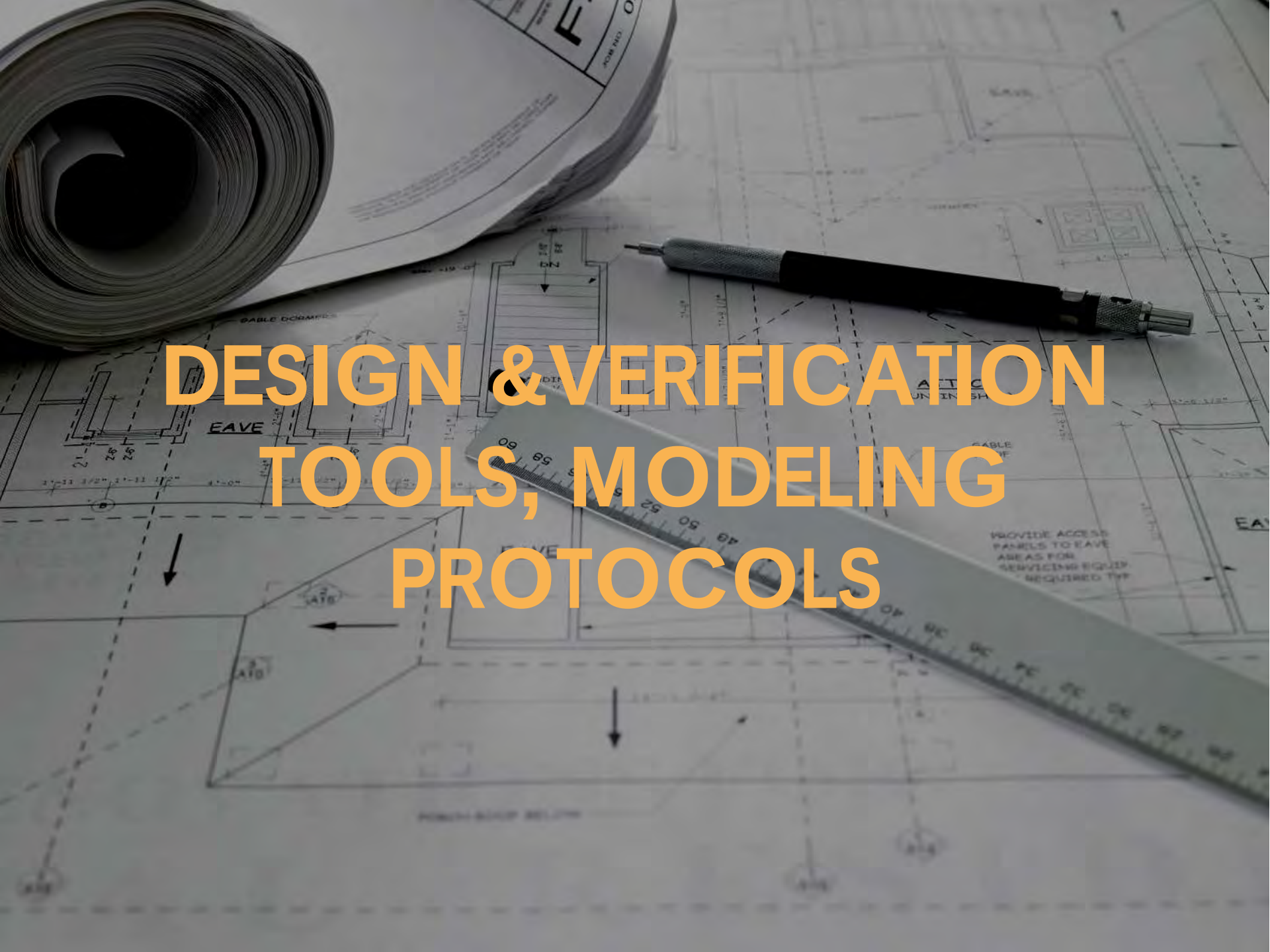
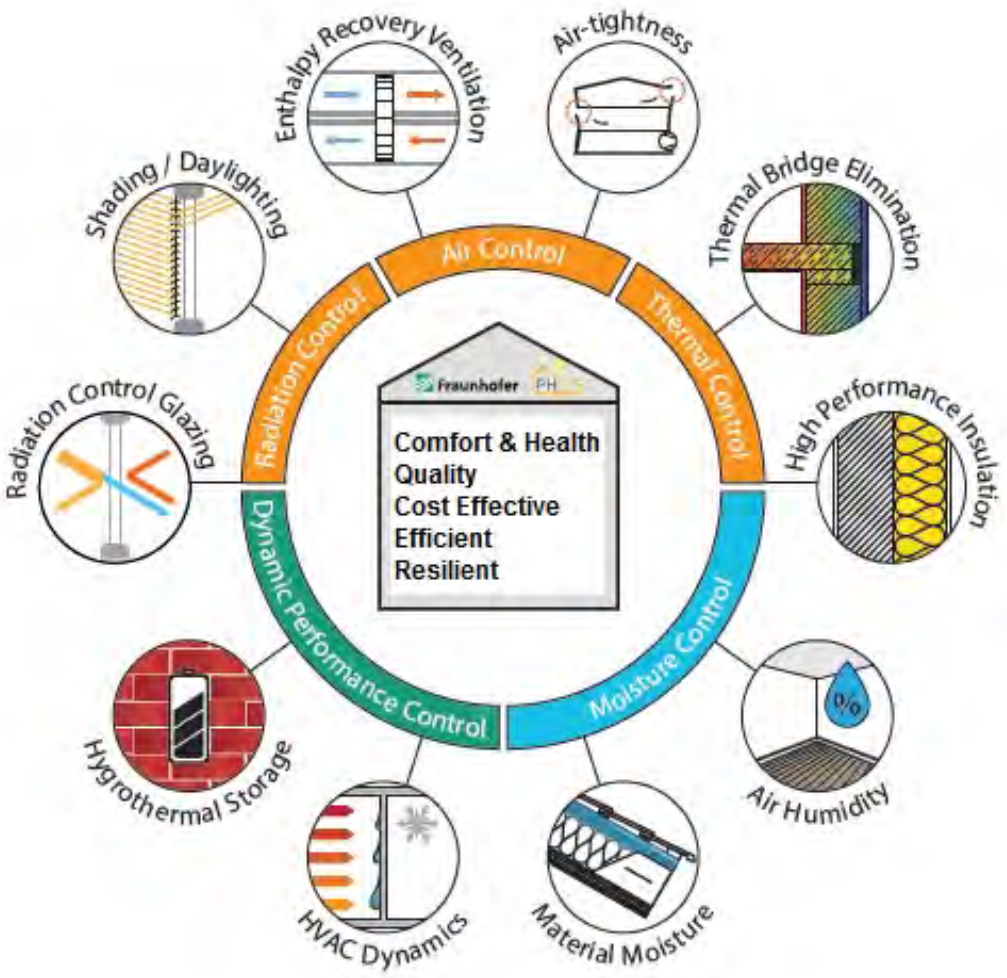
Where We Went Right & Where We Went Left:

Measured vs. Modeled Performance Data Analysis for Affordable Occupied Passive Multifamily Projects

Village Centre Apartments - Brewer, ME


DESIGN &VERIFICATION
TOOLS, MODELING
PROTOCOLS

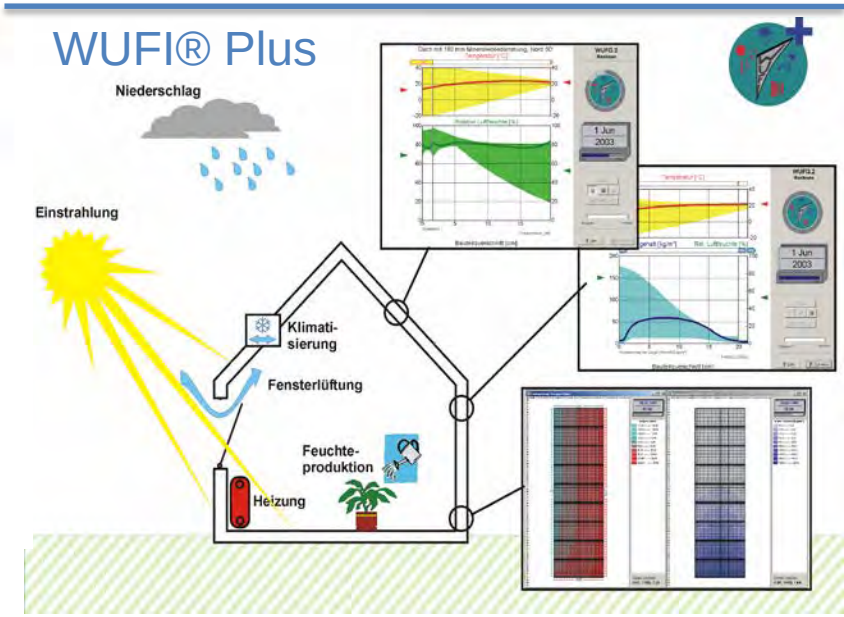
WHOLE BUILDING ENERGY BALANCE



WUFI® Passive

PHPP

WUFI® Plus



TERMINOLOGY

Demands, Peaks, Site & Primary Energy

Annual Demand [kBTU/yr.ft^2]: Space conditioning energy consumed over the course of the year, delivered by the equipment to the space.

Peak Load [BTU/hr.ft^2]: Space conditioning requirement during the peak climate conditions (average over the worst 24 hours). Determines the size of the mechanical system.

Site Energy [kWh/person.yr] OR [kBTU/yr.ft^2]: Total energy consumed over the course of the year, including space conditioning, hot water, plug loads, lighting, appliances, systems, etc. (Excludes electrical vehicle charging energy, and ligthing energy specific to vehicle parking areas)

*No requirement for PHIUS+ Certification

Source (Primary) Energy [kWh/person.yr] OR [kBTU/yr.ft^2]:

Site energy as described above, multiplied by the source/primary energy factor for the specific fuel type used.

Ex: Electricity has a PE factor of 3.16 kWh/kWh (generation at the source vs use on site)

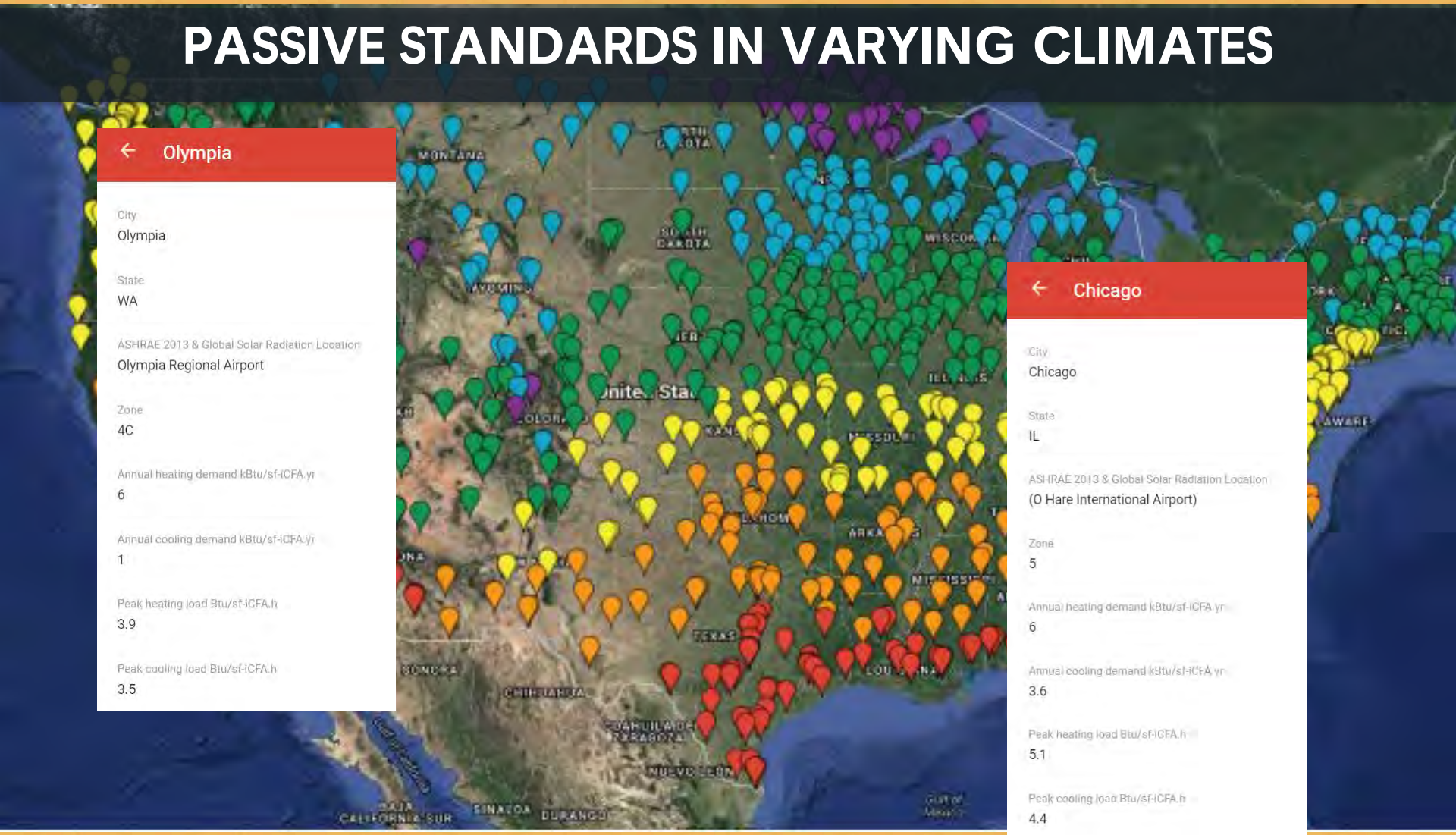
CERTIFICATION TARGET DIFFERENCES

	PHIUS+ 2015	PHI
Annual Heat Demand (kBTU/ft^2.yr)	Varies by Climate	4.75
Annual Heating Load (BTU/ft^2.hr)	Varies by Climate	3.14
Annual Cooling Demand (kBTU/ft^2.yr)	Varies by Climate	4.75 (+ allowance for latent)
Annual Cooling Load (BTU/ft^2.hr)	Varies by Climate	2.54
Airtightness	*0.05 cfm/ft^2 (Based on Envelope Area)	0.6 ACH50 (Based on Net Volume)
Source Energy Factor (Residential)	6,200 kWh/person.yr	38 kBTU/ft^2.yr

*0.08 cfm/ft^2 for non-combustible construction >5 stories

CLIMATE SPECIFIC METRICS

PASSIVE STANDARDS IN VARYING CLIMATES



CERTIFICATION PROTOCOL DIFFERENCES

	PHIUS+ 2015	PHI
Internal Heat Gains (Residential)	Varies Calculated	0.67 BTU/hr.ft^2 (2.1 W/m^2) Default
Square Footage	Interior Conditioned Floor Area (iCFA)	Treated Floor Area (TFA)
Occupancy	# Bedrooms + 1	TFA ÷ 376.7ft^2 (TFA ÷ 30m^2)
Residential Lighting	80% RESNET Lighting Assumptions	*11W light x 8 hrs/day x Occupancy
Residential Miscelleneous Electric Loads (MELS)	80% RESNET MELS Assumptions	**80W x 1.5 hrs/day x Occupancy + 50 kWh x Occupancy
Source Electric Energy Factor	3.16 kWh/kWh (US Average)	2.6 kWh/kWh (German Average)

*Assumes one light on per person at a time

**Reference: 25” color TV consumes 150W/hr

3 Protocols Tested + 1 Hypothetical Adjusted Model

	ASHARE 90.1 -2010 Appendix G Baseline	***PHI***	***PHIUS+ 2015***	***PHIUS+ 2015 Adjusted***
Roof	R-value by Climate Zone from Table 5.5	Same as Designed	Same as Designed	Same as Designed
Walls	R-value by Climate Zone from Table 5.5	Same as Designed	Same as Designed	Same as Designed
Windows	U-Value/SHGC by Climate Zone from Table 5.5	Same as Designed	Same as Designed	Same as Designed
Area	Same as PHIUS+ 2015	TFA	iCFA	iCFA
Lighting	RESNET Values	PHI Defaults	80% RESNET Values	80% RESNET Values
MELS	RESNET Values	PHI Defaults	80% RESNET Values	80% RESNET Values
HVAC	50% Efficient ERV H/AC – Same as Designed	Same as Designed	Same as Designed	System Efficiencies adjusted
DHW	140F Supply Temp Same gal/person/day as PHI/PHIUS	120F Supply Temp 6.6 gal/person/day	120F Supply Temp 6.6 gal/person/day	Varies by project
Occupancy	Same as PHIUS+ 2015	376.7sf/person	Number Bedrooms + 1	Same as PHIUS+ 2015

