BUILDINGENERGY BOSTON

The Results are In: Lessons Learned from Post Occupancy Data in Multifamily Passive Houses

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Northeast Sustainable Energy Association (NESEA)
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Course Objectives

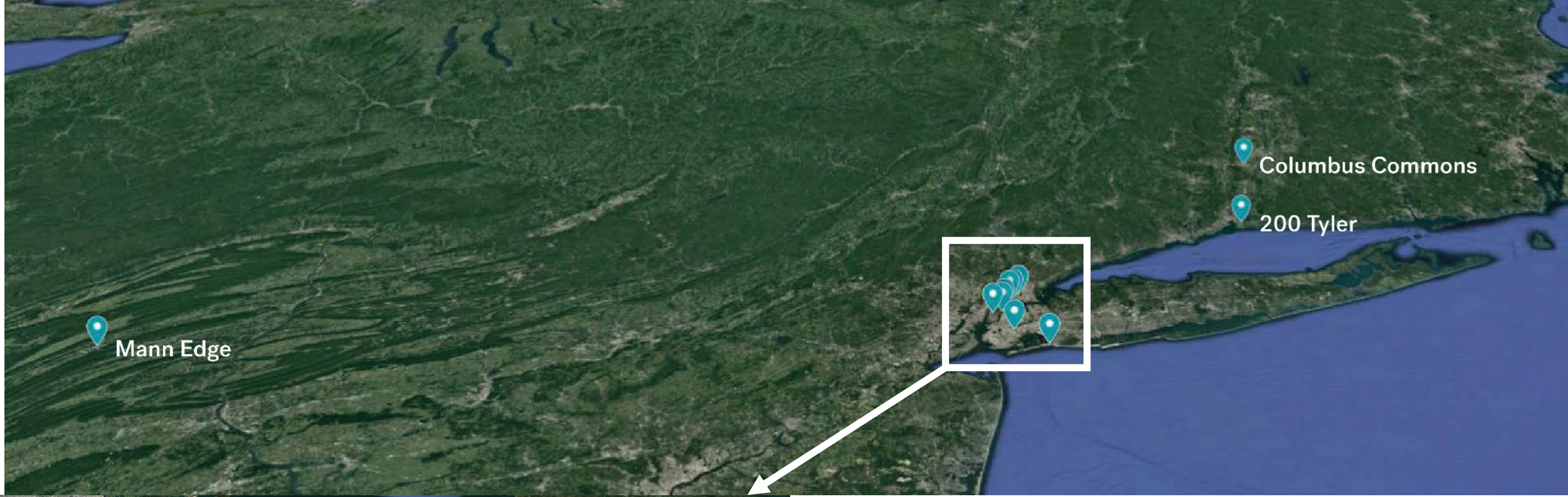
Curtis + Ginsberg Architects has completed 5 multifamily Passive House buildings, with two more in construction and six more in design. Steven Winter Associates has completed over 20 Passive House buildings, with 15 more in construction and 30+ more in design. We have collaborated on many of these projects. By reviewing variations in the systems, we can draw conclusions about what works best for:

- structure, envelope
- ventilation strategy
- heating and cooling systems
- On-site generation
- Residents
- Owners
- We will present the details of at least 6 buildings, what we have learned, and how they are performing to help develop best practices.

Learning Objectives

1. Lean about the performance of many different multifamily Passive House buildings.
2. Learn about tenant and operator feedback on Passive houses.
3. Lean about mechanical systems in Passive House buildings and the pros and cons of each.
4. Learn about different Passive House Envelope Systems and the pros and cons of each.

Site Locations



Data

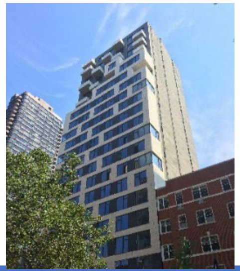




	BGDII	BGDI	3365	Mapes	Park Ave. Green	MG Phase I
Location	NYC	NYC	NYC	NYC	NYC	NYC
SF-Gross	121,433	108,979	51,954	33,473	163,743	92,754
# of Stories	8	8	8	6	15	7
Units	127	101	30	30	154	96
Floor area / Unit	685	809	982	703	809	672
Common Area	34,484	27,245	17,518	12,418	39,227	28,230

Data





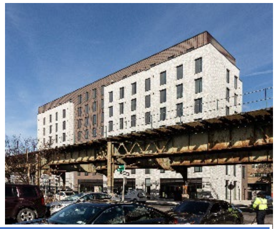

	200 TYLER	211 W 29th	511 E 86 th Street	Columbus Commons	Cornell	Mann Edge
Location	CT	NYC	NYC	CT	NYC	PA
SF-Gross	93,791	65,000	140,000	110,612	266,964	44,718
# of Stories	3	23	22	8	26	4
Units	70	55	140	80	352	34
Floor area / Unit	634	523	583	1,079	465	1,139
Common Area	32,125	9005	26,670	24,269	103,297	5,987

Structures and Facades

Exterior Wall



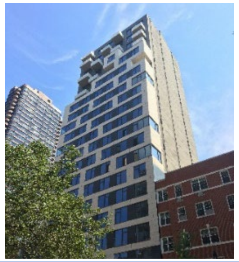




	BGDII	BGDI	3365	Mapes	Park Ave. Green	MG Phase I
Solid	R = 26.72	R = 23.65	R=29.84	R=29.64	R = 27.3	R = 15.60
Windows	U = 0.24	U = 0.22	U=0.12	U=0.17	U = 0.17	U = .29
Roof	R = 30	R = 26	R=40	R=35	R = 50	R = 30
Air Infiltration	0.1 CFM75/ft2	0.096 CFM75/ft2	0.1 CFM75/ft2	0.107 CFM75/ft2	0.04 CFM75/ft2	NA

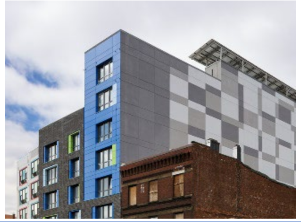
Exterior Wall






	200 TYLER (historic)	211 W 29th	511 E 86th Street	Columbus Commons	Cornell	Mann Edge
Solid	R-10.9*	R-33	R-26	R-34	R-19	R-26
Windows	U - 0.50*	U-0.14	U-0.15	U-0.28	U-0.25	U-0.18
Roof	R-42	R-36	R-26	R-31	R-50	R-54
Air Infiltration	0.23 cfm75/ft2	0.06 cfm75/ft2	0.10 cfm75/ft2	0.10 cfm75/ft2	0.04 cfm75/ft2	0.07 cfm75/ft2

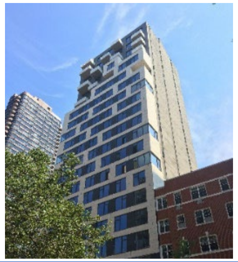
Structures & Facades


	BGDII	BGDI	3365	Mapes	Park Ave. Green	MG Phase I
Structure	Block and Insulation	ICF	ICF	Block and Insulation	Poured in Place / CMU wall	Poured in Place / Stud
Insulation	XPS/EPS/ Spray Foam	ICF	ICF	Polyiso & GPS	XPS /Polyiso Aerated concrete block	Polyiso
Fenestration	UPVC	UPVC	UPVC	UPVC	UPVC	UPVC
Thermal Break Strategies	Structural Fiberglass Thermally Broken Wing Nut Brick Ties	Custom Relieving angle Embed	Febreek Thermal Break at Relieving Angle	Fero Clip	Structural Thermal Isolation blocks	Hohmann& Barnard TBS for relieving angle.

Structures & Facades

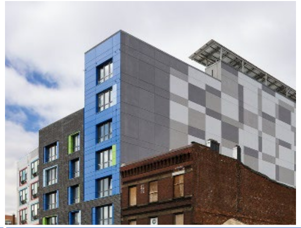


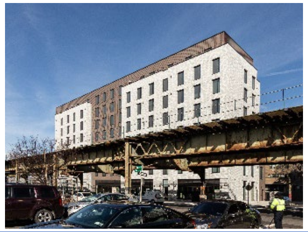



	200 TYLER	211 W 29th	511 E 86th Street	Columbus Commons	Cornell	Mann Edge
Structure	Solid masonry	Concrete/AAC block	Concrete/AAC block	Wood frame construction	Concrete + mega panel	Wood frame construction
Insulation	3.5” ccsf interior	5” ext MW + 1.5 int	1) 3”ext MW + 4” int MW 2) 2.25” Rigid EIFs + 2.5”int MW	3” eps ext + R-19 FG batts interior	11” & 7” MW - varies	2” XPS ext + R21 cell interior
Fenestration	Double pane, metal frame	Triple pane, metal	Triple pane, metal	Triple pane, UPVC	Triple pane, metal	Triple pane, UPVC
Thermal Break Strategies	Custom window surround	AAC block + thermal pads	AAC block + thermal pads	Wood frame– good details	Knightwall clip system, Shock	Wood frame– good details

HVAC Systems

Mechanical Systems

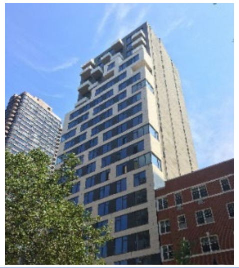



	BGDII	BGDI	3365	Mapes	Park Ave. Green	MG Phase I
Heating / Cooling	Ground Source Heat Pumps	VRF	VRF	Window AC / Hydronic	VRF	Ground Source Heat Pumps
Ventilation	Central ERV's	Unitized ERV's	Unitized ERV's	Central ERV's	Unitized ERV's	Central ERV
Hot Water	Gas Fired	Co-Gen/ Gas Fired	Gas Fired	Gas Fired	Co-Gen/ Gas Fired	Ground Source Heat Pumps

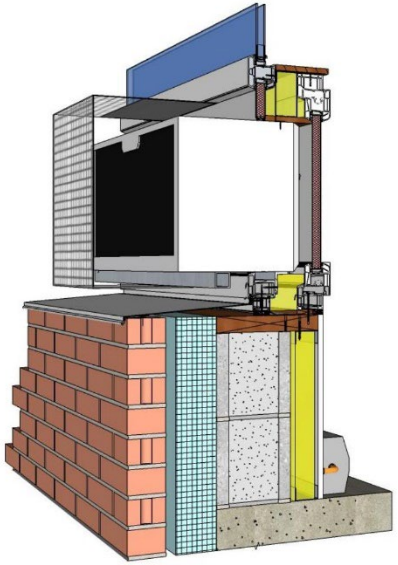
Mechanical Systems






	200 TYLER	211 W 29th	511 E 86 th Street	Columbus Commons	Cornell	Mann Edge
Heating / Cooling	VRF	VRF	VRF	Mini-splits	VRF	Mini-splits
Ventilation	Central ERVs	Central ERVs	Central ERVs	Unit ERVs	Central ERVs	Unit ERVs
Hot Water	Gas fired	Gas fired	Gas fired	Gas fired central	Gas fired	Gas fired central

Low Temp Hydronic/Window AC



MAPES AVENUE APARTMENTS

Design

+ Can be designed for gas today and electric tomorrow, or for hybrid operations
+ Flexibility in terminal units (floor units, ceiling mounted, vertical units in cabinets)
+ Heat recovery for DHW possible
- Simultaneous heating-cooling options are more limited

Hydronic Heating and Window AC

Performance

- \+ Boiler/radiator sizing better matched to load
- \+ Heat recovery option allows for simultaneous heating and cooling
- \- Pumping power for hydronic can be high
- \- Least efficient cooling option

Design

- \+ Less riser and ceiling space
- \- Need rigorous system to prevent air leakage through window A/C during winter months

Maintenance Operation

- \+ Cooling on tenant meter
- \+ Lower coolant leakage
- \+ Occupants can turn on cooling whenever they want

Co-Gen

Combined Heat and Power

- Provide emergency power
- Utilize Generated Heat for domestic hot wall
- Reduces demand of domestic hot water heater
- Creates carbon.

