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

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Stellar Apartments

Orchards at Orenco

Knickerbocker Commons

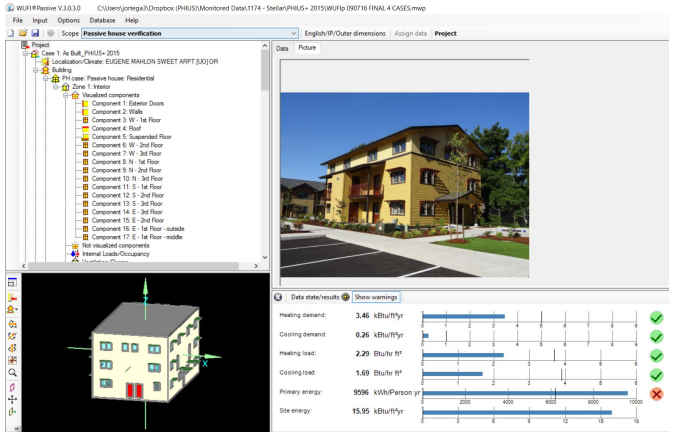
Importance of Monitoring Energy Use

1. Verify Energy Model Predictions
2. Guide Energy Modeling Protocol
3. More Accurate Modeling & Building Performance Certification
4. Provide Feedback to Occupants
5. HVAC Performance Verification

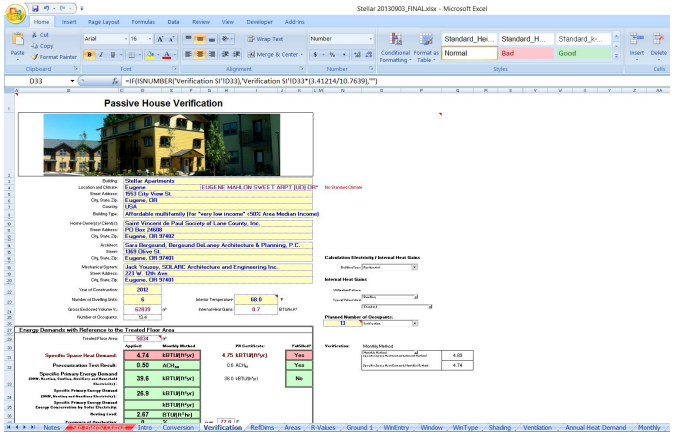
Methods - Modeling

3 Comparative Data Sets per Project

1. **Monitored:** Actual Measured Energy Use
2. **PHIUS+:** Modeled Energy Use under PHIUS+ Passive Building Standard
   a. ‘Passive House Planning Package’ (PHPP)
3. **PHIUS+ 2015:** Modeled Energy Use under PHIUS+ 2015 Passive Building Standard
   a. WUFI-Passive

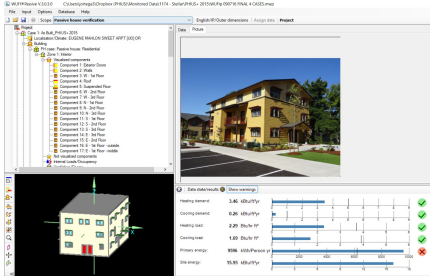


WUFI-Passive

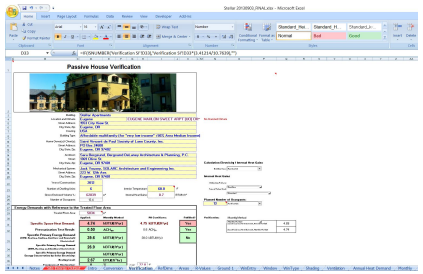


PHPP

Methods - Variances in Modeling Protocol



WUFI-Passive (PHIUS+ 2015)



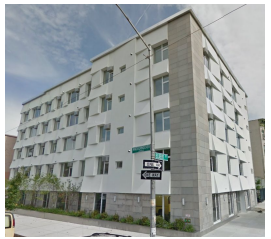
PHPP (PHIUS+)

Occupancy	# bedrooms + 1, per unit	1 person per 377 sf
Internal Heat Gains	Calculated Value	Default Value
Misc Loads & Lighting	80% RESNET Assumptions	PHPP Default
Space Conditioning Criteria	Climate Specific	Passivhaus Targets

Methods - Derivation of Estimated Monthly Data

- Monthly Estimates from Static Model
  - Limitation: PHPP & WUFI Passive - Output Annual Energy Use
- Systems:
  - Heating Energy - Monthly Demand + Seasonal Performance of System
  - Cooling Energy - Monthly Demand
  - Hot Water (Heat Pump Water Heaters only) - Seasonal Performance of System
- Appliances:
  - Major Appliances (Refrigerators, Freezers, Clothes Washers, Clothes Dryers, Dishwashers, Cooktops, Lighting, etc…) - Divided Evenly
  - Hot Water (Electric Resistance or Natural Gas)
  - Heat Recovery Ventilation (HRV & ERV)

Three Case Studies



	Stellar Apartments	*Orchards at Orenco Phase 1*	*Knickerbocker Commons*
Location	Eugene, OR	Hillsboro, OR	Brooklyn, NY
Square Footage (iCFA)	5,848 ft^2	48,035 ft^2	31,903 ft^2
Number of Units	6	57	24
Modeled Occupancy	13 (PHIUS+) 18 (PHIUS+ 2015)	113 (PHIUS+) 131 (PHIUS+ 2015)	72 (PHIUS+) 72 (PHIUS+ 2015)
PHIUS+ Project #	1174	1203	1274

Stellar Apartments

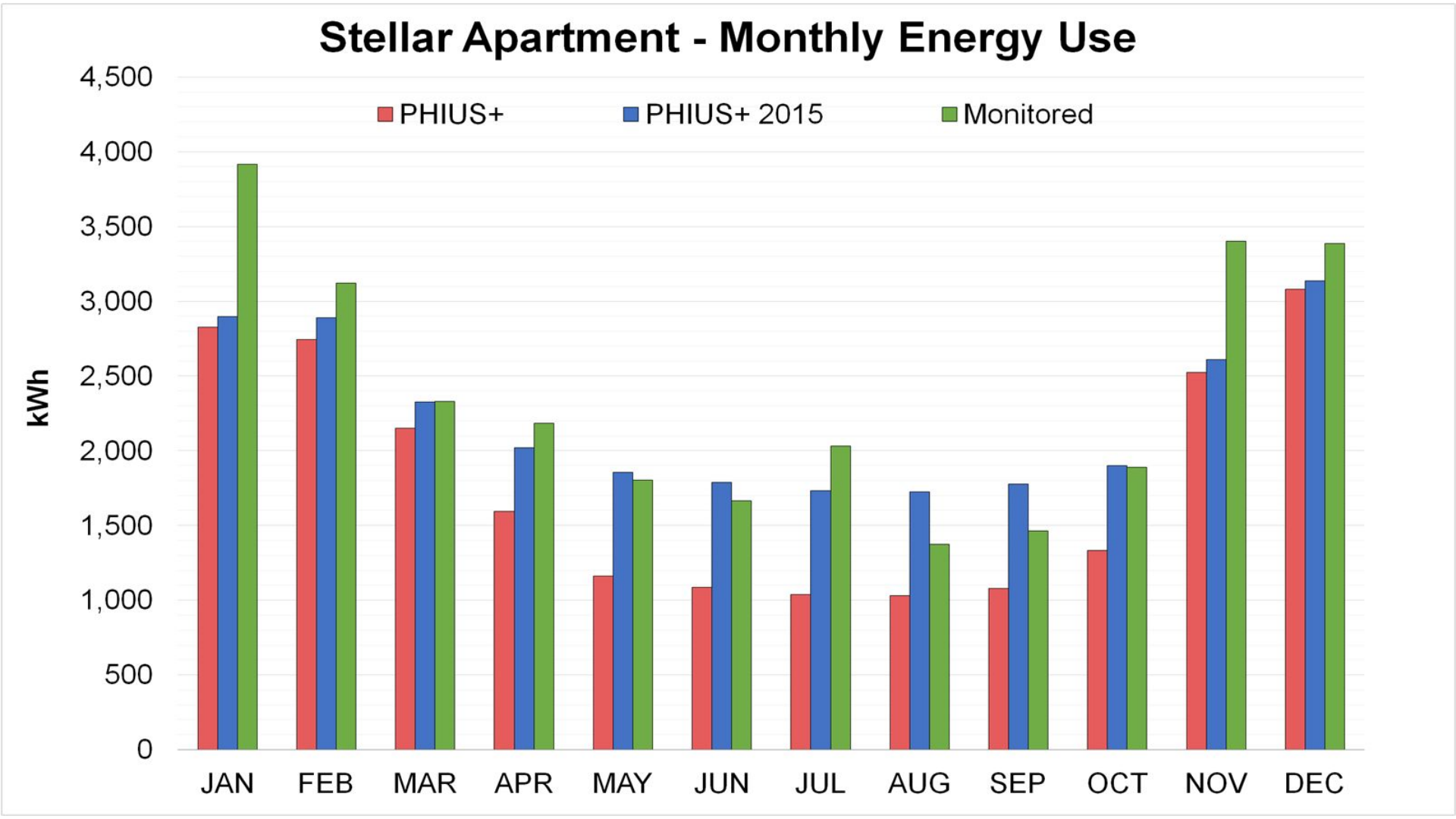
Stellar Apartments

Monitored Data

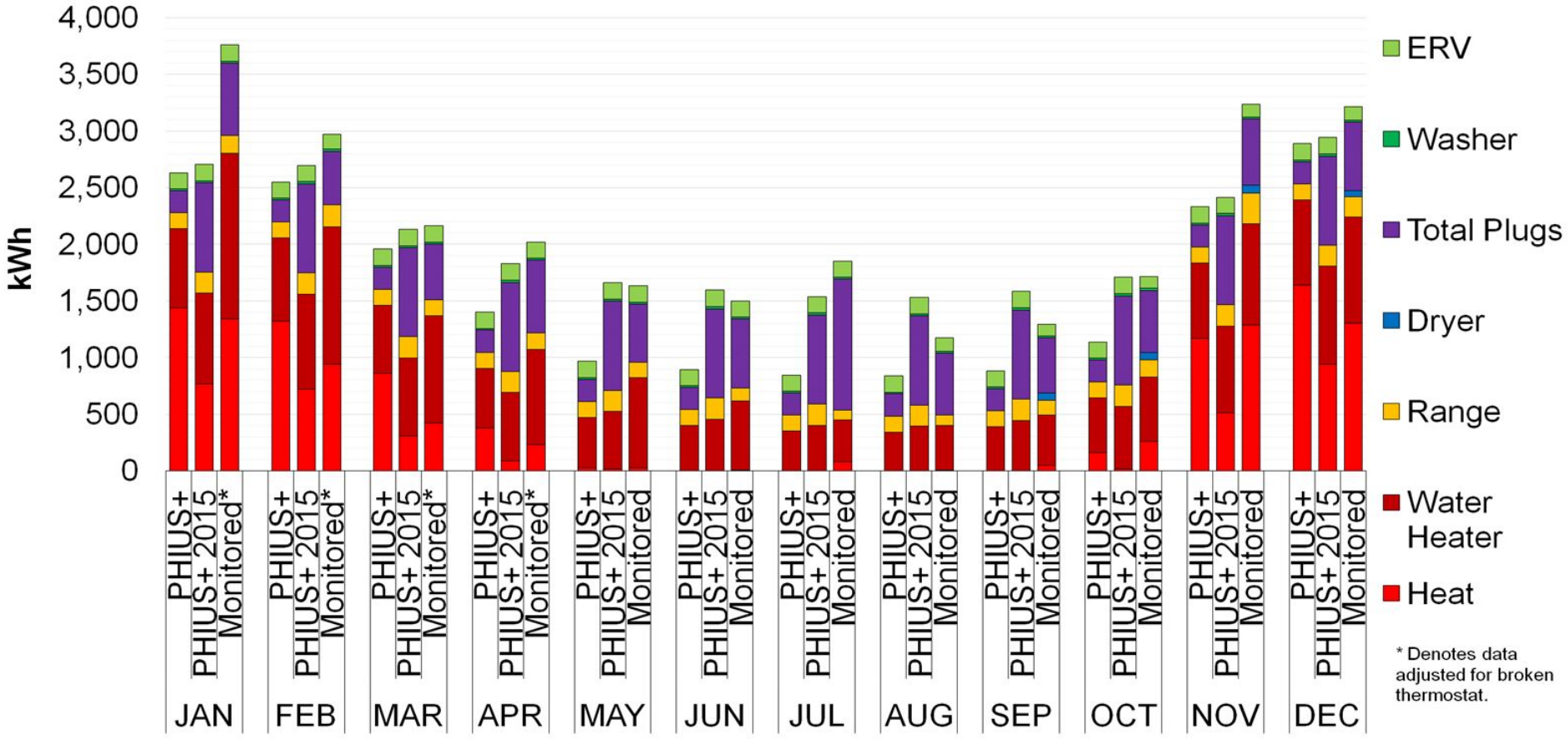
- 54 - Unit Multifamily Affordable Housing Development
- One - 3-Story (6 units) built to PHIUS+ Standard
- Monitoring Systems
  - 8 Electricity Monitors per Unit
    - Heating
    - ERV
    - Water Heater
    - Kitchen Range
    - Kitchen Outlets
    - Kitchen Fridge
    - Clothes Washer
    - Other

Limitations

- Energy Model Limitations
  - ‘Other’ + ‘Kitchen Outlets’ = ‘Lighting/Plug Loads’
  - 7 total categories for comparison
- Shared Space
  - Small Central Stairwell - Not included
- Actual Occupancy Recorded (9)
  - 7 - Adults
  - 1 - Teenager
  - 1 - Toddler
- PHIUS+ Occupancy (13)
- PHIUS+ 2015 Occupancy (18)


Stellar Apartment - Monthly Energy Use
PHIUS+
PHIUS+ 2015
Monitored
kWh
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