CERTIFICATION PROTOCOL DIFFERENCES

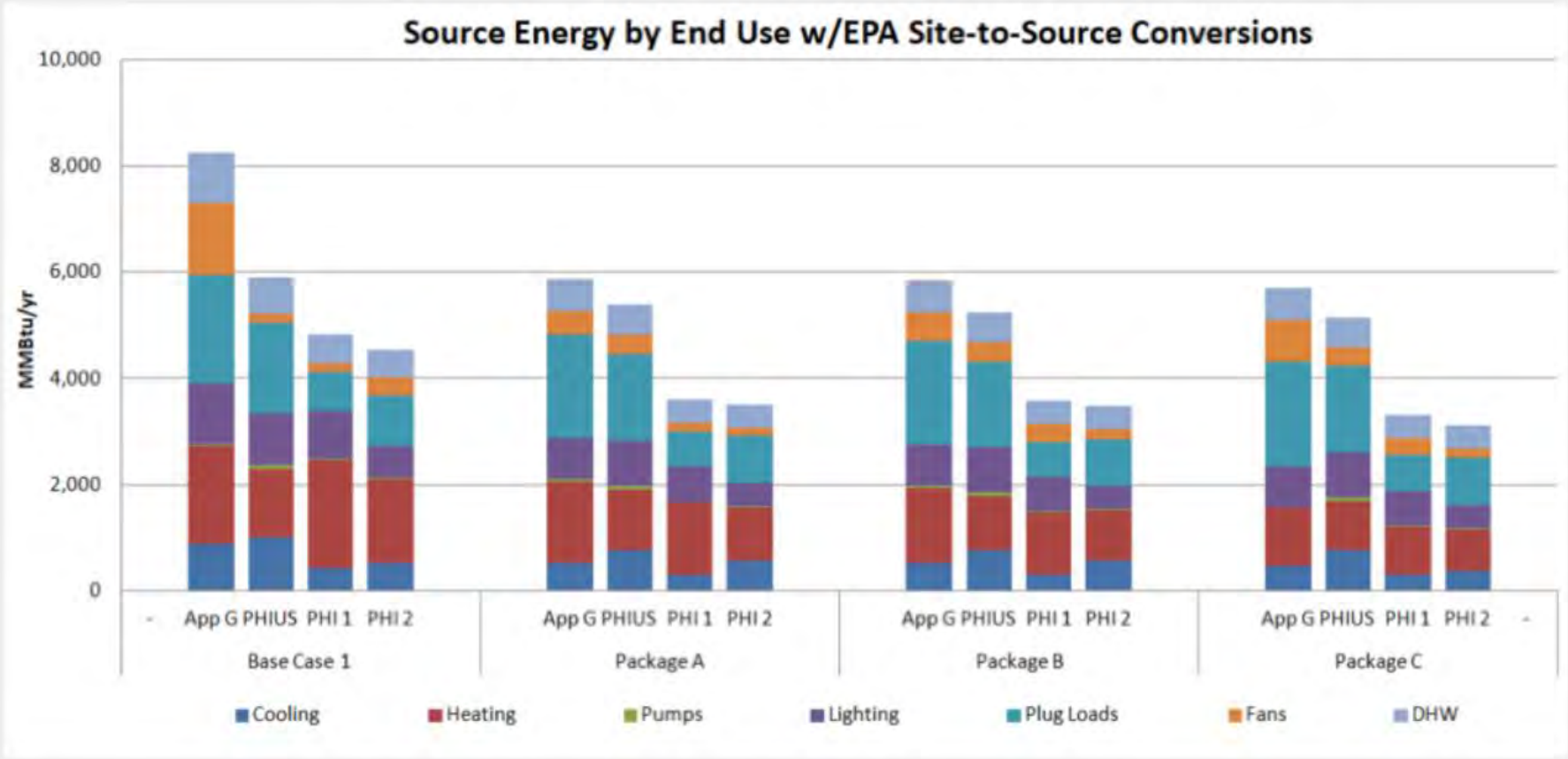
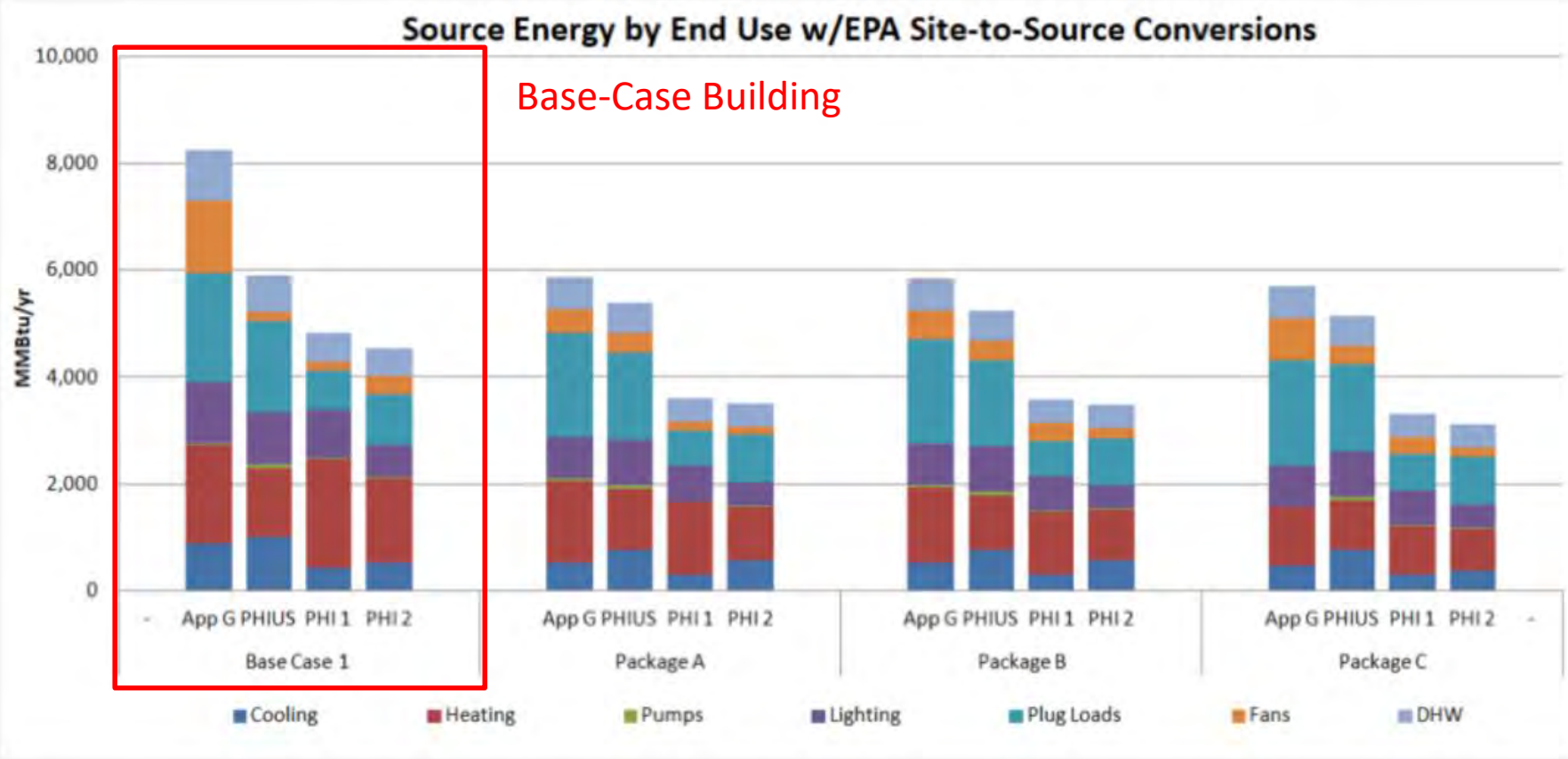


Figure 1: Annual Source Energy by end use and Protocol (Using EPA Portfolio Manager Site-to-Source Conversions)

Comparison Evaluation of ASHRAE 90.1 Appendix G vs. Passive House
https://www.nyserda.ny.gov/About/Publications/EA-Reports-and-Studies/Energy-Efficiency-Services-Reports
Image from blog post - http://blog.phius.org/comparing-ashrae-90-1-appendix-g-phius-passivhaus-methods-and-standards/

CERTIFICATION PROTOCOL DIFFERENCES



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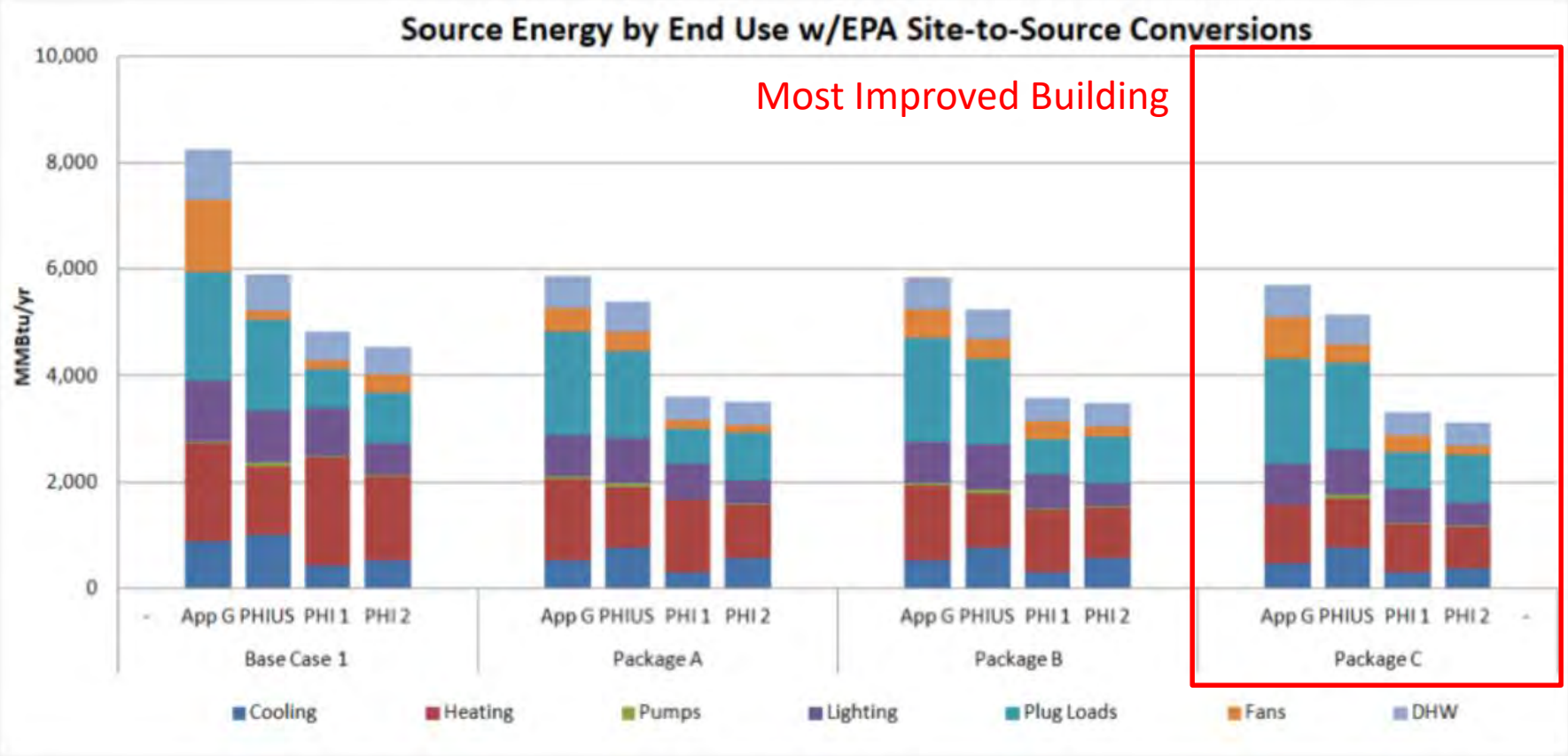

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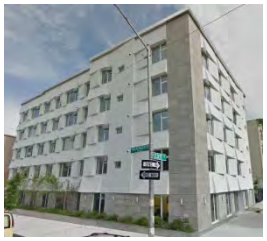
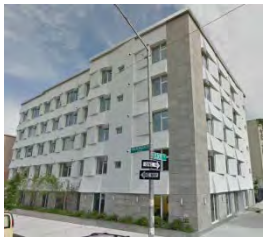
Three Case Studies



	Uptown Lofts	***Knickerbocker Commons***	***Orchards at Orenco Phase 1***
Location	Pittsburgh, PA	Brooklyn, NY	Hillsboro, OR
Square Footage (Gross)	25,000 ft^2	36,350 ft^2	54,700 ft^2
Number of Units	24	24	57
Modeled Occupancy	52 (PHI) 48 (PHIUS+ 2015)	71 (PHI) 72 (PHIUS+ 2015)	113 (PHI) 131 (PHIUS+ 2015)
Actual Occupancy	24	64	?
PHIUS+ Project #	1188	1274	1203

Three Case Studies



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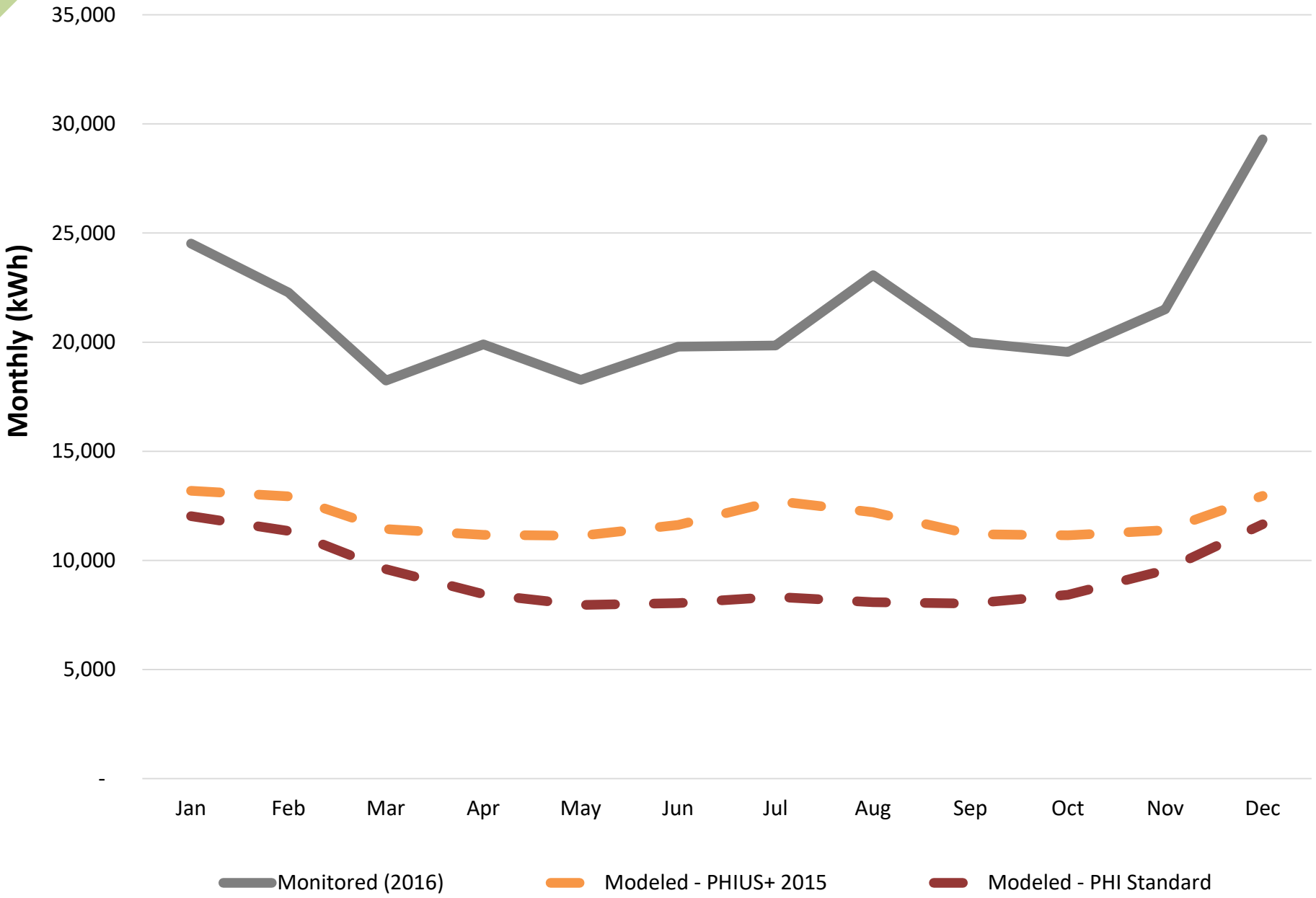
Uptown Lofts

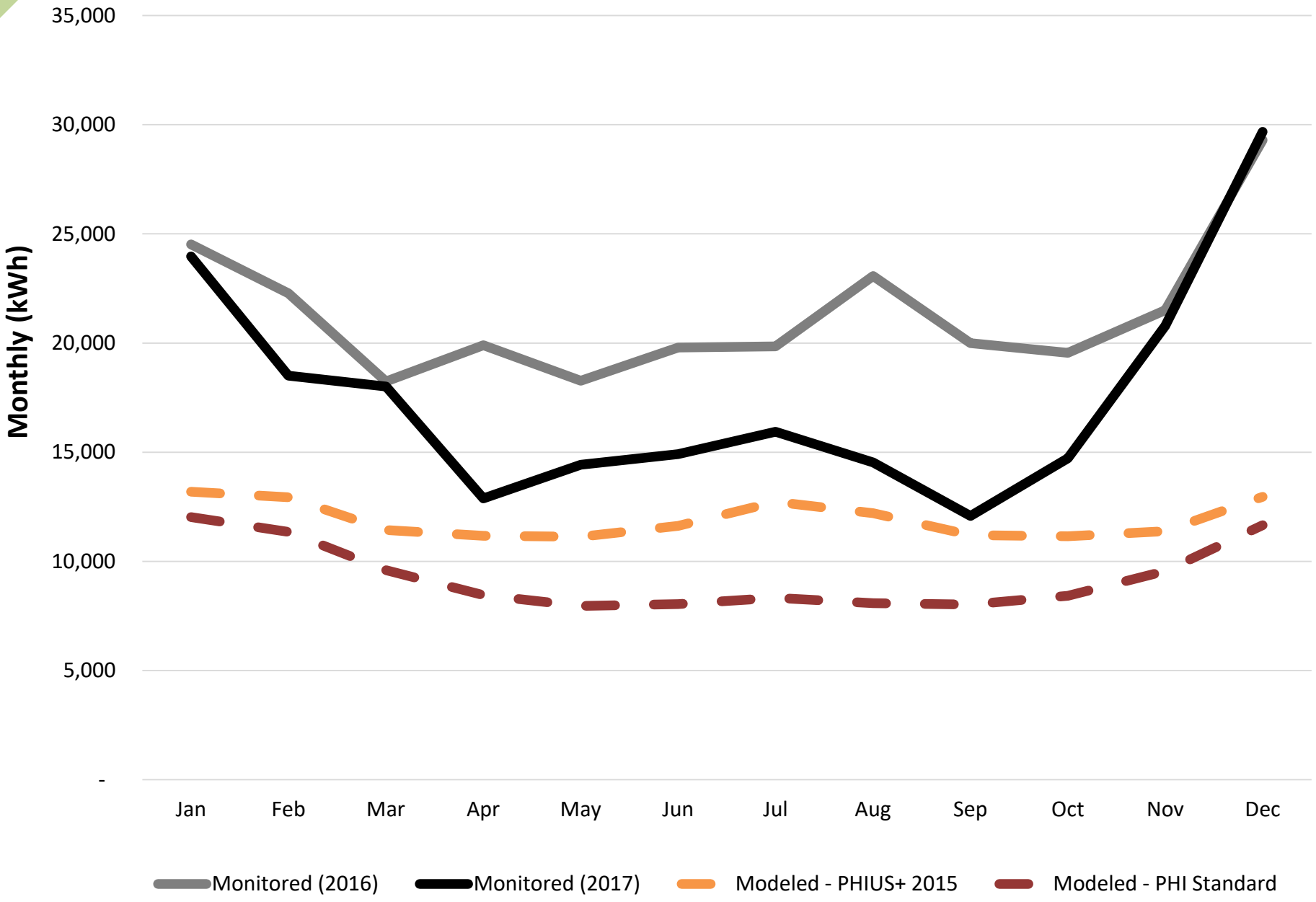
Things to keep in mind

- Site Energy analyzed
- All electricity monitored together (includes all HVAC, hot water usage, lighting and MELs)
- Heat pumps (heating/cooling) in apartments
- Direct Electric baseboards in common stairs
- HRV
- Direct Electric WH

