BUILDINGENERGY BOSTON

Monitored VRF Performance in New Multifamily Buildings

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Northeast Sustainable Energy Association (NESEA) | March 20, 2024

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Building America

U.S. DEPARTMENT OF ENERGY

Scope

- Data Collection: May 2023 – March 2024
  - Temperature + humidity
  - VRF output
  - ERV
- Data Analysis – cooling season
  - Equipment sizing
  - VRF cycling
  - Temperature + humidity control

Research Questions

- How does the sizing of equipment affect humidity control in apartments?
- During peak cooling conditions, how does equipment sizing affect VRF cycling?
- How often did indoor dew point temperatures exceed 60°F? **&** How often did relative humidity within apartments exceed 60%?
- How much electric energy was consumed by the VRF systems during cooling season?

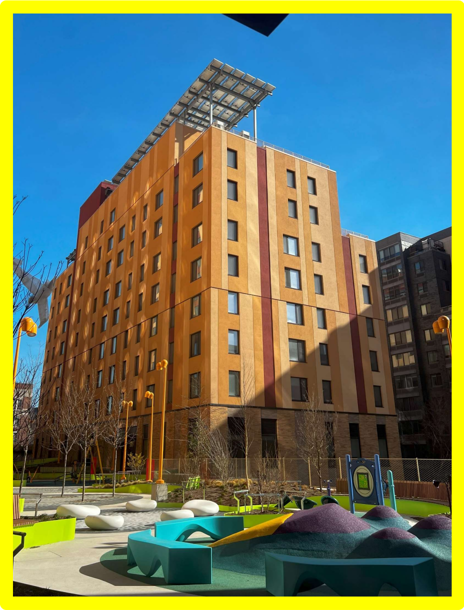
Buildings Monitored in NYC

Building A

Passive House,
Affordable

Building B

Passive House,
Affordable

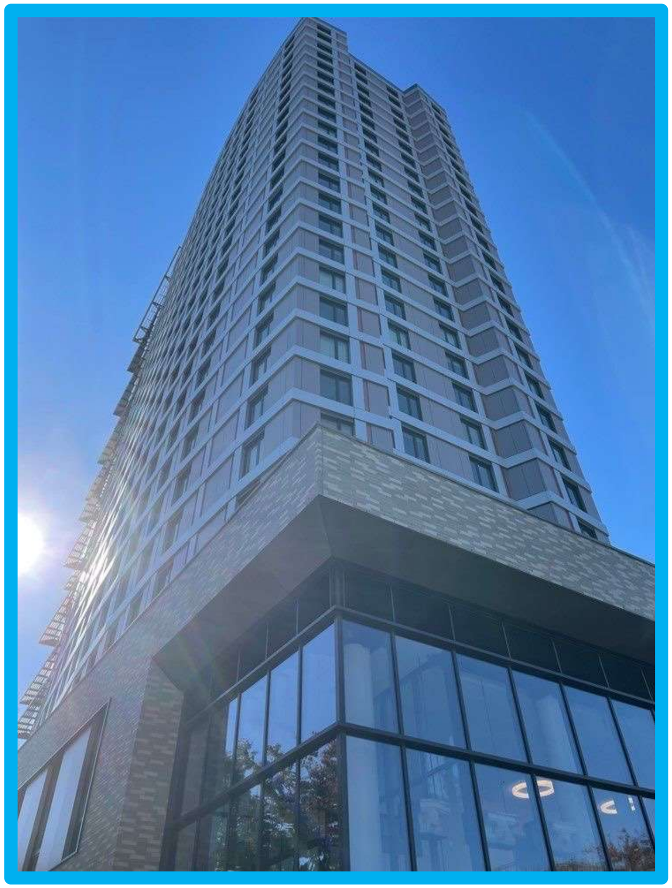


Building C

LEED NC,
Market Rate

Building A Description

Building	A
Location	The Bronx
Type	Affordable
Certification	PHIUS+ 2018
# of units	280
# of units monitored	68
# of Stories	26
VRF	Mitsubishi Heat Recovery Ducted + Ductless IDU
Ventilation	4 ERVs each serving 70 apartments



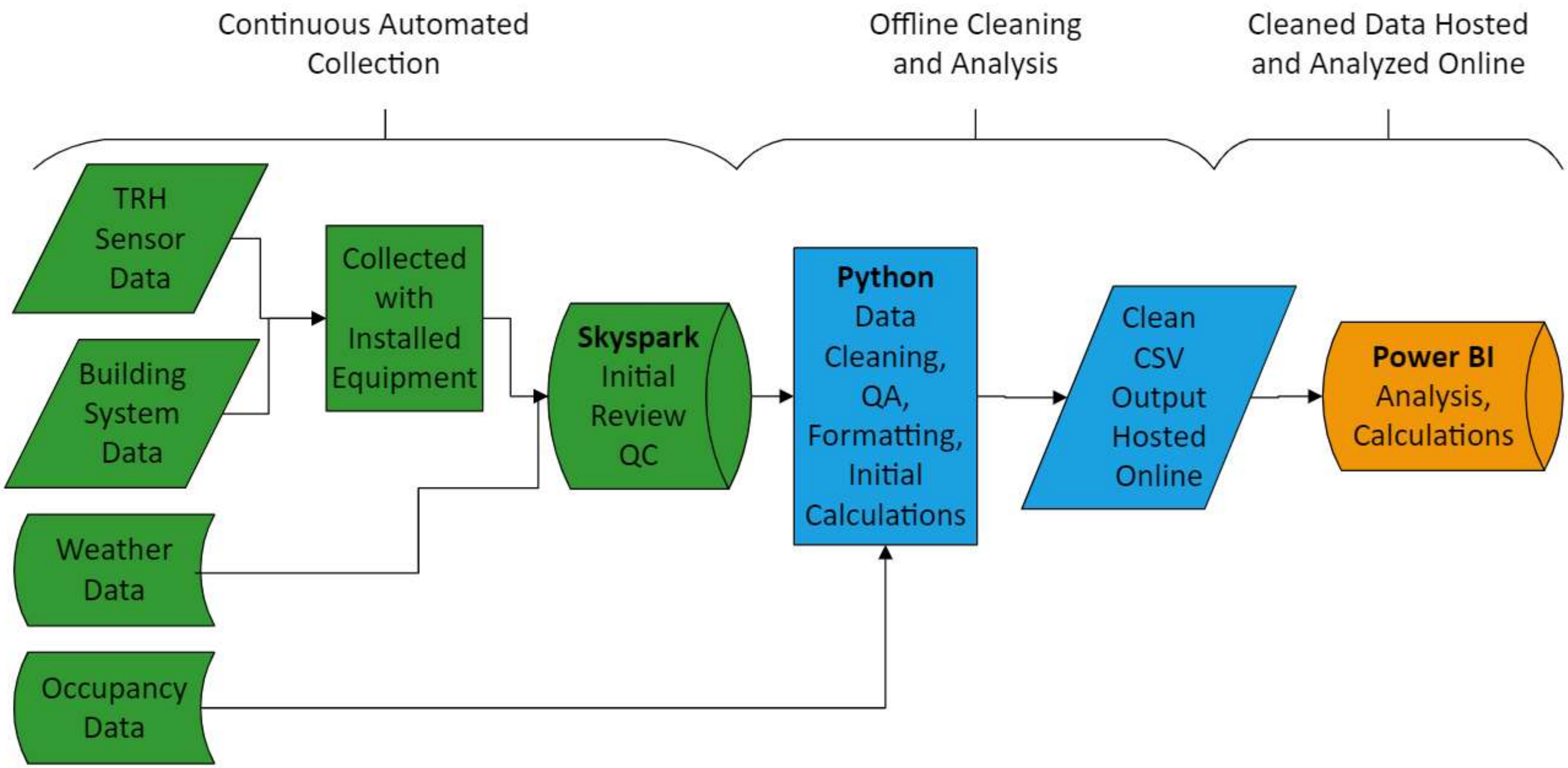
Building B Description

Building	B
Location	East Harlem
Type	Affordable
Certification	PHI
# of units	85
# of units monitored	27
# of Stories	10
VRF	Daikin Ducted + Ductless IDU
Ventilation	2 ERVs serving all apartments

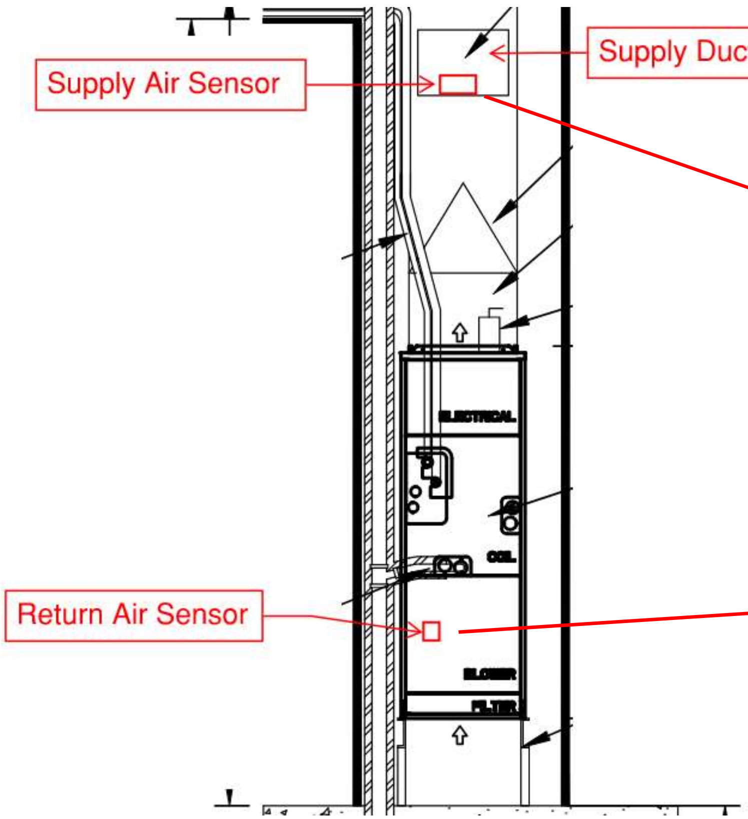
Building C Description

Building	C
Location	The Bronx
Type	Market Rate
Certification	LEED NC
# of units	458
# of units monitored	57 total, 24 humidity only
# of Stories	26
VRF	Mitsubishi Heat Recovery Ducted IDU
Ventilation	Exhaust only in apartments

