Air Source Heat Pumps: Measured Performance & Best Practices

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Case Study:
Energy Futures Group Building

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Overall Goal

A net zero, energy efficient, green building

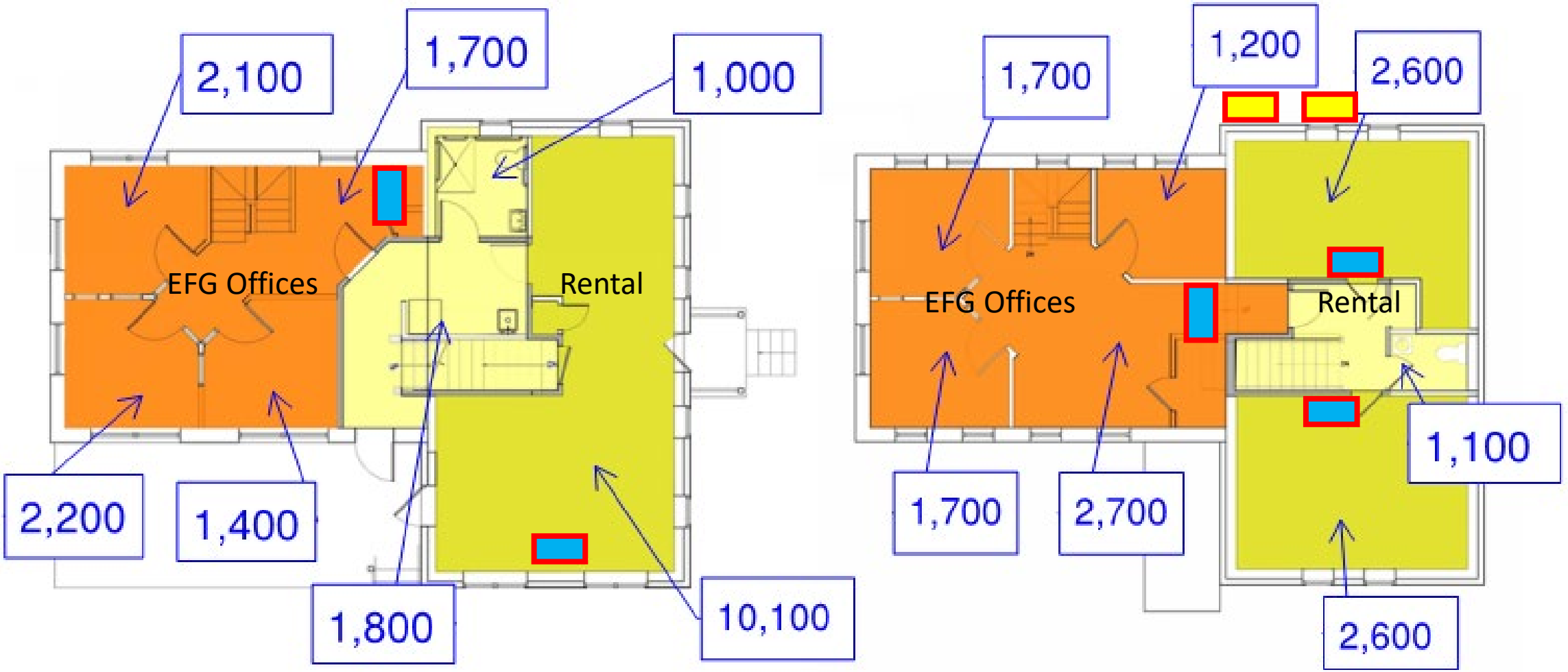
David Pill, Architect
Chuck Reiss, Builder
Andy Shapiro, Energy Design

Before and After -- ~2,400 sq.ft.

