The Bullitt Center in Review

Modeled vs. Actual Energy Use and Lessons Learned for Energy Modeling

February 15, 2017
Building Energy Simulation Forum

Ben Burnett, PE, PAE

The Bullitt Center

Net Zero Energy

100% of a building's energy use is supplied by on-site renewable energy on a new annual basis.

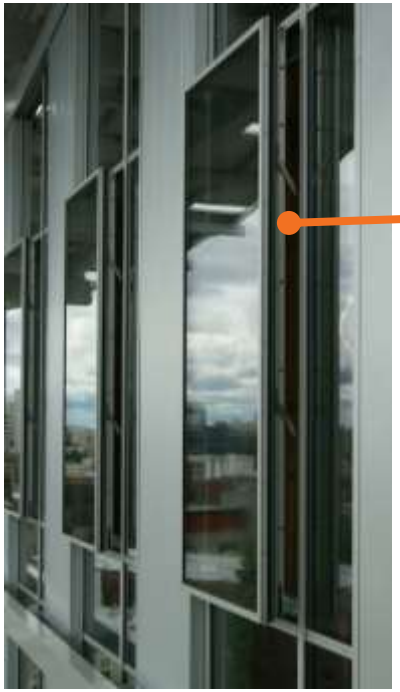
Strategies

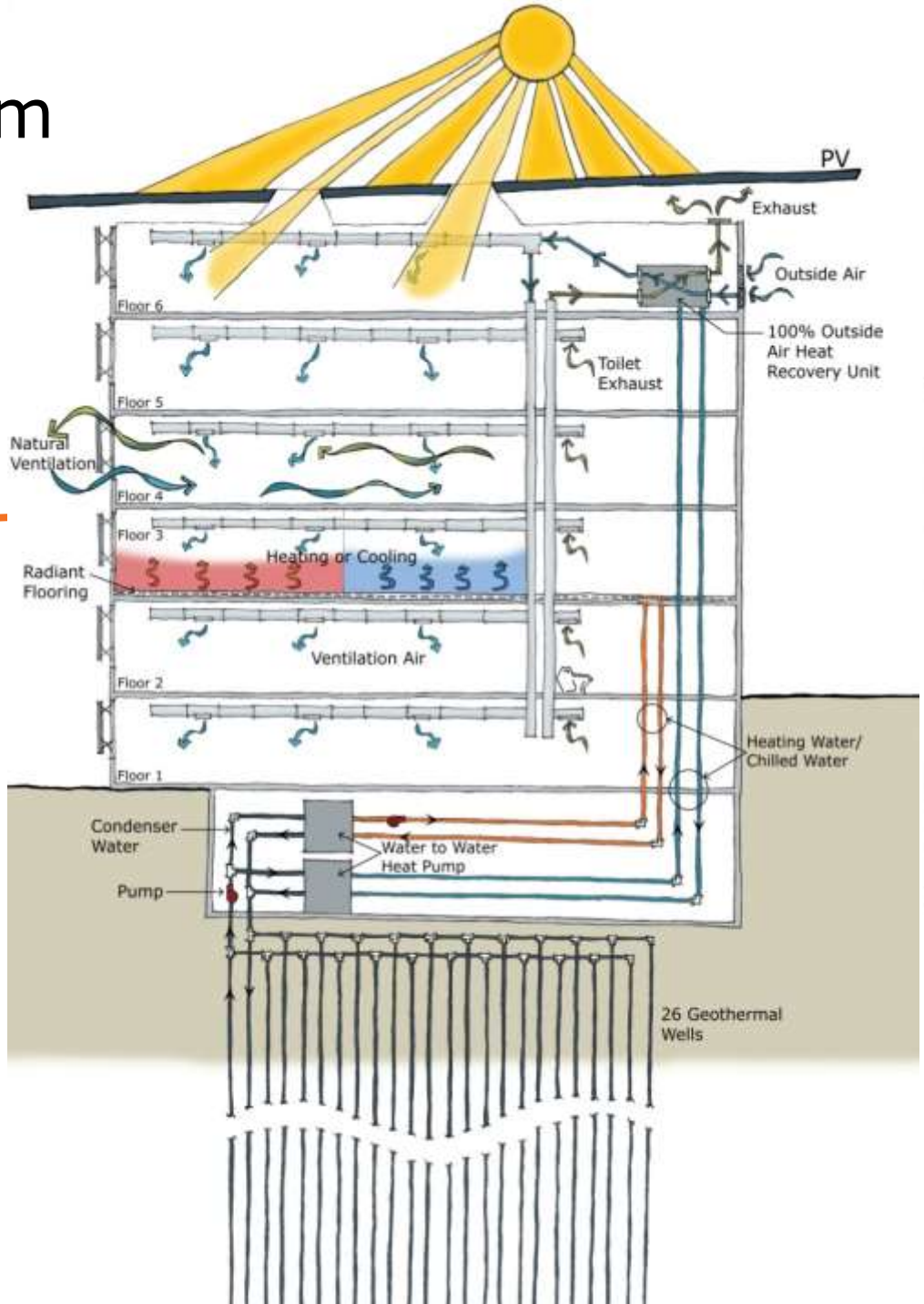
Heating/Cooling

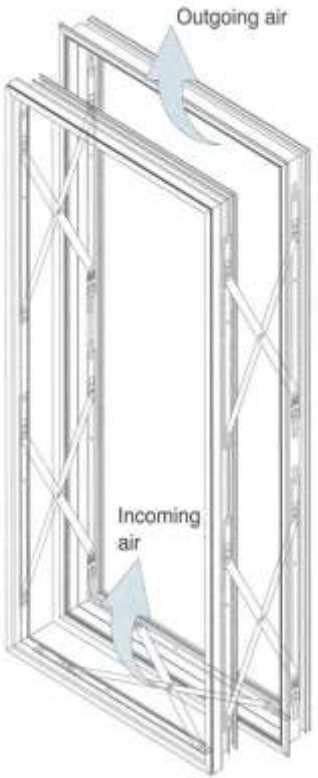
Lighting

Plug Load Reductions

HVAC System

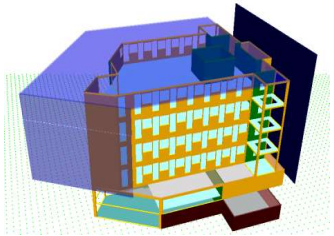



PV
Exhaust
Outside Air
Floor 6
100% Outside Air Heat Recovery Unit
Toilet Exhaust
Floor 5
Natural Ventilation
Floor 4
Floor 3
Heating or Cooling
Radiant Flooring
Ventilation Air
Floor 2
Heating Water/ Chilled Water
Floor 1
Condenser Water
Water to Water Heat Pump
Pump
26 Geothermal Wells

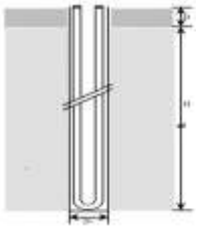

Outgoing air
Incoming air

Modeling Tools & Methods

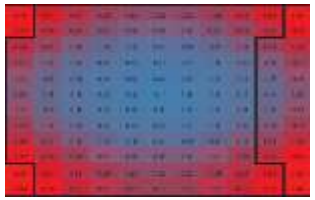
Bentley



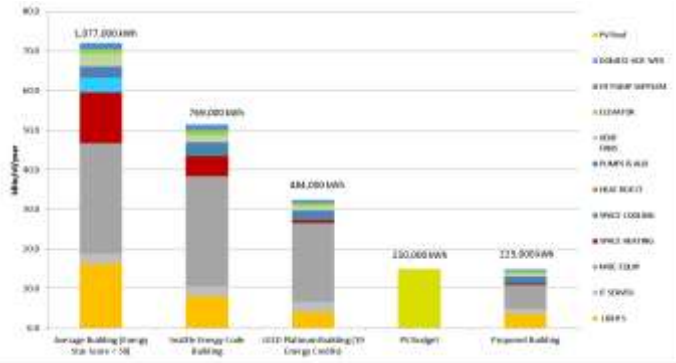
GLHE



Integrated Design Lab

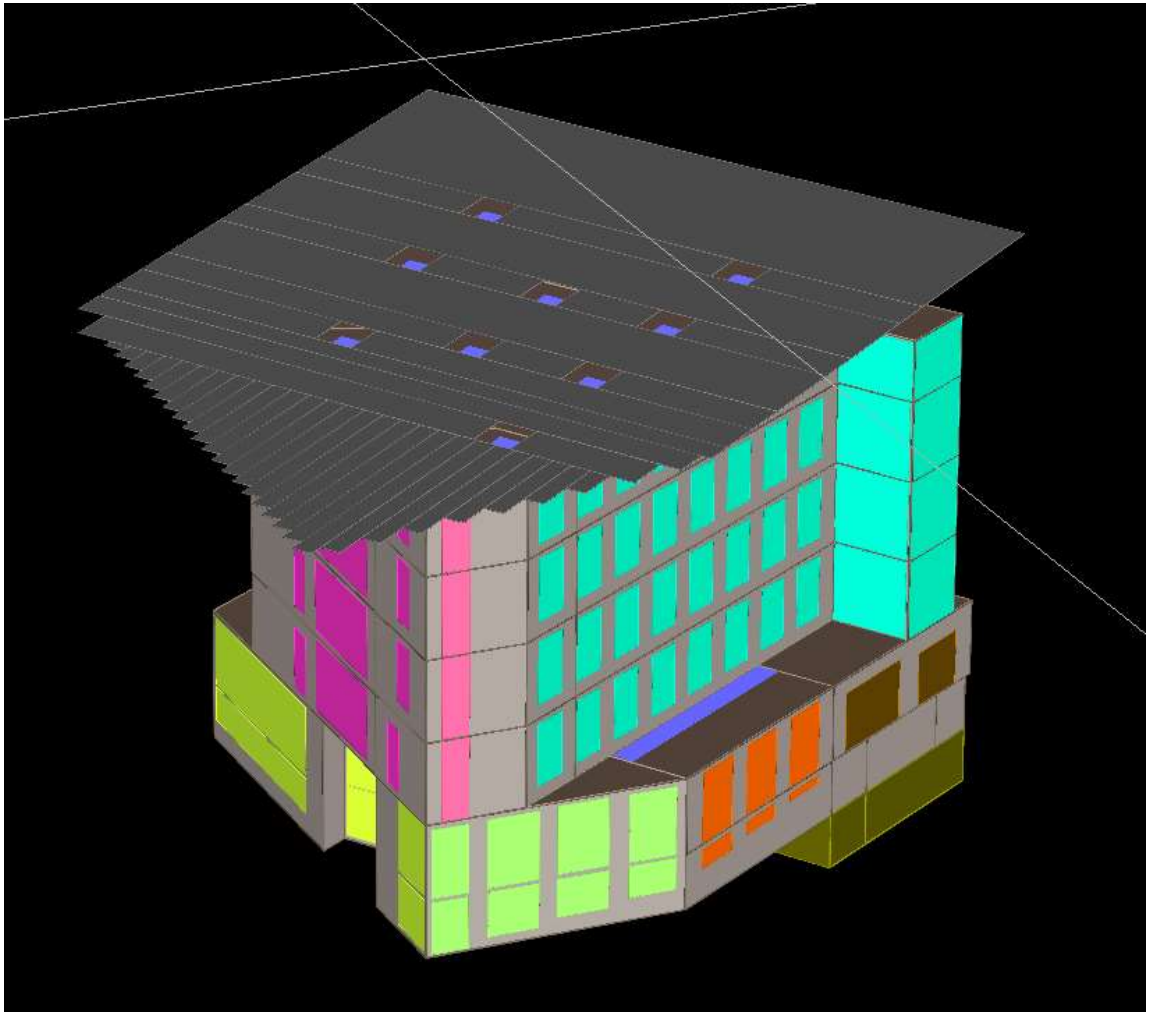


eQUEST



Modeling Tools & Methods

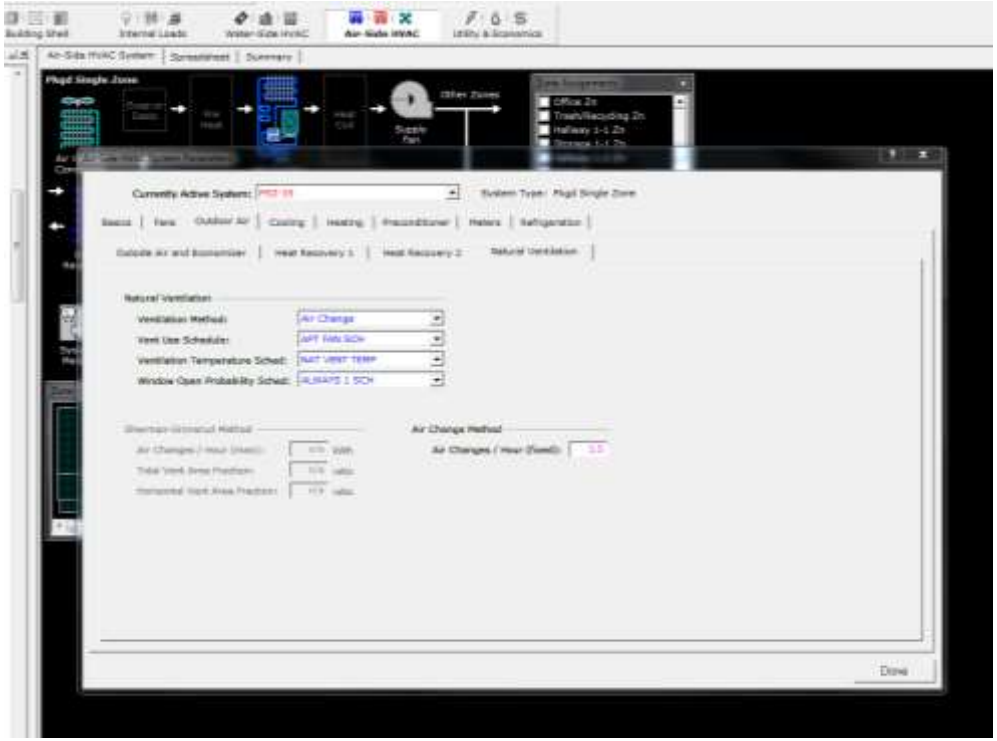
eQUEST – Overall Energy Use



Modeling Tools & Methods

eQUEST Natural Ventilation

- Limited to certain system types
- Limited to fixed air changes or crack method
- Limited algorithms for opening/closing schedules

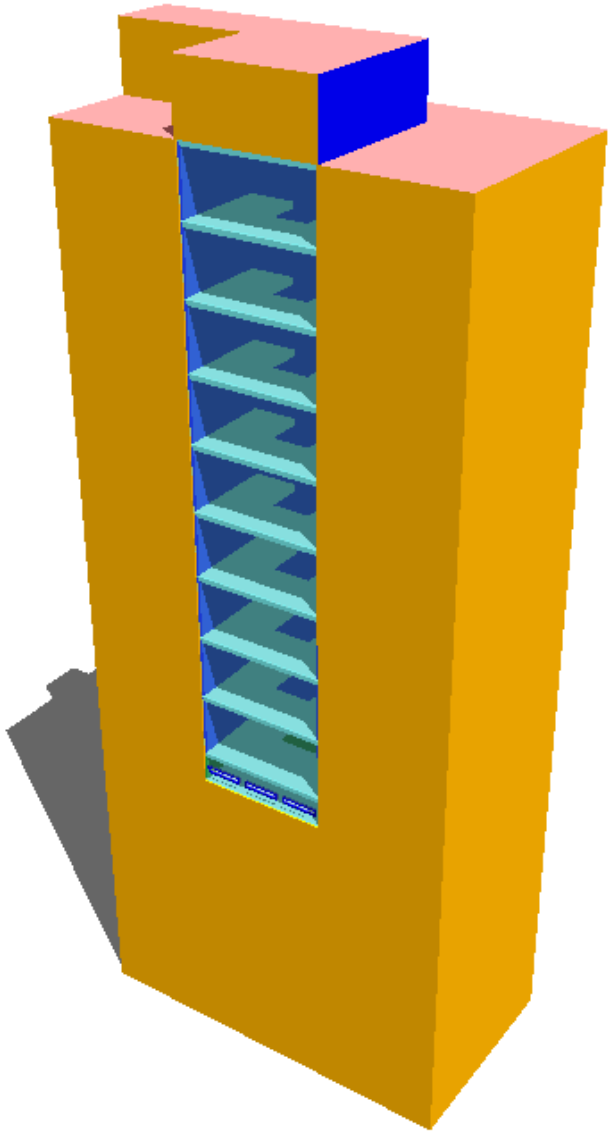


Modeling Tools & Methods

Bentley Tas

Hourly natural ventilation analysis

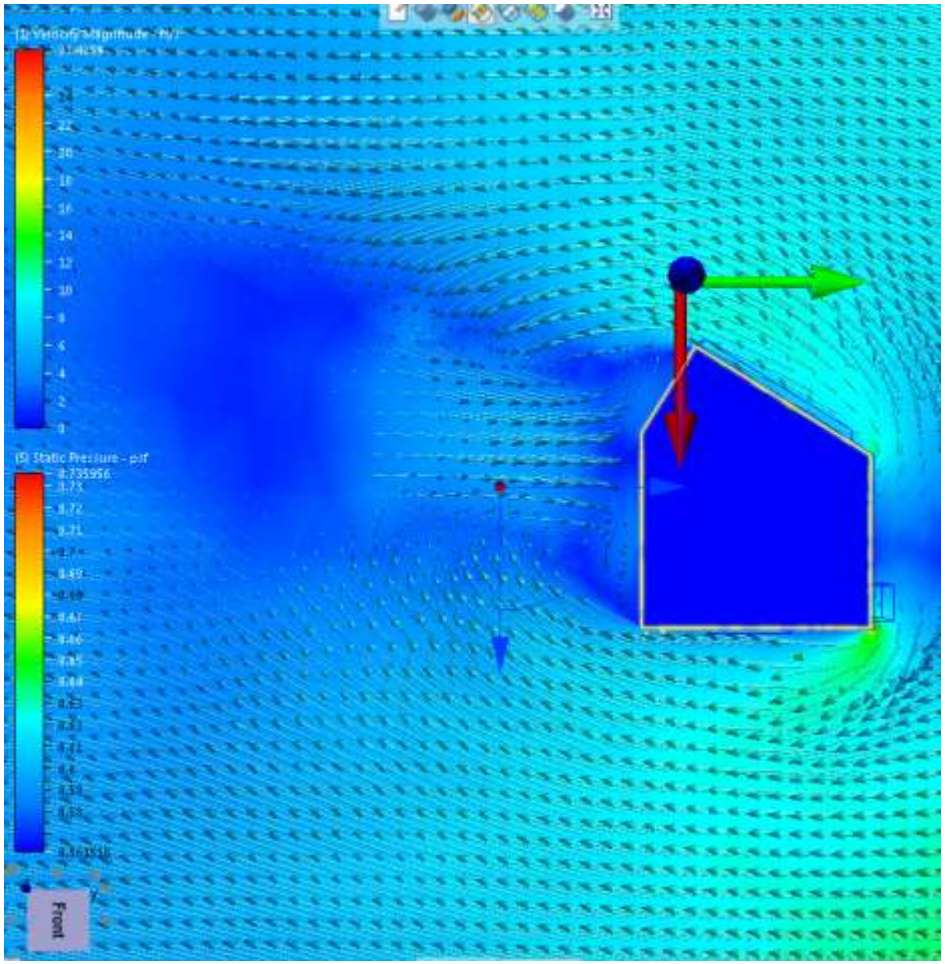
- Multi-zone
- Single-sided, cross-flow, stack-drive ventilation
- Accounts for thermal mass effects
- “Operates” building openings based on user inputs