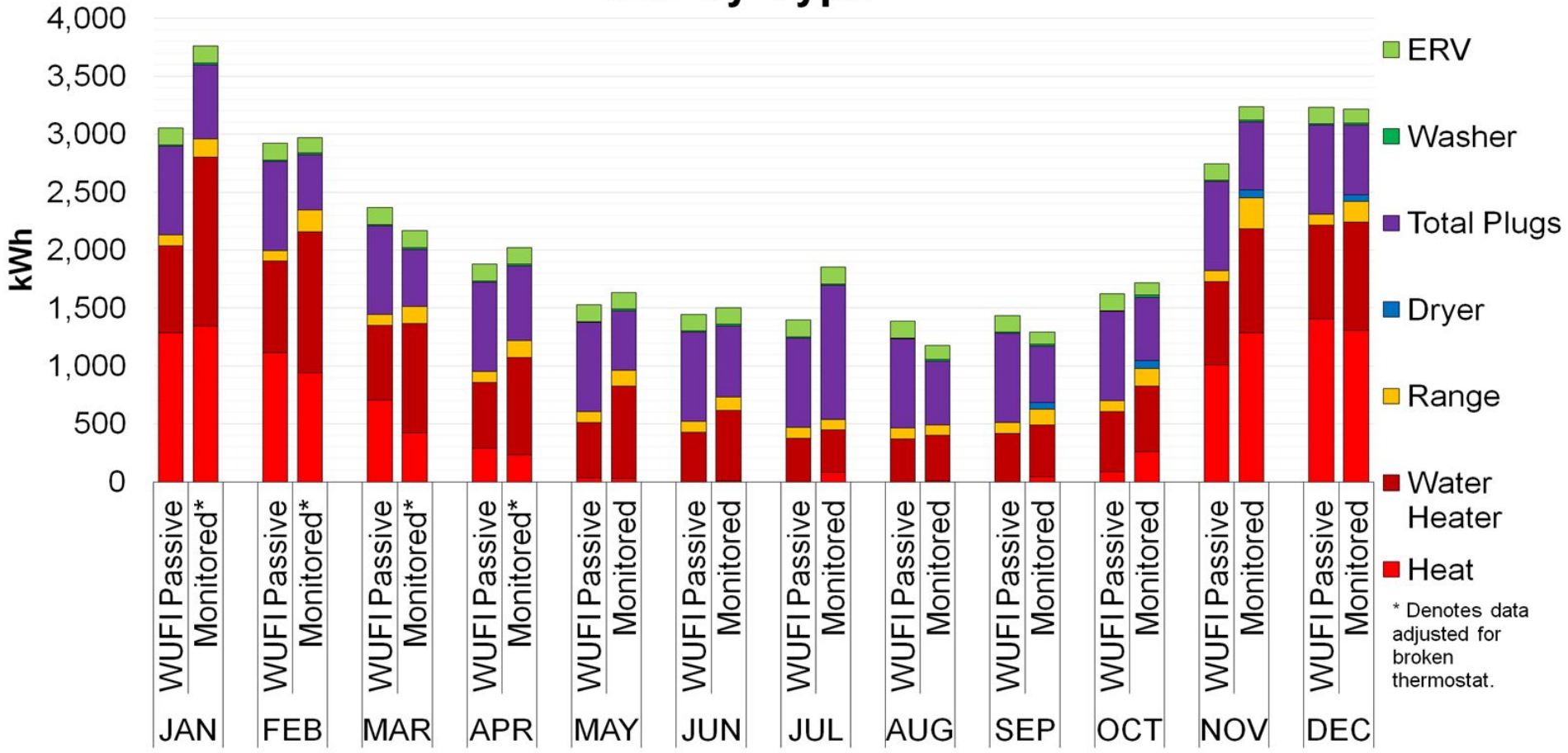
Stellar Apartments - Monthly Energy Use by Type

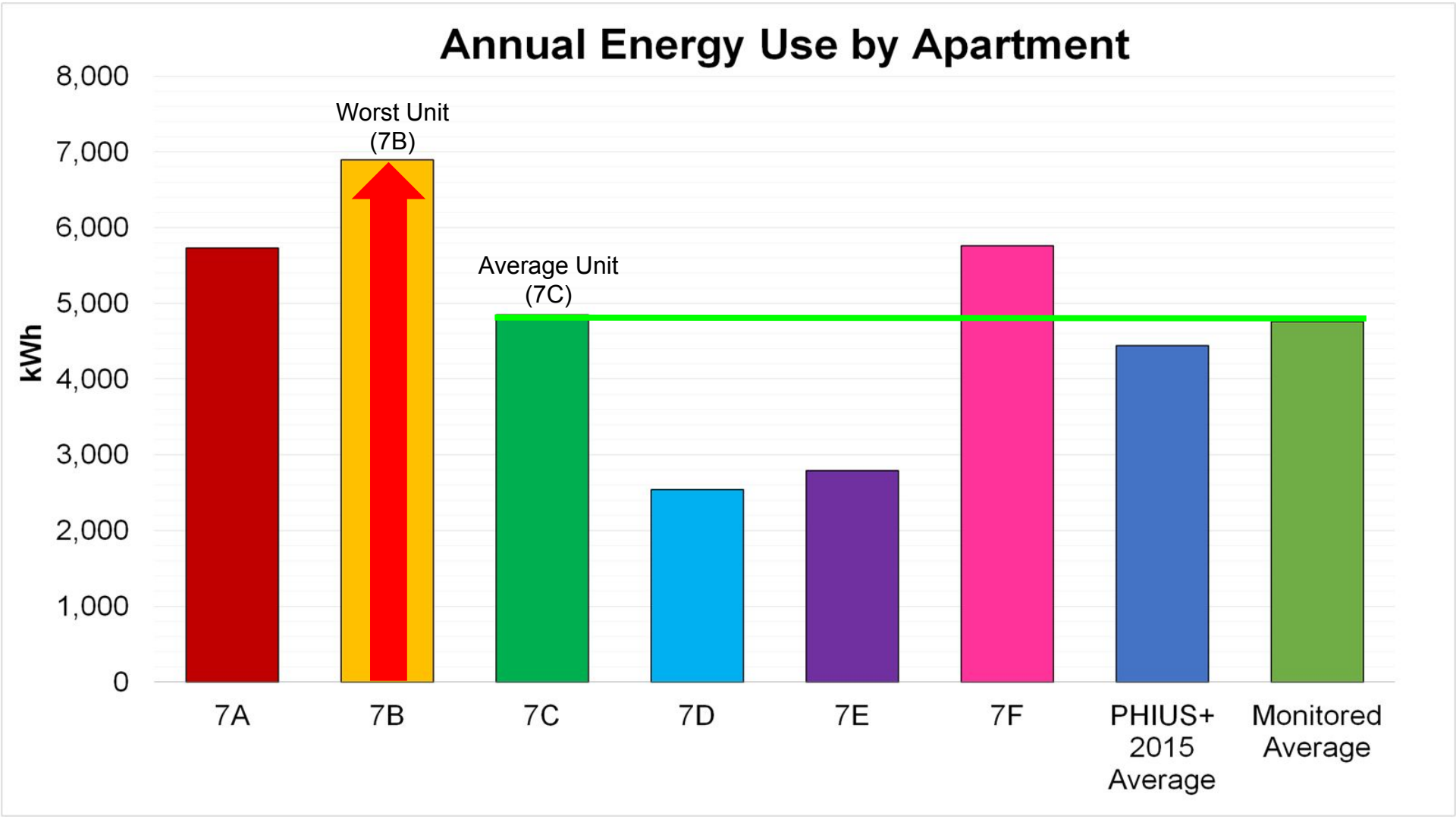


Stellar Apartments - Test Case

- Modeled PHIUS+ 2015 Hypothesis Test
- Occupancy
  - Changed from 18 to 9 (to match recorded occupancy)
- Heating Set-Point
  - Changed from 68F to 70F
- Hot Water Usage
  - Changed from 6.6 Gallons/Person/Day to 13.2 Gallons/Person/Day (Doubled)

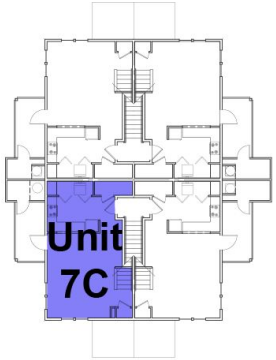
Stellar Apartments Test Case - Monthly Energy Use by Type



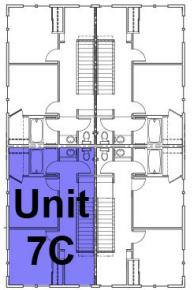

Annual Energy Use by Apartment
kWh
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Worst Unit
(7B)
Average Unit
(7C)
7A
7B
7C
7D
7E
7F
PHIUS+
2015
Average
Monitored
Average

Stellar Apartments - Best & Average Units

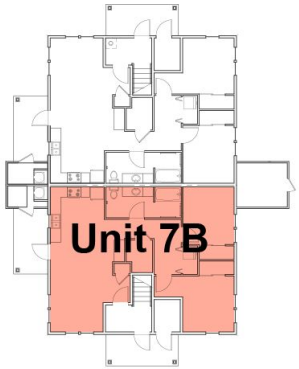
- Unit 7B - Worst Case Apartment
  - 3 Occupants Assumed
- Unit 7C - Average Apartment
  - 3 Occupants Assumed