Energy Consumption / Generation

Solar Arrays

Mark, can we remove MG and just show this one slide for the projects that actually have solar?





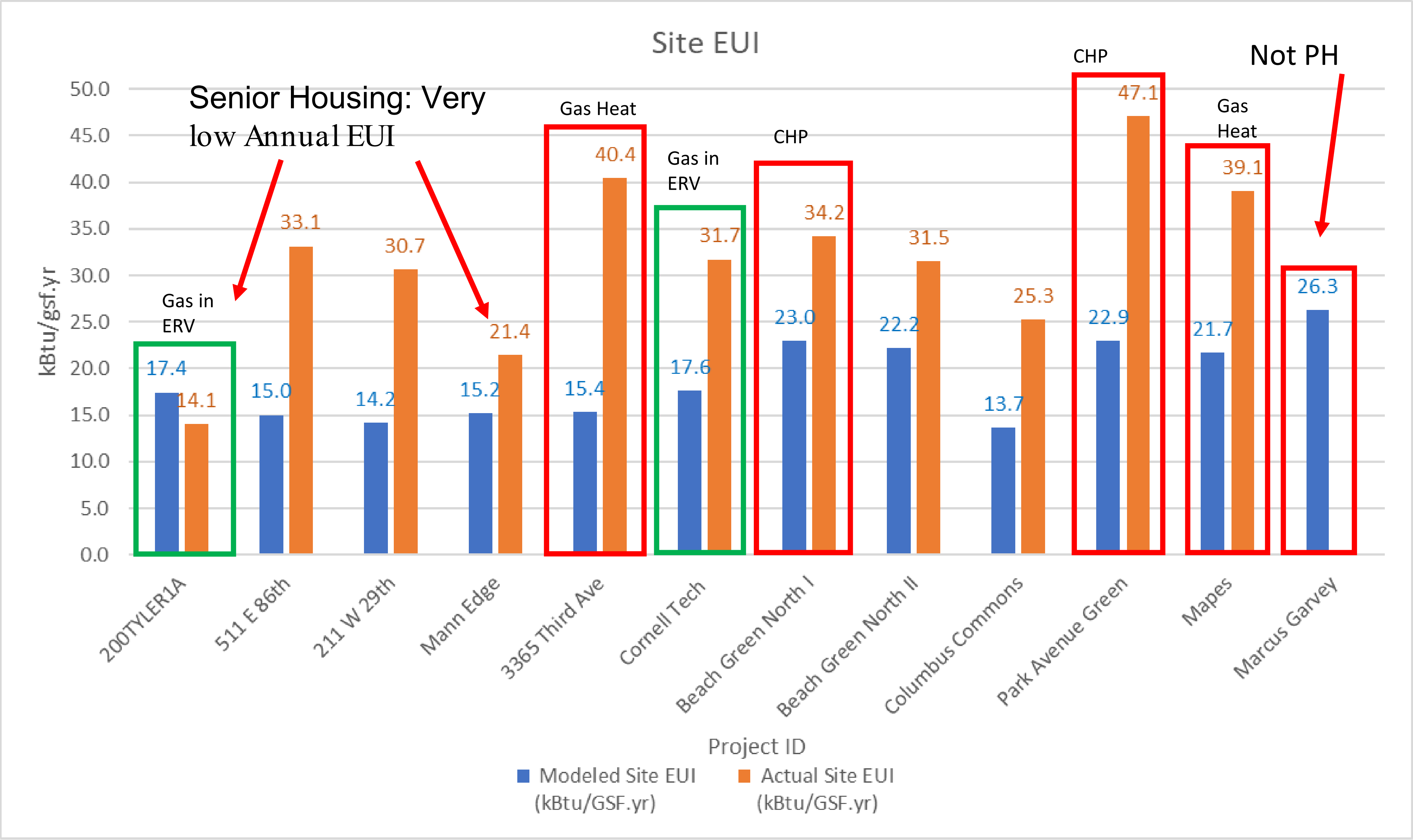
	BGDII	BGDI	3365	200 TYLER	Park Ave. Green	MG Phase I
Size (ft2)	10,200	8,000	2,300	5,977	1,615	n/a
Capacity (kW)*	≈ 180	≈ 144	41.3	94	34	n/a
Potential Output (kWh)	78,000 yr 1, 155,000 yr 2	120,000	52,838	93,797 yr 1 113,902 installed	44,648	n/a
Issues	Invertors issues yr 1	n/a	n/a	Invertors issues	n/a	n/a

* Approximated based on array area x 18W/ft2

Notes on the Following Data & Graphs

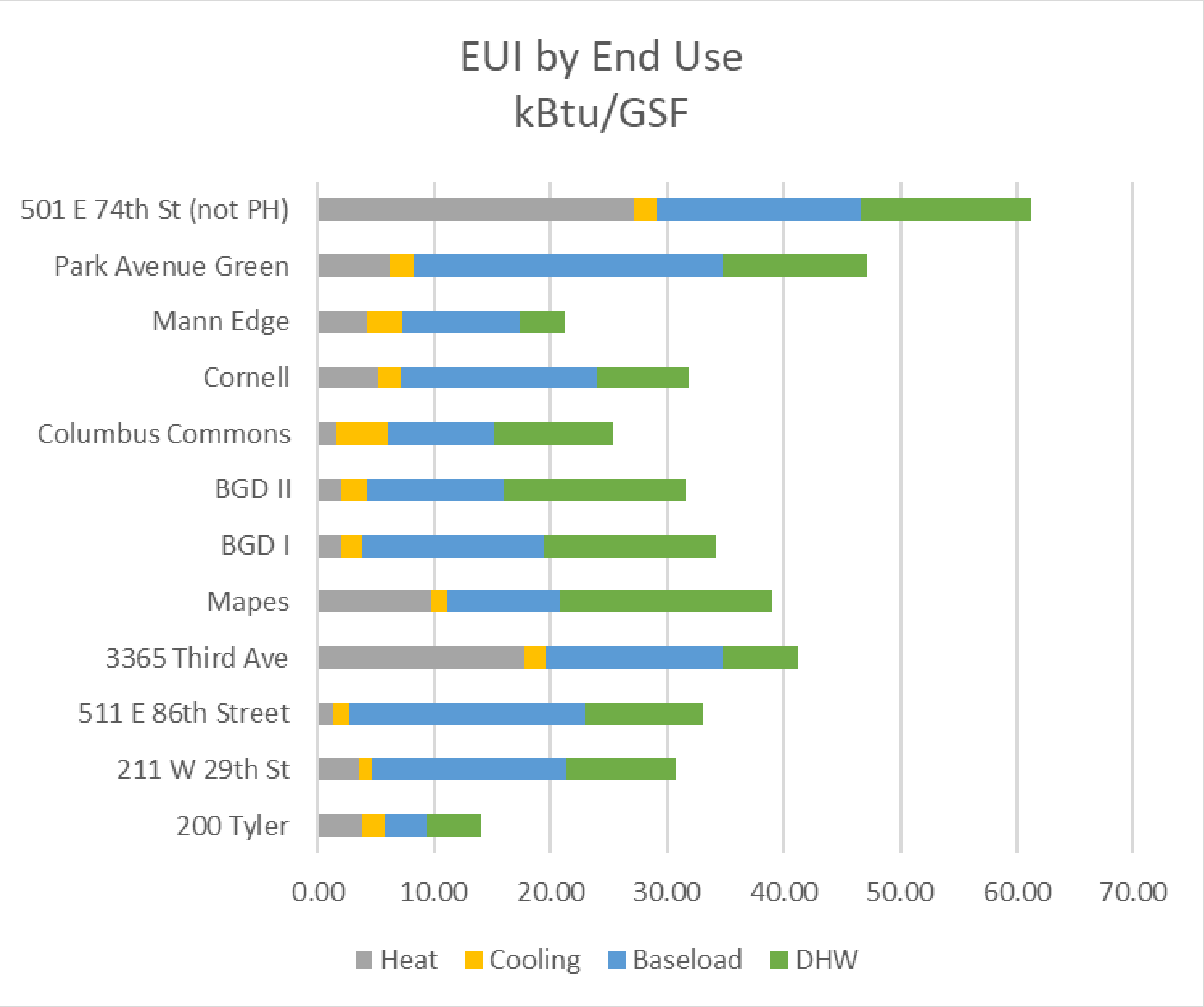
- Initial Analysis – monthly data for house meter only
- Tenant data not available at that time
- Estimates from models were used for tenant lighting, appliances and plugs
- PH design for all but 1
- Most projects have heating, cooling and DHW included on the house meter
- Exceptions are Mann Edge (PA) and Columbus Commons (CT) - mini-splits
- DHW is central gas recirc in all cases except MGI which has no available utility data at this time

Predicted vs. Actual Site EUI

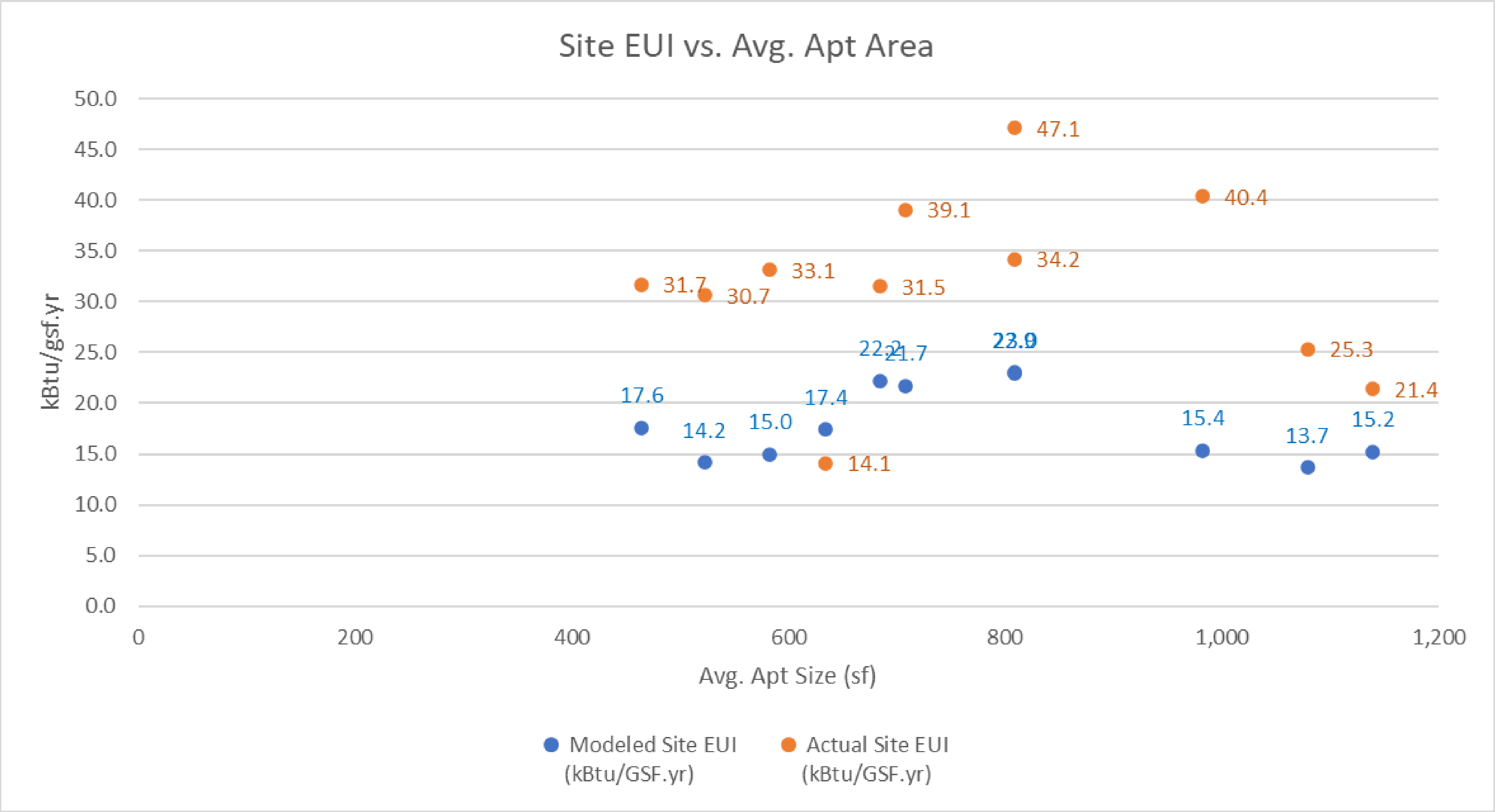


Issues with Monthly Data

- Very hard to determine
  - baseload – non-heating/cooling energy use
  - Heating vs. cooling energy – not needed at the same outdoor temps as typical construction
  - Apartment lighting and plugs vs. common areas
  - Correlations between building characteristics & demands