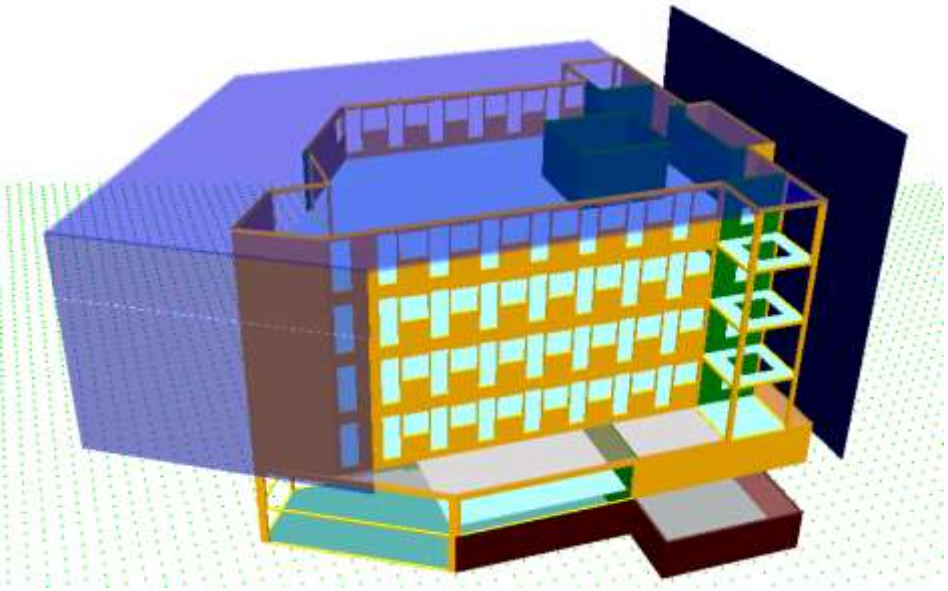
Modeling Tools & Methods

Bentley Tas does not…

- Calculate airflow patterns in the zone
- Calculate external flow patterns.
- Directly model HVAC system energy use

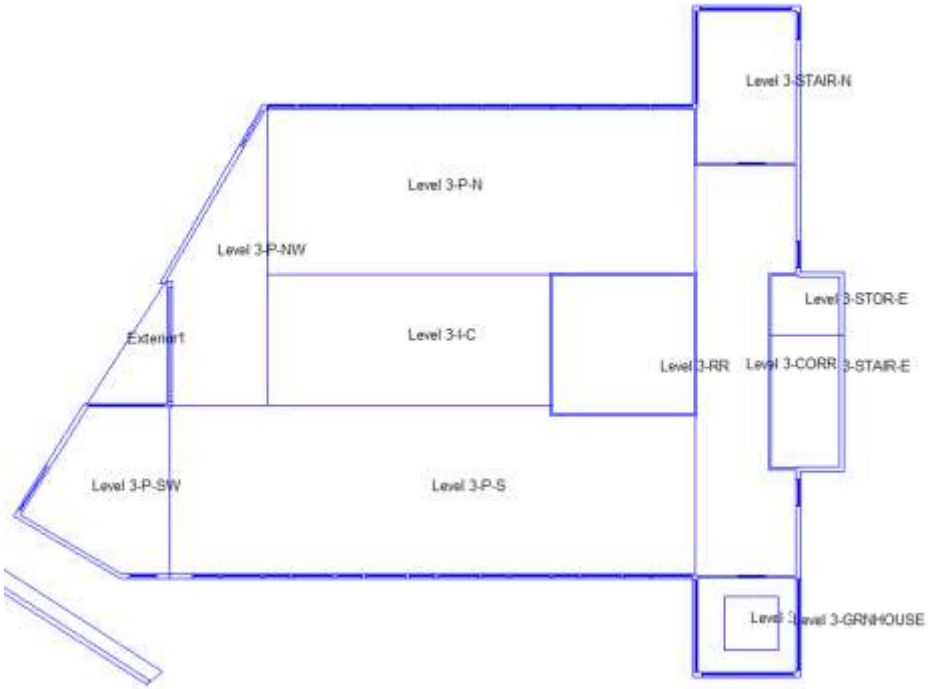


Tas Passive Cooling Model



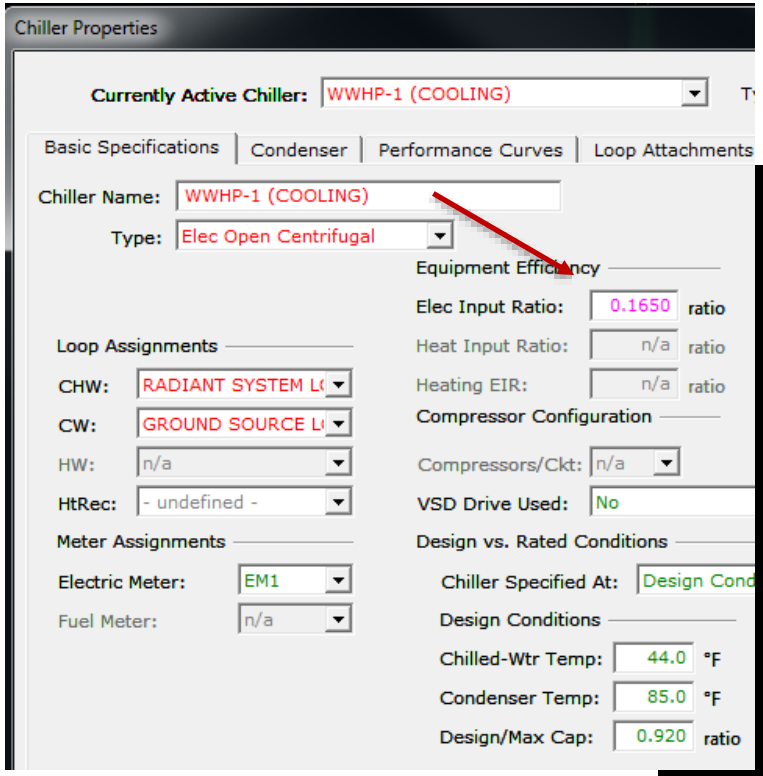
- Based on same GBXML file used to create the DOE2 model

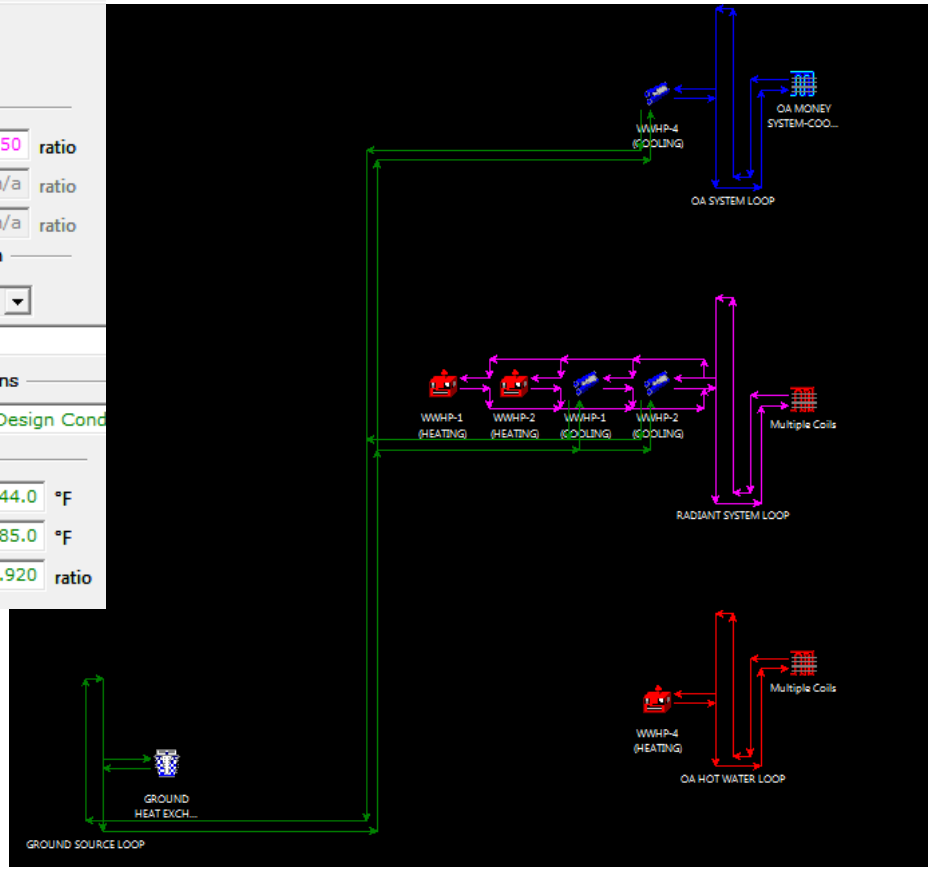
- Used Tas to create an hourly infiltration schedule



Modeling Tools & Methods

eQUEST Ground Source Heat Pumps

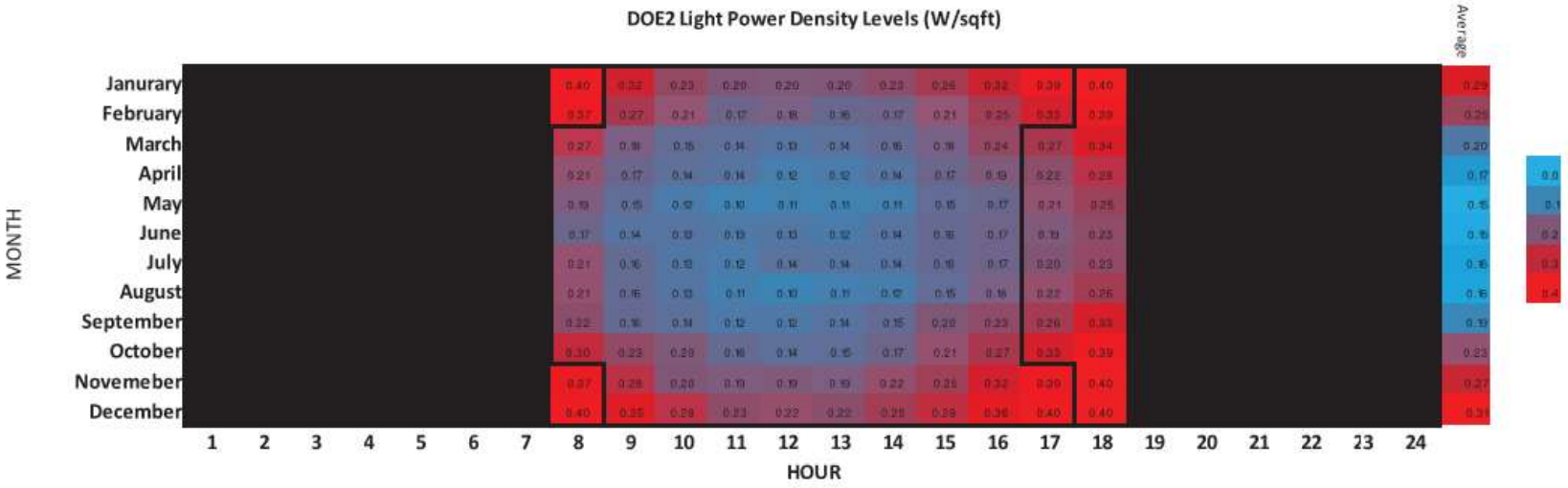


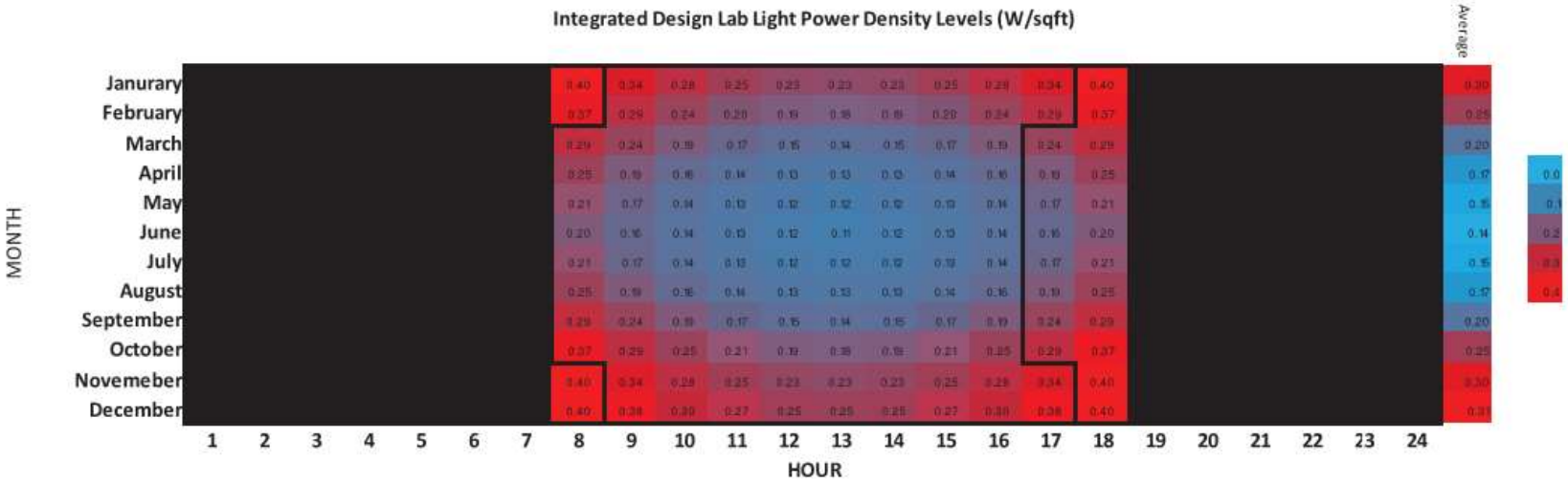


- GLHE used to size loop and generate water temperature spread for sensitivity analysis on COP/EIR

Modeling Tools & Methods

eQUEST Daylighting Calibration





Modeling Tools & Methods

Plug Loads

			Laptop	PC	Monitors	Laster Cutter	BIG ASS FANS	COPIERS	REFRIGERATOR	WATER COOLER	MICROWAVE	DISHWASHER	THIN CLIENT	MISC EQUIPMENT	FLATSCREEN TVs or Projectors
Phantom Load Factor	0	Equip/Person	0.20	0.65	1.65		0.18	0.05	0.02	0.05	0.03	0.02	0.15	1.00	
		Watts/Equip	40	65	25	2000	290	1100	200	770	1000	500	20	15	1600
		Watts/person	8.00	42.25	41.25		52.20	55.00	3.34	38.50	33.00	8.35	3.00	15.00	
		Watts/sf	0.05	0.28	0.28	0.06	0.35	0.37	0.02	0.26	0.22	0.06	0.02	0.10	0.05
USER INPUTS															
"		WEEKDAY SCHEDULE													
1	12-1AM	0	0%	0%	0%	0%	0%	3%	50%	0%	0%	0%	0%	0%	0%
2	1-2	0	0%	0%	0%	0%	0%	3%	50%	0%	0%	0%	0%	0%	0%
3	2-3	0	0%	0%	0%	0%	0%	3%	50%	0%	0%	0%	0%	0%	0%
4	3-4	0	0%	0%	0%	0%	0%	3%	50%	0%	0%	0%	0%	0%	0%
5	4-5	0	0%	0%	0%	0%	0%	3%	50%	0%	0%	0%	0%	0%	0%
6	5-6	0.05	5%	5%	5%	5%	0%	3%	50%	0%	0%	0%	5%	5%	5%
7	6-7	0.1	10%	10%	10%	7%	0%	3%	50%	0%	0%	0%	10%	10%	10%
8	7-8	0.2	20%	20%	20%	7%	0%	30%	50%	0%	0%	0%	20%	20%	20%
9	8-9	0.800	80%	80%	80%	7%	16%	30%	50%	0%	0%	0%	80%	80%	80%
10	9-10	0.800	80%	80%	80%	7%	16%	30%	50%	0%	0%	0%	80%	80%	80%
11	10-11	0.800	80%	80%	80%	7%	16%	30%	50%	0%	0%	0%	80%	80%	80%
12	11-12 PM	0.800	80%	80%	80%	7%	16%	30%	50%	0%	25%	0%	80%	80%	80%
13	12-1	0.500	50%	50%	50%	7%	16%	30%	50%	0%	100%	100%	50%	50%	80%
14	1-2	0.800	80%	80%	80%	7%	16%	30%	50%	0%	25%	0%	80%	80%	80%
15	2-3	0.800	80%	80%	80%	7%	16%	30%	50%	0%	0%	0%	80%	80%	80%
16	3-4	0.800	80%	80%	80%	7%	16%	30%	50%	0%	0%	0%	80%	80%	80%
17	4-5	0.800	80%	80%	80%	7%	16%	30%	50%	0%	0%	100%	80%	80%	80%
18	5-6	0.6	60%	60%	60%	7%	16%	30%	50%	0%	0%	0%	60%	60%	60%
19	6-7	0.4	40%	40%	40%	5%	0%	30%	50%	0%	0%	0%	40%	40%	40%
20	7-8	0.2	20%	20%	20%	5%	0%	3%	50%	0%	0%	0%	20%	20%	20%
21	8-9	0.1	10%	10%	10%	5%	0%	3%	50%	0%	0%	0%	10%	10%	10%
22	9-10	0.1	10%	10%	10%	5%	0%	3%	50%	0%	0%	0%	10%	10%	10%
23	10-11	0.05	5%	5%	5%	0%	0%	3%	50%	0%	0%	0%	5%	5%	5%
24	11-12 AM	0.05	5%	5%	5%	0%	0%	3%	50%	0%	0%	0%	5%	5%	5%