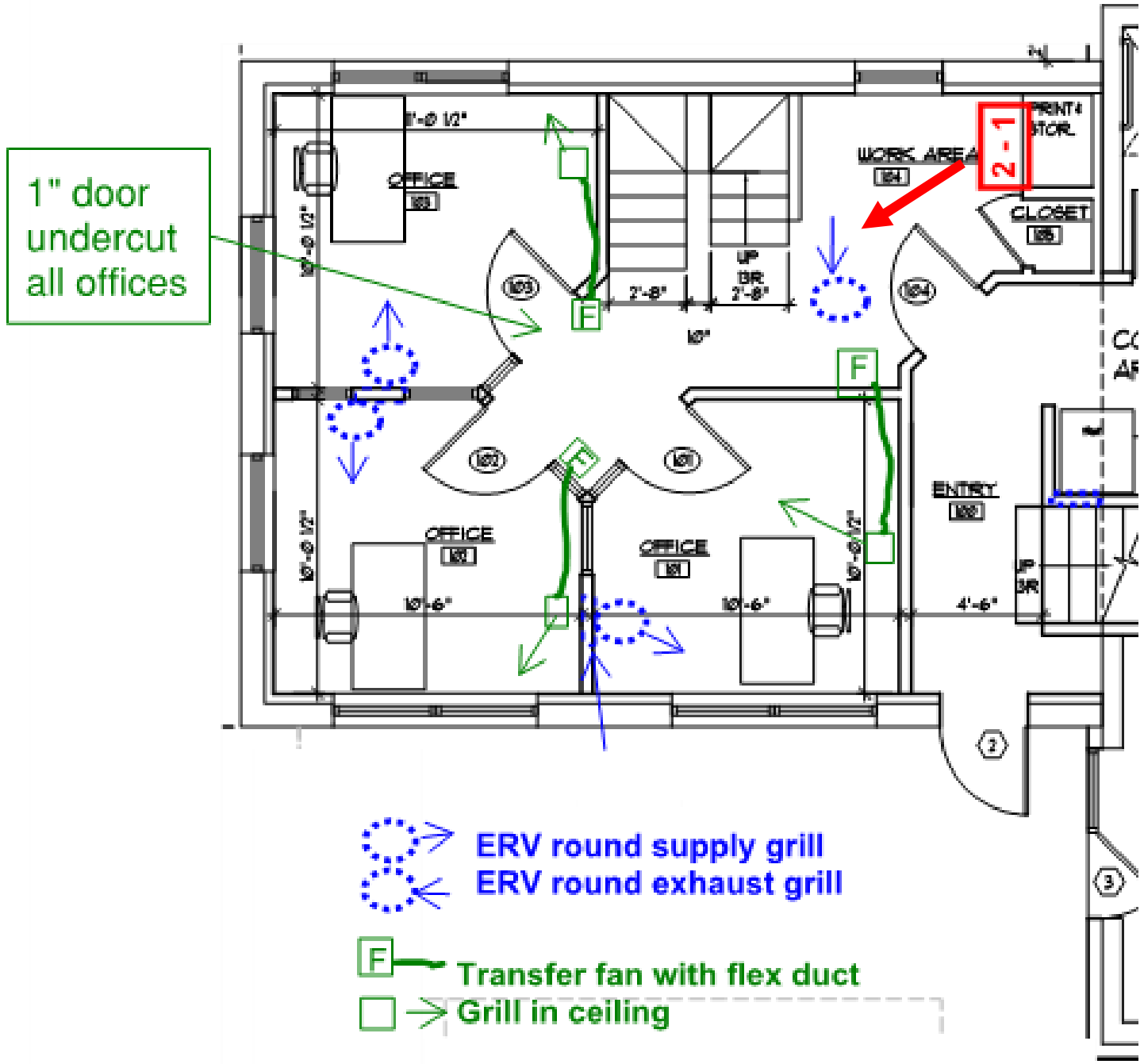
EFG's Energy Goals

- All-electric net zero model project
  - Tight: 1.0 ACH50
  - R-5 windows
  - R-20 foundation
  - R-40 walls
  - R-60 ceilings
  - Cold climate heat pumps
  - Energy recovery ventilation, ~70% effectiveness, 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

Design Heat Loads – Btu/hr – Original Calculations



Two Heat Pumps: Office Total: 17,500 Btu/hr
Rental Total 16,400 Btu/hr



Transfer Fans

(Panasonic 110-150 cfm)

So did we make Net Zero???

After the first three months of heating the building, the heat pumps used as much energy as the model showed they would use in a full heating season!

What's Up???