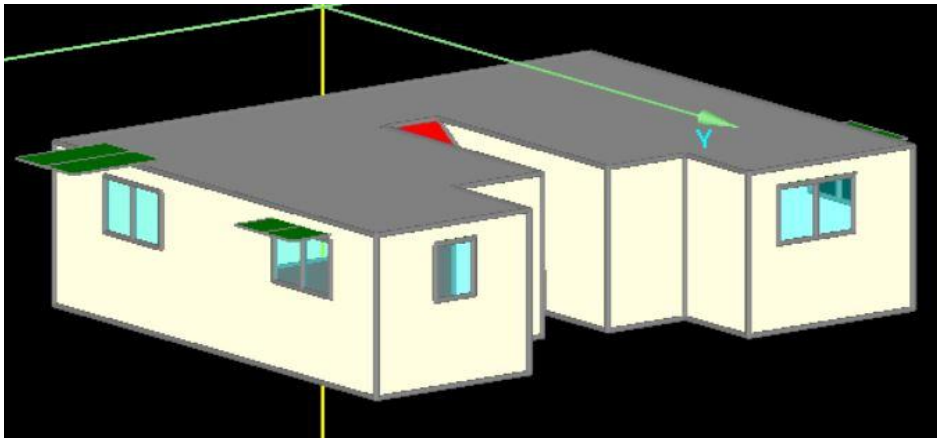
Second Floor

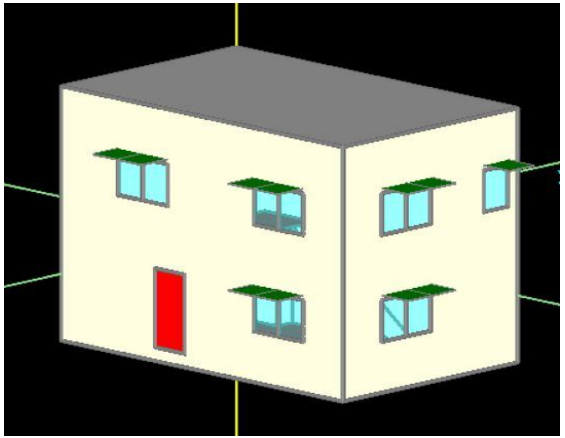


Third Floor



First Floor

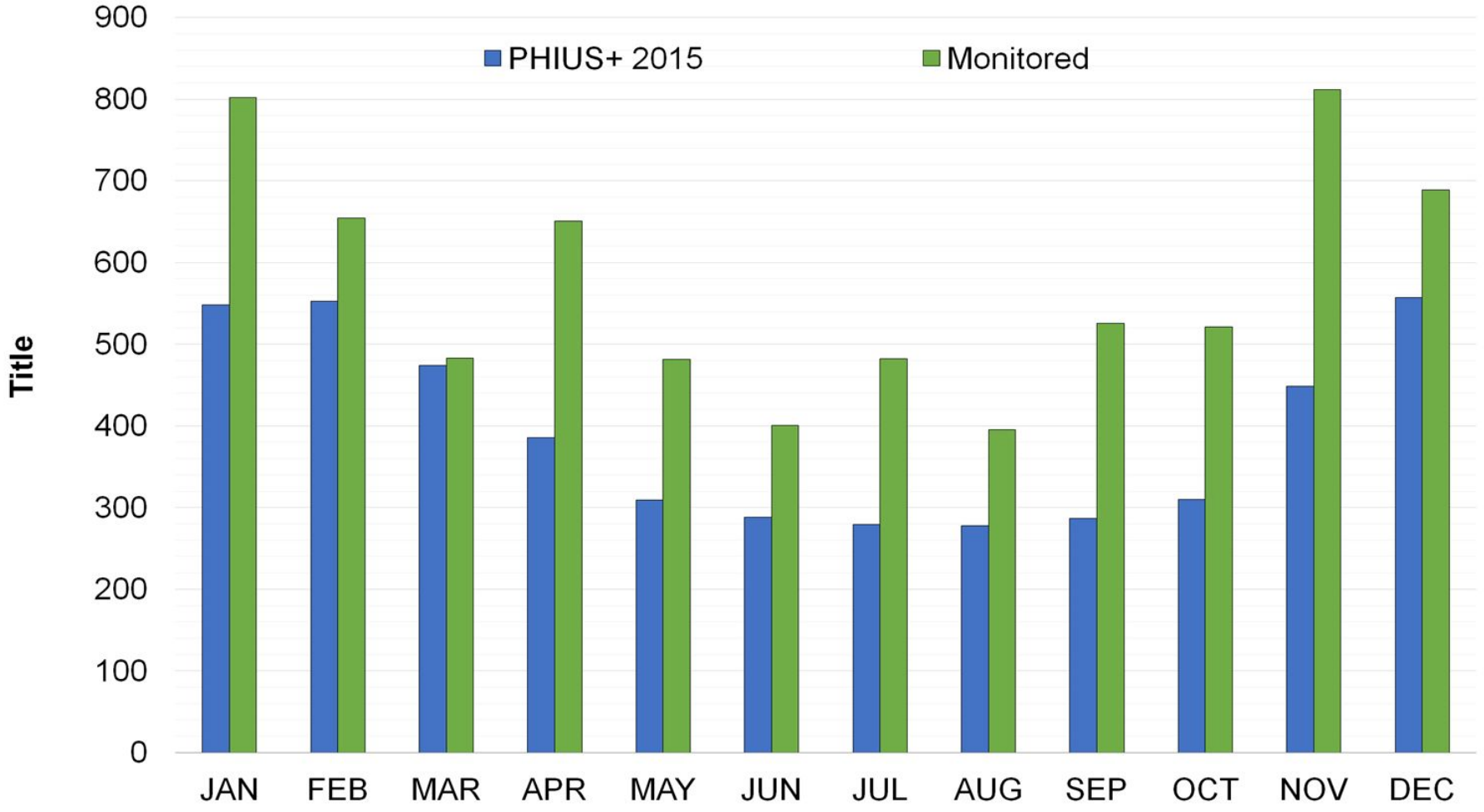




N

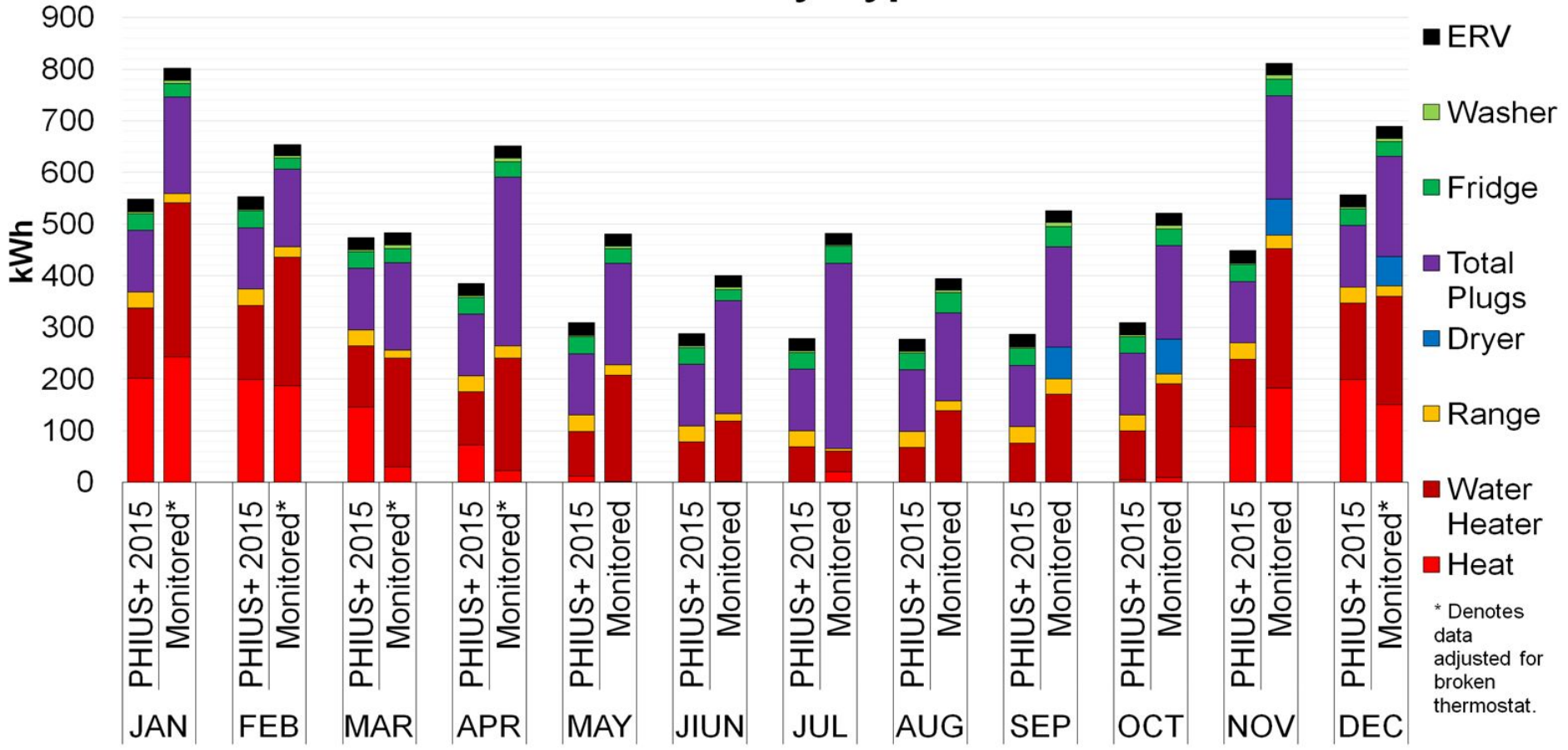
*Worst Case

Stellar Apartments Unit 7B - Monthly Energy Use



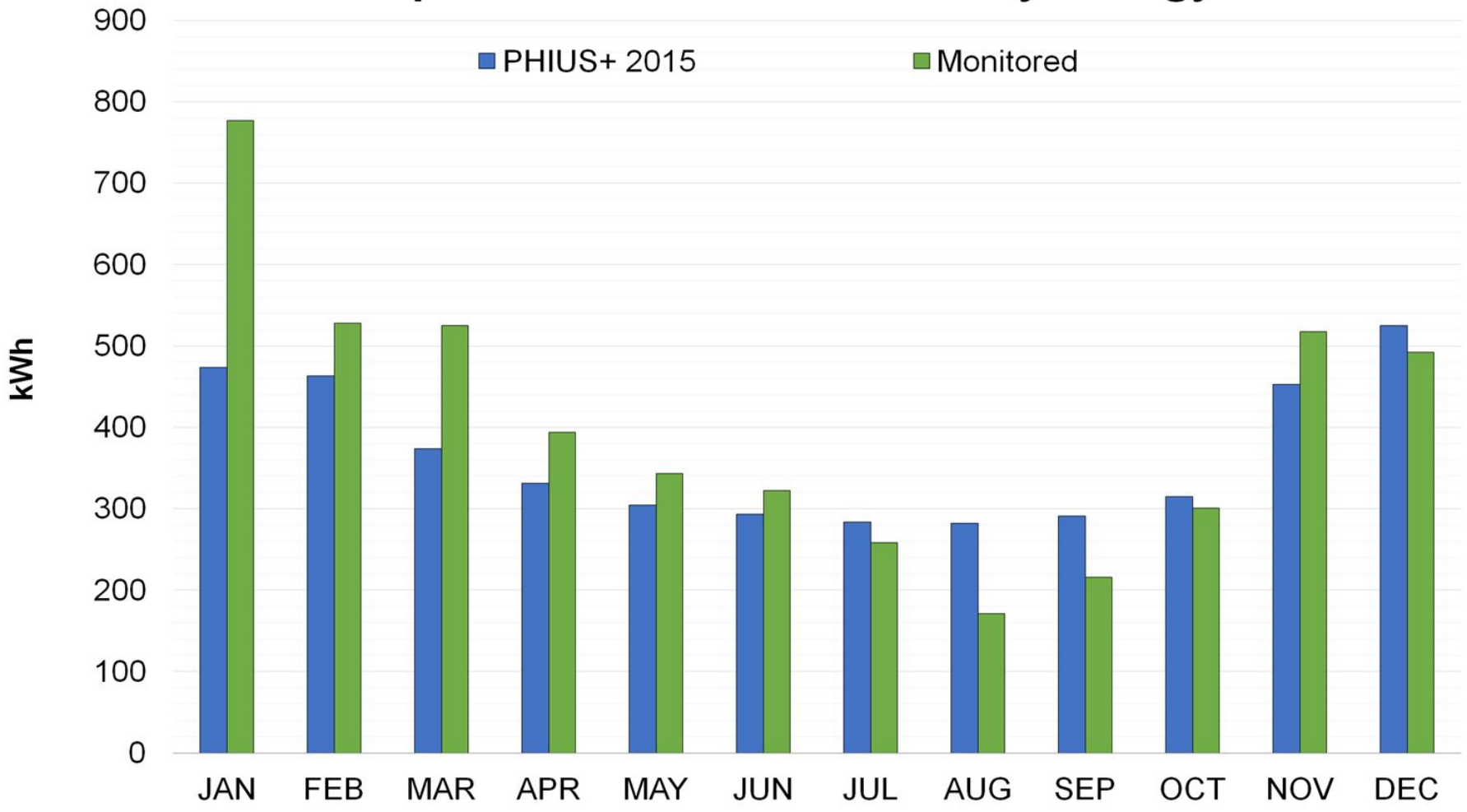
*Worst Case

Stellar Apartments Unit 7B - Monthly Energy Use by Type



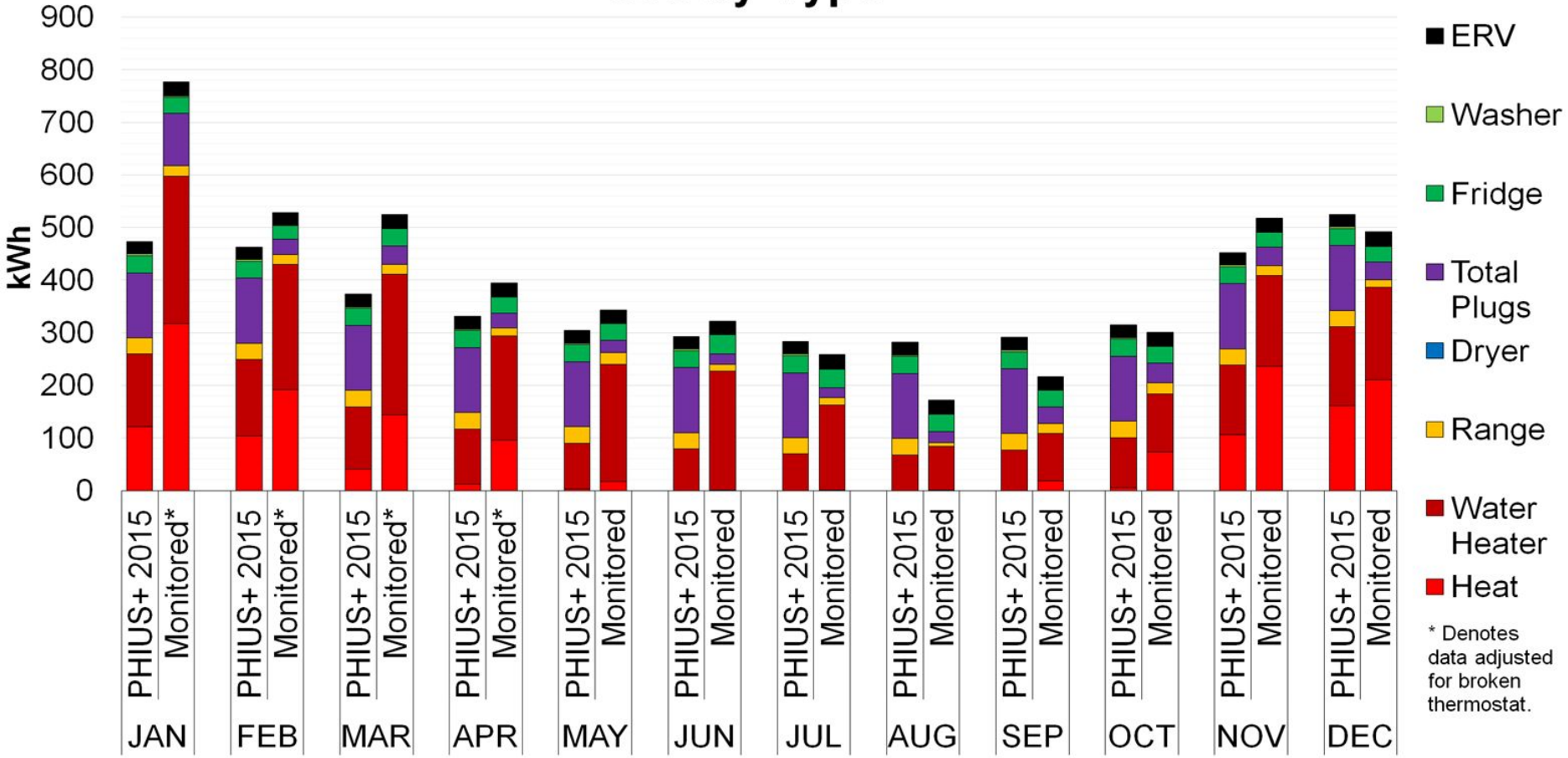
*Average Case

Stellar Apartments Unit 7C - Monthly Energy Use



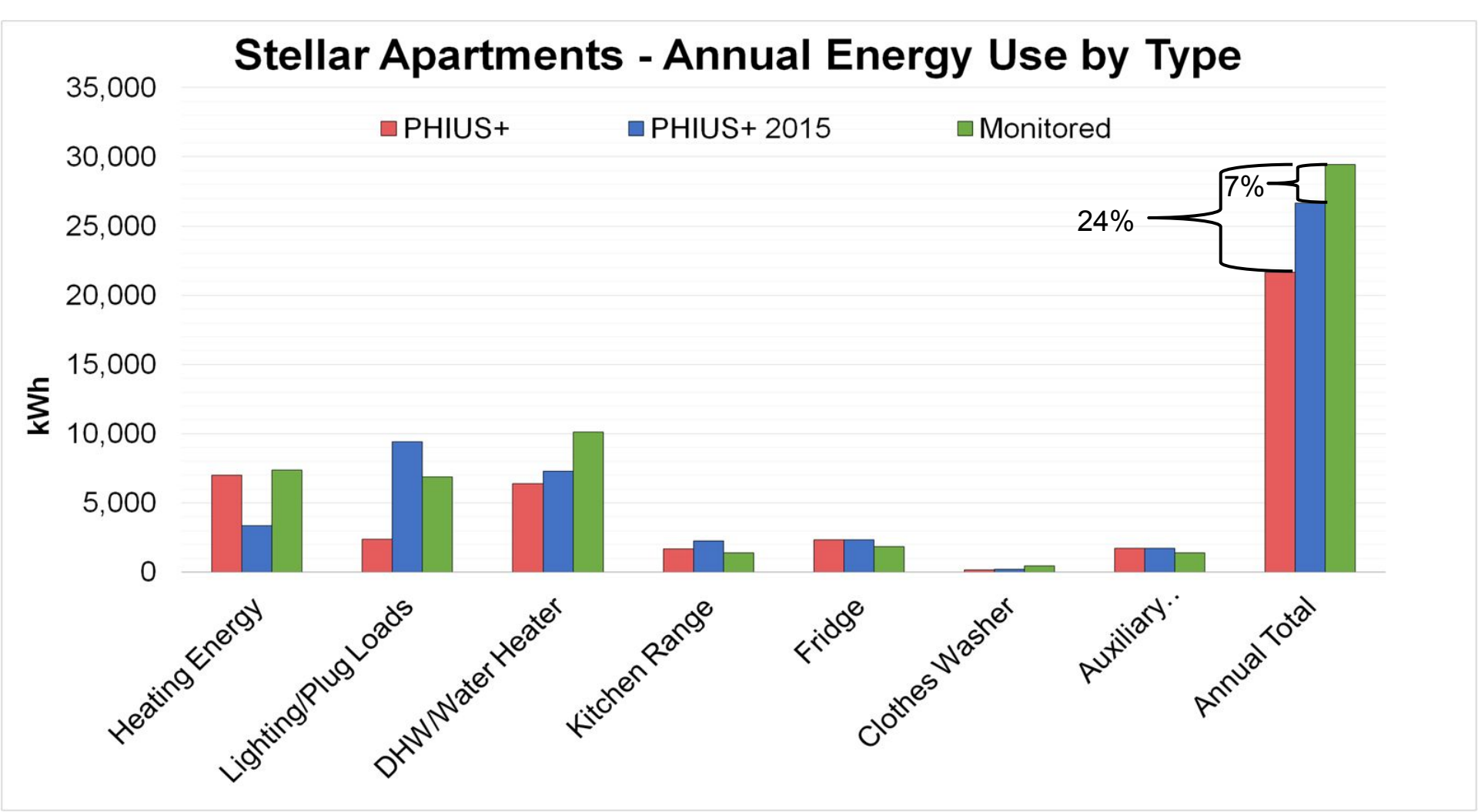
*Average Case

Stellar Apartments Unit 7C - Monthly Energy Use by Type



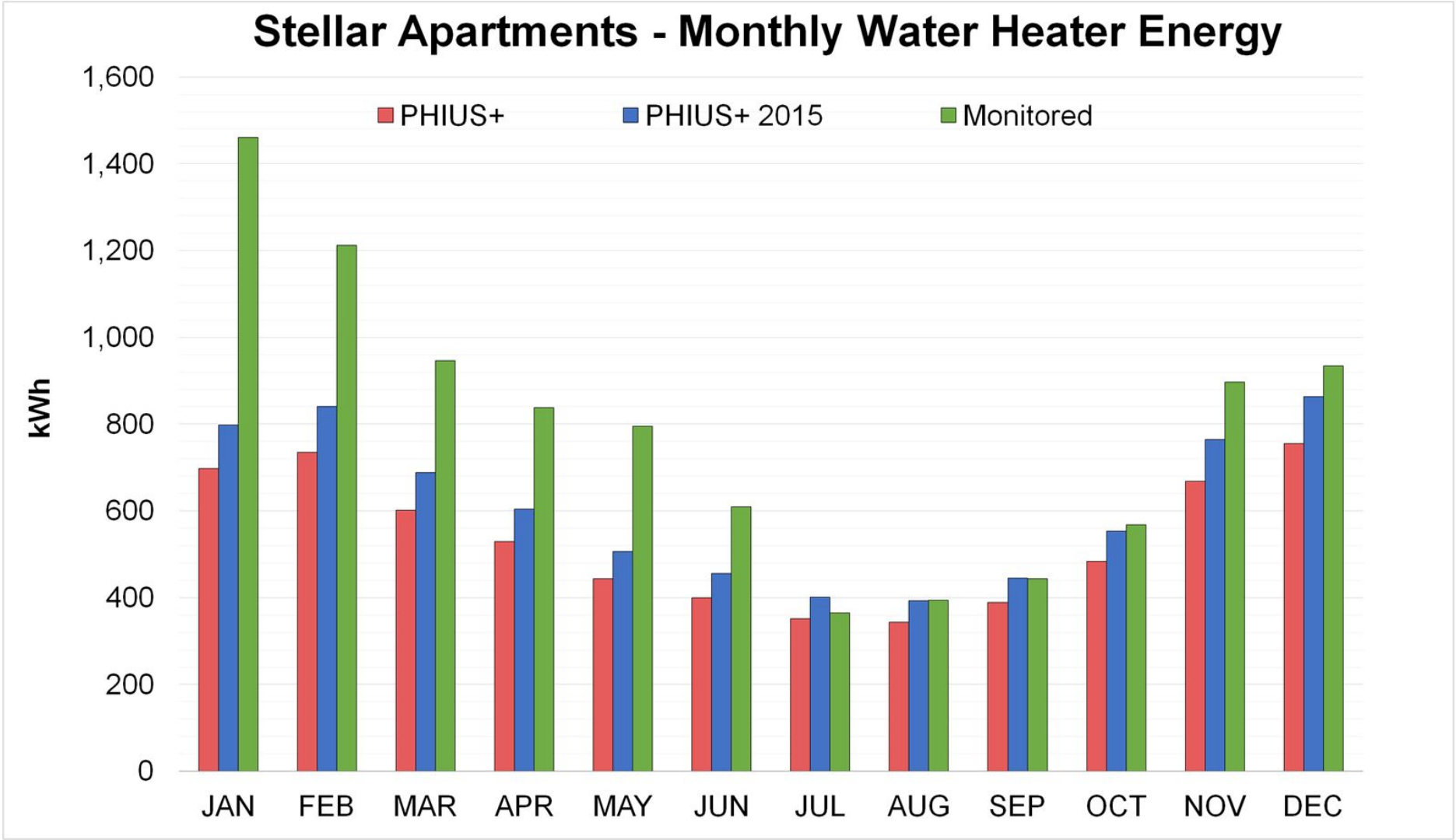
Stellar Apartments - Results Analysis

- **Annual Energy Use by Type**
- Discrepancies
  - Domestic Hot Water Use - Heat Pump Water Heaters
  - Lighting/Plug Loads
  - Space Heating
    - Broken Thermostat
    - July Heating
    - Actual Weather vs TMY3 Climate data


Stellar Apartments - Annual Energy Use by Type
PHIUS+