Modeling Tools & Methods

Plug Loads

Additional Direct Loads:

- Servers
- Ceiling Fans
- DDC System
- Elevator
- Toilets
- Garage Door

Bullitt Center Performance

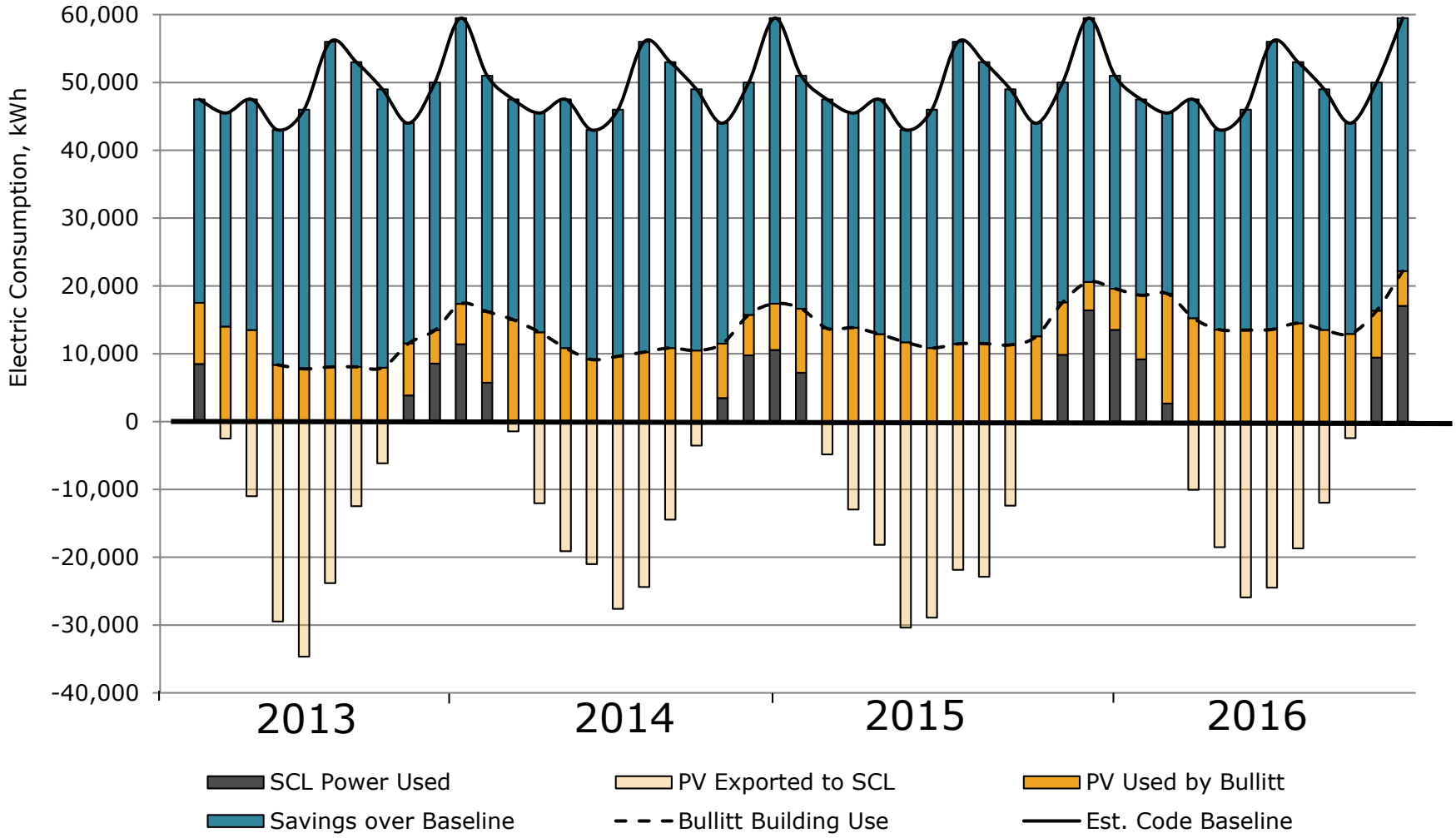
Net **positive** building

EUI **12.1** in 2016 | Predicted EUI of 16

85% occupied

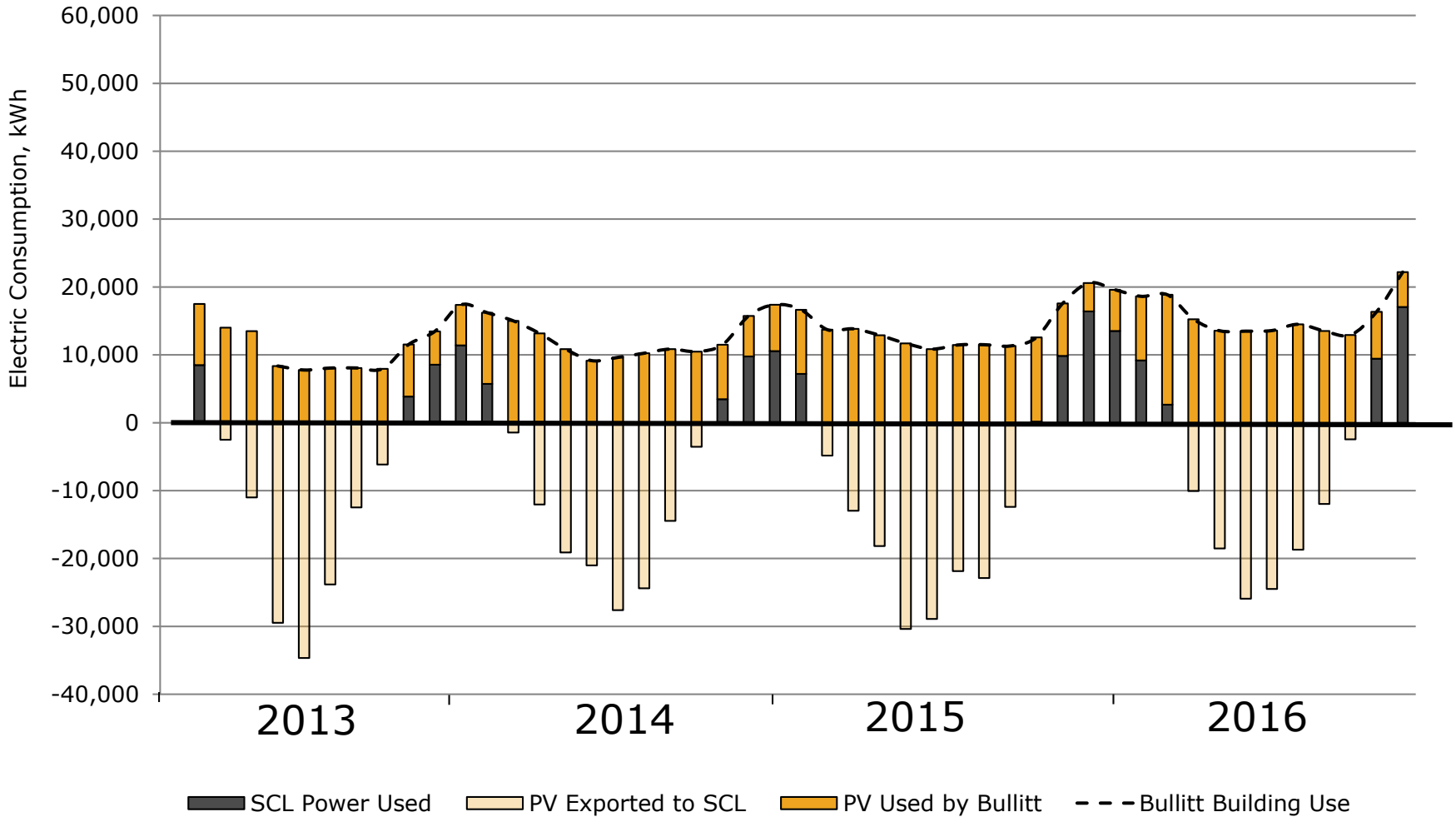
Bullitt Center Performance

Predicted vs. Actual



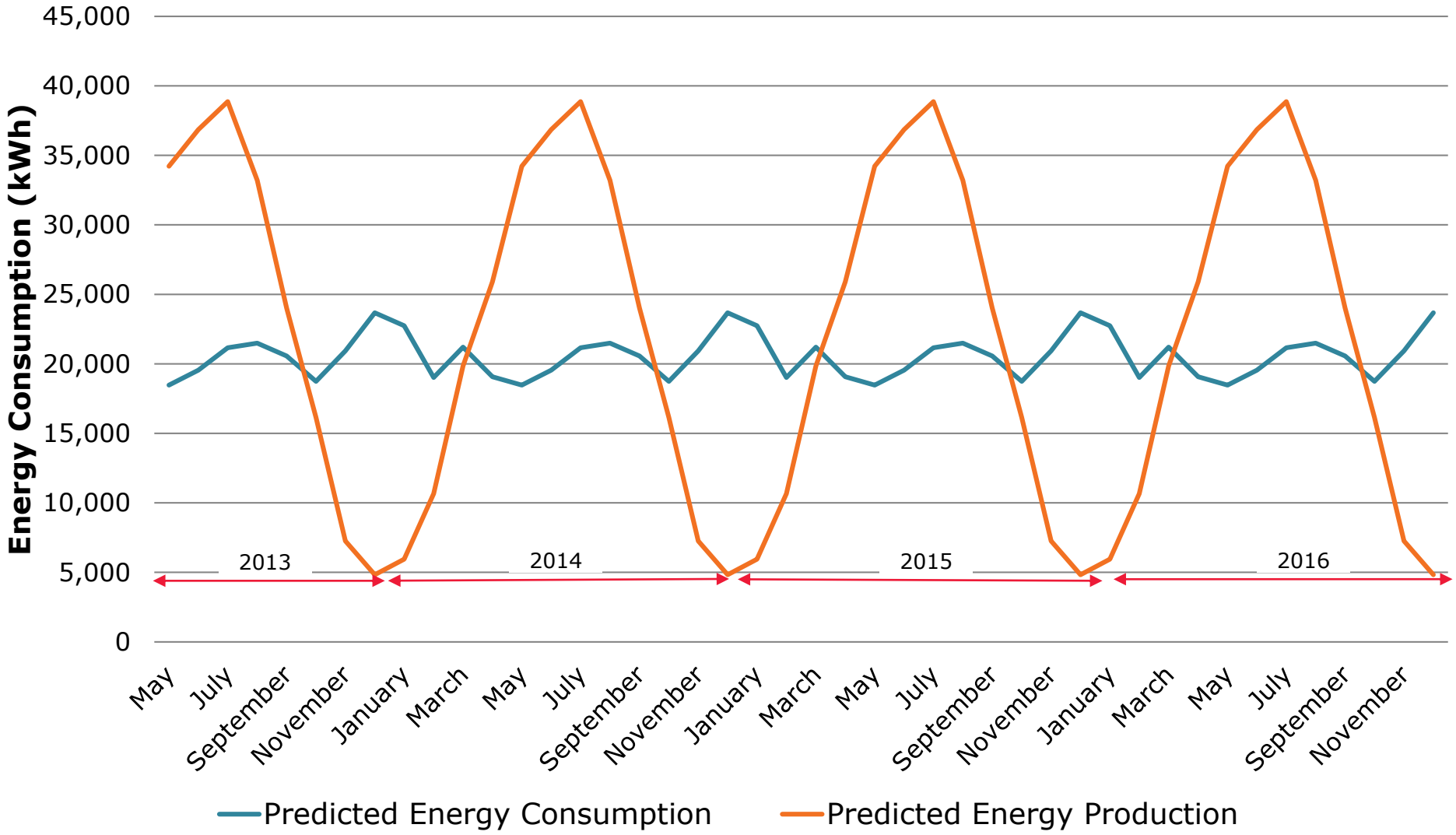
Bullitt Center Performance

Predicted vs. Actual



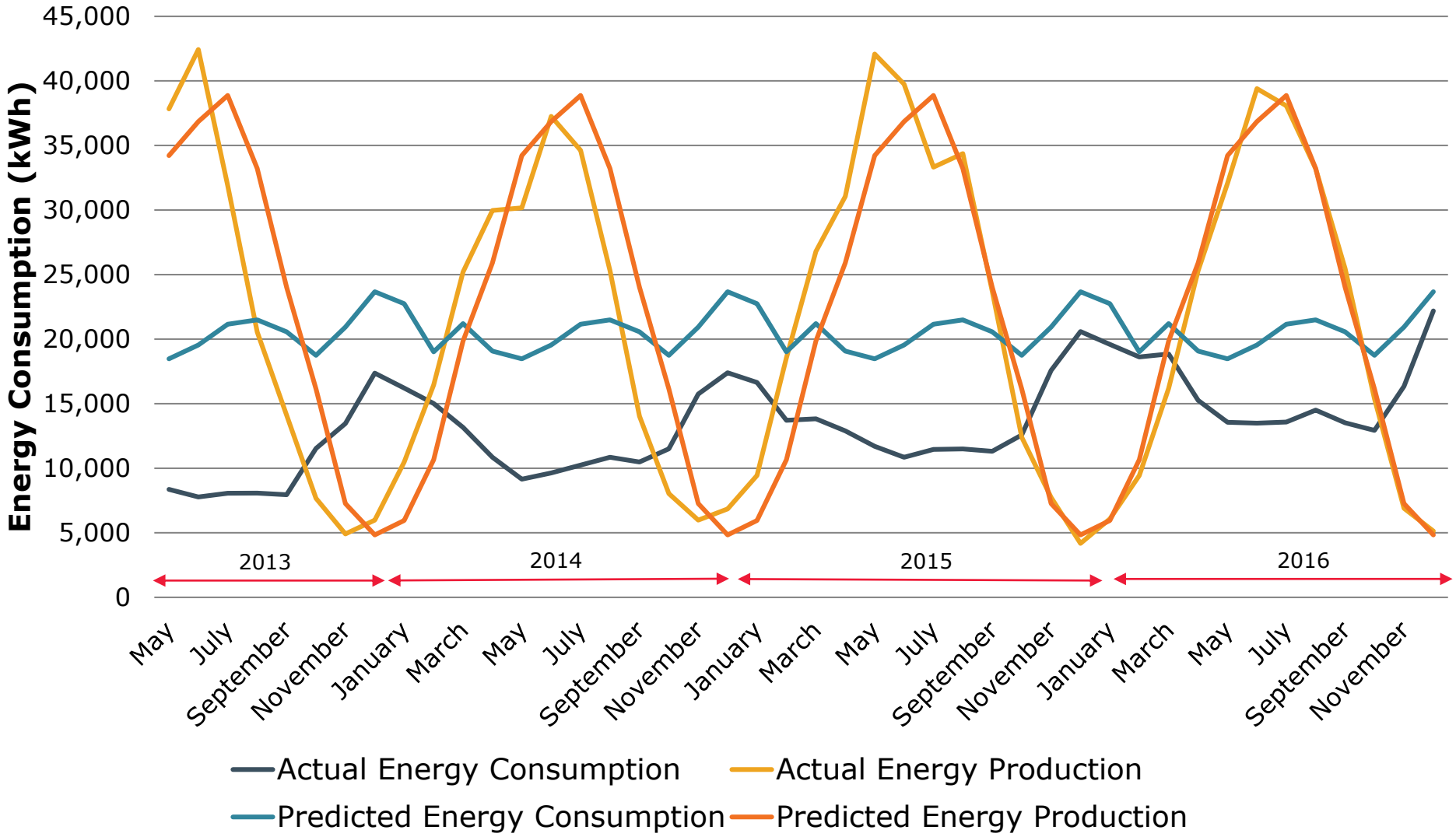
Bullitt Center Energy