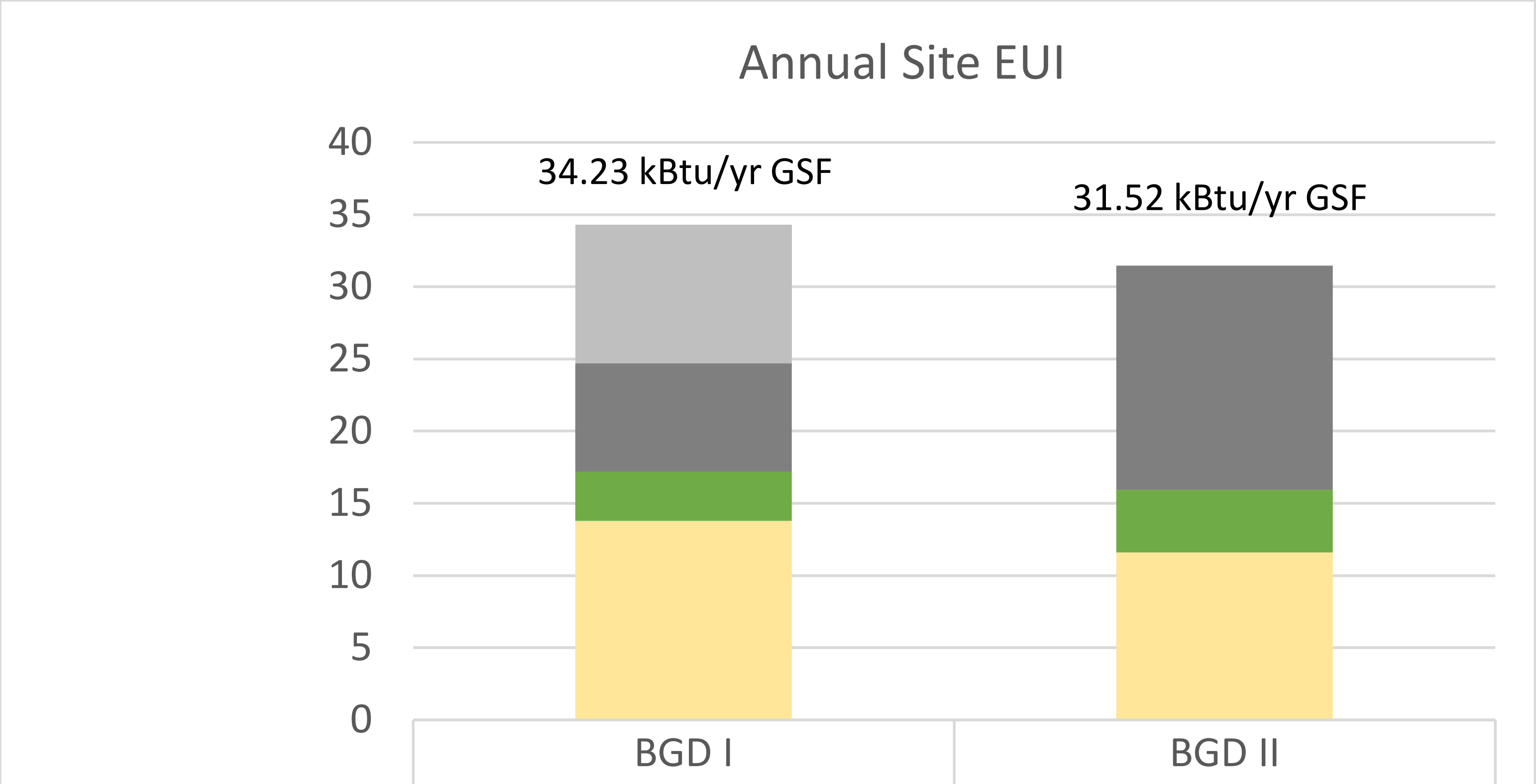


EUI vs. Average Apartment GSF



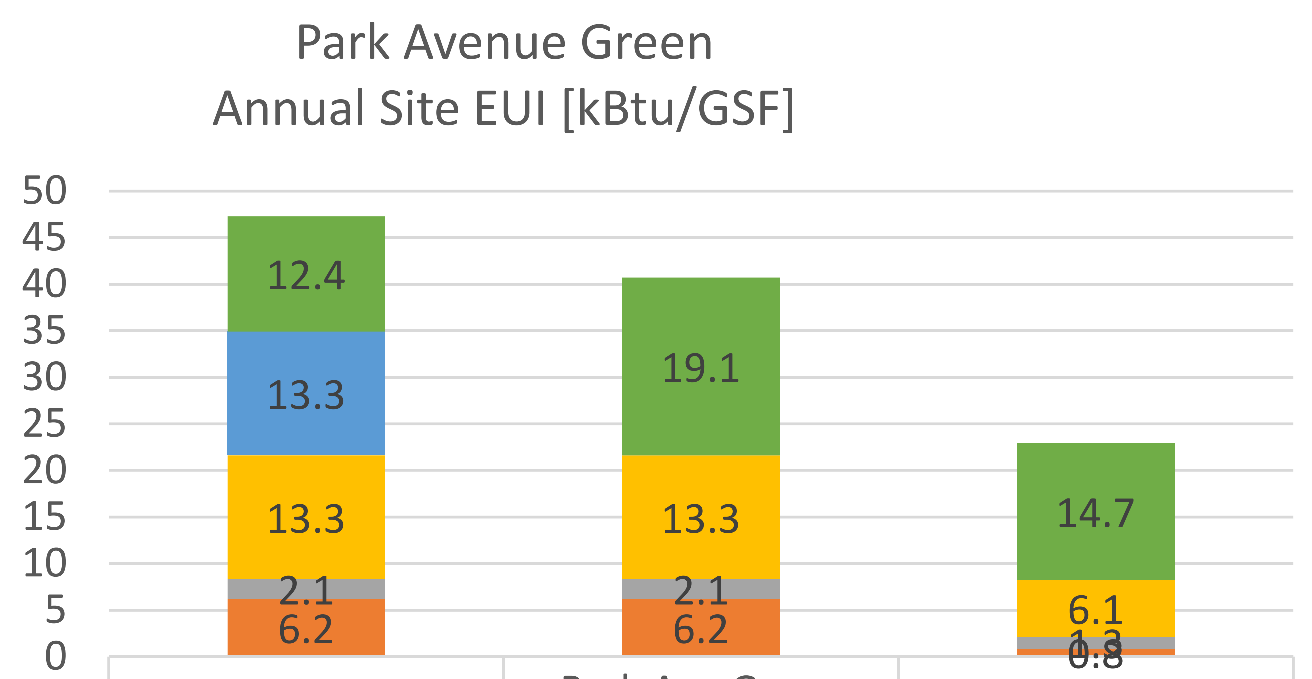
Site EUI Comparison: CHP vs no CHP

- Major differences
  - CHP
  - Solar PV array size
  - # of apartments



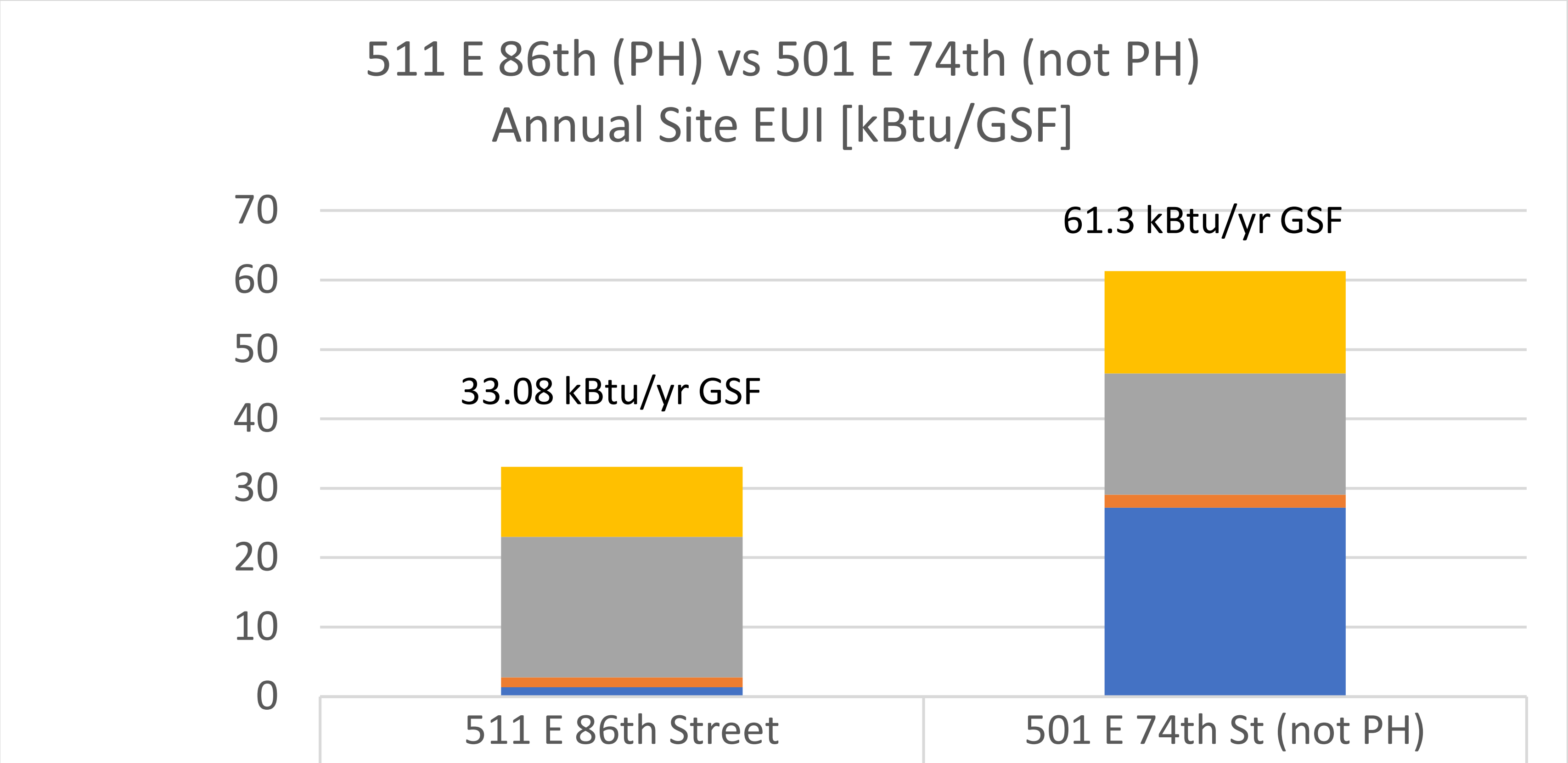
	BGD I	BGD II
CHP Gas	9.6	0.0
WH Gas	7.5	15.5
Solar to Building	3.4	4.4
Grid Electric	13.8	11.6

Site EUI Comparison: CHP vs no CHP



	Park Ave Green 2021 (actual - Site)	Park Ave Green 2021 (est. no cogen - Site)	Predicted (no cogen - Site)
Electric Baseload	12.4	19.1	14.7
CHP	13.3	0	0.0
Baseload Gas	13.3	13.3	6.1
Cooling	2.1	2.1	1.3
Heating	6.2	6.2	0.8