Methodology

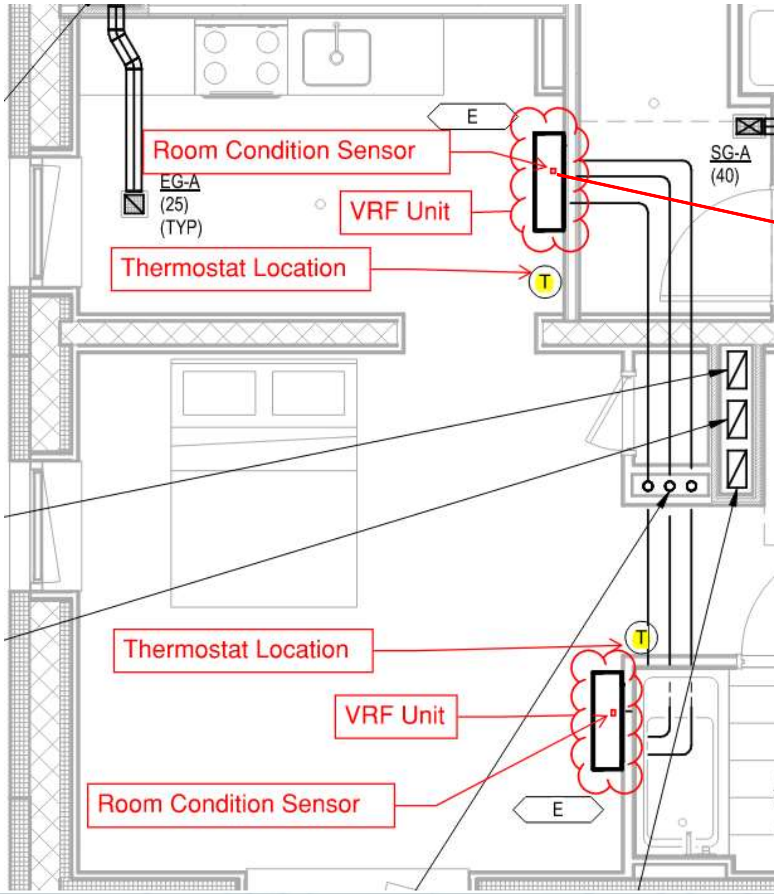


Data Collection – Ducted systems



Monnit temperature and humidity sensors

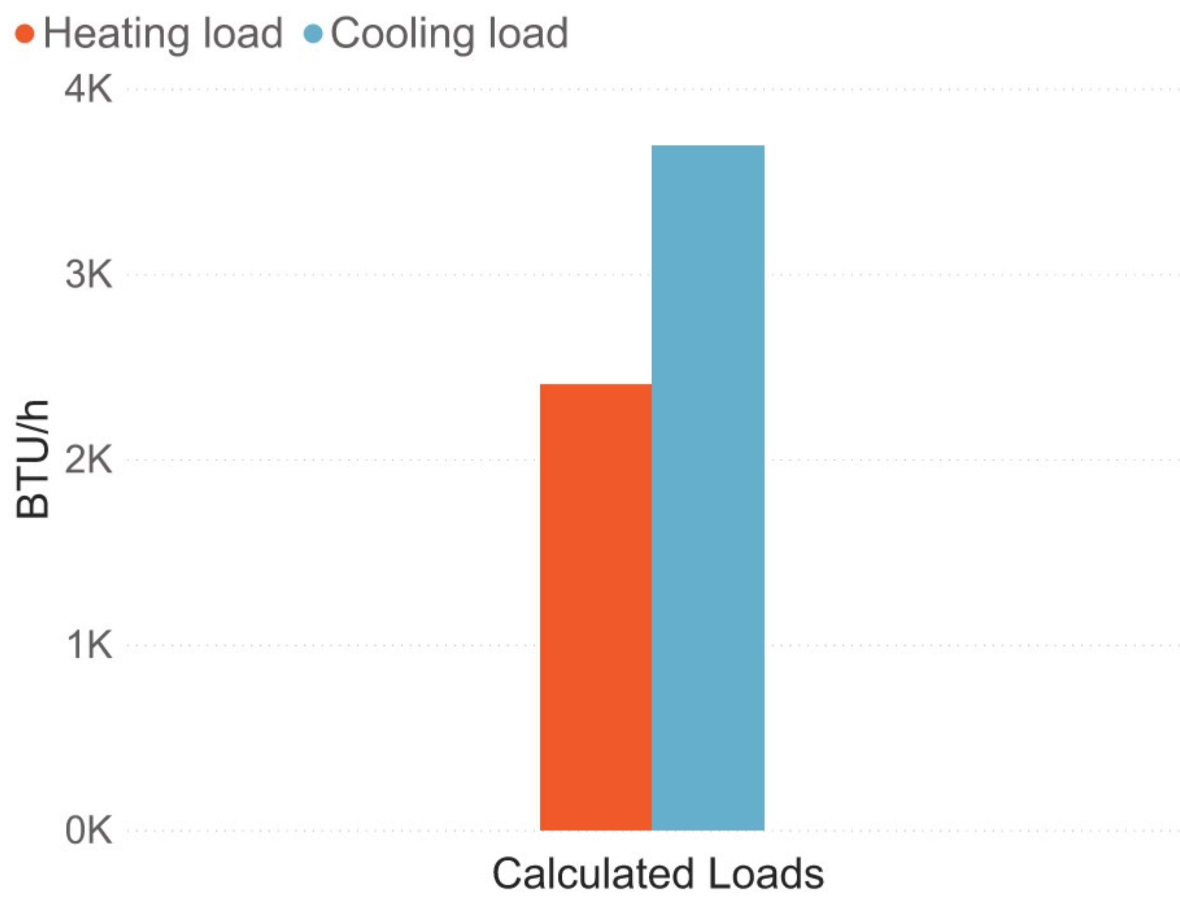
Data Collection – Ductless systems



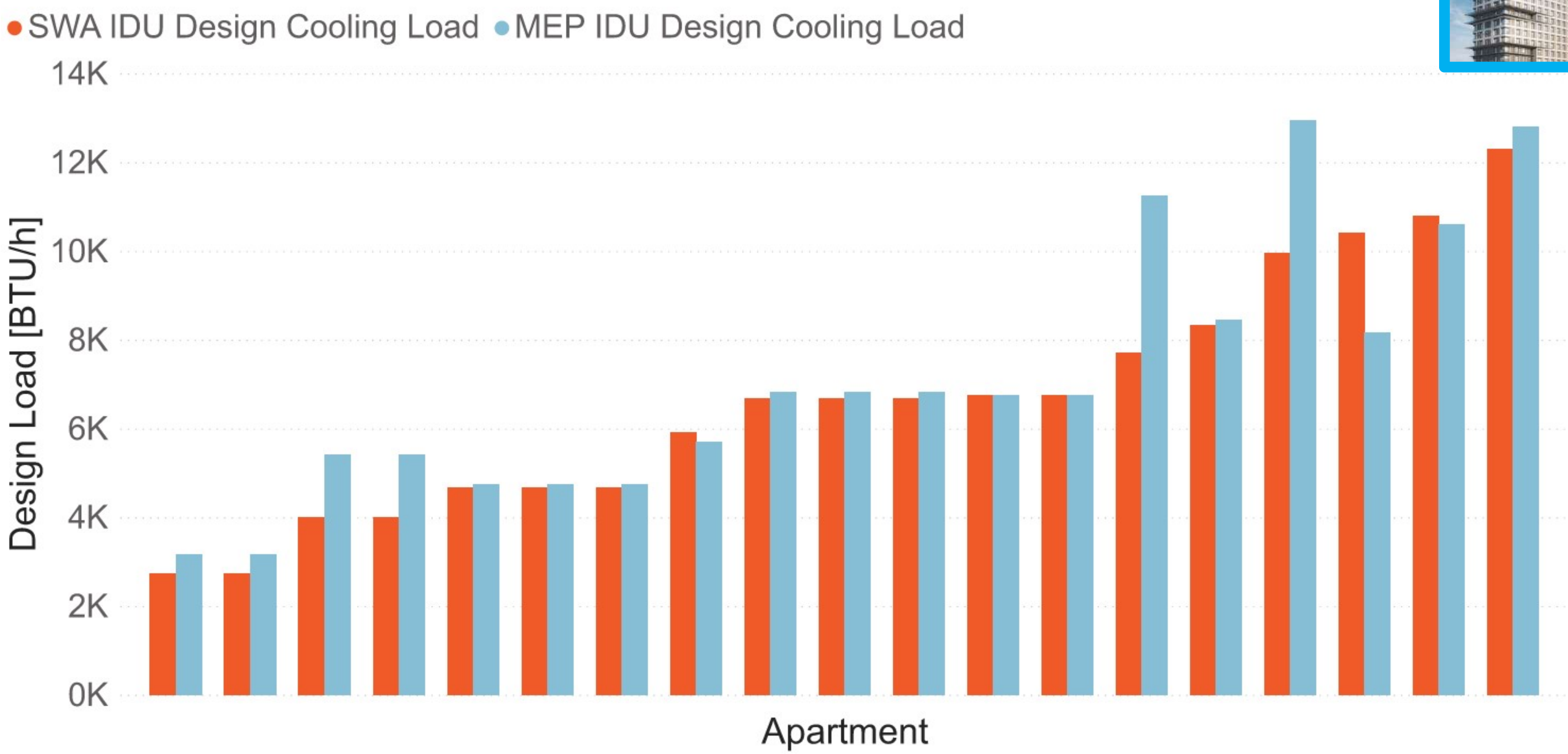
ERV Building B

Load and Sizing Analysis

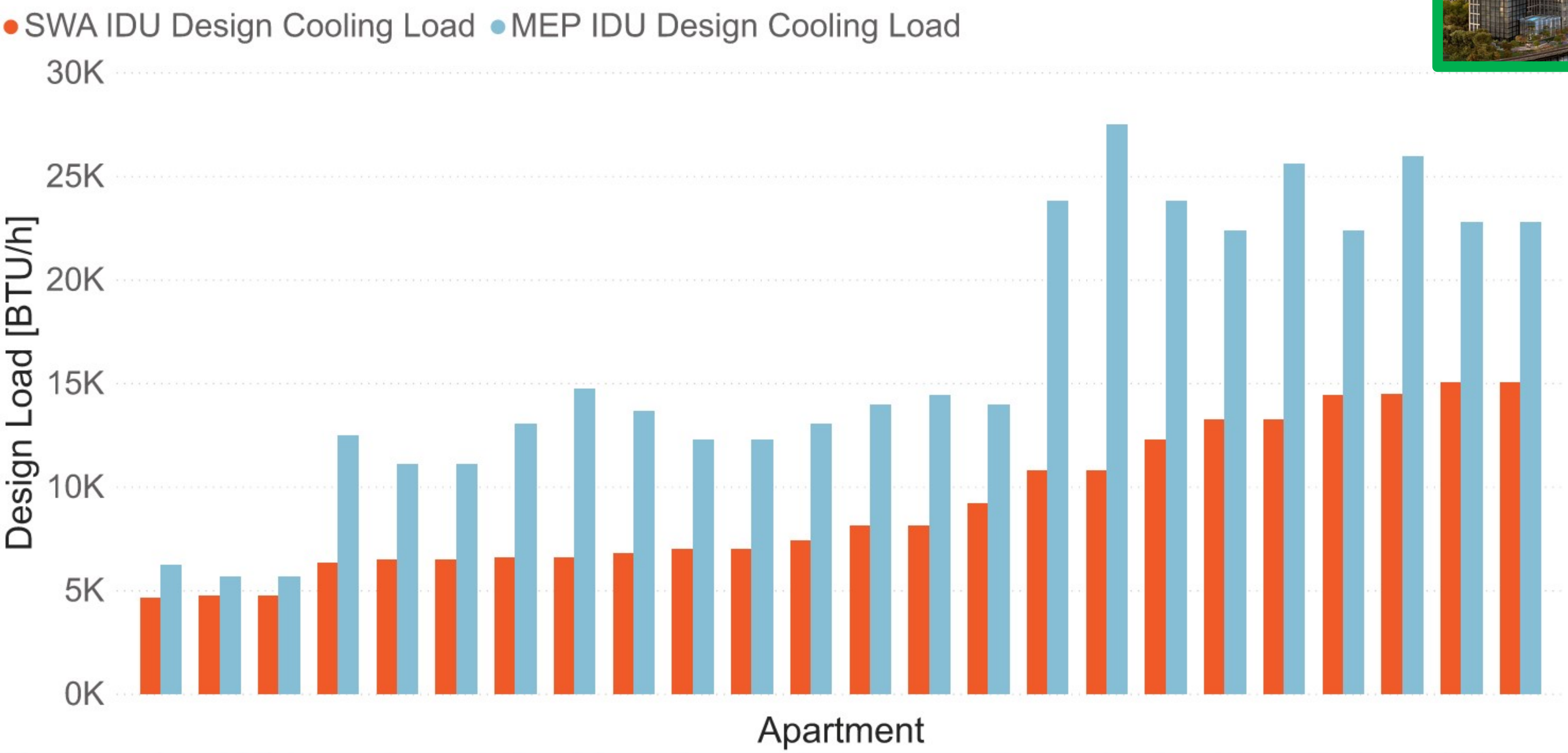
Cooling Load Drives Sizing



Building A: Cooling Load Analysis



Building C: Cooling Load Analysis



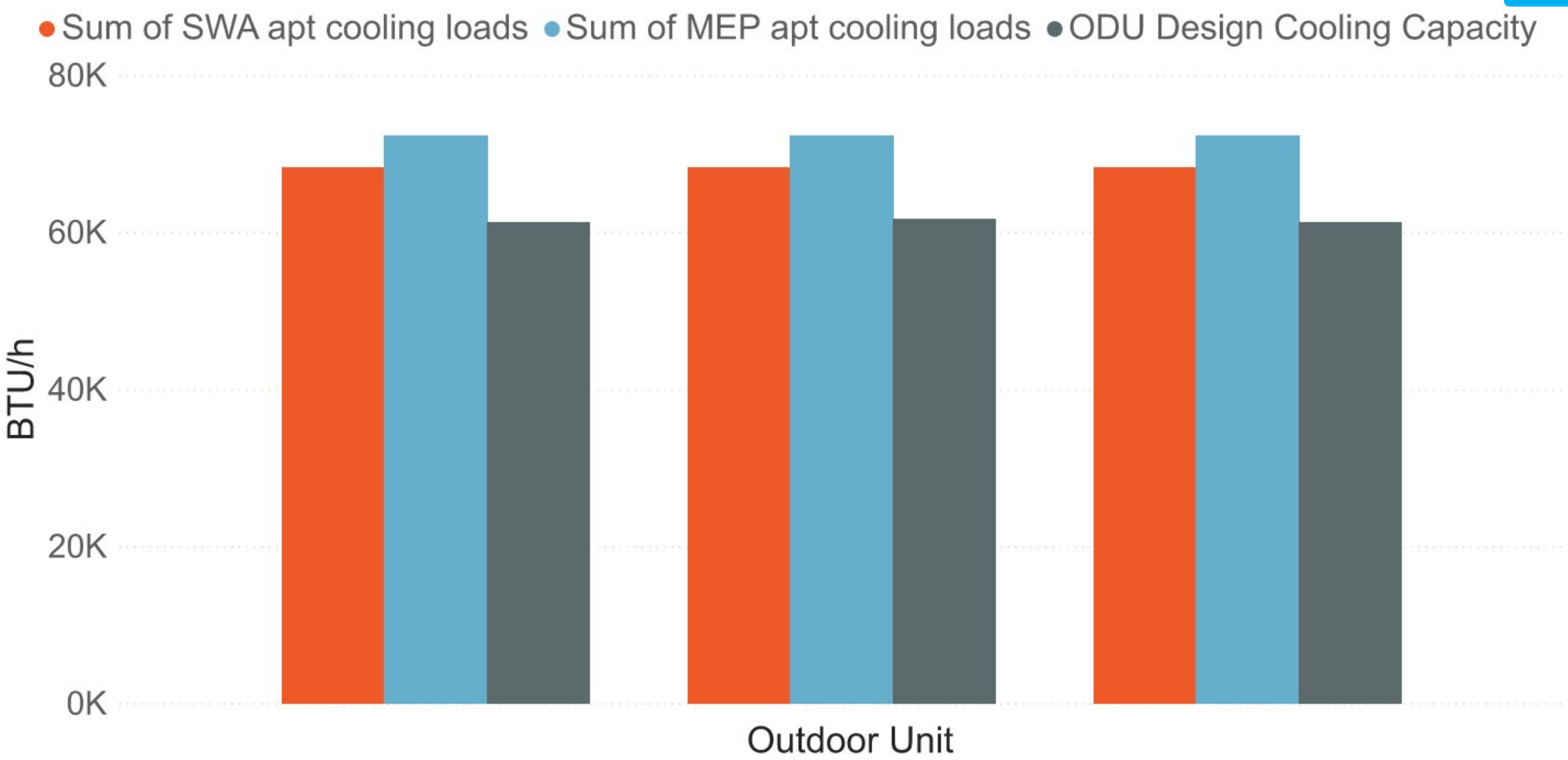
Internal Gains of Typical 1-Bedroom Apt

Building	Design Internal Gains [Btu/h]		
	Designer	SWA	Difference
B	3,480	1,340	+2,140
C	3,410	1,230	+2,180

