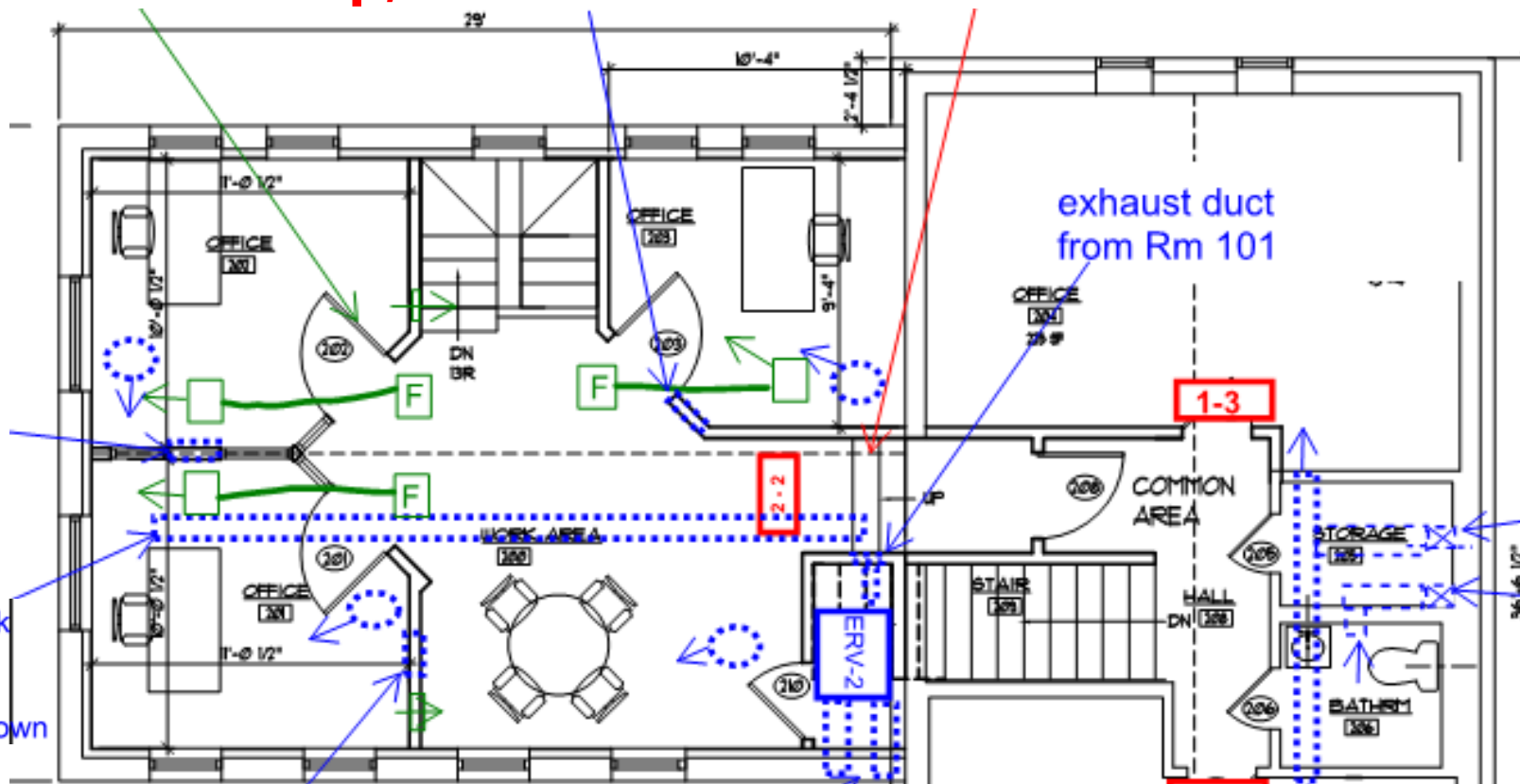
- Can't get small enough wall mount units

# Wall Mount Heat Pump, 1<sup>st</sup> Flr





# Wall Mount Heat Pump, 2<sup>nd</sup> Flr

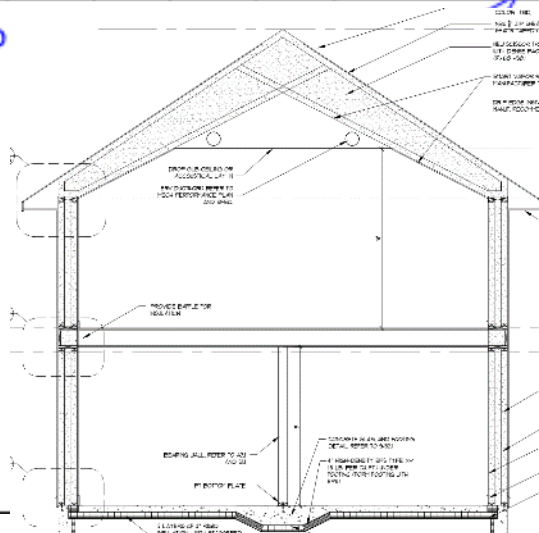


\* 6" ERV supply trunk above flat ceiling  
 \* 4" runouts to grills and ducting not shown

duct down to supply RM 101. Connection to trunk not shown

**SCHEMATIC KEY:**

	EXISTING WALL
	NEW CONSTRUCTION



① 2ND LEVEL PLAN  
 SCALE: 1/8" = 1'-0"



# Final Heat Pump System



- Wall mount in retail and rental offices
- Wireless remote thermostats
  - ▣ Vs. hand-held remotes
- Fix air direction vanes on wall mount units
- ~~□ Set indoor unit fans to run only on call for heat/cool~~
- Transfer fans in closed EFG offices
  - ▣ With thermostats

# Ventilation System

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- ERV to reduce summer humidity and increase winter humidity
- Dedicated ductwork for ventilation
- Broan ERV140TE (was Venmar)
- One for EFG office; one for rental spaces
- Run on 7-day schedule from ERV controller



## EFG Office and Retail

### Building Enclosure -- 2015 Energy Code and Proposed

	Code	Proposed Net Zero Ready
Roof, new and old	<b>R-49</b>	<b>R-60</b> 18" cellulose,
Walls above grade	<b>R-20</b>	<b>R-40</b> Existing:5.5" cellulose + 4" polyiso rigid New 12" double-wall cellulose
Under slab	<b>R-10</b> to 48" from edge of slab in new	<b>R-18</b> 4" EPS
Slab edge	<b>R-0</b> No slab edge insulation required	<b>R-18</b> 4" EPS slab edge plus 2" vertical to footing
Basement Walls	<b>R-10</b> vertical, to footing	<b>R-24</b> Zero GWP Spray foam
Basement Floor	<b>R-0</b> no insulation	<b>R-20</b> 4" EPS continuous
Windows, R-value fixed	<b>R-2.8</b>	<b>R-5</b> tripane windows
Windows, R-value operable	<b>R-2.3</b>	<b>R-5</b> tripane windows
Window SHGC	<b>0.40</b>	<b>0.27</b>
Opaque doors (includes doors with some glass)	<b>R-2.7</b> -- solid doors insulated	<b>R-4.5</b> insulated w/low-e glass and glass storm with hard-coat low-e <b>R- 3</b> Outswing (no storm door)
Air leakage	<b>0.50 cfm50/sq.ft.-shell;</b> <b>2,200 cfm50</b> <b>ACH50</b>	<b>0.10 cfm50/sq.ft.-shell</b> <b>440 cfm50</b> <b>1.3 ACH 50 (actual 0.45 ACH50)</b>
Air leakage natural + ventilation	<b>.66 ACH</b> (natural + ventilation)	<b>.21 ACH</b> (natural + ventilation)