PHIUS+ 2015
Monitored
kWh
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
24%
7%
Heating Energy
Lighting/Plug Loads
DHW/Water Heater
Kitchen Range
Fridge
Clothes Washer
Auxiliary…
Annual Total

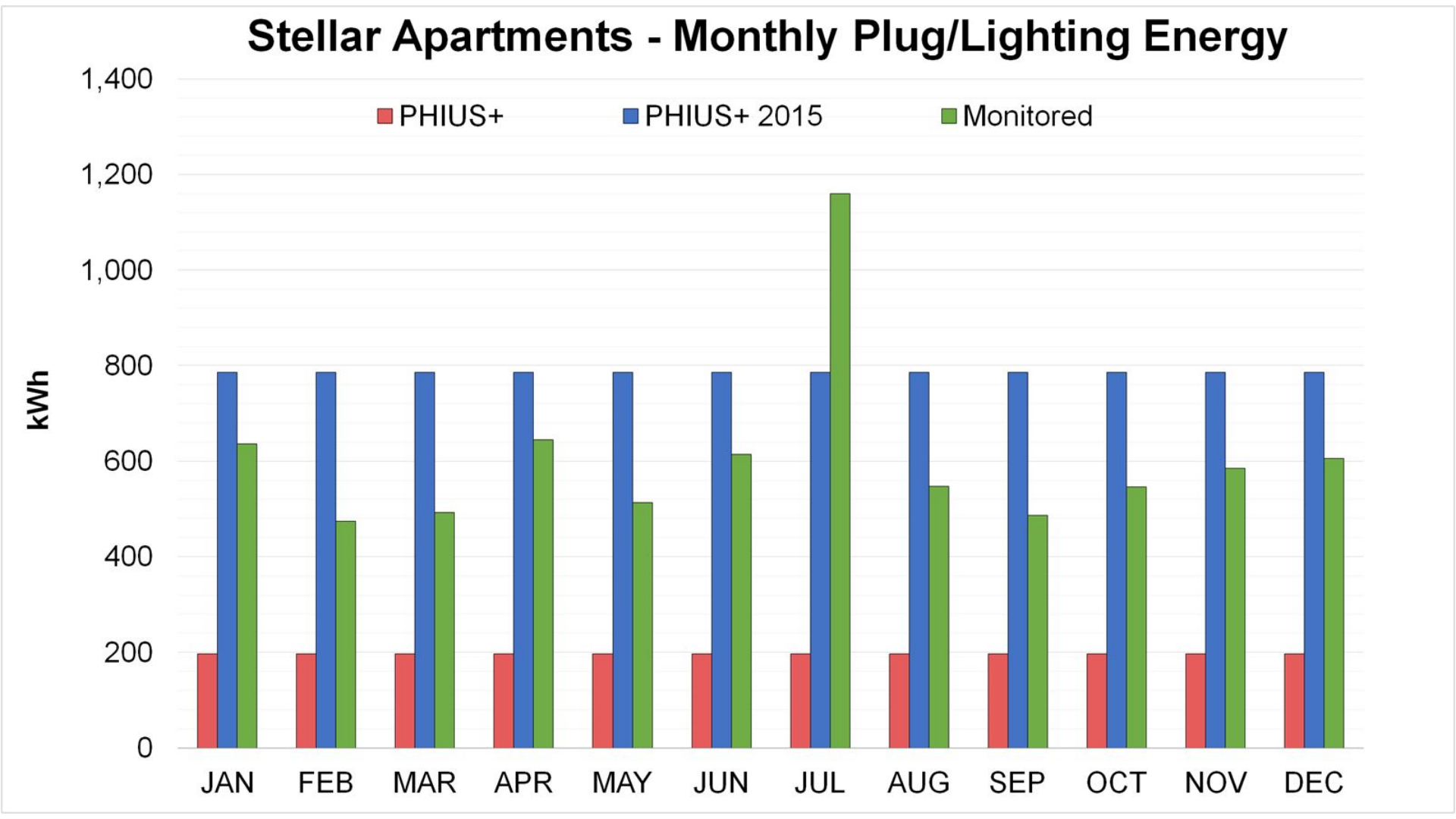
Stellar Apartments - Results Analysis

- Annual Energy Use
- **Discrepancies**
  - **Domestic Hot Water Use - Heat Pump Water Heaters**
  - Lighting/Plug Loads
  - Space Heating
    - Broken Thermostat
    - July Heating
    - Actual Weather vs TMY3 Climate data

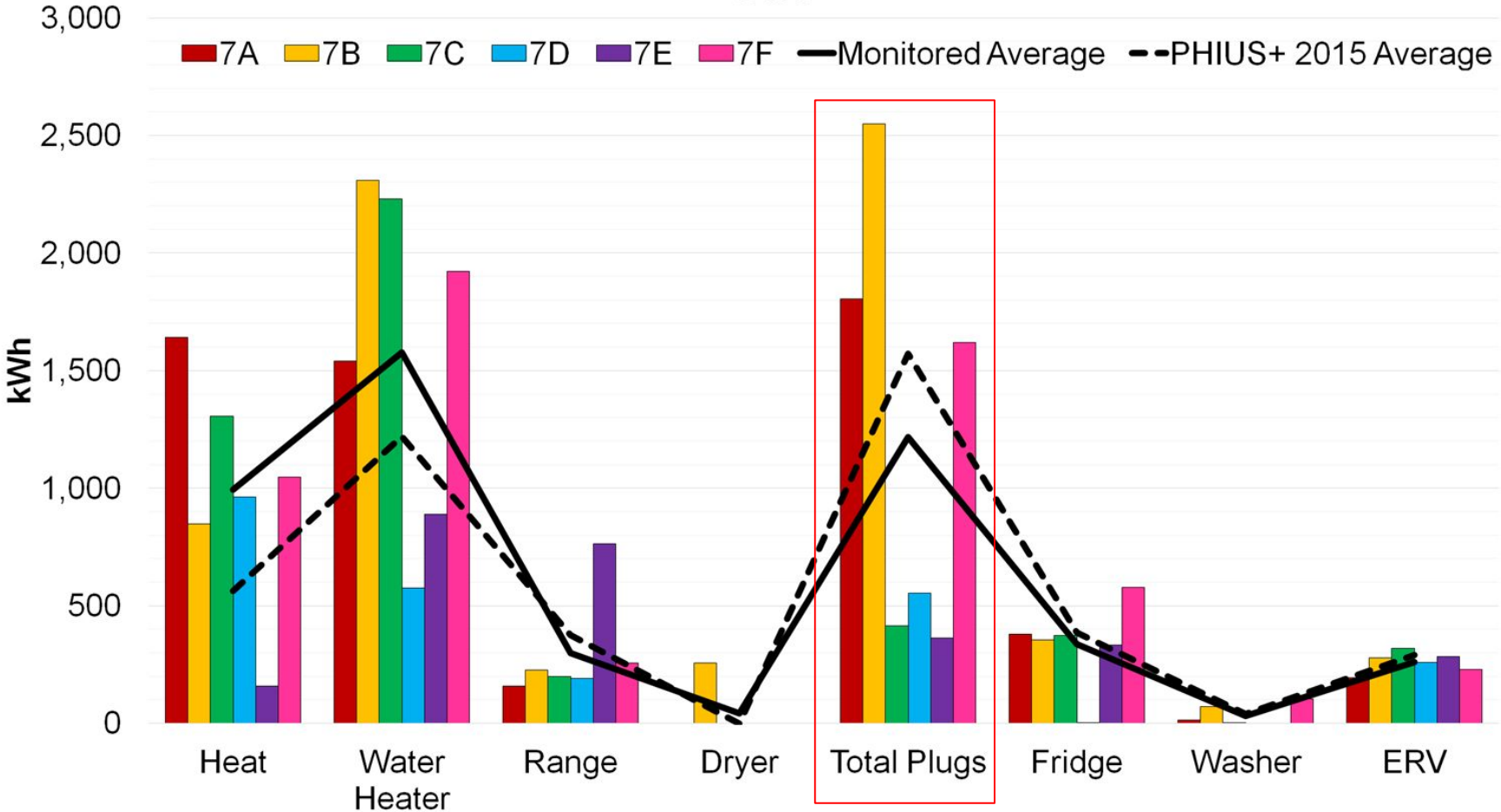

Stellar Apartments - Monthly Water Heater Energy
PHIUS+
PHIUS+ 2015
Monitored
kWh
1,600
1,400
1,200
1,000
800
600
400
200
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Stellar Apartments - Results Analysis

- Annual Energy Use
- **Discrepancies**
  - Domestic Hot Water Use - Heat Pump Water Heaters
  - **Lighting/Plug Loads**
  - Space Heating
    - Broken Thermostat
    - July Heating
    - Actual Weather vs TMY3 Climate data