HP Sizing

Conventional "UA - delta T" calculation

Conventional Heating Systems Sizing			
	Area	U-Value	UA
Roof	1,317	0.017	22
Wall	2,313	0.025	58
Window	292	0.2	58
Doors	103	0.33	34
	Perimeter	Btu/ft-F	
Slab/Basement	171	0.25	43
	Volume	ACH	
Infiltration**	17,125	0.39	120
TOTAL UA -- Btu/hr-F			**335**
** Includes ventilation and natural ACH			
Heating Design Outdoor Temp			-20
Inside Design Temp			68
Design Heat Load, Btu/hr			29,500
Add for "Pick-Up"		15%	**33,900**
Split into two outdoor units (EFG offices and rental)			Design Heat Load, Btu/hr
		Offices	**17,500**
		Rental	**16,400**

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design	
0.12	**Natural ACH**
290	peak cfm from ventilation
100%	duty cycle
290	avg cfm from ventilation
0.74	HRV apparent effectiveness
75	average effective cfm
0.26	**avg. effective ventilation ACH**
0.39	**Total ACH for model**

Picking the Heat Pump

Area / No. Heads	Btu/hr Required
Rental / 3	16,400
Offices / 2	17,500

Picking the Heat Pump

Area / No. Heads	Btu/hr Required	Model
Rental / 3	16,400	MXZ-3C24NAHZ
Offices / 2	17,500	MXZ-2C20NAHZ

Picking the Heat Pump

Area / No. Heads	Btu/hr Required	Model	Btu/hr at -13F	% Oversize
Rental / 3	16,400	MXZ-3C24NAHZ	20,500	25%
Offices / 2	17,500	MXZ-2C20NAHZ	22,500	29%

HP Sizing

Dialing in the Peak Heat Load

ACH based on actual air leakage

Improved Heating Systems Sizing for ASHP			
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Roof	1,317	0.017	22
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Doors	103	0.33	34
	Perimeter	Btu/ft-F	
Slab/Basement	171	0.25	43
	Volume	**ACH**	
Infiltration**	17,125	**0.18**	55
TOTAL UA -- Btu/hr-F			**271**
Heating Design Outdoor Temp			-20
Inside Design Temp			68
Design Heat Load, Btu/hr			24,000
Add for "Pick-Up"		**15%**	**28,000**
Split into two outdoor units (EFG offices and rental)			**Design Heat Load, Btu/hr**
		Offices	**14,400**
		Rental	**13,600**

0.03 cfm50/sq.ft. shell instead of 0.1

HP Sizing

Dialing in the Peak Heat Load

Lose the "Pick-Up"

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TOTAL UA -- Btu/hr-F			**271**
Heating Design Outdoor Temp			-20
Inside Design Temp			68
Design Heat Load, Btu/hr			24,000
Add for "Pick-Up"		**0%**	**24,000**
Split into two outdoor units (EFG offices and rental)			Design Heat Load, Btu/hr
		Offices	12,400
		Rental	11,600

HP Sizing

Dialing in the Peak Heat Load

Use current ASHRAE 99% Heating Design Temp

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	Volume	**ACH**	
Infiltration**	17,125	**0.18**	55
TOTAL UA -- Btu/hr-F			**271**
Heating Design Outdoor Temp			**-1.8**
Inside Design Temp			68
Design Heat Load, Btu/hr			**19,000**
Add for "Pick-Up"		**0%**	**19,000**

Split into two outdoor units (EFG offices and rental)			Design Heat Load, Btu/hr
		Offices	9,800
		Rental	9,200

Outside design temp, F	-20	-7	**-1.8**
Source of design temp	Common VT practice	ASHRAE 1977 99%	ASHRAE 2017 99%

Summary:

Dialing in the Peak Heat Load

Design Heat Load, Btu/hr				
	Initial	As-Built Air Leakage	Lose Pick-Up	Warmer -1.8F Design Temp
Total load	33,900	28,000	24,000	19,000
Load/HP Capacity	**133%**	**161%**	**188%**	**237%**
Capacity: NEEP -13F Btu/hr total for two 24K units				45,000

*Two **24k** units were installed, not on 20 and one 24….*

What's the **REAL** COP of the Heat Pumps?

What's the REAL COP of the Heat Pumps???