Predicted Energy Production & Consumption

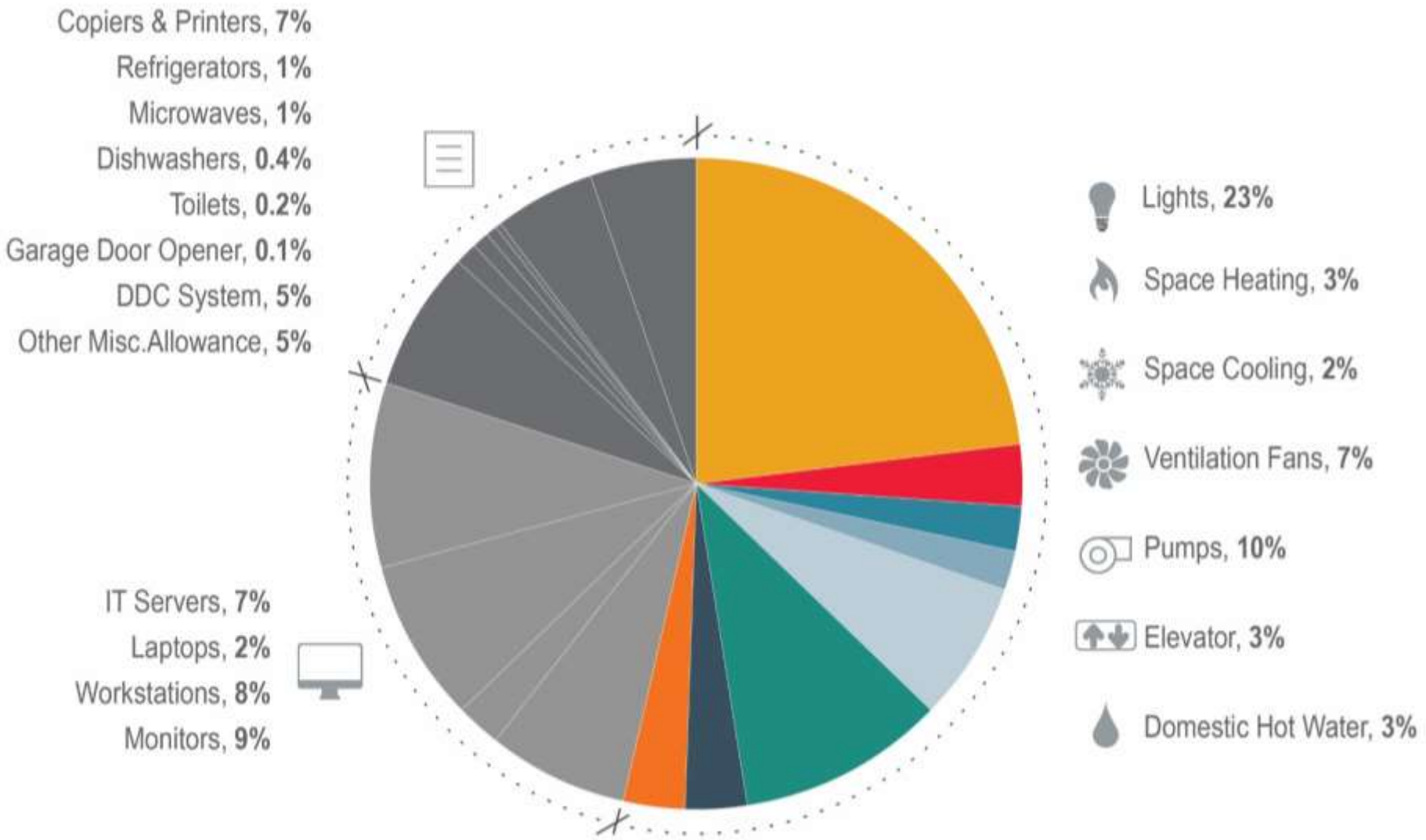


Bullitt Center Energy

Actual Energy Production & Consumption



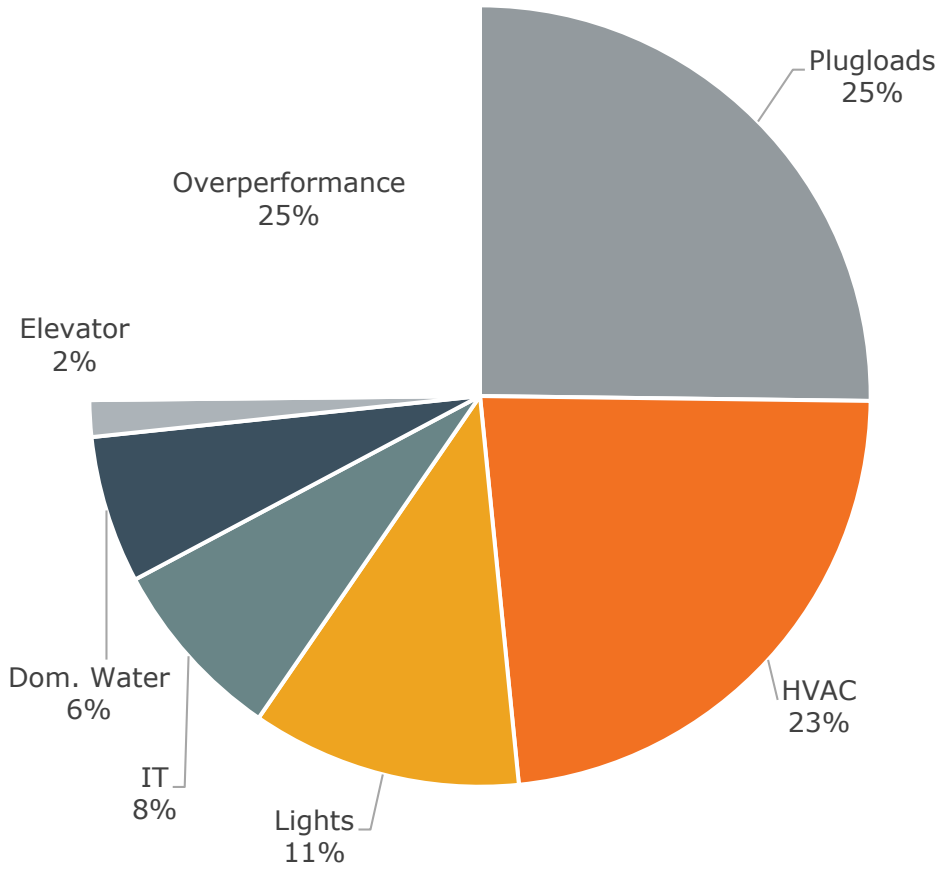
Bullitt Center Energy- Proposed Energy Use



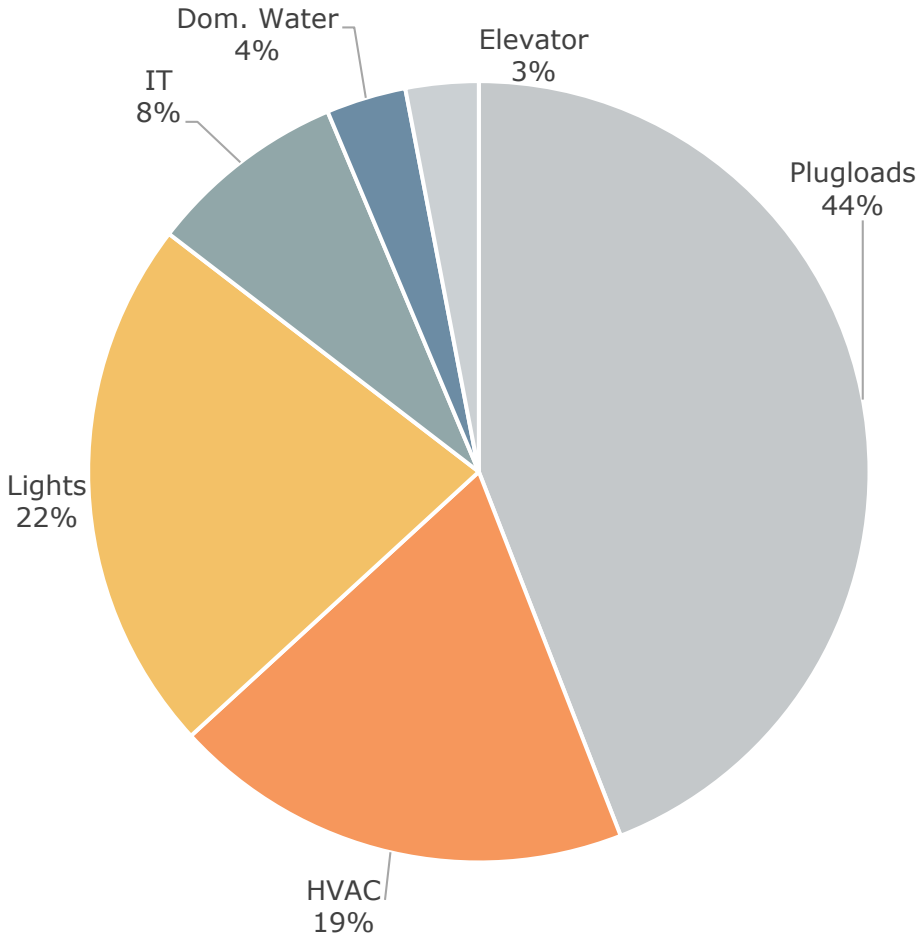
Bullitt Center Energy

Actual Energy Production & Consumption

BULLITT CENTER ACTUAL ENERGY USE BY END USE



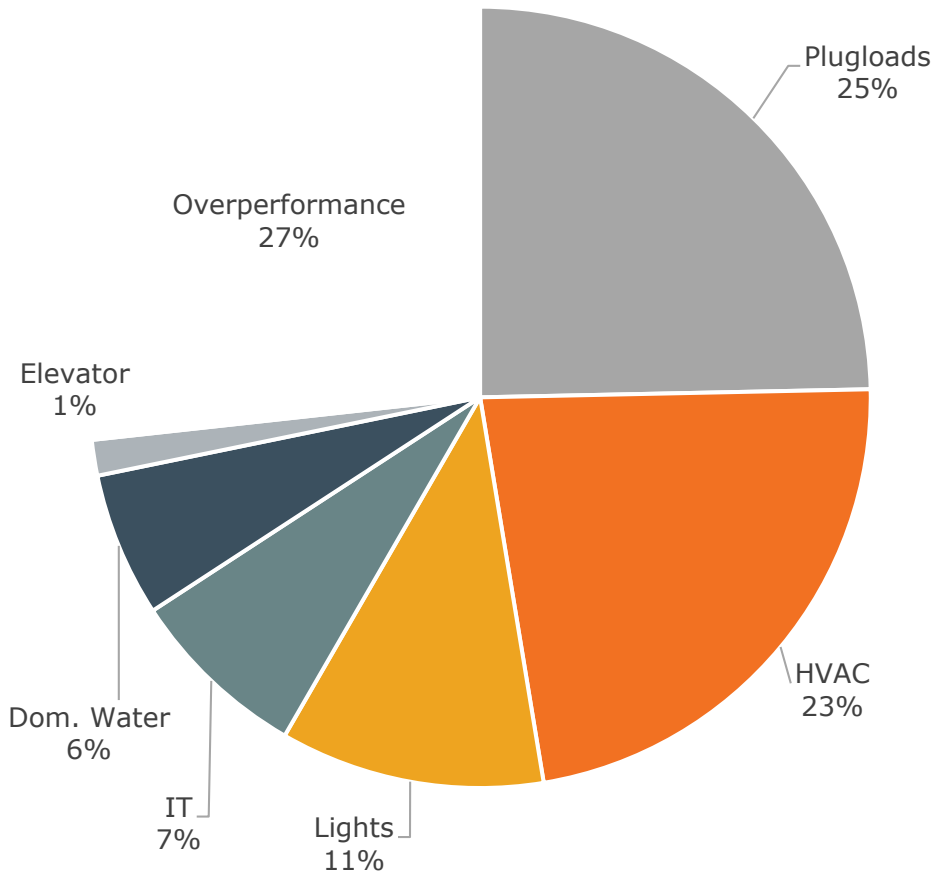
BULLITT CENTER MODELED ENERGY USE BY END USE



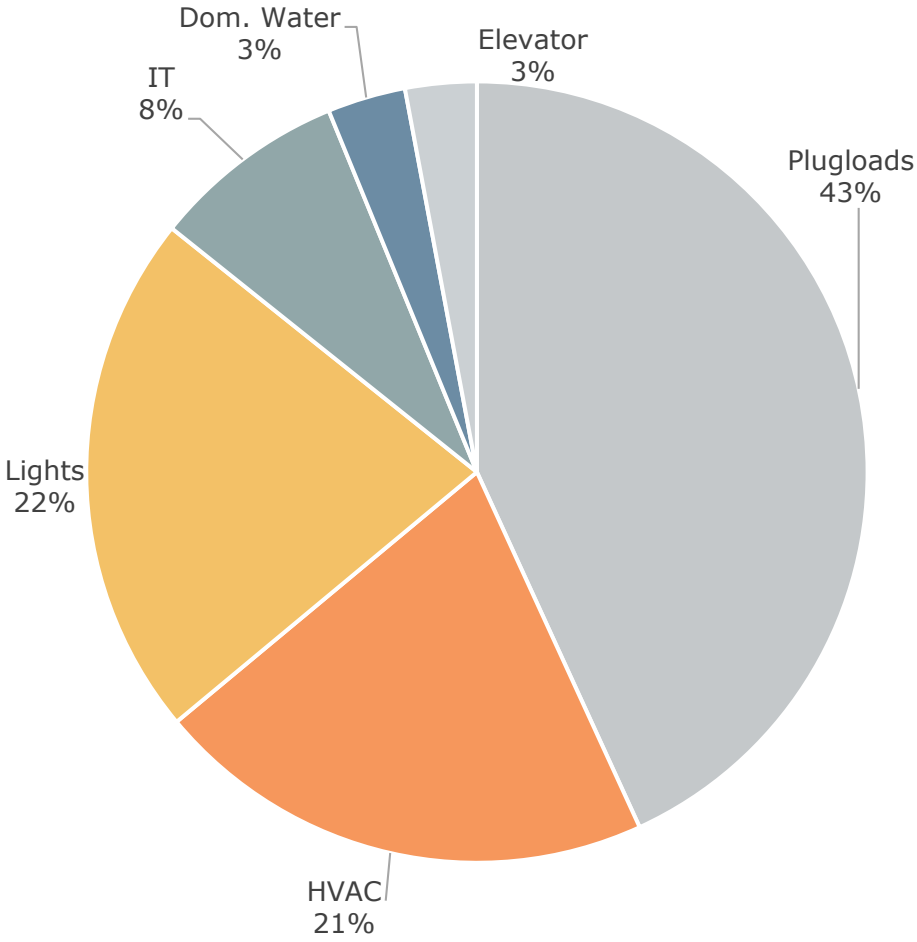
Bullitt Center Energy

Remove Tas Discounts?