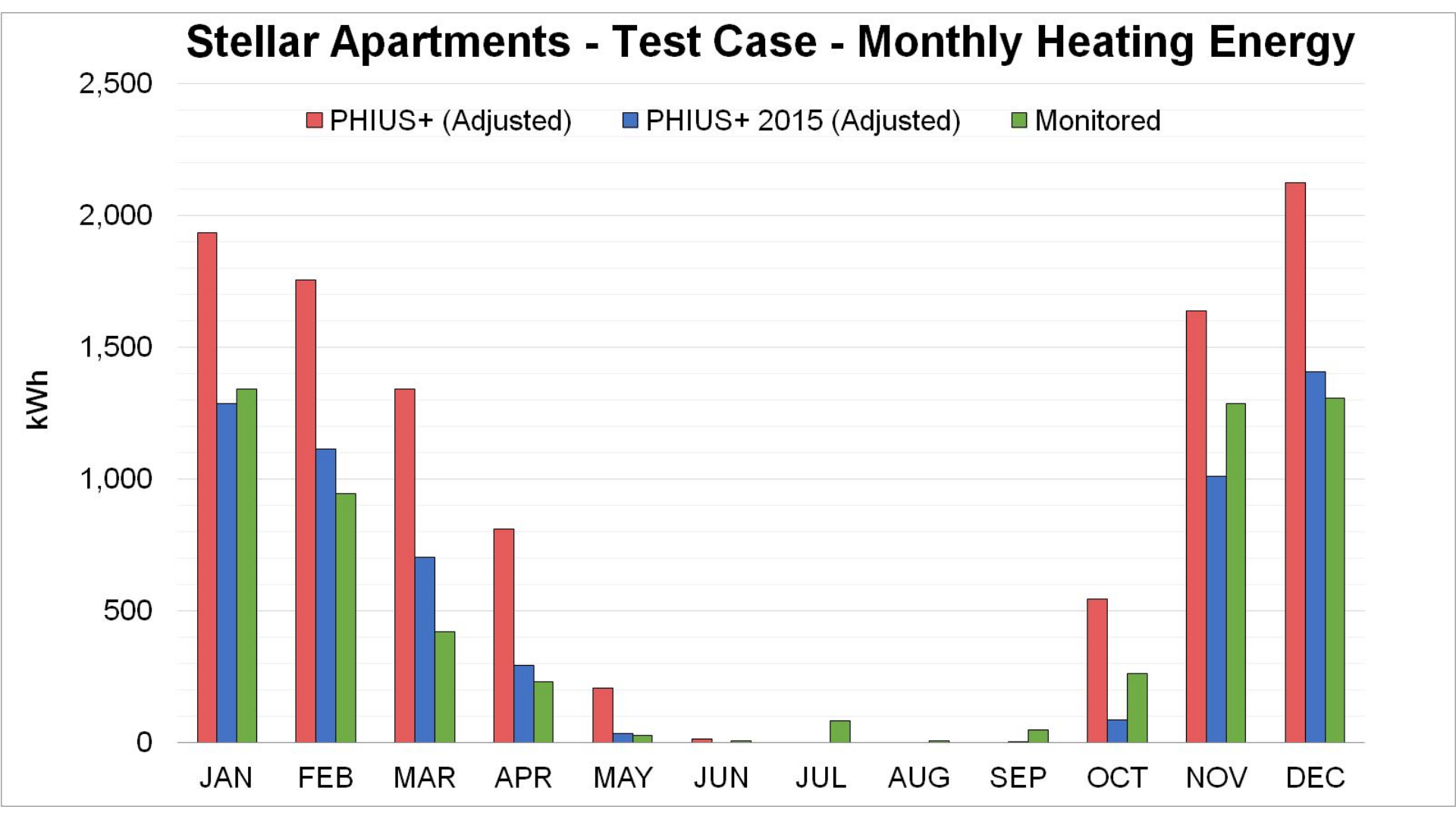

Stellar Apartments - Monthly Plug/Lighting Energy
1,400
1,200
1,000
800
600
400
200
0
kWh
PHIUS+
PHIUS+ 2015
Monitored
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Individual Apartment Energy Use vs Average Energy Use

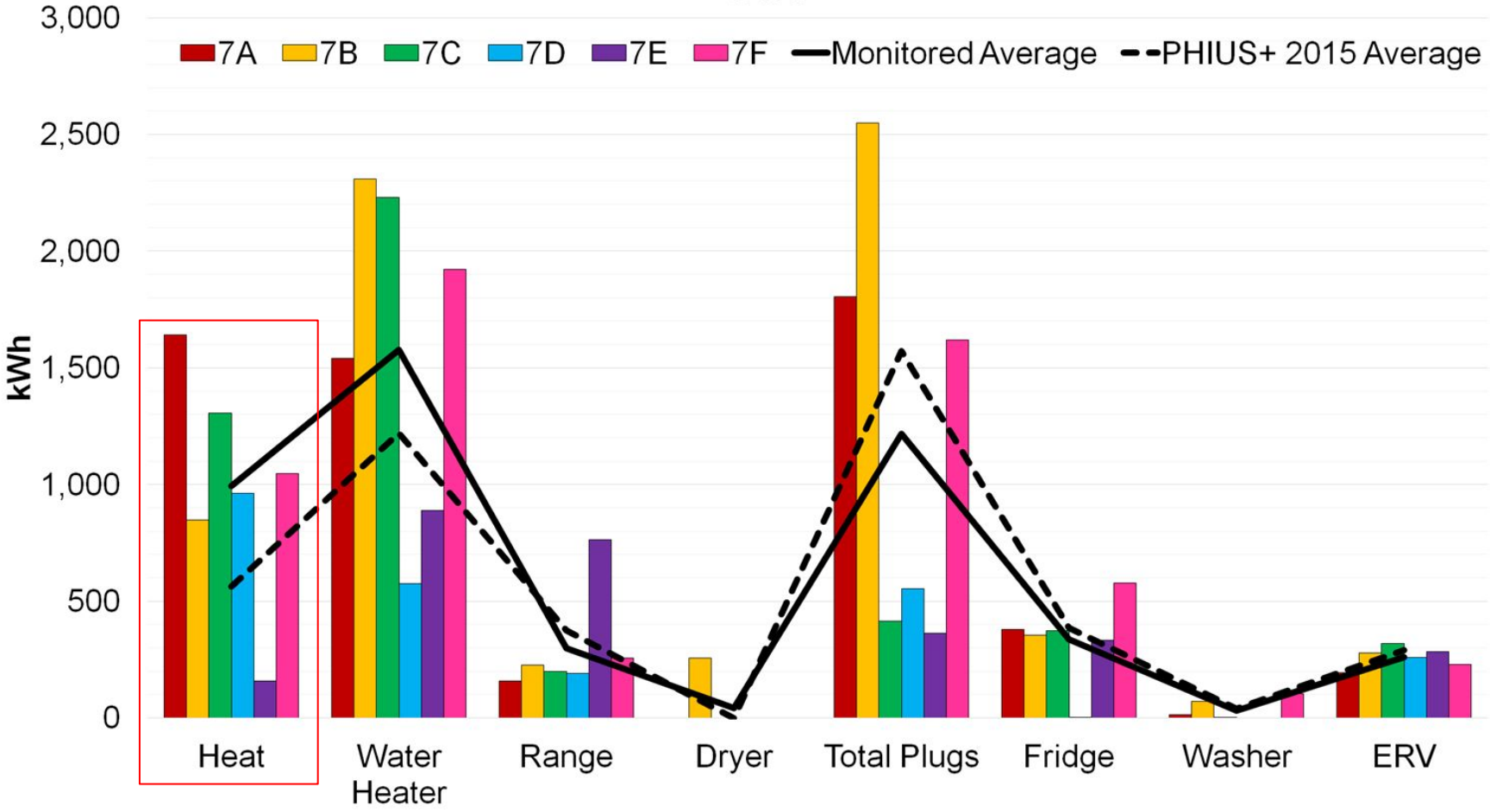


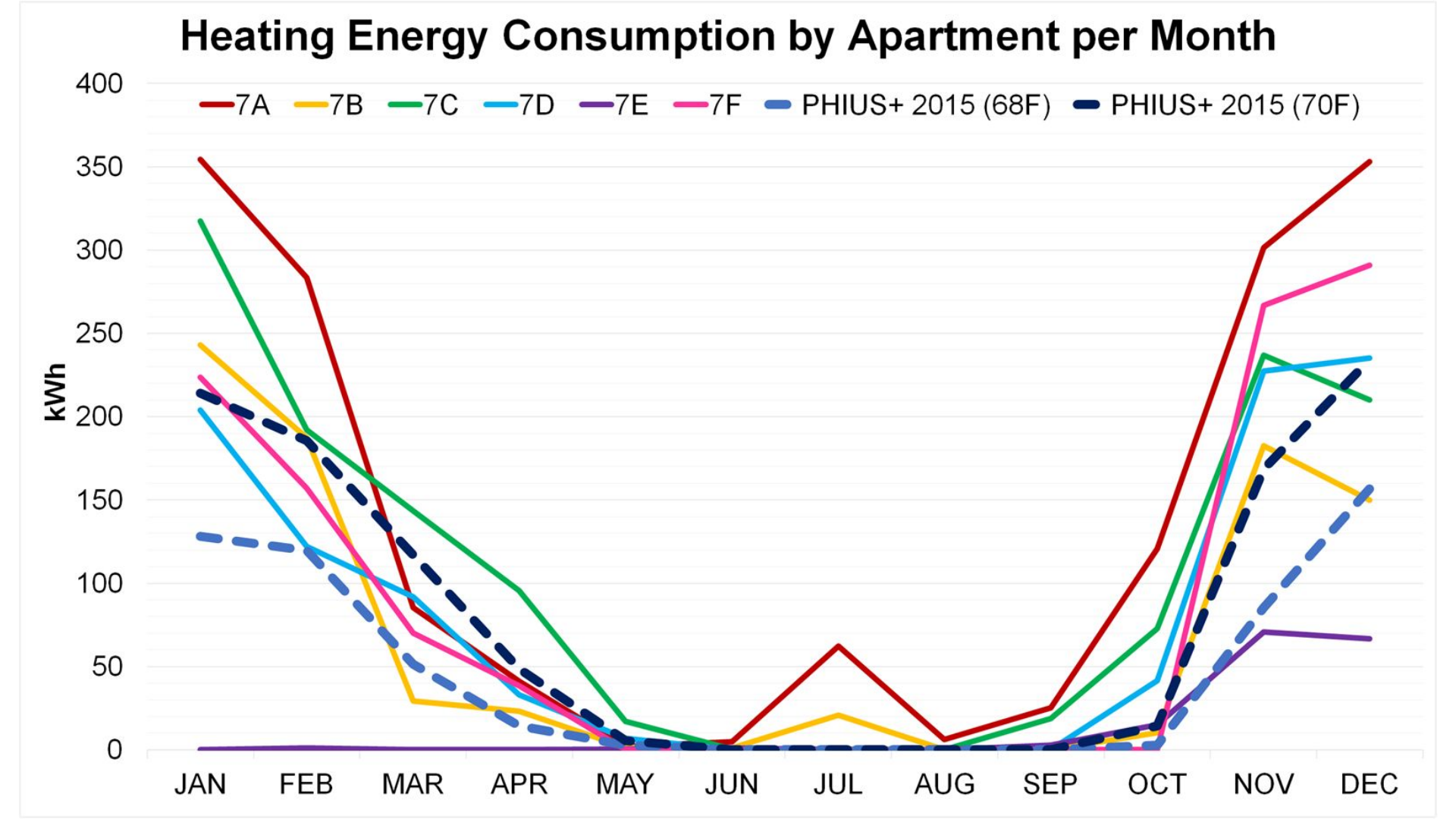
Stellar Apartments - Results Analysis

- Annual Energy Use
- **Discrepancies**
  - Domestic Hot Water Use - Heat Pump Water Heaters
  - Lighting/Plug Loads
  - **Space Heating**
    - **Broken Thermostat**
    - **July Heating**
      - Actual Weather vs TMY3 Climate data


Stellar Apartments - Test Case - Monthly Heating Energy
PHIUS+ (Adjusted)
PHIUS+ 2015 (Adjusted)
Monitored
kWh
2,500
2,000
1,500
1,000
500
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Individual Apartment Energy Use vs Average Energy Use

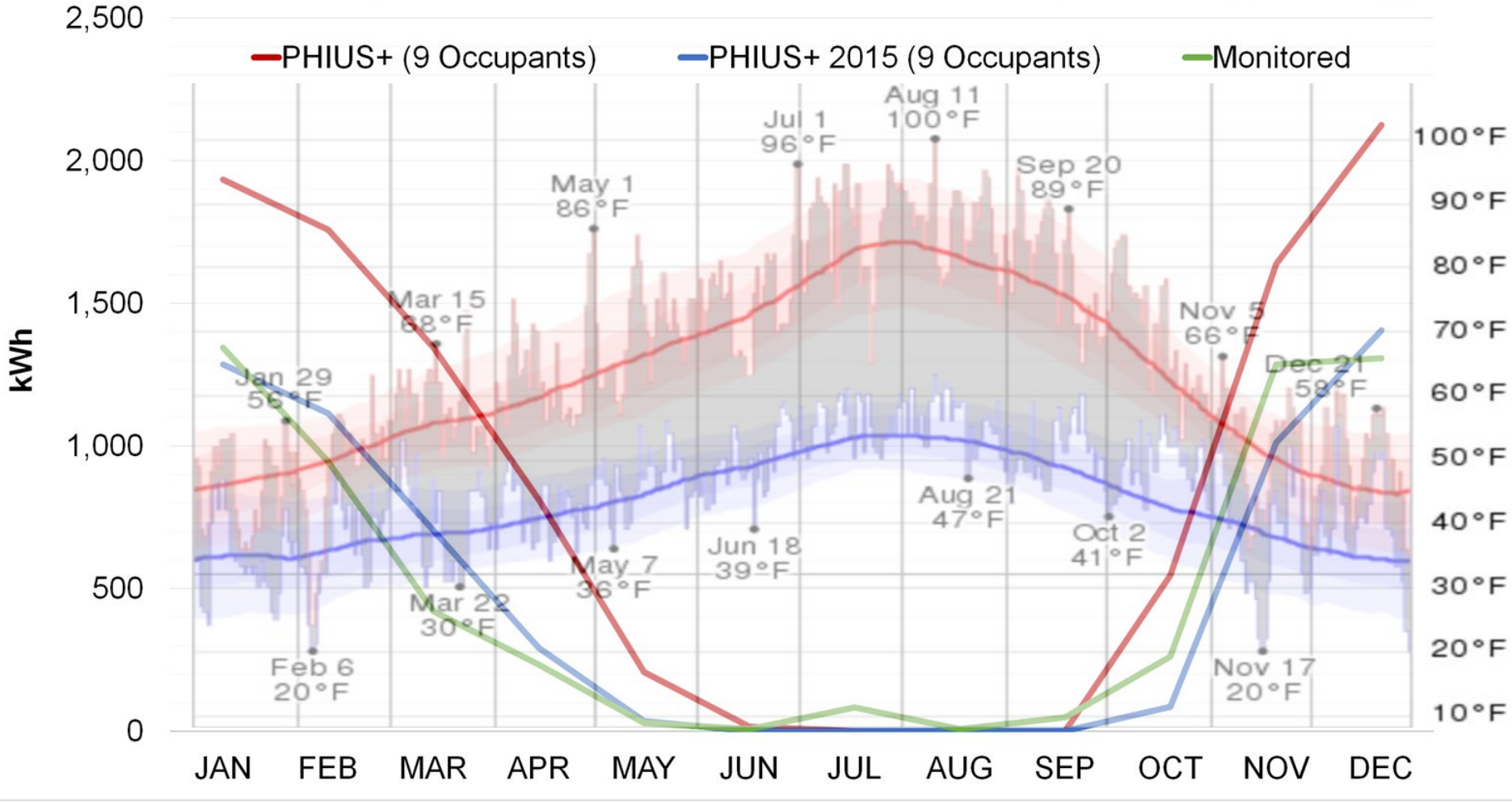



Heating Energy Consumption by Apartment per Month
7A
7B
7C
7D
7E
7F
PHIUS+ 2015 (68F)
PHIUS+ 2015 (70F)
kWh
400
350
300
250
200
150
100
50
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Stellar Apartments - Results Analysis

- Annual Energy Use
- **Discrepancies**
  - Domestic Hot Water Use - Heat Pump Water Heaters
  - Lighting/Plug Loads
  - **Space Heating**
    - Broken Thermostat
    - July Heating
    - **Actual Weather vs TMY3 Climate data**