If we know the heat load of the building and we know how much energy the heat pump takes we can calculated COP:

COP =
heat load energy /heat pump energy

Calculating COP

If it takes 1 kW of resistance heat to keep the building 30 degrees warmer than outside

and

It takes 0.5 kW to do that using the heat pumps

then

COP = 1.0 kW heat/0.5 kW electricity

COP = 2.0

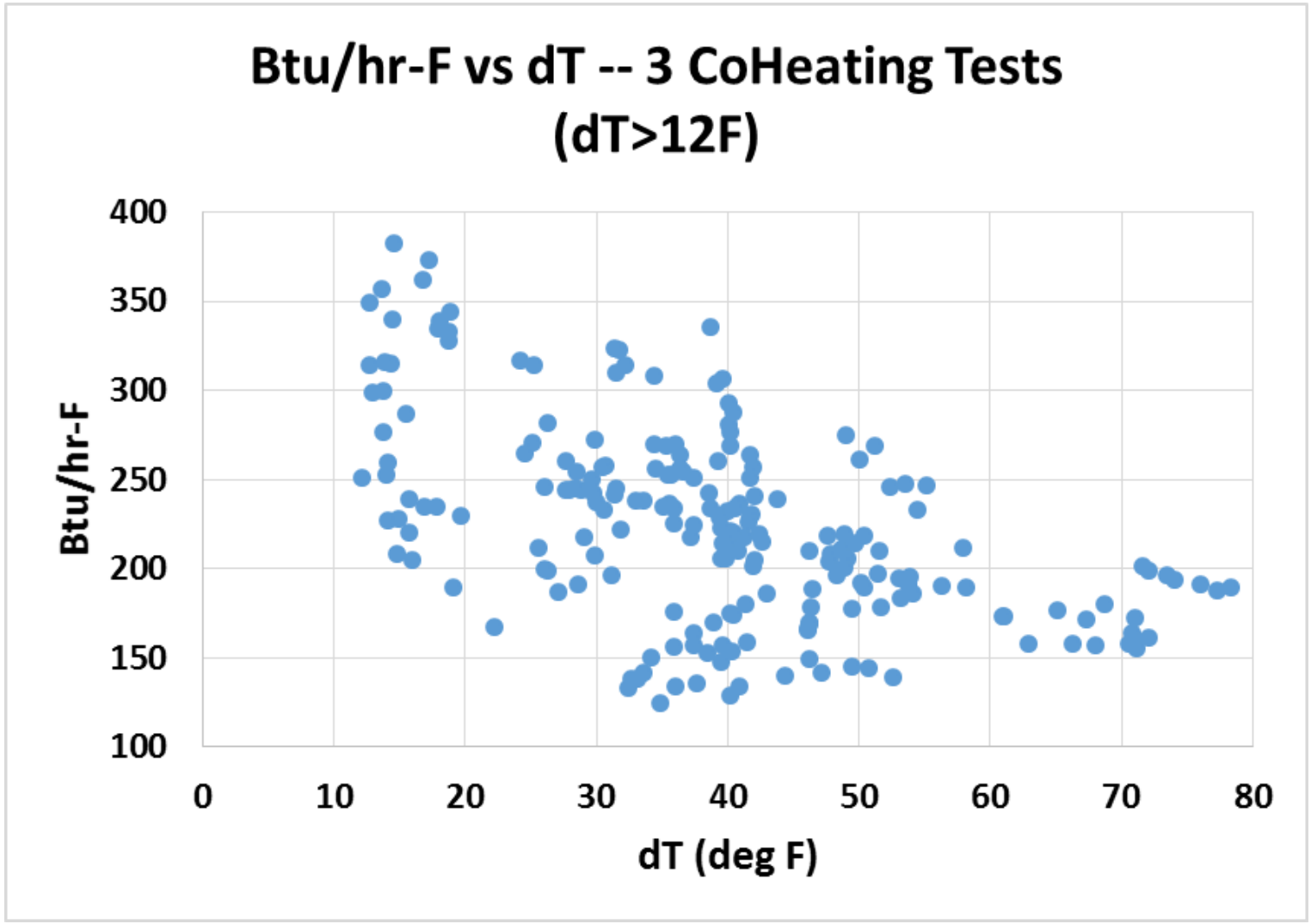
How to find the REAL COP???