2021 PH vs. 2016 non-PH

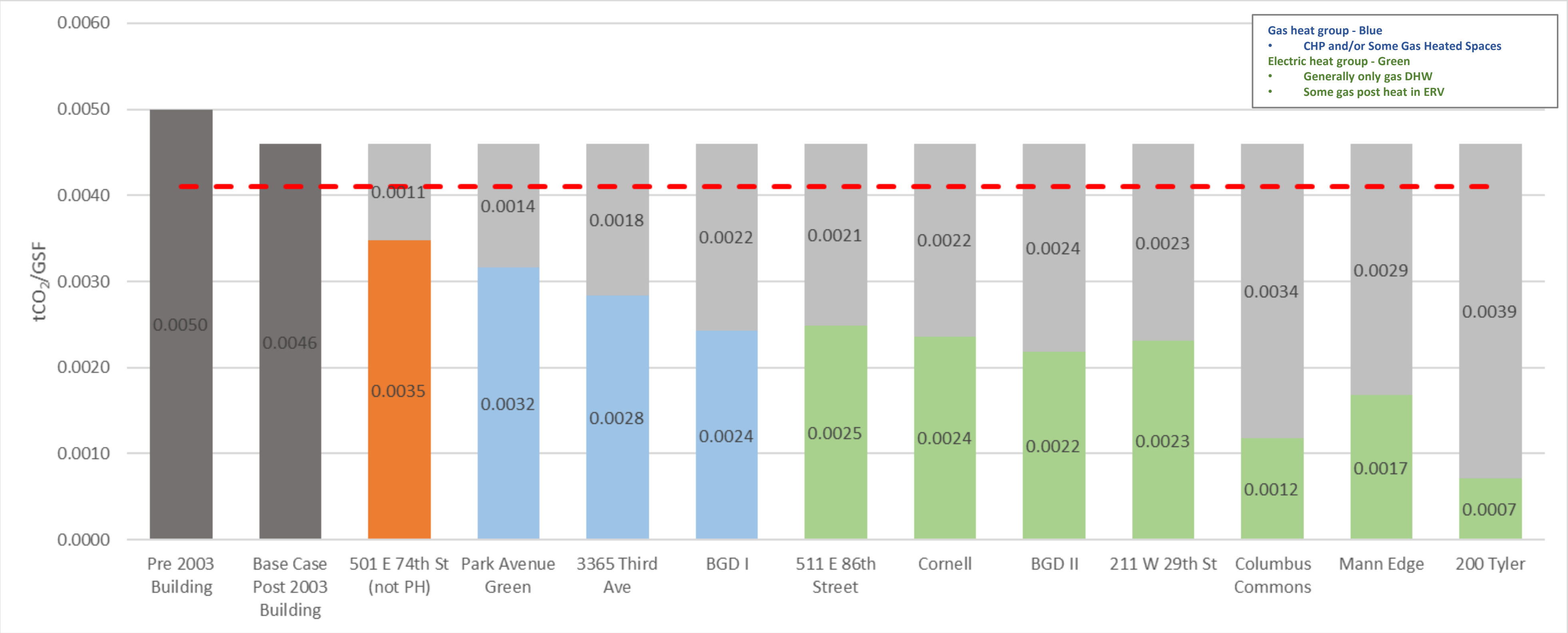


	511 E 86th Street	501 E 74th St (not PH)
DHW - Gas	10.04	14.8
Baseload	20.28	17.5
Cooling	1.39	1.9
Heat	1.36	27.2

WHOLE BUILDING SITE EUI

1. Post 2003 Building sample is made up of NYC buildings with at least one full year of consumption data and includes approximately 94% buildings with gas heating, 6% with electric heating.
2. PH-1A & PH-1B have gas heating and hot water. The remaining projects have electric heating (VRF)
3. PH current target based on PHI standard 38 kBtu/sf/yr. Ranges from 20 (model) upper 20's-low 30s (25% gas + 75% electric fuel mix – typ. of gas DHW + elec heat) when building commissioned.

WHOLE BUILDING GREENHOUSE GAS EMISSIONS: RELATIVE TO LL97 2030 TARGET



1. GHG emissions use 2024-2029 emissions coefficients outlined by Local Law 97 of NYC. Note that the emissions factors for 2030 have not yet been established. There is a strong likelihood that the combination of Indian Point closing and gains made as part of the CLCPA, the coefficient will be similar to the one set for 2024-2029.

ENERGY USE: MODELLED VS. ACTUAL

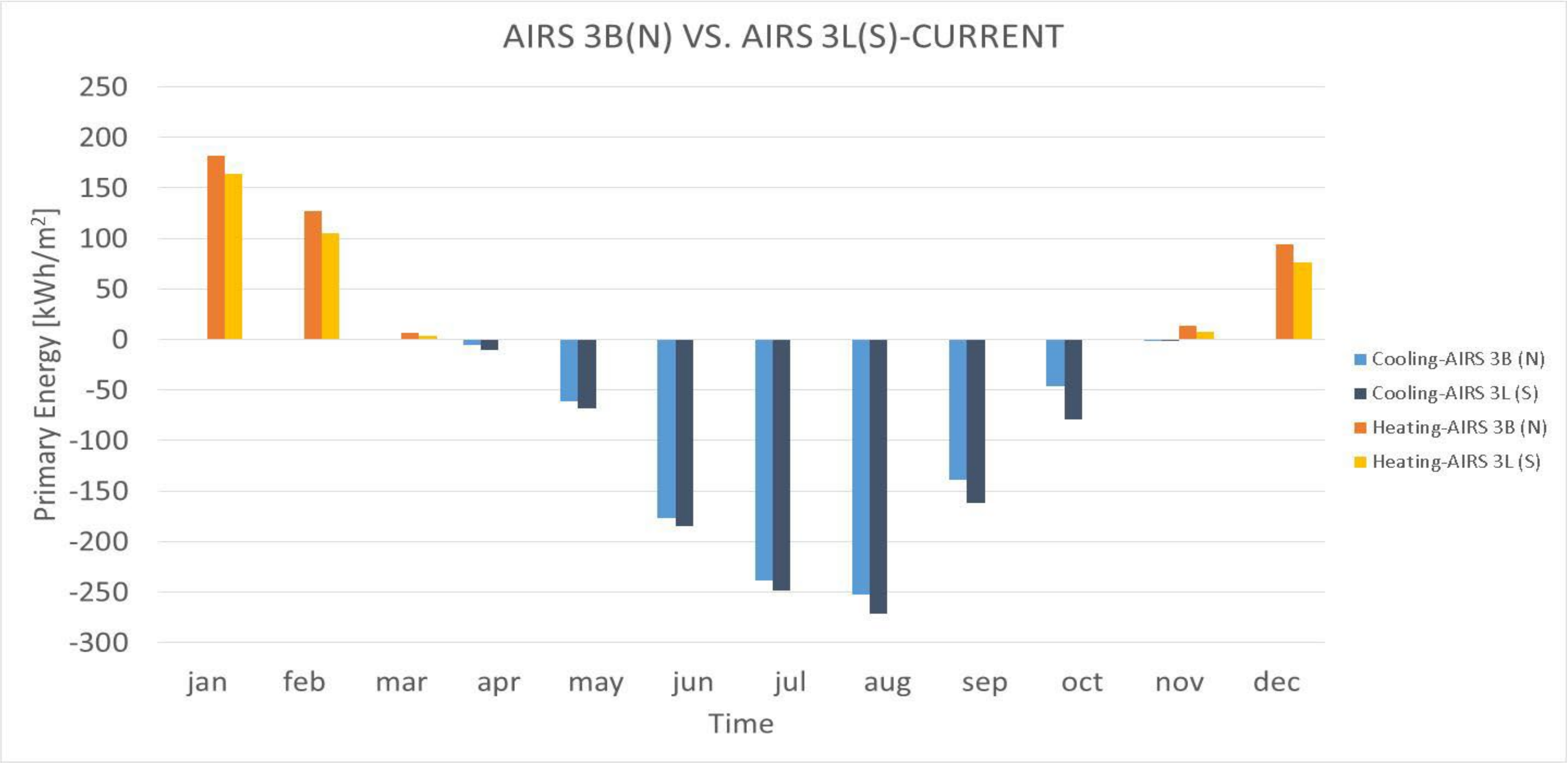
ENERGY MODEL

Informed estimate based on defaults + operational assumptions

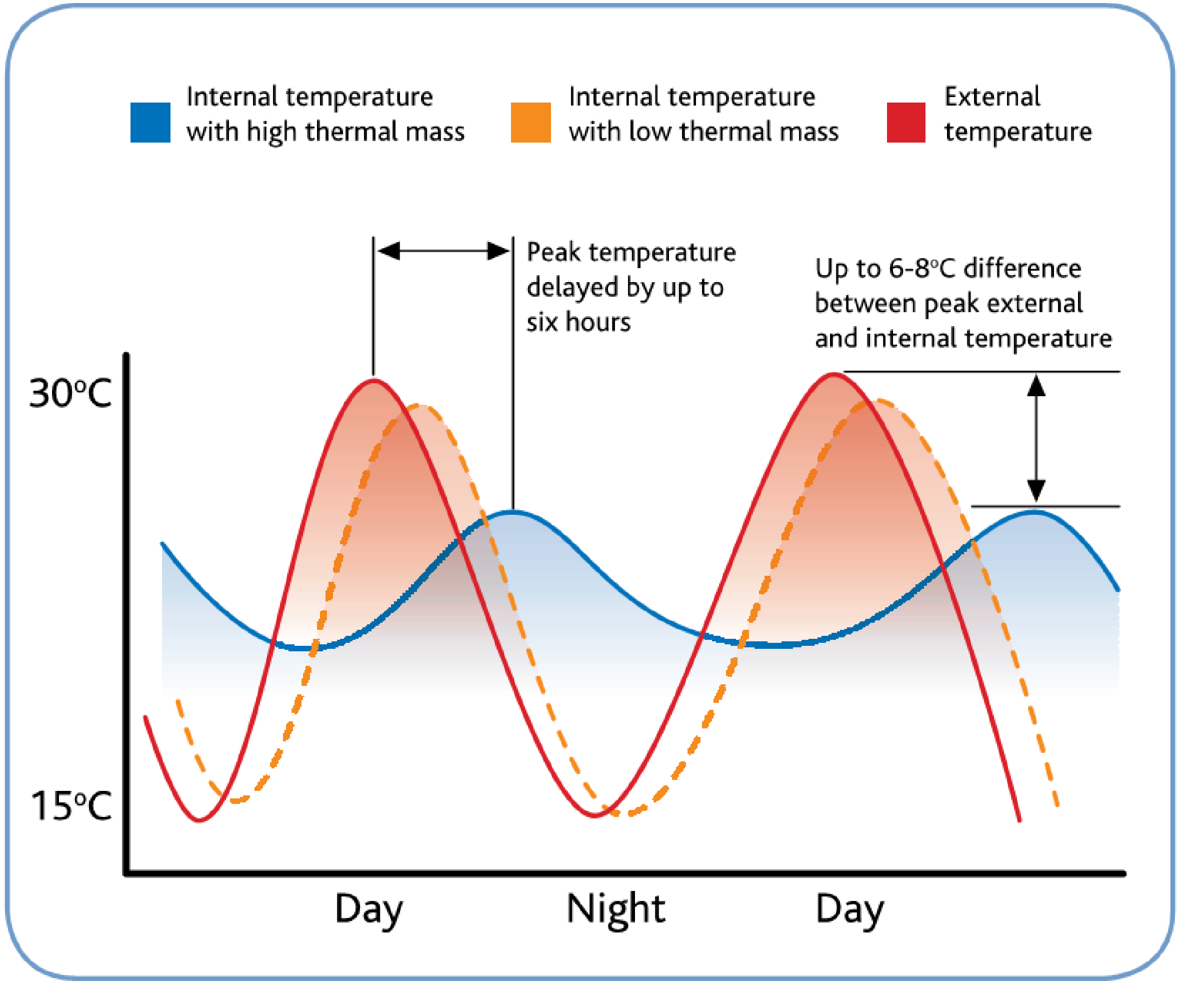
REALITY

Occupant behavior + true operation

When do you heat / When do you cool?