Stellar Apartments - Test Case - Monthly Heating Energy



Orchards at Orenco Phase 1

Orchards at Orenco Phase 1

Monitored Data

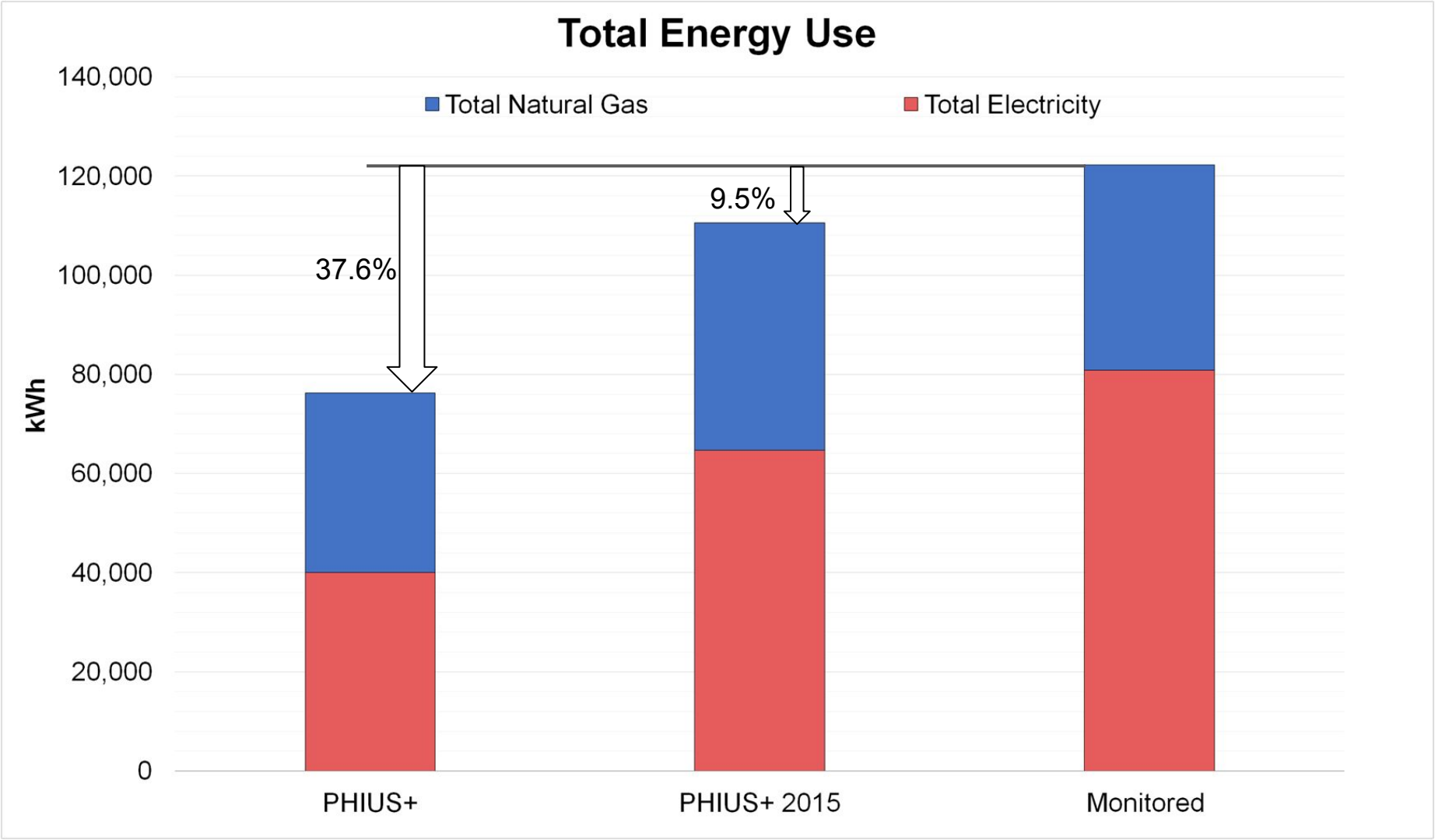
- 150 - Unit Multifamily Affordable Housing Development
- **One - 3-Story (57 units) built to PHIUS+ Standard**
- Monitoring Systems Installed
  - Track & Improve Tenant Energy Use Habits
- Data for November 2015 - March 2016

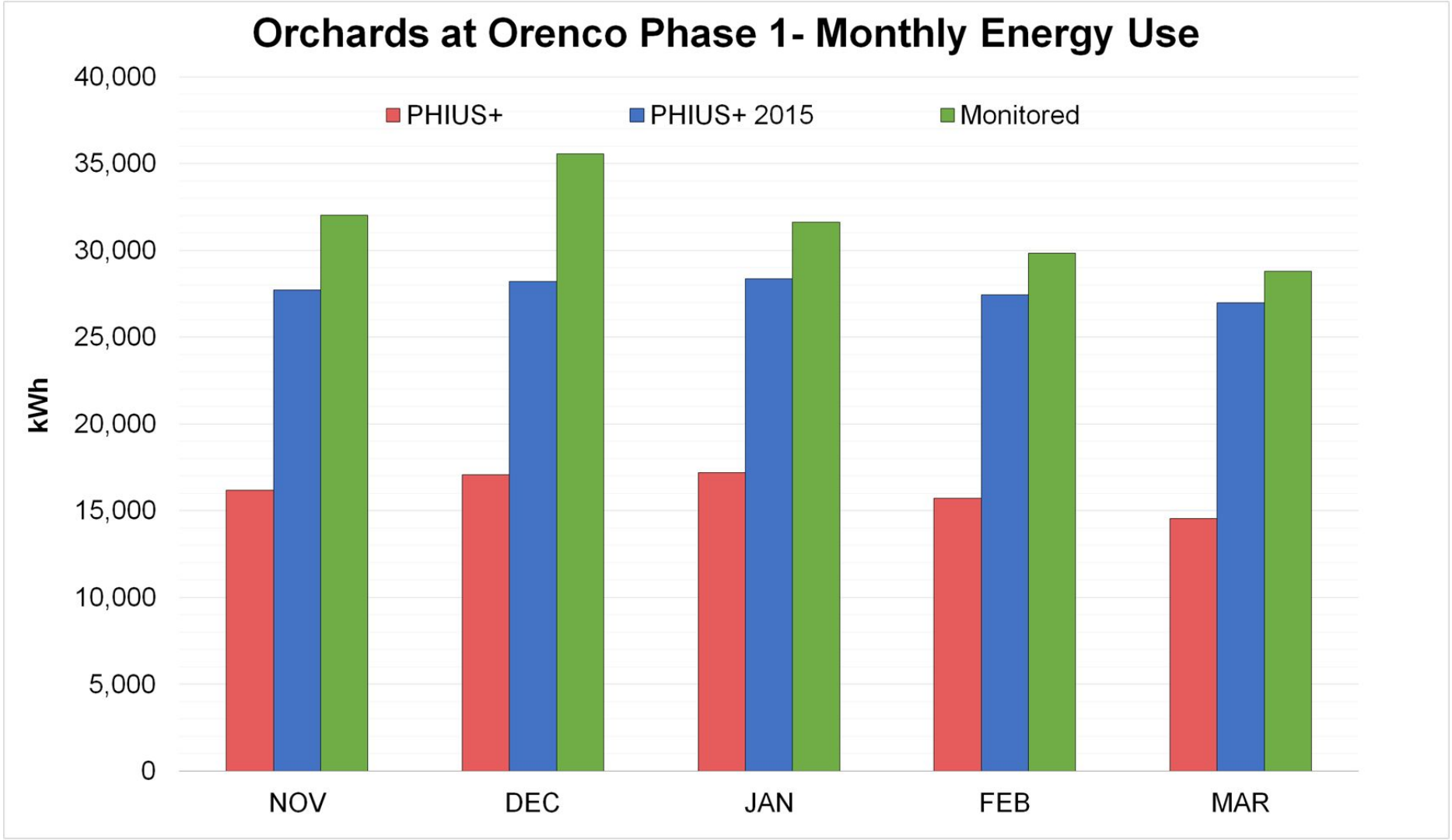
Limitations

- Electricity Monitored (5 categories)
  - Per Unit
  - Strip Heating (8 of 57 units)
  - Common Space - Total per Month
  - Air Handlers + HRVs
  - Central Heat Pump
- Natural Gas
  - Gas Bill - Whole Building
  - Individual Hot Water Meter - Problem Prevented Separate Metering
  - 15% Natural Gas - Dryers (estimate)
  - 85% Natural Gas - Hot Water (estimate)

Orchards at Orenco Phase 1 - Results Analysis

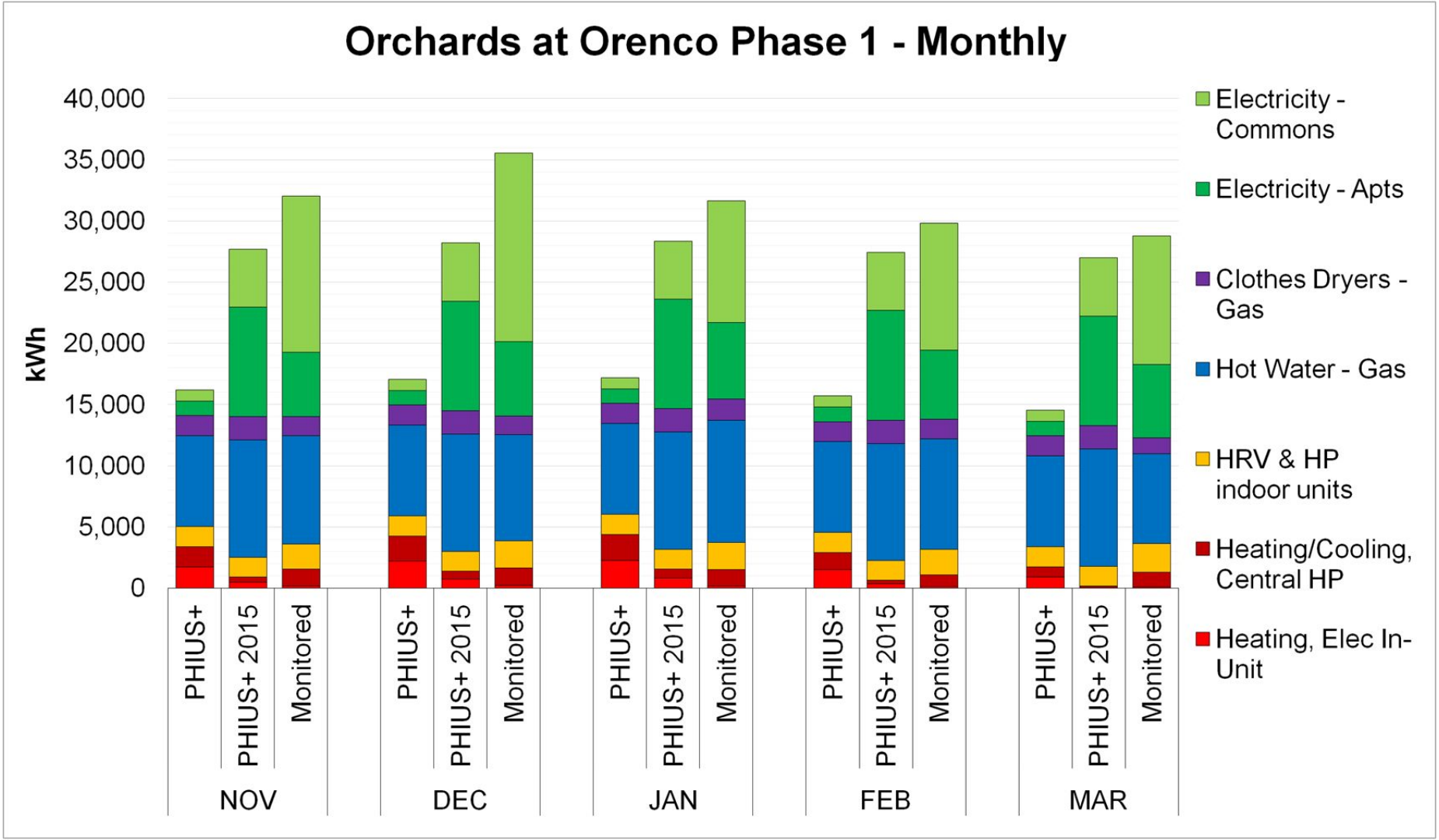
- **Whole Building Energy Use**
- Discrepancies
  - Lighting/Plug Loads
  - Common Space Energy Use
    - Exterior Stairwells
    - Distributed Antenna System (DAS)
    - Heating Energy
    - Unoccupied Units
- Hot Water Usage


Total Energy Use
Total Natural Gas
Total Electricity
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
kWh
37.6%
9.5%
PHIUS+
PHIUS+ 2015
Monitored

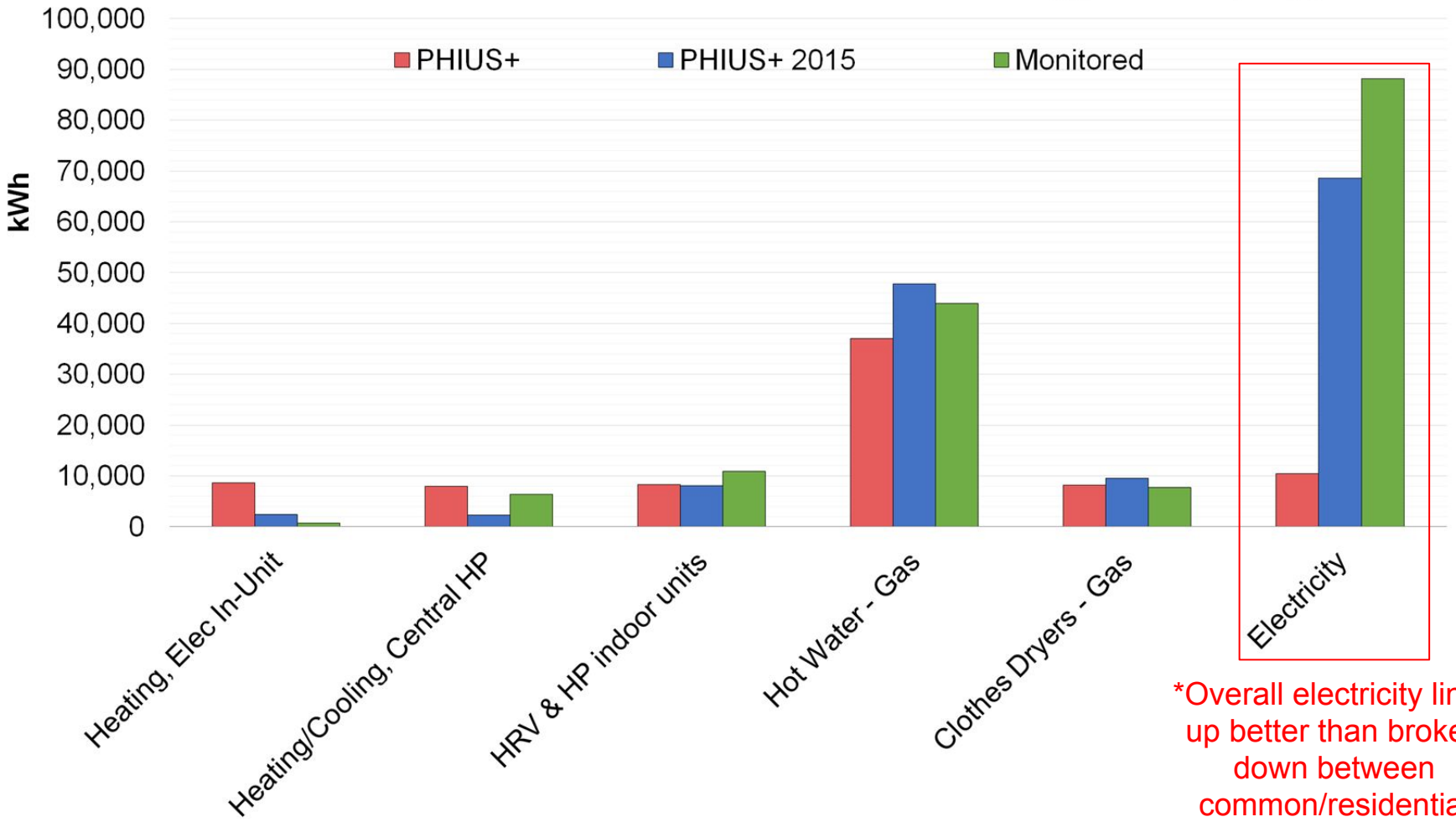

Orchards at Orenco Phase 1- Monthly Energy Use
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
kWh
PHIUS+
PHIUS+ 2015
Monitored
NOV
DEC
JAN
FEB
MAR