# Energy Modeling Assumptions

## EFG Office and Retail Systems -- 2015 Energy Code and Proposed

	Code	Proposed Net Zero Ready
Heat	Warm air natural gas furnace, <b>AFUE=0.78</b>	Cold climate heat pump with <b>COP=2.3</b>
Cooling	<b>SEER 13</b>	<b>SEER 19</b>
Hot Water	<b>0.97</b> EF tank-type	Heat Pump Water Heater -- <b>COP - 2</b>
Ventilation	<b>HRV with 65% ASRE</b>	<b>ERV with 74% ASRE latent 46%</b>
Lighting	<b>0.82</b> wsf	<b>0.82</b> wsf*

# Domestic Hot Water

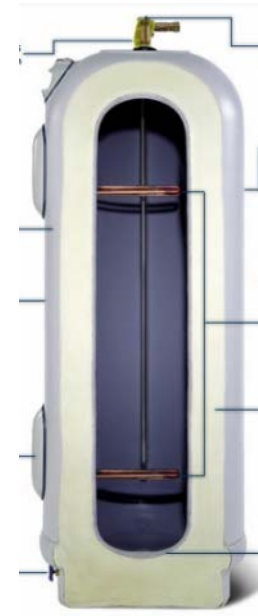
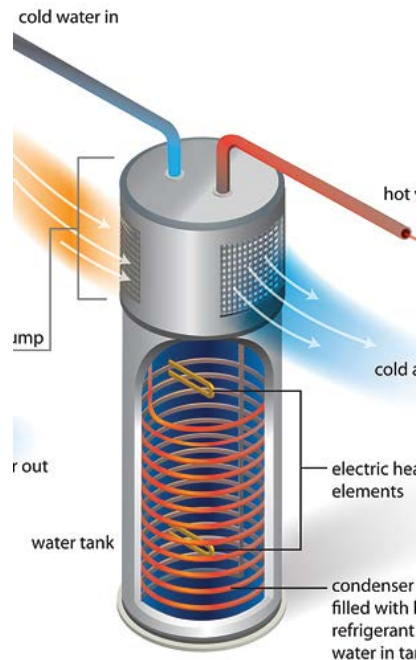
- 12 gallons/day average

Domestic Hot Water, Annual load and fuel use			
	Resistance	Heat Pump	
Annual Load	1.8	1.8	MMBtu/yr
Annual Load, usage	524	524	kWh/yr
Annual load, standby and piping losses	623	623	kWh/yr
Annual Load, Total	1,147	1,147	kWh/yr
	Resistance	Heat Pump	
COP of water heating	1.00	2.0	COP
Annual Consumption	<b>1,147</b>	<b>574</b>	kWh/yr

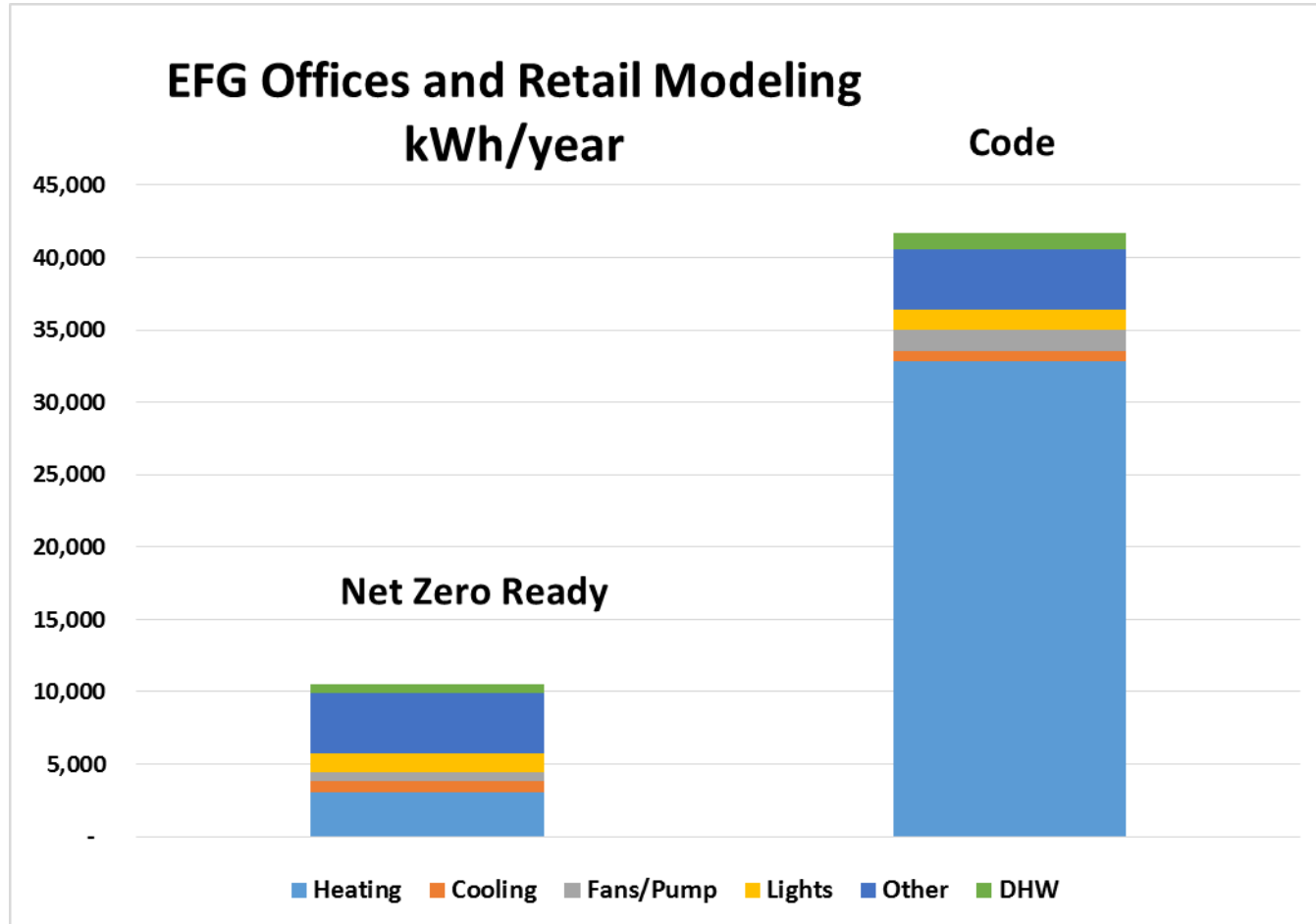


# Domestic Hot Water Choice

	Resistance	Heat Pump	
Annual Consumption	<b>1,147</b>	<b>574</b>	kWh/yr
Savings of Heat Pump over Resistance		574	kWh/yr
PV's required for added kWh for Resistance		499	Wp of PV
Cost per watt, net		\$ 2.00	
Add cost for PV for Resistance DHW		\$ 1,000	