BULLITT CENTER ACTUAL ENERGY USE BY END USE

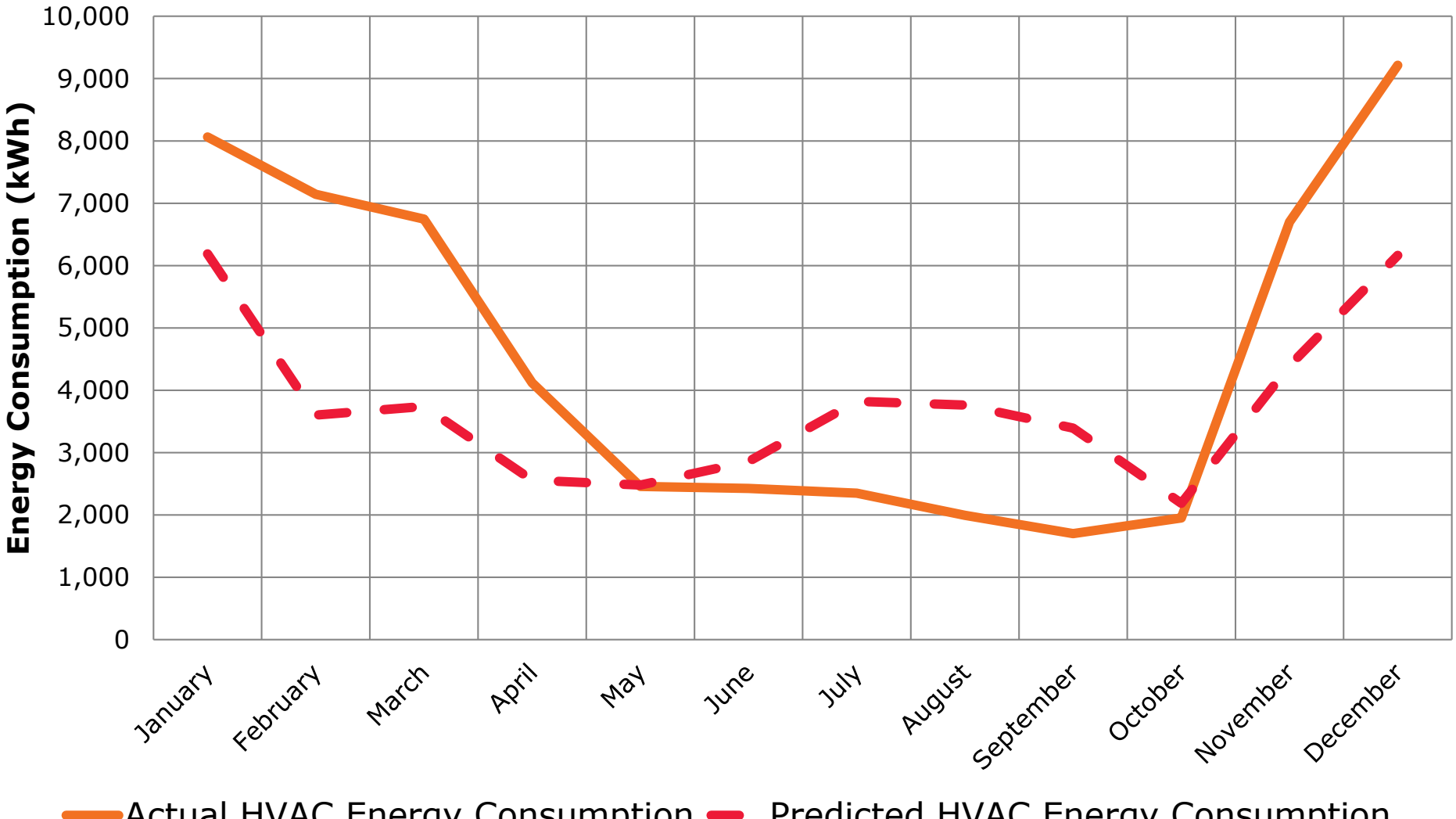


BULLITT CENTER MODELED ENERGY USE BY END USE



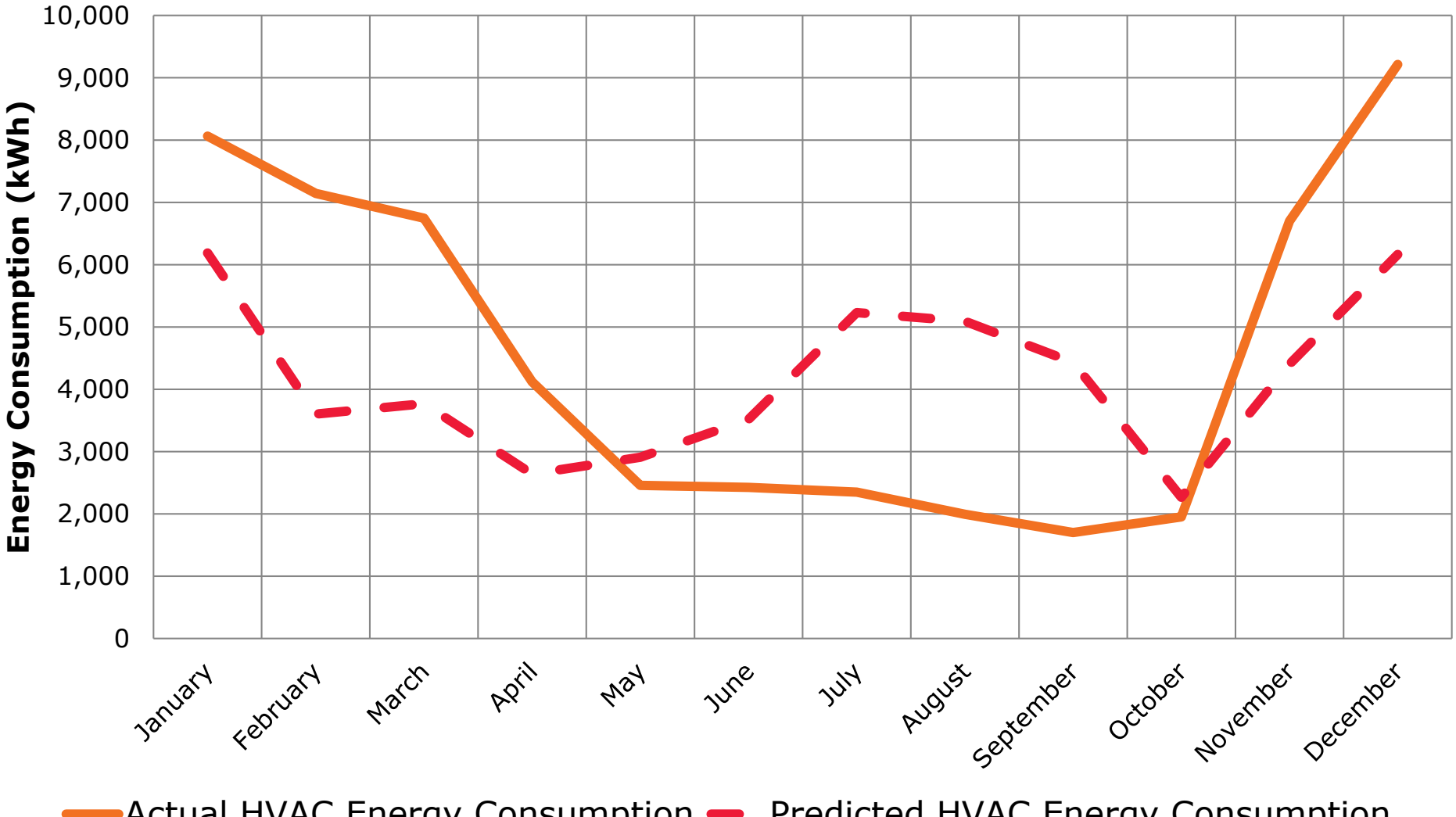
Bullitt Center Energy

HVAC



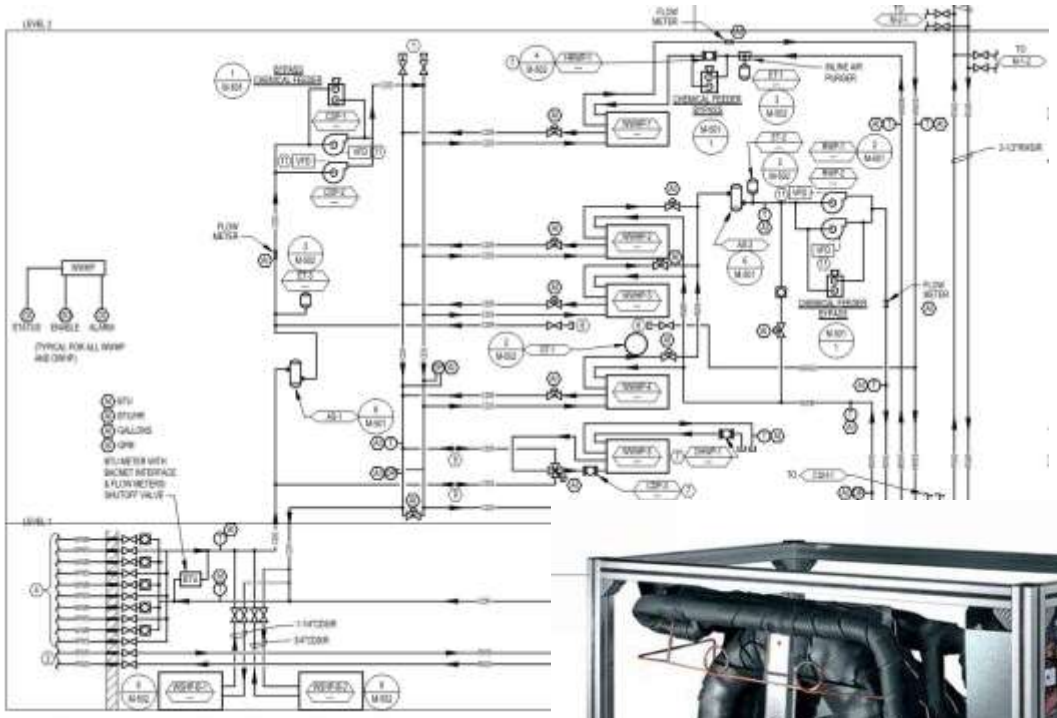
Bullitt Center Energy

HVAC – No Tas Discount



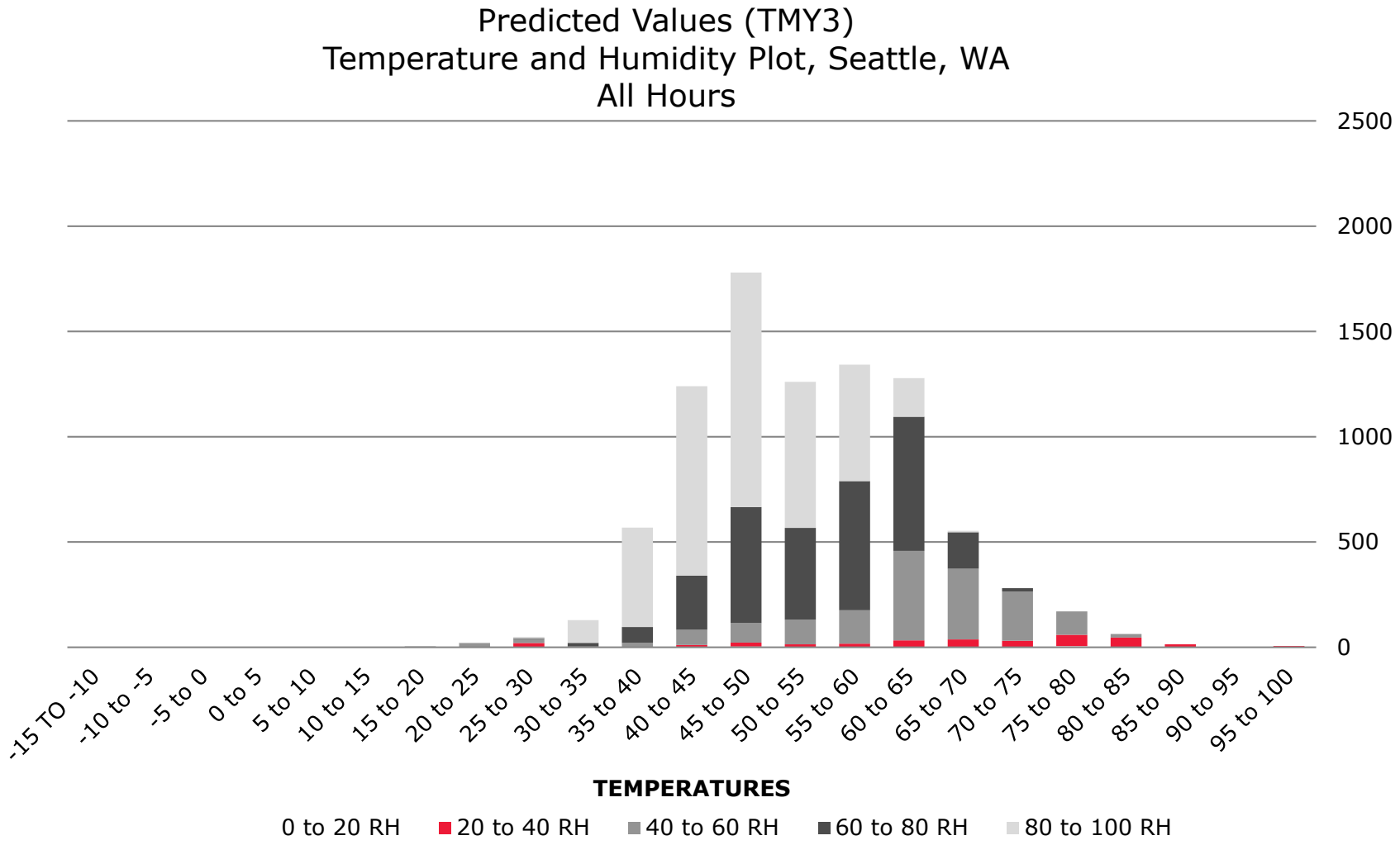
Bullitt Center Energy

HVAC – Causes?