Passive House Buildings are More Resilient



Electric Resistance Older vs. Newer CCHP (PH)

Site #	Year Built	Heating/Cooling System; Metering Config; on-site generation	Gross Floor Area (GFA) [square feet]	Number of Apartments	Height [number of stories]
Site 01	2017	Air source VRF (CCHP); Submetered	266,964	356	26
Site 02	2019	Ground Source HP (CCHP); Direct metered except H/C; solar PV	121,433	127	9
Site 03	2014	1 air source HP per Apt (CCHP); Direct metered except H/C; solar PV	89,760	101	11
Site 04	1975	Elec resistance baseboard (ERBB) / sleeve AC; Master Metered	665,747	555	38
Site 05	1975		795,110	710	42
Site 06	1975		693,459	578	40
Site 07	1969		804,200	1,017	16
Site 08	1974		680,000	600	34
Site 09	1974		43,941	64	9
Site 10	1972		360,418	306	13
Site 11	1974		343,006	341	32
Site 12	1975	PTHP/ elec resistance (PTHP); Submetered	447,431	360	40
Site 13	1975		447,431	360	40
Site 14	1973		341,981	370	37
Site 15	1983		1,881,612	1712	34

**Site 1 is on a meter that is part of a larger campus electricity setup, so it doesn't have an electricity meter of its own to share access to. This building also has a submeter for just the heating and cooling system, but that data was not accessible, so the data is for whole-building usage like the rest of the buildings in this study.*

Peak Heating vs. Peak Cooling

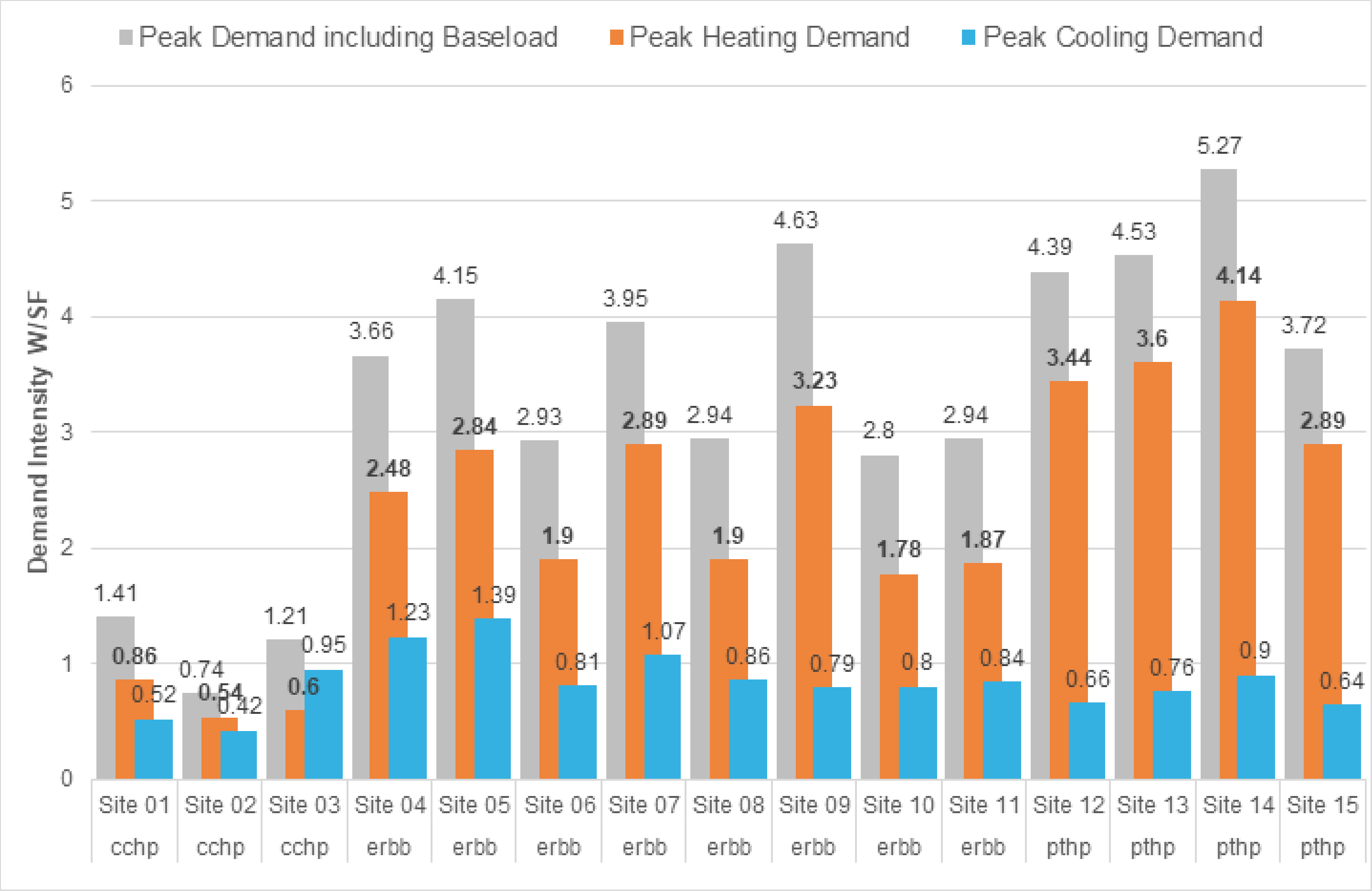


Figure 1. Measured peak demand values for the analyzed buildings. "cchp": cold climate heat pump, "erbb": electric resistance baseboard, "pthp": packaged terminal heat pump (not cold climate, likely 100% electric resistance).

Peak Heating vs. Outdoor Temperature

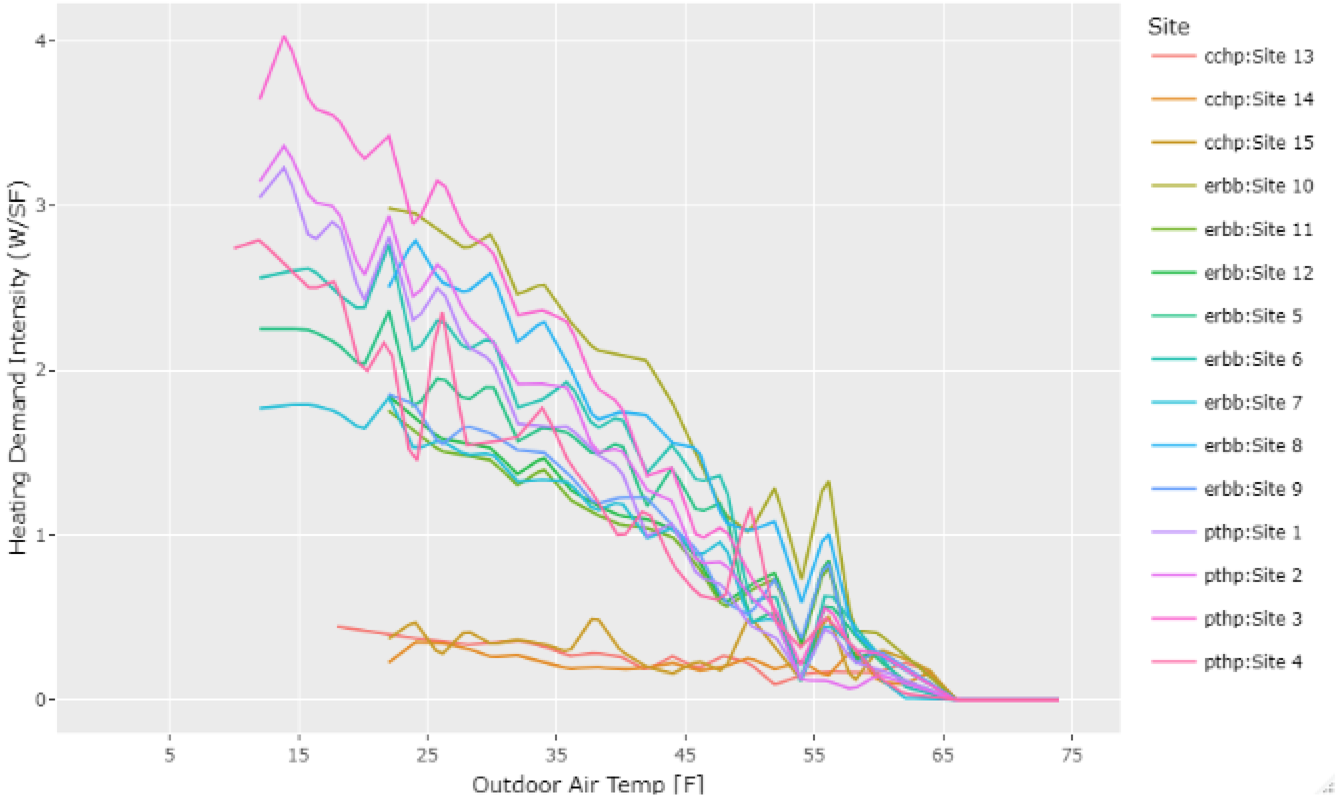


Figure 9. Peak heating demand intensity at each outdoor air temperature for all buildings. For each building, the line represents the 95th percentile heating demand intensity, ***not the average.***

Methodology for Future Analysis

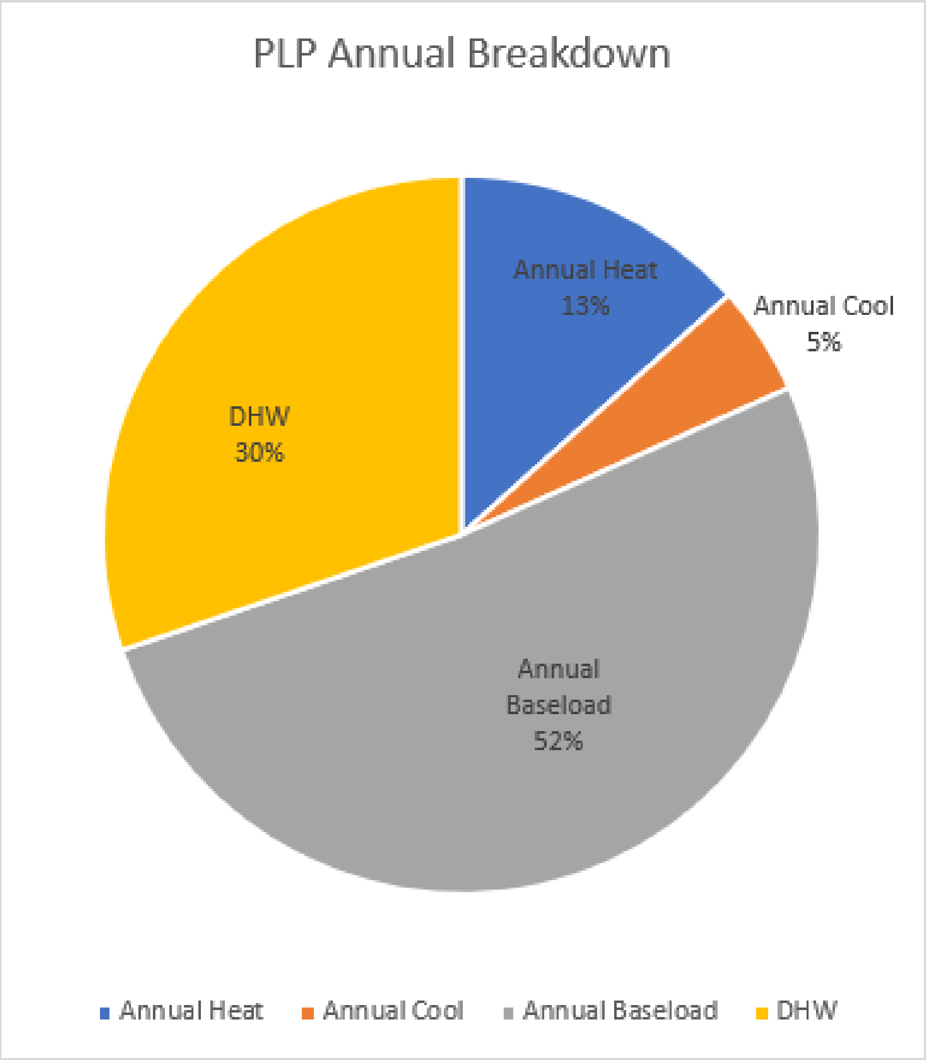
1. Building electricity demand data: merge with outdoor air temperature (OAT) data and bin to 2°F increments
2. Inspect demand distribution for each OAT bin and identify the maximum demand
3. Calculate average electricity demand for each OAT bin
4. Identify maximum demand during the monitored period for heating (coldest times) and cooling (hottest times), and the maximum when neither heating nor cooling are needed (mild weather).
5. Calculate non-heating demand by:
   - Find days in November through April with an outdoor temperature of 55-65°F
   - Average the hourly profile for those days, by building, weekday/weekend, and pandemic state