# Energy Modeling to Achieve Net Zero



# Photovoltaics

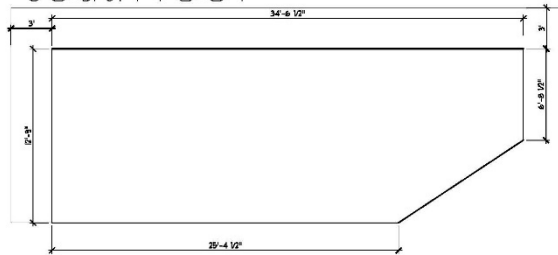


	<u># of panels</u>	<u>Watts / panel</u>	<u>Total watts</u>	<u>KWH/yr</u>
South facing roof	20	310	6200	7440
West facing roof	4	310	1240	1240
East facing roof	10	310	3100	3100
<b>Totals</b>	<b>34</b>		<b>10,540</b>	<b>11,780</b>

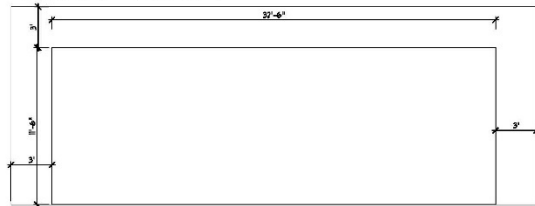
# Photovoltaics



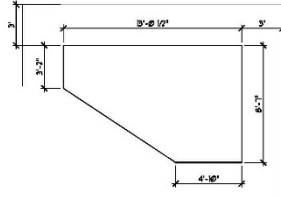
PV area  
south roof



east roof



west roof



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# The Construction Process









10298





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# Commissioning

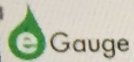






Moisture  
Content 8% -  
10% at Inside  
of Exterior  
Sheathing in  
Both Wall  
Types





# Energy Futures Group

[View](#) | [LAN Access](#) | [Tools](#) | [Settings](#) | [Help](#)

10/2/2017 8:55am - 10/9/2017 8:55am

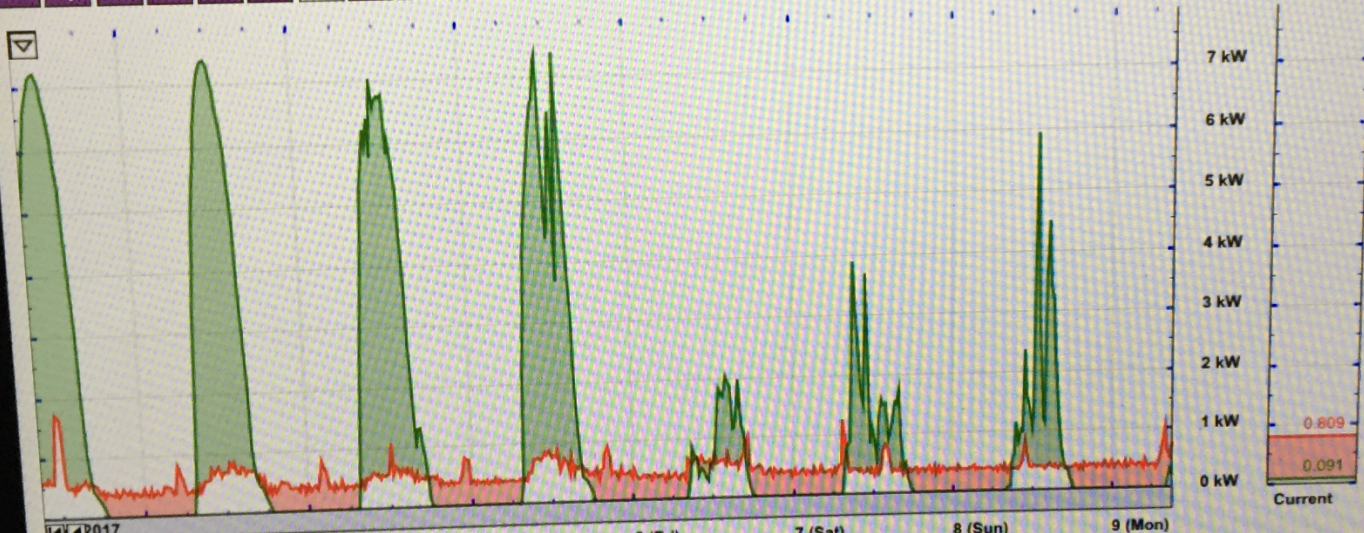
**Summary for time-period shown in graph**

Energy Used	81.8 kWh	(approx. \$10.64 used)
Energy Generated	213 kWh	(approx. \$34.01 saved)
Net	131 kWh sold	(approx. \$23.37 earned)

**Summary over last 30 days**

Energy Used	181 kWh	(approx. \$23.49 used)
Energy Generated	422 kWh	(approx. \$67.50 saved)
Net	241 kWh sold	(approx. \$44.01 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



<input checked="" type="checkbox"/> Power used	<input checked="" type="checkbox"/> Energy from grid	<input checked="" type="checkbox"/> Power generated	<input checked="" type="checkbox"/> Energy to grid
<input type="checkbox"/> Grid gen./use	<input type="checkbox"/> Solar gen./use	<input type="checkbox"/> Solar+ gen./use	<input type="checkbox"/> Hot Water Heater gen./use
<input type="checkbox"/> Kitchen / Fridge gen./use	<input type="checkbox"/> HP-1 (Rental Units) gen./use	<input type="checkbox"/> HP-2 (EFG) gen./use	<input type="checkbox"/> ERV-1 (Rental Units) gen./use