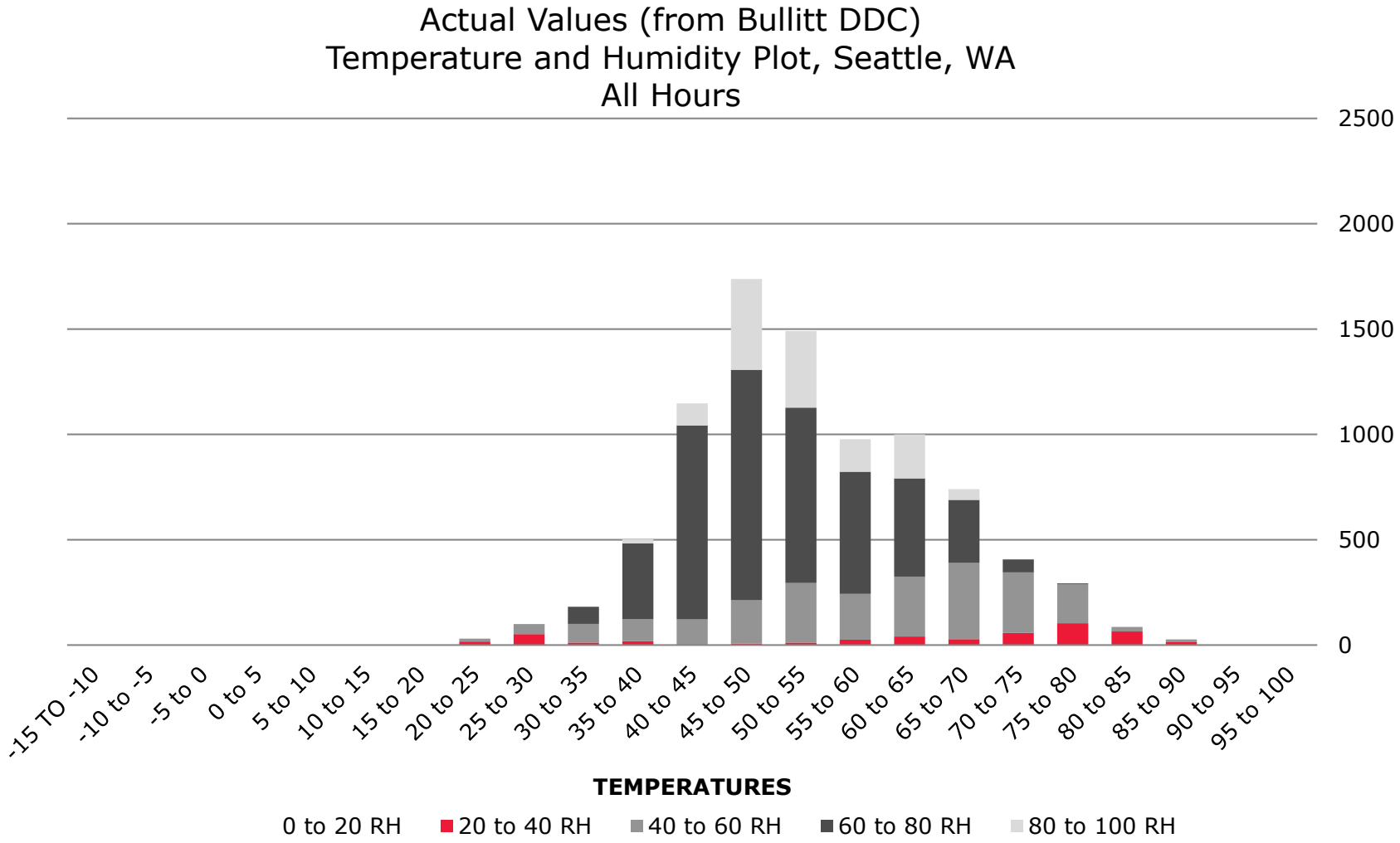
Performance

Predicted Weather



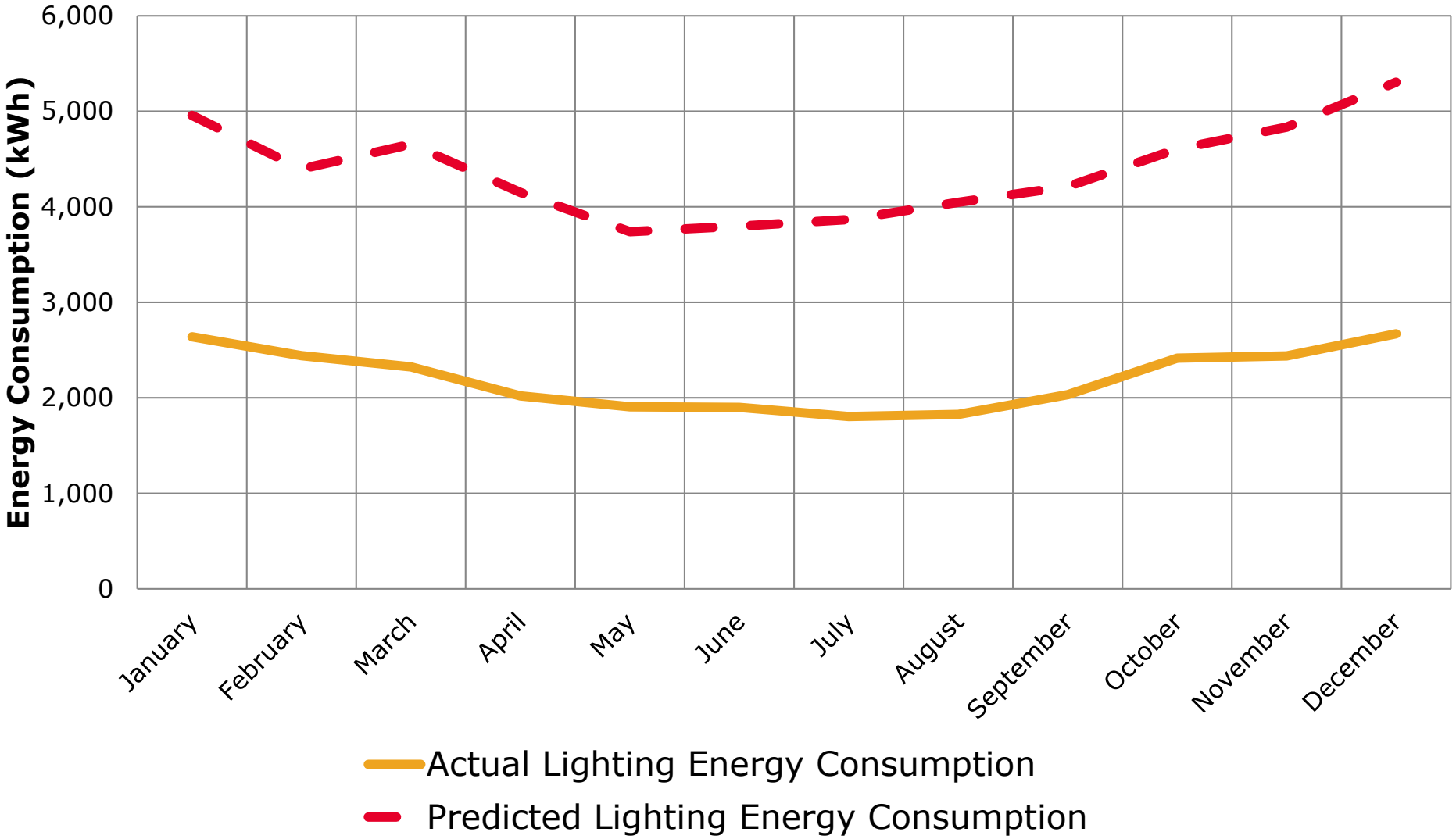
Performance

Actual Weather



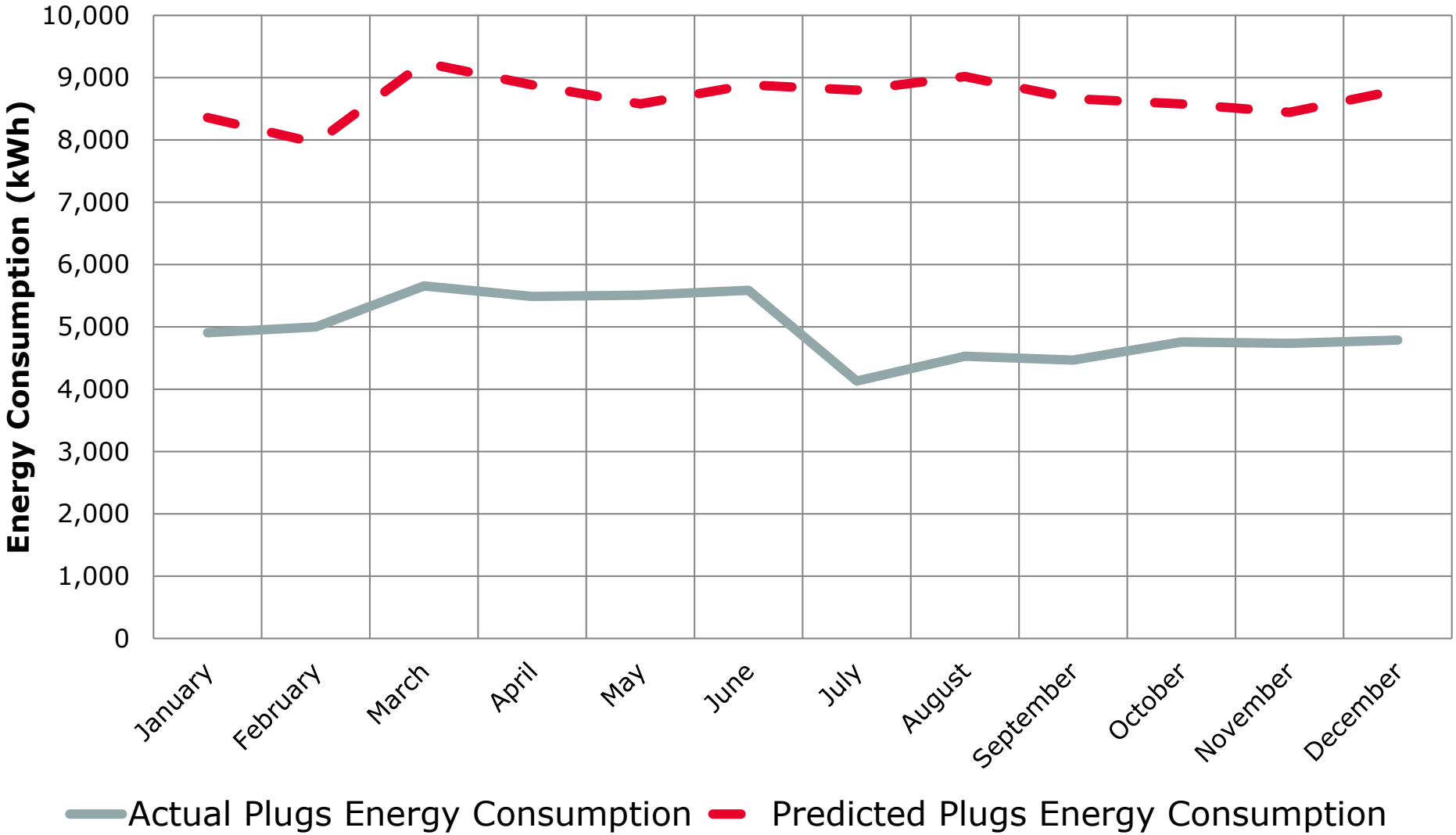
Bullitt Center Energy

Lighting



Bullitt Center Energy

Plug Loads



Lessons Learned

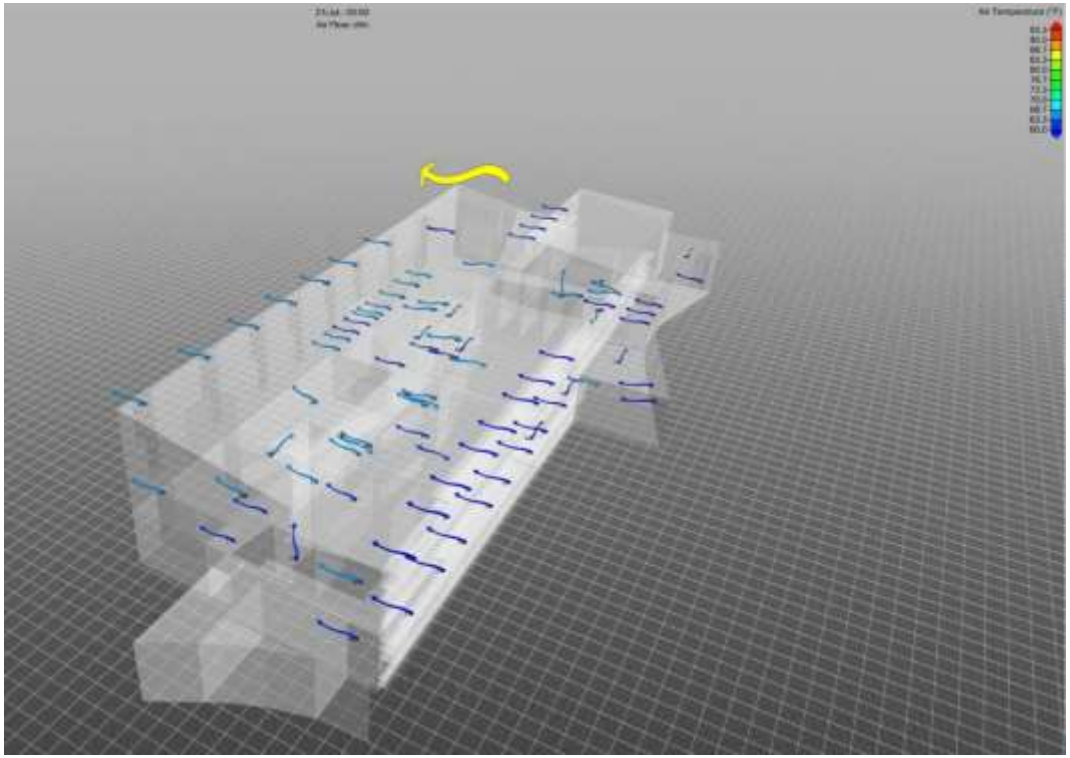
HVAC – Better Tools?

Integration of Natural Ventilation

- IES
- Energy+/OpenStudio?

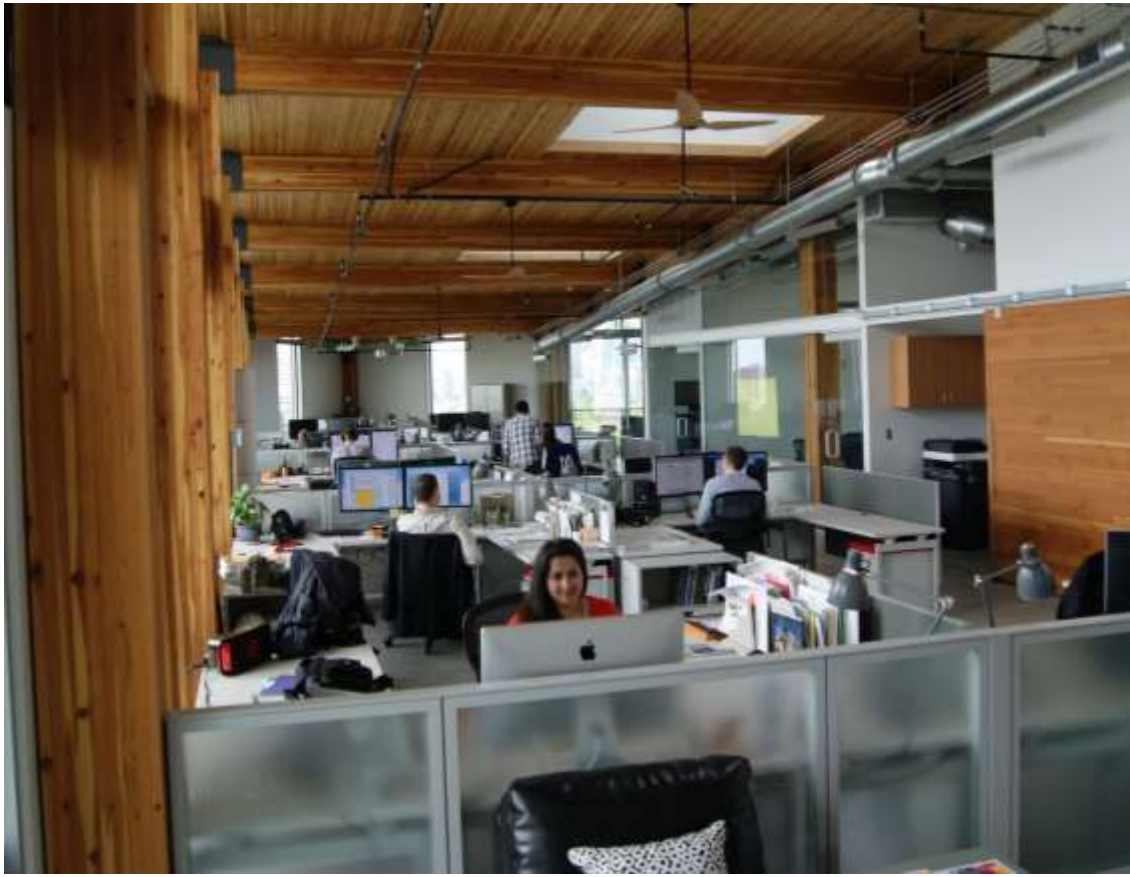
Integration of Ground Source

WWHP Models?



Lessons Learned

Lighting/Plug Loads



Creating a better environment

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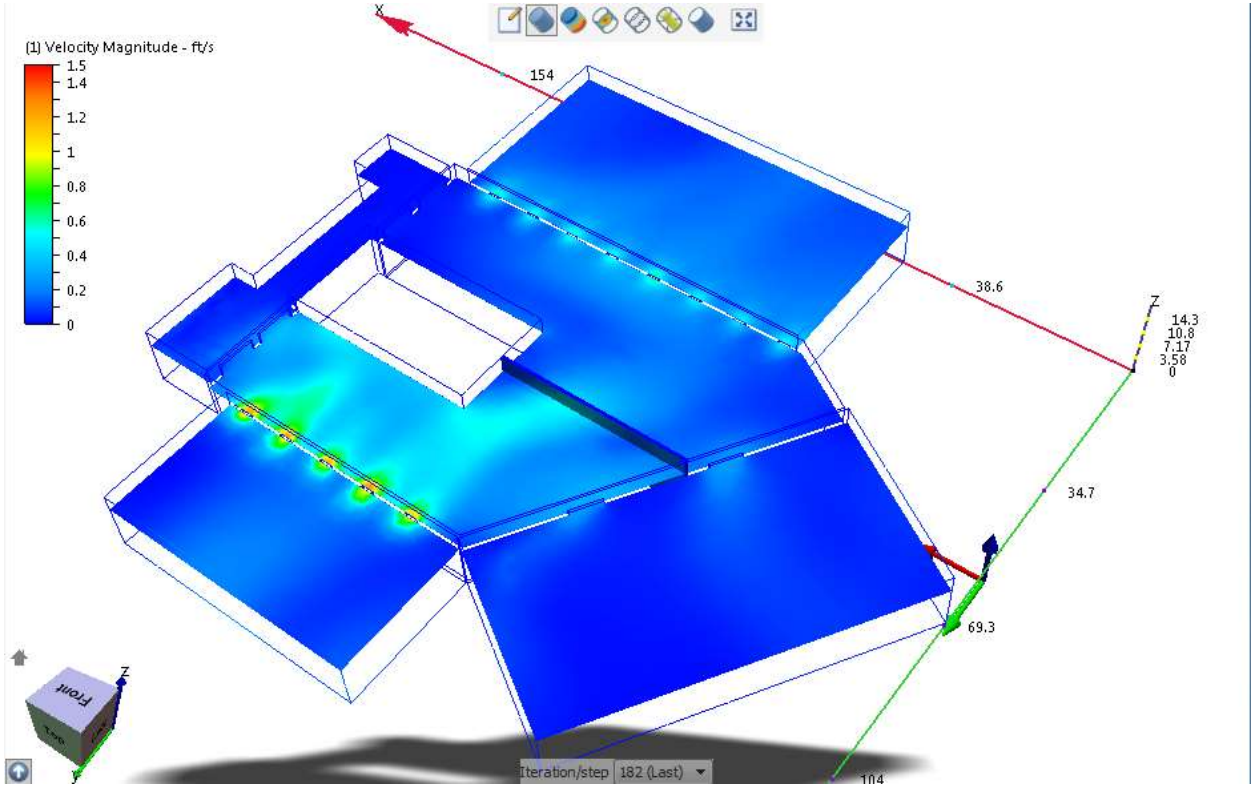
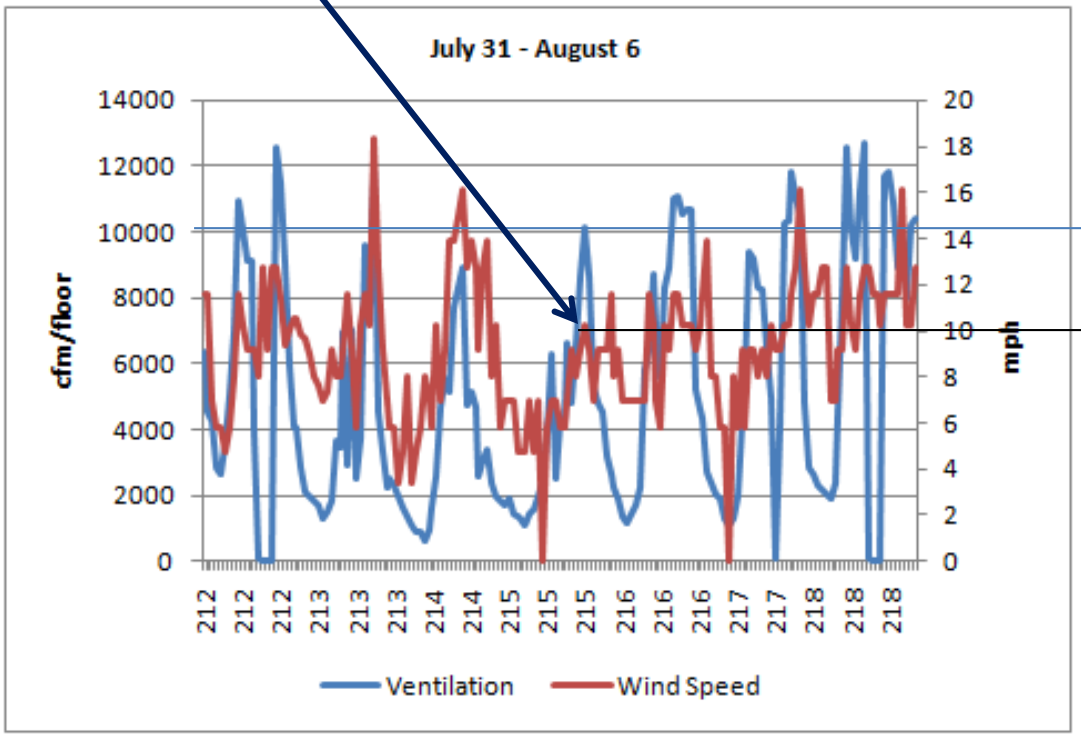
Comparison with CFD



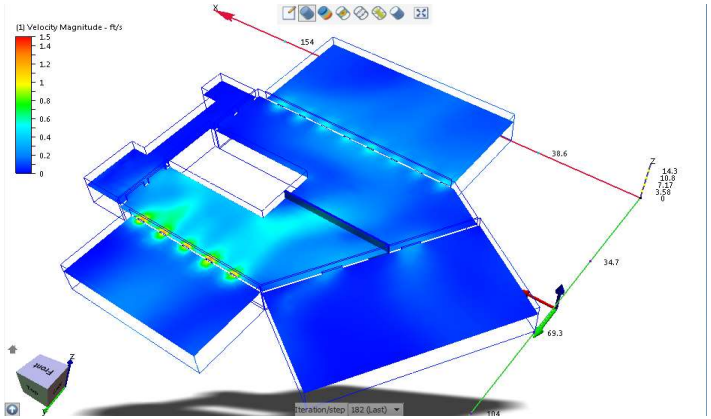
- Modeled at 10 MPH wind
- Total Airflow between 2500 and 10,000 CFM.