Site Energy: Monitored vs Modeled



Site Energy: Monitored vs Modeled



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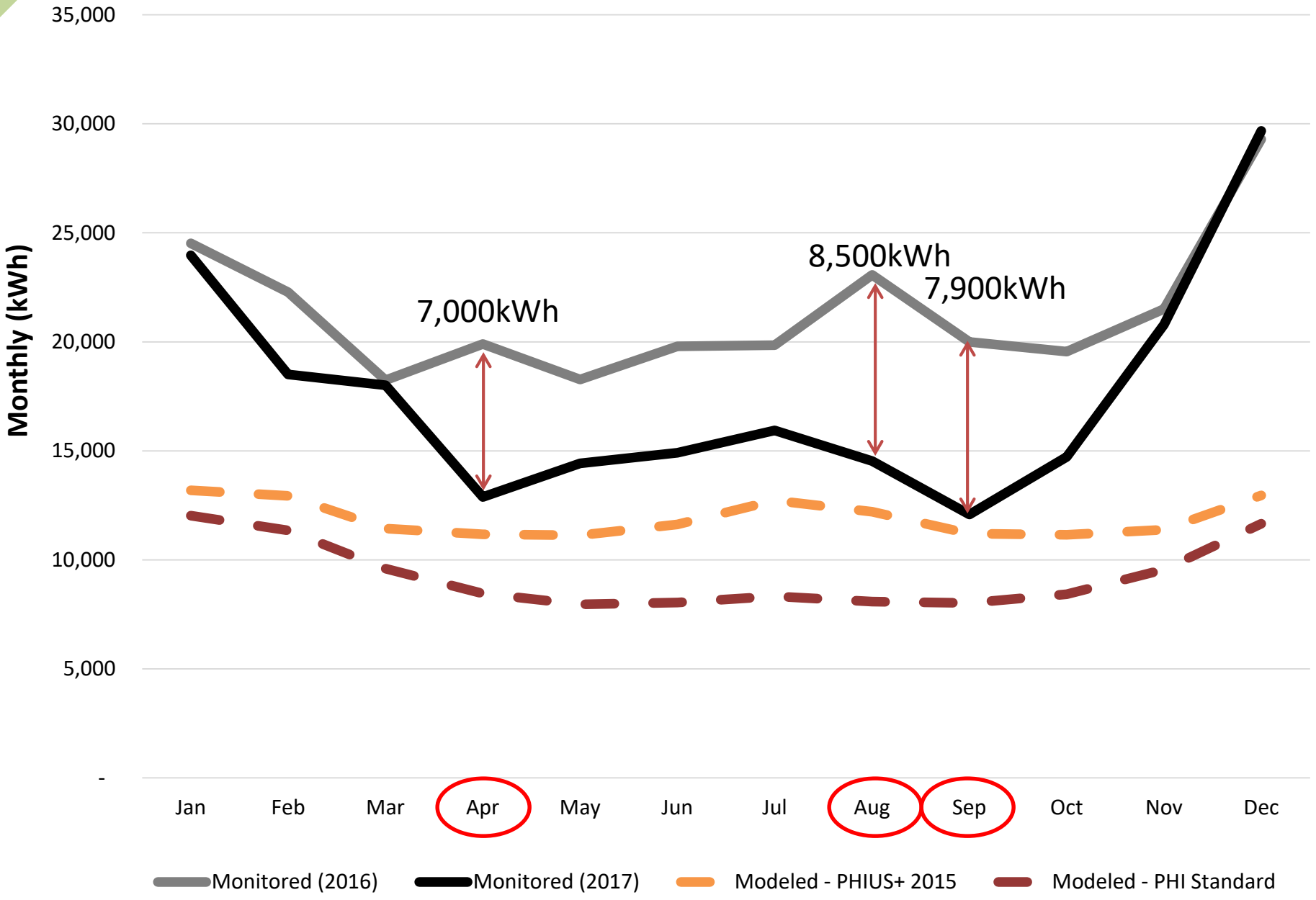
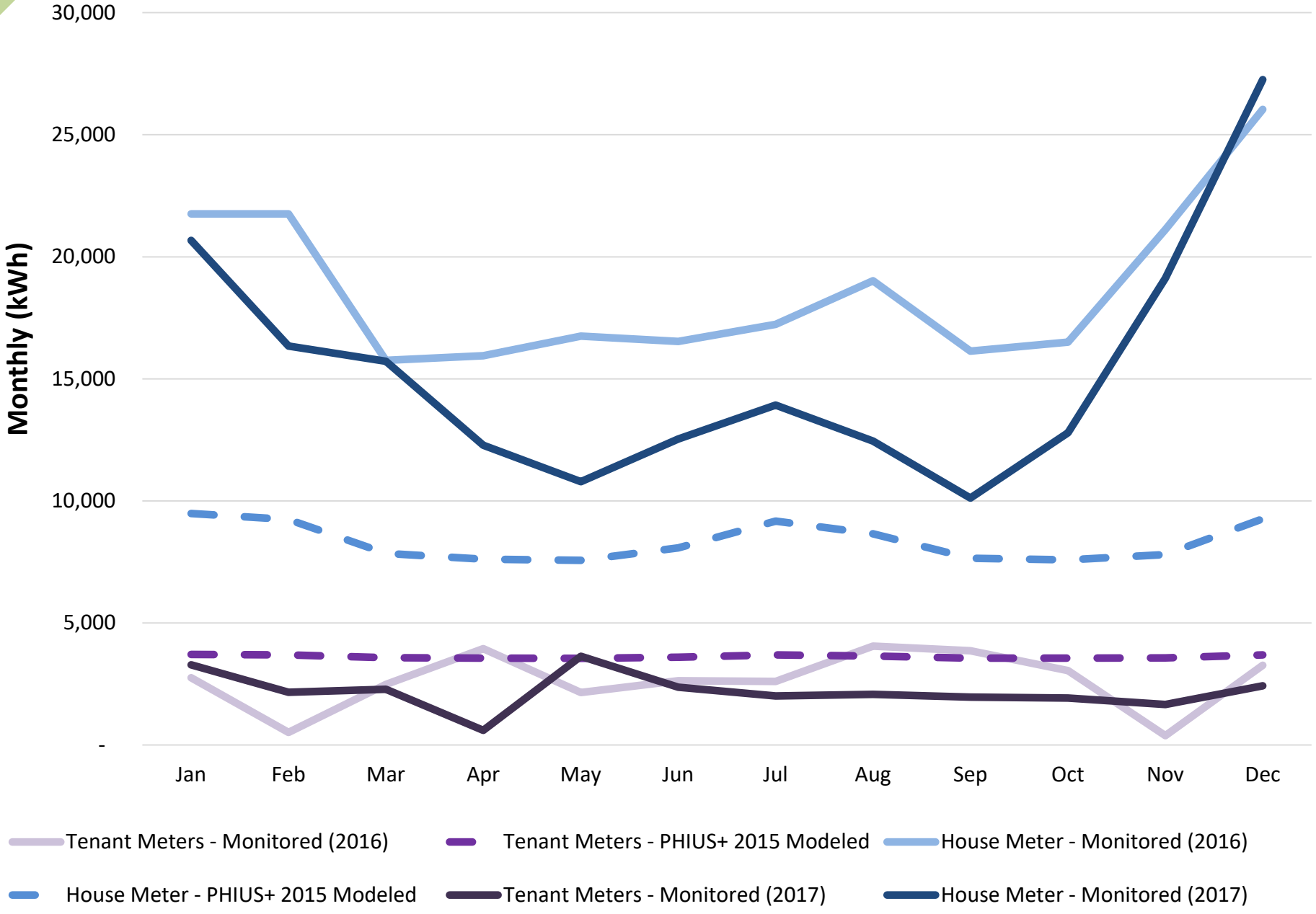


Two Meters

- Tenant Meter: Unit Plug loads/electricity, Unit Lighting & Fans for Heating/Cooling
- House Meter: Hallway/Stairwell/Exterior Lighting, 1st Floor Office Plug Loads, Laundry, Heat Pumps, Hot water tanks, all Ventilation

Site Energy: Monitored vs Modeled



Site Energy: Monitored vs Modeled

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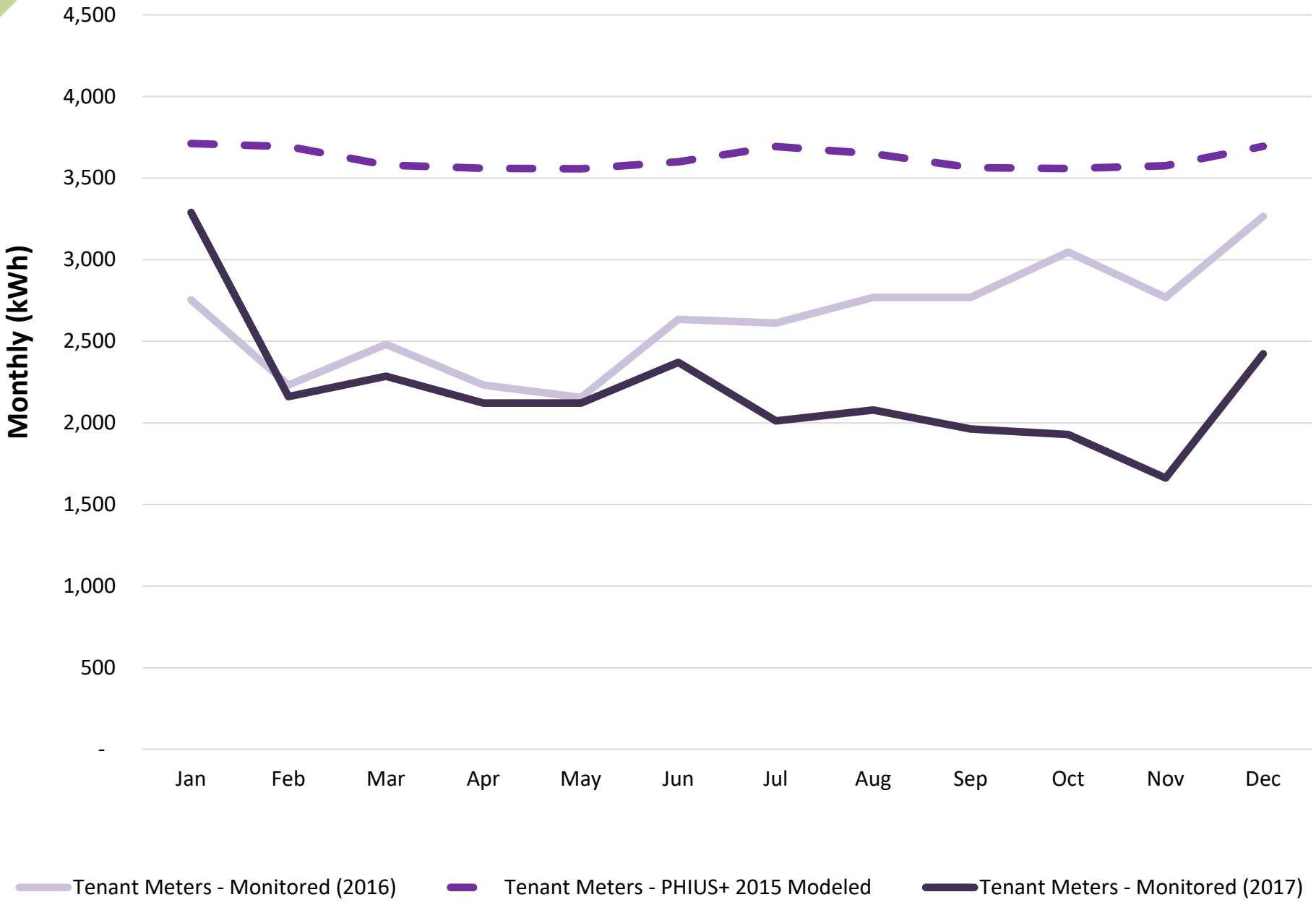

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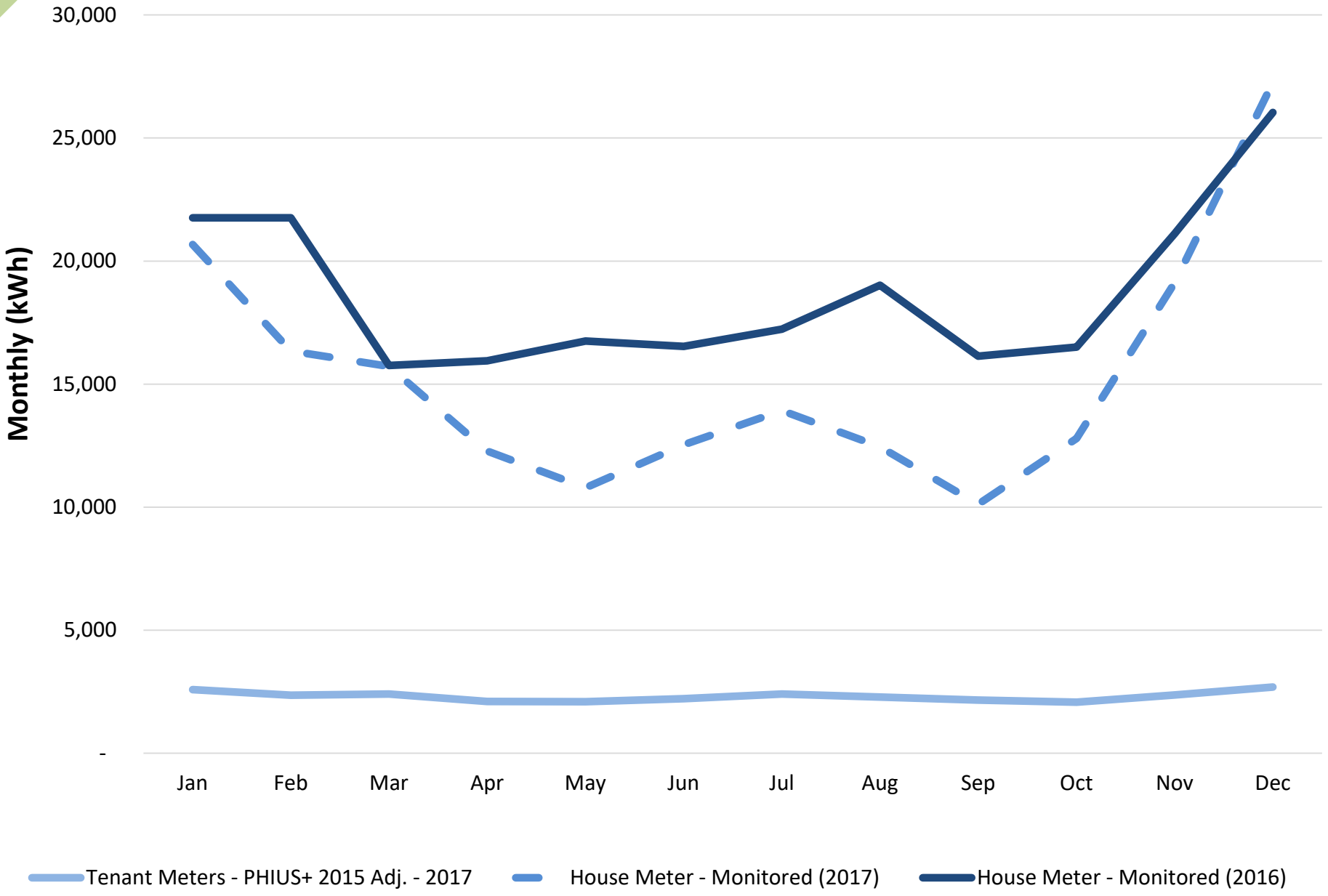