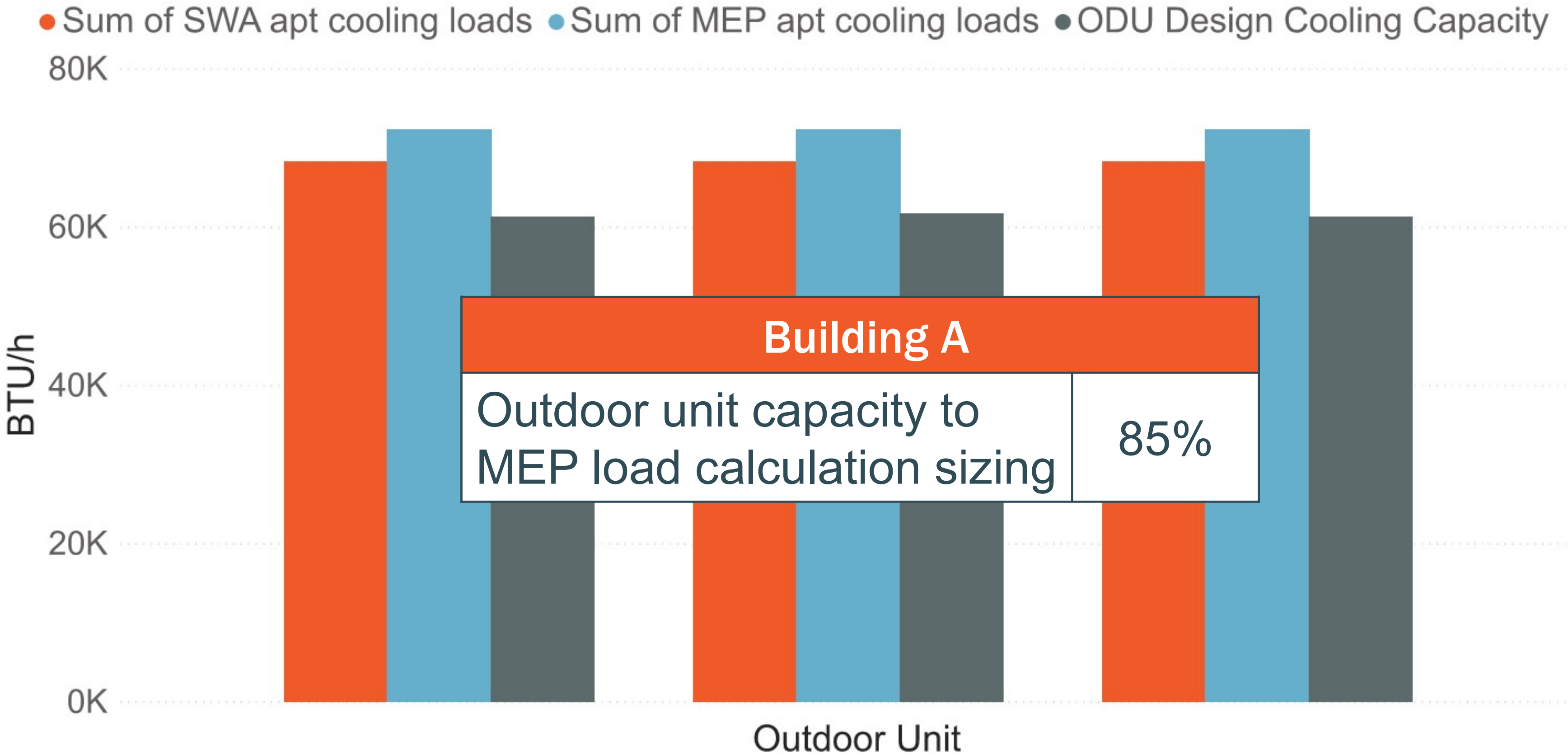
Load Calculation Analysis

Building	MEP Design Loads / SWA Design Loads
	Cooling
A	1.06
B	2.10
C	1.78

Building A: Outdoor Unit Sizing

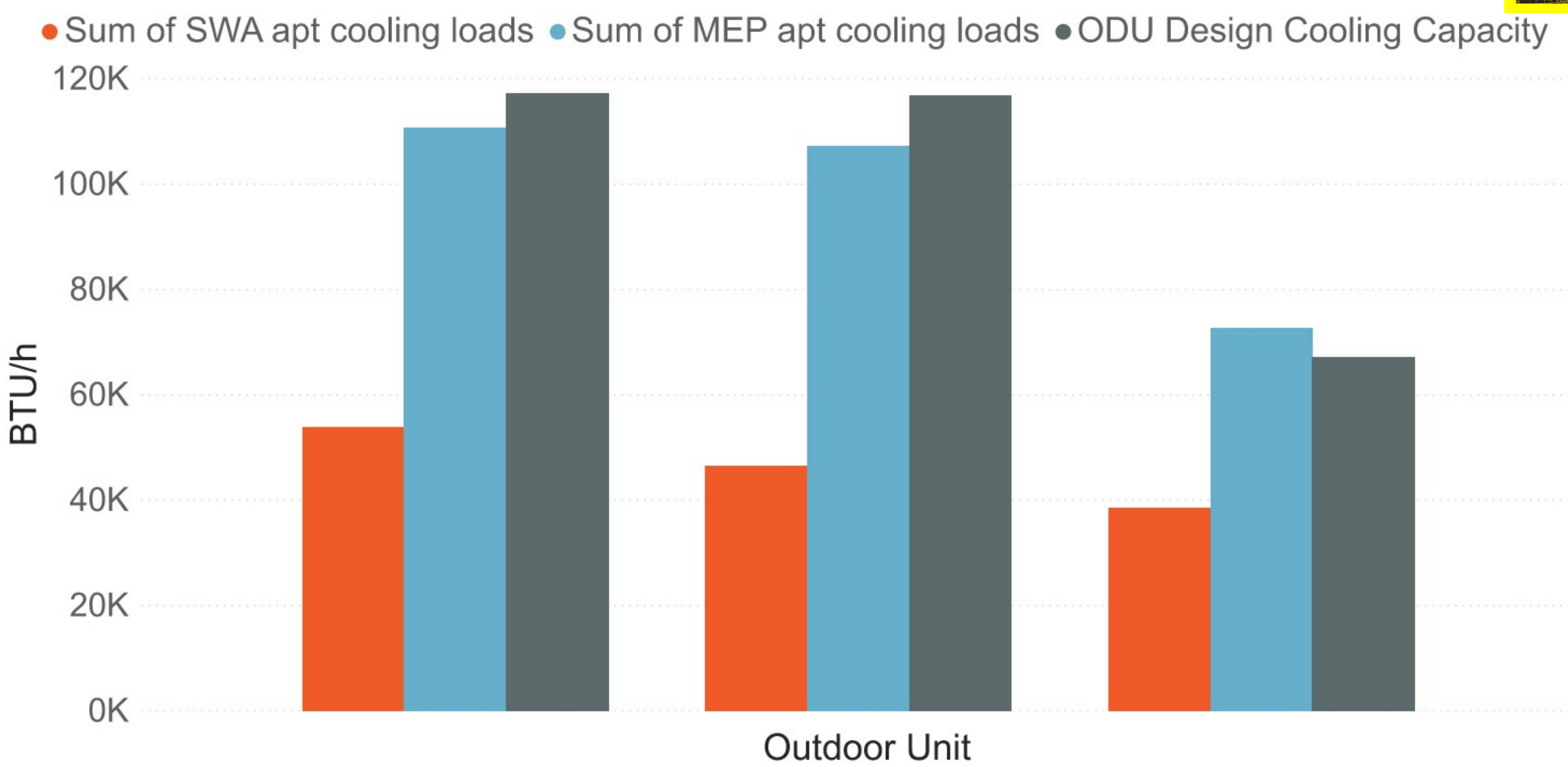


Building A: Outdoor Unit Sizing

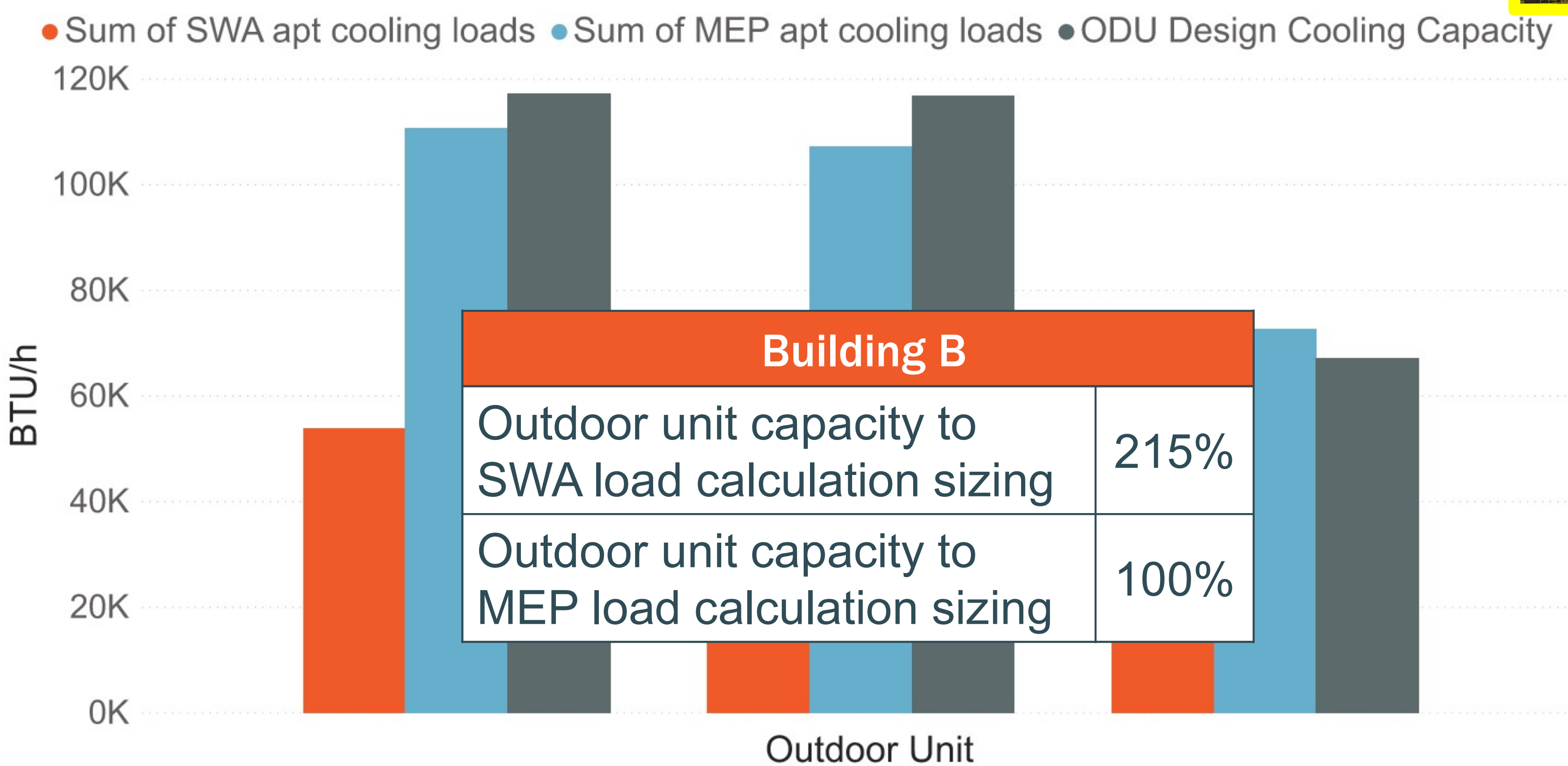


Building A	
Outdoor unit capacity to MEP load calculation sizing	85%

Building B: Outdoor Unit Sizing

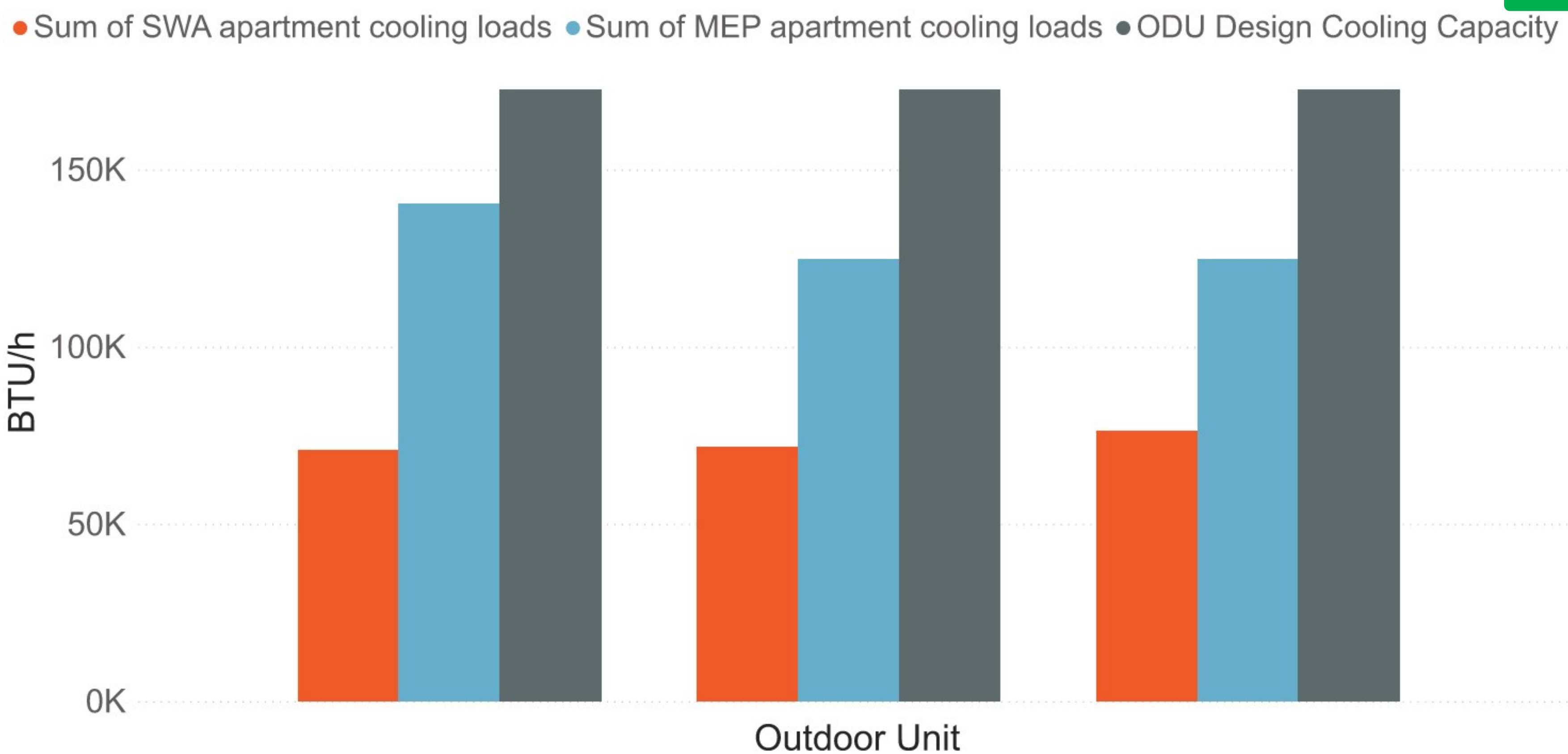


Building B: Outdoor Unit Sizing

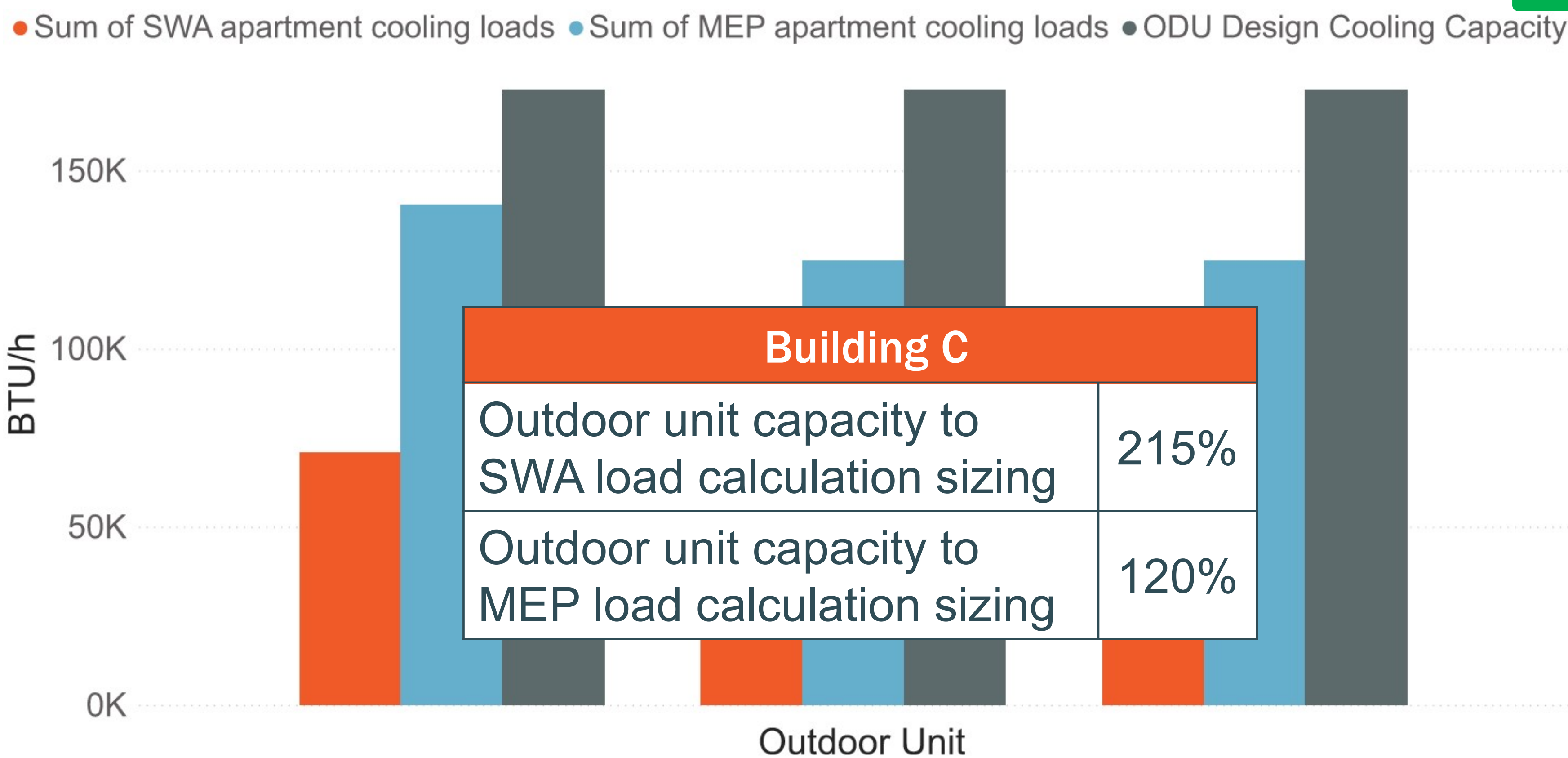


Building B	
Outdoor unit capacity to SWA load calculation sizing	215%
Outdoor unit capacity to MEP load calculation sizing	100%