Comparison with CFD

10 MPH Wind, windows open



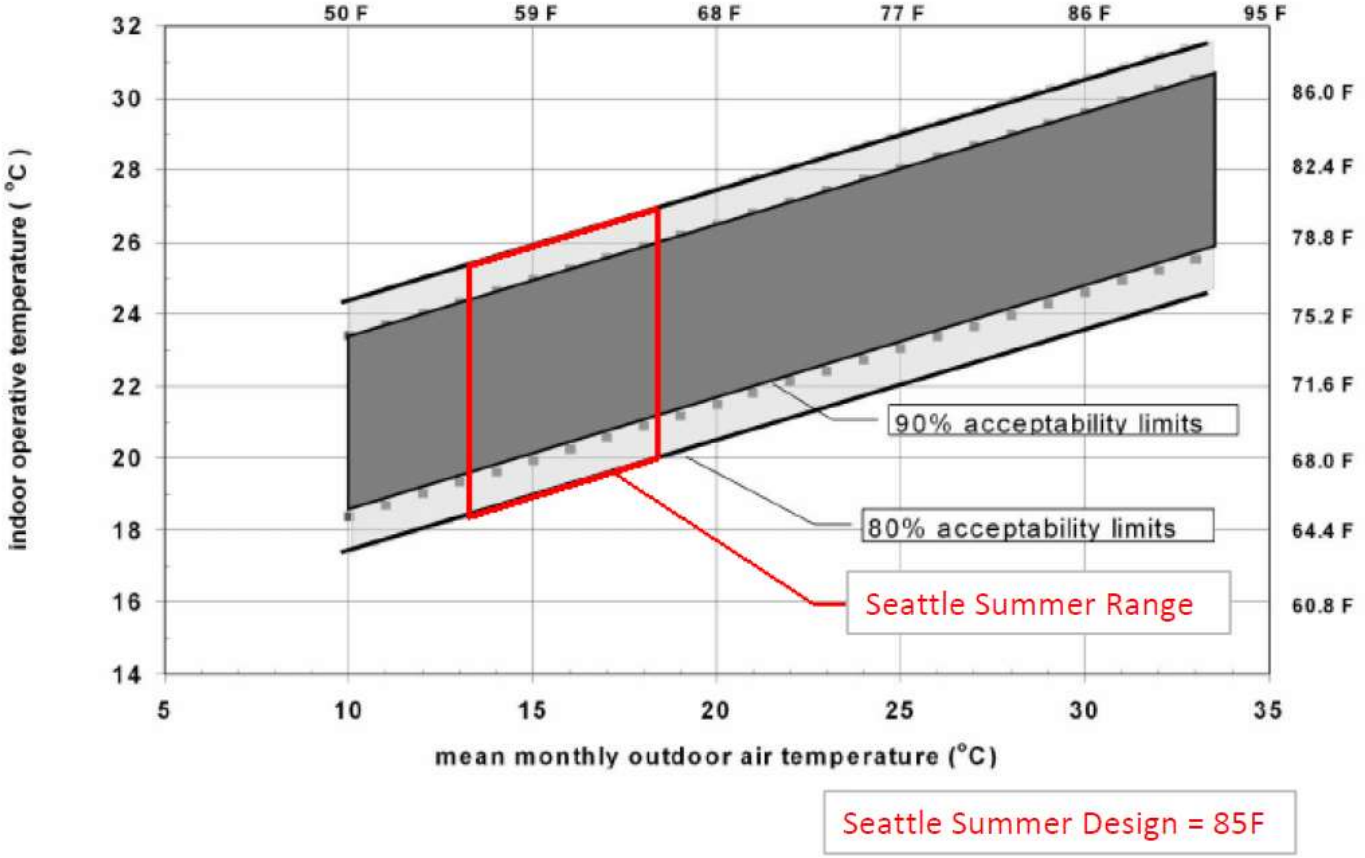
~10,000 CFM Ventilation



Select Ventilation Data from Tas Study

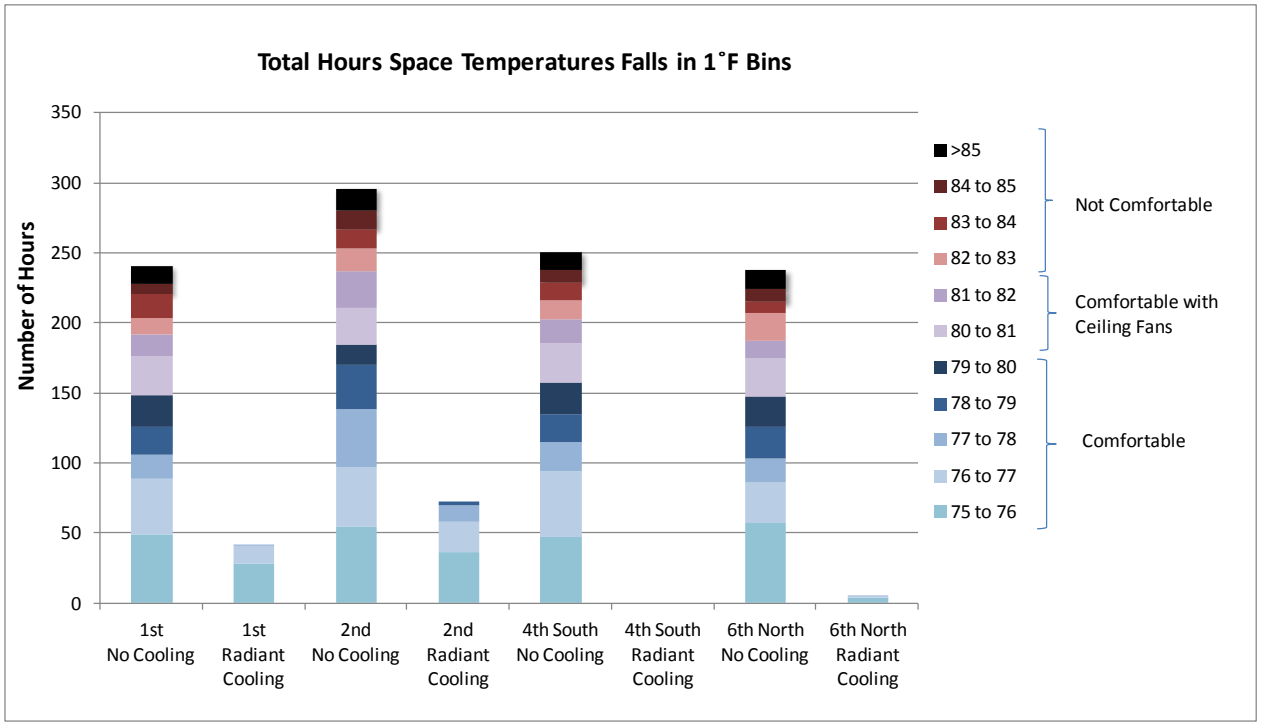
Natural Ventilation and Cooling

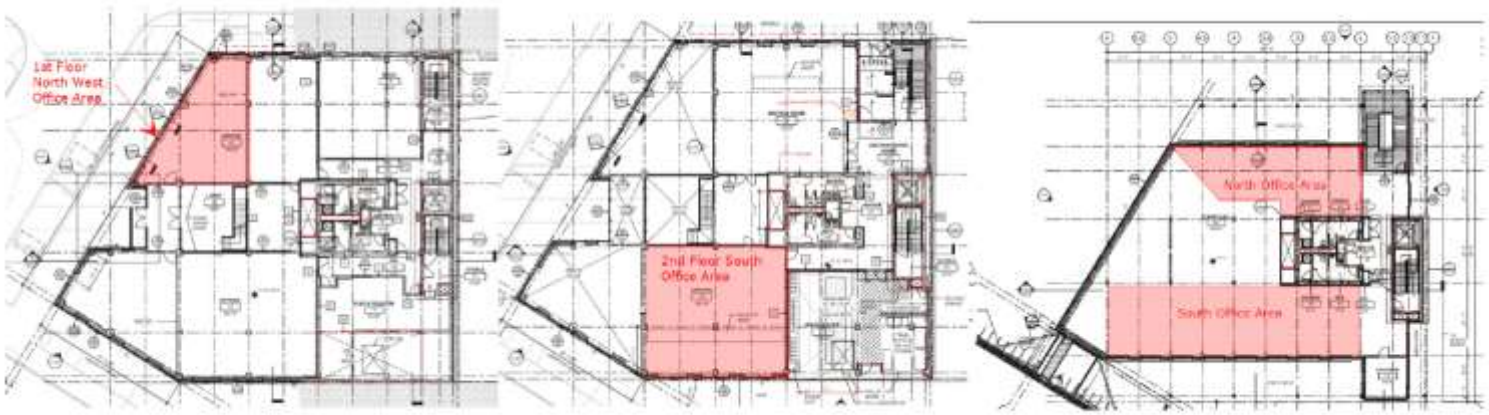
Seattle, Washington



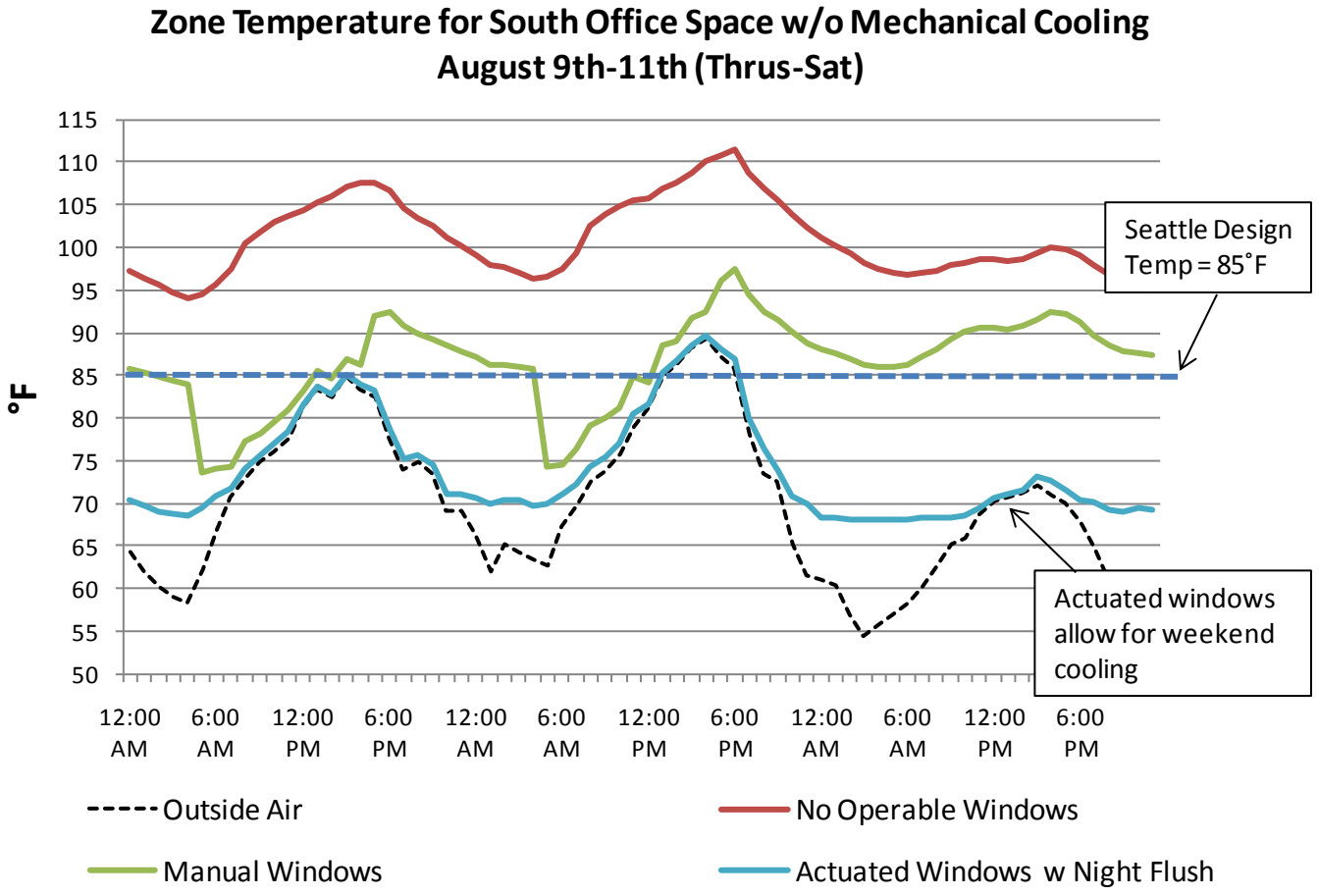
Acceptable Indoor Temperatures

Bullitt Center Comfort Study



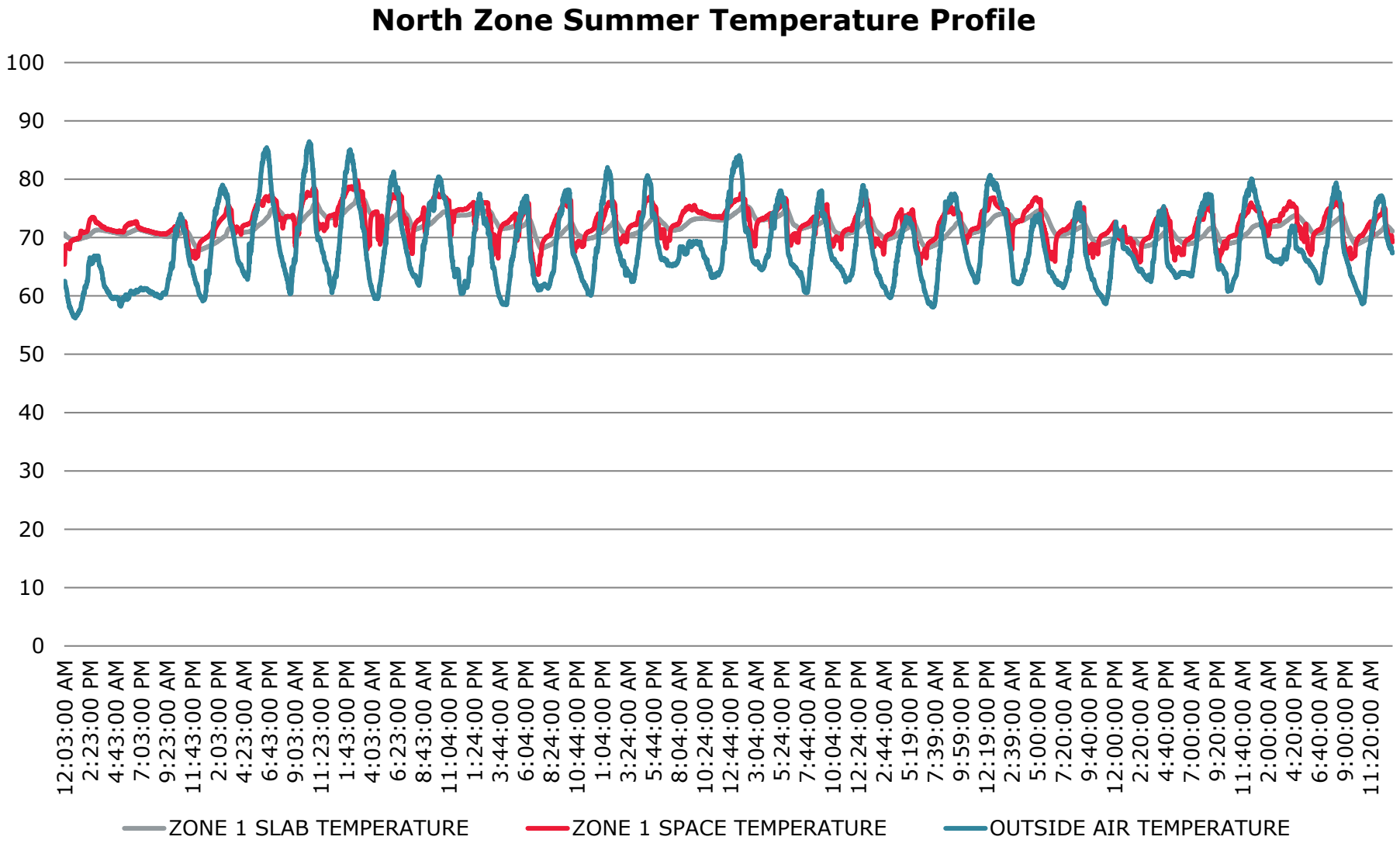


Passive Cooling