Orchards at Orenco Phase 1 - Results Analysis

- Annual Energy Use
- **Discrepancies**
  - **Lighting/Plug Loads**
  - **Common Space Energy Use**
    - Exterior Stairwells
    - **Distributed Antenna System (DAS)**
    - Heating Energy
    - Unoccupied Units
- Hot Water Usage


Orchards at Orenco Phase 1 - Monthly
kWh
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
PHIUS+
PHIUS+ 2015
Monitored
NOV
DEC
JAN
FEB
MAR
Electricity - Commons
Electricity - Apts
Clothes Dryers - Gas
Hot Water - Gas
HRV & HP indoor units
Heating/Cooling, Central HP
Heating, Elec In-Unit

Orchards at Orenco Phase 1 - 5 Month Energy Use by Type

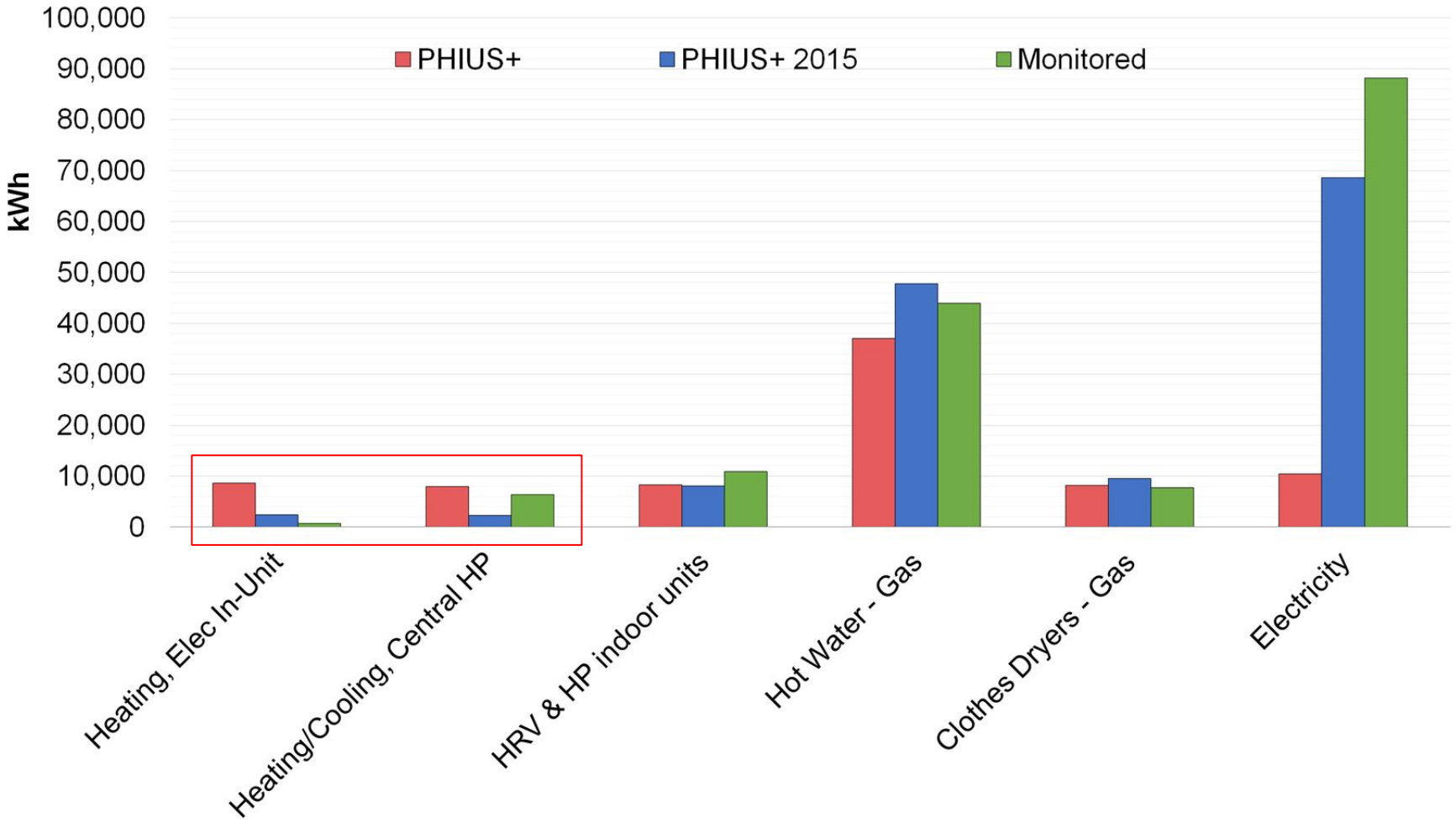


*Overall electricity lines up better than broken down between common/residential

Orchards at Orenco Phase 1 - Results Analysis

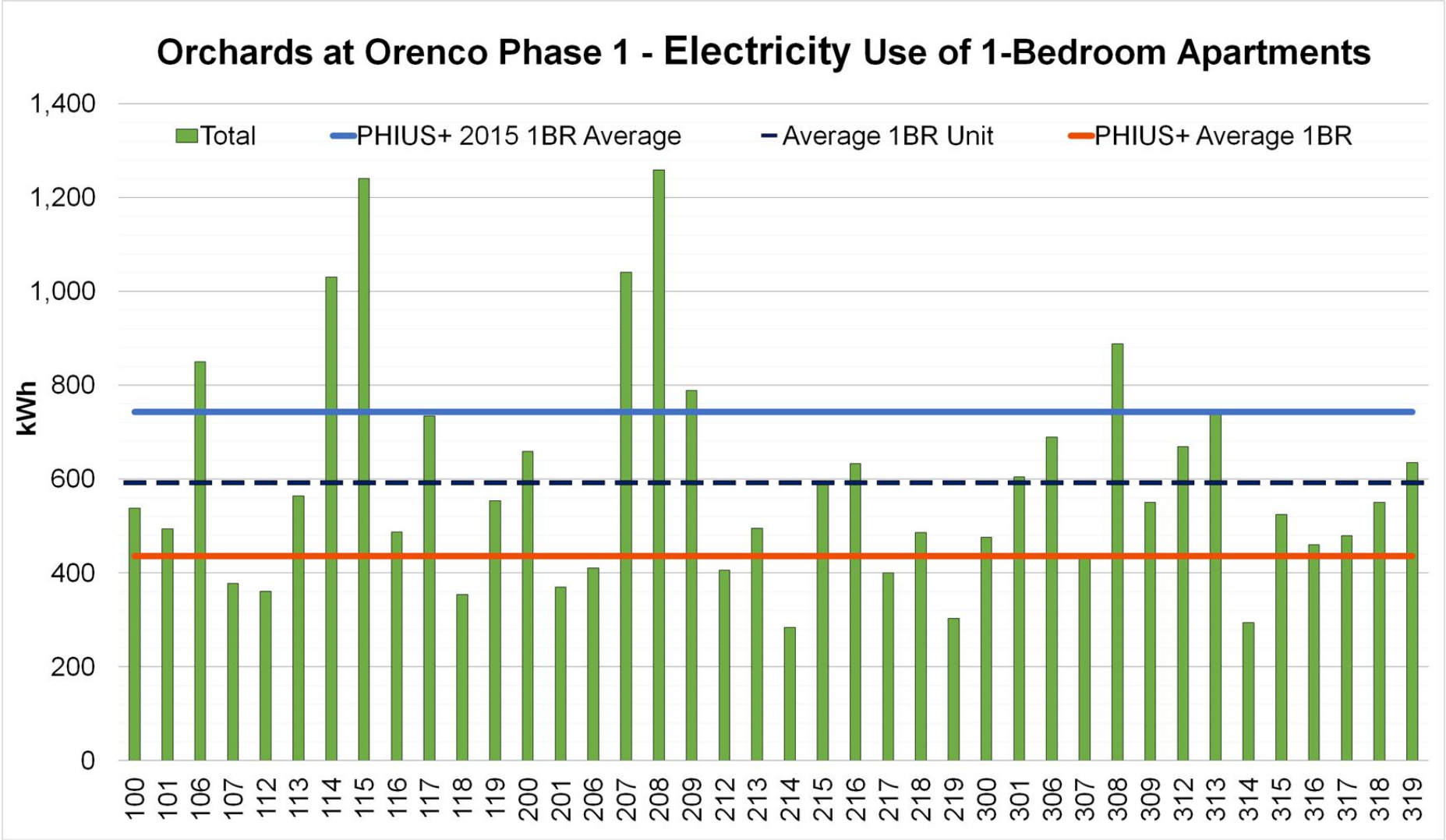
- Annual Energy Use
- **Discrepancies**
  - Lighting/Plug Loads
  - **Common Space Energy Use**
    - **Exterior Stairwells (40F to 68F)**
      - Distributed Antenna System (DAS)
    - **Heating Energy**
      - Unoccupied Units
- Hot Water Usage

Orchards at Orenco Phase 1 - 5 Month Energy Use by Type



Orchards at Orenco Phase 1 - Results Analysis

- Annual Energy Use
- **Discrepancies**
  - Lighting/Plug Loads
  - **Common Space Energy Use**
    - Exterior Stairwells
    - Distributed Antenna System (DAS)
    - Heating Energy
    - **Unoccupied Units**
- Hot Water Usage