Building C: Outdoor Unit Sizing

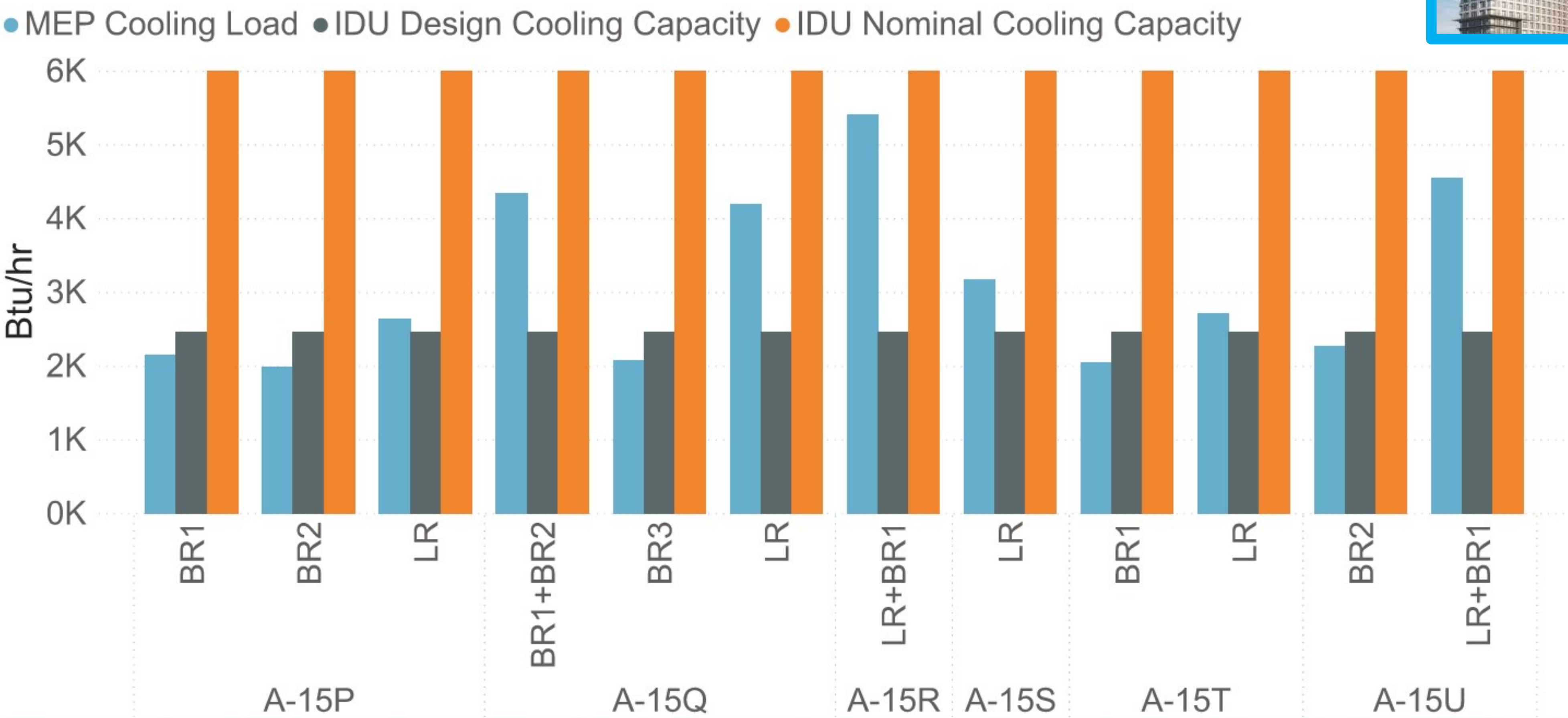


Building C: Outdoor Unit Sizing

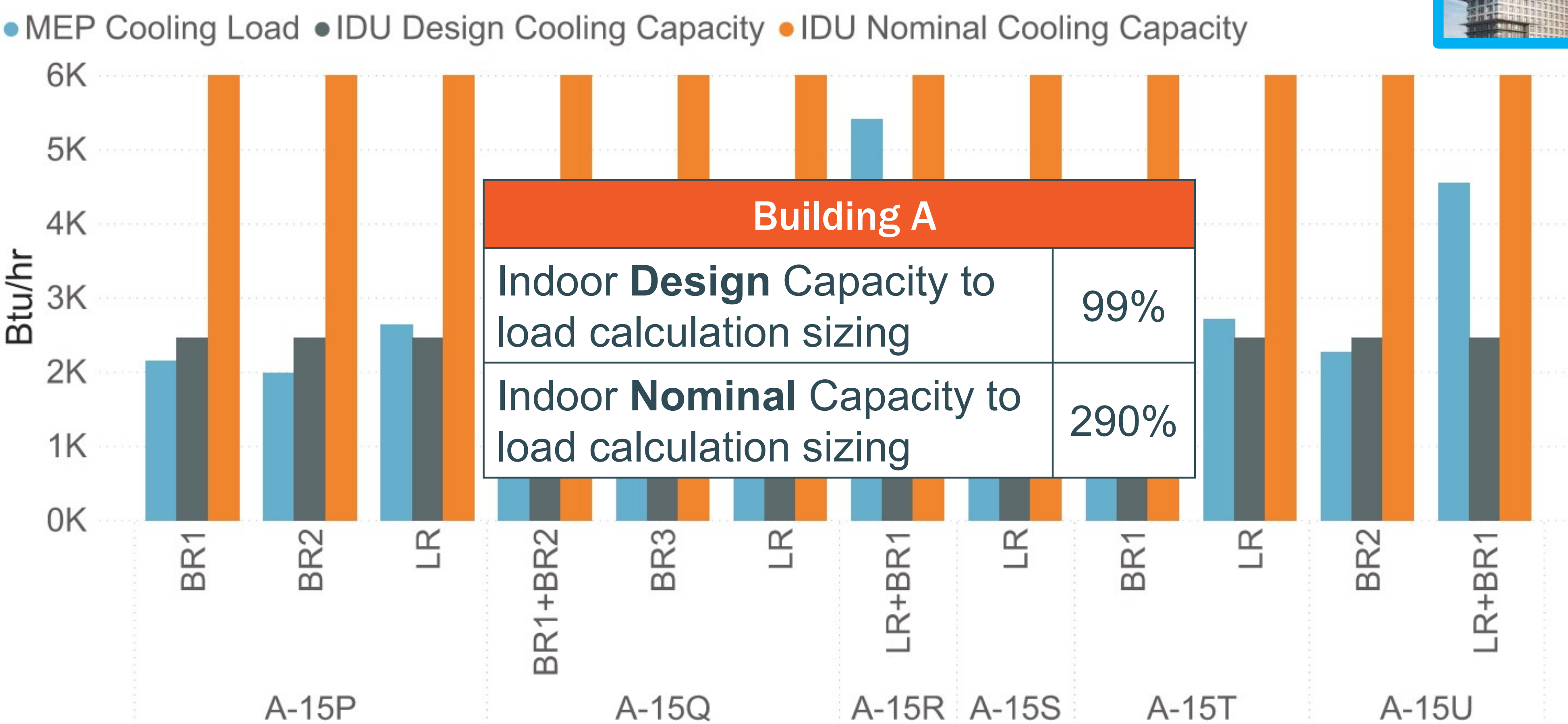


Building C	
Outdoor unit capacity to SWA load calculation sizing	215%
Outdoor unit capacity to MEP load calculation sizing	120%

Building A: Indoor Unit Sizing



Building A: Indoor Unit Sizing

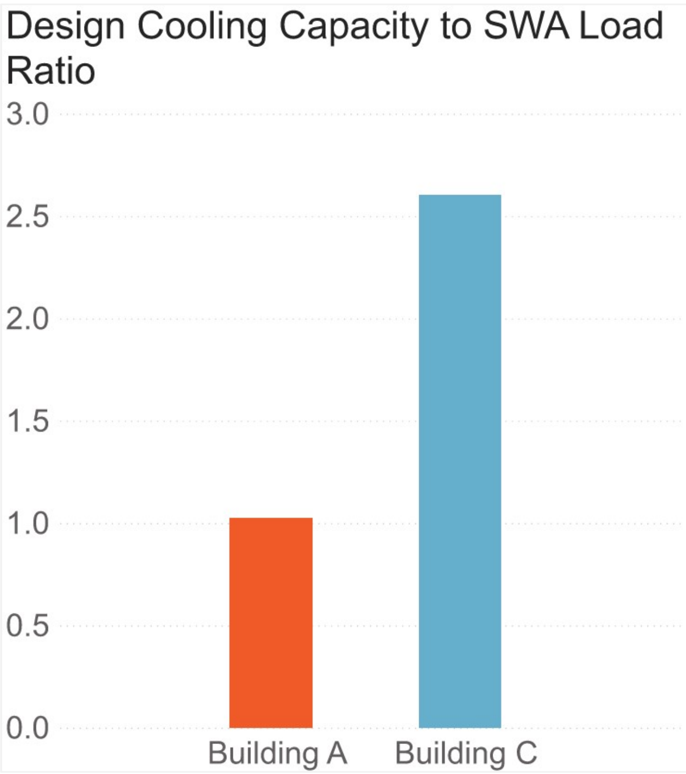


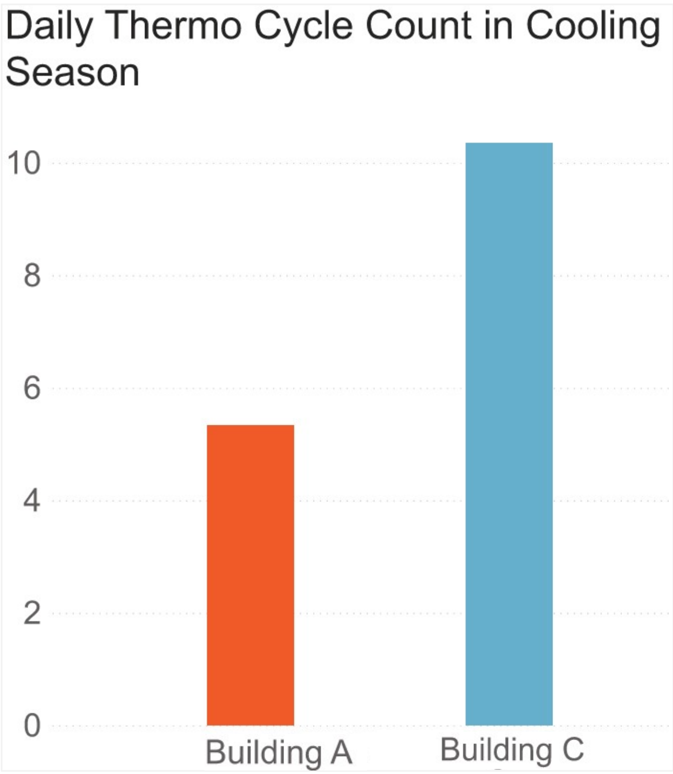
Building A	
Indoor **Design** Capacity to load calculation sizing	99%
Indoor **Nominal** Capacity to load calculation sizing	290%

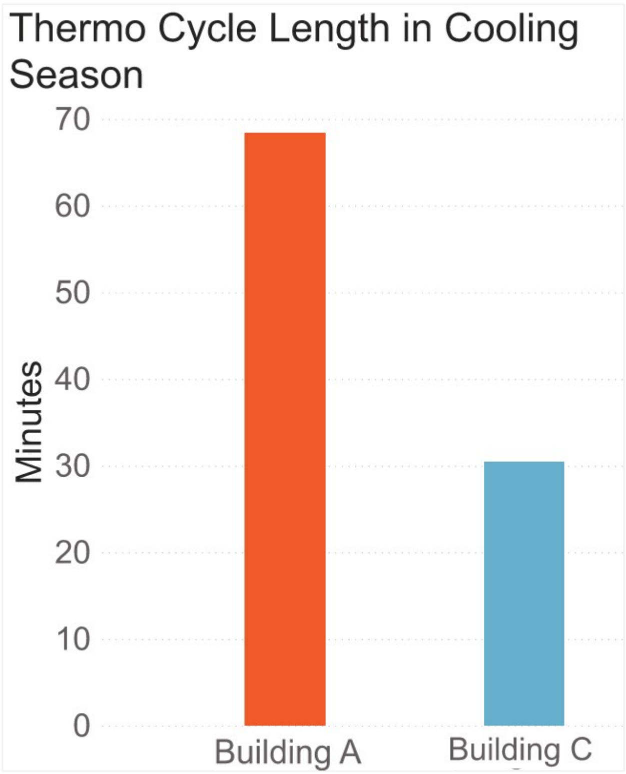
Does Sizing Affect Cycling + Humidity?