The average profile per building is the non-heating-cooling demand ("baseload")

6. Calculate heating demand by subtracting baseload from total demand when OAT is less than 65°F - Must be changed for PH
7. Calculate cooling demand by subtracting baseload from total demand when OAT is higher than 65°F - Must be changed for PH
   - NOTE: The method used in this study may overestimate heating usage in mild weather, but this should not impact the demand peaks at very cold temperatures.
8. Compare heating demand intensity across buildings to identify trends and correlation with other building characteristics.

211 W 29th Street – 15 min Data Analysis

- Certified PH
- 31 kBtu/yr GSF
- High surface area to volume ratio
- Some ERV maintenance issues August - September



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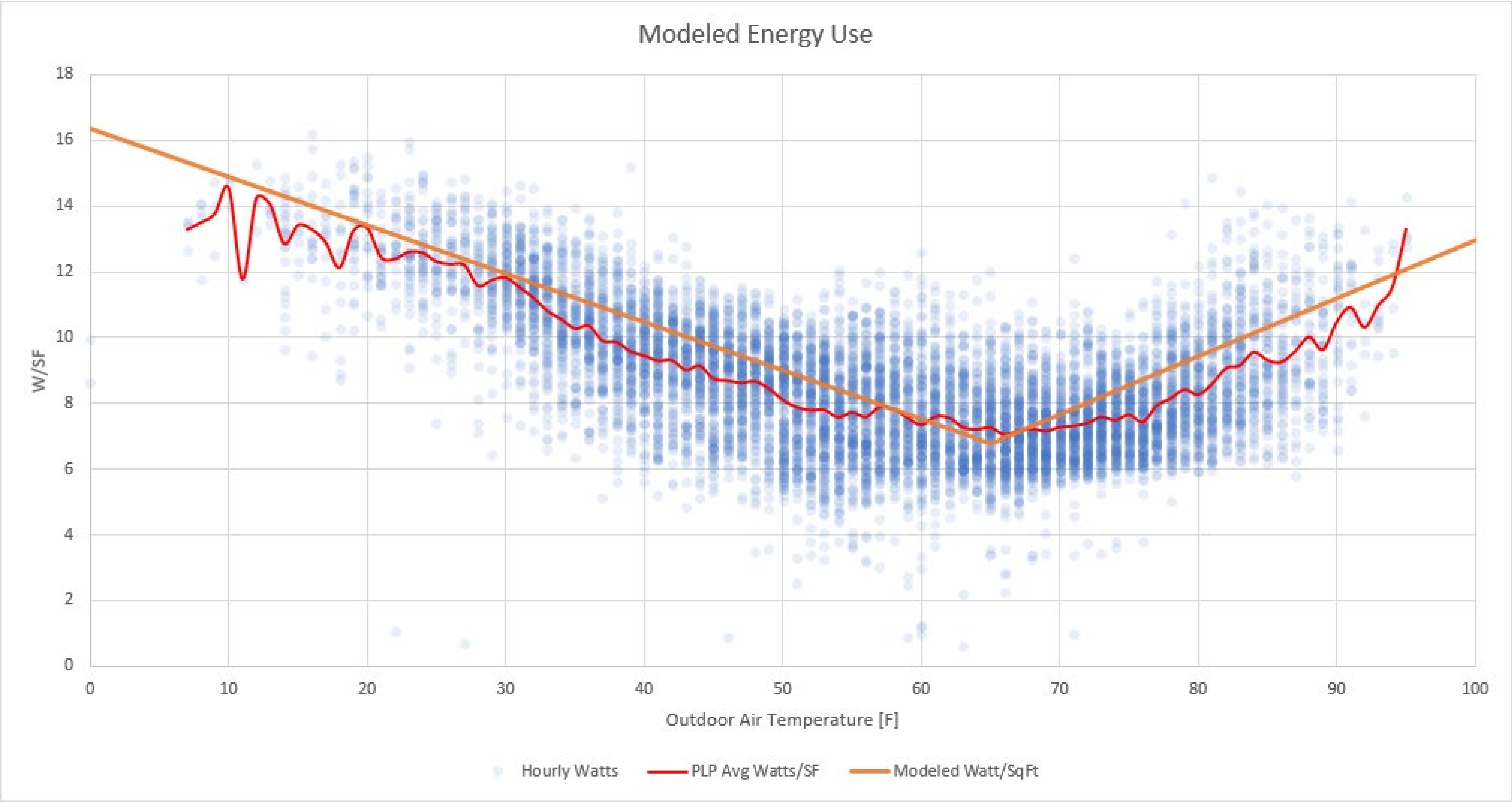

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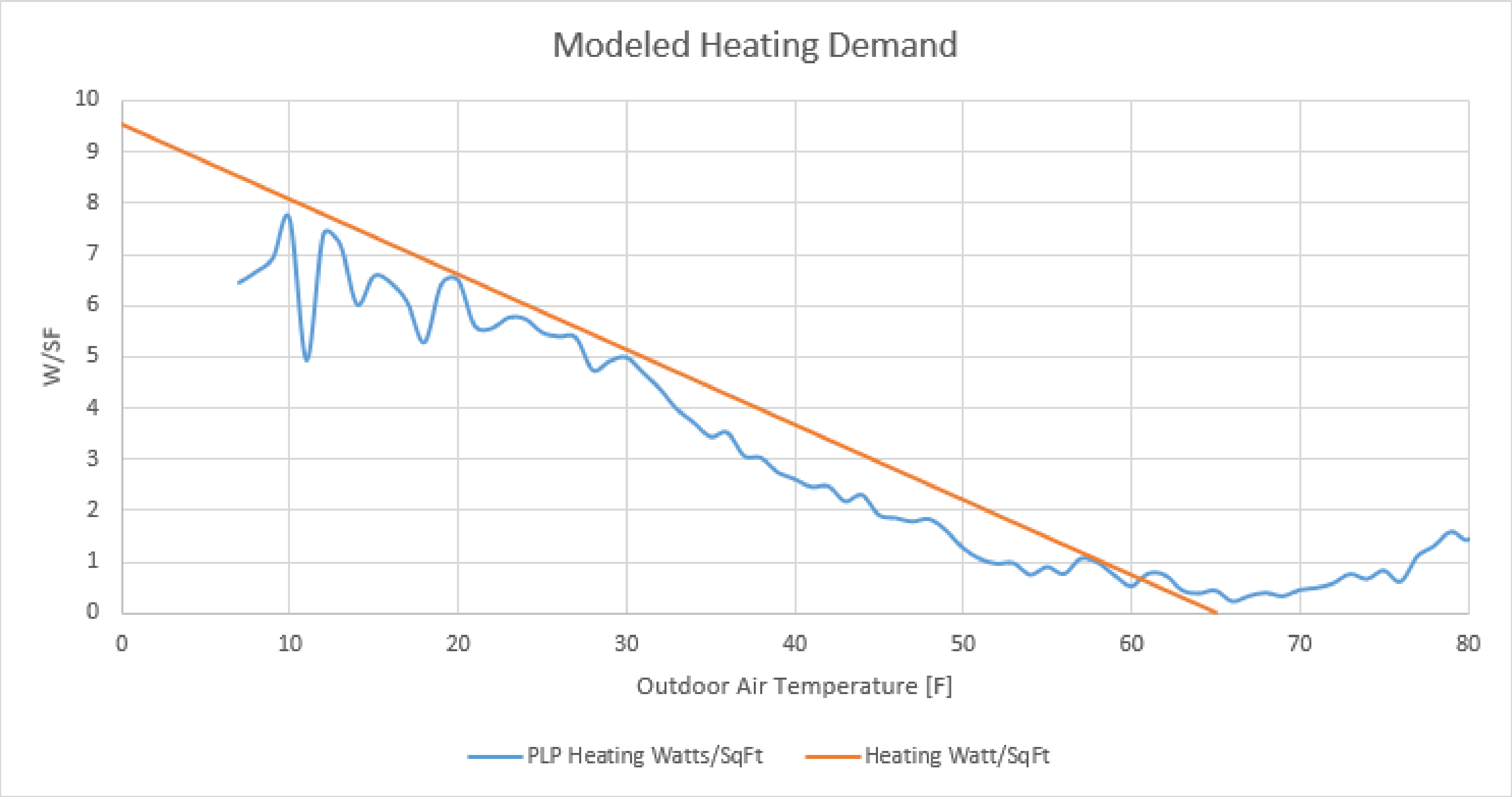