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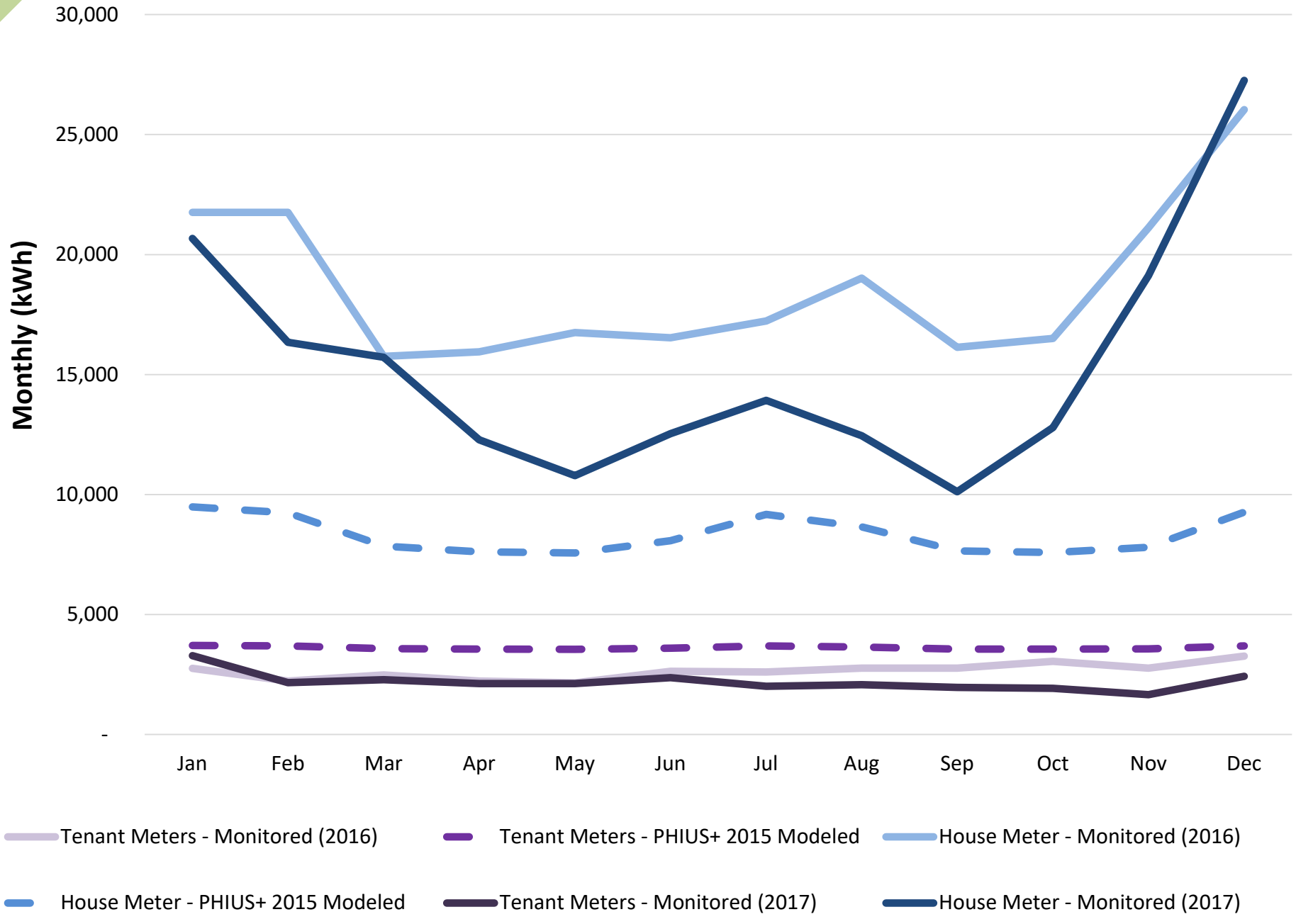
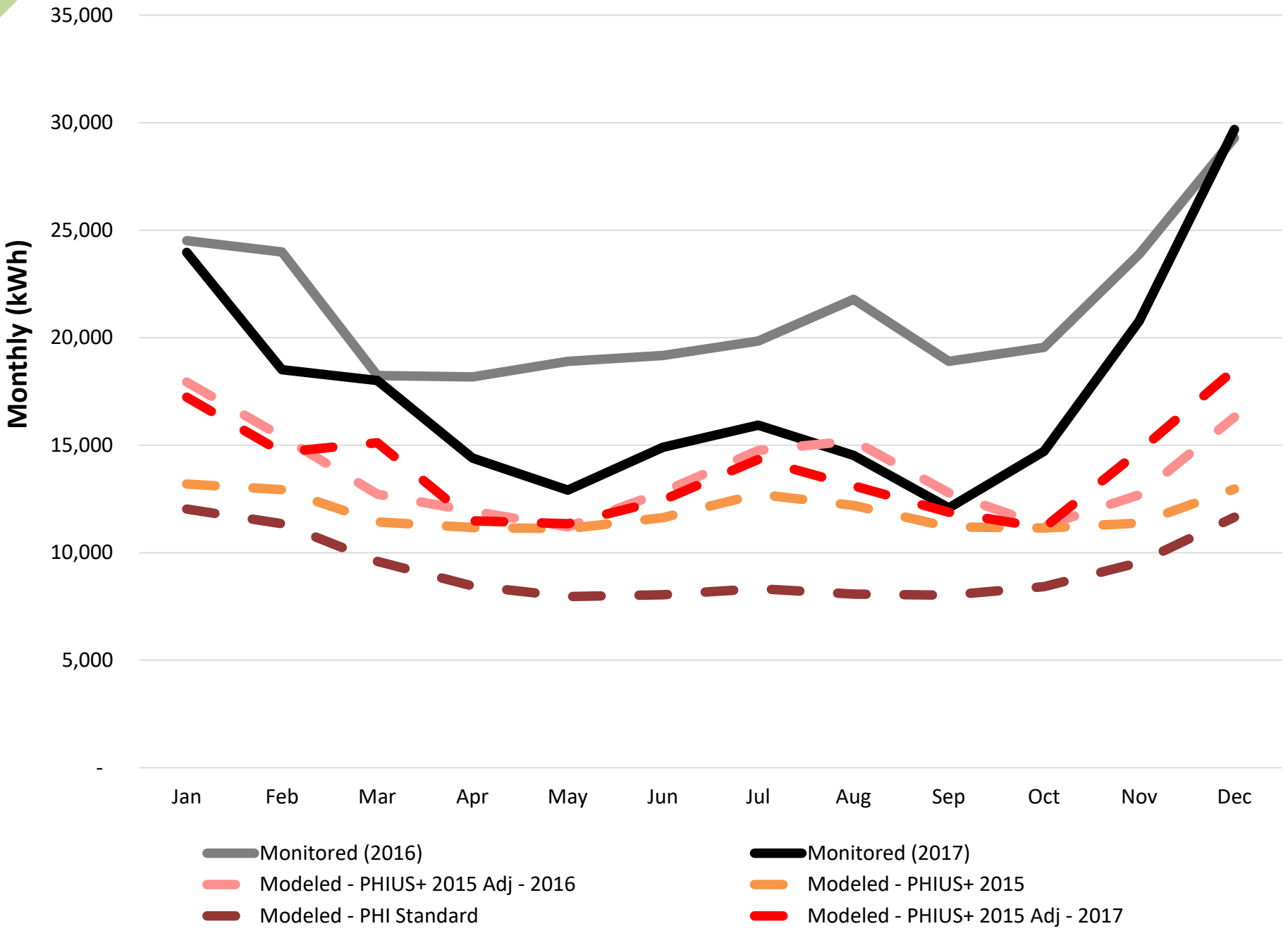


PHIUS+ 2015 – Adjusted Model

- Mean Temperatures Adjusted (2016 & 2017)
- Actual Occupancy
- Unit MELS/Lighting Reduced
- Thermostats set to 80F (Winter) 72F (Summer)
- Doubled Hot Water Usage
- Eliminated Summer Natural Ventilation
- Heat Pumps Malfunction? (2.7 COP to 1.5 COP)

Site Energy: Monitored vs Modeled



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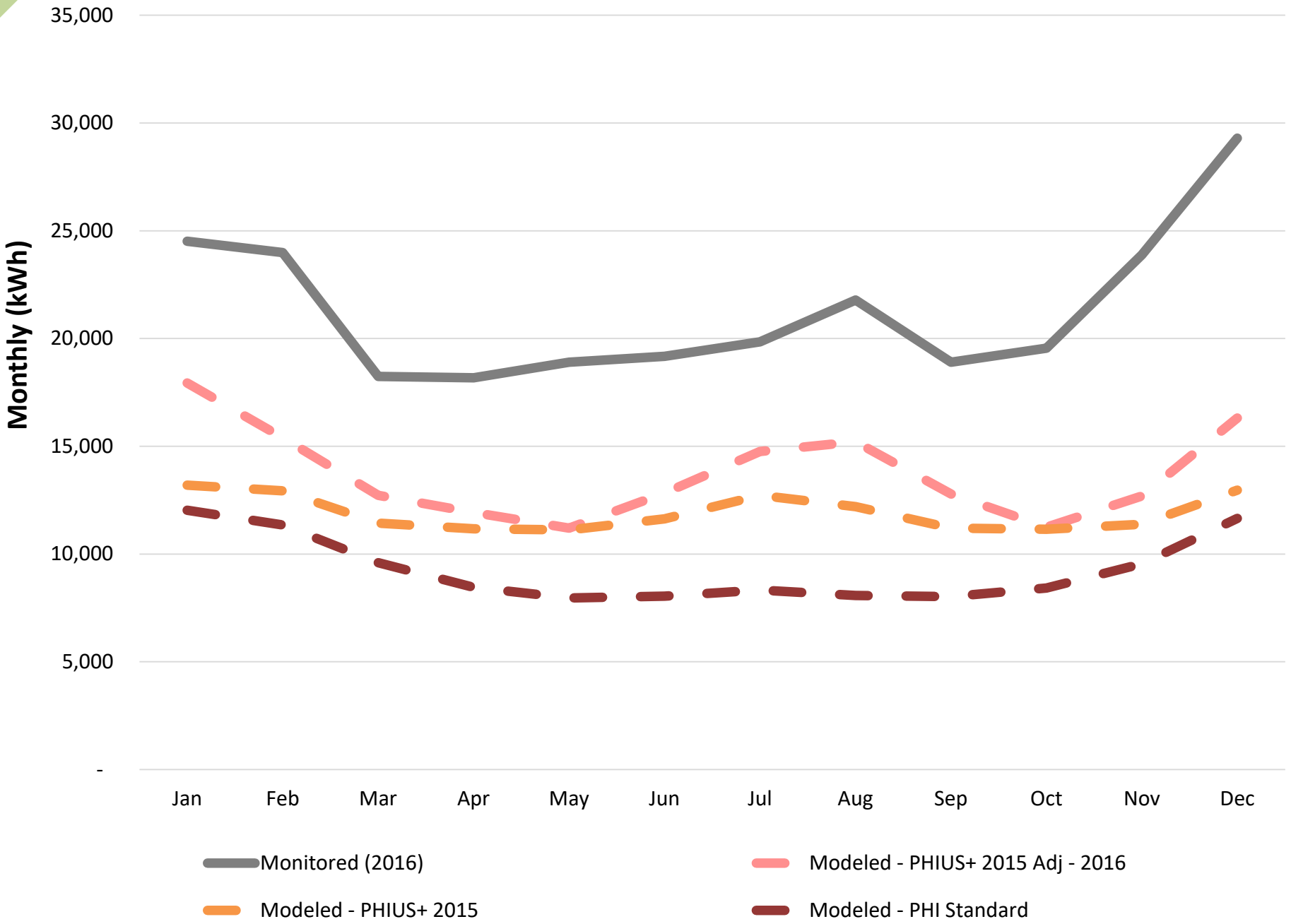

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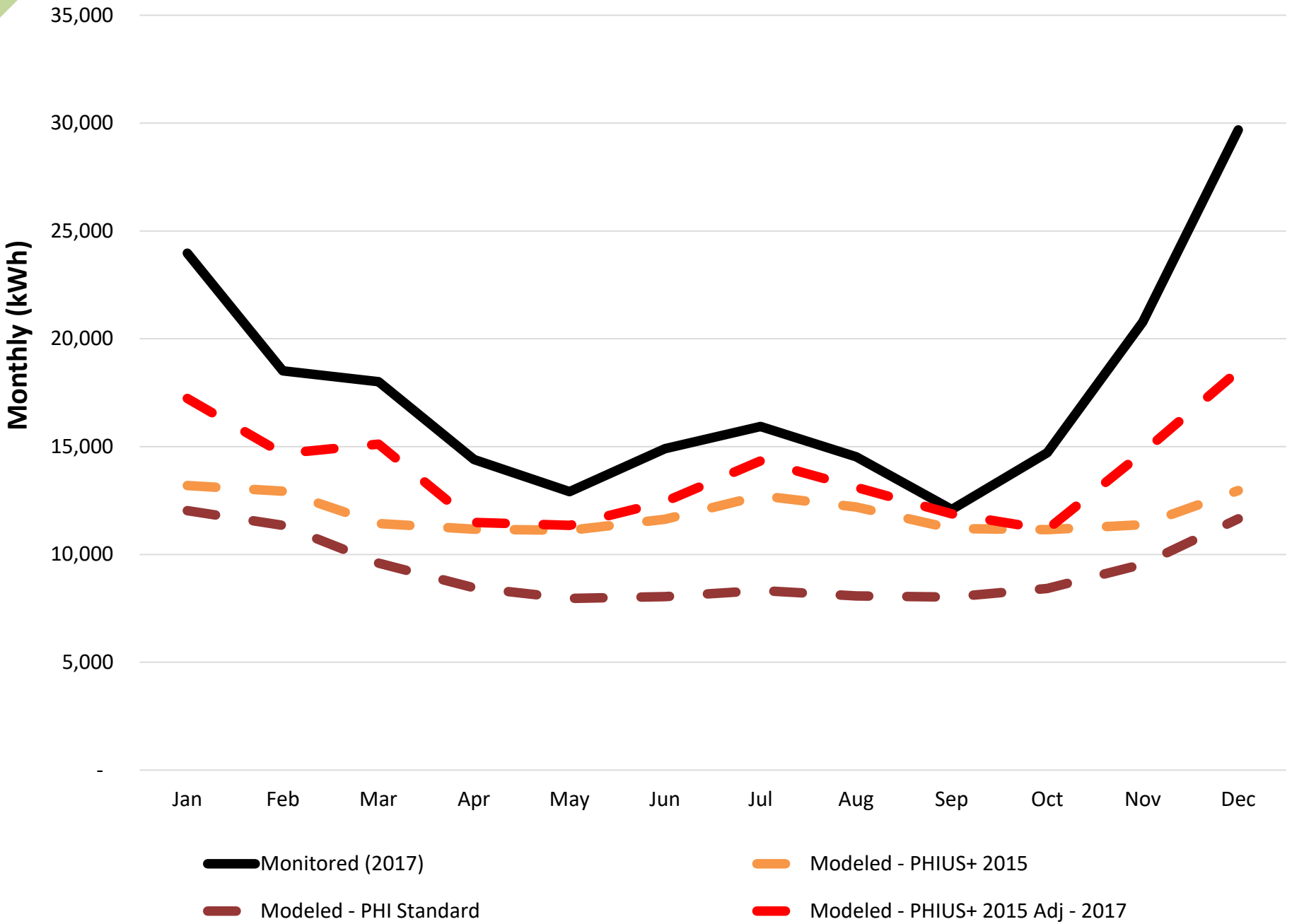

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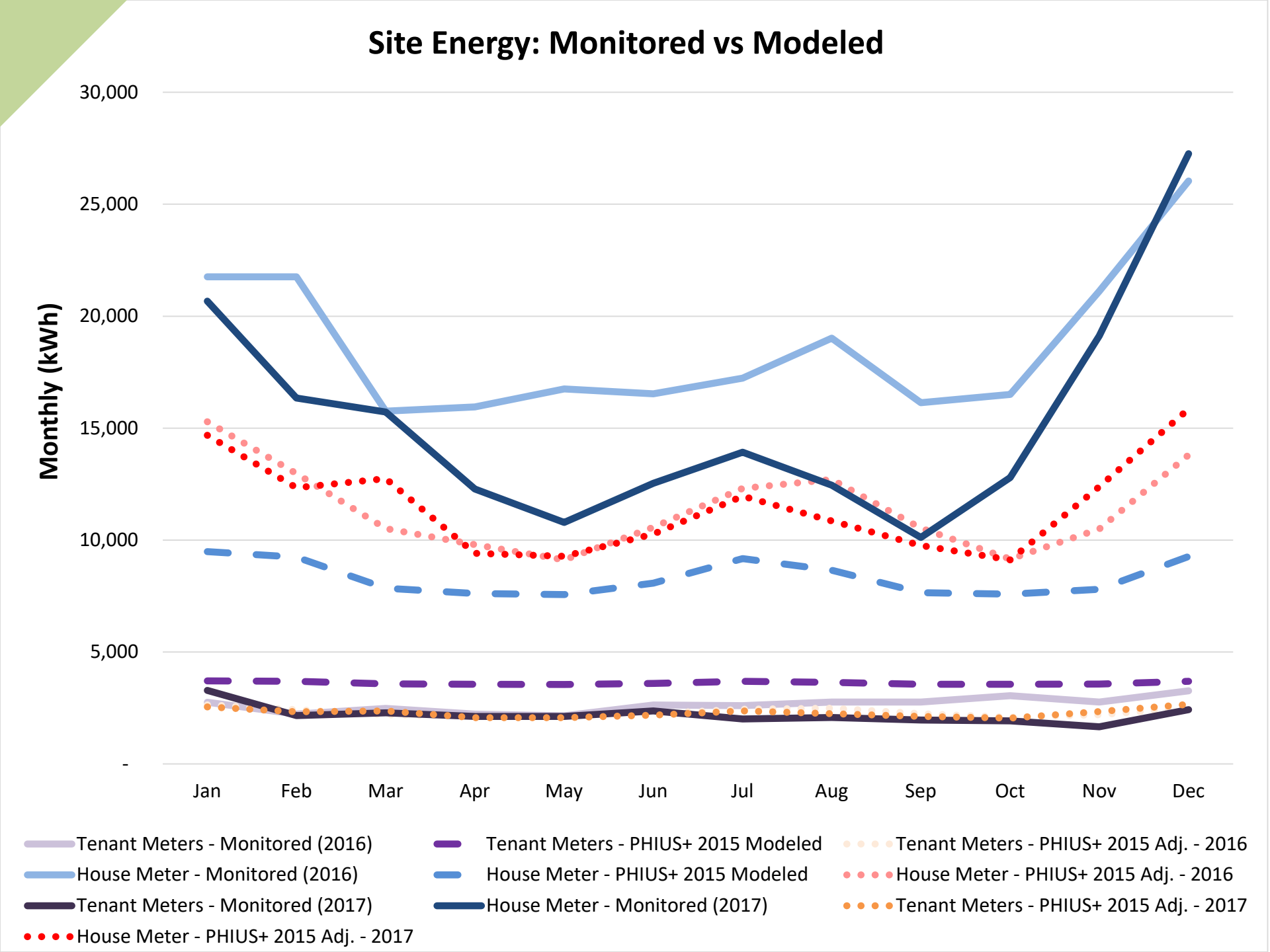