Orchards at Orenco Phase 1 - Electricity Use of 1-Bedroom Apartments
1,400
1,200
1,000
800
600
400
200
0
kWh
Total
PHIUS+ 2015 1BR Average
Average 1BR Unit
PHIUS+ Average 1BR
100
101
106
107
112
113
114
115
116
117
118
119
200
201
206
207
208
209
212
213
214
215
216
217
218
219
300
301
306
307
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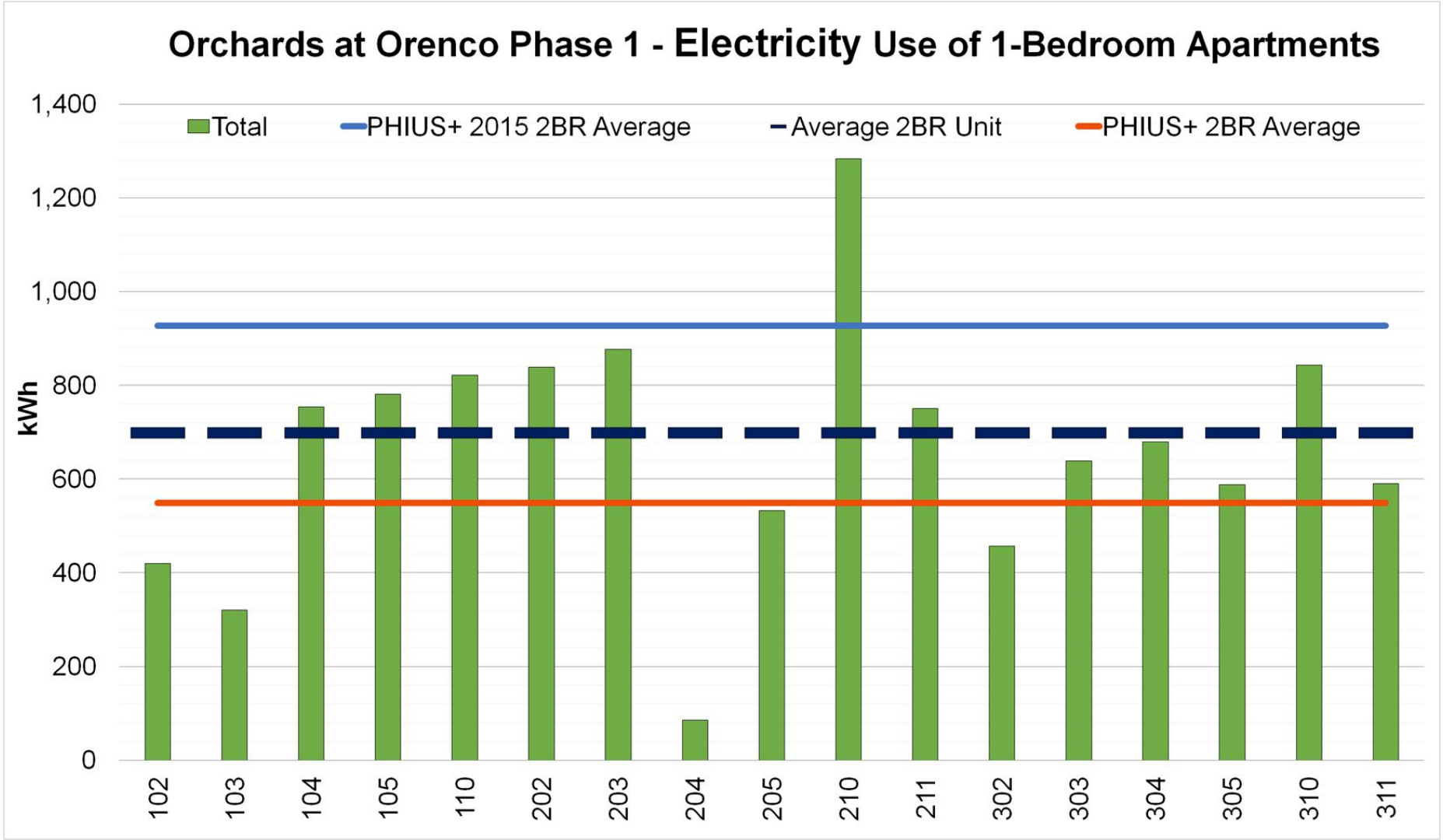
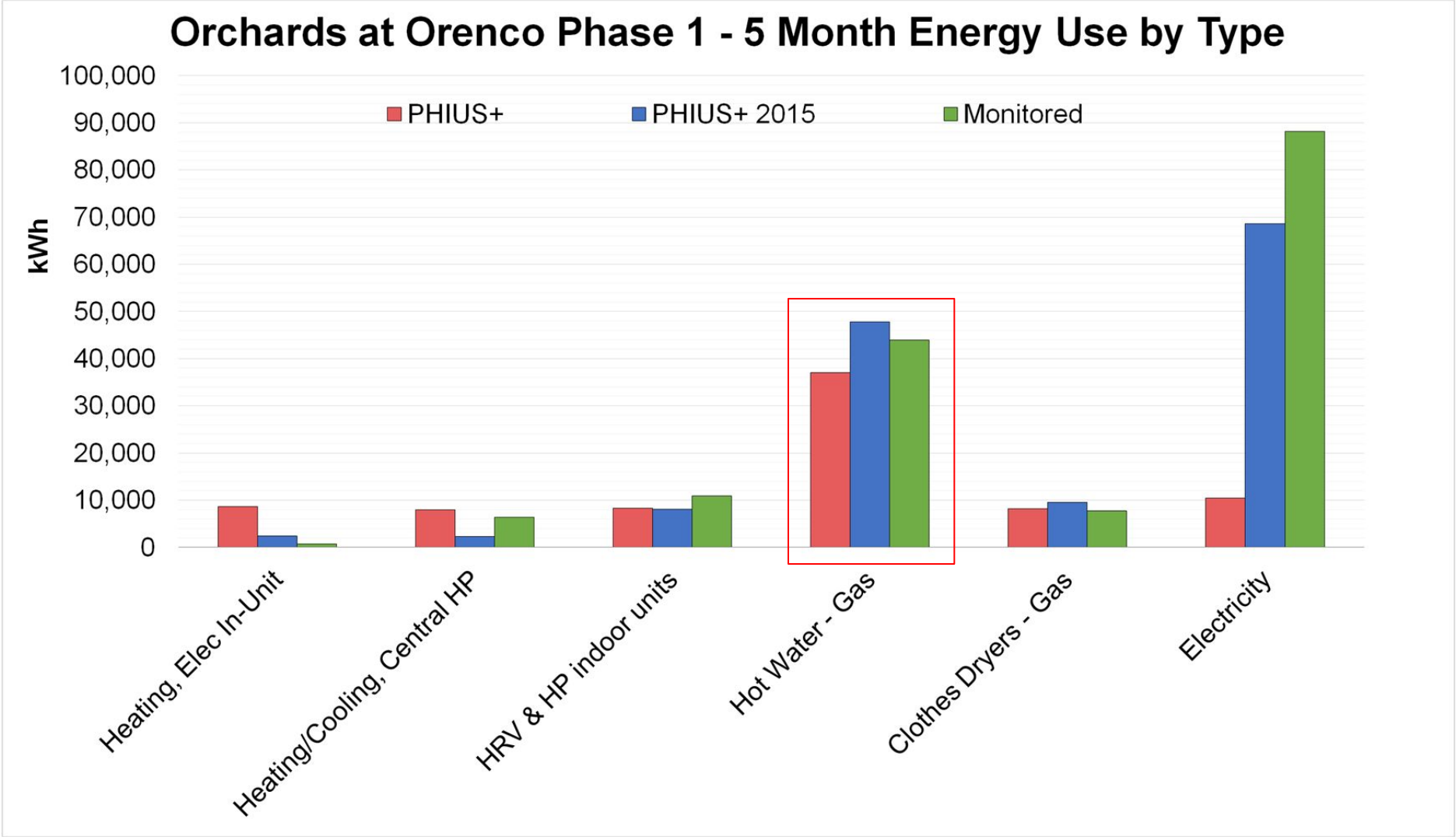
316
317
318
319


Orchards at Orenco Phase 1 - Electricity Use of 1-Bedroom Apartments
1,400
1,200
1,000
800
600
400
200
0
kWh
Total
PHIUS+ 2015 2BR Average
Average 2BR Unit
PHIUS+ 2BR Average
102
103
104
105
110
202
203
204
205
210
211
302
303
304
305
310
311

Orchards at Orenco Phase 1 - Results Analysis

- Annual Energy Use
- Discrepancies
  - Lighting/Plug Loads
  - Common Space Energy Use
    - Exterior Stairwells
    - Distributed Antenna System (DAS)
    - Heating Energy
    - Unoccupied Units
- **Hot Water Usage**


Orchards at Orenco Phase 1 - 5 Month Energy Use by Type
kWh
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
PHIUS+
PHIUS+ 2015
Monitored
Heating, Elec In-Unit
Heating/Cooling, Central HP
HRV & HP indoor units
Hot Water - Gas
Clothes Dryers - Gas
Electricity

Knickerbocker Commons

Knickerbocker Commons

Monitored Data

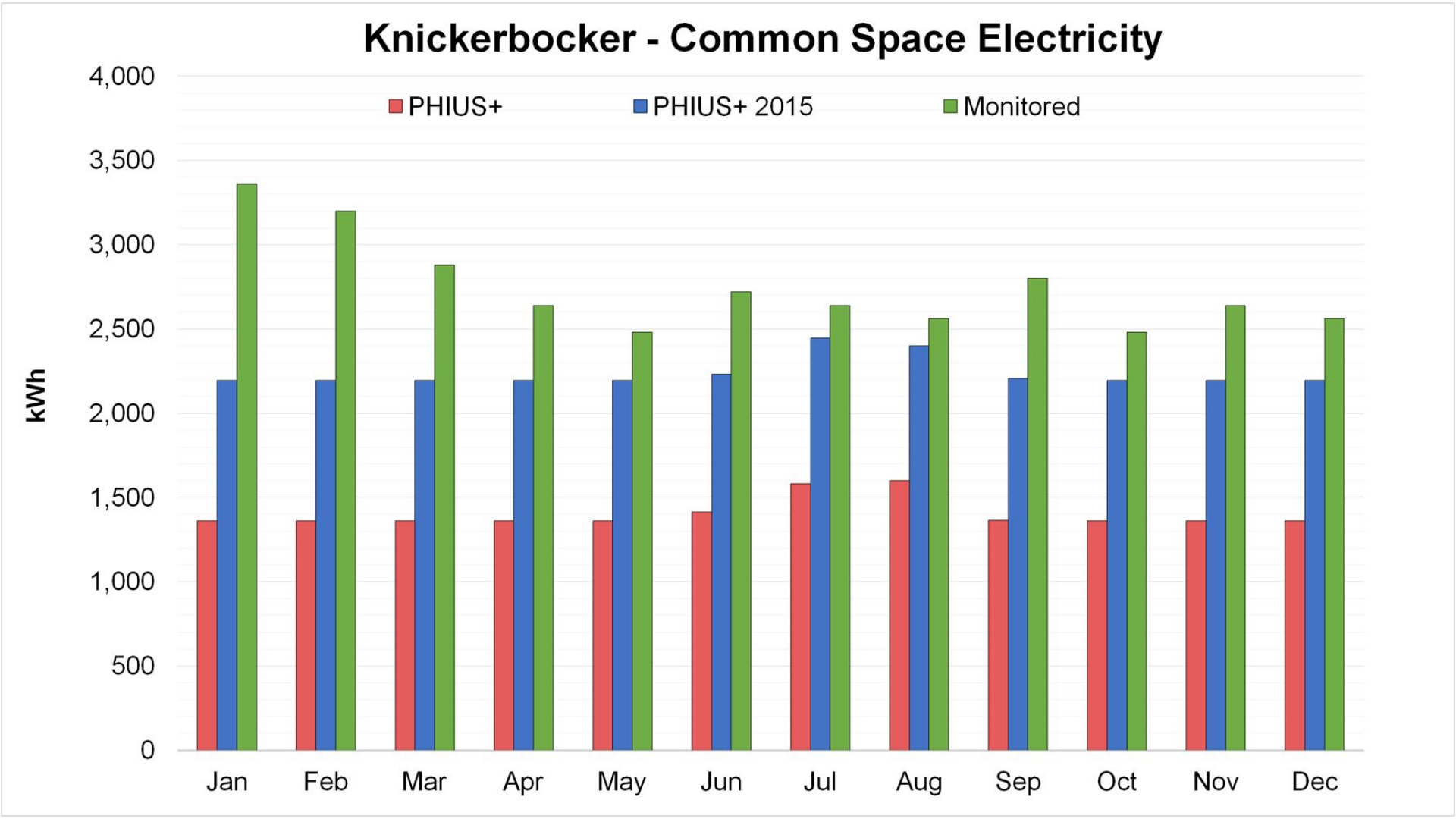
- One - 6-Story (24 units) built to PHIUS+ Standard
- Common Electricity (single value) Includes:
  - Common Space Lighting
  - Common Space Miscellaneous Plug Loads
  - Elevator
  - Common Auxiliary Energy
  - Common Space ERVs
  - Clothes Washers

Limitations

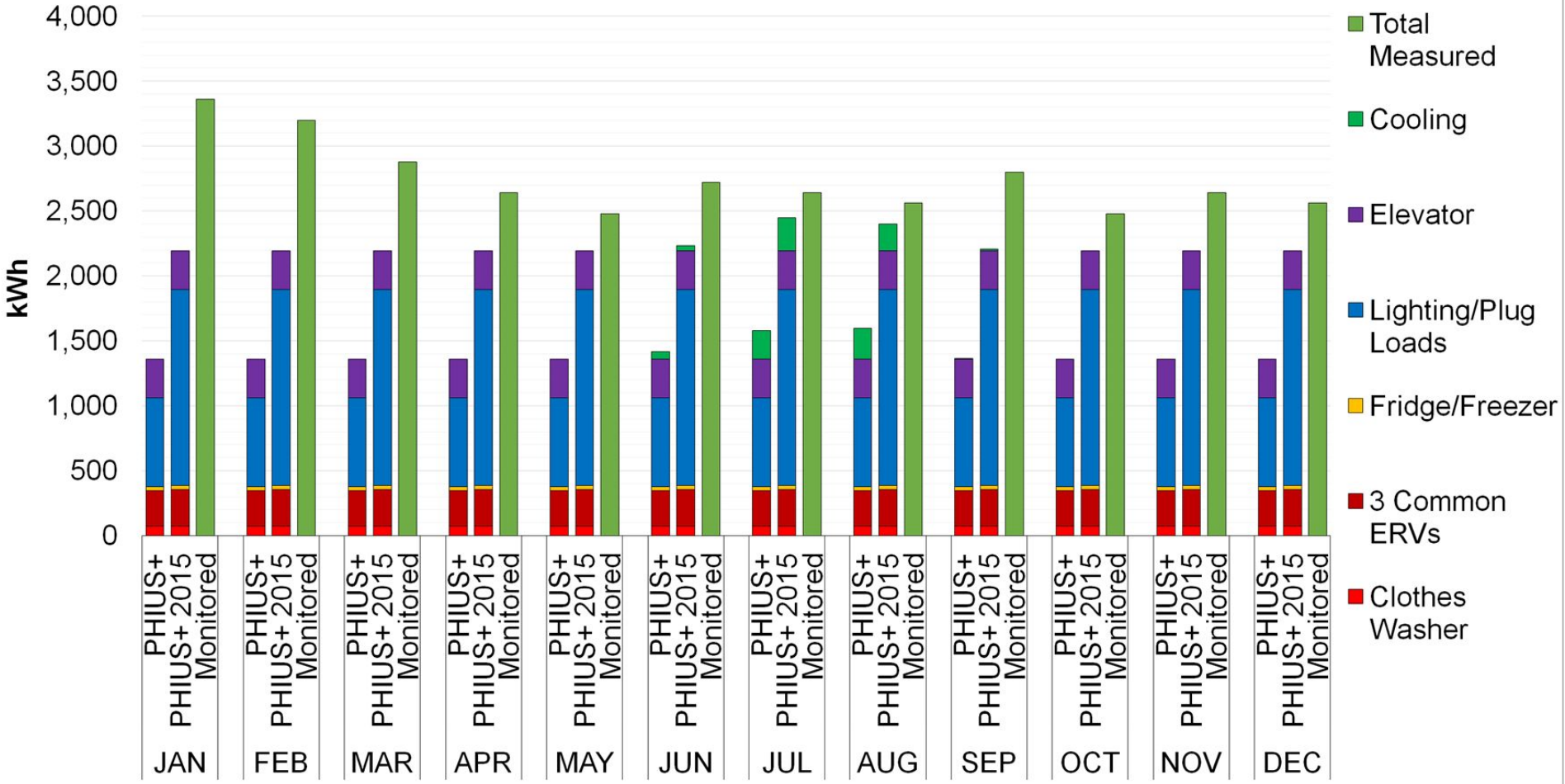
- PHIUS+ 2015 Electricity
  - Default Lighting Power Density (LPD)
- Unit Electricity not Provided
  - No Data Provided, Yet
  - Separately Metered - Future Analysis Possible
- Natural Gas
  - Dead Meter Battery - Incomplete Data
  - Not Included in Study

Knickerbocker - Results Analysis

- Discrepancies
  - Common Space Electricity
    - Seasonal Lighting Increase
    - Spike in Winter Electricity usage


Knickerbocker - Common Space Electricity
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
kWh
PHIUS+
PHIUS+ 2015
Monitored
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Knickerbocker - Common Space Electricity Use by Type



Conclusions

Major Differences:

Monitored > Modeled

- Stellar Apartments
  - Hot Water Heating Energy
  - Heating Energy
- Orchards at Orenco Phase 1
  - Common Space Electricity
- Knickerbocker Commons
  - Lighting
  - MELS
- Monitored Energy Use by Type

Note: PHIUS Technical Committee - Draft Monitoring Data Protocol
Contact certification@passivehouse.us if interested.

Thanks!

Questions?

References

NetZED Case Study Laboratory. (2016) The Stellar Apartments Story. Eugene, OR: NetZED Case Study Laboratory.

PHIUS (2016, July 27). *PHIUS+ Certification GuideBook Version 1.03.* http://www.phius.org/PHIUSplusdocs/PHIUS+CertificationGuidebook_v1.03.pdf

PHIUS (2016). *Multifamily Resource Center.* http://multifamily.phius.org/service-group/multifamily-passive-building-projects