“Co-Heating” Test:

Heat the building with electric resistance heat for some days and heat it with the heat pumps other days, alternating.

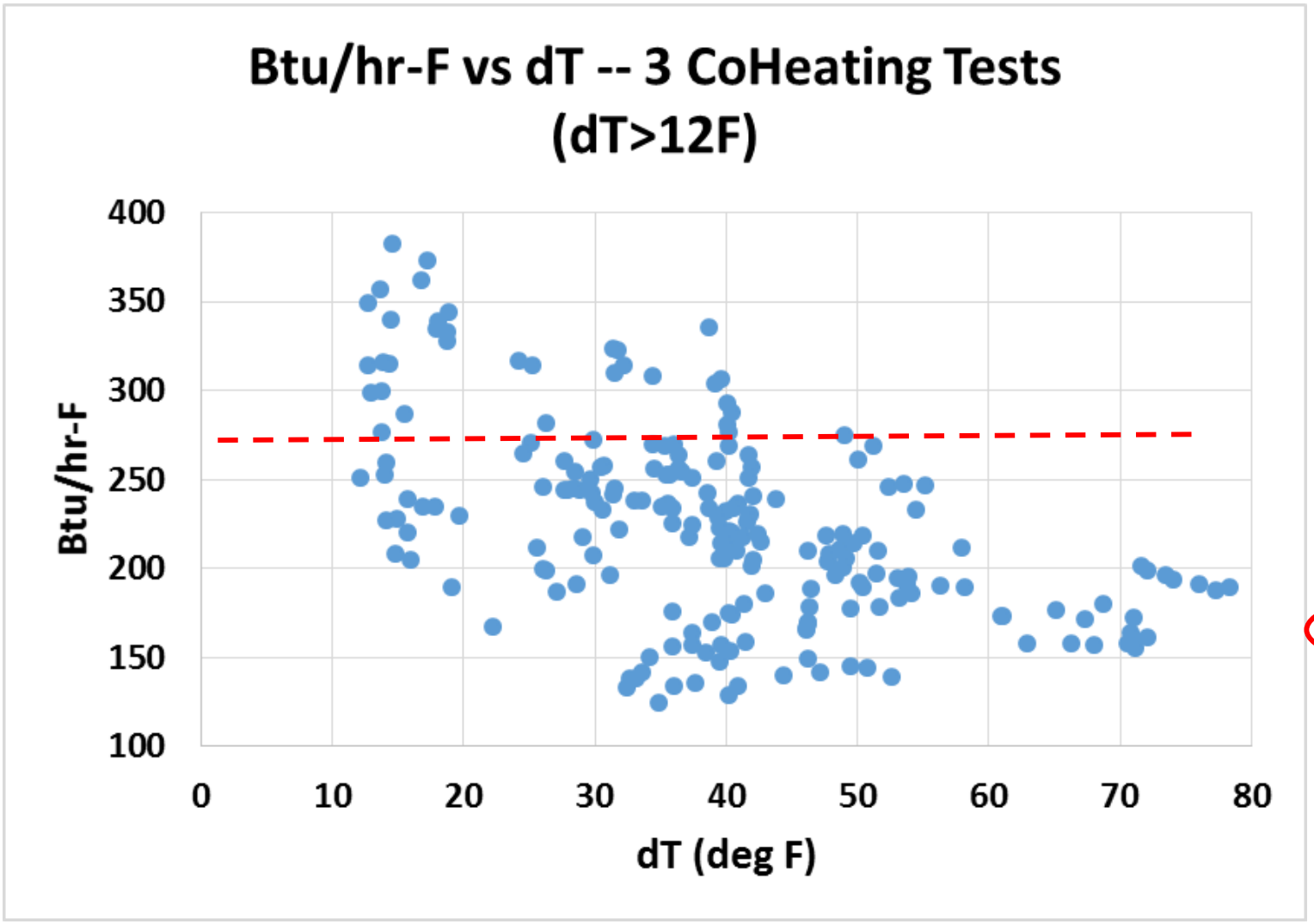
Measure:

- Electricity used for heat
- Temperature inside
- Temperature outside



Electric Resistance Heating, Midnight to 6 AM Only

Field data is messy!