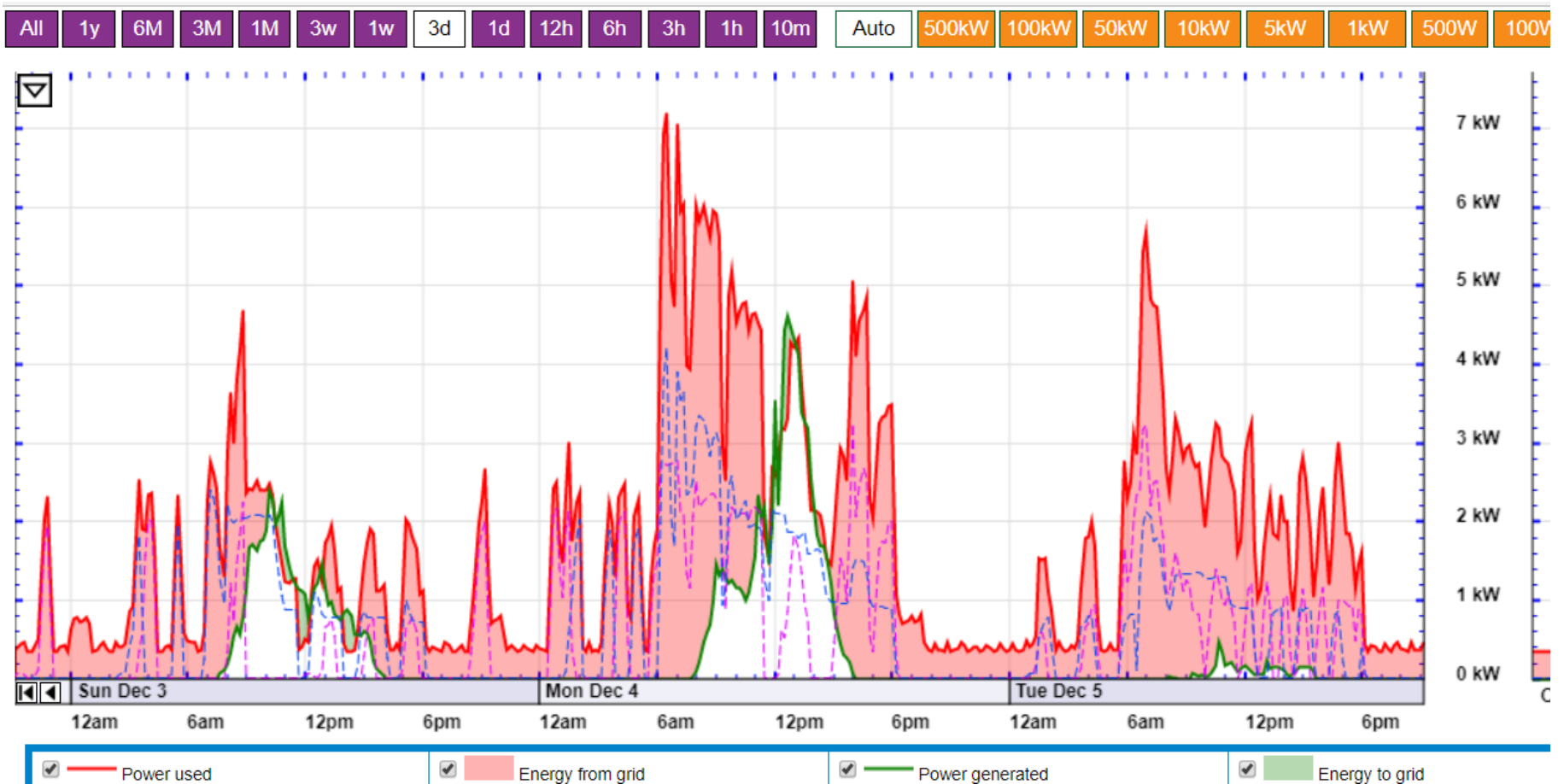
0.809  
0.091  
Current



# eGauge Data



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Previous Account Balance	\$86.42
Payments Received	-\$86.42
Balance Forward	\$0.00
Bill Correction	\$23.58
New Charges	-\$162.36
Adjustments	\$138.78



### Your Account

Bill Date 10/31/17

Account Number 80898860871  
 Account Name EFG ENTERPRISES LLC  
 Service Address 10298 RT 116  
 HINESBURG VT 05461-0188



### Your Bill

Total Amount Due

# \$0.00



### My Energy Use Snap Shot

Learn how your renewable generation has contributed towards a sustainable energy future. For more details visit your account at [greenmountainpower.com](http://greenmountainpower.com)

Total Solar Generated

# 1,429

kWh



- 261 kWh used by your home
- 1,168 kWh Solar to the grid

Total Energy Used

# 583

kWh



- 322 kWh delivered to your home
- 261 kWh from generation



### My Net Meter Summary

#### Actual Balance

Previous Balance \$86.42  
 Payments Received -\$86.42  
 Balance Forward \$0.00  
 Actual Charges/Adjustments -\$162.36  
 Total Account Balance -\$138.78

#### Net Meter Bank

Previous Credits Balance \$0.00  
 Total Net Meter Adjustments -\$138.78  
 Total Credits Balance -\$138.78

5

Continued on back



163 Acorn Lane  
 Colchester, VT 05446

Contact Us: 1.888.835.4672

Bill Date	10/31/17
Account Number	80898860871
Balance Forward	\$0.00
New Charges/Adjustments	-\$23.58

Total Amount Due **\$0.00**

This account is currently enrolled in Speedpay Recurring Payment Plan.

0001000

# Modeled vs. Usage

<b>EFG Offices and Retail</b>		
<b>Preliminary modeled vs actual Heat Pump Heating Usage</b>		
	Modeled Average year	Actual "clean data" period *
Heat Pump heating usage, kWh	3,061	2,662
Avg Heating Degree-Days	7,700	2,456
Heat Pump kWh / Heating-DDay	0.40	1.08
Implied Annual HP Heating usage, kWh	3,061	8,347
* clean data period with no cooling or anomalies		
	11/01/17	start
	12/04/17	end
	12/08/17	start
	01/04/18	end
	01/15/18	start
	01/17/18	end



# Heat Pump Issues

65

- Mysterious cycling under low loads
- Sometimes temp in some spaces too high
- Apparent heat pump heating COP -- *PRELIMINARY*
  - Predicted COP – 2.6 overall for winter
  - Measured ASHP and resistance heat kWh usage
    - ASHP: 0.035 kWh/hr-degree temp difference
    - Resistance Heat: 0.057 kWh/hr-degree temp difference
    - Implies a COP of ~1.6 for “clean data period”
  - Other methods estimate higher heating COP

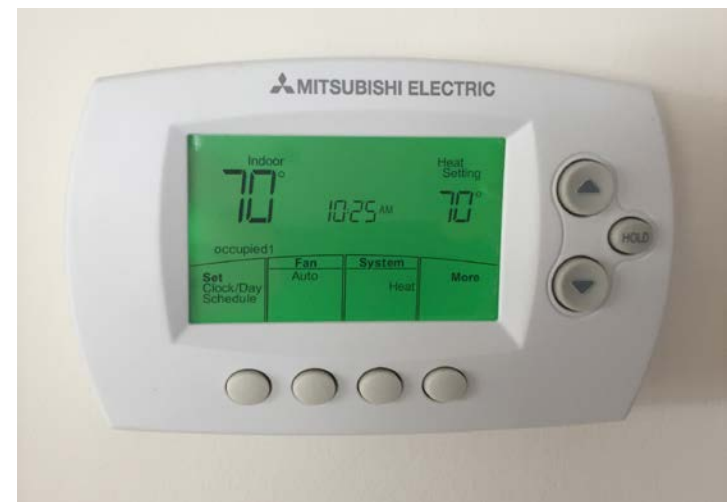
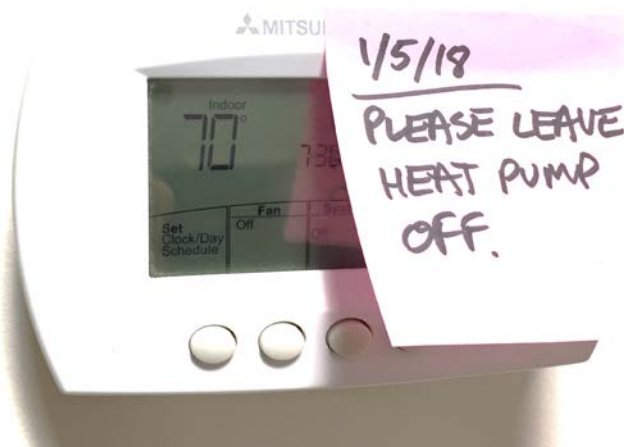