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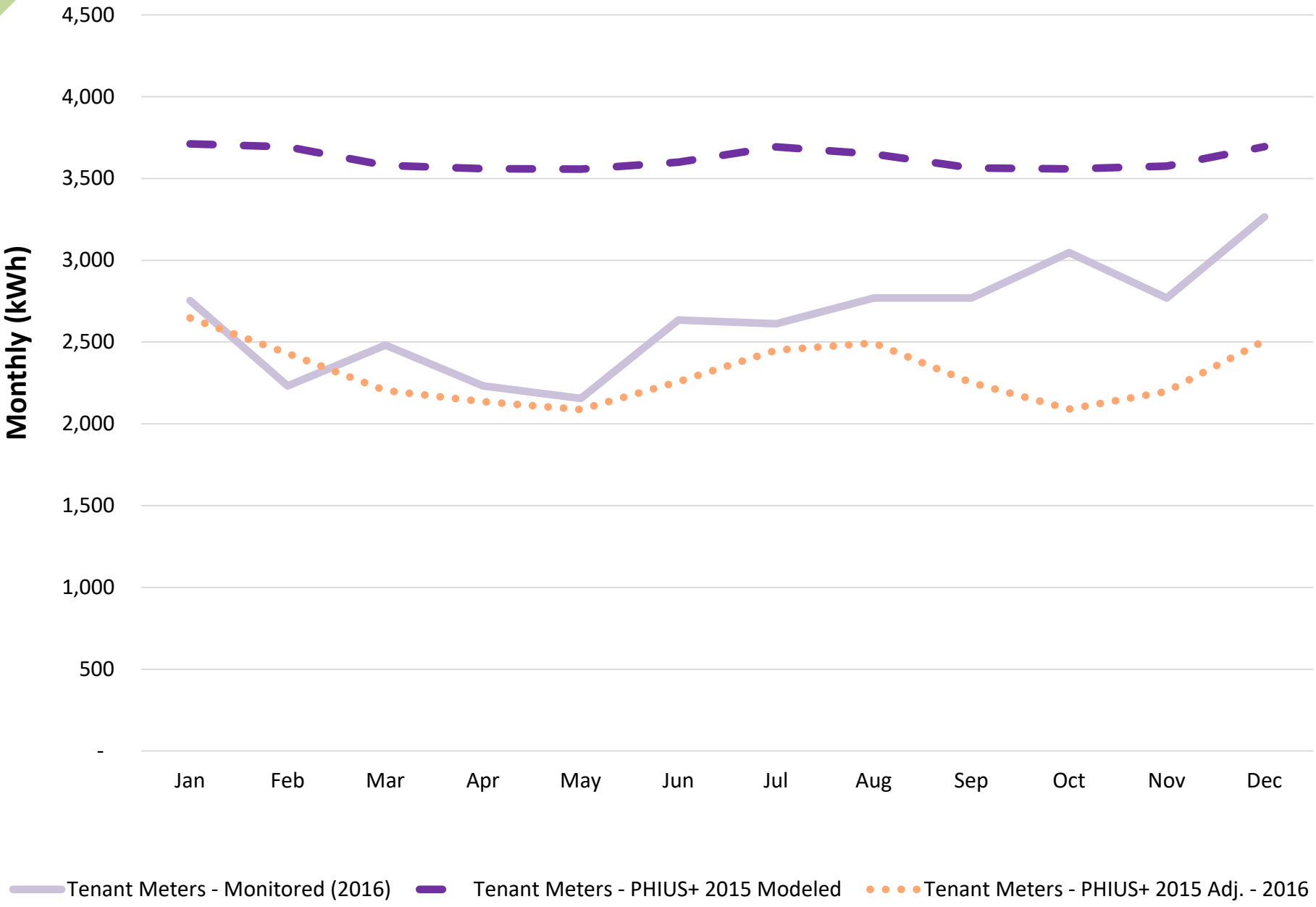

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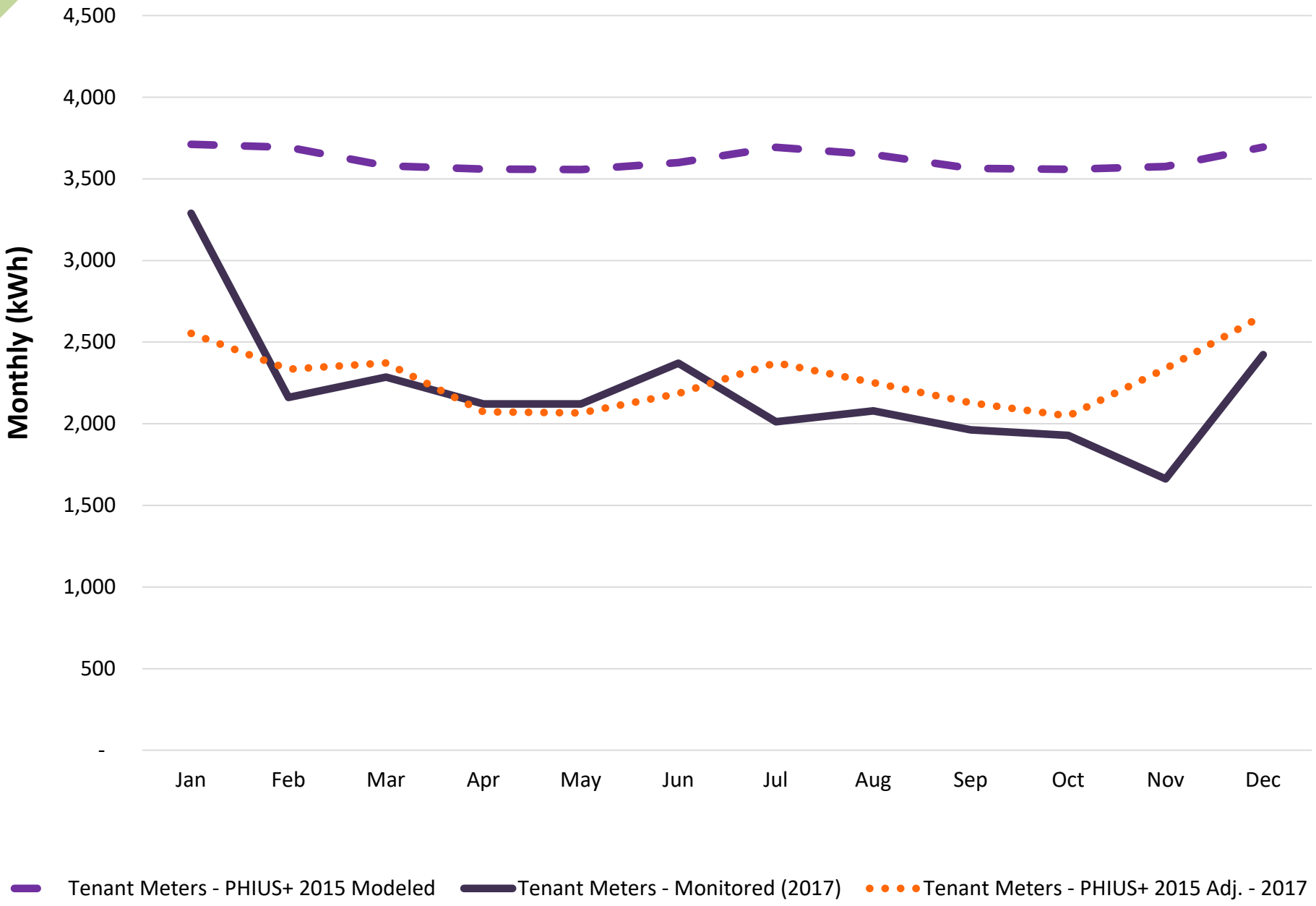

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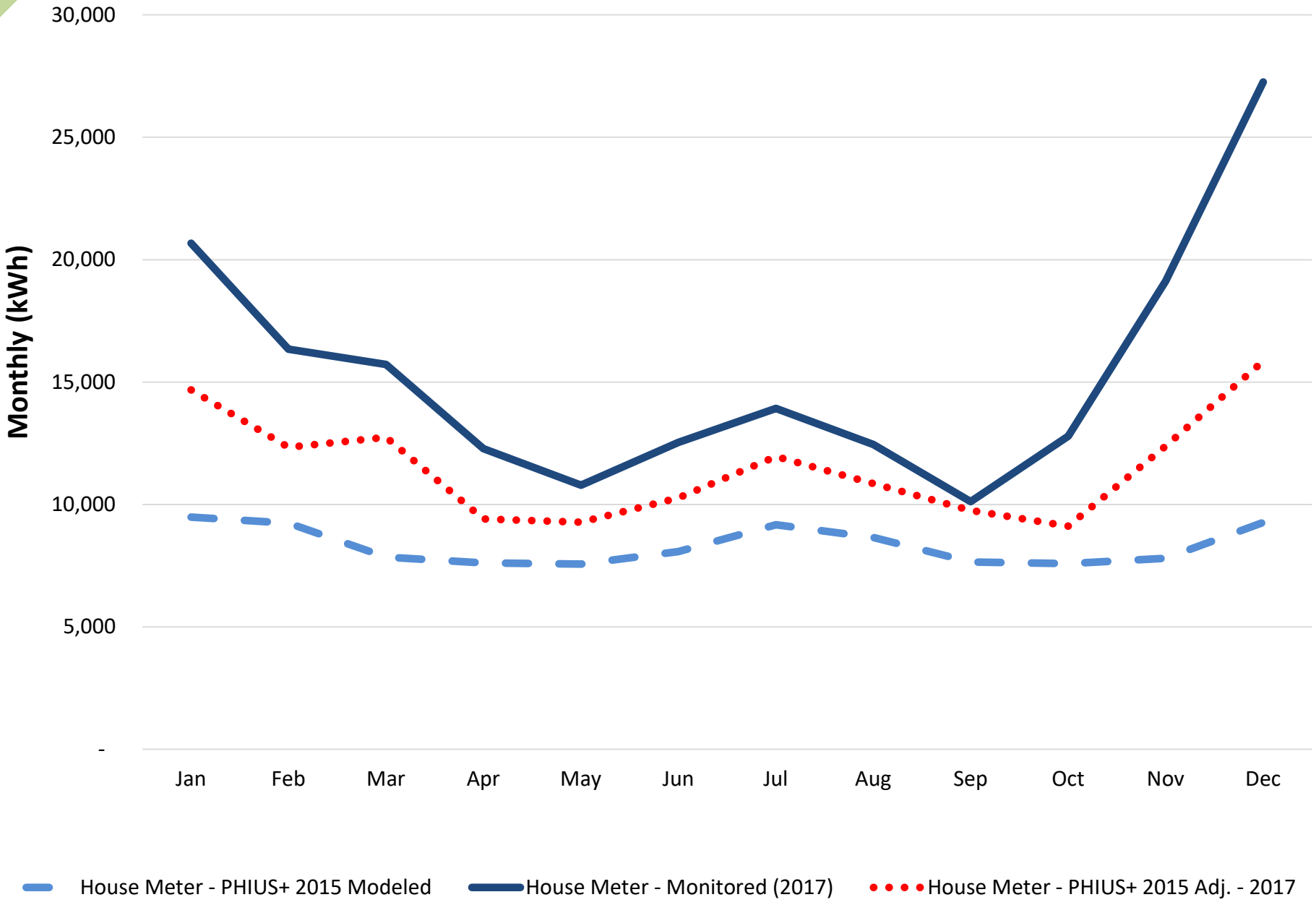
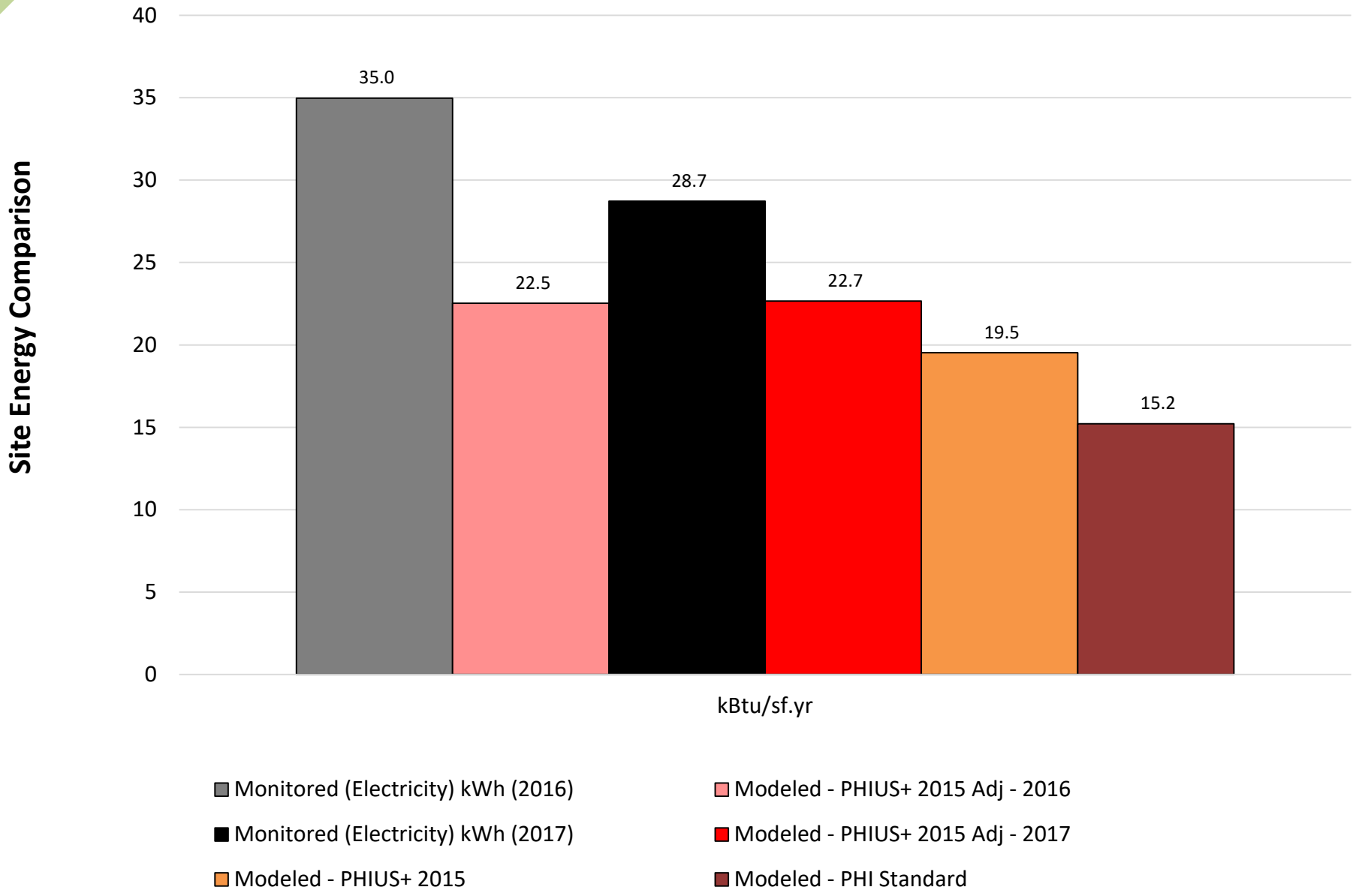
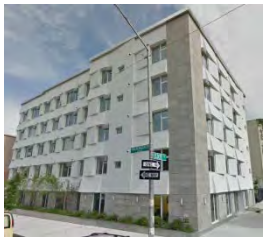


Site Energy: Monitored vs Adjusted Models



Three Case Studies



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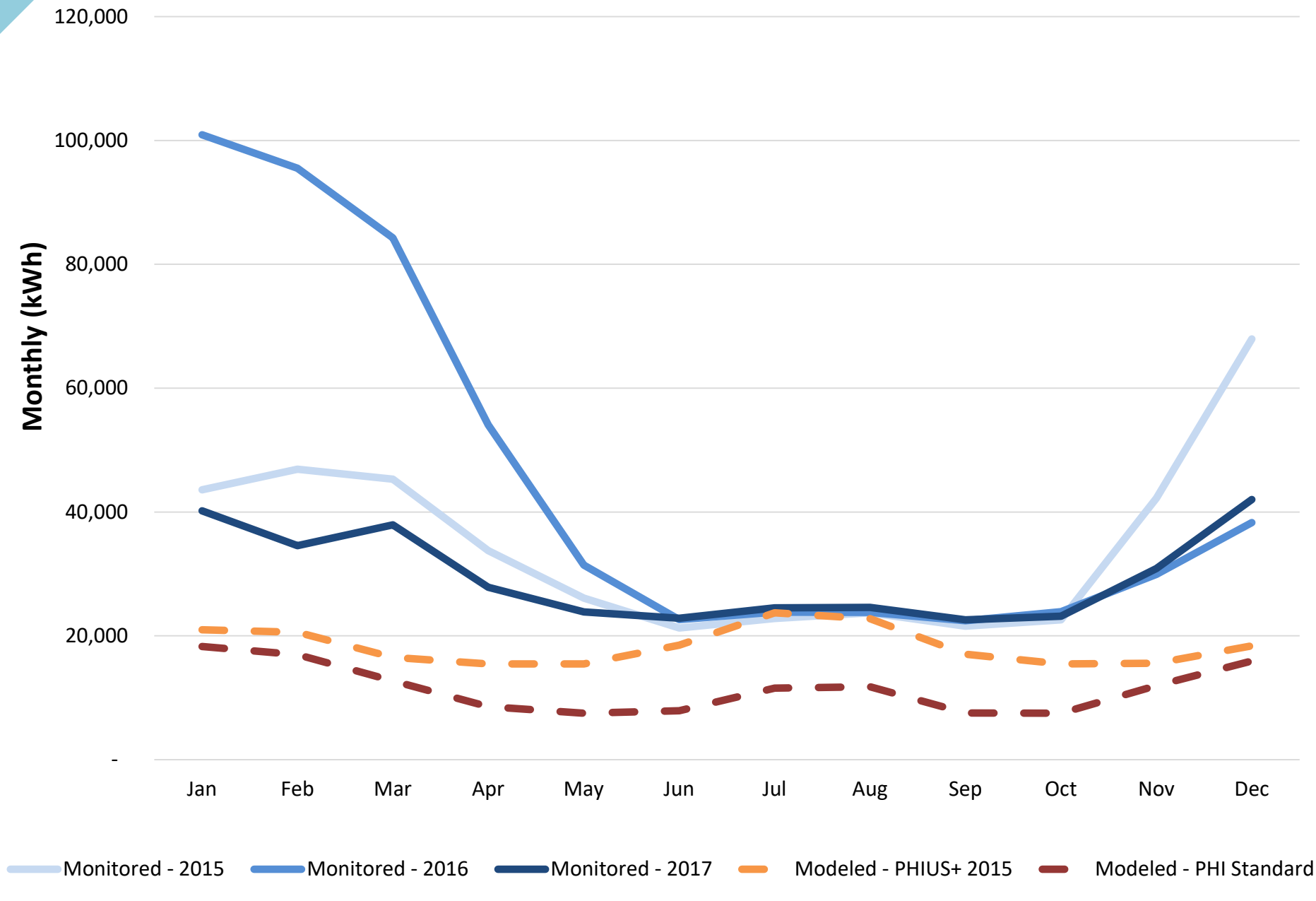
Actual Occupancy	24	**64**	?
PHIUS+ Project #	1188	**1274**	1203