Sizing Affecting Cycling

Larger Capacity = More Cycling + Shorter Cycle Lengths

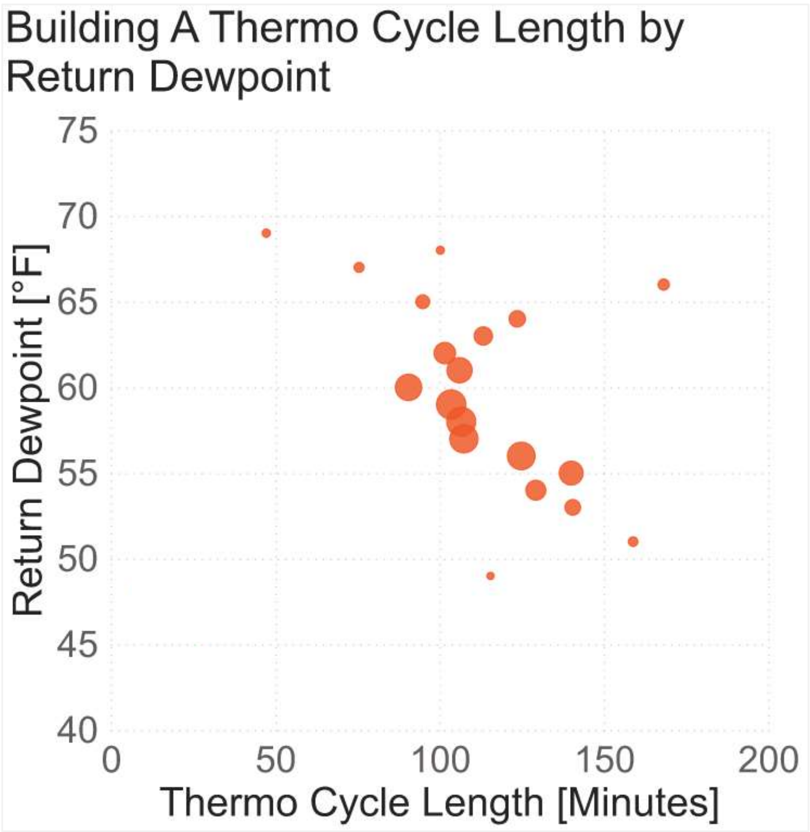


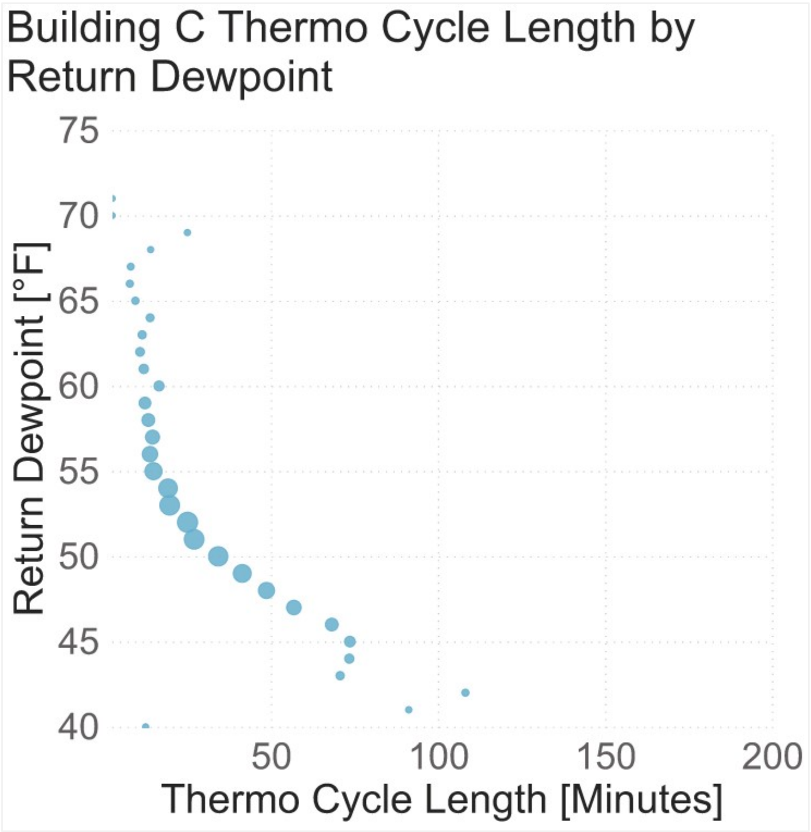




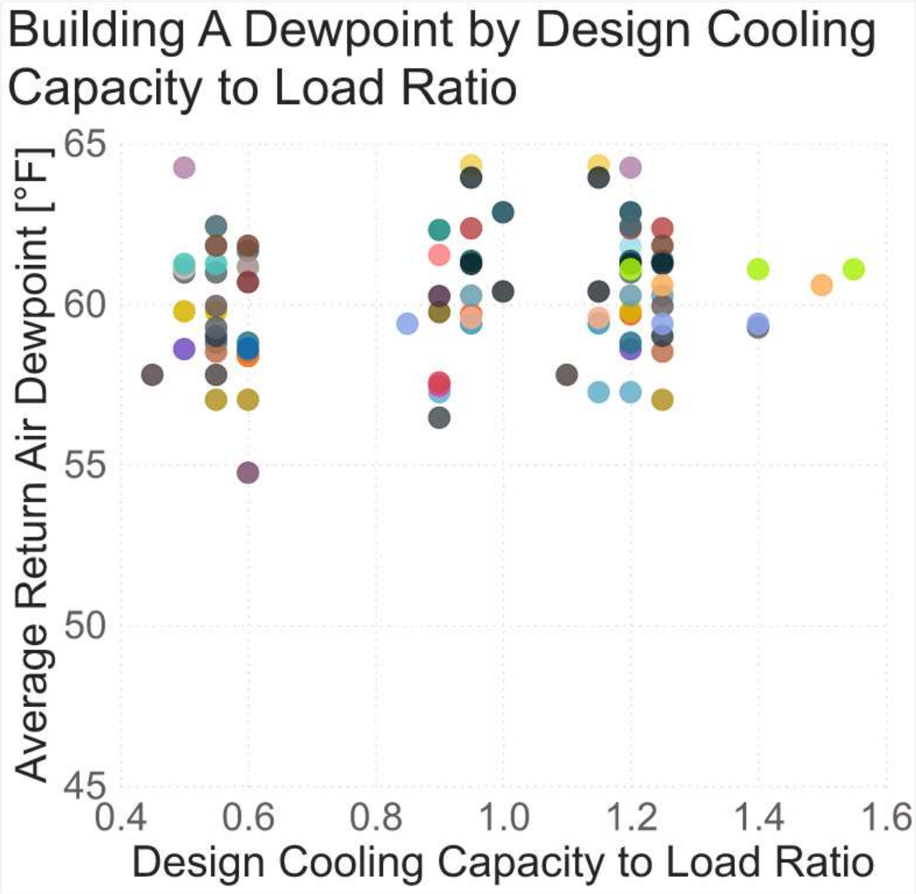
Cycle Length to Dewpoint Correlation

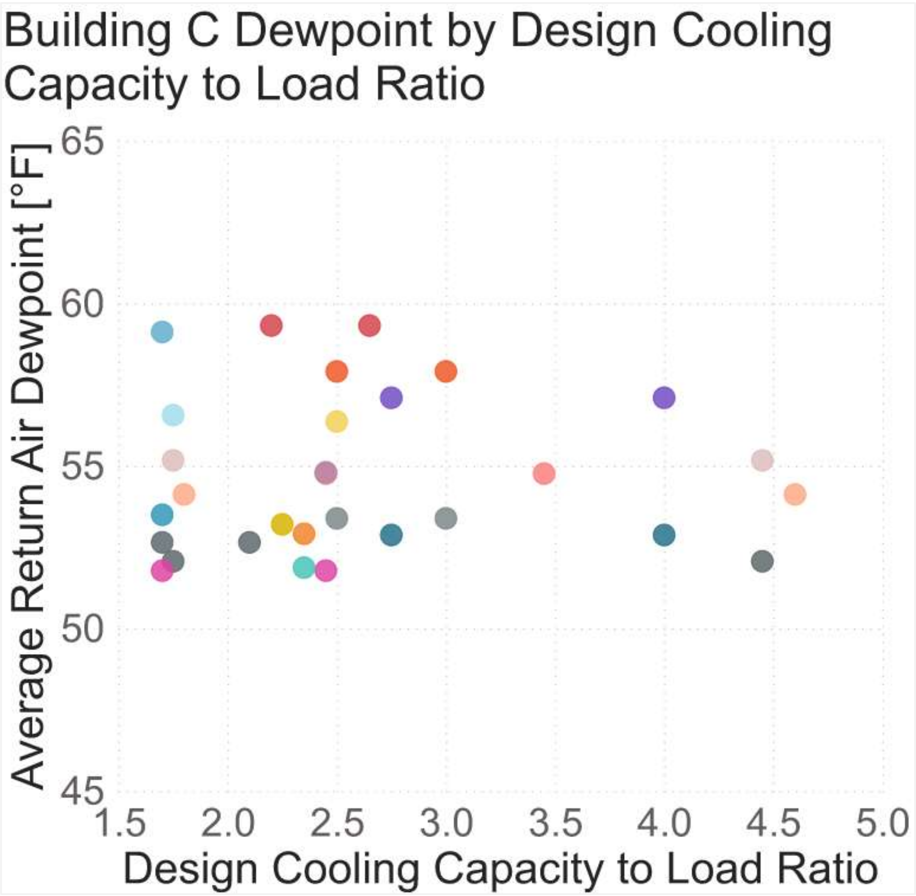
Longer Cycle Lengths = Lower Dewpoint





No Relationship between Sizing and Dewpoint





Research Questions

How does the sizing of equipment affect humidity control in apartments?

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Not as much as we thought! Though VRF units that have short cycle lengths show some correlation with higher apartment dew points

Humidity Analysis

Why We Look At Dewpoint

Dewpoint is a direct measure of moisture content in air.

Relative humidity truly is relative (to temperature)!

Dewpoint takes away the "relativity". Thus, easier for apples-to-apples comparison of humidity / moisture levels.

Examples		
Temperature	Relative Humidity	Dew Point
68°F	52%	50°F
70°F	60%	55°F
77°F	47%	55°F
77°F	64%	64°F
68°F	86%	64°F

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Comfortable?

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68°F	52%	50°F	😄
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77°F	64%	64°F	☹
68°F	86%	64°F	☹

Importance of Having Thermostat On

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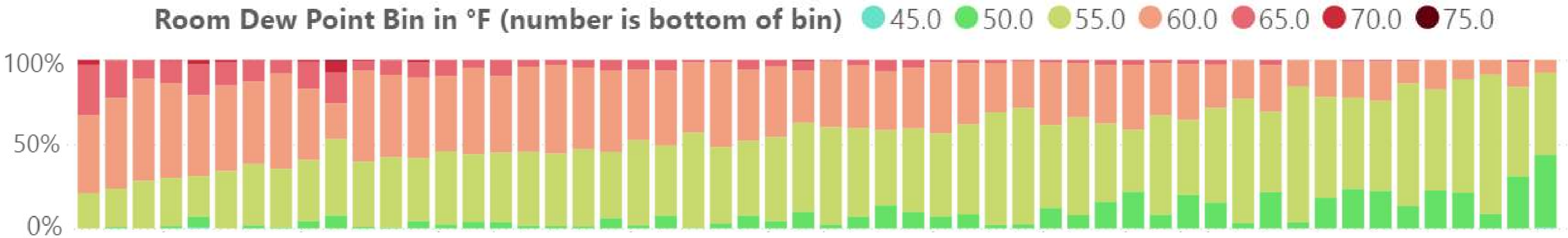
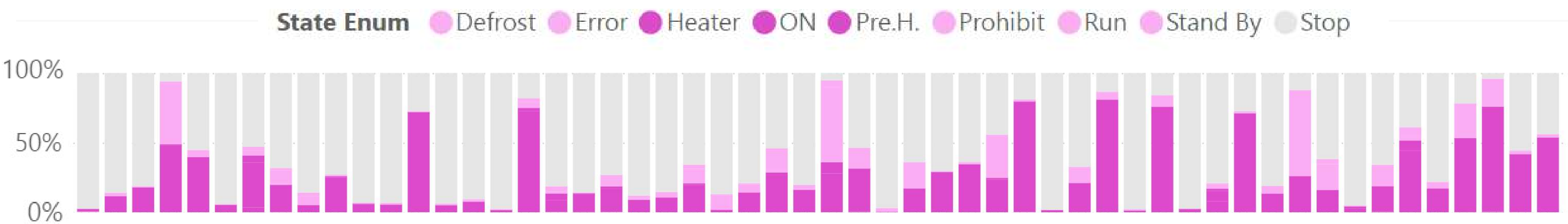
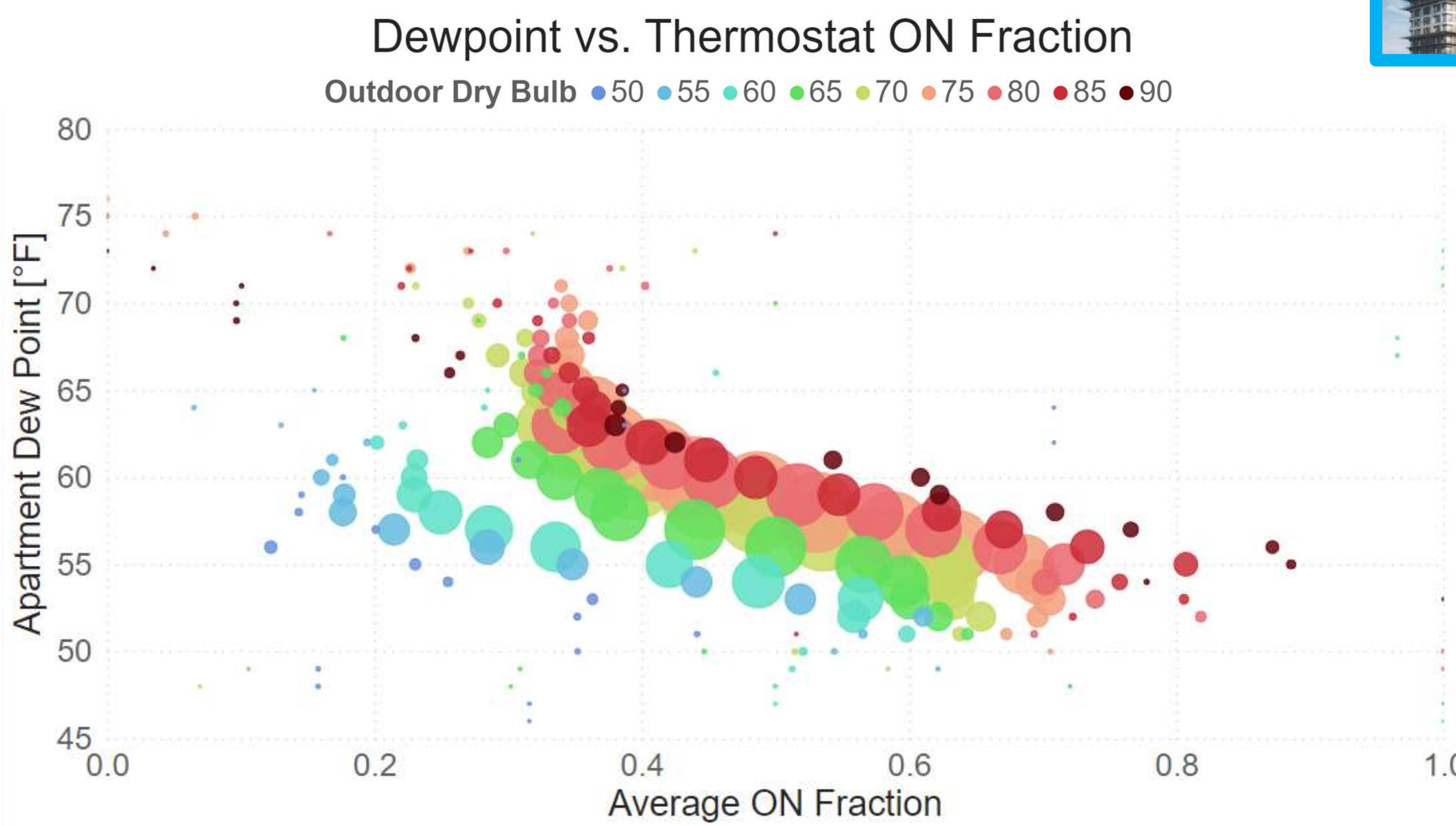
Bldg. A