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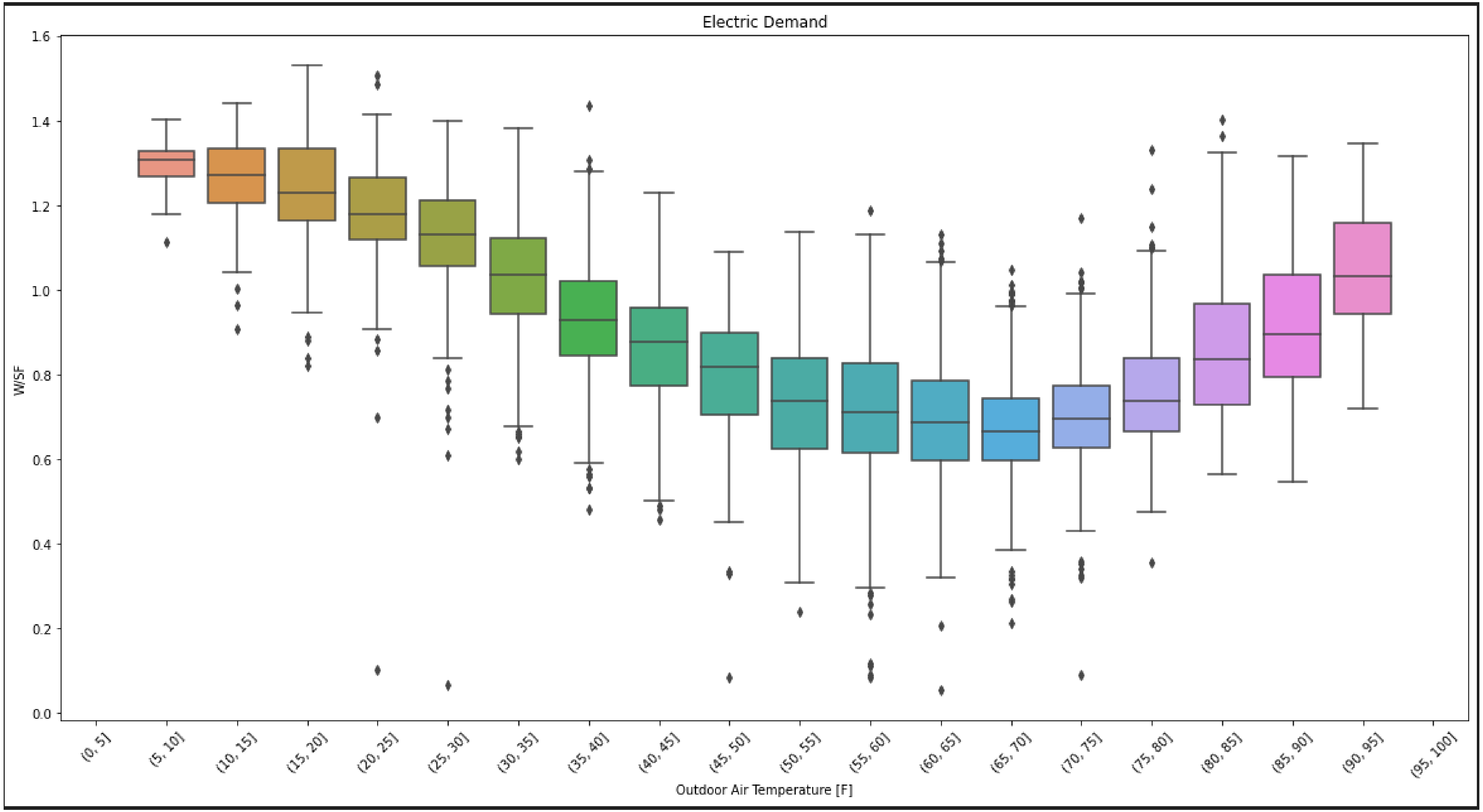
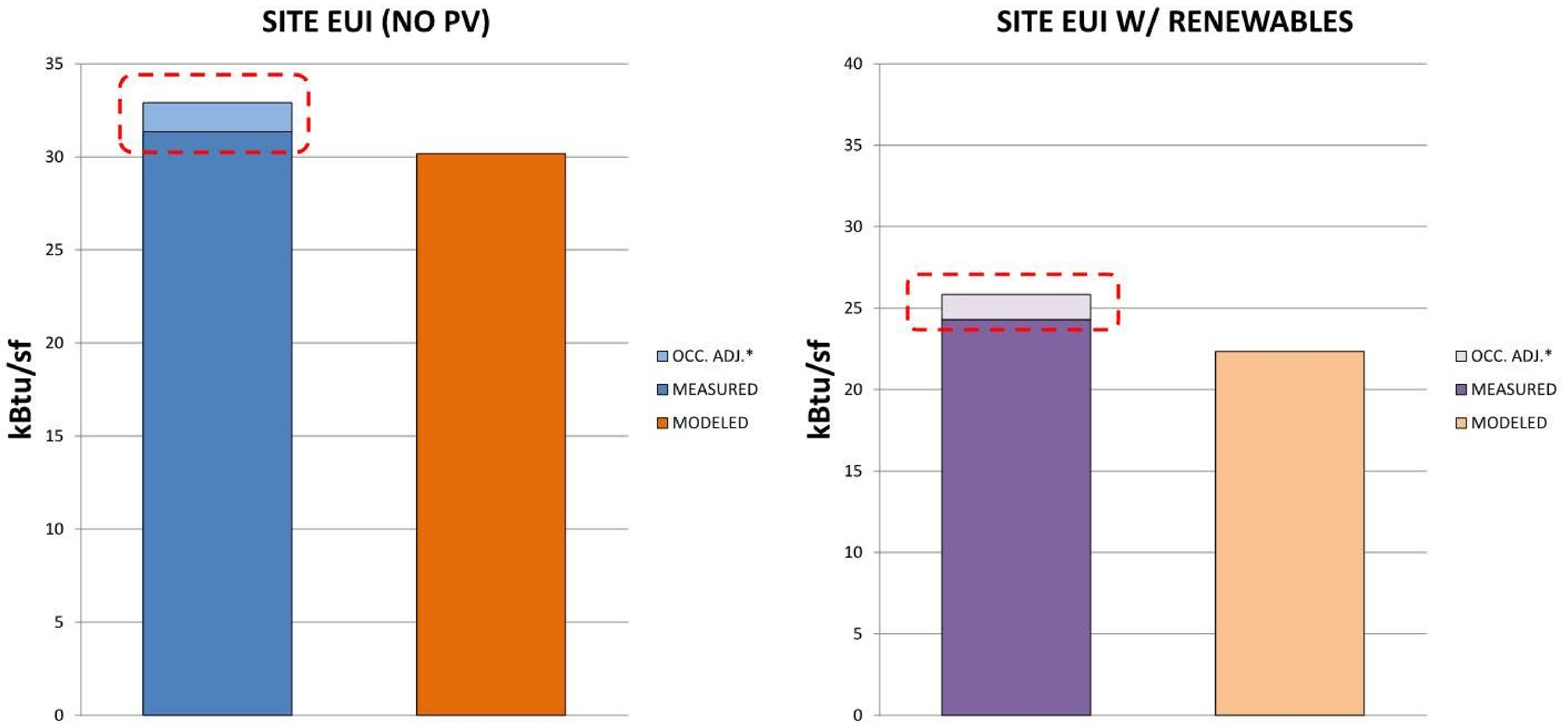


Lessons Learned

BEACH GREEN DUNES

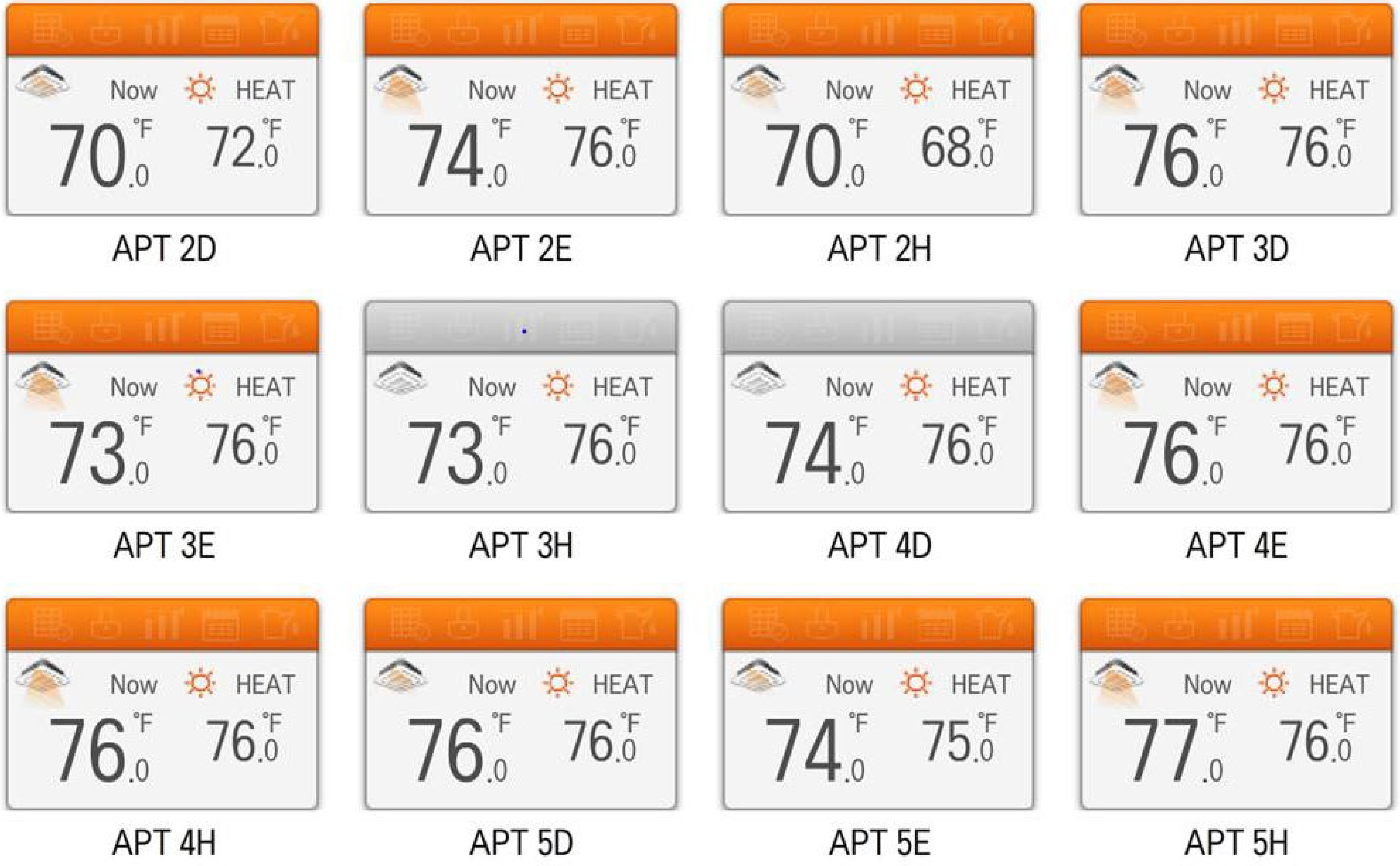
89% Modeled vs Actual



BGD-I

Why?

Thermostat Settings



BGD-I

Why?

Co-Gen

Valve

BGD-I

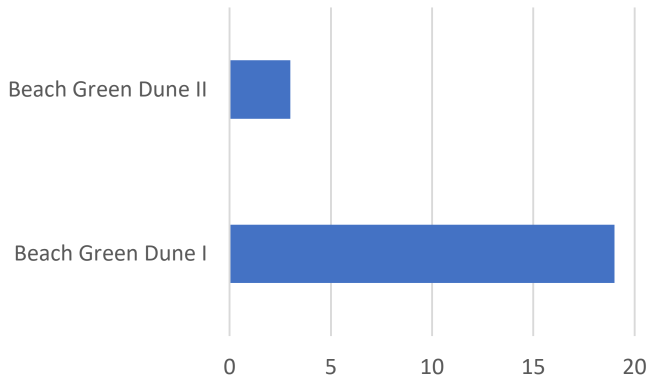
Super Interviews

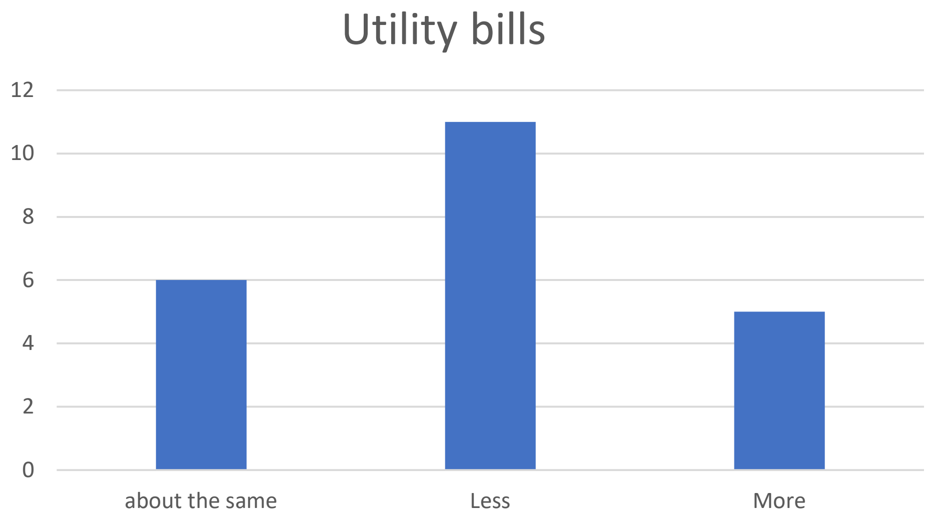
- Spoke with: Director of Property Management, Manager, Supers
- Heating/Cooling
  - Get technical support from HVAC vendors, didn’t have additional training at turn over
  - Need more HVAC contractors trained on VRF
  - VRF setup is important– trouble shooting has been an issue
  - One unit down, takes down the entire loop in some systems
  - Key components that need inspection should not be behind walls
  - Setpoint limits in apartments cause complaints– 72 winter, 68 summer
  - Cooling is needed beyond turnover date of 10/1 and earlier than spring turnover