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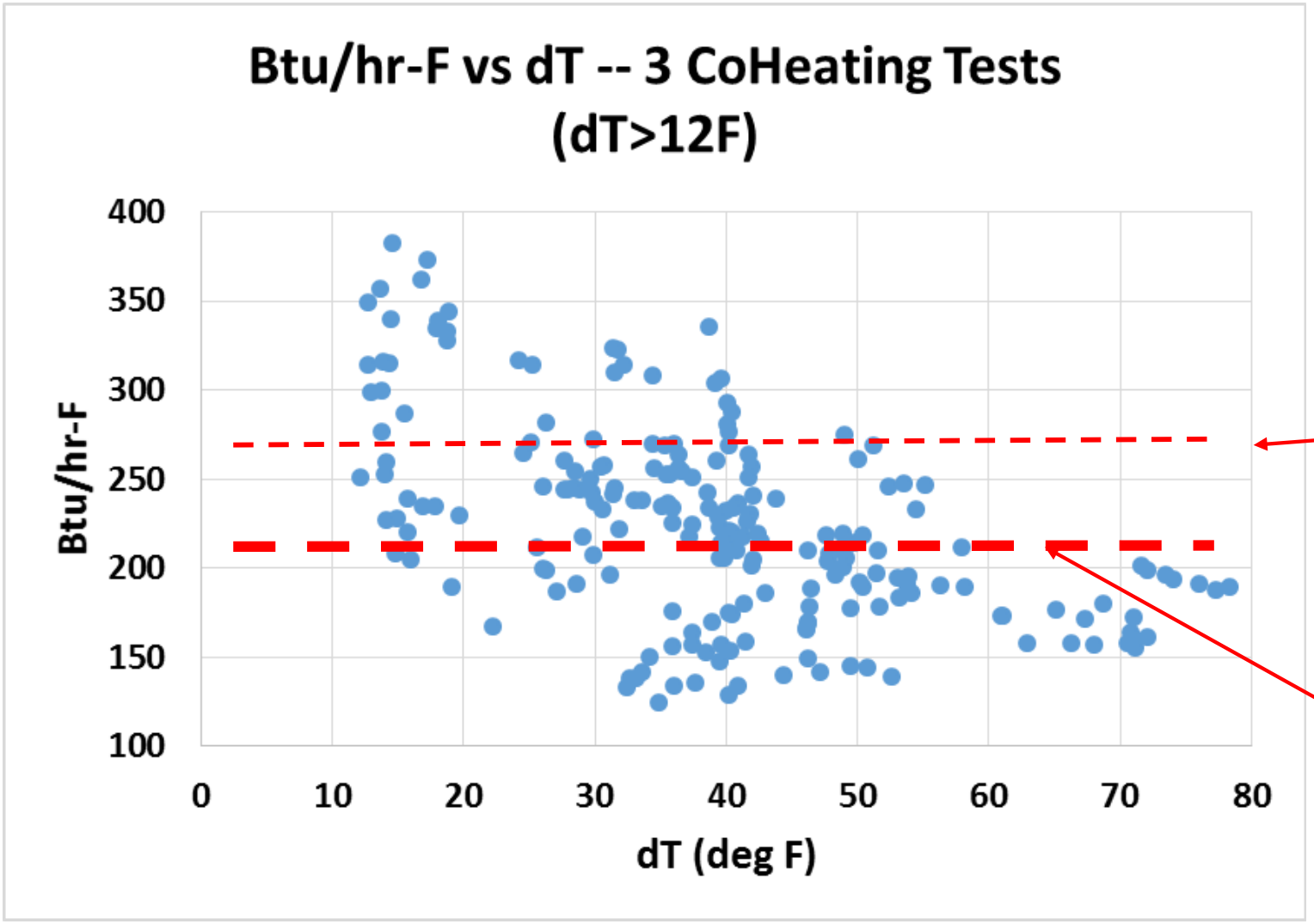