# Heat Pump Performance



66

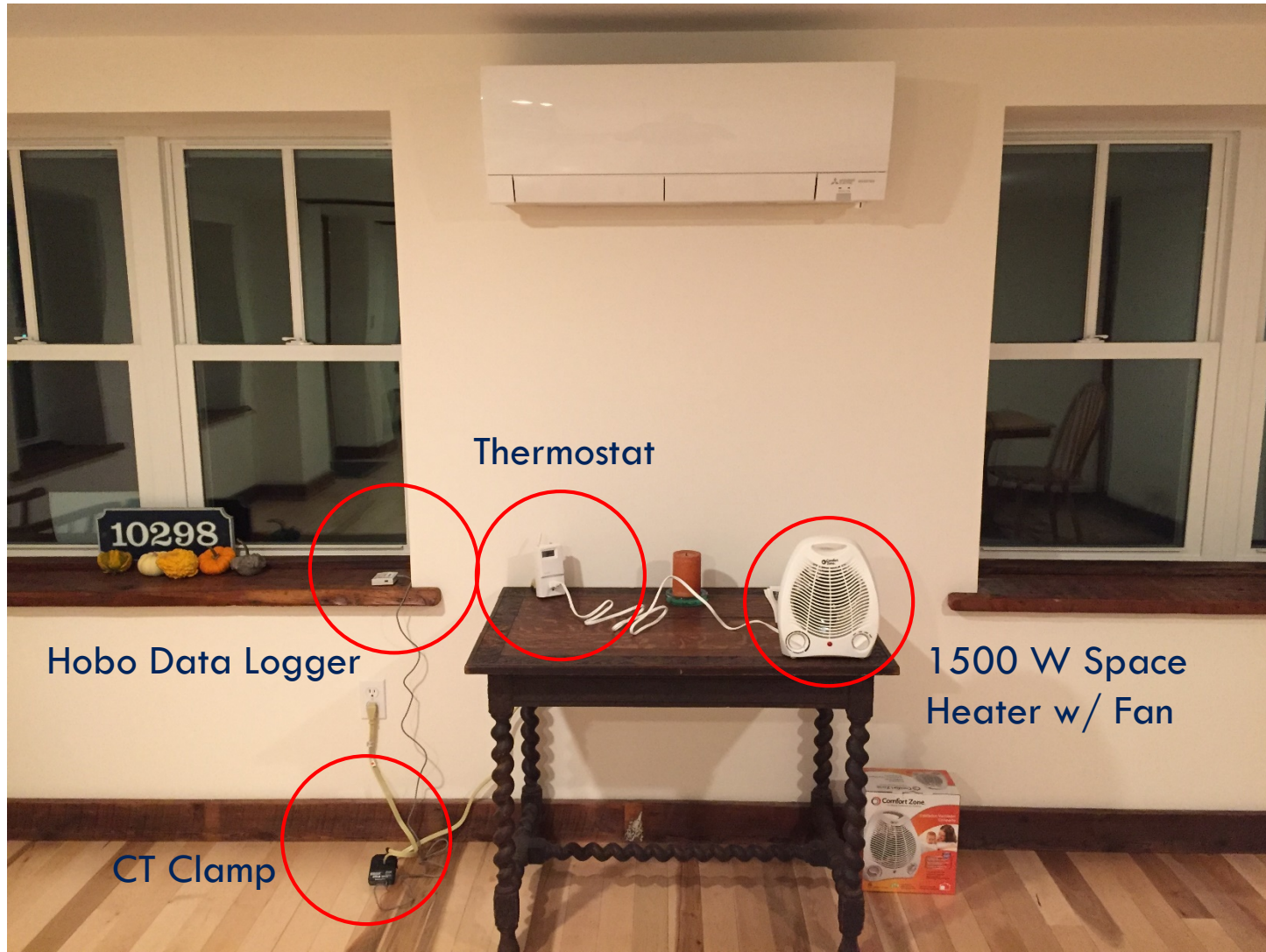
- “Co-Heating Test”
  - ▣ Turn off heat pumps and run electric resistance heat instead – to compare energy used by heat pumps
  - ▣ Wide range of outdoor temperatures for each
  - ▣ Consistent indoor temps and scheduling