Knickerbocker Commons

Things to keep in mind

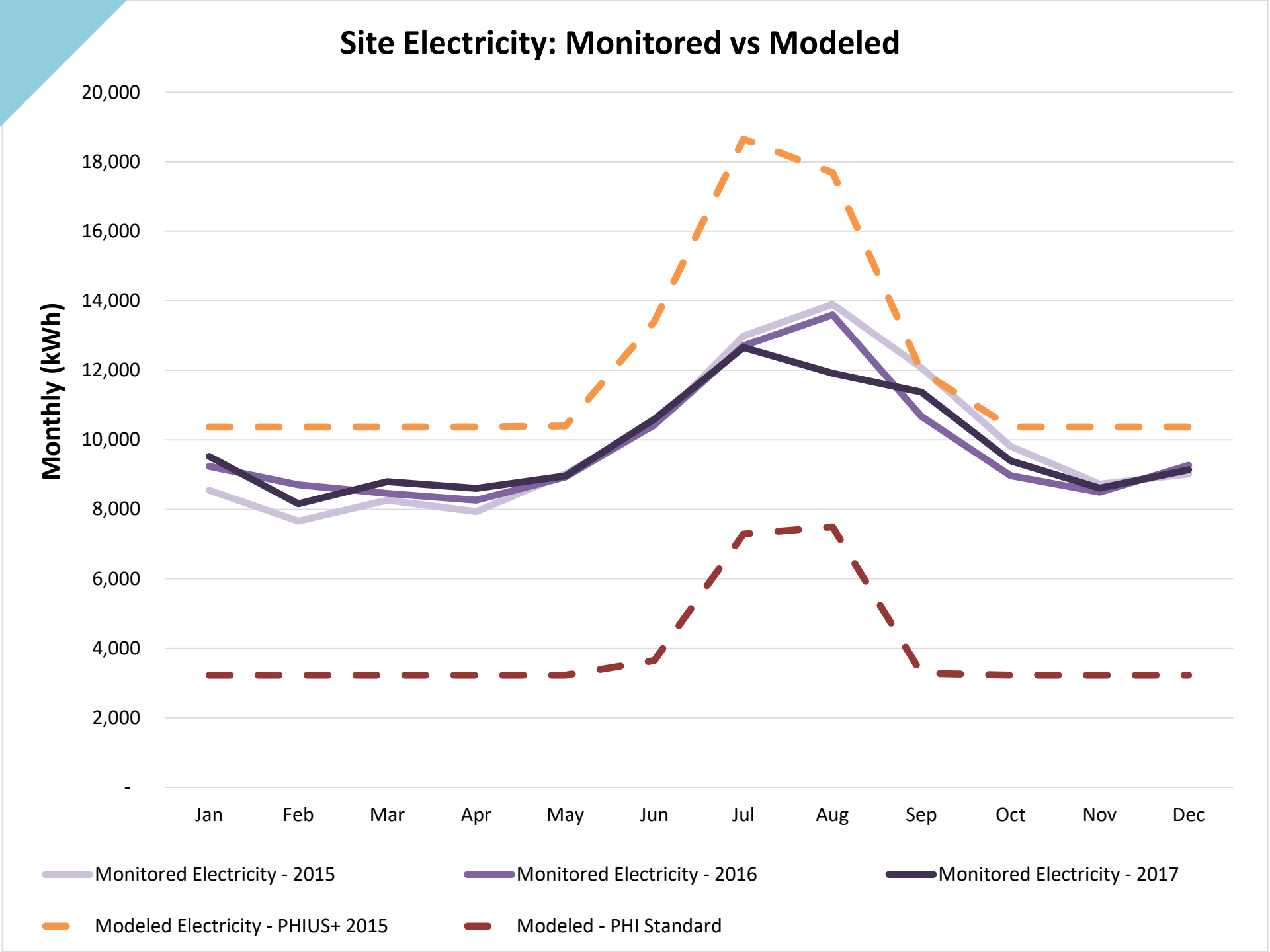
- Project did not go through on-site Verification to become a Certified Passive House Project
- Site Energy analyzed (converted to kWh)
- Electricity and gas monitored separately
  - Electric: cooling, lighting, MELs
  - Gas: heating, water heating, dryers
- Hydronic Heating/water heater system
- ERV
- Individual AC units for cooling

Site Energy: Monitored vs Modeled

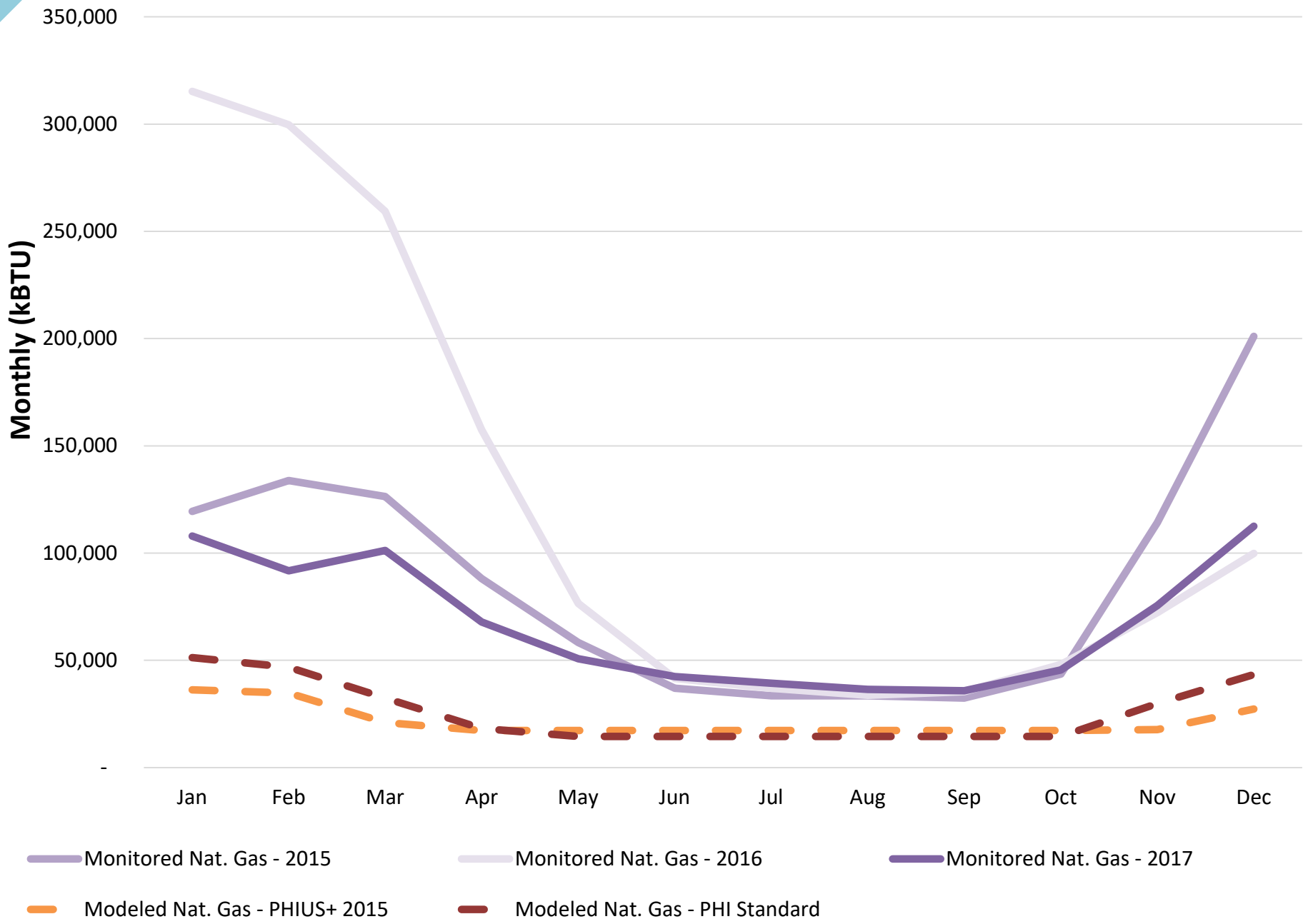


Things to keep in mind

- Electric Meter
  - AC Units
  - Lighting
  - MELS
- Natural Gas Meter
  - Hydronic Heating
  - Water Heaters
  - Exhaust Clothes Dryers


Site Electricity: Monitored vs Modeled
Monthly (kWh)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Monitored Electricity - 2015
Monitored Electricity - 2016
Monitored Electricity - 2017
Modeled Electricity - PHIUS+ 2015
Modeled - PHI Standard

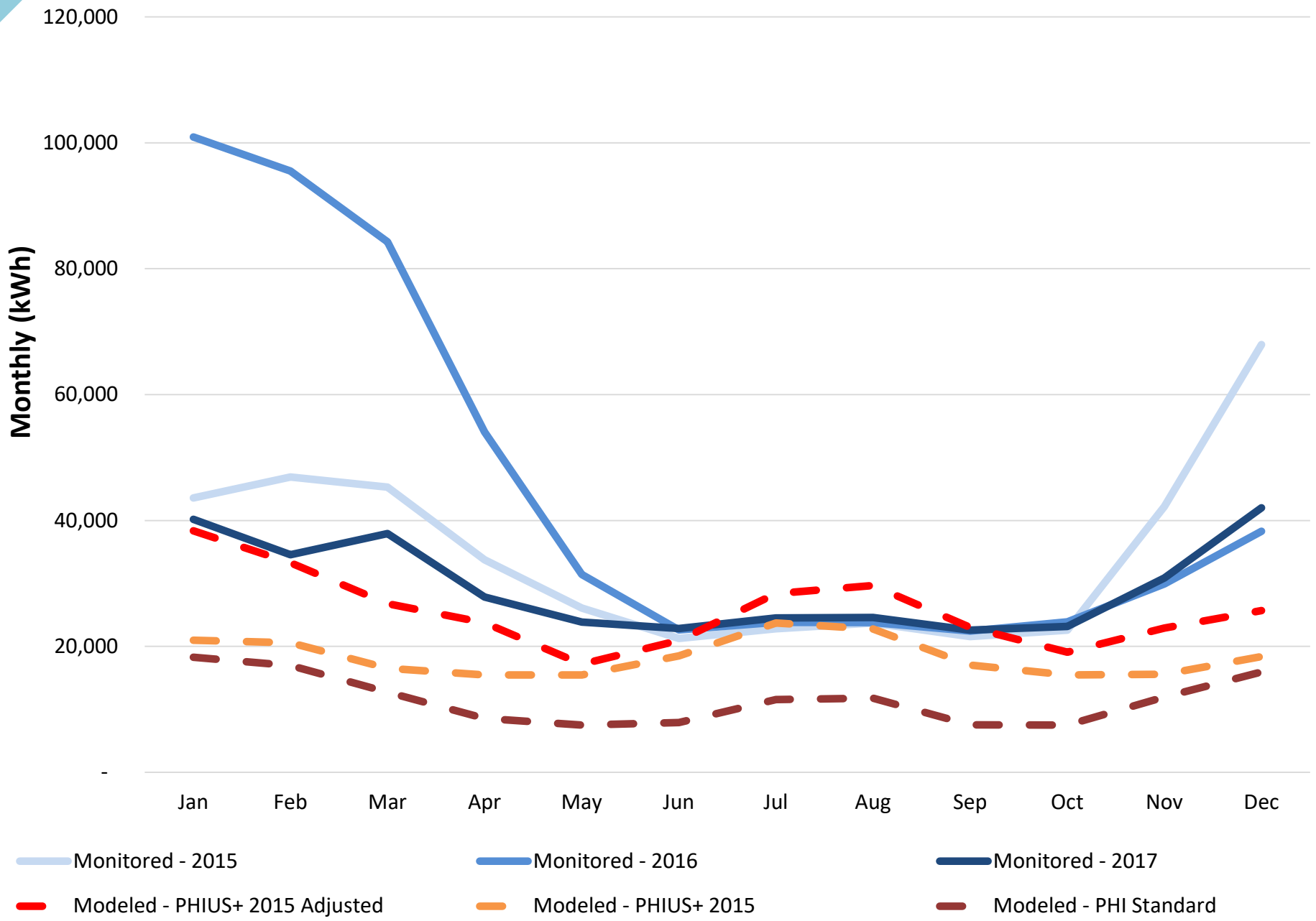
Site Natural Gas: Monitored vs Modeled



PHIUS+ 2015 – Adjusted Model

- Mean Temperatures Adjusted (2016 & 2017)
- Thermostats set to 77F (Winter)
- Actual Occupancy
- Doubled Hot Water Usage
- 0.5 ACH50 -> 3 ACH50
  - (Leaky AC Units/Open Windows?)
- Lower Efficiency Boilers