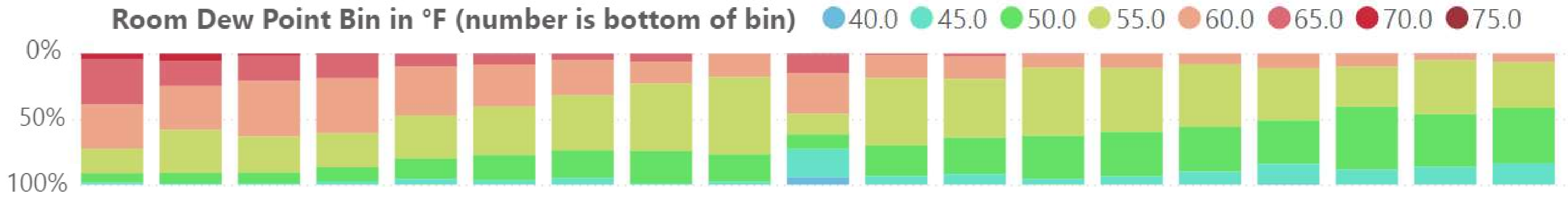


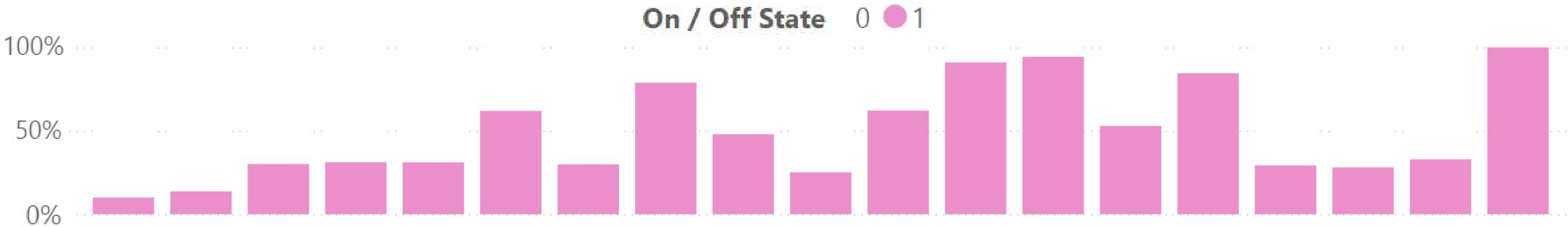


Importance of Having Thermostat On
Bldg. A

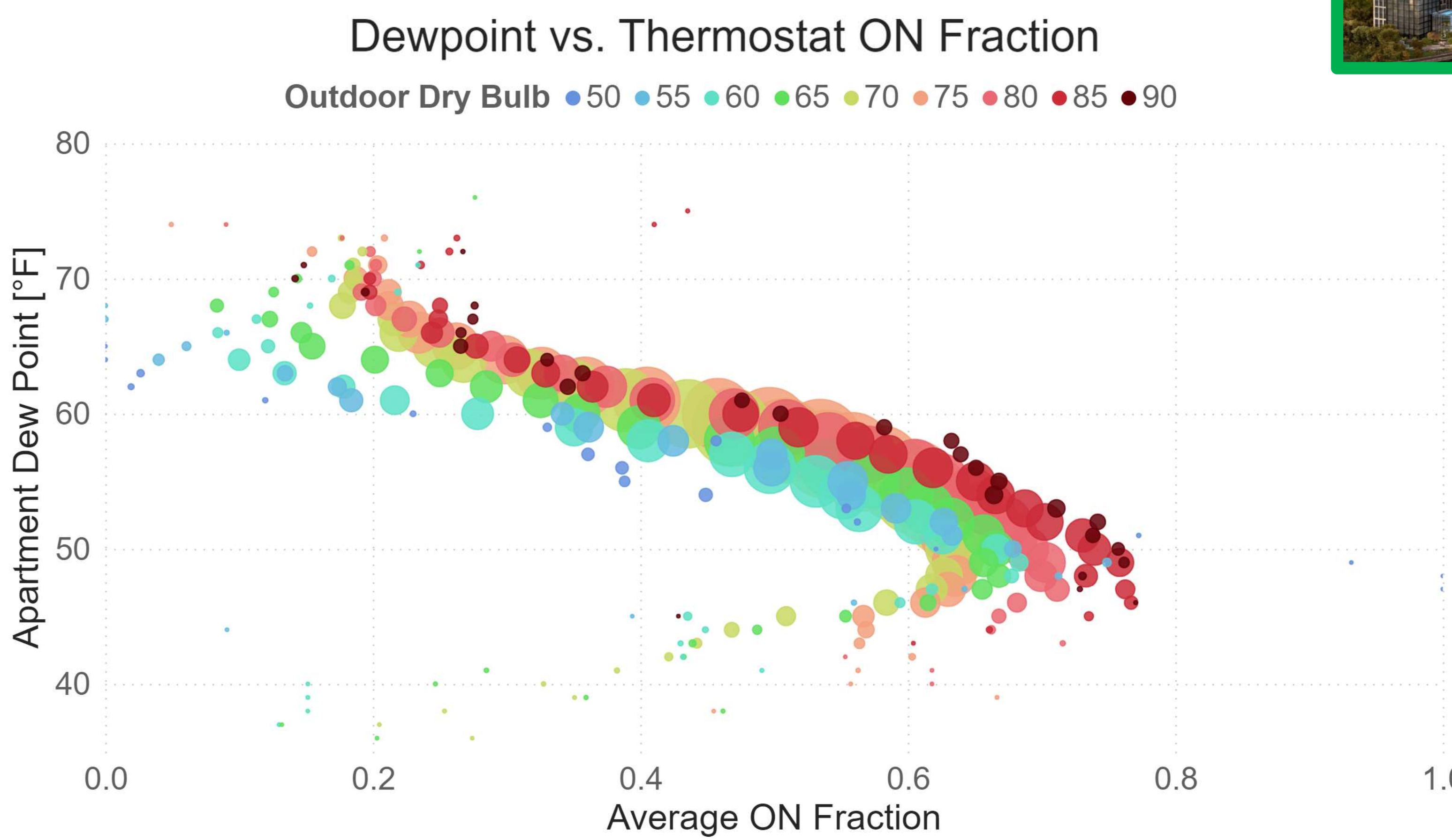


Importance of Having Thermostat On
Bldg. C



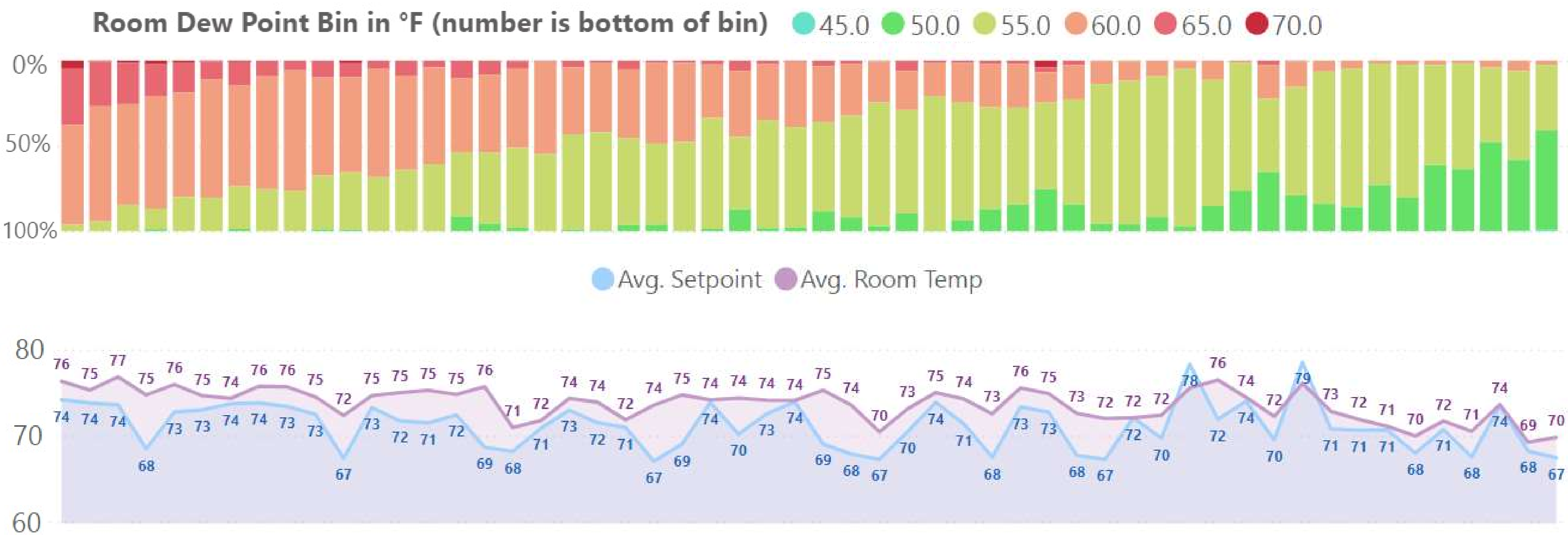


Importance of Having Thermostat On
Bldg. C

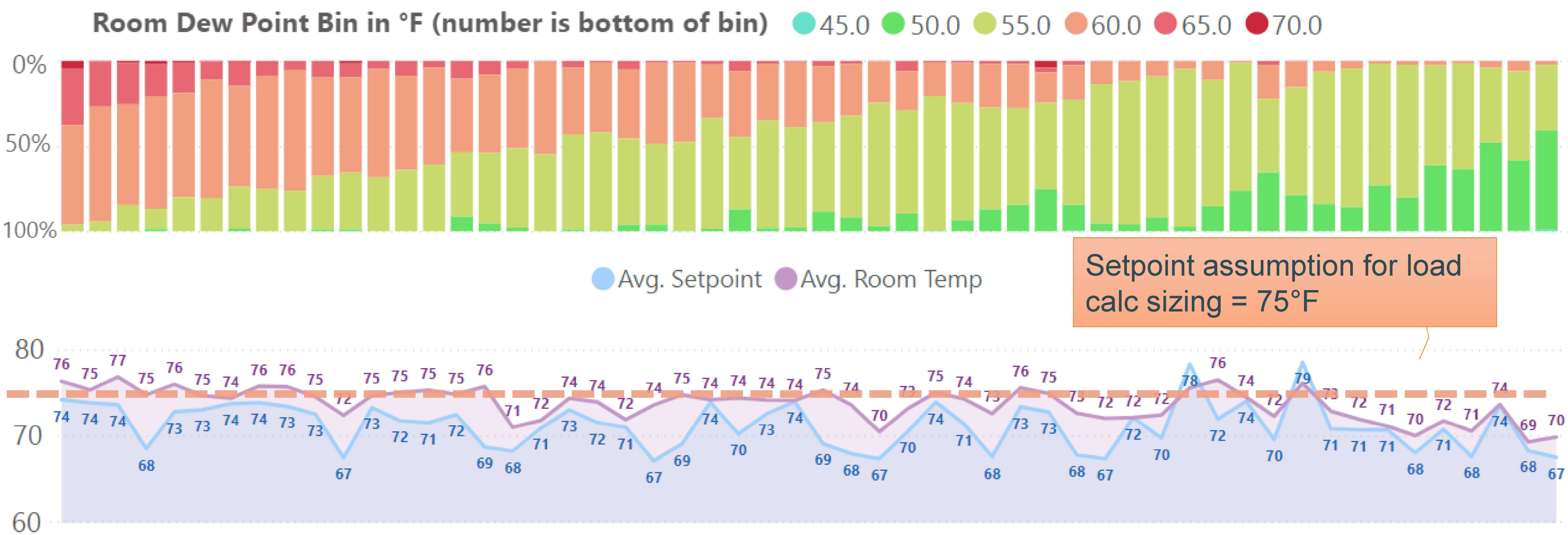


Thermostat Setpoints

Thermostat Setpoints
Bldg. A

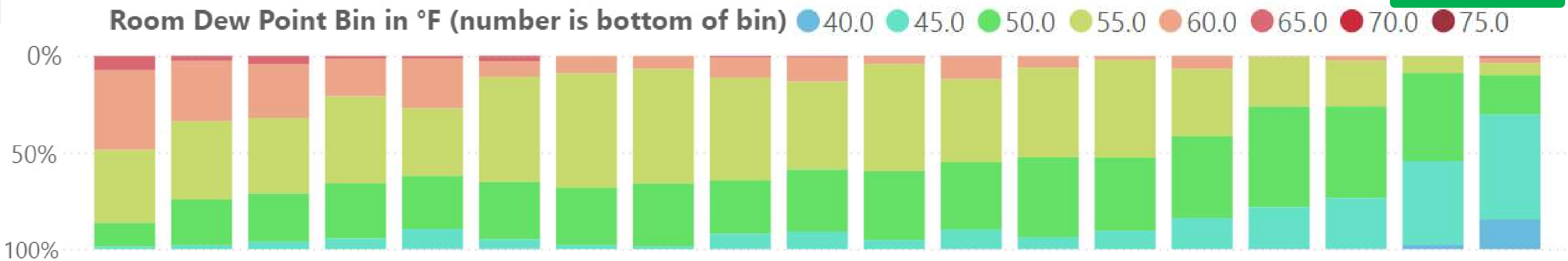


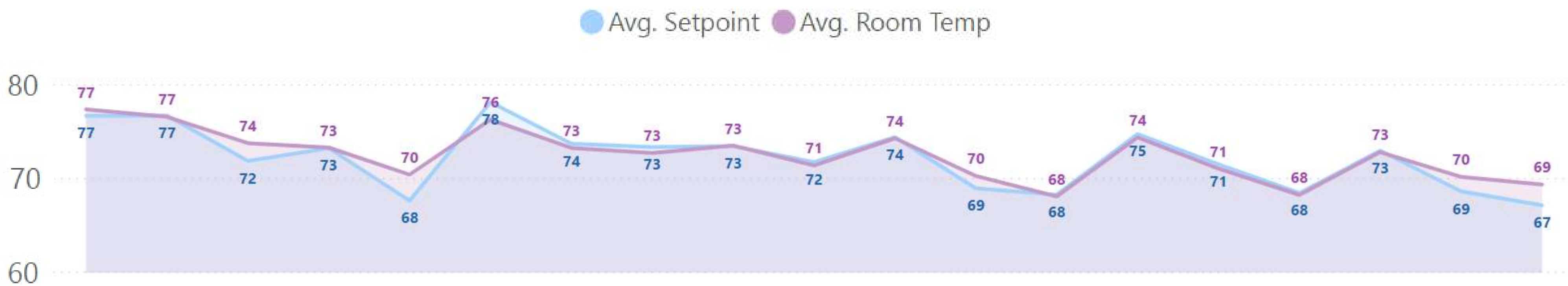
Thermostat Setpoints
Bldg. A



Setpoint assumption for load calc sizing = 75°F

Thermostat Setpoints
Bldg. C





Apt. Type Influence on Apt. Dew Point

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Bldg. Averages for All Monitored Apts.			
	Bldg. A	Bldg. B	Bldg. C
Studios	58.1	57.6	
1 BR Apts.	59.3	60.2	
2 BR Apts.	60.0	58.1	
3 BR Apts.	60.4	n/a	

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How often did relative humidity within apartments exceed 60%?

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A lot.