# Co-Heating Test Set-up

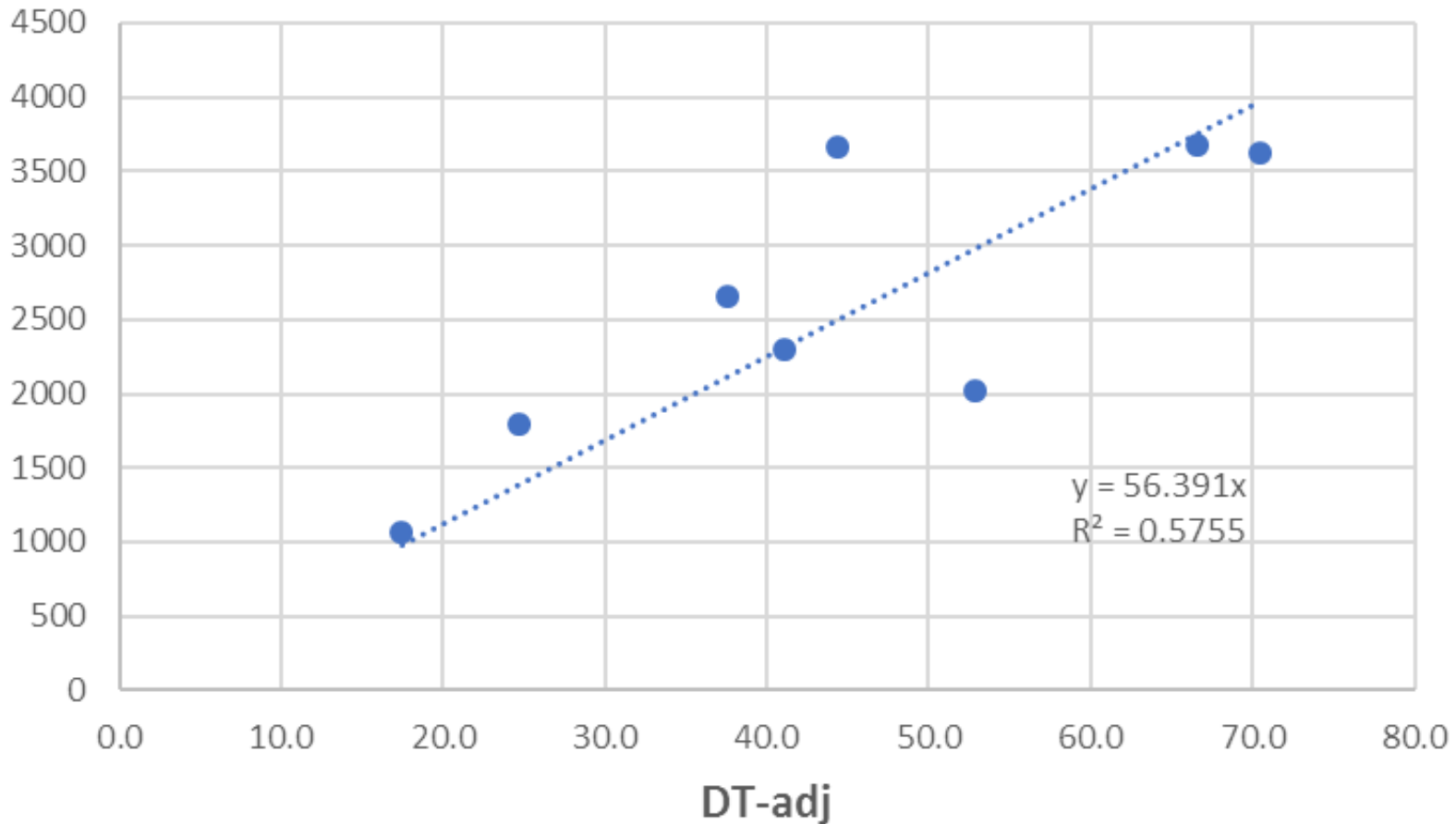


67



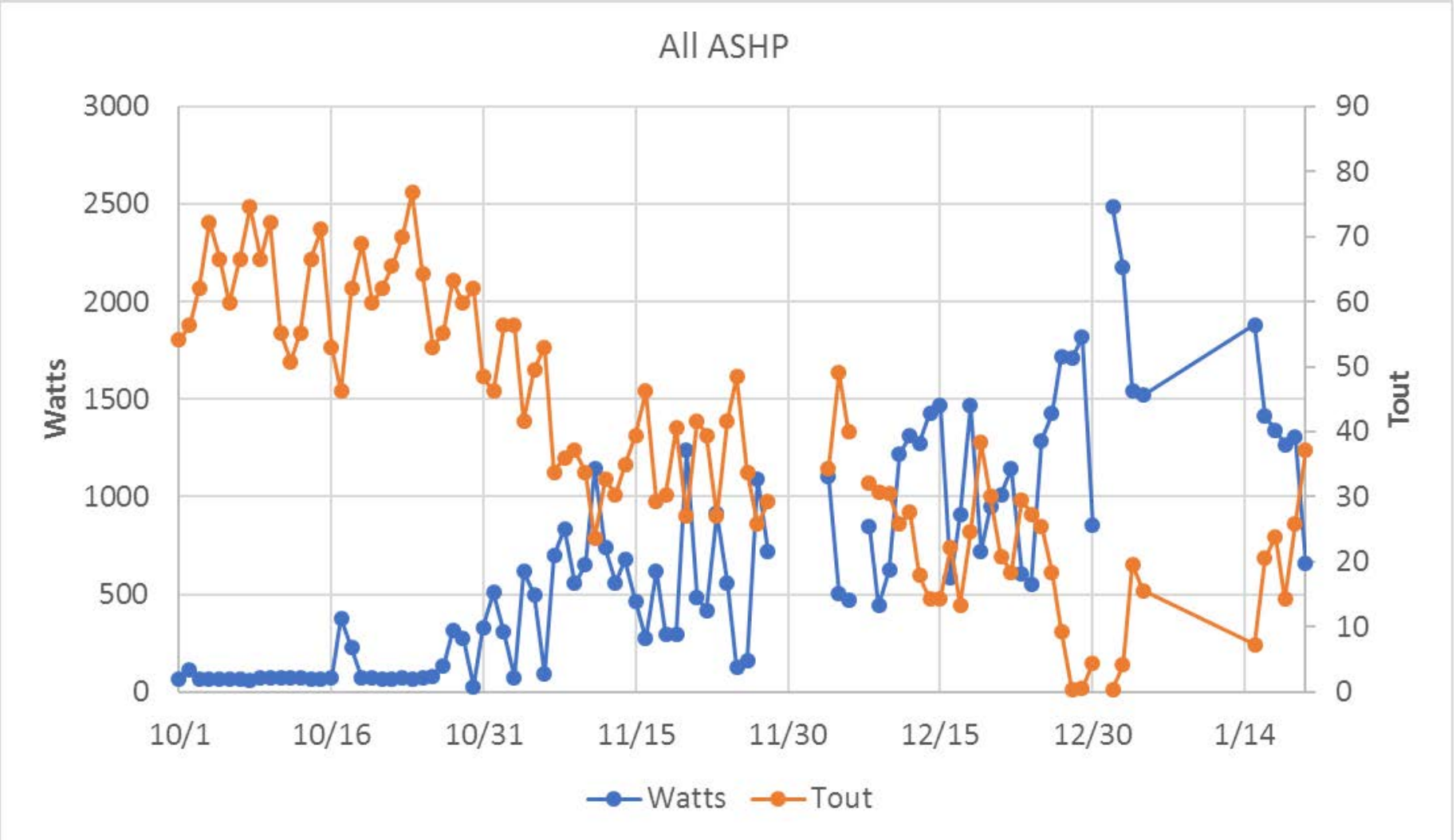
# Co-Heating Test Results

### All Coheat days Watts vs. Temperature Difference

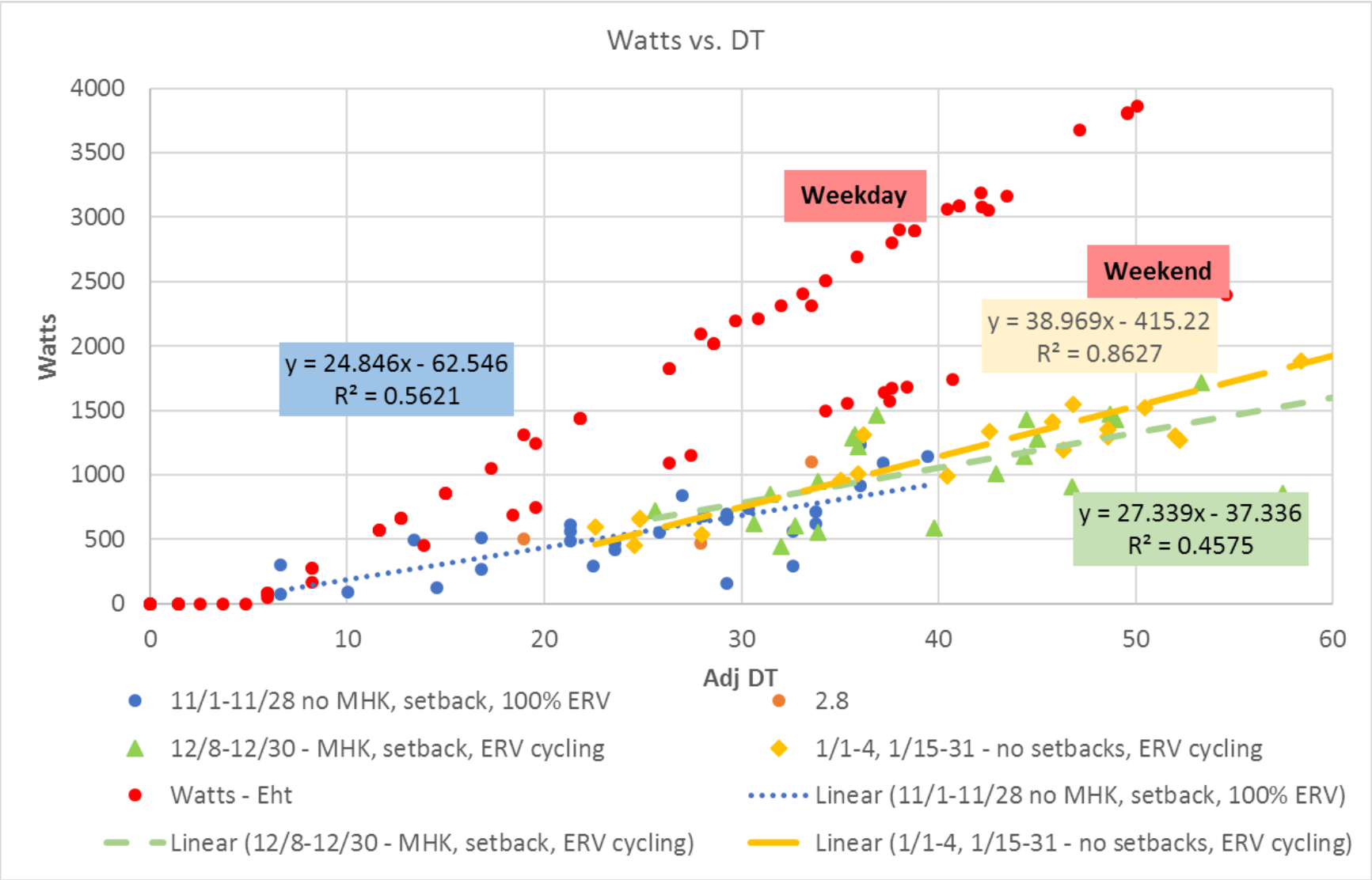




# Heat Pump Energy



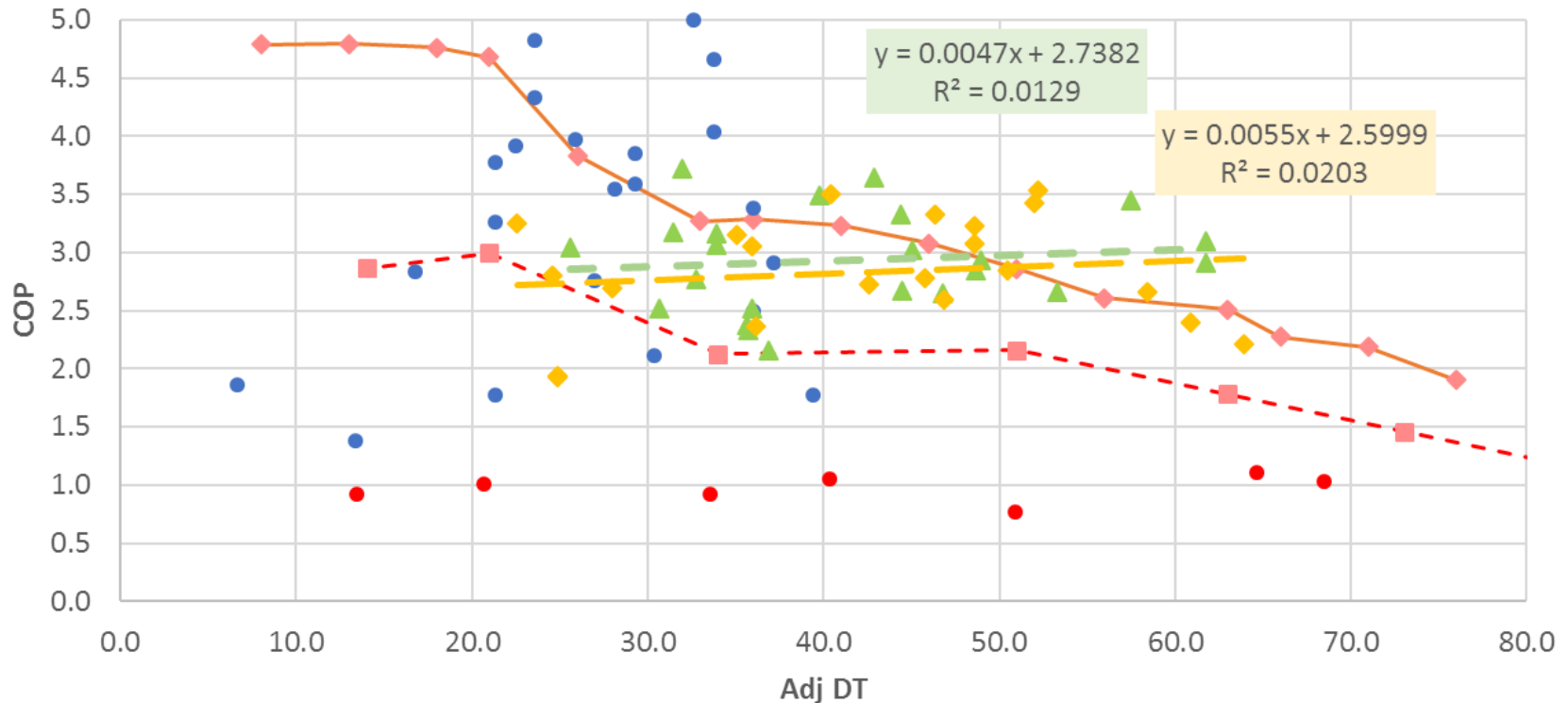
# ASHP & Resistance Watt



# COP vs. Temp Diff

71

Estimated Daily COP vs. DT, 3 Regimes



- 11/1-11/28 no MHK, setback, 100% ERV
- ◆ 1/1-4, 1/15-31 - no setbacks, ERV cycling
- Adj Manuf Specs
- Linear (12/8-12/30 - MHK, setback, ERV cycling)
- ▲ 12/8-12/30 - MHK, setback, ERV cycling
- ◆- Manuf Specs
- Coheat
- Linear (1/1-4, 1/15-31 - no setbacks, ERV cycling)



# Preliminary Test Results

Tout Avg	COP	No sun COP	Rated COP	Time
51	3.4	3.7	4.8	11/1-11/28 no MHK, setback, 100% ERV
21	2.9	2.8	3.0	12/8-12/30 - MHK, setback, ERV cycling
22	2.8	2.6	3.1	1/1-4, 1/15-31 - no setbacks, ERV cycling
38	3.0	2.9	3.5	all since 11/01/17