Site Energy: Monitored vs Modeled



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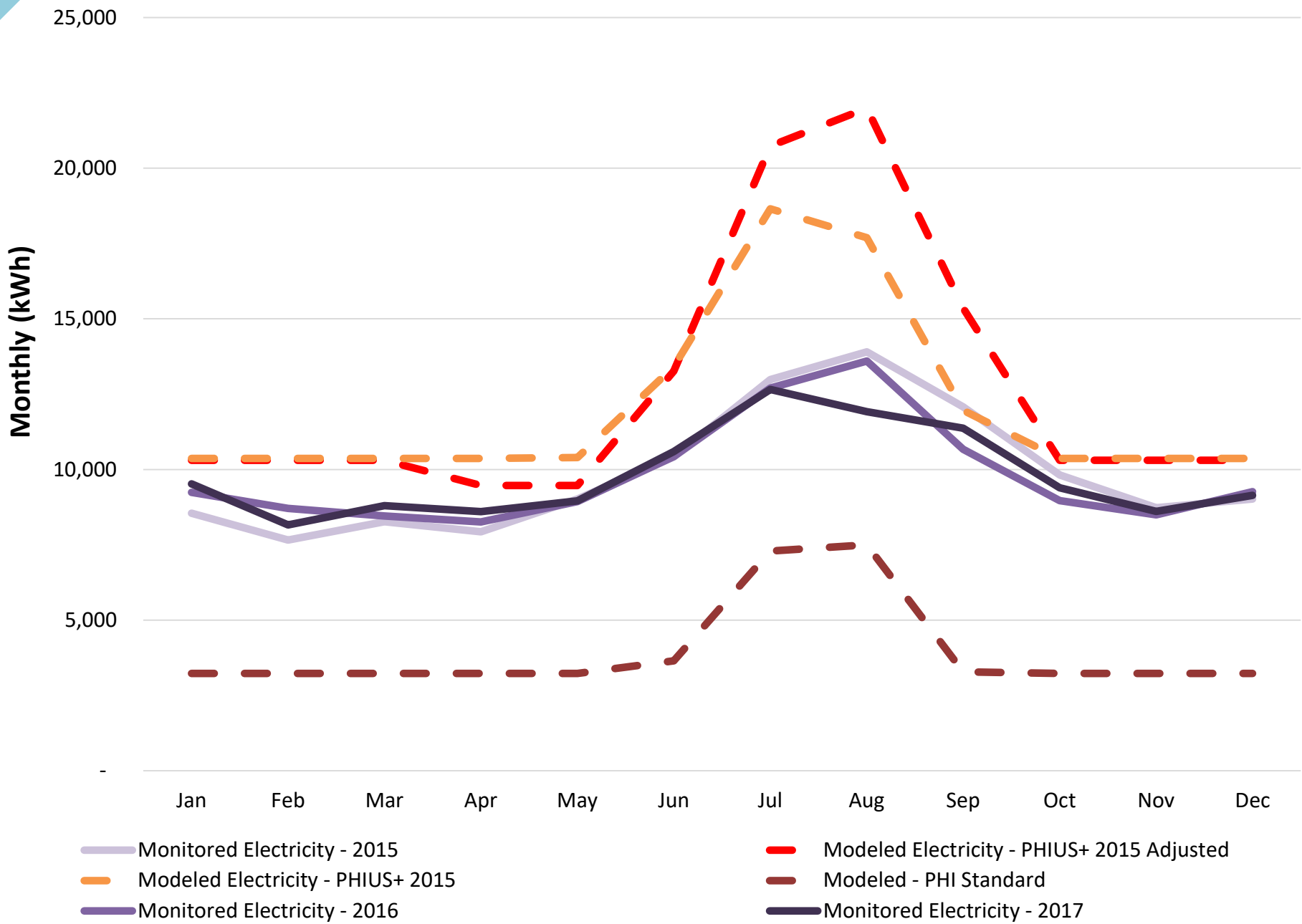
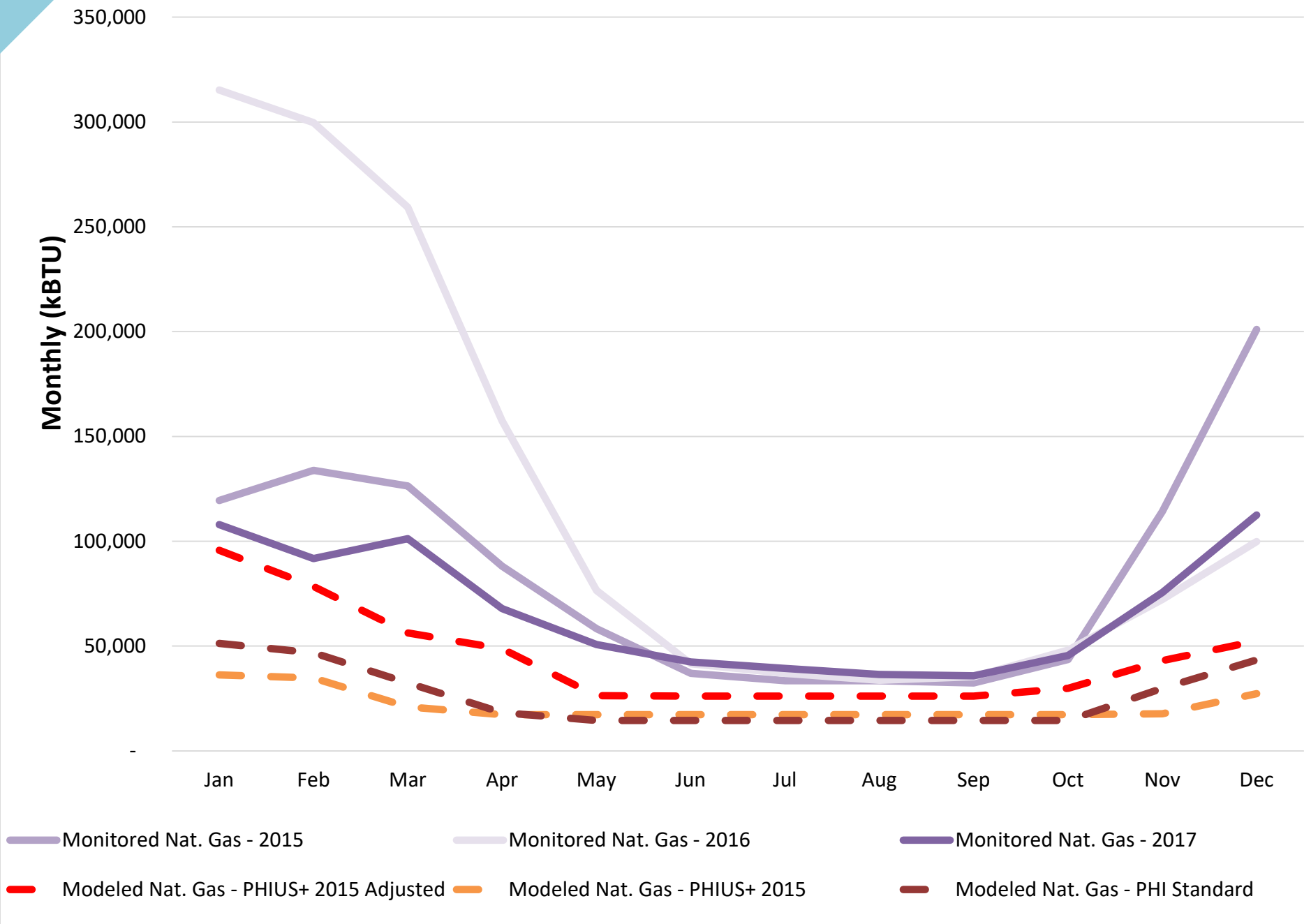
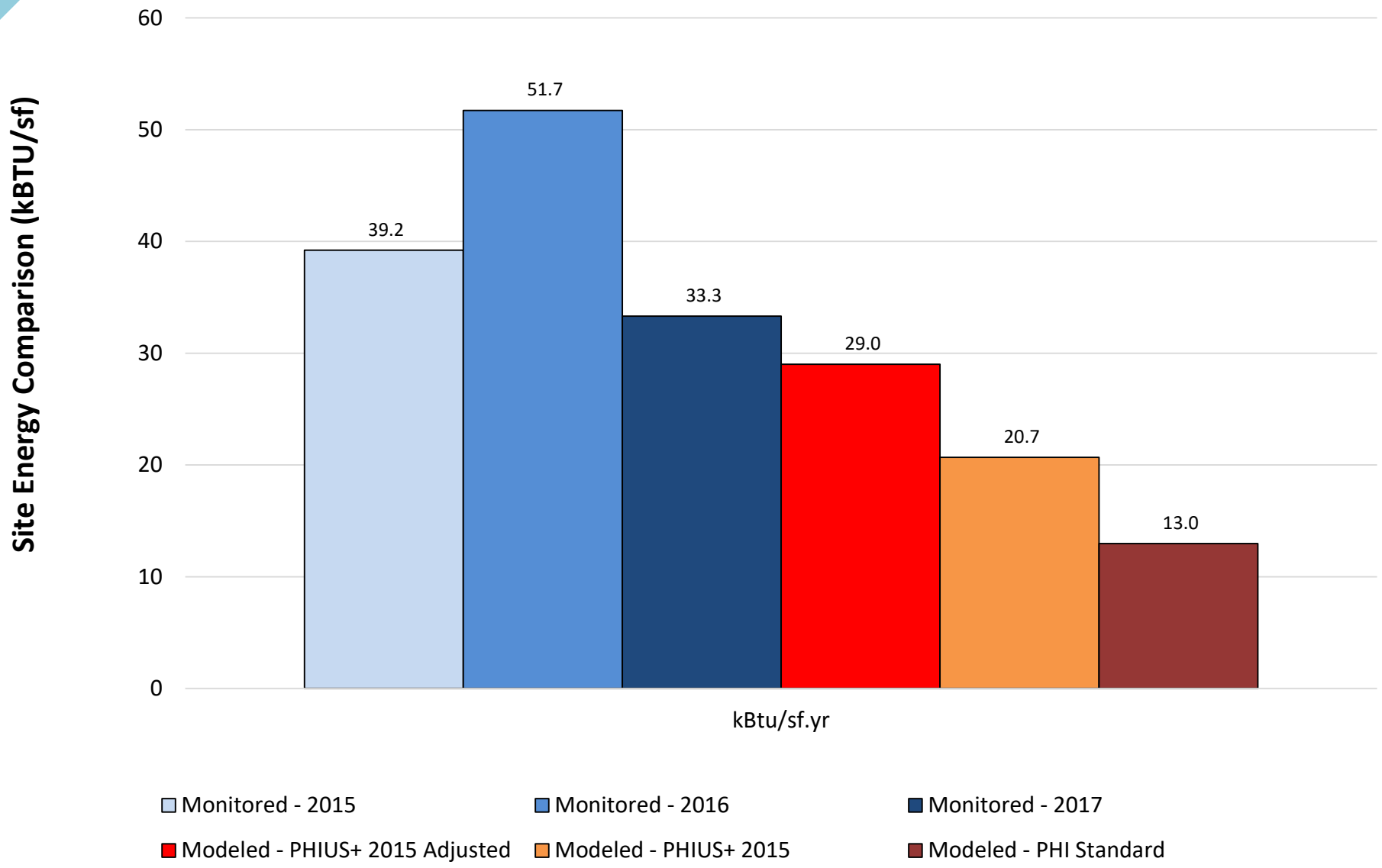


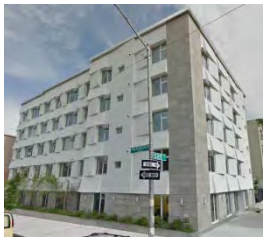
Site Natural Gas: Monitored vs Modeled



Site Energy: Monitored vs Adjusted Models



Three Case Studies



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Actual Occupancy	24	64	**?**
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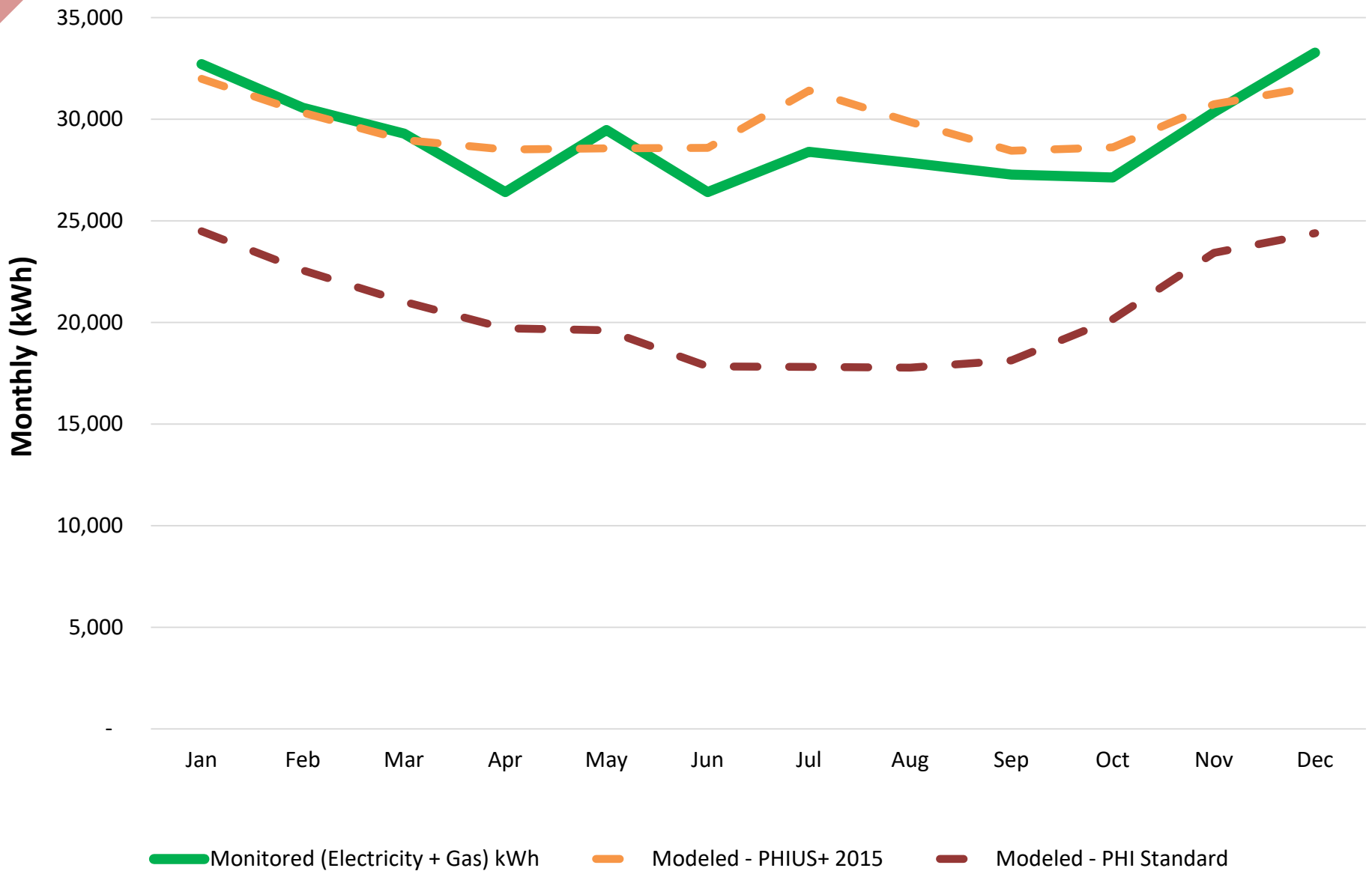
Orchards at Orenco I

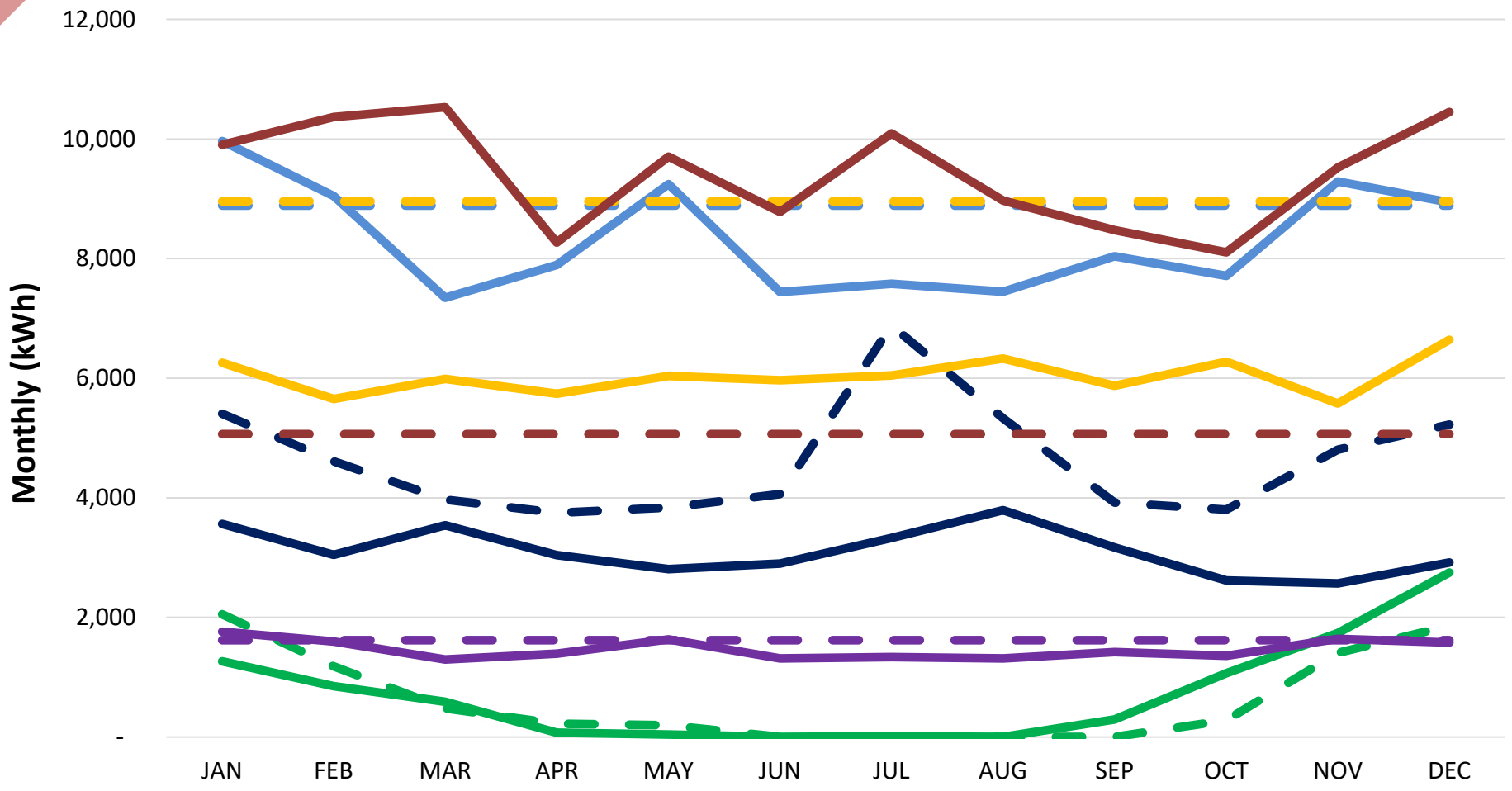
Things to keep in mind

- Site Energy analyzed (converted to kWh)
- Electricity monitored separately
- Heat pumps (heating/cooling) in apartments w/ direct electric backup
- HRV
- Natural Gas WH
- Natural Gas Clothes Dryers

Site Energy: Monitored vs Modeled

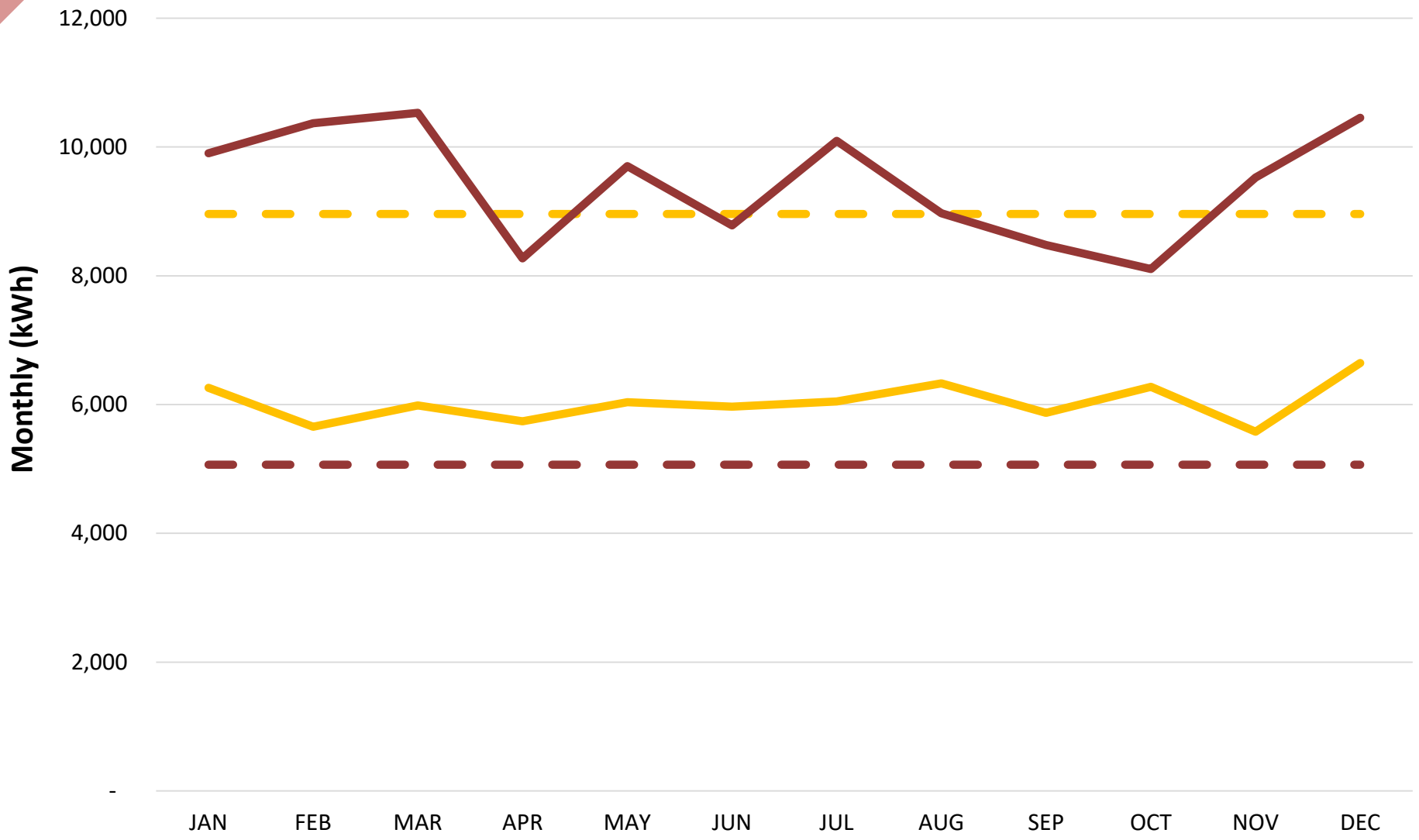


Site Energy: Monitored vs PHIUS+ 2015 Predicted



- Monitored - Unit Electric Heating
- Monitored - Heating/Cooling Heat Pumps + ERV
- Monitored - Hot Water - Gas
- Monitored - Clothes Dryers - Gas
- Monitored - Electricity - Apts
- Monitored - Electricity - Commons
- Predicted - Unit Electric Heating
- Predicted - Heating/Cooling Heat Pumps + ERV
- Predicted - Hot Water - Gas
- Predicted - Clothes Dryers - Gas
- Predicted - Electricity - Apts
- Predicted - Electricity - Commons