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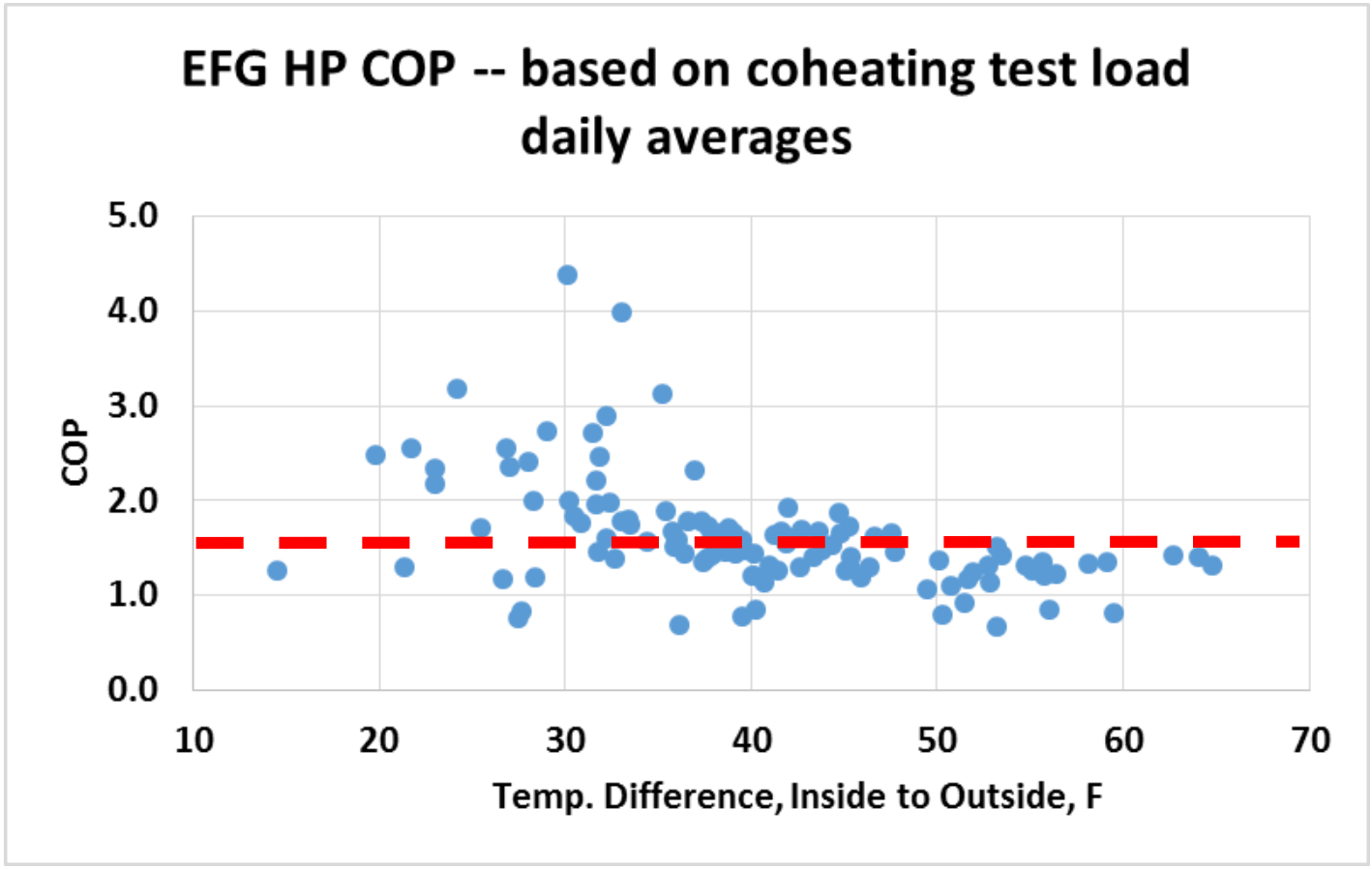
Average of midnight to 6AM coheating test: 212 Btu/hr-F



Average Midnight to 6AM Heat Pump COP

Average COP ~1.3

EFG Heat Pump COP

Heat Source	kWh	degree-hrs	Btu/hr-F
Resistance Heating	517	8,306	212
Heat Pump	1,560	32,386	164
		COP	1.3