# Construction Cost

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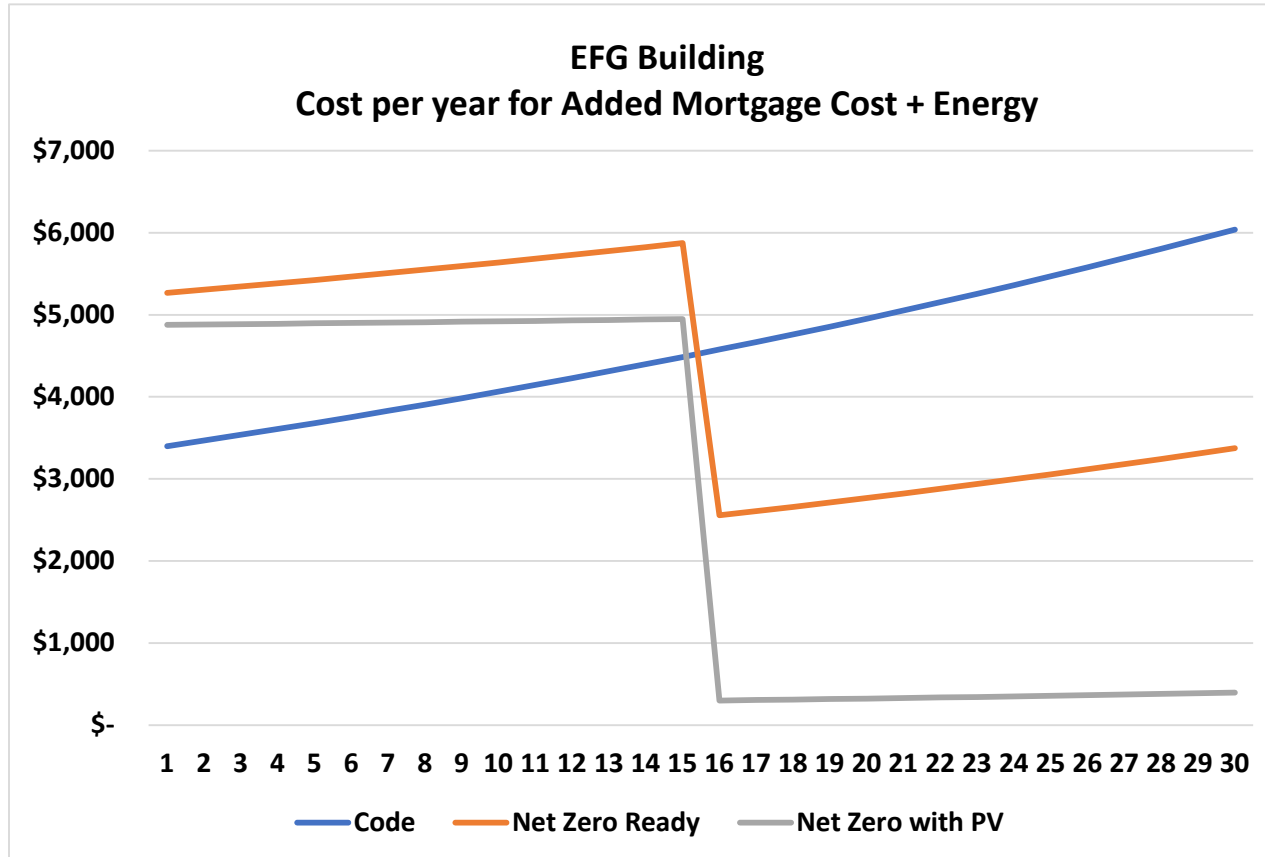
	Code	Net Zero Ready	Net Zero with PV
<b>Construction Cost</b>	\$ 529,000	\$ 568,000	\$ 582,000
<b>Cost per sq.ft.</b>	\$ 192	\$ 207	\$ 212
<b>Cost Increment</b>		7%	10%

Code cost estimated based on actual NZ construction costs

	Code	Net Zero Ready	Net Zero with PV
<b>First Year Energy Cost</b>	\$ 3,400	\$ 1,900	\$ 220
<b>1st Year Energy Cost Savings</b>		\$ 1,500	\$ 3,200
<b>Added Mortgage Cost</b>	0	\$ 3,367	\$ 4,654

Based on energy modeling

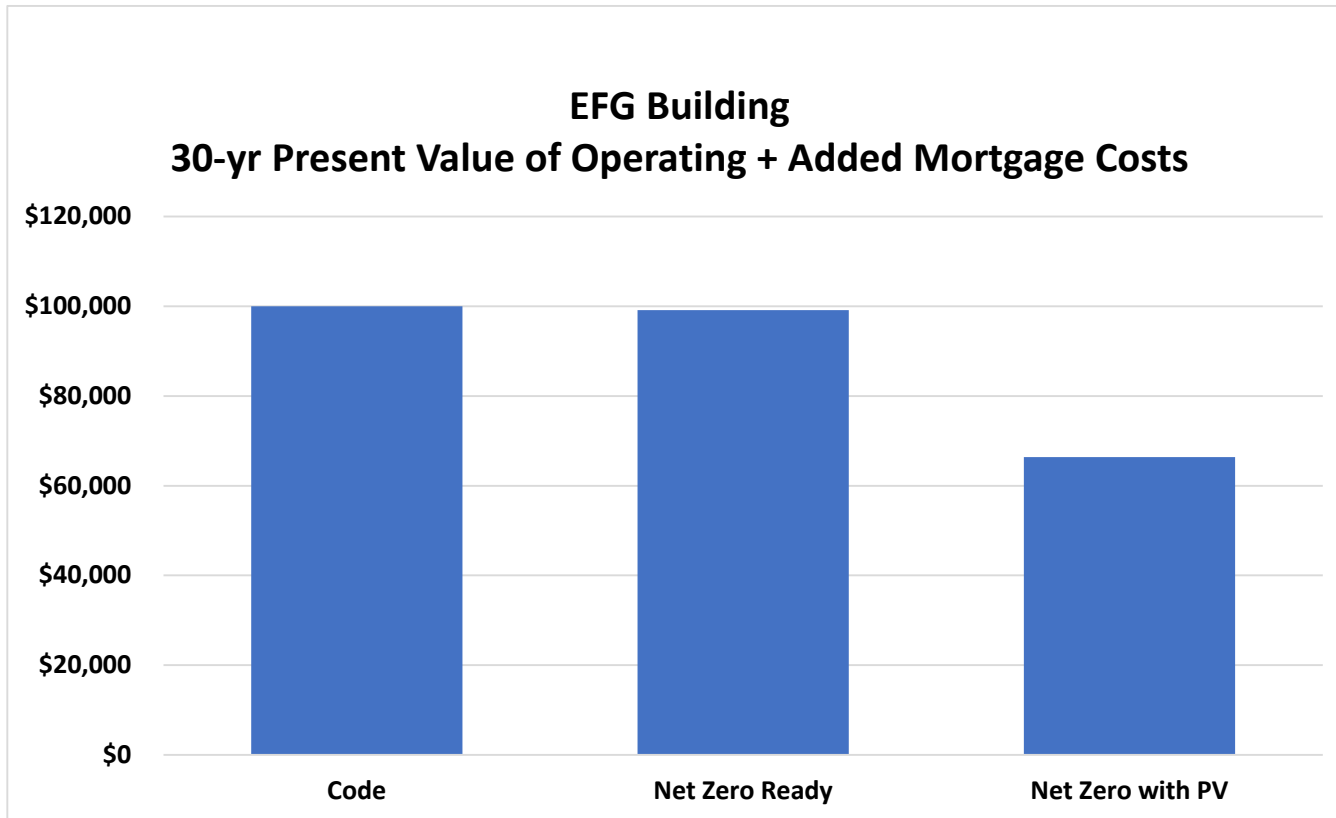
# Cost Effectiveness



2% fuel escalation, mortgage 3.5%/15 yrs, based on modeling



# Cost Effectiveness



2% discount rate, based on modeling

# Lessons Learned

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- Building to zero net energy standards in Vermont is achievable and cost-effective
- High-performing buildings are comfortable, resilient...
- And can also be beautiful
- Getting it right takes a lot of time, thought, effort and collaboration
- Real-time data is really helpful
- Heat pumps can be mysterious

# Q&A

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