Site Energy: Monitored vs PHIUS+ 2015 Predicted



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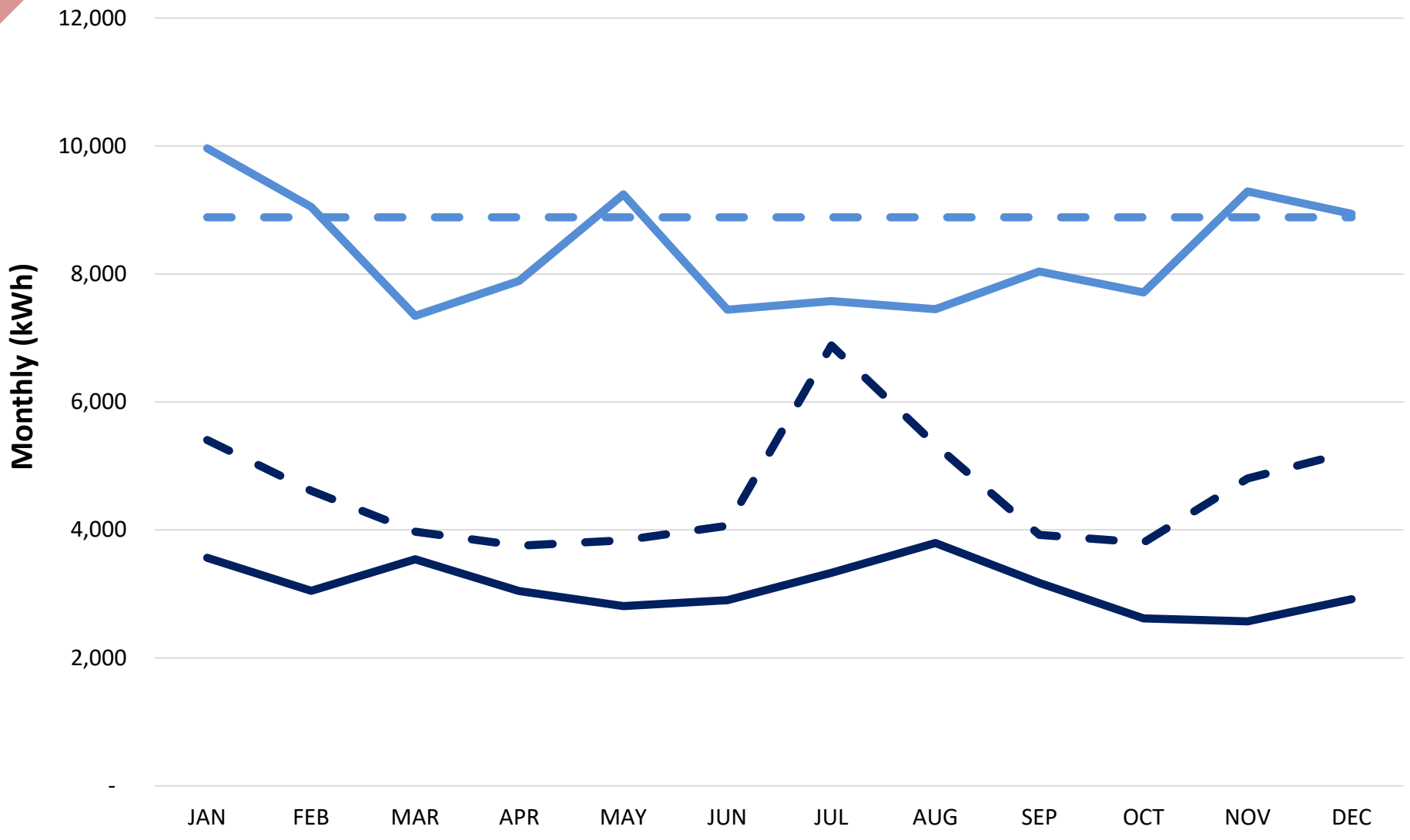
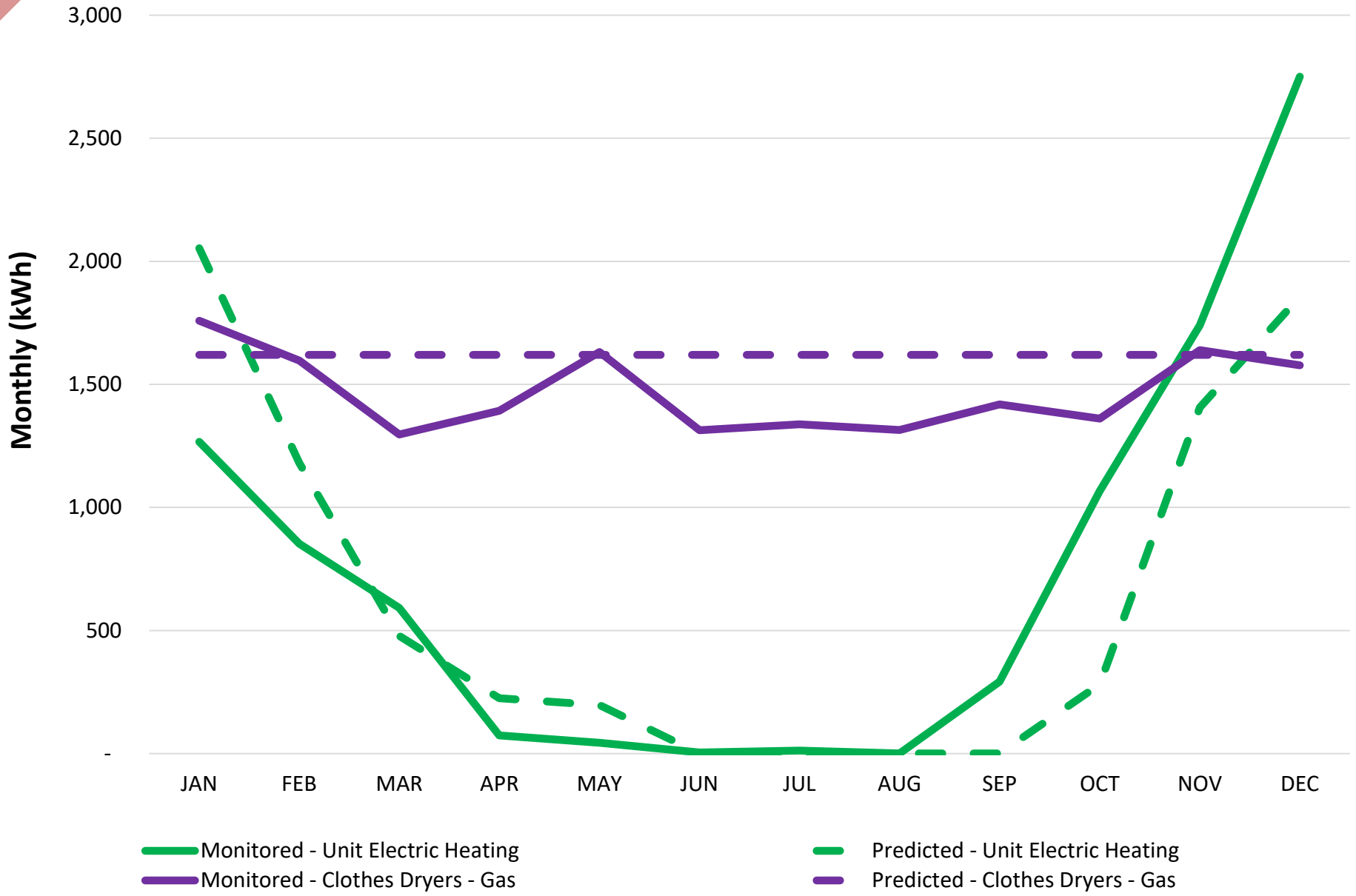
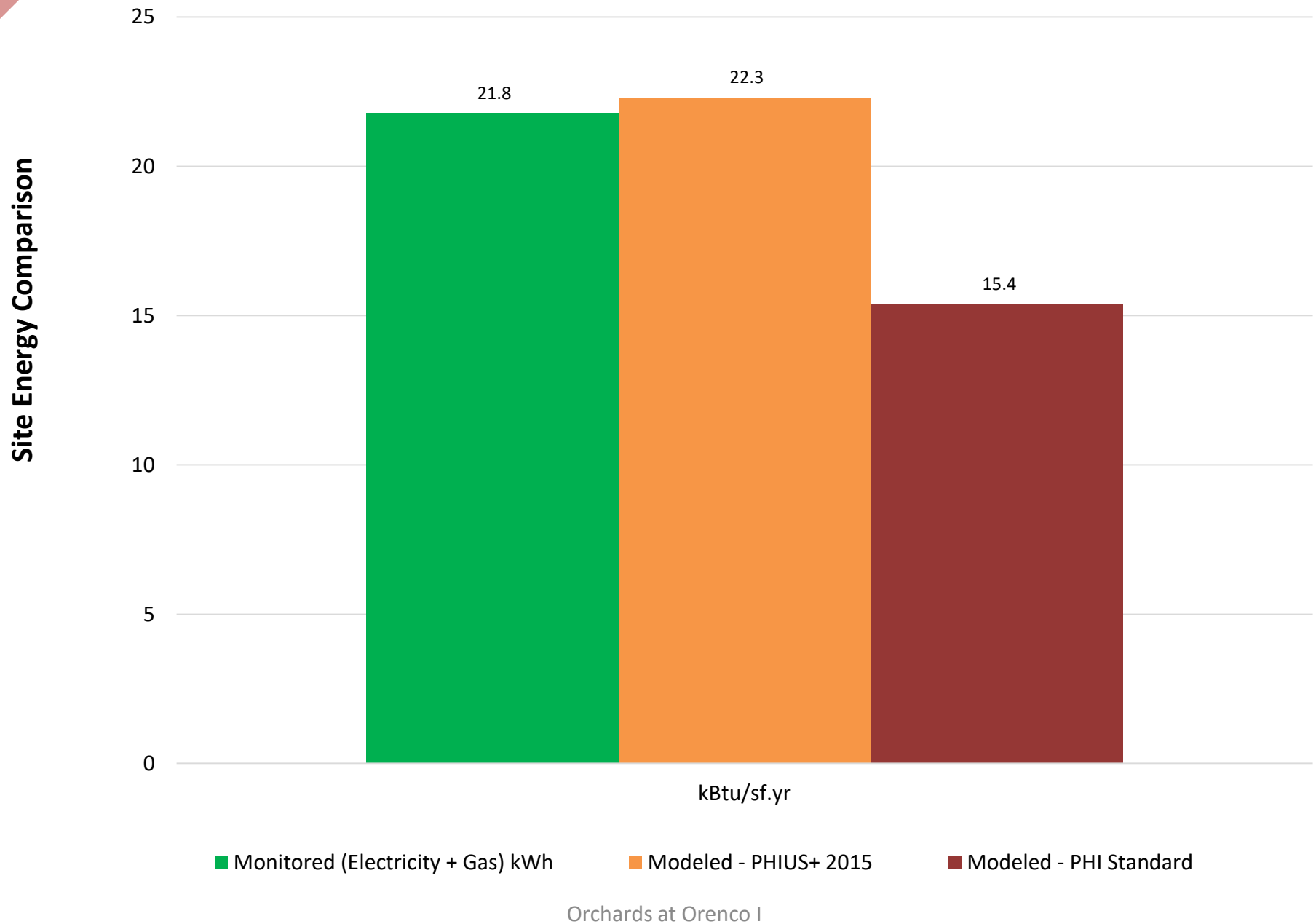
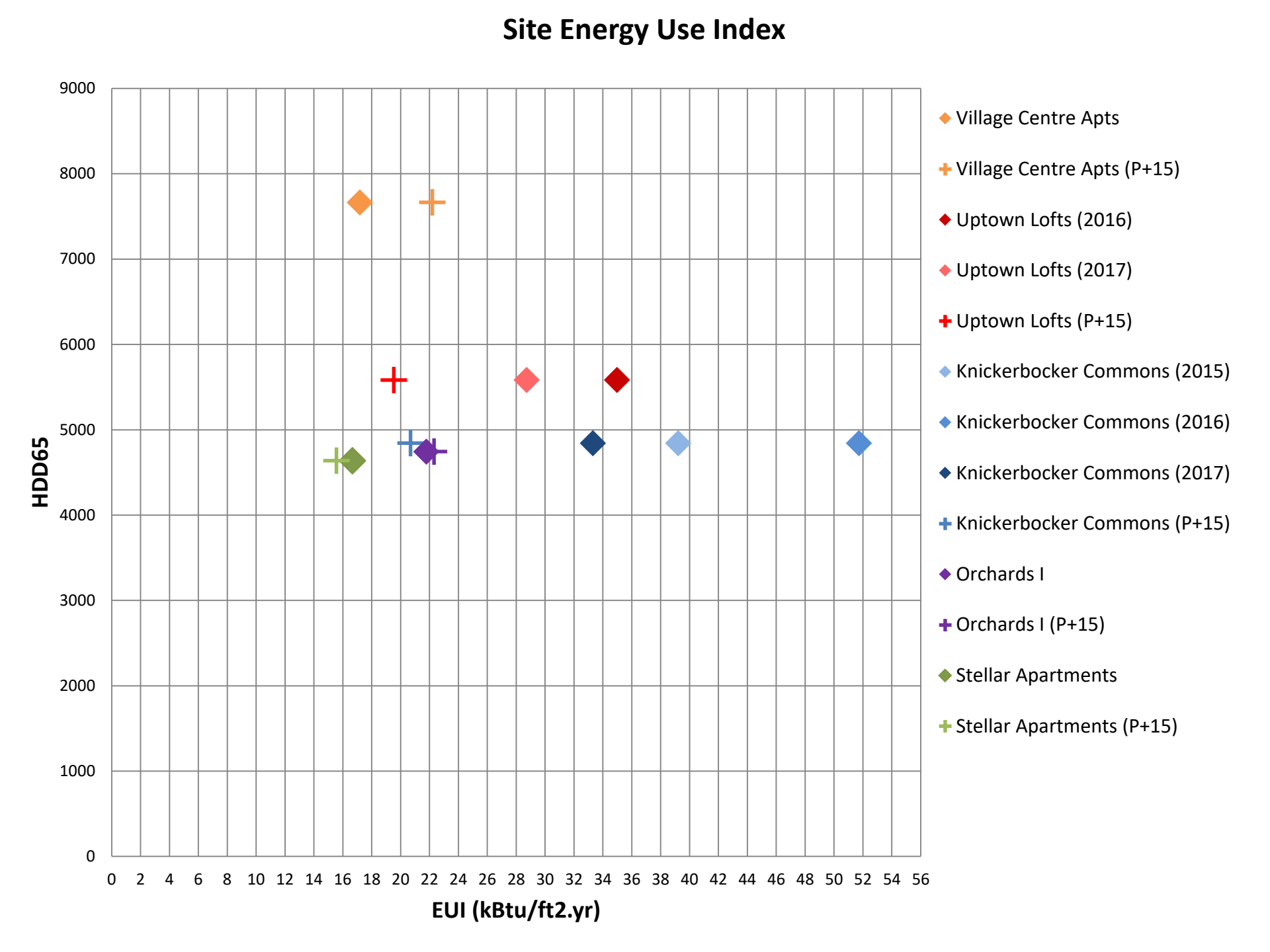


Site Energy: Monitored vs PHIUS+ 2015 Predicted



Site Energy: Monitored vs Adjusted Models




Site Energy Use Index
HDD65
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56
EUI (kBtu/ft2.yr)
Village Centre Apts
Village Centre Apts (P+15)
Uptown Lofts (2016)
Uptown Lofts (2017)
Uptown Lofts (P+15)
Knickerbocker Commons (2015)
Knickerbocker Commons (2016)
Knickerbocker Commons (2017)
Knickerbocker Commons (P+15)
Orchards I
Orchards I (P+15)
Stellar Apartments
Stellar Apartments (P+15)

Elm Place– Milton, VT

PASSIVE BUILDING

PART OF THE SOLUTION

James Ortega, Certification Staff

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