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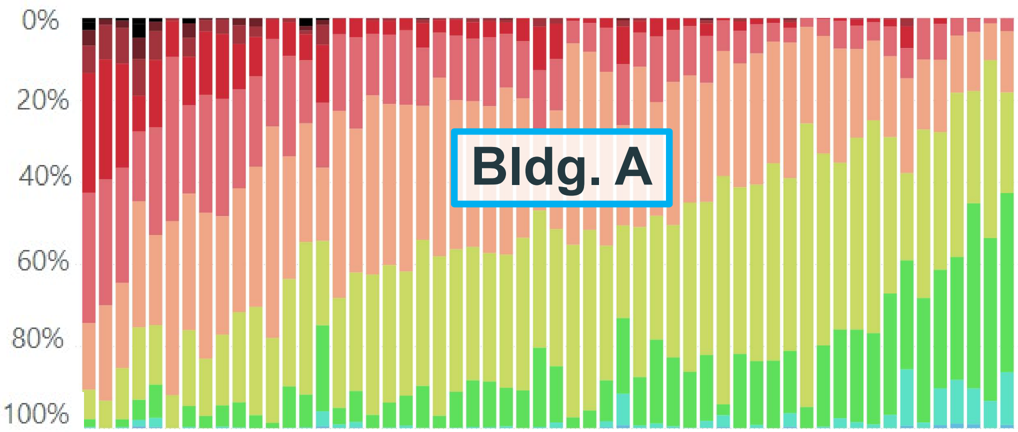

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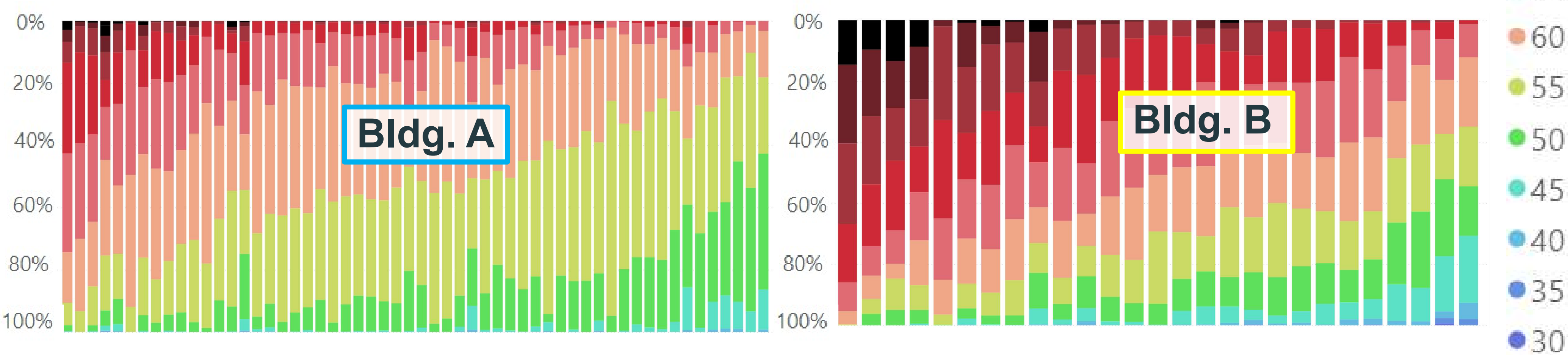

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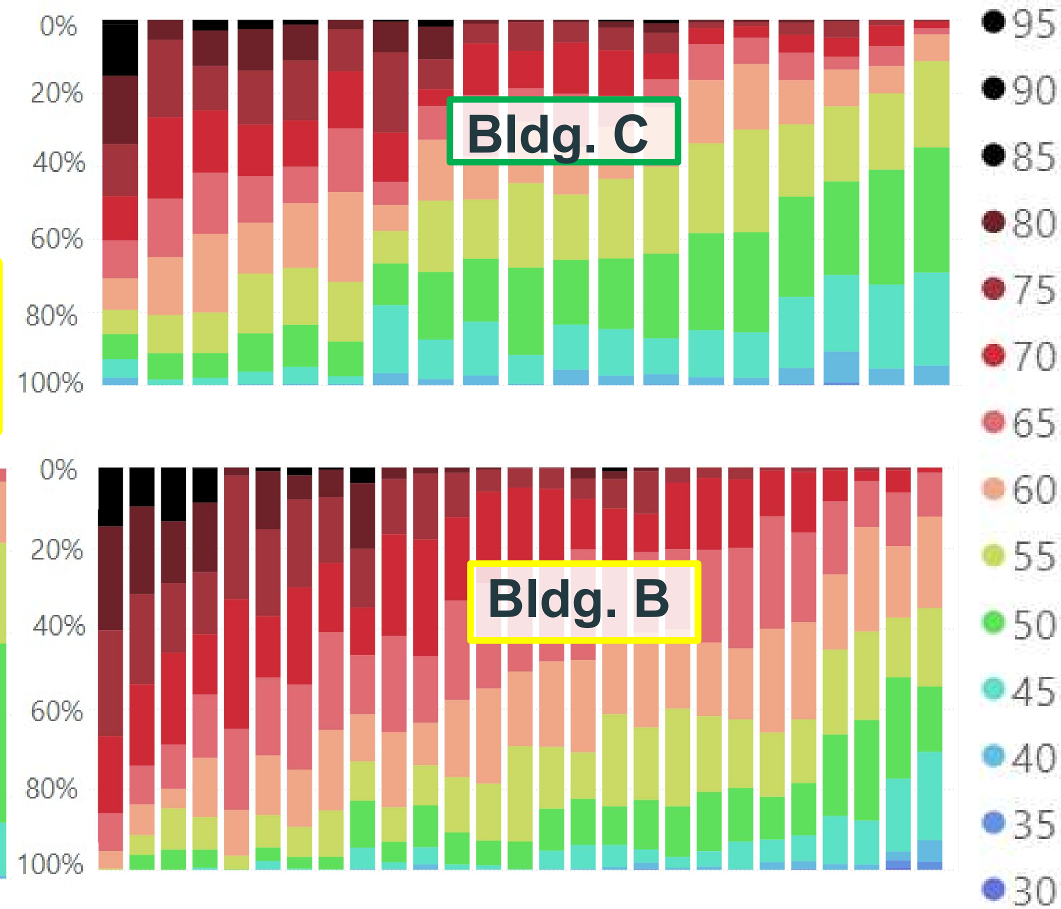

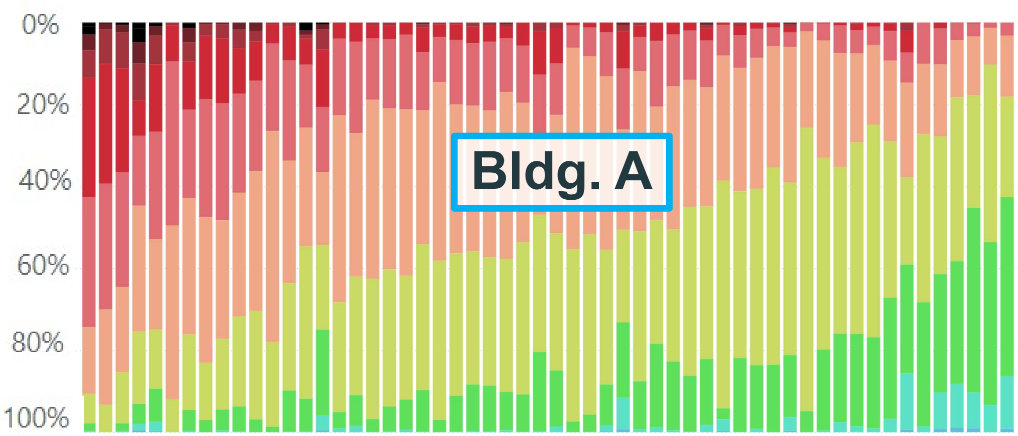

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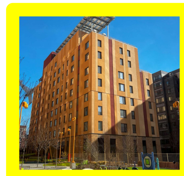

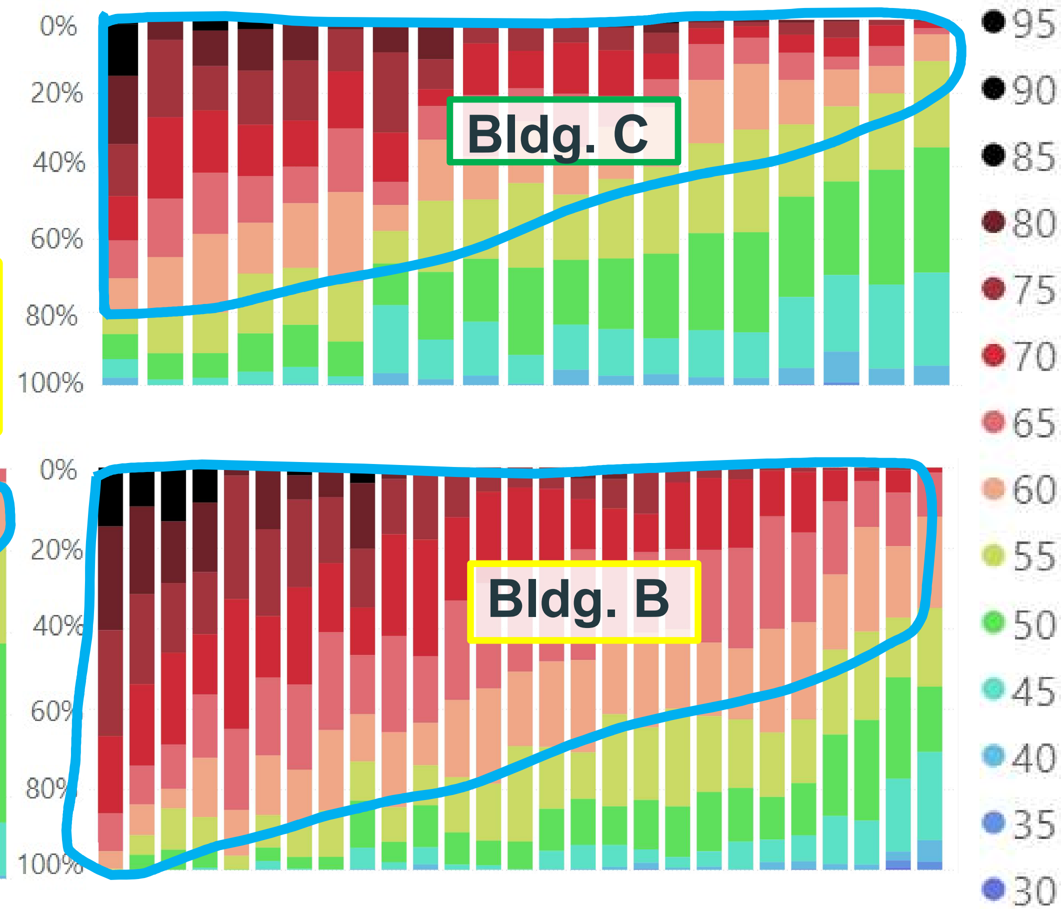

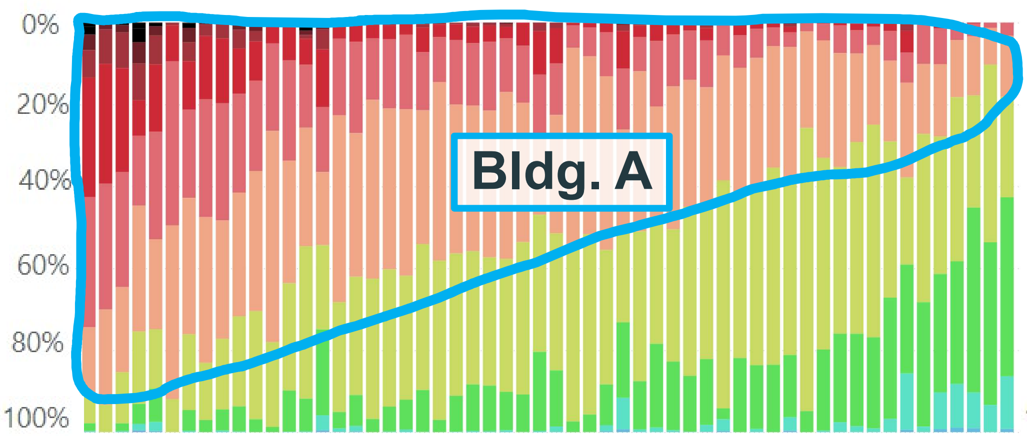

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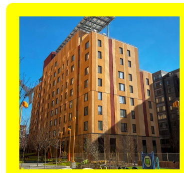
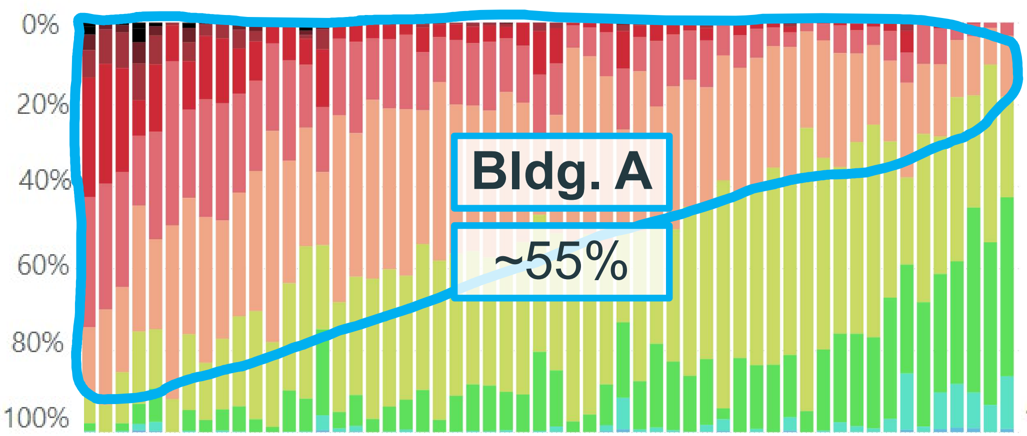
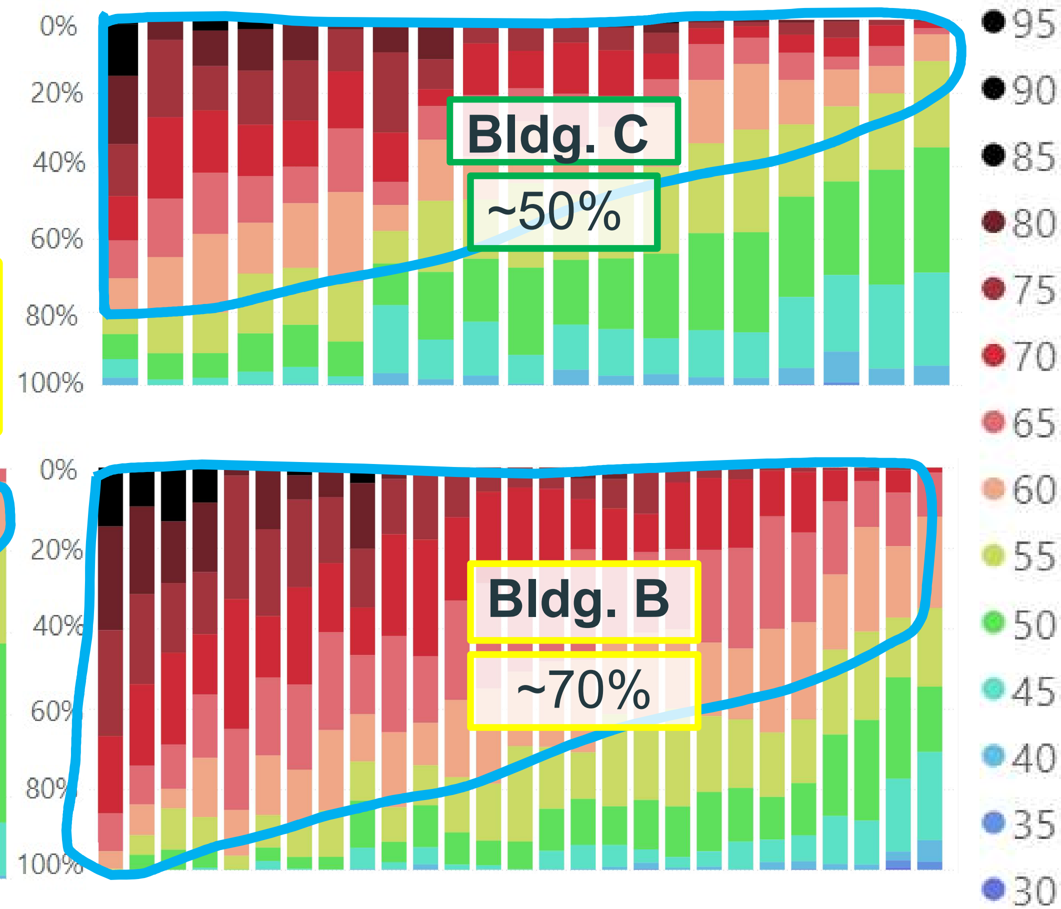