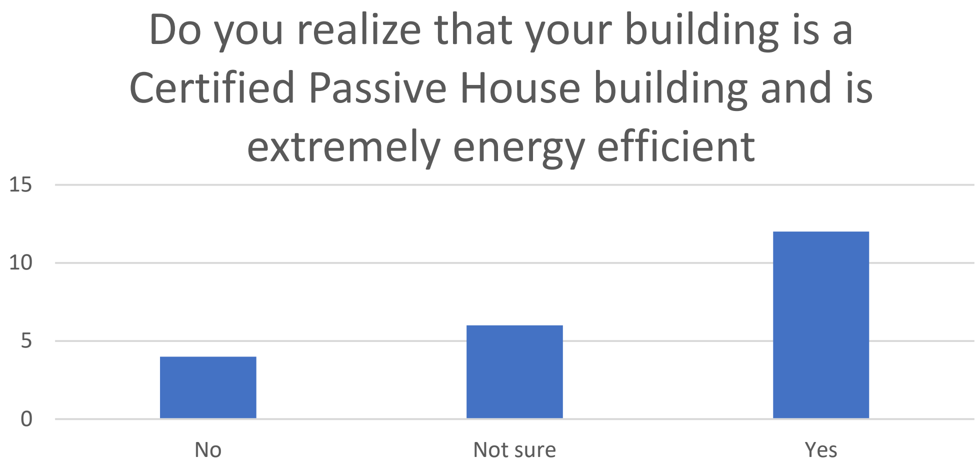
Super Interviews

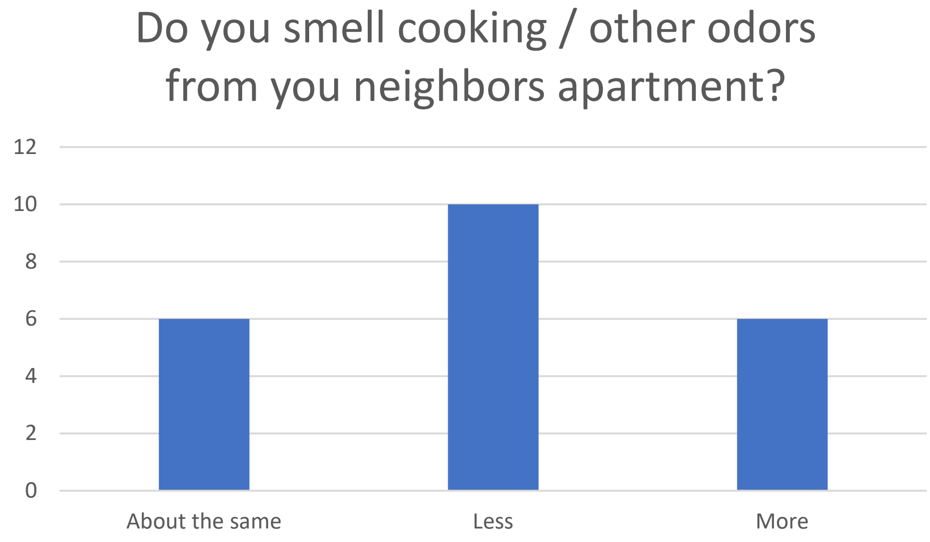
- Ventilation
  - For some: things are fine w/ filter changes, happen every 6 months, more if necessary
  - For others: never taught maintenance schedules, filters are often clogged
  - All projects: Supply air on ERVs in winter can be a source of complaint
  - In-unit ERVs: Occupants commonly turn them off, need more education of why they are important

Resident survey



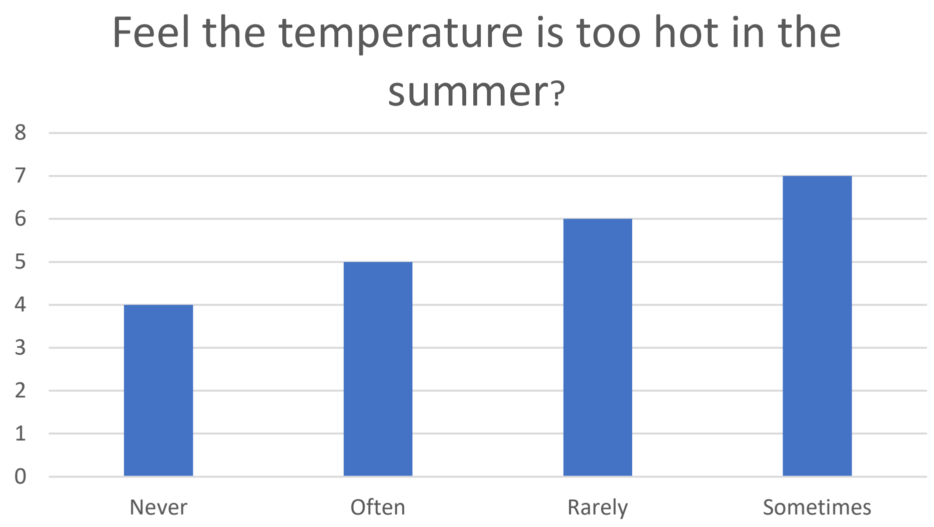


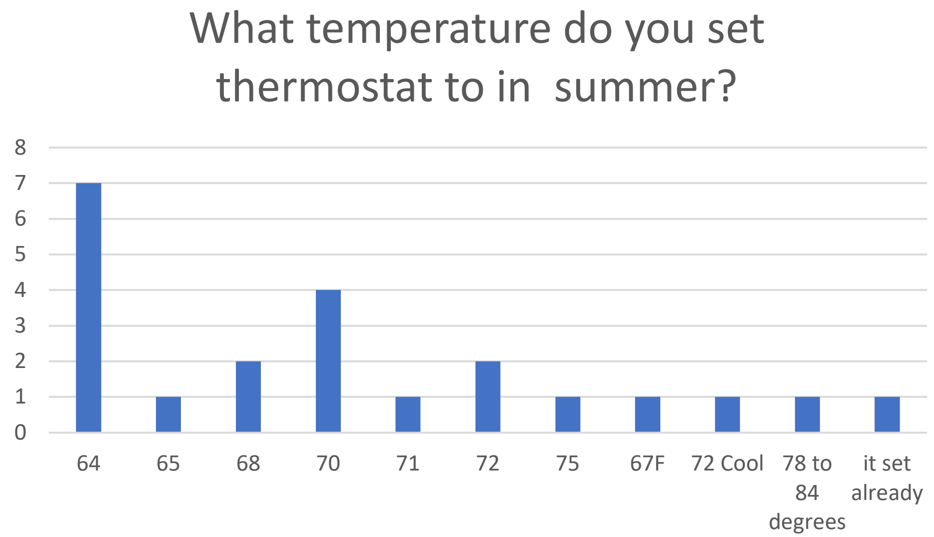


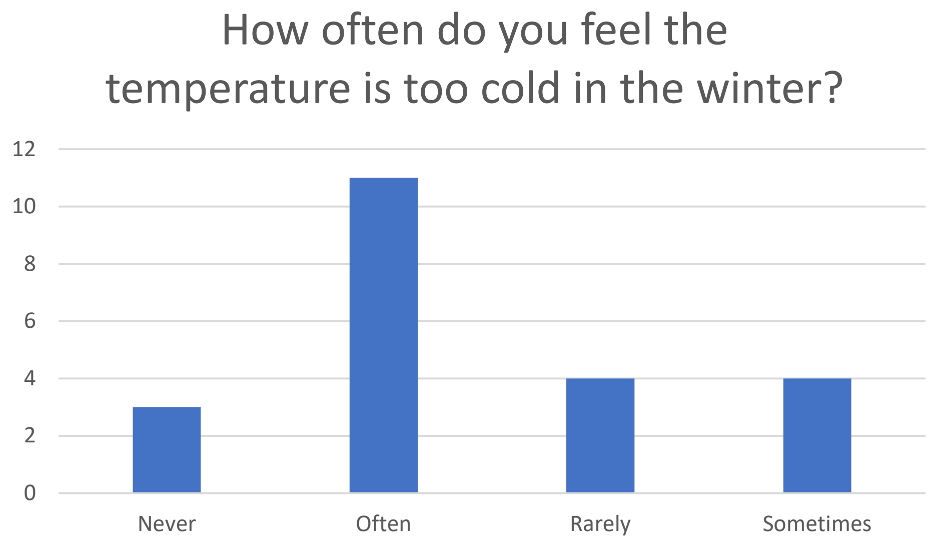


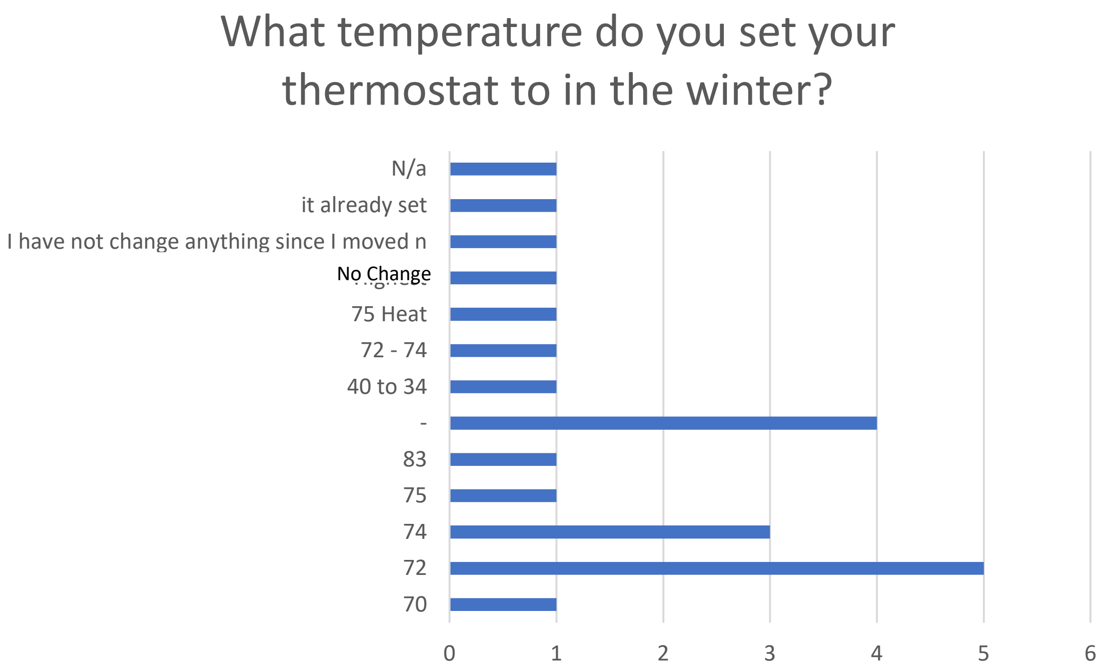
- BGD I had many more responses since they sent out electronically.
- Even with air sealing and ERV's there seem to be some smell issues.

Resident survey









- People like it very cold in the summer and hot in the winter. There needs to be an education campaign.

Conclusions

Conclusions:

- Many ways to meet Passive House and get similar results.
- ICF’s have many advantages but need more sub contractors who want and know how to do.
- Operation and Maintenance is critical.
- Resident education is critical.
    - Need to educate people about sweaters and short sleeve shirts etc.
- Senior behavior seems to have lower energy use.
- Cogen– design for DHW not electric load.
- Heating and Cooling are a small part of the load. So, spending a lot of money on those systems does not make sense but making buildings electric does.
- Waste Water / Ground Source heat pump recovery systems for hot water are the next frontier. Ground source, not Passive House has lowest EUI.
- Ground Source Heat pumps higher first cost and lower operating cost– slightly.
    - Ground source may give greater resident comfort.
- Unitized vs. Centralized ERV, similar operation costs, different first costs, user and maintenance issues
    - Residents turn off unitized ERV’s, again need education

Thank You!

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