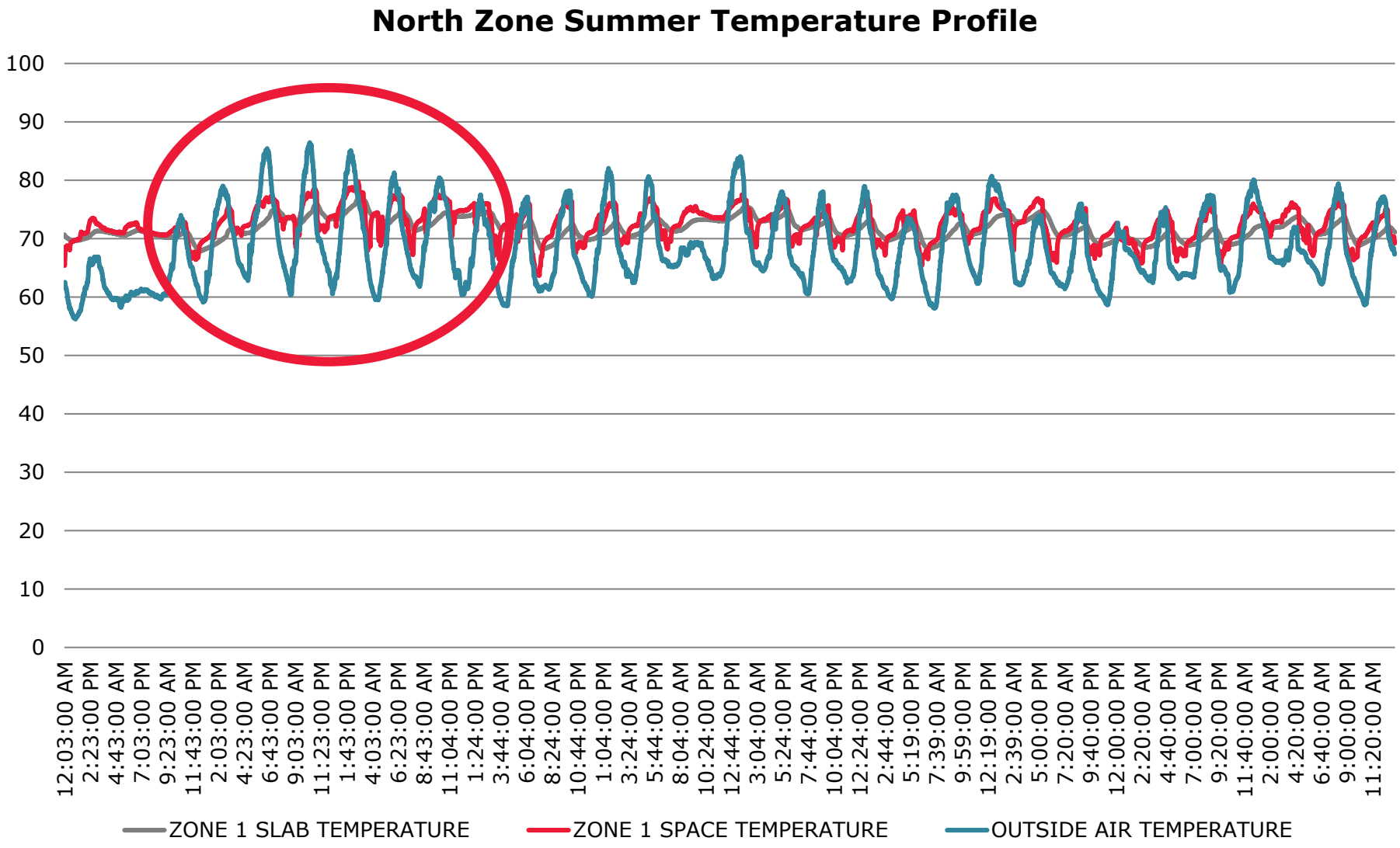


Performance- Thermal Comfort

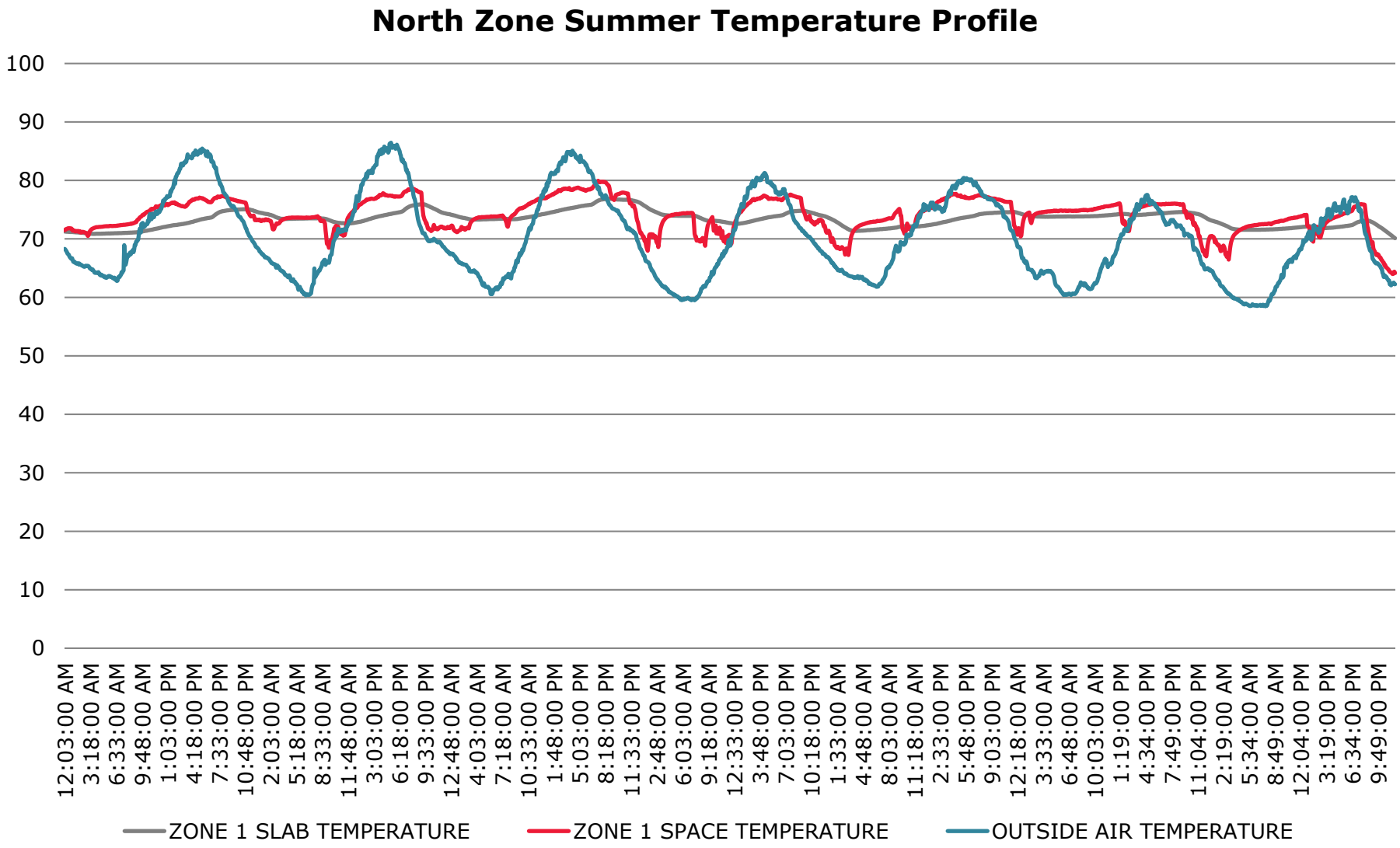
Performance- Thermal Comfort



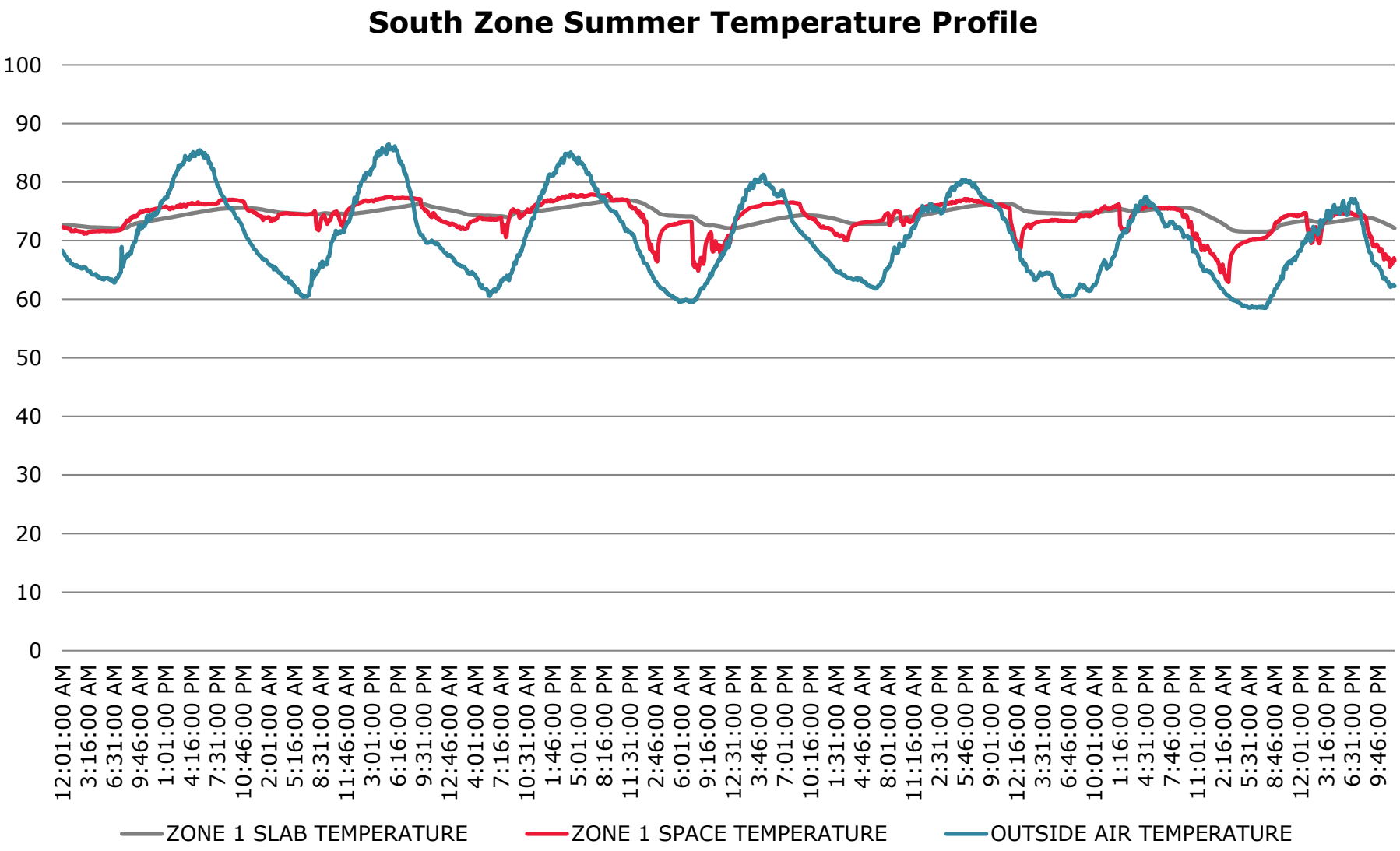
Performance- Thermal Comfort



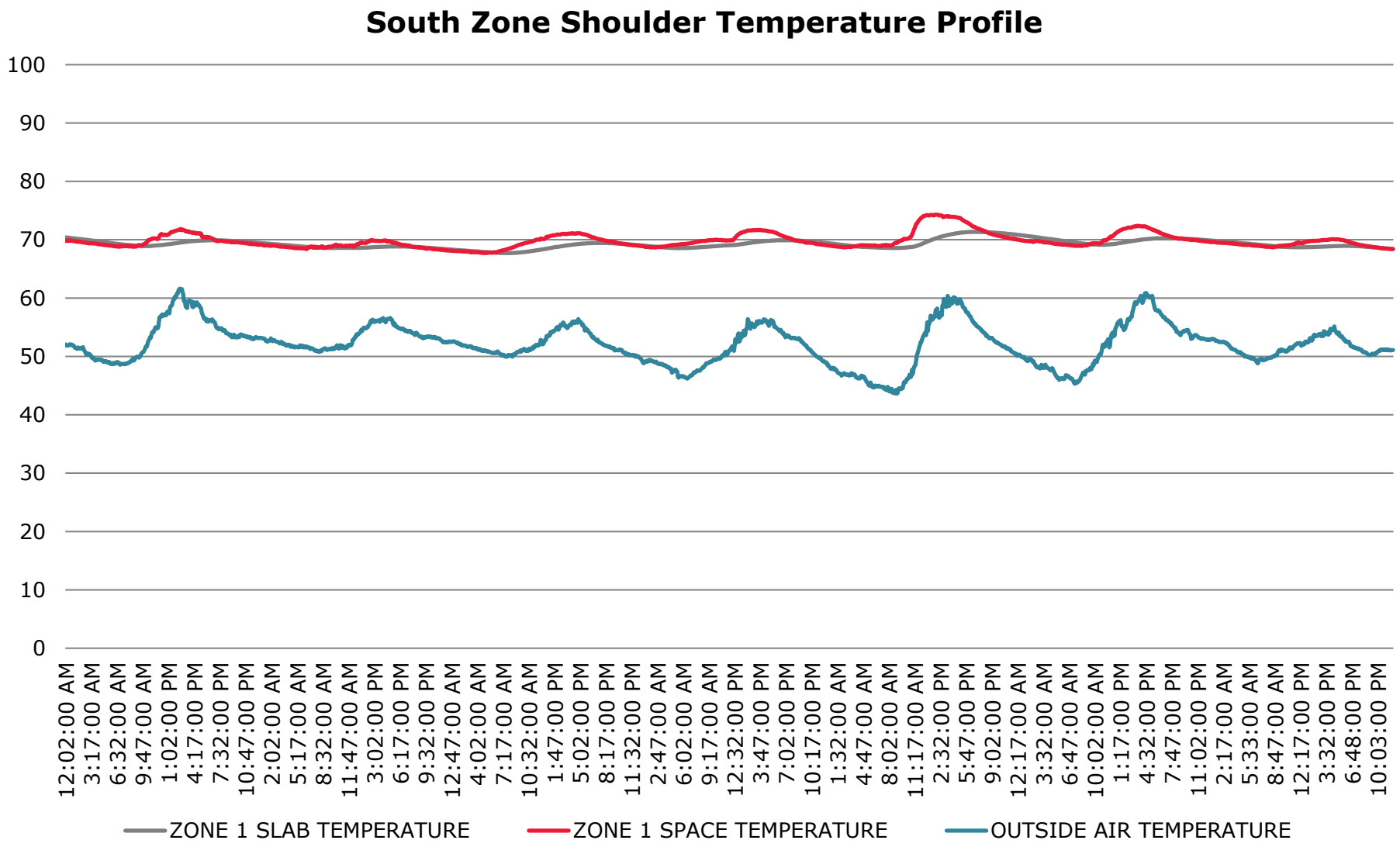
Performance- Thermal Comfort



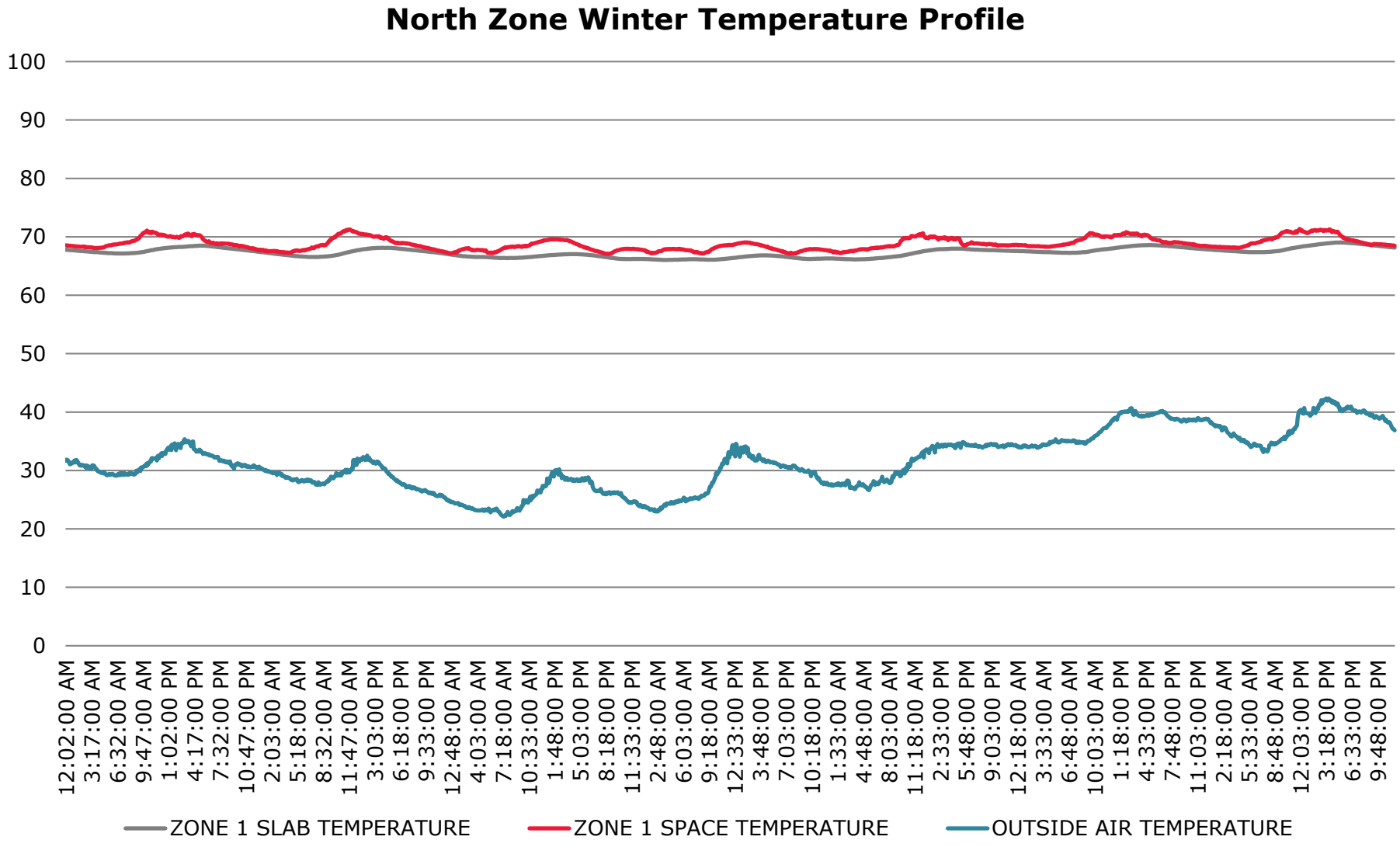
Performance- Thermal Comfort



Performance- Thermal Comfort



Performance- Thermal Comfort



Performance- Thermal Comfort