VRF Performance

VRF performance - Summer

Building C

Rated COP = 3.3 per AHRI

Calculated summer COP = 1.7

No evidence that heat recovery increases efficiency of VRF

VRF performance - Summer

Building C

Rated COP = 3.3 per AHRI

Calculated summer COP = 1.7

No evidence that heat recovery increases efficiency of VRF

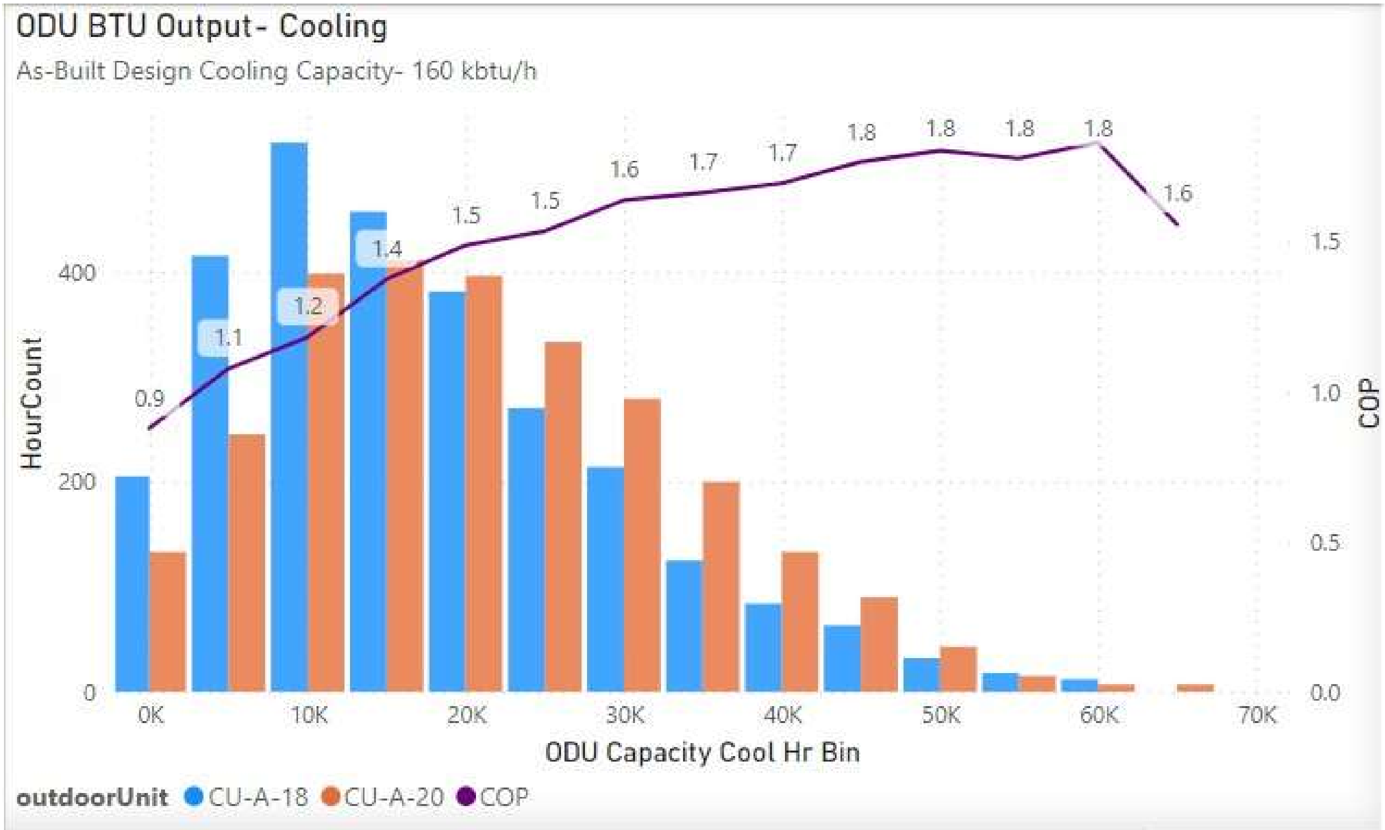
Building A

No COP data

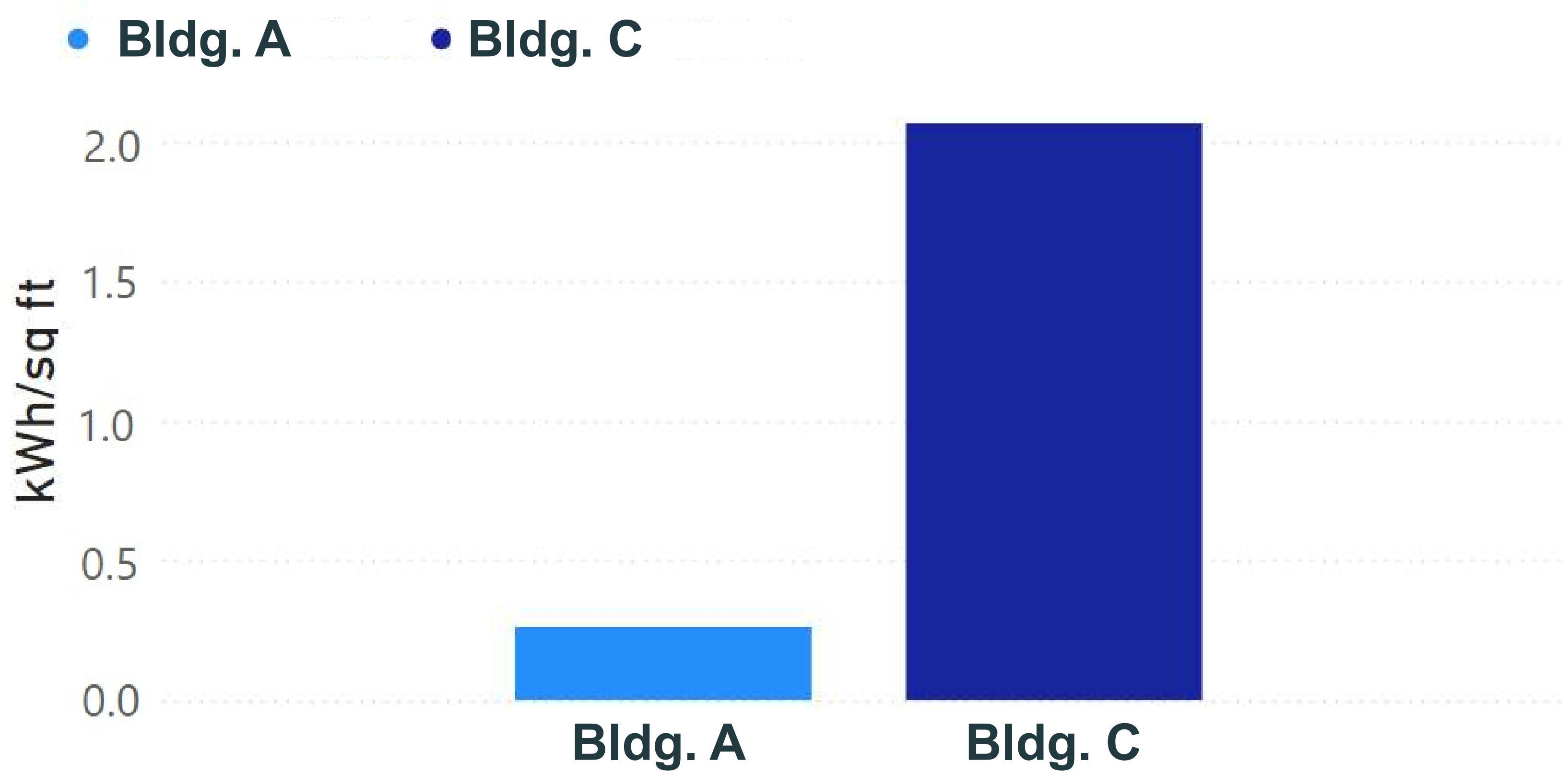
We do have energy data though

Building C – Summer COP

- Capacity: 160 kBTU/h
- SWA Load Estimate: 72 kBTU/h
- Peak output <50% nominal capacity
- COP low at low load



Summer Energy Use Intensity



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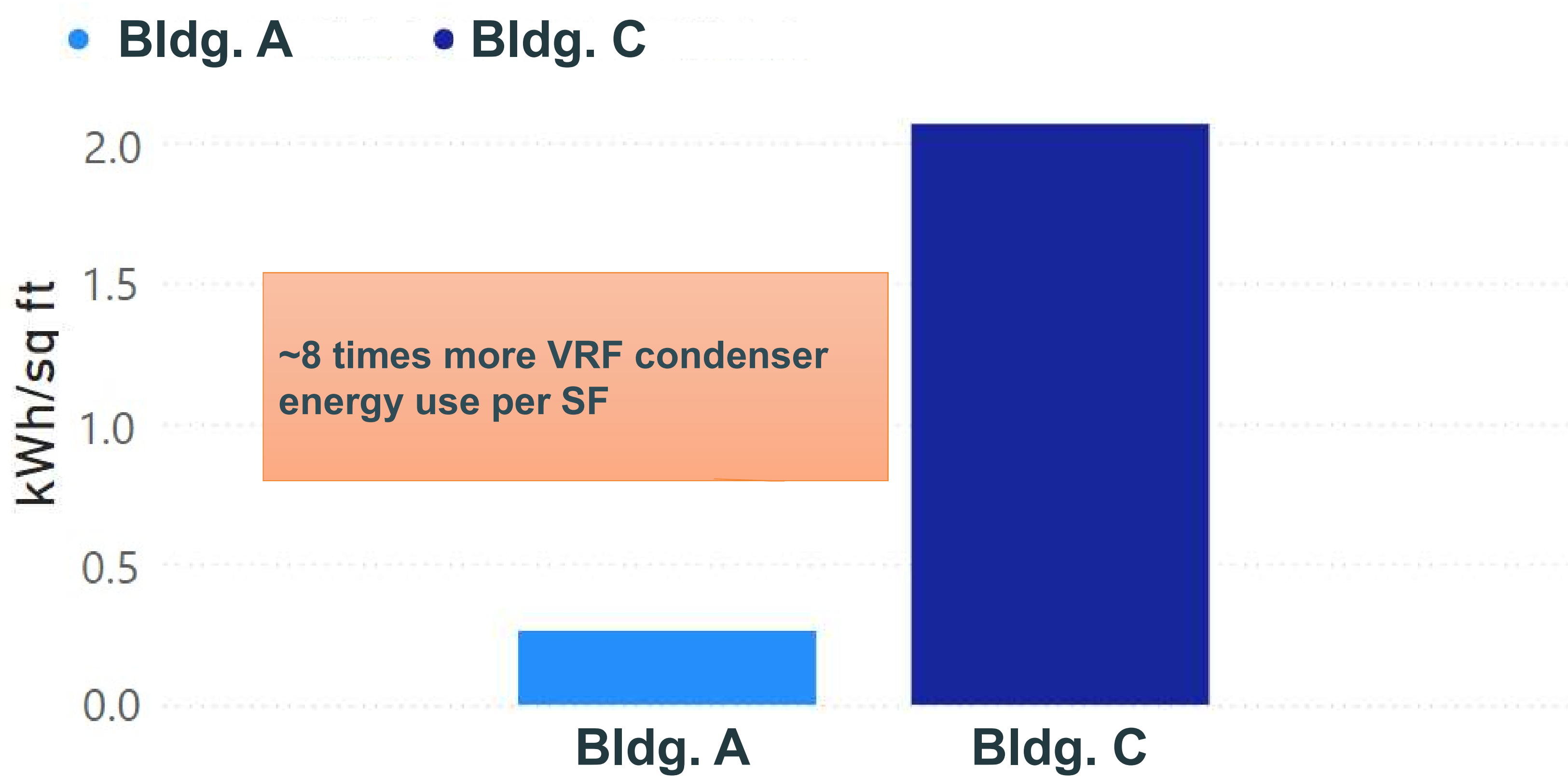
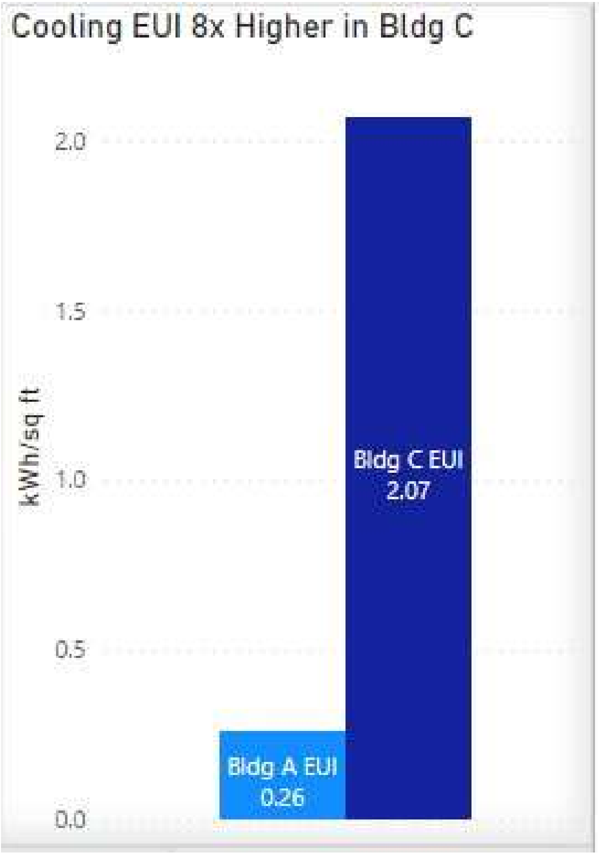


VRF Performance Conclusions

- **Oversizing increases EUI?**

Summer Cooling Comparison of Typical Floor		
Building	**A**	**C**
Design Load	72 kBTU/h	72 kBTU/h
Nominal Capacity (ODU)	72 kBTU/h	168 kBTU/h
Capacity/Load: “Oversizing”	100%	230%
Energy Use Intensity	1X	8X



Preliminary Conclusions

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- **Apartments are Humid!**

Preliminary Conclusions

- **Apartments are Humid!**
  - ERV not running correctly
  - VRF thermostats are off
    - Off 60% of the time on average
    - Used as an on/off switch
  - IDU cycling
    - Shorter cycle lengths = higher dewpoints

Preliminary Conclusions

- **There is a correlation to sizing and VRF efficiency**
  - Building C has much higher VRF EUI than Building A
  - COP in Building C is much worse when equipment is running at a lower capacity
  - Account for diversity in outdoor unit sizing

Additional Research

Additional Research

- Analysis of Fall and Winter seasons
- DOE report later this year

Unfunded Step 2

- Occupancy Survey
- Tenant Education

Contact Us

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